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Research Article

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Comparative Study on Axial Load Behaviour of CFST Columns with Different Stiffeners

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ABSTRACT

Concrete-filled steel box column is widely used as a major structural element in tall buildings as it provides efficient structural performance in resisting axial compression. The concrete core adds stiffness and compressive strength to the tubular column. The steel tube acts as longitudinal and lateral reinforcement for the concrete core helping it to resist tension, bending moment and shear and providing confinement for the concrete But when the slenderness ratio of the plate is large, box columns fails under local buckling. From the past researches, it is also found that the thin walled sections are less stiffened. To overcome these defects, different types of stiffeners should be used inside the tube section. Thus, there is a need to investigate of the structural behavior of concrete filled thin walled steel tube column with different type of stiffeners, to increase stiffness and to reduce the local buckling failures. In this research, the effects of five different types of stiffeners were investigated experimentally and the results were compared with the column without stiffeners. Stiffeners were attached to the columns by using weld connections. From the results, it was observed that the stiffener enhances both the axial load carrying capacity and stiffness of the concrete filled thin walled steel tube columns.

Keywords: Concrete filled tubes; Thin walled column; Stiffeners

INTRODUCTION

Concrete filled steel tubular (CFST) column is a structural system with excellent structural characteristics, which resulted from the confinement provided by the steel tube to the concrete core. However, this confinement is not very effective in a square section as compared to that of a circular section. Therefore, when a thin walled square steel section of CFST is used, a stiffening method is desirable. There are several types of stiffening methods available for use in CFST columns like welding longitudinal stiffeners on the inner surfaces of the steel tube, inserting shear studs in the steel tube and by using either tie bars or restraining rods to strengthen the plastic zones of the CFSTs. The previous studies demonstrated that the longitudinal stiffeners effectively delay the local buckling of the tube, increase the sectional capacity and improve the lateral confinement of the concrete core. However, they did not significantly influence the ductility of the stiffened CFST specimens. The shear studs function as shear connectors to ensure reliable stiffness of the composite cross section even in the region of elastic behavior. This stiffening scheme primarily aims at enhancing the ultimate strength of the steel tube and improving the bond between the steel tube and concrete core interface. However, the shear studs only enhance the ductility of square CFT columns but they contribute nothing to the strength. The literature study indicates that strength and ductility are equally important in CFST stiffening design. A CFST stiffener that possesses both characteristics is still lacking, therefore further study in this area is desirable.
This paper presents an experimental investigation on the axial load carrying capacity of concrete filled thin walled tubular columns with various stiffeners. The main purpose of this stiffening method is to increase the ultimate load carrying capacity, to improve the ductility and also to overcome the shortcoming of weak concrete confinement at the center of the sidewalls of the steel tubes [1-8].

Stiffeners Used in the Study
Longitudinal Stiffeners are attached to CFT Columns to increase the local buckling strength of thin walled skin.

A series of parametric studies was performed to characterize and quantify the collected data analytically. A new equation for the minimum required moment of inertia for the longitudinal stiffeners was derived. Through the evaluation of a few selected case studies and a design example, the validity and reliability of the proposed equation was demonstrated. To increase the column stiffness the various types of stiffeners are used as shown in Figure 1.

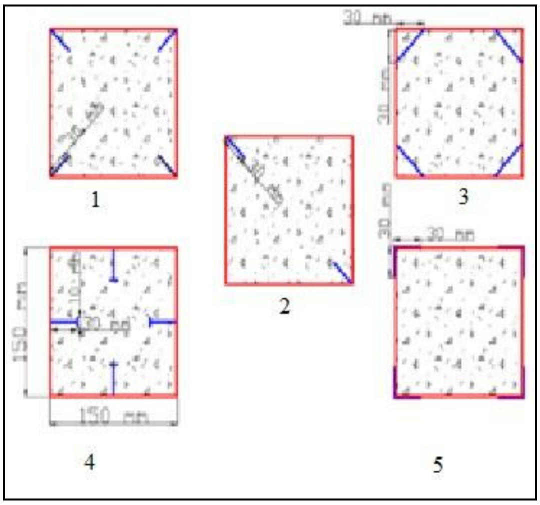

Figure 1: Type of stiffeners

EXPERIMENTAL SECTION

General

In the experimental study, six square specimens with various stiffeners were prepared. All the specimens were subjected to compression test, to determine the axial load capacity. The primary parameter studied was the behaviour of different types of stiffeners in CFST columns. The specimens are square shaped with an overall width (B) of 150 mm, height (h) of 600 mm, thickness (t) of 1.25 mm and average yield strength (fy) of 250 MPa. According to the design code, the slenderness of the walls must satisfy the limiting value of B/t to avoid local buckling of the steel. The limiting value of B/t for CFTs is given in equation 1.

$$B/t \geq 52\sqrt{\frac{235}{fy}} \quad (1)$$

According to this equation, the slenderness limit of all the specimens is 120. However, a width-to-thickness ratio (B/t) of all the specimens in this study is 120; all specimens were considered to be thin walled sections. A stiffening measure was taken to compensate for the local buckling effects of the thin walled tubes. The length of each specimen is chosen to be three times the height of the square thin walled steel columns to avoid the effects of overall buckling and end conditions.

Mix Design

The basic raw materials used in the Concrete Filled Steel Tube with columns are Ordinary Portland Cement of 53 grade, Fine Aggregate confirming to zone II, Coarse Aggregate of size 10mm and below, water, class F fly ash, and Conplast SP 430. Self-Compacting Concrete is used as an infill to avoid external vibrations requirements for the compaction of concrete. The Mix design was done by ACI method. For the test trial M30 grade self-compacting concrete with water cement ratio 0.4 and mix proportion 1:1.3:2.1 was used. Based on EFNARC acceptance criteria, the filling and flowing ability of concrete is investigated by slump flow test V-funnel test, L-box test and U-box test. The slump value of concrete obtained from the experiment was 600 mm, the flow time in V-funnel test was 6 seconds, the value of (h_1/h_2) in L-box test was 0.876 mm and the value of (h_1-h_2) in U-box test was 5.26. It was observed that all the values satisfy the EFNARC guidelines.

Casting and Curing of Specimens

The six columns in the study were divided into two sets A and B. Set A contains one column without stiffener with an ultimate load carrying capacity of 240 kN. Set B contains five columns 2, 3, 4, 5 and 6 with an ultimate load carrying capacity of 540 kN, 300 kN, 420 kN, 360 kN and 800 kN respectively. The specifications of different columns under study are given in Table 1. The outer mould of the CFST column was made using mild steel sheets with different stiffeners as shown in Figure 2. Before casting, machine oil was applied on the inner surface of the mould. Concrete was mixed using a tilting type laboratory mixer and was poured into the moulds.

Table 1: Column specifications with stiffeners

Column No	Type of Stiffener
1	Internal Stiffener at 4 corners
2	Internal Stiffener at 2 opposite corners
3	Diagonal Stiffener at 4 corners
4	Intermediate Stiffeners at 4 phases
5	External Stiffener L-angle type at 4 corners

Standard cubes of size 150×150×150 mm were also casted to test the strength of the self-compacting concrete at 3 days, 7 days and 28 days of curing period. The typical samples of cubes were shown in Figure 3. The characteristic compressive strength of concrete obtained at 3 days, 7 days and 28 days were 23.85 N/mm^2, 27.26 N/mm^2 and 38.23 N/mm^2 respectively. The typical samples of cubes and columns were shown in Figure 2. After casting, the specimens were covered with gunny bag and left for curing for 28 days.

Figure 2: Steel tube mould with stiffeners

Figure 3: Typical sample of cubes and columns

Testing of Specimens

The Specimens were tested in Compression Testing Machine. Strain gauge strip was placed at top, bottom and middle of the specimens. All Strain gauge strips are directly connected to data logger, to which the strain indicator was connected. Dial gauge was fixed to the bottom of the specimen. Axial load was constantly applied through the hydraulic jack. The column was subjected to a constant deflection till the ultimate load was reached. For every 20 kN increase in load, deflection and strain values were noted using dial gauge and strain gauge strip respectively.

RESULTS AND DISCUSSION

From the experimental investigation, the values of stress, strain and deflections of six columns were noted down at every 20 kN interval of load and the values were tabulated. During the testing of specimen pre deflection behaviour, post deflection behaviour was also studied. The first buckling appeared at one of the top or bottom faces of the column and slowly propagates to the entire depth of the face. After cracking, concrete behaves as a nonlinear discontinuous medium forming a truss action in which steel box acts as a tensile link and concrete as a compression diagonal. Due to the self-weight of the column, deflections occur before the application of the load. To study the post deflection behavior, the deflection and strain values were noted using dial gauge and strain gauge strip respectively. From the observed data, the stress strain graph and the load deflection graph were created and shown in Figure 4.

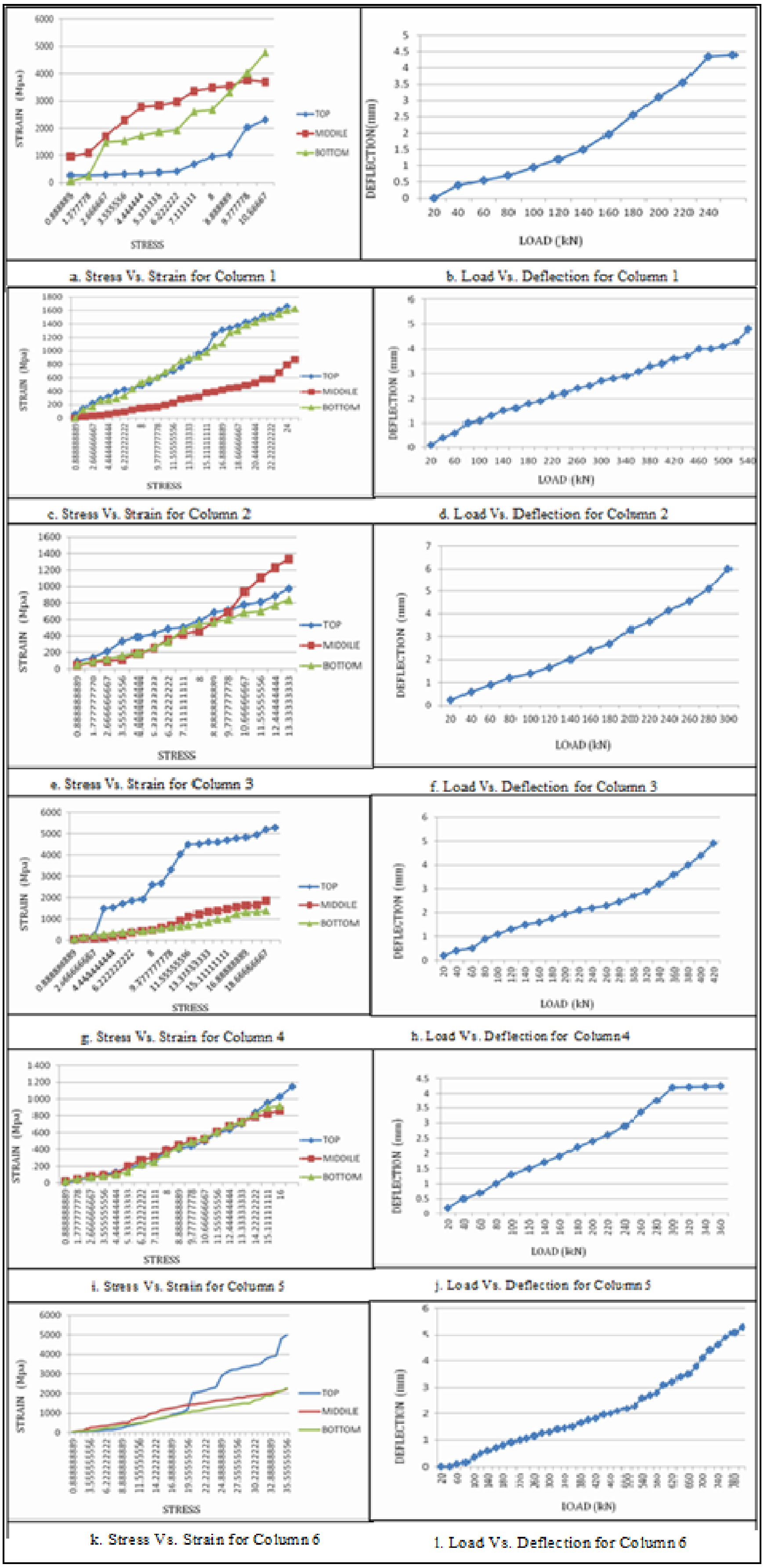

Figure 4: Stress strain graph and load deflection graph for six column types

CONCLUSION

In this study, the axial load behavior of six columns with different stiffeners was studied experimentally. Based on the results, it was observed that the ultimate load carrying capacity of composite column with various stiffeners shows increased load carrying capacity by 2.25, 1.25, 1.75, 1.5 and 3.33 times more than the composite columns without stiffeners. Also the maximum deflections of the columns 1, 2, 3, 4, 5 and 6 are 4.4 mm, 5.2 mm, 6 mm, 4.9 mm, 4.25 mm and 5.3 mm respectively. It is also observed that the CFST column with External L-angle stiffener at 4 corners shows improved performance than the other stiffeners.

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