International Journal of Scientific Research in Civil Engineering
© 2021 | IJSRCE | Volume 5 | Issue 6 | ISSN : 2456-6667

Experimental Investigation on The Buckling Behavior of CFRP Confined Hollow Steel Column Filled with Prosopis Juliflora Wood – A Review

Valli. D [*1], S. Arivalagan[2], Dr. M. Narmatha[2]

[*1]PG Student, Department of Civil Engineering, Dr. MGR Educational and Research Institute, Chennai, Tamil Nadu, India

[2]Professor, Department of Civil Engineering, Dr. MGR Educational and Research Institute, Chennai, Tamil Nadu, India

[3]Assistant Professor, Department of Civil Engineering, Dr. MGR Educational and Research Institute, Chennai, Tamil Nadu, India

Article Info
Volume 5, Issue 6
Page Number : 126-138

Publication Issue :
November-December-2021

Article History
Accepted : 01 Dec 2021
Published : 10 Dec 2021

ABSTRACT

In the project, experimental studies have been devoted to investigating the buckling behavior of timber Filled Circular hollow Steel Tube (CHST) stub columns strengthened by Carbon Fiber Reinforced Polymer (CFRP) laminates. The present Stub Columns were under pure axial Compression. Several tests were conducted on different specimens such as bare Circular Hollow Columns and Timber, Hollow columns wrapped with CFRP, Hollow Columns filled with timber, and CFRP wrapped tubes with timber infill specimen respectively and the impact of each material was studied on the structural behavior of these members under axial compression. The CFRP confined members preventing local outward buckling. At the time, the buckling was occurred inside of the specimen. The results indicated the application of CFRP sheets for strengthening steel short CHS columns. significantly increment on the load-bearing capacity and delaying local buckling were observed. Thus, the timber-filled specimens were found to significantly improve the strength by preventing local inward buckling. The practical benefits of composite timber-steel encased columns are also discussed, notably the potential to express the materially of wood and offer a market for low-grade timber with smaller cross-sections.

Keywords : Circular hollow section, timber filled, axial compression, local inward and outward buckling, strengthening

I. INTRODUCTION

There is a continuous demand for various construction materials, in the construction industry, particularly for composite materials, which gives higher load-bearing strength with cost-effectiveness. Steel plays a major role in the construction industry because the major part of the project cost is spent on steel. Hence, there is much researches are being done to reduce the usage of steel for bringing down the project cost. One among the solution is that the use of composite members by combining the steel with

other construction suitable materials. The locally available materials have always influenced any Industry for its speedy growth. The Prosopis juliflora tree is grown everywhere in Villages over the country. It grows in all seasons because it does not require regular watering. Its fast growth helps to meet the continuous demand of the market. The strength of the Prosopis juliflora timber is very good compared to other local timbers.

Considering the strength, easily available, and cheaper, this Prosopis juliflora timber has been chosen as a composite material with steel tube to attain more strength with less cost. It will reduce the project cost and also be environmentally friendly.

Steel generally appears in composites as the basic material as its characteristic feature such as being lightweight yet strong allow engineers to have reasonable designs. Notwithstanding, to minimize the weaknesses of the steel, e.g. buckling, designers often need recourse to different types of stiffeners and/or composite materials.

In the literature, various types of FRP are strengthened steel tube columns [1-10]. Among these materials have been widely used in construction engineering [11-12] because of their tensile strength, corrosion resistance, and handling, in addition to the economic advantages [13-14]. Buckling behavior of steel tubes confined by FRP composites. Further ductility as a consequence of the mentioned confinement was obtained in this project. A few major aspects of the work, such as reinforcing steel hollow section, bonding between FRP and steel, and fatigue crack development in composite members, were exhaustively discussed in this project.

Steel girders with CFRP reinforcement were found that based on several experimental programs referred to in the projects, CFRP plates can be effectively used to strengthen steel girders [15]. The use of CFRP to strengthen structural elements such as reinforced concrete, masonry, and timber structure, and to some extent for metal has been popular in recent decades [16-17]. Two different studies investigated the effect of CFRP and GFRP confinement of steel CHS members under compression. CFRP was involved to make a composite element led to a considerable increase of the ultimate capacity, while the latter in which the GFRP was taking part, resulted in a remarkable enhancement of the ductility with the insignificant capacity increase in a remarkable enhancement of the ductility with insignificant capacity increases [18-20].

Over the past decade, on the other hand, widespread usage of concrete-filled tubes are found to play a leading role to make modern composite elements used due to their superior structural behavior [21-25]. A significant increase in the capacity was obtained for concrete-filled tubes relative to the bare steel tubes, which was attributable to load-carrying capacity, ductility, and energy absorption of the concrete and steel respectively and, in turn, the interaction of the two materials was also of importance [26-33]. Recently, CFST columns with an inner PVC-U (unplasticized polyvinyl chloride) pipe or a timber infill were proposed. Axial compressive tests and numerical analysis results showed that the inner PVC-U pipe had almost no influence on the circumferential strain of the outer steel tube and contributed little to the axial load-carrying capacity [34]. Moreover, the other types of fillers for CHS tubes have been utilized as well in different researches projects such as polyethylene, different foams e.g. aluminum foam, mortar, and so forth [35-43]. A CHS tube element with a moderate D/t ratio – where D is the diameter and t is the thickness - generally buckles in elephant foot mode of buckling. In previous research where tubes were confined with sufficient plies of FRP, outward buckling (elephant foot buckling) was fully arrested by different types of FRP; as a result, inward plastic Buckling governed the failure.

All the Literature review shows that the composite materials any mostly made up of steel with other manmade materials. Very few have tried timber as the second material, though it is easily available in the market. Teakwood has been taken in most of the very costly studies, rarely grown and it takes many years to attain required good strength whereas juliflora timber is easily available, grown in most of the Villages and very cheaper. Hence, a steel tube with juliflora timber has been considered for analysis and study. In this paper, the authors present an idea in which inward and outward buckling is prevented and/or delayed so that the ultimate capacity increases. To this end, the authors designed the current composite element comprising a CHS member, which was restricted inside by filling with timber and reinforced outside by confining with CFRP.

Thus, the maximum capacity of the timber, as well as the steel CHS member, was fully employed through the composite action to gain further capacity. Different specimens with various geometric features and material combinations were examined. In this study: the buckling modes of the present specimens, the capacity rise, and load-displacement and load strain response were thoroughly discussed. Furthermore, this paper compares the proposed composite with previous studies and equivalent steel sections and includes a summary of the practical benefits of the new composite

II. LITERATURE SURVEY

An The literature review shows that many research and analysis have been carried out for composite steel members and some of them are narrated below

Tohid Ghanbari Ghazijahani, Hui Jiao, Damien Holloway, **"Rectangular steel tubes with timber infill and CFRP confinement under compression: Experiments"**, Journal of Constructional Steel Research, Volume 114, issue 2015 [43].

A new composite element comprising rectangular steel tubular sections filled with timber and confined with carbon fiber reinforced polymer (CFRP) was investigated in this study. Several tests were conducted on different specimens with varying geometrical conditions and the impact of each material was studied on the structural behavior of these members under axial compression. The timber infill was found to significantly improve the capacity by preventing local inward buckling. This effect was further enhanced when the short columns were confined with sufficient layers of CFRP to prevent local outward buckling. In both cases, the strength increase (up to 75%) was substantially greater than the corresponding weight increase (up to 44%).

A new composite element comprising rectangular steel tubular sections filled with timber and confined with CFRP was undertaken in this study. Several tests were conducted on different specimens with varying geometrical conditions and the impact of each material was studied on the structural behavior of these structures.

The timber infill together with the CFRP confinement provided an additional capacity of around three-quarters of the bare specimen for this composite specimen. In all cases, but particularly for Timber-filled RHS, 3 layers partial CFRP (RTYU.7), the strength gains significantly exceeded the weight gain. In this light, timber as an infill for the hollow sections can certainly stimulate further research considerations, leading to significant developments of this innovative idea.

Tohid Ghanbari Ghazijahani, S.M.ASCE; Hui Jiao, Ph.D.; and Damien Holloway, Ph.D. **"Composite Timber Beams Strengthened by Steel and CFRP"**, American society of civil engineering, volume 5, Issue 2016 [44].

Composite timber beams strengthened by U-shape steel sections and carbon fiber–reinforced plastic

(CFRP) are studied experimentally in this paper. Specimens with various strengthening, i.e., steel only, CFRP only, and a combination of the two, were considered under three-point flexural tests. The present tested models evaluated failure, displacement and strain response, ductility, bending capacity, and structural efficiency. Dramatic enhancement of the capacity in addition to improved deflection and ductility were gained for the strengthened beams relative to the plain specimens, indicating the effectiveness of the reinforcement on the flexural strength of such composite beams.

This paper aimed to experimentally investigate U-shape steel and CFRP reinforced timber beams under three-point bending. Different specimens were tested with various geometric and material specifications. The salient findings are as follows.

The failure in the plain timber specimens was quite abrupt with a sudden rupture in the timber. Although a dramatic rise in the flexural capacity was gained for Steel reinforcement with a thickness of 2.5mm (ST)-ST-Screwed connection (Sc), the existence of the screws presumably initiated the onset of the cracks. However, epoxy provided reliable steel to timber connection for the other specimens, as the failure took place with no debonding. Typical brittle failure of the plain timber specimens was largely prevented and/or delayed in the specimens reinforced with the steel sections. Nonetheless, brittle behavior overwhelmingly governed the failure in Steel reinforcement with a thickness of 2mm (St)-CFRP reinforcement (FR) – Epoxy connection (E) relative to the specimens fully strengthened by the U-shape steel(s).

The compressive stress of the timber in combination with the steel in the top half, coupled with significant tensile stress provided by the CFRP on the bottom, yielded an appropriate composite beam element. On this basis, St-FR-E achieved the greatest bending resistance: gaining a capacity of nearly five times the average capacity of the plain specimens. St-St-E with double-sided steel reinforcements consisted of the second-highest capacity increase.

U-shape steel sections not only enhanced the timber beams in tension but also brought about a significant capacity increase. The similar flexural capacity of No reinforcement (NA) -FR-E and NA-St-E demonstrated a similar effect of single reinforcements in the tension side of the present specimens whether it is a U-shape steel section or CFRP.

Despite having only a few replicates of each configuration, the differences in the mean values for the various configurations are considerable, indicating that the reinforcement produced substantial benefits for each configuration. Further testing may be required to quantify the statistical significance of the results.

Considering the structural efficiency of the plain specimens, the reinforcements dramatically enhanced the structural efficiency. In light of this, the present reinforcements of steel and CFRP provided a promising lightweight structural element against bending.

J.Zeghiche, K. Chaoui, **"An experimental behavior of concrete-filled steel tubular column"**, Journal of Construction Steel Research, Issue 2005 [45].

In this paper results of tests conducted on 27 concrete-filled steel tubular columns are reported. The test parameters were the column slenderness the load eccentricity covering axially and eccentrically loaded columns with single or double curvature bending and the compressive strength of the concrete core. The test results demonstrate the influence of these parameters on the strength and behavior of concrete-filled steel tubular columns.

A comparison of experimental failure loads with the predicted failure loads under the method described in Euro code 4 Part 1.1 showed good agreement for axially and eccentrically loaded columns with single curvature bending whereas for columns with double

curvature bending the Euro code loads were higher and on the unsafe side. More tests are needed for the case of double curvature bending.

Within the limits of the investigations reported above, it may be concluded that the column squash resistance calculated by the EC4 method is a reasonable estimate of the actual failure load of a stub column of concrete-filled CHS. The increase in the column slenderness decreases the load-carrying capacity of composite columns.

The use of high concrete strength enhanced the load-carrying capacity of the tested columns, but with a load–slenderness relationship decreasing at a higher rate compared to that for columns using normal strength concrete. EC4 predictions for axially and eccentrically loaded columns with single curvature bending were on the safe side and in good agreement with the experimental and numerical failure loads.

However, for columns in double curvature bending, both numerical and test results show that the EC4 prediction is on the unsafe side. All tested columns failed by overall buckling with no sign of local buckling of the steel wall. More tests are needed to check the validity of EC4 predictions for columns subjected to double curvature bending.

S. Jayaganesh, J. Raja Murugadass, G.Ganesh Babu, and J.Jegan, **"Effects of Concentrical Partial (Local) Compression on the Structural Behavior of Concrete Filled Steel Tubular Column"** Volume 5, Issue 2015 [46].

This paper is to investigate the structural behavior of square and circular stub columns subjected to axial partial/local compression. The experimental parameters were local compression area and section type. Among the twelve specimens, six specimens were tested under full compression and the remaining six specimens were tested under local compression. The experimental observation indicated that the failure pattern of the CFST column with partial compression is fairly different from the CFST column subjected to full compression. The confinement provided by the circular section is quite different than the confinement provided by the square section when the CFST column is subjected to axially local compression. It was found that the elastic modulus (stiffness) and the ultimate bearing capacity of the CFST column decreased with the increase in local compression ratio. The circular and square CFST columns subjected to partial/local compression achieved an ultimate strength of 4.45% and 14.15%, respectively, less than that of the columns subjected to full compression. From the above observation, it can be inferred that the structural performance of the CFST column is significantly influenced by the local area compression ratio and this effect should be taken into account in design models.

An experimental investigation was performed to understand the structural behavior of CFST stub columns subjected to partial/local compression. Based on the test results of twelve specimens, the following conclusions were made:

(i) The failure pattern of the CFST column subjected to partial compression was different than that of the CFST column subjected to full compression.

(ii) While being the CFST column subjected to partial compression, the confinement provided by the circular section is quite different than the confinement provided by the square section; furthermore, the confinement action between the concrete and the steel tube for the circular section was significant compared to that of the square section.

(iii) The columns subjected to local compression achieved low stiffness and bearing capacity when compared to the column subjected to full compression. The circular column with partial compression decreased its stiffness and ultimate strength by 63.88% and 4.45%, respectively,

when compared to the column with full compression.

(iv) The higher confinement provided by the steel tube in partial compression increased the ductility performance of the CFST column; furthermore, it was very obvious in the circular section.

(v) A theoretical bearing capacity of the CFST columns subjected to partial compression was predicted using simple equations and the predicted values were in good agreement with the experimental results.

P.Kiruthika, S.Balasubramanian, M.C.Sundarraja, J.Jegan, **"Strengthening of Concrete Filled Steel Tubular Columns using FRP Composites",** International Journal of Innovative Research in Science, Volume 4, Issue 2015 [47].

Over the past few decades, concrete-filled steel tubular (CFST) column plays an eminent role in the construction industry owing to their structural behavior like large deformation and energy absorption capacity. But these members get deteriorated due to environmental effects like corrosion and aging. The external strengthening of using fiber-reinforced polymer (FRP) material is emerging as a new trend in enhancing the structural performance of CFST members to counteract the drawbacks in using the past rehabilitation work. In this paper, an experimental investigation has been carried out to investigate the behavior of FRP strengthened slender circular CFST members under compression. The size of the specimens includes 42.4mm diameter, 3.2mm thickness, and 1500mm height. In the experimental work, three columns are externally bonded by 200mm width of CFRP strips with the spacing of 60mm and another three columns with 300mm width and 100mm spacing. Experiments are undertaken to examine the interaction of FRP with the CFST column in terms of the failure modes, axial load Vs lateral deformation, and enhancement in load-carrying capacity. In the end, the results demonstrated that there is an improvement in the behavior and the load-carrying capacity of CFST columns by strengthening those externally using FRP composites.

Longitudinal wrapping of unidirectional CFRP strips over CFST columns was put forth in this research work. The performance was observed and discussed in terms of failure modes; axial load vs lateral deformation and load-carrying capacity. Based on the axial compression tests on the CFRP wrapped CFST columns, the following conclusions can be made:

1. The axial compressive behavior of CFRP strengthened CFST columns was enhanced both in terms of strength and stiffness, by reducing the lateral deformation and increasing the load-carrying capacity when compared to unstrengthen CFST columns.
2. In the case of unwrapped CFST columns, the outward buckling of steel tube was observed, as the inward buckling was prevented by in-filled concrete. In addition, the overall buckling of the steel tube at the mid-height was delayed and it was followed by crushing of resin and rupture of CFRP strips, for strengthened CFST columns under ultimate load.
3. The reduction in lateral deformation of CFST columns such as CF-200-60-1, CF-200-60-2 and CF200-60-3 were 12.31%, 30.61% and 41.98% for the corresponding failure load of CS.
4. The lateral deformation was decreased up to 38.13% than the control specimen by using three-layer CFRP strip width of 300 mm and 100 mm spacing.
5. The load-carrying capacity of the CFST columns was enhanced by 45.12%, 31.71%, and 15.85% respectively for CF-300-100-3, CF-300-100-2, and CF-300-100-1 than that of CS.

6. From the results, it was clear that the spacing and number of layers of CFRP strips played a dominant role in the strengthening of CFST columns, as the former controlled the confining area and the latter improved the intensity of confinement pressure.

Tohid Ghanbari Ghazijahani, Hui Jiao, Damien Holloway, **"Timber filled CFRP jacketed circular steel tubes under axial compression"** Construction and Building Materials, Volume 94, Issue 2016 [48].

This project discusses the buckling behavior of the steel hollow column of an experimental study. The new composite comprised steel cylindrical hollow sections known as CHS, solid timber infill, and CFRP confinements. The present stub columns were under pure axial compression. Plastic buckling, failure modes, and the deformational response of the mentioned elements were assessed. The ultimate capacity enhancement was evaluated for specimens with different conditions and comprehensive discussions were made to clarify the effect of each material on the structural behavior of different specimens.

In this study, new composite elements comprising steel cylindrical hollow sections, solid timber infill, and CFRP confinements were tested under pure axial compression. The use of timber-filled specimens can potentially gain the attention of the researchers and designers if proper equipment is proposed and developed for the fabrication of such elements. This is concluded in light of a higher weight increase of the equivalent concrete filled tubes compared to the present specimens and the rate of the capacity enhancement for each case.

Vishwajeet Patel, P. S. Lande **"Analytical Behavior of Concrete Filled Steel Tubular Columns under Axial Compression"**, International Journal of Engineering Research, Volume 5, Issue 2016 [49].

Steel-concrete composite columns are used extensively in high-rise buildings and bridges, as a type of hybrid system. However, this approach is a relatively new concept for the construction industry. In concrete-filled steel tube (CFST) columns, the steel tube provides formwork for the concrete; the concrete prevents local buckling of the steel tube wall. The load-carrying capacity and behavior in compression, bending, and shear are all superior to reinforced concrete. An analytical investigation of the behavior of the Concrete Filled Steel Tubes column and a theoretical design procedure according to EN 1994-1-1 Euro Code-4 are presented. The investigation has been carried out for rectangular and circular CFST columns under axial compression. The analytical model is developed to predict the capacity of CFST accounting for the interaction between steel and concrete. The results obtained by theoretical calculation is validated using ANSYS 11.0
Multiphysics utility tool. The results are illustrated by the load-carrying capacity table and modes of failure.
In this work behavior of CFST rectangular and circular columns has been elaborately done by theoretical calculations according to EC 4 and FE analysis of given specimens has been carried out, we can draw the following general conclusions,
The strength of Rectangular and circular CFST columns increases as the grade of concrete has been increased. The cross-sectional area of the steel tube has the most significant effect on both the ultimate axial load capacity and the deformation of a column. From the above analysis geometric parameters like the thickness of steel tube, grades of concrete and D/t ratio of the tube it has been observed that strength of CFS column has been affected.

A.P.Ghorapada, H.S.Jadhav, **"Study of the behavior of hollow square steel column strengthened with CFRP"**,

International Journal of Engineering Research, Volume 3, Issue 2015 [50].

Retrofitting of the structure is a better alternative instead of the whole replacement of the structure. Retrofitting by using Carbon Fiber Reinforced Polymer (CFRP) has been gaining increasing interest. Recently, CFRP is being used for metallic structures also. The purposes of using CFRP materials are i) High Strength to Weight ratio ii) Better durability in the worst environment. CFRP bonded structures have less cost as compared to the cost of replacement of the structure. It increases load-carrying capacity and improves the stiffness and buckling behavior of a structure. In this paper, a study of the behavior of the Hollow Square Section strengthened with Carbon Fiber Reinforced Polymer is carried out. Square hollow sections were used as columns and CFRP as a strengthening material. CFRP bonded columns with change in width of CFRP strip and various numbers in layers were tested. Strip wrapping sections increased load about 4% to 6% and full wrapping of CFRP sections increased load about 13% to 16%. These column sections were analyzed using finite element software ABAQUS. In a comparison of intact sections and CFRP bonded sections, the load-carrying capacity of CFRP bonded sections was increased by about 4% to 16%.

CFRP strengthening just delays buckling; it doesn't make any change in the mode shape of the buckling. CFRP strengthening improves the load-carrying capacity of the Square Hollow Section up to 4 % to 16%. Thus, it can be used as an alternative strengthening method. For sections with changing CFRP strips, it was effective for 60mm strip wrapping as it covers more buckling regions of the section than 80mm.

E K Mohanraj, S Kandasamy, R Malathy, **"Behaviour of steel tubular stub and slender columns filled with concrete using recycled aggregates"**, Journal of the South African Institution of Civil Engineering, Volume 53, Issue 2011 [51].

This paper is based on a study that was done by utilizing construction and demolition debris that had been effectively recycled, in structural members. The steel tubular columns were filled with different types of waste material, as well as recycled aggregate concrete, instead of normal conventional concrete. The results were subsequently analyzed. The behavior of circular and square concrete-filled steel tubular sections (CFSTs) under axial load, in which coarse aggregate had been partially replaced by recycled aggregates, is presented. The effects of steel tube dimensions, shapes, and the confinement of concrete are also examined. Measured column strengths are compared with the values predicted by Euro code 4, Australian Standards, and American Codes. Twelve specimens were tested with 20 MPa concrete and steel sections with diameter-to-thickness ratios of 18,5, 25,3, and 36,0.

The columns were of two different shapes – a circular-shaped set with diameters of 76 mm and 89 mm, and a square-shaped set with sizes 72 mm and 91 mm. The circular-shaped columns of 76 mm diameter and the square-shaped columns with 72 mm diameter are 900 mm long. The circular columns with a diameter of 89 mm and the square columns of 91 mm diameter are 350 mm long. Euro code 4 (EC4) gives the best estimation for both conventional and recycled aggregate concrete. However, the American Concrete Institute (ACI) / Australian Standards (AS) equation predicted lower values than measured during the experiments. Hence the ACI/AS equation has been modified by introducing a multiplying factor 'k' to predict good results for columns of L/D < 12. The values of the k factor for the L/D ratio varying from 4 to 12 are suggested in this study.

From the results, it has been noted that square columns save 30% of steel when compared with circular columns. It was also observed that the

ultimate load of steel tubular columns filled with recycled aggregate concrete is higher than that of conventional concrete and columns filled with recycled aggregate concrete, and can result in a 10% saving in the cost of concrete. This research, therefore, proposes a solution for effective solid waste management, which will also prove to be cost-effective.

K.Santhiya, G.Vimalanandan, Dr.S.Senthil Selvan, **"Behavior of GGBS concrete infilled steel tubular columns",** International Research Journal of Engineering and Technology, Volume 3, Issue 2016 [52].

In this study, a test on the compressive strength of concrete-filled steel tubular columns was performed. Compressive strength of hollow, conventional as well as Ground Granulated Blast-furnace Slag (GGBS) concrete-filled tubes was determined. Cross-section, Compressive strength, and height of column were selected as the variables to be investigated. Circular sections (CS) and square sections (SS) were chosen for the experimental procedure. The relationship between the load and the lateral displacement at the mid-height of the columns in the directions of both the strong and weak axes and the relationships of load versus end shortening for each specimen were duly recorded. It was found that load carrying capacity varies concerning the cross-section of the specimen, compressive strength of the infill, and type of infill material. Circular specimens show a higher load carrying capacity compared to square specimens. GGBS concrete infilled steel tubes have 6%-15% higher strength than conventional concrete-filled steel tubes.

The following conclusions were made from the experiments performed:

1. Concrete-filled steel tubes have 1.8times higher strength than hollow tubes.
2. The increase in compressive strength of infill increases the load-carrying capacity by 10% for conventional concrete infill and 20% for GGBS concrete infill
3. GGBS concrete infilled steel tubes have 6%-15% higher strength than conventional concrete-filled steel tubes.
4. Circular sections have a 10% higher load carrying capacity compared to square sections.
5. Load-carrying capacities of specimens are observed to increase by 35%-40% with a decrease in the height/thickness ratio.

III. CONCLUSION

All A new composite element comprising Circular steel tubular sections filled with Prosopis juliflora wood and confined with CFRP was undertaken in this study. Several tests were proposed on different specimens under concentric axial compression conditions and the impact of each material was studied on the structural behavior of these structures. Local buckling around the end areas coupled with an inward buckling near the mid-length was dominant in specimens. Plastic buckling appeared in several zones in the top half of the bare timber-filled specimen. Three layers of CFRP sufficiently reinforced these specimens and the buckling was arrested for the timber-filled CFRP confined (3 layers) specimen. In the proposed hybrid columns, the near-full composite action between the steel bars and Prosopis juliflora wood is achieved by an adhesive bond between the encased steel rods/bars and the timber casing. The proposed novel composite columns offer several practical benefits which include (i) being lightweight with a high strength/weight ratio, (ii) use of cheap low-grade timber, (iii) connection possibilities by taking advantage of encased steel bars acting as dowels, (iv) protection of steel from fire with Prosopis juliflora wood casing when designed for charring, (v) reduced cross-section compared to bare

timber columns that allow for efficient use of space and (vi) easily deconstruct able and recyclable, in the case of composite columns without adhesive. (vii) Confined with CFRP behaved with more ductility than its counterpart bare Steel. (viii) The effect of which was additionally accompanied by preventing and/or delaying of the inward buckling of the steel by the timber infill. The confinement of the CFRP reinforced these specimens against the outward buckling as CFRP sufficiently restrained the surface of the steel; therefore, the capacity increased. The structural performance of the Prosopis juliflora wood-steel encased composite columns under concentric compressive load was investigated by laboratory experimentation. In this light, timber as an infill for the hollow sections can certainly stimulate further research considerations, leading to significant developments of this innovative idea.

IV. REFERENCES

[1]. Abdollahi CN, Zamin JM, Ramli NH, et al. Experimental and theoretical investigation on torsional behavior of CFRP strengthened square hollow steel section. Thin-Walled Struct.2013:68:135-40.

[2]. Bambach MR, Jama HH, Elchalakani M. Axial capacity and design of thin-walled steel SHS strengthened with CFRP. Thin-Walled Struct. 2009;47(10):1112-21.

[3]. Haedir J, Zhao XL, Design of short CFRP reinforced steel tubular columns. J Construction steel Res 2011;67(3):497-509.

[4]. J. Teng, Y. Hu, Suppression of local buckling in steel tubes by FRP jacketing, Proceedings, 2nd International Conference on FRP Composites in Civil Engineering, Adelaide, Australia 2004, pp. 8–10.

[5]. M. Seica, J. Packer, P. Ramirez, S. Bell, X. Zhao, Rehabilitation of Tubular Members With Carbon Reinforced Polymers, 2006.

[6]. X.-L. Zhao, L. Zhang, State-of-the-art review on FRP strengthened steel structures, Eng. Struct. 29 (2007) 1808–1823.

[7]. T.C. Miller, M.J. Chajes, D.R. Mertz, J.N. Hastings, strengthening of a steel bridge girder using CFRP plates, J. Bridg. Eng. 6 (2001) 514–522.

[8]. J. Haedir, M. Bambach, X.-L. Zhao, R. Grzebieta, Strength of circular hollow sections (CHS) tubular beams externally reinforced by carbon FRP sheets in pure bending, Thin-Walled Struct. 47 (2009) 1136–1147.

[9]. J.M. Rotter, Local collapse of axially compressed pressurized thin steel cylinders, J. Struct. Eng. 116 (1990) 1955–1970.

[10]. L. Hollaway, J. Cadei, Progress in the technique of upgrading metallic structures with advanced polymer composites, Prog. Struct. Eng. Mater. 4 (2002) 131–148.

[11]. L.C. Hollaway, A review of the present and future utilization of FRP composites in the civil infrastructure concerning their important in-service properties, Constr. Build. Mater. 24 (2010) 2419–2445.

[12]. K. Gamage, R. Al-Mahaidi, B. Wong, Fe modeling of CFRP-concrete interface subjected to cyclic temperature, humidity and mechanical stress, Compos. Struct. 92 (2010) 826–834.

[13]. T.H. Almusallam, Load–deflection behavior of RC beams strengthened with GFRP sheets subjected to different environmental conditions, Cem. Concr. Compos. 28 (2006) 879–889.

[14]. H. Saadatmanesh, M. Tavakkolizadeh, D. Mostofinejad, Environmental effects on mechanical properties of the wet lay-Up fiber-Reinforced polymer, ACI Mater. J. 107 (2010) 267–274.

[15]. Zerbo, V., Di Tommaso A. and Ceriolo, L. 2005, "FRP strengthening systems for metallic structures: a state of the art", Structural

Analysis of Historical Constructions - Modena, Lourenço & Roca (eds), Taylor and Francis Group, London, ISBN 04 15363799, pp 891-900.

[16]. ACI Committee 440, Guide for the design and construction of externally bonded FRP systems for strengthening concrete structures. ACI 440.2R-02, American Institute, Farmington Hills, MI, 2002.

[17]. L. Hollaway, Polymer Composites for Civil and Structural Engineering, 1st ed., Blackie Academic and Professional, Glasgow, UK, 1993.

[18]. J. Haedir, X.-L. Zhao, Design of short CFRP-reinforced steel tubular columns, J. Constr. Steel Res. 67 (2011) 497–509.

[19]. J. Teng, Y. Hu, Behaviour of FRP-jacketed circular steel tubes and cylindrical shells under axial compression, Constr. Build. Mater. 21 (2007) 827–838.

[20]. K.Santhiya, G.Vimalanandan, Dr.S.Senthil Selvan, Behaviour of GGBS Concrete infilled steel Tubular Columns, Volume:03, Issued 2016.

[21]. Morino S. Recent developments in hybrid structures in Japan-research, design, and construction. Eng Struct 1998;20(4–6):336–46.

[22]. Gourley BC, Tort C, Denavit MD, Schiller PH, Hajjar JF. A synopsis of studies of the monotonic and cyclic behavior of concrete-filled steel tube members, connections, and frames Report No. NSEL-008, NSEL Report Series Department of Civil and Environmental Engineering. Urbana: the University of Illinois at Urbana-Champaign; 2008.

[23]. Perea T, Leon RT, Hajjar JF, Denavit MD. Full-scale tests of slender concrete-filled tubes: axial behavior. J Struct Eng 2013;139(7):1249–62.

[24]. Han LH, Li W, Bjorhovde R. Developments and advanced applications of concrete-filled steel tubular (CFST) structures: members. J Constr Steel Res 2014;100:211–28.

[25]. Yu M, Wang T, Huang WJ, Yuan HX, Ye JQ. Fire resistance of concrete-filled steel tube columns with preload. Part I: Experimental Investigation. Compos Struct 2019;223:110994.

[26]. J. Teng, T. Yu, Y. Wong, S. Dong, Hybrid FRP–concrete–steel tubular columns: concept and behavior, Constr. Build. Mater. 21 (2007) 846–854.

[27]. Y. Yang, L. Han, Concrete filled steel tube (CFST) columns subjected to concentrically partial compression, Thin-Walled Struct. 50 (2012) 147–156.

[28]. Y.-F. Yang, L.-H. Han, Behaviour of concrete-filled steel tubular (CFST) stub columns under eccentric partial compression, Thin-Walled Struct. 49 (2011) 379–395.

[29]. Z. Tao, B. Uy, F.-Y. Liao, L.-H. Han, Nonlinear analysis of concrete-filled square stainless steel stub columns under axial compression, J. Constr. Steel Res. 67 (2011) 1719–1732.

[30]. M. Dundu, Compressive strength of circular concrete-filled steel tube columns, Thin-Walled Struct. 56 (2012) 62–70.

[31]. M.V. Chitawadagi, M.C. Narasimhan, S. Kulkarni, Axial strength of circular concrete-filled steel tube columns – DOE approach, J. Constr. Steel Res. 66 (2010) 1248–1260.

[32]. Ghazijahani TG, Jiao H, Holloway D. Concrete-filled circular steel tubes with a timber infill under axial compression. J Struct Eng 2017;143(7):04017037.

[33]. T. Ghanbari Ghazijahani, H. Jiao, D. Holloway, Rectangular steel tubes with timber infill and CFRP confinement under compression: Experiments, J. Constr. Steel Res. 114 (2015) 196–203, 11/01/2015.

[34]. Yuan WB, Yang JJ. Experimental and numerical studies of short concrete-filled double skin composite tube columns under axially compressive loads. J Constr Steel Res 2013;80(1):23–31.

[35]. G. Campana, G. Bertuzzi, G. Tani, L. Bonaccorsi, E. Proverbio, Experimental investigation into laser welding of aluminum foam-filled steel tubes, in Proceedings of the 5th International Conference on Porous Metals and Metallic Foams, MetFoam, 2008, pp. 453–456.

[36]. I. Hall, O. Ebil, M. Guden, C.-J. Yu, Quasi-static and dynamic crushing of empty and foam-filled tubes, J. Mater. Sci. 36 (2001) 5853–5860.

[37]. M. Iwata, M. Murai, Buckling-restrained brace using steel mortar planks; performance evaluation as a hysteretic damper, Earthquake Eng. Struct. Dynam. 35 (2006) 1807–1826.

[38]. Sun G, Song X, Baek S, et al. Robust optimization of foam-filled thin-walled structure based on sequential Kriging metamodel. Struct Multidiscipl Optim 2014;49(6):897–913.

[39]. Kavi H, Toksoy KA, Guden M. Predicting energy absorption in a foam-filled thin walled aluminum tube based on experimentally determined strengthening coefficient. Mater Des 2006;27(4):263–9.

[40]. Mantena PR, Mann R. Impact and dynamic response of high-density structural foams used as filler inside a circular steel tube. Compos Struct 2003;61(4):291–302.

[41]. H. Kavi, A.K. Toksoy, M. Guden, Predicting energy absorption in a foam-filled thin walled aluminum tube based on experimentally determined strengthening coefficient, Mater. Des. 27 (2006) 263–269.

[42]. L. Aktay, A. Toksoy, M. Güden, Quasi-static axial crushing of extruded polystyrene foam-filled thin-walled aluminum tubes: experimental and numerical analysis, Mater. Des. 27 (2006) 556–565.

[43]. Tohid Ghanbari Ghazijahani, Hui Jiao, Damien Holloway, Rectangular steel tubes with timber infill and CFRP confinement under compression: Experiments, Journal of Constructional Steel Research, Volume 4, issued 2015.

[44]. Tohid Ghanbari Ghazijahani, S.M.ASCE; Hui Jiao, Ph.D.; and Damien Holloway, Ph.D. "Composite Timber Beams Strengthened by Steel and CFRP", American society of civil engineering, volume 5, Issued 2016.

[45]. J.Zeghiche, K. Chaoui, "An experimental behavior of concrete-filled steel tubular columns", Journal of Construction Steel Research, Issued 2005.

[46]. S. Jayaganesh, J. Raja Murugadass, G.Ganesh Babu, and J.Jegan, "Effects of Concentrical Partial (Local) Compression on the Structural Behavior of Concrete Filled Steel Tubular Column" Volume 5, Issued 2015.

[47]. P.Kiruthika, S.Balasubramanian, M.C.Sundarraja, J.Jegan, "Strengthening of Concrete Filled Steel Tubular Columns using FRP Composites, International Journal of Innovative Research in Science, Volume 4, Issue 2015.

[48]. Tohid Ghanbari Ghazijahani, Hui Jiao, Damien Holloway, "Timber filled CFRP jacketed circular steel tubes under axial compression" Construction and Building Materials, Volume 5, Issued 2016.

[49]. Vishwajeet Patel, P. S. Lande "Analytical Behavior of Concrete Filled Steel Tubular Columns under Axial Compression", International Journal of Engineering Research, Volume 5, Issue 2016.

[50]. A.P.Ghorapada, H.S.Jadhav, "Study of the behavior of hollow square steel column strengthened with CFRP", International Journal of Engineering Research, Volume 3, Issue 2015.

[51]. E K Mohanraj, S Kandasamy, R Malathy, "Behaviour of steel tubular stub and slender columns filled with concrete using recycled aggregates", Journal of the South African

Institution of Civil Engineering, Volume 53, Issue 2011.

[52]. K.Santhiya, G.Vimalanandan, Dr.S.Senthil Selvan, “Behaviour of GGBS concrete infilled steel tubular columns”, International Research Journal of Engineering and Technology, Volume 3, Issue 2016.

Cite this article as :

Valli. D, S. Arivalagan, Dr. M. Narmatha, "Experimental Investigation on The Buckling Behavior of CFRP Confined Hollow Steel Column Filled with Prosopis Juliflora Wood – A Review", International Journal of Scientific Research in Civil Engineering (IJSRCE), ISSN : 2456-6667, Volume 5 Issue 6, pp. 126-138, November-December 2021.
URL : https://ijsrce.com/IJSRCE215530