An Exposition of Speculative and Numerical Analysis of CFST Columns

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Abstract. Owing to the advantages like intense compressive strength, large ductility and enormous energy incorporation, Concrete filled steel tube column system is gaining momentum when set side by side to regular steel or reinforced concrete system. Local buckling is one such major advantage that CFST gives experimental results from various articles has proven that there is an increase in the properties of CFST over normal concrete systems. This paper aims to give brief understanding on the experiments works conducted and numerical results obtained from various articles are discussed. Experimental works exposed to view that circular concrete filled steel tubes were more appropriate than square concrete filled steel tubes. In this paper, nonlinear finite element analysis for concrete filled steel tube is effectuated through varied parameters like concrete infill grade, as short columns with diameter ratio (L/D) not exceeding 4.5 with devoid of slenderness have also been discussed. The past studies divulged that the increment of D/T ratio dwindles the load carrying capacity of CFST and moreover, the high concrete infill grade buttress the load carrying capacity. From various literature reviews it was also concluded that the confinement efficacy of concrete enlarges the resistance to axial loading of compound columns with concrete filled circular sections. Furthermore for the CFST columns the buckling failure can be evaded, as well as the load carrying capacity can be strengthened by hauling down the slenderness ratio. Therefore ample scope exists in carrying of numerical analysis using ANSYS to find the potential of CFST columns.

1. Prelude
CFST – Concrete Filled Steel Tube structural system is basically infilled steel tubes with high-strength concrete that exploits both concrete as well as steel. They consist of hollow steel sections plugged with plain or reinforced concrete with rectangular or circular shape such a way that they are fabricated to hold up the floor load to a maximum of three to four storey height. Therefore these are implemented largely as columns as well as beams where in need of effective structural system like in high rise, multi-storey buildings and low rise industrial buildings.

To attain higher strength and superior functioning of the structure, concrete blended with supplementary cementitious material like silica fume is assimilated in disruptive CFST structures that are called as high strength concrete filled steel tubular columns. In the wake of the blended action between the key elements which promotes the high strength thereby inhibiting the inward buckling of the wall of steel. Customarily two types of compound columns were exercised in the
buildings; one with steel sections encased in concrete and the other with steel sections in-filled with concrete. Various researchers performed hypothetical studies as well as instigated methodical CFT models by utilizing nifty software tools to comprehend and to evaluate the compound performance of CFT. Regularly ANSYS software was employed and the models were simulated nonlinearly by the finite element method.

Column slenderness, eccentric loading embracing axial as well as with single or double bending curvature and compressive strength of concrete core were the evaluating criterion that effect the results in terms of strength and potential of concrete filled steel tubular columns. These CFST with square, rectangular and hollow circular cross sections are taking precedence over a miscellany of engineering structures.

2. Behaviour of CFST
The past studies divulged that juxtapose with cross sections, the CFST with circular sections serve better than the CFST with square sections. As a result of lesser confining pressure in the concrete core which incites the local buckling that plausibly occur in the square steel tube. In the concrete filled steel tube the structural behavior is conditioned on both the steel and concrete’s Poisson ratio. Because of the higher Poisson’s ratio of the steel at the early stage of loading, it does not accord a confining impact to the concrete. The steel tube happen to be bi-axially stressed and concrete core to be tri-axially stressed with the increase of longitudinal strain increases the lateral expansion of concrete than that of steel. As a consequence of this, the steel tube shifts the load from the tube to the core as it cannot hold up the normal yield stress which is similar in both the square and circular sections of CFST.

![Fig 1 Varied Cross-Sections of Concrete Filled Steel Tubular Sections](image)

3. State of the art
This section gives a brief outline of experimental and numerical works which are conducted by various researchers performed on Concrete Filled Steel Tubular Columns.
3.1 Concrete filled steel tubular columns: Numerical research

Neetu Devi Singh and Shubha Vaghmarey (2018) carried a non-linear analysis by employing ANSYS to the concrete filled steel tubes and deduced that the potential of circular cross-section count on the pivotal specifications like; column diameter, length, thickness, L/D and D/t ratios. Also they inferred that the slenderness ratio influences the failure mode of CFST compound column, where lesser the slenderness ratio incites the column failure at the support due to the local buckling and is crushed under direct compression. And buckling failure is seen in the column due to the larger slenderness ratio. Also the load carrying capacity of the CFST column diminishes with the increase of L/T ratio and enlarges with the increase of D/t ratio.

Alfahad B Vishnu Ramesh (2017) researched on the performance of CFST columns and contrasted the experimental and analytical results. Finite element software ANSYS was employed to analyze the CFST columns and in contrary 12 CFST column specimens with rectangular and circular sections were assessed for the failure load when subjected to axial loading. Additionally two CFST specimens with chick mesh, four cylinders filled with conventional concrete and one hollow steel tube filled with conventional concrete were also studied. Referring to the deflection values in the output, trivial dissimilarity is perceived in the experimental and numerical analysis. It is also observed that the CFST column with larger length is not as good as the shorter length CFST column. And with the increment in the height of the column, the CFST columns inclusive of wire mesh showcased load carrying capacity streets ahead of other CFST columns. Furthermore, the circular section CFST columns inclusive of wire mesh exhibited increased strength and the ductile behavior of all the CFST columns were equitably good.

Shams and SaadeghVaziri collated the results of the established three dimensional finite element model of CFST columns with the prevalent experimental values. The results showcased that the geometrical configuration of the columns and material properties of the concrete hold a great impact on the stress-strain properties of the confined concrete. Higher confinement ratio is recognized in the lower unconfined compressive strength of concrete than the higher strength concrete. Few variables like D/t ratio, unconfined compressive strength of concrete and the cross-sectional shape have a substantial effect on the increment of maximal compressive strength of concrete.

3.2 Concrete filled steel tubular columns: Experimental research

Abelmaseeh Bakos, GailanJibrael (2014) tested a total of 23 specimens and studied the axial load carrying capacity when plugged with waste glass concrete in thin walled HSS stub columns. With the replacement of fine and coarse aggregates with waste glass of 25% each displayed almost the same strength when CFST plugged with normal concrete and waste glass concrete.

Shehdeh Ghannam, N et al (2010) researched on the actual performance and the load carrying capacity of the steel columns plugged with usual and lightweight concrete. Each of four specimens with full scale rectangular cross-sections were filled with lightweight aggregate concrete and normal weight aggregate concrete respectively. The specimens were subjected to axial loads and the output delineates that the weight of the column is reduced with the use of lightweight concrete filling and on contrary a high load carrying capacity is attained simultaneously. According to the visual observations and due to the experimental failureloads, the assessed design values referring to the composite codes were surplus in almost all the columns. Moreover, the lightweight aggregate concrete filled sections sustained a squash load more than 92% and descried local failure as well as buckling failure in the column. Similarly the normal weight aggregate concrete filled sections sustained a squash load more than 87% and descried overall buckling failure at the mid height of the column. And the formulae used to calculate the squash load,

\[ Nu = \frac{A_{fs}f_{sk}}{\gamma_{ms}} + \frac{A_{cf}f_{ck}}{\gamma_{mc}} \]

Han et al (2009) experimentally investigated a sum total of 32 specimens to study the working of concrete filled steel tubular columns under axial compression. The varied dominant specifications in the study were: square and circular sections, local area compression ratio 1.44 and
1.6, end plate thickness varying from 2 to 12 mm. The evaluation of CFST stub columns put through axial compression loading was done by finite element analysis modelling and the outcome reaffirmed a good concurrence with the test results. To examine the system of compound columns under axial compression loading, theoretical modelling was developed and studied.

Shan-Tong and Yu (1987) researched experimentally also analytically under axial compression and obtained the stress-strain relationship and strength of the concrete filled tubular specimens for discrete L/D values ranging from 2 to 5m. The authors propounded conventional test and rough methods for deducing the primary stress-strain relationship and ultimate strength of the tubes respectively. Also inferred that a plain steel tube with good ductility and energy absorption capacity is similar to the deformed behavior of a concrete filled tube.

Muhammad Naseem N et al (2006), analyzed the potential of 28 short CFST columns of circular and square sections that are axially loaded compression by varying the lengths of columns with an incremental of 500 mm from 2 m to 4 m. It was observed that the circular columns of diameter 160 mm and 111.25 mm carried a maximal axial load of 1153kN and 526kN respectively. Whereas the square columns of sides 125.66 mm and 87.38 mm carried an utmost axial load of 595kN and 450kN respectively corresponding to the ACI and LRFD codes.

J. Zeghiche and K. Chaoui (2005) have tested a total of 27 CFST columns with geometrical parameters; 5 mm wall thickness, 160 mm external diameter, varying lengths from 2 m to 4 m with an incremental of 500 mm. Three sets of columns were employed with compressive strengths of concrete 40 MPa, 70 MPa and 100 MPa. The experimental ultimate loads were varying from 126 KN for axially loaded columns filled with 40 MPa concrete to 2000kN for axially loaded columns filled 100 MPa. The experimental ultimate loads were varying from 1697kN to 963kN for single and double curvature ending.

Elremaily, Azizinamini (2002) examined the concrete-filled steel tube columns for cyclic lateral loads subjected to axial loading and under seismic loads. In regard to the interaction between the steel and concrete, analytical model was generated to anticipate the capacity of circular CFST beam-columns furthermore collated with the experimental data. The output showcased good concurrence that the CFST columns displayed better ductility and preserved their strength until its failure. They inferred that, provided the confinement of the steel tube achieves concrete strength thereby remarkably enhances the column capacity.

Lanhui, Sumiem, N et al (2007) experimentally examined the behavior of circular hollow steel tube as well as circular tubes plugged with concrete. A sum total of 24 CFST columns were tested in four series of specimens where all were loaded axially till their failure.

Shankar Jagadish (2014) studied the ultimate load carrying capacity as well as behavior of stiffened concrete filled single and double skinned thin walled steel tubular column specimens by employing finite element analysis. Ten different specimen models were analyzed for this. A conventional column with rectangular and circular cross section was first modelled and analyzed for validation. Then a circular and a rectangular column are modelled by providing outer skin only without providing conventional reinforcement and analyzed. Then in addition to the outer skin, the specimen was analyzed by providing an inner steel skin. Then the test is repeated by providing Stiffeners inside the column throughout the length and analyzed for all the cases. When the stiffened double skinned Rectangular column is compared with conventional rectangular one, the compressive strength is increased by 309.72 %. When the stiffened double skinned circular column is compared with conventional circular one, the compressive strength is increased by 297.79 %. It is noticed that the rectangular column shows greater change than circular column when stiffener is used. Contrast to the regular specimens, the load carrying capacity is increased when the double skin is provided. As a scope of study cases of variant loadings and more complicated types of CFST specimens with various cross sections can be tried. Besides, cyclically loaded CFST beams can be studied in extension to the work.

N. Jamaluddin, N et al (2013) this journal is about the study including a sum total of 26 CFST columns of slender as well as stub members that were set up productively with the elliptical steel
hollow sections at hand centralized on slenderness ratio. In order to analyze the ascendancy of slenderness on the column strength, stub column length considered two times the outer diameter and three discrete lengths were adopted for the long column specimens. Which were categorized into four series hinged on length such as series 1 delineate stub columns of length 300 mm and series 2, 3, 4 represent long columns of length 1500, 1790, 2500 respectively or in accordance with the section. Concrete Compressive strength of 30Mpa, 60Mpa and 100Mpa have been used. It was observed that the examined elliptical CFST columns had 37.5 and 40 D/t ratios and the long columns’ slenderness ratio varied from 16 to 143. The axial carrying capacity ranged from 71% to 136%.

Brain Uy (2000) investigated the high strength steel box columns plugged with concrete, took up in three series of experiments to ascertain the blended response under bending and compression. All the series were deemed to be compact speaking of restrained local buckling slenderness limits nevertheless discrete plate slenderness limits. Therefore no reduction along with the local buckling was anticipated in the component plates. A cycle of tensile coupon also stub column checks were carried out under both tension and compression in order to ascertain the stress-strain behavior of the steel. The columns were casted in plates with plaster on either side in order to make certain uniform loading surface and were assessed under pure compression also under the combined bending and compression. The 28 columns were loaded at the top and the bottom of the column wielding a knife-edge concomitantly with the eccentric loading. The author judged that under pure compression, the maximal loads were derived from the curves of the specimens. Further the results as envisioned under compound actions for a column, the improved eccentricity shortened the attained largest axial load.

Morino, Tsuda (2003) worked assiduously for the past 15 years in Japan that includes “NewUrbanHousingProject”, “US Japan Cooperative Earthquake Research Program” besides the work done at the annual meeting of the Architectural Institute of Japan (AIJ) by individual universities and industries. They instigated a structural system and ventilated on the advantages, latest inclinations and findings of the CFST column system. Further through profound indagation of AIJ, a rational design method for the CFST column has been initiated. They also inferred that by dint of system’s construction effectiveness and the characteristics of CFST incline the system peculiarly towards high-rise and long-span structures as it saves cost of construction, time and labor.

Brain Uy (2001) performed an experimental work on the efficacy of steel plate slenderness limits and studied the potential of steel-concrete compound columns including CFST columns. Wielding the results, a numerically progressed model was augmented as well as calibrated based on rigid plastic method of analysis holding on to the international codes of practice. The study was appreciable in case of large plate slenderness values especially for larger axial forces but was not deemed for the effects of local buckling. Furthermore to conclude the author put few alterations forward in the design for the insertion of slender plated columns.

4. Peroration
In contradiction to the lengths, the CFST columns of shorter length is streets ahead of longer length and visibly less deflection is seen in increased cross sectional area of the tube. Also greater load carrying capacity is observed in these CFST columns. Juxtapose with regular CFST columns, if any enlargement in height of the column along with wire mesh have greater load carrying capacities. The steel tube’s cross-sectional area has consequential upshot on ultimate axial load capacity and deformation of the column, whereas the ultimate strength is consistently improved comparatively to higher concrete areas. Also circular concrete filled steel columns have displayed increase in strength in presence of wire mesh and well-nigh all columns acquit oneself in a reasonably ductilemanner.

Finite element software ANSYS is employed to analyze the potential of steel tubular section filled with concrete (CFST) and fathom out the failure load of varied sections like circular and
rectangular columns under axial loading where in consideration of both material and geometric linearity. Three-dimensional finite element models of varied cross sections have been simulated nonlinearly to delve deeper into the load transfer and under the axial compression to study the interaction between steel tube and the concrete core of concrete-filled steel tubes.

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