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Study on Concrete Filled Steel Tube Columns Reinforced with Diagonal Stiffener

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Abstract: *In modern construction use of composite sections such as CFST columns was improved because of their numerous benefits in construction processes. In this study, a novel stiffening scheme was proposed to use with unstiffened CFST column. The stiffening scheme is named as diagonal stiffeners which comprises diagonal stiffeners attached at diagonally opposite ends of steel tube. The stiffeners can be provided in three formats viz, binary, tertiary, and quaternary arrangement. In this paper the response of diagonal stiffeners CFST columns under axial compression was investigated through experimental program Additionally, to assess the performance of the proposed stiffener arrangement, a finite element model were developed using ANSYS software and validated against experimental results. The study's findingsdemonstrated that, compared to unstiffened CFST sections, CFST columns strengthenedwith the suggested stiffening arrangements had an ultimate load capacity that was roughly 20% higher. The column section's strength increased and the local buckling of the exterior steel casing was removed. It was concluded that stiffened CFST columns improved the composite interaction between the infill concrete and the outer steel casingand provided better confining pressure on the concrete.*

Key Word: *CFST column, Ultimate loading capacity, Stiffener.*

I.INTRODUCTION

Concrete-filled steel tube (CFST) columns are becoming more and more popular in contemporary construction projects because of their many advantages over conventional steel and concrete constructions. These benefits include superior mechanical properties, load-bearing capacity, and resilience against seismic activity, as well as a reduction in localized steel buckling and efficient prefabrication. CFST columns have become a prominent choice in various structural applications such as skyscrapers, bridges, and other architectural elements. In contrast to conventional steel columns, CFST columns utilize a combination of an outer steel casing providing axial support and confining pressure to the concrete core, which in turn bears the axial load and prevents localized buckling of the steel tube. Moreover, the absence of the need for formwork during construction lowers the overall cost of constructing composite columns filled with concrete. One common approach to mitigating local buckling issues in thin-walled CFST columns is the use of stiffeners, which improve the structural reliability of steel tubes in buildings and serve as a conventional solution to this challenge. The main objective of this project is to evaluate the structural performance of CFST column with diagonal stiffeners placed in different arrangements such as binary, tertiary, and quaternary configurations and the type of diagonal stiffener used is steel bar. The results of these experimental studies were then validated through numerical investigations conducted using ANSYS software.

II.EXPIREMENTAL PROGRAM

2.1 Test specimen

Fig. 1. Cross section of CFST column with steel bar stiffener

Multiple test specimens were casted and a series of experiments were carried out to assess the performance of the circular diagonal stiffened CFST column section under uniaxial compressive loads. A steel tube with a diameter of 150 mm and a thickness of 3 mm and length of 150 mm was used to evaluate the axial compressive behaviour of CFST specimens with diagonal stiffener as steel bar with a diameter of 6 mm. As indicated above, the diagonal stiffeners were available in binary (2-stiffener), tertiary (3-stiffener), and quaternary (4-stiffener) designs. The connection was established by welding the diagonal stiffeners to the steel tube using plate support in steel bars.

2.2 Material properties

Compression experiments on three cubical specimens measuring 150 mm × 150 mm × 150 mm were used to determine the compression behaviour of concrete. The mix of concrete utilised was M20, and the concrete mix was prepared and poured in a cubical mould. The cubes were cured for 28 days, and the findings of the compression test revealed the cube strength as 25.65 N/mm^2. The steel tube used is having a yield strengthof 294.5 N/mm^2.

2.3 Test setup and measurement

Axial compression studies were performed on column specimens utilizing universal testing equipment (UTM) capable of exerting a force of 1000 kN. The specimens were placed between the UTM's base and loading frame, with their vertical axis aligned with the axis of the applied load. To achieve complete contact with the loading platen, the columns' terminal surfaces were levelled. LVDTs were installed to record the column'saxial shortening.

III. EXPIREMENTAL RESULTS AND DISCUSSION

Table 1. Experimental result of CFST column specimens

Specimen	Deformation (mm)	Ultimate load (kN)
S0	1.4	716
S2	1.2	780
S3	1.2	815
S4	1	868

(a) S2 *(b) S3* *(c) S4*

Fig.2. Failures of specimens with steel bar as stiffener

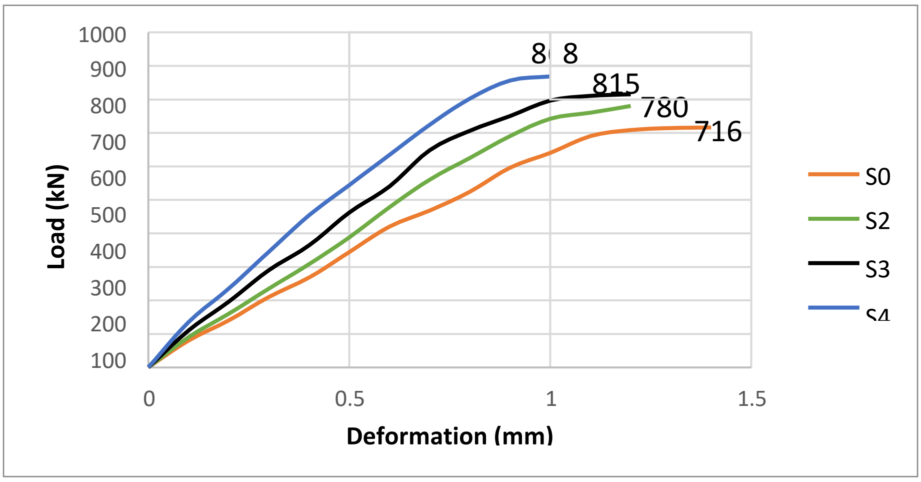


Fig. 3. Load vs Displacement curve of steel bar stiffened columns

After loading it observed a failure pattern of localized buckling in the un stiffened specimen because of poor confining effect of expanding concrete and the steel tube. The results of stiffened specimens shows that the inclusion of stiffeners increased the confining effect of the concrete and the bonding between steel tube and concrete allowed the specimens to take higher loads. Among the arrangements of stiffeners quaternary arrangement showed a 21% increased load carrying capacity than control specimen while compared to other arrangements.

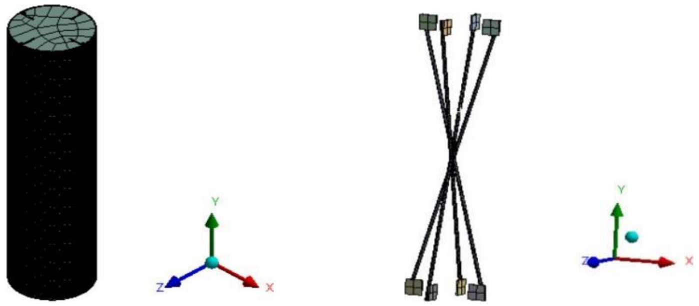
IV. FINITE ELEMENTS ANALYSIS

The effectiveness of diagonal stiffeners in CFST columns under axial compression was assessed using experimental methods. To further analyse the response of the proposed column section, a numerical study was carried out in this part with the numerical simulation software ANSYS. IT is a finite element analysis software that provides structural analysis solutions for engineers of various levels and backgrounds, allowing them to handle complicated structural engineering issues more quickly and efficiently.

4.1 Boundary condition and element division

Boundary conditions were used to enforce assembly loading. The bottom end plate was restrained in translation and rotation in all three axes directions, while the top end plate was only restrained in translation and rotation in the x and z axes. The top end plate is free to move in the vertical direction. Because of the varying part sizes, the mesh size and element division for each part of the diagonal stiffeners CFST section varied. Consider two mesh sizes: 25 mm for steel tubes and concrete sections, and 10 mm for diagonal stiffeners.

4.2 Modelling



(a) *(b)*

Fig. 4. Modelling of CFST column and steel bar as stiffener

4.3 Result and discussion

Table 2. Analytical result of CFST column specimens

Specimen	Deformation (mm)	Load (kN)
S0	1.4	740
S2	1.2	805
S3	1.2	837
S4	1	901

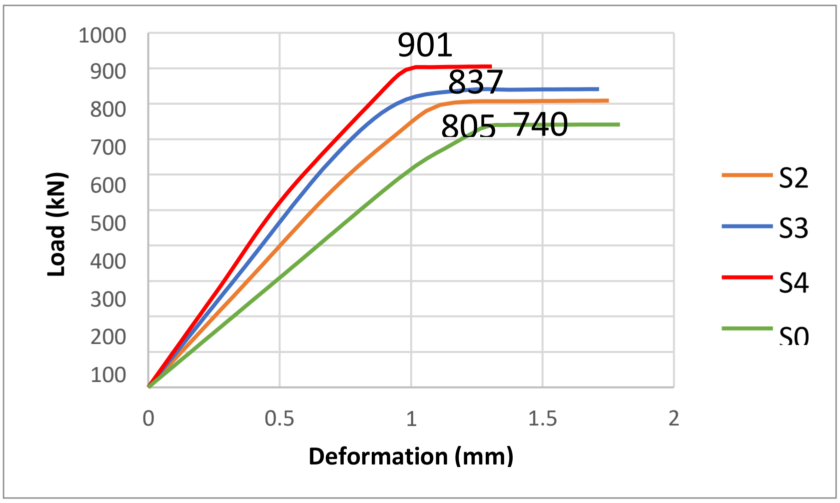


Fig. 5. Load vs Displacement curve of steel bar stiffened columns

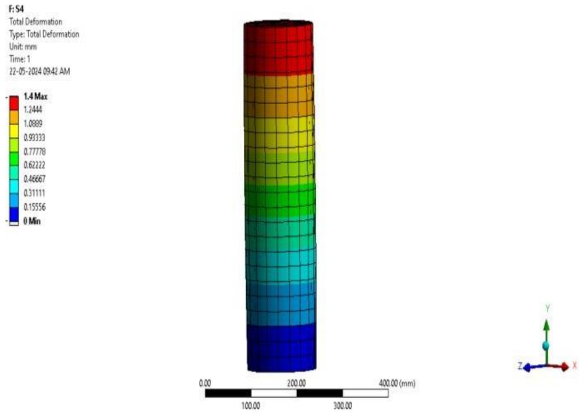


Fig. 6. Total deformation of steel bar stiffened CFST column

Analytical study showed almost a similar result to experimental study were among the arrangements quaternary arrangement showed a 21.7% increased load carrying capacity than control specimen compared to other arrangements. Small variations are caused dueto environmental variations.

V.CONCLUSION

An experimental and numerical study was carried out in this investigation to evaluate the axial load-carrying ability and performance of the proposed diagonal stiffeners CFST column section subjected to concentric loading. The results of experimental study were validated via FEM analysis of proposed stiffened section. After performing the analysis, noticeable points had concluded below:

- The use of diagonally stiffening scheme enhances the load-carrying capacity of CFST columns, allowing them to take higher loads.
- The un stiffened specimen failed due to localized buckling caused by the steel tube's poor confining effect on expanding concrete. The addition of a diagonal stiffening scheme involving the stiffeners stiffens the CFST columns and resists the forces that cause local buckling in the column.
- In both stiffening schemes among the arrangements of stiffeners quaternary arrangement showed a 21% increased load carrying capacity than control specimenand observed better performance than other arrangements.
- The recommended stiffening system can be simply implemented inside the CFST column section without cutting or drilling holes in the steel tube, resulting in a fasterconstruction process and improved column strength.

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