ANALYTICAL STUDY OF SHORT CFST COLUMNS OF DIFFERENT DIAMETER UNDER AXIAL COMPRESSION USING ABAQUS

Bhavana R[1], Athiq Ulla Khan[2], Dr. N S Kumar[3]

[1]M. Tech, Structural Engineering, Ghousia College of Engineering, Ramanagara, Karnataka, India
[2]Assistant Professor, Dept. of Civil Engineering, Ghousia College of Engineering, Ramanagara, Karnataka, India
[3]Prof. & HOD, former Director (R & D), Dept. of Civil Engineering, Ghousia College of Engineering, Ramanagara

---***---

Abstract - *In developed countries across the world, high rise buildings are booming up and CFST columns has gain more importance in the civil construction field like high rise buildings, bridges, flyover, ribs in transmission towers and other earthquake resistant structures. CFST columns are more advantageous and structurally sound. More research works are undergoing on numerical analysis of CFST columns using software as it is a time saver. ABAQUS is one of the finite element software broadly used for numerical analysis of CFST columns. This paper presents modelling of steel tube and confined concrete of short CFST columns using ABAQUS 6.13, steel tube and concrete properties, steel tube and concrete, interactions, boundary conditions. Axial compressive load, load deformation curve and failure mode of short CFST columns are determined using ABAQUS 6.13 and validated against the experimental result available in the journal.*

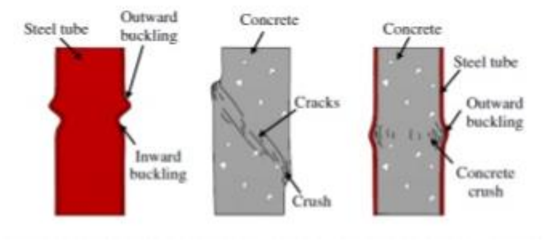
Key Words: **Concrete filled steel tube, confined concrete, peak load, failure modes, ABAQUS 6.13.**

1. INTRODUCTION

Different combination of concrete and steel tube for the construction of CFST column are using in construction field especially in multistory buildings ,bridges etc. to suit the purpose of construction like fire resistance, to carry heavy loads etc. This CFST column may be a simply concrete filled circular or square or rectangular steel tube, reinforced concrete filled steel tube, simple or reinforced concrete filled double wall steel tubes. Because of its ultimate performance as a structural membe, it is widely using in the infrastructure developments.

The merits of cfst columns are as follows . infilled concrete prevents early buckling of outer steel tube ,formwork is eliminated and the outer steel tube acts as a permanent formwork,the load carrying of CFST column is more due to confinement by outer steel tube,maintenance free etc .Demerits are more research and studies required to know the behaviour of cfst columns under loading ,complications in the analysis due to composite nature of different materials of CFST columns.

1.1 Nature of failure of CFST columns under axial load



(a) (b) (c)

Fig1: Failure of simple hollow steel tube, concrete and CFST columns.

Fig 1(a) shows the simple steel fails by inward buckling followed by outward buckling tube under compression, the RCC concrete column. Fig 1(b) fails by shear and concrete in in filled steel tube. Fig 1(c) fails by only outward buckling as steel tube provides strength to in filled concrete.

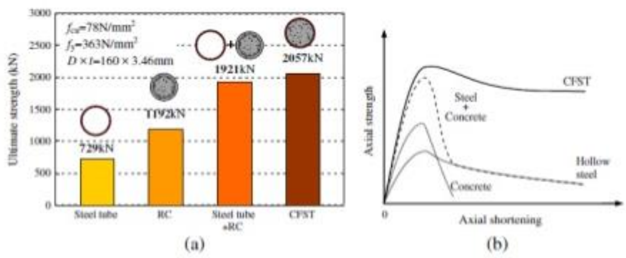


Fig 2: Axial compressive behavior of CFST stub columns.

Fig 2(a) shows that the load bearing capacity of CFST columns is more than that of simple steel tube and RC column .Fig 2(b) shows load versus axial shortening of RC ,simple steel tube and CFST columns .The CFST columns ductility has been increased.

1.2 Applications of CFST columns.

CFST column successfully adopted for the first time in Beijing for the construction of subway no 1. There are more than 200 projects impounded CFST columns in China.

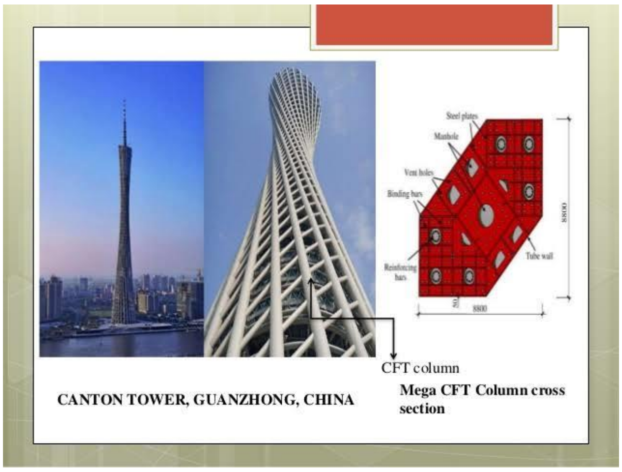


Fig3: Canton Tower.

Fig4: Shenzhen seg plaza, china.

2. FINITE ELEMENT MODELLING.

Finite element modelling of CFST column is created using ABAQUS 6.13. Perfect modelling of CFST columns depends on characterizing the properties of center concrete and steel tube, interaction properties of in filled concrete and the steel tube. Selection of suitable mesh size and element type is required for determination of behavior of the columns in a brief time. The failure modes of short CFST columns under axial compressive load is accompanied by in filled concrete crushing and yielding of steel tube. Suitable model should be adopted in modelling for in filled concrete and steel tube to capture the failure of CFST columns.

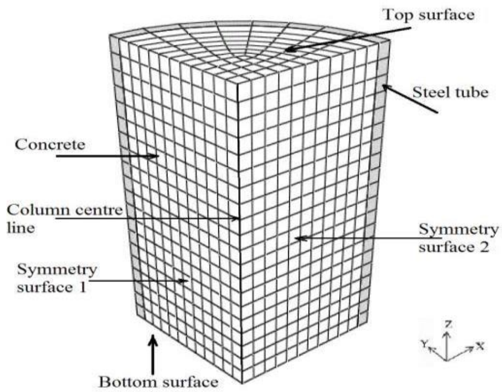


Fig 5: Mesh and element type

2.1. MATERIAL MODELLING

In ABAQUS steel tube is modelled as shell part and concrete core is modelled as solid part separately as different part and are assembled together using interference option provided in the ABAQUS.

a)Steel Tube

The behavior of steel tube is modelled using an elastic perfectly plastic model .Fig 6 shows a tri linear stress strain of a steel tube .Its consists of three part, the first part is elastic part and defined in ABAQUS using elastic option. Elasticity modulus 206 GPA and Poisson's ratio 0.28 are considered. Plastic option is used in ABAQUS library to define the inelastic part of the steel tube which includes yield and strain hardening stages. Yield stress (fy), ultimate stress (fsu), yield strain (Ɛ y), strain at the beginning of strain hardening (Ɛ p) and ultimate strain (Ɛsu) are the required parameters to define the stress strain of steel tube.

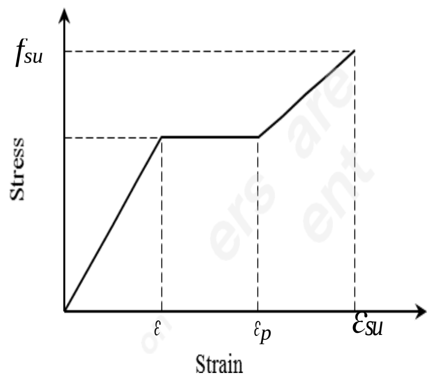


Fig 6: Steel tube stress-strain behavior

TABLE 1: Properties of steel tube

Model no	Yield strength f_y (MPa)	Ultimate strength (MPa)	Yield Strain ε_y	Strain hardening modulus (GPa)	Ultimate strain ε_u
CS 2	590.4	619.5	0.0028	0.0280	0.280
CS 4	259.8	418.4	0.0012	0.0120	0.120
CS 6	276.0	437.9	0.0013	0.0130	0.130
CS 8	278.8	416.2	0.0013	0.0130	0.130

b) Confined concrete

The uniaxial stress-strain curve is used to describe the behavior of in filled concrete in ABAQUS and the curve is as shown in fig 7. Linear stage is defined using E known as modulus of elasticity and poisons ratio of confined concrete [1]

Elasticity Modulus of confined concrete is Ecc=4730 $\sqrt{fcc}$, Ecc and fcc are Elasticity Modulus and confined compressive strength of concrete in MPa respectively. fcc is calculated using Equations proposed by Richart et al. (1928).

Strain corresponding to fcc, Ɛcc can be determine by Equations proposed by Mander et al. (1988), based on the experimental results of Richart et al

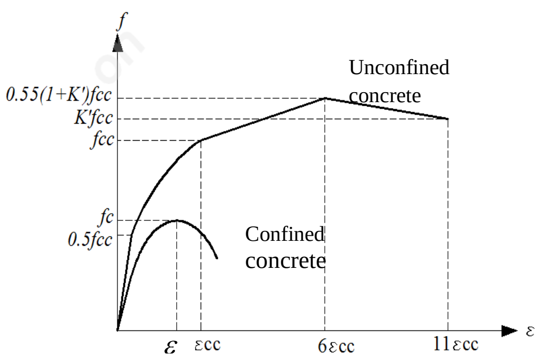


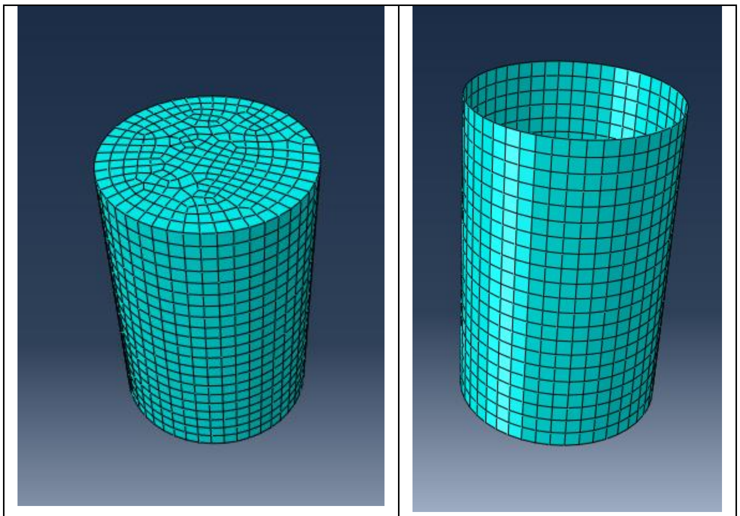
Fig 7: uniaxial stress-strain curves of confined and unconfined concrete [1]

2.2. Top and bottom end boundary conditions

The bottom end nodes of the model is made fixed, displacement degrees of freedom in X, Y, and Z directions i.e., U1, U2, U3 as well as rotational degrees of freedom in X, Y and Z directions were restricted to zero. The displacement degree of freedom in X and Y directions i.e., U1 and U2 were restricted to zero for top nodes of the model. On top end nodes 1N concentrated load is applied.

2.3. Interactions and meshing

Hard contact is provided between the concrete core & steel tube. Coefficient of friction 0.25 is chosen in tangential behavior of interaction option available in ABAQUS 6.13. Finer mesh provided for both concrete and steel tube .Finer mesh gives accurate and acceptable results. ABAQUS 6.13 commonly provides four-node linear tetrahedron (C3D4) elements, six-node linear triangular prism (C3D8) elements and eight-node linear brick (C3D8) elements. (C3D8R) eight-noded brick elements, reduced integration are used for meshing of concrete core and (S4R) four-node doubly curved thin or thick shell, reduced integration thick shell is used for meshing of steel tube. The concrete core & steel tube geometry generated in ABAQUS 6.13 is illustrated in Fig 8.



(a) In filled concrete (b) Steel tube

Fig 8:Meshing of CFST column components

3. RESULTS

After modelling of CFST columns using ABAQUS 6.13 under axial compressive load, the results are evaluated. Simulated load bearing capacity of CFST columns of different diameter obtained using ABAQUS 6.13 is matched with the experiment results taken from the journal, and their properties are tabulated. Finite element model results well agrees with the experimental results. Fig 10 shows graphical representation of variation of peak load obtained from FE model results and the experimental results. The deformed shape of the specimen after loading is shown in fig9. Variation of axial load capacity with increase in diameter is shown in the fig 11

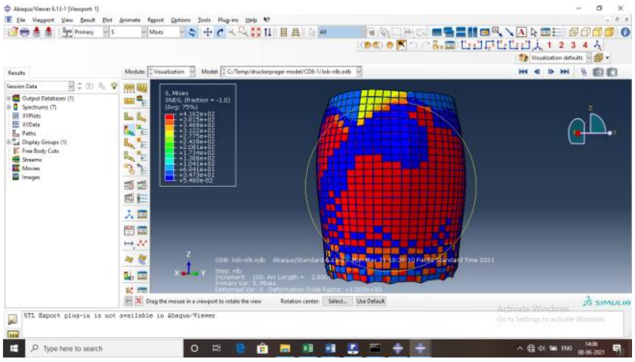


Fig 9: The deformed shape of CFST column

Table 2: Design details of models.

Model no	Diameter, D (mm)	Height, H (mm)	Steel tube thickness (mm)	D/t	L/D
CS2-1	215.4	657	2.5	85.0	3
CS2-2	216.6	657	2.5	86.6	3
CS4-1	425.8	1278	5.2	82.4	3
CS4-2	427.1	1278	5.1	83.8	3
CS6-1	628.5	1890	6.9	91.1	3
CS6-2	628.0	1890	7.1	88.0	3
CS8-1	817.4	2460	9.0	90.8	3
CS8-2	820.8	2460	9.3	87.9	3

Table 3: Experimental results versus simulation results

Model no	Size(DxHxt)	Exp axial load capacity N_{exp}, kN	Simulation axial load capacity N_u, Kn	N_{exp}/N_u
CS2-1	215.4x657x2.5	3357	3118	-10.4%
CS2-2	216.6x657x2.5	3483	3169	-9%
CS4-1	425.8x1278x5.2	10523	10781	+1.88%
CS4-2	427.1x1278x5.1	10784	10396	-3.59%
CS6-1	628.5x1890x6.9	21207	20706	-2.36%
CS6-2	628.0x1890x7.1	21582	25718	+19%
CS8-1	817.4x2460x9.0	36933	32222	-12.7%
CS8-2	820.8x2460x9.3	37221	35870	-3.6%

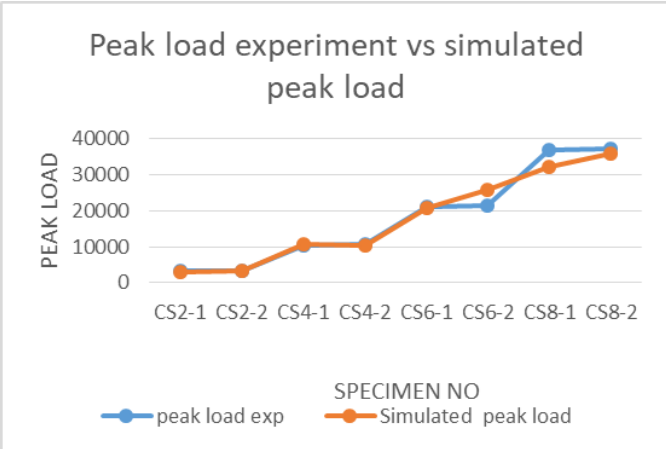


Fig 10: Comparison of peak load experiment and simulated peak load

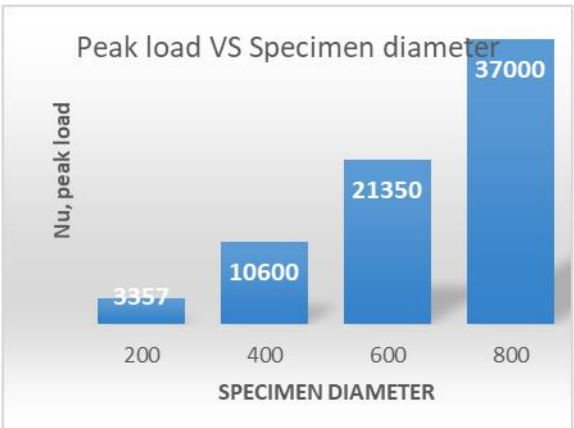


Fig 11: Peak load vs specimen diameter

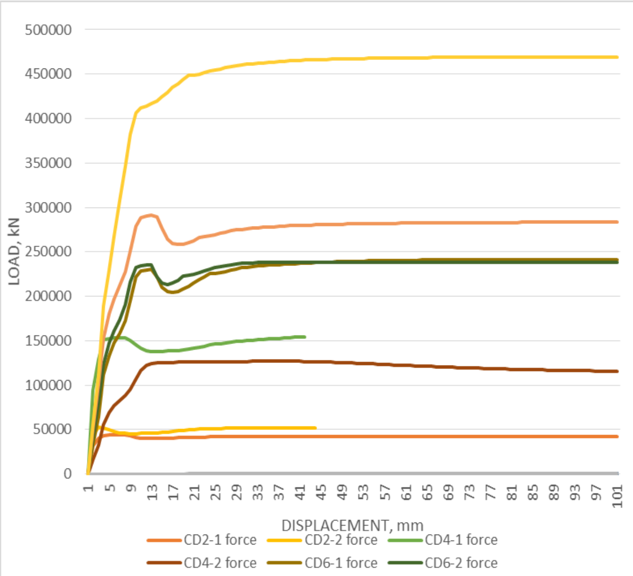


Fig12: load deformation curve from finite element method.

4. CONCLUSIONS

1. There FE model results matches with the results of journal in terms of axial load capacity.
2. It is clearly observed in the graph shown in fig11, that as diameter of CFST column increases, the load bearing carrying capacity also increases.
3. The load bearing carrying capacity of CFST column raises with the raise in steel tube thickness.
4. Load deformation curves well agrees with the load deformation curve of specimens taken from the journal and there is a little variation

REFERENCES

[1]. Akbar Haghinejad, Mahdi Nematzadeh. "Three-Dimensional Finite Element Analysis of Compressive Behaviour of Circular Steel Tube-Confined Concrete Stub Columns by New Confinement Relationships". Latin American journal of Solid and Structures.

[2]. Tusshar Goel and Aditya Kumar Tiwary, "Finite Element Modeling of Circular Concrete Filled Steel Tube (CFST), Indian Journal of Science and Technology", Vol 11(34), DOI: 10.17485/ijst/2018/v11i34/130853, September 2018.

[3]. Alireza Bahrami, Ali Mahmoudi Kouhi, "Compressive Behaviour of Circular, Square, and Rectangular Concrete-Filled Steel Tube Stub Columns," Civil Engineering and Architecture, Vol. 8, No. 5, pp. 1119-1126, 2020. DOI: 10.13189/cea.2020.080538.

[4]. ABAQUS 6.13 documentation, ABAQUS user's and analysis user's manual 2014, Providence RI

[5]. Faisal Hafiz, "Analytical and Numerical Study on Behaviour of Concrete Filled Steel Tabular Columns Subjected To Axial Compression Loads", International Journal of Scientific & Engineering Research, Volume 7, Issue 9, September-2016.

[6].Wenjing Wang, Zhenyun Tang, Zhenbao Li, and Hua Ma, "Bearing Capacities of Different-Diameter Concrete-filled Steel Tubes under Axial Compression "Hindawai Publishing corporation, Advances in Materials Science and Engineering, Volume 2016,Article ID 7982365, 10 pages, http://dx.doi.org/10.1155/2016/7982365.

[7].Alhussainy, Faez; Sheikh, M. Neaz; and Hadi, Muhammad N. S, "Behaviour of small-diameter self- compacting concrete-filled steel tubes" (2018). Faculty of Engineering and Information Sciences - Papers: Part B. 826. https://ro.uow.edu.au/eispapers1/826.

[8]. Z. B. Li, W.J. Wang AND Z.Y. Tang, "Size effect on Confining stress of Circular filled in Steel tube under Axial Compression",9th International conference on Facture Mechanics of concrete and concrete Structures ,DOI 10.21012/FC9.103.

[9]. A Ilanthalir et al, "Concrete-filled steel tube columns of different cross-sectional shapes under axial compression: A review", 2020 IOP Conf. Ser.: Mater. Sci. Eng. 983 012007

BIOGRAPHIES

Bhavana R completed Bachelor degree in civil engineering from Sri Jayachamarajendra college of engineering Mysore under VTU in the year 2008.Worked as Quality control In Brigade Enterprises Ltd for 3 years .And have a 9 year experience in the field of teaching in Diploma engineering college. Now I am pursuing master's degree in Structural Engineering under VTU from Ghousia College of Engineering Ramanagara.

Mr. Athiq Ulla Khan completed his Bachelor degree in Civil Engineering from Ghousia College of Engineering, under VTU in the year 2012. He completed his master's degree in Structural Engineering under VTU from the same college in the year 2015. He is now pursuing his PhD at GCE Research Centre under the guidance of Prof. Dr. N S Kumar. He is working as an assistant professor in the department of civil engineering for the past 5 years. He teaches various subjects for both UG and PG students.He has successfully guided 30 students at UG and PG level. He has published 10 papers at the National and International level. His areas of interest are composite columns.

Dr. N S Kumar, Graduated in the year 1985 from Mysore University, M.E. in Structural Engineering., in the year 1988 from Bangalore University and earned his PhD from Bangalore University during the year 2006 under the guidance of Dr. N Munirudrappa, the then Chairman and Prof. UVCE, Faculty of Civil Engineering, Bangalore University. Presently, working as Prof. & HoD, Department of Civil Engineering, Ghousia College of Engineering, Ramanagaram and completed 31 years of teaching. He is involved in the Research field related to the behaviour of Composite Steel Columns and Nano Materials for a decade. To his credit, over 150 publications, and travelled abroad for his research presentations including world conferences too. Also, more than 3PhD's completed and ongoing 5 are working under his guidance. Also, authored more than 8books to his credit.