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An overview on Concrete Filled Double Skin Steel Tube (CFDST) column with FRP wrapping

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Abstract: *CFDST is a composite construction which consists of two steel layers embedding a concrete layer in between The inner hollow steel section acts as formwork and reinforcement for the concrete. Concrete delays the local buckling of hollow steel section and hence improves the ductility of the section. CFDST have many advantages such as high strength, high bending stiffness, good seismic and fire performance. But the columns were proven to have certain shortcomings such as ageing of structures, corrosion of steel tubes. Therefore, the implementation of strengthening techniques with the new material is essential to eliminate this problem. Fibre reinforced polymer (FRP) can be used as an external reinforcement to strengthen the structure. Although significant research has been underway on advanced analysis for many years for better understanding of the behaviour of CFDST columns wrapped with FRP , the results of these various research works are scattered and unevaluated. Hence, a transparent understanding of more recent work on CFDST column is highly desired. The main objective is to give a clear vision about the CFDST column. This study would enable structural engineers for better understanding of the behaviour of CFDST column externally reinforced with FRP composites.*

Key Words: CFDST, FRP

INTRODUCTION

Composite columns are widely used in the construction of modern buildings, even in the regions of high seismic risk. Composite columns combines the advantages of both steel and concrete namely light weight and high strength of steel, speed of construction and stiffness, damping and inherent mass of concrete. Composite columns are of different forms: steel encased concrete section, concrete filled steel tubular section, concrete filled FRP tube, steel reinforced concrete section, concrete filled double skin tubular column (CFDST).

Concrete Filled Steel Tubes (CFSTs) are composite members consisting of a steel tube infilled with concrete. Concrete Filled Tubular (CFT) columns are mainly used in the primary lateral resistance systems of both braced and unbraced building structures. The CFT structural member has a number of distinct advantages over an equivalent steel, reinforced concrete, or steel-reinforced concrete member. The orientation of the concrete and steel in the cross section optimizes the stiffness and strength of the section. The steel lies at the outer perimeter where it performs most effectively in tension and in resisting bending moment. The steel has a much higher modulus of elasticity than the concrete and is situated farthest from the centroid. This makes the greatest contribution to the moment of inertia. As a result the stiffness of the CFT is increased. The concrete forms a core to resist the compressive loading and it delays and often prevents local buckling of the steel, particularly in rectangular CFTs. The confinement of concrete core by steel increases the compressive strength and ductility for circular and rectangular CFTs respectively. Therefore, it is most advantageous to use CFTs for the columns subjected to the large compressive loading. In comparison with reinforced concrete columns with transverse reinforcement, the steel tube also prevents spalling of the concrete and reduces congestion of reinforcement in the connection region, particularly for seismic design.

CFDSTs are structural members that have a double steel skin with concrete sandwiched between the two steel tubes. These structural elements can be concrete-filled double-skin rectangular tubes (CFDSRTs), concrete-filled double-skin circular tubes (CFDSCTs) or concrete-filled double-skin rectangular-circular tubes (CFDSRCTs). Similarly to CFTs, these members are economical and quicker to construct than conventional concrete-reinforced columns because the steel tube serves as form-work. This means that high rise buildings can be completed swiftly when CFDST columns are used. The concrete fill prevents the outer steel tube from buckling inwards whilst the steel prevents the concrete from deforming laterally, under compressive loads. CFDST columns have structural benefits similar to CFT columns. In addition they are lighter, stronger and possess better energy absorption.

From structural point of view, this form of column has higher strength (uni-axial, flexural and torsion). By replacing the central concrete with a steel tube of much smaller cross-section area, the strength-to-weight ratio of the columns is improved significantly. Furthermore, the inner tube expands laterally during compression and hence improves the confining pressure provided to the concrete. Thus, the initial confining pressure builds up more rapidly than that in CFST columns that enhances the elastic strength and stiffness. From environmental point of view, CFDST column uses less concrete, which creates a more sustainable environment by reducing the embodied energy levels of the column. From cost effectiveness point of view, the tubes act as both the longitudinal reinforcement and form work that save the construction cost and cycle. Lastly, the cavity inside the inner tube provides a dry atmosphere for possible catering of facilities or utilities like power cables, telecommunication lines and drainage pipes. This form of construction is particularly useful for maritime structures, in which the sub-sea facilities can be accommodated in the dry atmosphere. Double-skin composite structures have also been adopted in an alternative form of sandwich structures, in which concrete is filled between two steel plates. None the less, this type of structure is seldom adopted in columns as the panels are not closed sections that limit the confining pressure provided to the concrete. Instead, this type of member is more popular in horizontal flexural members where the compressive axial load is not significant.

In recent years, many steel and CFDST structures have been found to be suffering from a variety of deteriorations, including cracking, yielding and large deformation. These deteriorations are caused by a variety of factors, including fire, ageing, environmental degradation and corrosion. Above all, during an earthquake, many structures, even if they do not collapse, are damaged to some extent. Hence, these structures require armor to support the designed load, or even furbishing to resist possible higher loading. There are several strengthening or rehabilitation techniques that can be applied to enhance performance, including section enlargement, external bonding using steel plates and fibers, among others. The external strengthening of structures using steel plates had some problems due to the addition of weight, corrosion of the steel plate, the need of skilled labor and the higher cost. In contrast, use of fibre reinforced polymer (FRP) composites for rehabilitation does not have any of these drawbacks. One of the main forces driving the development of external strengthening methods that uses the FRP composite is that they enable deteriorated members to be upgraded without significantly altering the appearance of the member. In addition, FRP composites are light weight, durable, and resistant to corrosion, and have high tensile strength, stiffness and fatigue strength. In recent years, there have been many investigations on the use of FRP to strengthen the steel structures emerged, particularly in the area of thin-walled steel structures.

LITERATURE REVIEW

Concrete-filled double-skin circular tubes (CFDSCTs) are a recent development, with most research having been performed in China in the last two decades. Research about these structural elements has also been conducted in Australia, Egypt, Japan, Singapore and the United States of America. Various literature reviewed on CFDST column is presented in this section. A number of works have been carried on the behavior of CFDST column. A review of literatures is summarized in brief by various scholars and researchers on CFDST columns.

Lin-Hai Han et al (2012), conducted a study on the behavior and calculations of Concrete-Filled Double Skin Steel Tubular (CFDST) Members. In this paper, the study of members subjected to dynamic and static loading, long term loading effects, fire performance and residual strength after exposure to fire are conducted. Based on the results obtained from this study, it was found that the CFDST generally demonstrates a similar behavior as that of a CFST, when the hollow ratio of a CFDST is within the normal range of 0 – 0.5, whereas the fire resistance of the CFDST is superior to that of the latter.

Jun wang, ding zhou,(2014) conducted a detailed investigation on the mechanical behaviour of concrete filled double skin steel tubular (CFDST) stub columns confined by fiber reinforced polymer (FRP). In this study, a series of axial compression tests were conducted on two CFDST stub columns, eight CFDST stub columns confined by FRP and a concrete-filled steel tubular (CFST) stub column externally reinforced with FRP, respectively. The influences of hollow section ratio, FRP wall thickness and fibre longitudinal-circumferential proportion on the load-strain curve and the concrete stress-strain curve for columns with annular section were discussed in this paper. The test results point out that the FRP jacket can obviously enhance the carrying capacity of columns. Based on the test results, a model which includes the effects of confinement factor, hollow section ratio and lateral confining pressure of the outer steel tube was proposed to calculate the compressive strength of confined concrete. This paper also derived the formula to predict the carrying capacity of CFDST stub columns confined by FRP. It was found that the theoretically predicted results agree well with those obtained from the experimental and FE analysis.

J.C.M. Ho, C.X. Dong (2013) this paper focuses on Improving the strength, stiffness and ductility of CFDST columns by external confinement. In this study, a series of uni-axial compression test were performed on CFDST columns with external steel rings. This paper point out that the elastic strength, elastic stiffness and ductility were enhanced by installing the steel rings as external confinement. A theoretical model for predicting the axial strength of confined CFDST columns was also developed in this study.

Jin-Kook Kim, Hyo- Gyoung Kwak (2013) studied about the Behavior of Hybrid Double Skin Concrete Filled Circular Steel Tube Columns (HDSCF). In this study, a feasibility study on reducing the thickness of the tube below the specified design codes for CFTs was conducted based on an experimental approach. The variables such as thickness of the inner tube, hollow ratio, and strength of concrete were taken into consideration to investigate the behavior of the HDSCF column. In order to estimate the applicability of design equations of CFTs for HDSCF column, test results from CFT and HDSCF columns with design codes were compared. From the journal, it was found that the axial compressive performance of the proposed HDSCF column is equivalent to that of the CFT member irrespective of design variables.

Y. Essopjee, M. Dundu (2015) studied about the performance of concrete-filled double-skin circular tubes in compression. The parameters that were varied were the lengths, diameters and strength of the outer steel tubes. Two types of failure were found in the study. It was found that the compressive capacity of the CFDSCTs decreased, when the column lengths were increased and the strengths also increased as the diameters were increased. In this study, new formulae were developed to predict their axial compressive capacity.

G. Ganesh Prabhu, M. C. Sundar raja (2011) studied about the Compressive behavior of circular CFST columns externally reinforced using CFRP composites. In this paper, the feasibility analysis of CFST column member strengthened with CFRP strips under axial loading were conducted. The experimental parameters includes the spacing between the CFRP strips (20and30mm) and number of CFRP layers (one, two and three layers). From the journal it can be concluded that the bonding of CFRP composites effectively delayed the local buckling of the columns and the axial deformation is also reduced by providing a confinement / restraining effect against the elastic deformation at both spacings. This paper point out that the confinement effect provided by CFRP composites increased with the increase in the number of layers; however, the enhancement in buckling stress was not proportional. It was found that the load carrying capacity of the column showed a great improvement with the application of CFRP strips, by up to 30% compared to that of un- strengthened column. From the study it can be concluded that the application of CFRP strips at a spacing of 20 mm or 30 mm is suitable for improving the strength of a CFST circular column member; however, the application of strips at intervals of 30 mm recommended as an economical approach to strengthening compared to the 20 mm spacing. This paper also proposed an analytical equation to predict the load carrying capacity of the CFRP strengthened CFST column, and the average difference between the calculated and experimental value was found to be 75%.

Aritra Mandal (2008) conducted a study on the Concrete filled steel tube under axial compression. The experimental behavior of short Concrete Filled Steel Tubular Columns (CSFT) under axial compression was studied in this paper. An analytical study was also conducted to compare with the experimental results. Test results and theoretical results were compared and obtained using ACI , LFRD and EC4 code of practices. In this study, linear analysis was done by FEM model using ABAQUS software to obtain stress distribution and deflection pattern. The obtained ultimate load carrying capacity was compared with experimental results.

De Nardin and El Debs (2007) conducted an experimental study on concrete filled steel tubular columns. The main parameters included were cross-sections, steel tube thicknesses. From the journal, it is observed that the circular specimens presented an overall instability and no sign of local buckling was recorded in the stages of loading. It can be concluded from the study that the confinement effect on the square section is more effective than that of the rectangular sections, therefore they show greater ductility in the post-peak behaviour.

SUMMARY AND CONCLUSION

A concise review of different literatures presented shows that that there has been a number of published work on the study of Concrete Filled Double Skin Steel Tubular (CFDST) column. The different variations in parameters such as length, diameter, strength of outer steel tube, hollow section ratio, spacing of FRP strips, number of FRP layers and FRP wall thickness were studied. It is understood that the CFDST columns exhibited higher strength, higher bending stiffness, good seismic and fire performance compared to the CFST columns. Results based on CFDST column wrapped with FRP are scattered and unevaluated, hence there is a future scope of research on this area.

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