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Numerical Analysis of Concrete Filled Steel Tube Column and Comparing Results with Euro Code

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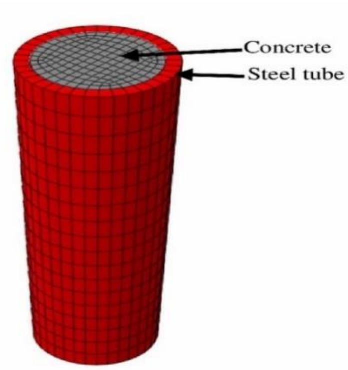
Abstract—*Structural elements that incorporate both concrete and steel are widely employed in contemporary construction practices. A prevalent technique in modern construction involves combining concrete and steel to create structural elements, which can be observed in the use of CFSTs for building columns and bridge piers. By conducting numerical analysis, this study aims to explore the behavior of CFSTs under axial compressive loadings. CFSTs are modeled using the finite element method, and the analysis is performed using ABAQUS software to investigate their behavior. Verification of the numerical models is achieved by comparing our results with available data from literature to ensure their accuracy. By investigating how varying parameters affect CFST behavior, this study examines the influence of factors like steel tube thickness, diameter/thickness ratio and concrete compressive strength. This study finds that the maximum load-bearing capacity of CFSTs is notably affected by the thickness of the steel tube and the grade of concrete. By investigating the behavior of CFSTs under axial loadings, this numerical analysis generates important findings that can inform the design of CFST columns and bridge piers for modern construction.*

INTRODUCTION

This numerical investigation sheds light on the behavior of CFSTs under axial loadings, revealing insights that can be applied in the design of CFST columns and bridge piers for modern construction, The exceptional ductility and enhanced resistance to multiple loads, such as axial compression, lateral loads, and seismic forces, make CFSTs a highly advantageous choice for modern construction projects. The use of concrete and steel in combination produces a composite material that leverages the advantages of both materials, resulting in an efficient and long-lasting structural system. The versatile nature of CFSTs has made them suitable for a variety of construction applications, including bridge piers building columns, and offshore structure. Therefore Understanding the behaviour of CFSTs under different loading scenarios is crucial to their successful design and implementation in modern construction. In recent times, the use of numerical analysis through the finite element method has become widely accepted for investigating the behaviour of complex structures such as CFSTs. When a compressive load is applied to the CFST, the concrete within the core undergoes lateral expansion, which is then confined by the steel tube. The passive confinement provided by the steel tube enhances both the ductility and strength of the CFST, leading to a synergistic composite action between the concrete and steel components.



LITERATURE REVIEW

Yahia Raad Al-Ani demonstrates the utilization of ABAQUS software for finite element analysis of circular CFST stub columns. The validity of the FE model is confirmed by evaluating the consistency between the results obtained from the FE simulation, the load-axial strain curves, and the failure load to the experimental results. To validate the proposed model, 382 previously tested data were used for comparison [1] . Ligui Yang investigated on the response of short concrete-filled corrugated steel tubular columns subjected to non-uniform confinement and eccentric compression. In order to examine the influence of confinement on the cross-sectional behavior, a total of 24 specimens were tested undern2 levels of confinement and 5 different load eccentricity ratios [2] .

Siqi Lin investigated behavior of high strength concrete-filled steel tube columns which are subjected to unequal end moments in an experimental setting [3] . Yong Zhu had done study on CFSTs which are subjected to impact loading [4] . Xi-Feng Yan had done both numerical and experimental study on circular sandwiched concrete which is axially loaded [5] . Guo-Bing Lu had done study double skinned CFST in which steel is confined between inner steel tube and outer steel tube [6] . Yong Hong Ran had investigated numerically and experimentally a CFST pile which is subjected to oblique impact [7] .

Fang Zhang had simulated the CFST against blast loading [8] . Xiaoqiang Yang investigated residual capacity and dynamic response of CFST which acted upon by axial impact [9] . Yan Li had study Concrete filled stell tubular ach bridge due the various moving vehicle loads [10] .

PROPOSED RESEARCH:

In the literature, it has been found that various experimental studies as well as numerical studies had done by changing parameters of CFST such as grade, thickness, kind of loading etc. In this study we are investigating the CFST capacity using FEM software Abaqus. And parameters we are considering in it are diameter to thickness ratio, length to diameter ratio and changing the grade of concrete. In this we have predicted the capacity of CFST at the time increment at which the steel tube starts yielding at that point the load is taken as the capacity of CFST.

FINITE ELEMENT MODELLING:

In this study we have used Abaqus software for the modelling of CFST. Here we have to parts steel tube and concrete core. So total there is 6 to 7 module we have used namely Part module, property module, assembly, step, Interaction, loading, meshing and finally submit the job. To model the concrete in core we have used CDP approach. In which we have taken the experimental value from previous study. To simulate concrete as it is we have to provide the various values to software.

To discretize the FE models for the core concrete and tube of steel, an 8-noded quadrilateral in-plane general-purpose continuum shell is utilized, incorporating reduced integration with hourglass control, finite membrane strains, and 8-noded linear brick (C3D8R) elements, an 8-noded quadrilateral in-plane general-purpose continuum shell is employed to discretize the FE models for the core concrete and tube of steel respectively. Surface to surface standard contact modelling is used to represent the interaction property between the steel tube and concrete core. Master surface selected is steel tube is inner surface and slave surface is concrete core surface. The coefficient of friction between concrete core and steel tube is considered 0.6 for all 9 columns.

Nonlinear FE analysis is performed for the static general study based on the Newton-Raphson method. The boundary condition considered for bottom is fixed in all direction and for top surface it is fixed in direction other than loading direction. The load is applied using pressure option by selecting the concrete core and steel tube cross-section. For mesh size of 20 the systems response tends to converge.

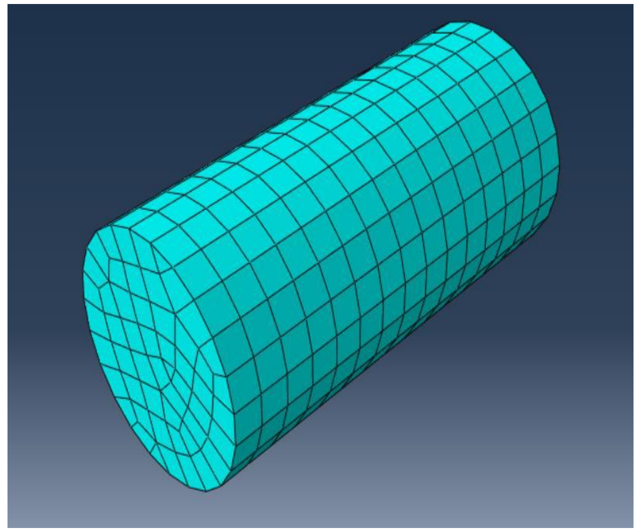


Figure 1: (CONCRETE CORE)

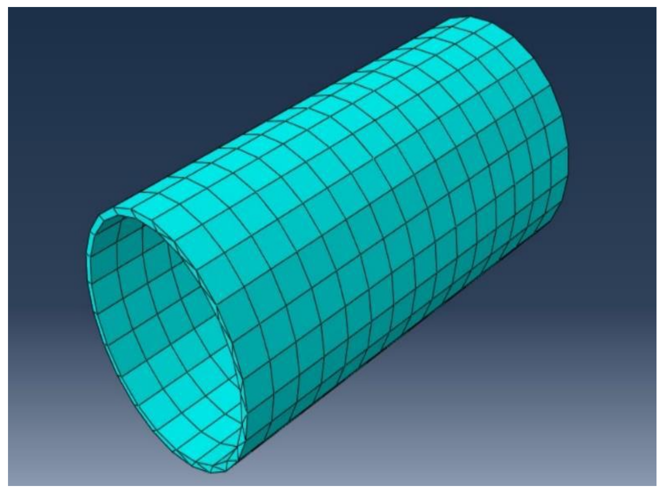


Figure 2:(STEEL TUBE)

MATERIAL PROPERTIES

To simulate the behaviour of concrete the various parameters are taken from literature [11]. In which there are some parameters like dilation angle, viscosity parameter, k value. It also includes the Young’s modulus and Poisson’s ratio. And the necessary information required for modelling the steel tube is included in the paper [12]. The stress strain relationship cure for steel is here

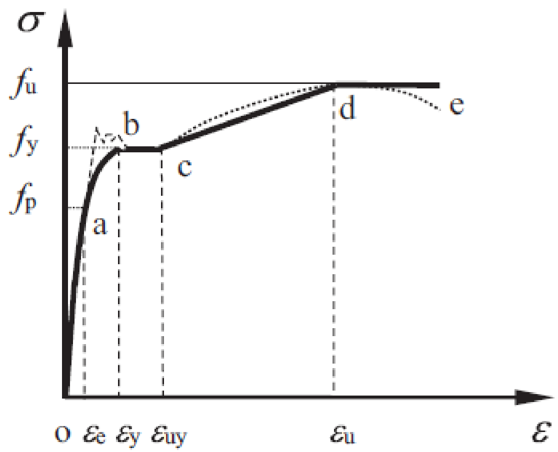


Figure 3: (stress-strain curve for steel)

VERIFICATION OF THE FEM:

The study carried out by Manikant [13] is used to verify the accuracy of the model. The parameters considered are concrete grade and thickness of the steel tube. The considered parameters D is 152.4, tube thickness are 4.5, 4.8, 5.4 . so the results of our model are in good coordination with the data provided by Manikant.

EUROCODE 4 FORMULAE:

$$N_{Euro} = \eta_a A_s \frac{f_y}{\gamma_{ma}} + A_c \frac{f_c}{\gamma_c} [1 + \eta_c \frac{t}{D} \frac{f_y}{f_c}]]$$

Where

Y_c =3 (safety factor for concrete)

Yma= 1 (safety factor for steel)

n_a and n_c are replaced by n_{ao} and n_{co} and require following values

ηao = 0.25 (3+2k)

$\eta co = 4.9 - 18.5k + 17k^2$

and k= $\sqrt{\frac{N_{PLRK}}{N_{CR}}}$

RESULTS AND DISCUSSIONS

In the below table, the results of FEM and Euro Code results are compared and there ratio is also mentioned. In the last column the failure index is the ratio of failure stress to yield stress of steel. And mention parameters are diameter of CFST, diameter to thickness ratio, length to diameter ratio, concrete grades. In this table we have analysed the CFST in three sets of 3 CFSTs in which in one set there is variation in the grade of concrete, in other set variation of thickness of tube and length variations.

In the fig.4 is for M30 the load variation with the length of the column is plotted in which we can see as the length increasing load carrying capacity decreasing.as we have taken three length 462.6, 616.8, 771. It has been observed that by just increasing the thickness of tube by 0.3 mm there is significant amount of load carrying capacity increased.

In the fig.5 is for M40 in this graph we can see the variation of load with the varying L/D ratios of 3,4,5 and graph is decreasing as the load carrying capacity is decreased as the length increases.

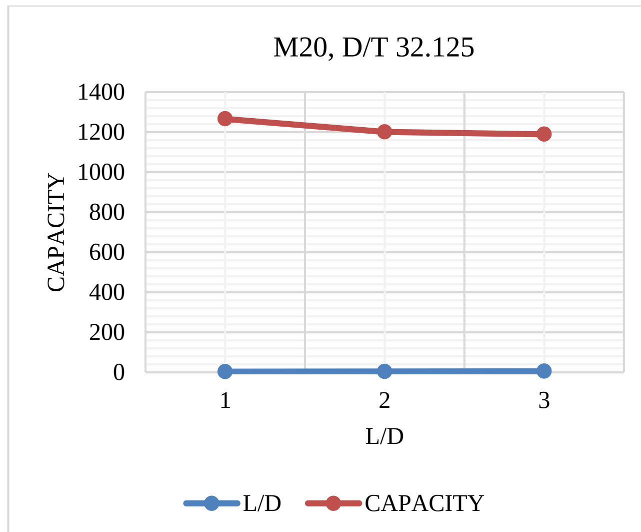


Figure 4 for M30

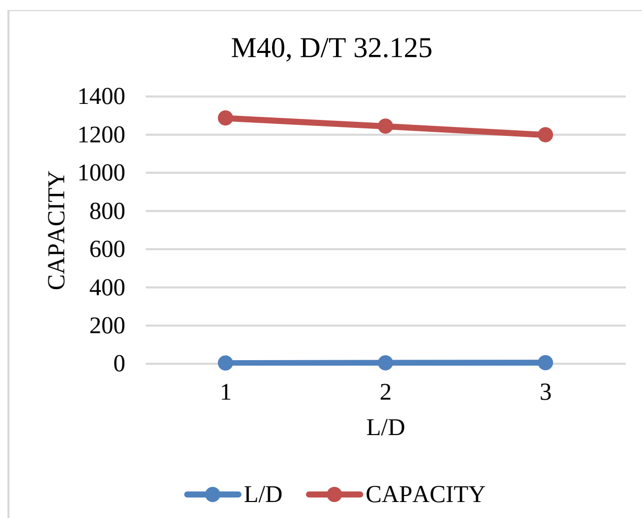


Figure 5: (FOR M40)

In the fig.6 we can see the variation of reaction force at the bottom (set-2) variation of reaction force as it goes up and stop increasing after yield stress of steel reaches maxima.

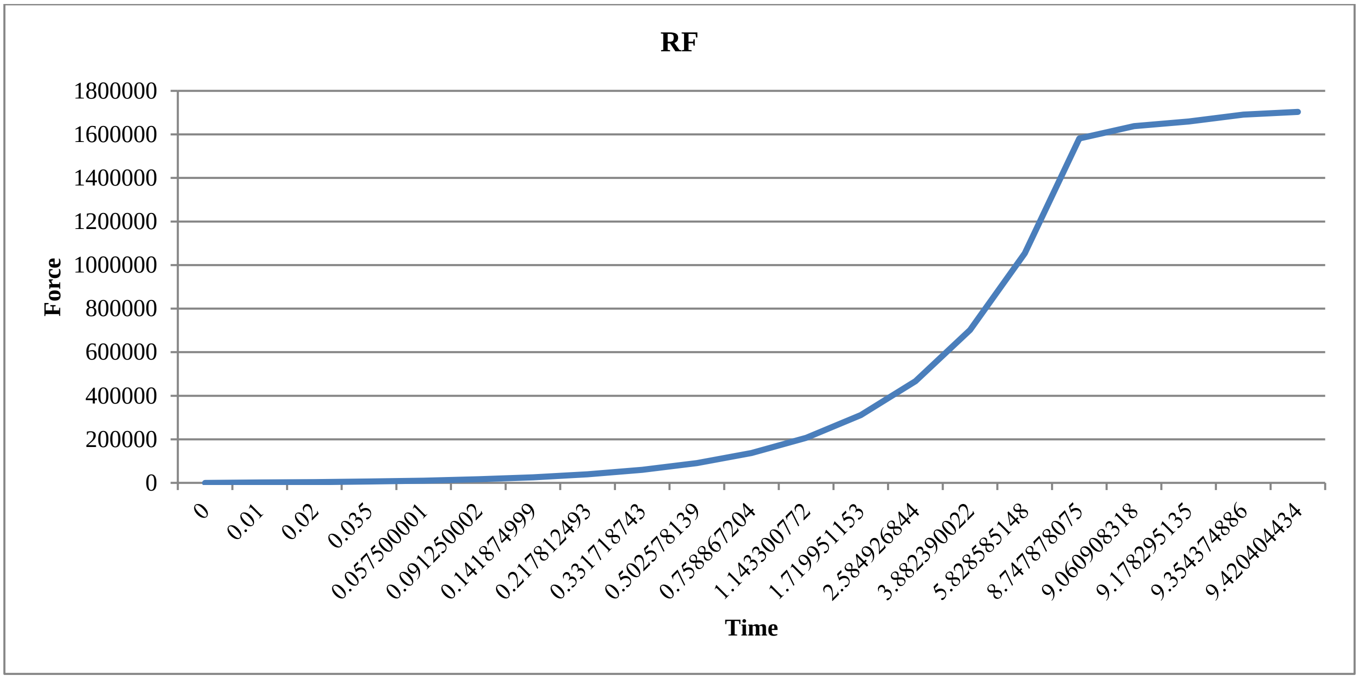


Figure 6: Variation of reaction at the bottom of CFST

Table.1

S. NO.	Diameter (Mm)	Length (Mm)	Thickness (Mm)	Length/ Diameter ratio	Diameter/thickness ratio	CONCRETE GRADES	Capacity (FEA) (kn)	Capacity (Euro Code 4) (Kn)	EURO / FEM	Yield stress (MPa)	Failure stress (MPa)	Failure index
1.	154.2	462.6	4.8	3	32.125	M30	1266.31	1263.71	0.997	304	321.7	1.058
2.	154.2	616.8	4.8	4	32.125	M30	1201.12	1208.13	1005	304	312.9	1.029
3.	154.2	771	4.8	5	32.125	M30	1189.732	1180.27	0.992	304	305.1	1.0036
4.	154.2	616.8	4.5	4	28.55	M30	1193.27	1195.11	1.001	304	315.6	1.038
5.	154.2	616.8	4.8	4	28.55	M30	1201.2	1211.11	1.008	304	314.7	1.035
6.	154.2	616.8	5.4	4	28.55	M30	1259.26	1265.23	1.004	304	322.3	1.060
7.	154.2	462.6	4.8	3	32.125	M40	1286.43	1298.11	1.009	304	307.56	1.011
8	154.2	616.8	4.8	4	32.125	M40	1243.91	1240.56	0.997	304	310.79	1.022
9	154.2	771	4.8	5	32.125	M40	1198.53	1189.63	0.9925	304	308.42	1.0115

CONCLUSIONS

i. The highest percentage increase in load carrying capacity for CFST columns with a D/t ratio of 32.125, resulting from an increase in concrete grade from M30 to M40, is observed in columns with an L/D ratio of 3
ii. The highest percentage increase in compressive stress for CFST columns with a Diameter/Thickness ratio of 32.125 resulting from a reduction in concrete grade from M30 to M20 is observed in columns with an L/D ratio of 4.
iii. The results obtained from the Finite Element Method (FEM) and Eurocode formulae for calculating the load carried by CFST columns show a deviation of within 4% for all nine columns. This suggests that the FEM results are in excellent agreement with the Eurocode 4 results.
iv. CFST columns with distinct Diameter/Thickness ratios, L/D:-2 exhibits the highest axial deformation when comparing with L/D 3 and 4.

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