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ANALYTICAL STUDY ON RECTANGULAR AND CIRCULAR SECTIONS OF VHS-STEEL SECTION STUB COLUMNS

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Abstract - *Nowadays researchers are continuously looking for better and efficient materials for construction. An answer to their research is Concrete Filled Steel Tubular (CFST) columns. It is an innovative design by attaching steel tubes at the vertices. The steel encasing eliminates the use of formwork by acting as its formwork during construction. VHS steel of nominal yield 1350 MPa is used as material for tubes and facet plates. Very high strength steel (VHS) was used in columns to increase their load-carrying capacity. In this paper a parametric study is conducted to check the load-deflection behavior of samples with variation in breadth to thickness (B/T) ratio. Finite element models are created to evaluate the load-deformation behavior of the fabricated columns well with the peak strength and post-peak behavior. For validation, a square section VHS Steel stub column was considered, finite element analysis of the square section VHS steel stub column was conducted in ANSYS. From the study, it was found that minimum deformation is for the circular sections and therefore it can be concluded that they are more efficient in carrying the axial loads.*

***Key Words*: Very high strength steel (VHS), Concrete Filled Steel Tubular columns, high strength steel, Finite element analysis**

1. INTRODUCTION

CFT columns have several advantages over conventional reinforced cement concrete (RCC) columns as they eliminate the use of formwork the steel encasing acts as its formwork during construction. Various innovative ideas have been implemented in refining the shape of the steel encasing, due to its molding flexibility. Innovative design by attaching steel tubes at vertices was considered for this investigation. The use of very high strength materials is currently being researched as how to scale back material use and improve sustainability. VHS steel of a nominal yield of 1350 MPa is employed as a material for tubes and facet plates.

At present, VHS tubes have typically found their application in the automotive and mechanical industries where they are used as side door impact bars. To provide better corrosion resistance and structural response, materials of stainless steel and aluminum and section type of concrete-filled double skin tube, T-shape and L-shape have been used in optimizing CFST specimens.

CFST columns have been increasingly used all over the world due to their inherent advantages, and in particular because of their favorable behavior under seismic loads. A previous study on VHS members revealed that VHS tubes meet the ductility requirements specified in the current steel design standard. Stub columns especially CFT columns find their application in bridges and offshore structures. Studies have been conducted on a square and triangular-shaped CFST stub columns, but lack of researches conducted on rectangular and circular shaped CFST stub columns lead to this investigation. The yield of the columns should increase if the mild steel plates are replaced with VHS steel plates and this act as the main objective of this investigation.

2. LITERATURE REVIEW

Nabi and Elavenil et al., (2018) conducted a study on very high strength steel stub CFT columns of a square and triangular-shaped sections and found that there is improvement in the failure load for both square and triangular sections.

Mashiri et al., (2014) conducted a study on stub columns with high strength (VHS) steel tubes and plates. This study shows that there's a benefit in concrete confinement through the utilization of higher-strength steel facet plates.

Evirgen et al., (2014) studied hollow cold-formed steel tubes and concrete-filled steel tube specimen models of circular, hexagonal, rectangular, and square sections. It was found that circular specimens are the most effective samples according to both axial stress and ductility values.

Tailor et al., (2017) conducted a studied the seismic performance of CFST columns by analysis of a G + 19 storied building. It was found that seismic performance of the Concrete-Filled Steel Tube (CFST) column frame was better than the steel frame.

Shuai Li et al., (2018) conducted a study on the analytical behavior of concrete-encased concrete-filled steel tubular members under the combined effects of compression and torsion using a finite element model established in ABAQUS. It was found out that CFST ratio have most influence on the behavior of concrete-encased CFST.

3. FINITE ELEMENT MODELING AND ANALYSIS

Transient structural analysis is carried out in ANSYS. A total of 8 models were taken for the analysis including 4 rectangular models and 4 circular models. To approximate the yield behavior of samples in FEA, defining the interaction of surfaces of steel encasing and concrete core is decisive. For this behavior, the Drucker–Prager model, Drucker and Prager (2003) were used for concrete.

3.1 RECTANGULAR CONCRETE FILLED STEEL COLUMN SECTIONS

3.1.1 Material and Section Properties

Steel

The very high strength (VHS) steel was used for both facet plates as well as tubular sections. The density of the steel was taken as 8.6e-9 tonne/mm3. Young's modulus, Shear modulus and Poisson's ratio was taken as 200000 MPa, 77000 MPa, 0.3, respectively. Nominal yield for VHS-steel and nominal tensile yield were taken as 1350 and 1500 MPa.

Concrete

Concrete grade M30 was used with the ultimate capacity of 30 MPa. Concrete was modeled with Hex-dominated sweep eight nodal brick elements. The density of the concrete was taken as 2.60e-9 tonne/mm^3. Young's modulus was taken as 27386 MPa with Poisson's ratio of 0.2.

The dimension details of the VHS and CFST rectangular columns are given below in table 1.

Table -1: Details of rectangular VHS steel stub CFST columns dimensions

Test series FSTS	VHS steel tubes		VHS steel plates			Height mm
	D mm	T mm	B mm	T mm	L mm	
R1	38.1	1.6	80	3	101.25	300
R2	38.1	1.8	80	3	101.25	300
R3	38.1	1.6	100	3	225	500
R4	38.1	1.8	100	3	225	500

3.1.2 Boundary Conditions

The boundary conditions were provided such as fixed support at the bottom and remote displacement at the top.

Remote displacement was provided along with coupled behavior to keep concrete and steel bonded together to move uniformly when a load is applied.

3.1.3 Loading and Analysis

The magnitude of force was given as tabular data corresponding to the time step of 10s. That is a range of 0 to 5e+006N was given for 0 to 10 s time steps. Figure 1 shows the rectangular section VHS steel stub column model created for the analysis in ANSYS. Model R1 is shown in the figure.

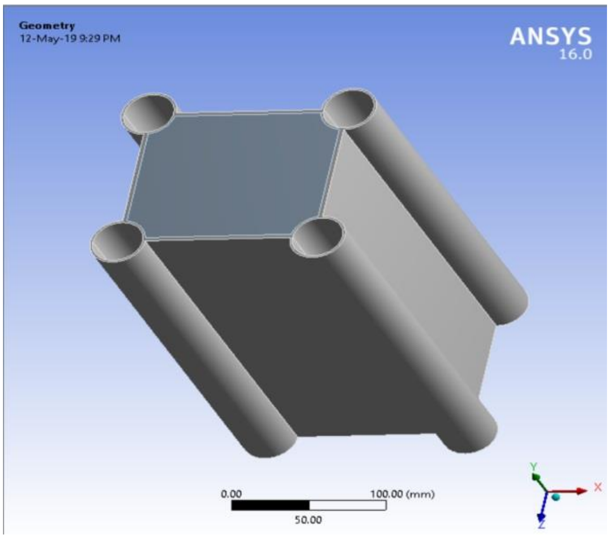

Fig 1: Model R1 of VHS steel stub column

3.1.4 Results Obtained

The analysis was carried out and the deformation results of each of the rectangular models are given below in table 2. The figure 2 shows the total deformation result.

Table -2: Table representing maximum value of deformation and corresponding D/T ratio

Model	D/T	Max. Value of Axial Deformation
R1	26.66	3.0808
R2	26.66	2.8464
R3	33.33	4.6213
R4	33.33	3.1911

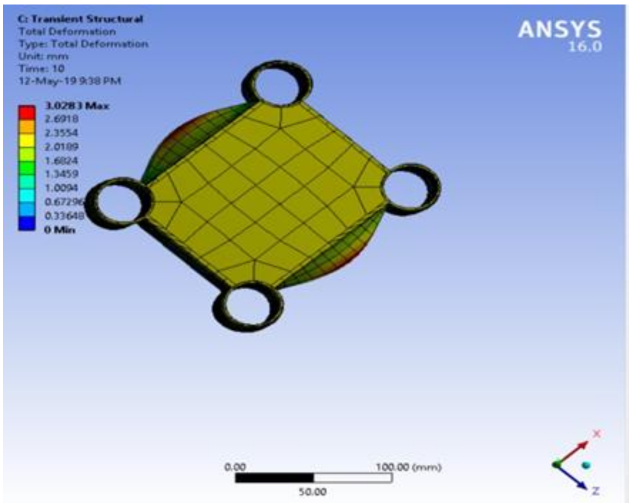

Fig 2: Total deformation value obtained by R1

3.2 CIRCULAR SECTIONS OF VHS STEEL STUB COLUMNS

Finite element analysis of a very high strength steel circular stub concrete-filled tubular (CFT) column was also conducted in ANSYS.

3.2.1 Material and Section Properties

VHS steel of 1350 MPa was used as material for steel tubes and facet plates. The VHS steel tubes were of 38.1mm diameter and a variation was given for the thickness of the steel tubes as 1.6 mm, thickness for C1 and C3, 1.8 mm thickness for C2 and C4. The thickness of the facet plates was kept constant as 3 mm.

The volume of Circular sections C1 and C2 were taken as 11250000mm^3. The diameter 101.554mm of the circular section was computed from this volume by assuming the height of the column as 300mm. The volume of the other two Circular sections C3 and C4 are taken as 2430000mm^3. Similarly, the diameter 169.256mm of the circular section C3 and C4 were computed from this volume by assuming the height of the column as 500mm. Table 3 given below shows the dimension details of the circular VHS and CFST column models.

Table -3: Details of Circular VHS steel stub CFST column dimensions

Test series FSTS	VHS steel tubes		VHS steel plates		Properties f_y in MPa	Height in mm
	d mm	T mm	D mm	T mm		
C1	38.1	1.6	101.554	3	1350	300
C2	38.1	1.8	101.554	3	1350	300
C3	38.1	1.6	169.256	3	1350	500
C4	38.1	1.8	169.256	3	1350	500

The figure 3 given below shows the circular VHS steel stub column section. Model C4 is shown in the figure.

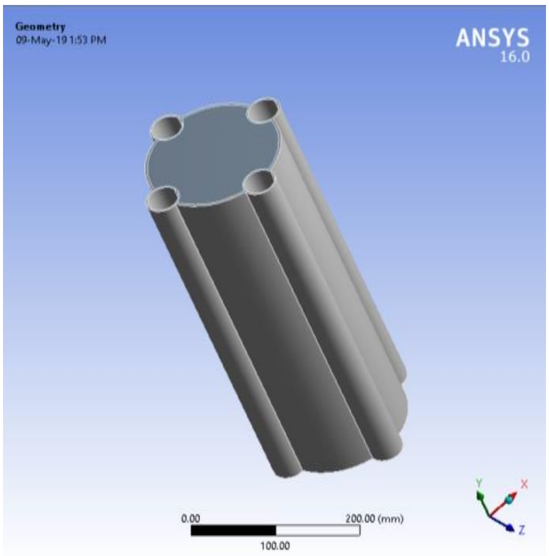

Fig -3: Model C4 of VHS steel stub column

3.1.2 Boundary Conditions

The boundary conditions were provided such as fixed support at the bottom and remote displacement at the top. Remote displacement was provided along with coupled behavior to keep concrete and steel bonded together to move uniformly when a load is applied.

3.1.3 Loading and Analysis

The magnitude of force was given as tabular data corresponding to the time step of 10s. That is a range of 0 to 5e+006N was given for 0 to 10 s time steps.

3.1.4 Results Obtained

The analysis was carried out and the deformation results of each of the circular models are given below in table 4. The figure 4 shows the total deformation result.

Table -4: Table representing maximum value of deformation and corresponding D/T ratio

Model	D/T (Diameter/ Thickness of steel plates)	Max. Value Of Axial Deformation
C1	33.85	6.4603
C2	33.85	6.2261
C3	56.42	2.7385
C4	56.42	2.7109

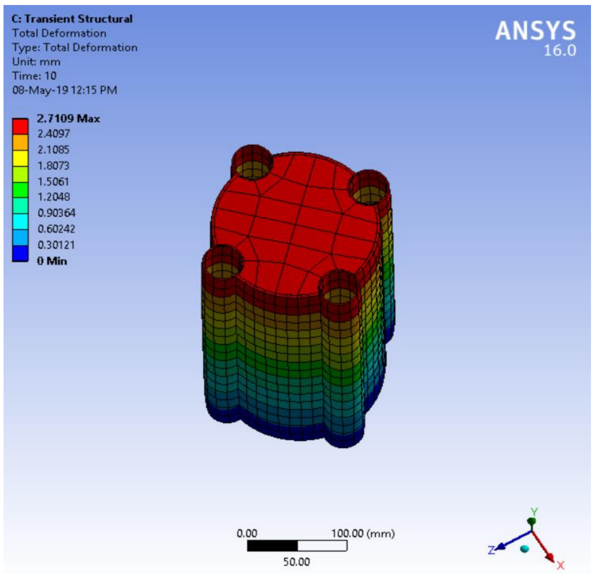

Fig 4: Total deformation obtained by C4

5. CONCLUSIONS

The breadth to thickness (B/T) of the steel facet plates was kept the same and thickness of steel tubes where varied. The rectangular section with larger dimensions and greater thickness of steel tubes showed lower value displacement when compared to other samples. Also, the Circular section with larger dimensions and greater thickness of steel tubes showed lower value displacement when compared to other samples. The circular Very High Strength steel stub columns are more efficient in taking up the load. They exhibit very little deformation compared to other sections.

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