International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-3 Issue-6, November 2013

Nonlinear Finite Element Study on the Circular Concrete Filled Steel Tubular Columns

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Abstract— ***The present study is an attempt to understand the behavior of this type of columns . In this research modeling of 11 circular cross-section model of the columns , these models are taken from pre - publication research , the models been simulated nonlinearly by the finite element method , with the help of the ANSYS software . models has been loaded in a concentric axial compression way, the failure loads were extracted , and has been compared to the results obtained from the experimental data. It been found from the nonlinear modeling by ANSYS program a significant influence of the proportion of the D/t on the axial load capacity of the concrete filled steel tubular , where concluded that the axial load capacity of the columns Increases significantly when lowering the value of the of D/t under the value 47 , but when increasing the value of the D/t over 47 the axial load capacity of the columns increases in small rates. All the specimens been simulated had the length to diameter ratio (L/D) not exceeding the value of 4.5 to act as a short column, and ,therefore, no slenderness effect would be taken in account .***

Index Terms— ***Concrete-filled steel tubesComposite columns , Nonlinear analysis , Strength , finite element analysis , ANSYS software.***

I. INTRODUCTION

1.1 general :

Concrete filled steel tubular (CFST) members utilize the advantages of both steel and concrete. They comprise of a steel hollow section of circular or rectangular shape filled with plain or reinforced concrete. They are widely used in high-rise and multistory buildings as columns and beam-columns, and as beams in low-rise industrial buildings where a robust and efficient structural system is required.

There are a number of different advantages related to such structural systems in both terms of structural performance and construction sequence. The inherent buckling problem related to thin-walled steel tubes is either prevented or delayed due to the presence of the concrete core. Furthermore, the performance of the concrete in-fill is improved due to confinement effect exerted by the steel shell. The distribution of materials in the cross section also makes the system very efficient in term of its structural performance. The steel lies at the outer perimeter where it performs most effectively in tension and bending. It also provides the greatest stiffness as the material lies furthest from the centroid. This, combined with the steel's much greater modulus of elasticity, provides the greatest contribution to the moment of inertia. The concrete core gives the greater contribution to resisting axial compression. The use of concrete filled steel tubes in building construction has seen resurgence in recent years due mainly to its simple construction sequence, apart from its superior structural performance. Typically, it was used in composite frame structures. The hollow steel tubes that are either fabricated or rolled were erected first to support the construction load of the upper floors. The floor structures consist of steel beams supporting steel sheeting decks on which a reinforced concrete slab is poured. Such structural system has the advantage of both steel and reinforced concrete frame. It has the structural stiffness and integrity of a cast-on-site reinforced concrete building, and the ease of handling and erection of a structural steelwork.

1.2 literature review :

We can say that Ambitious researches related cfst “concrete filled steel tubular” columns started at the beginning of the twentieth century by Swain and Holmes in 1915 , who first attempt to understand the behavior of this type of composite structures . then came Kloppel and goder was carried out tests on short columns with different slenderness values and different types of loading axial loading and eccentric .

Shams (1997) A detailed analytical study was performed using three dimensional nonlinear finite element analysis to identify the response of CFT columns under axial loading. Based on that study shams concluded the following : It is found that the *D*/*t*, unconfined compressive strength of concrete, and cross-sectional shape have significant effect on the response of CFT columns, and then the relative effect is quantified. The confinement effect in circular columns is higher than in square columns due to a more uniform stress distribution . O’Shea and Bridge (1997) made an experimental work to describe the behavior of circular concrete filled steel tubular , the pipes been used in that research has the diameter to steel pipe thickness ratio range : (55-200) , and length to diameter ratio equal to 3.5 . H. Hu et al. (2003) made a nonlinear finite element model for concrete filled steel tubular columns using abaqus software , the experimental data were collected from Schneider (1998) and Huang et al. (2002) . Yu , Zha , Ye and She (2009) a unified formulation is proposed to predict the composite compressive strength of circular concrete-filled steel tube (CCFST) columns . The formula is obtained from the analytic solution of an elastic composite cylinder under axial compression .

Manuscript published on 30 November 2013.
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The formula is further calibrated by introducing a number of correlation coefficients that are validated by test results .
Suliman Hassan Abdalla (2012) tested a total of one hundred and three specimens the compressive behavior of the Concrete Filled Steel Tubes (CFSTs) and the Confined Concrete Filled Steel Tubes (CCFSTs) under axial compressive loads is experimentally investigated .

1.3 Concrete model :

Shams and Saadeghvaziri (1999) : Shams and Saadeghvaziri made a model by using a finite element software abaqus , the results were validated against experimental results been collected from previous researches , the drawback of their model is not giving accurate and close results to the test data for the steel with yield strength over 300 mpa , they proposed the following equations :

$$fcc' = fc'\left(1+\frac{A}{1+(\frac{D/t}{B})^{\alpha}}\right)$$

α = 4 for square columns , and = to 1 for circular columns .

A and B for square columns :

$$A = 1.335 * e^{-(\frac{fc'}{3.55})}$$

$$B = 47.492 + \frac{30}{fc'}$$

And for circular columns :

$$A = 1.831 * e^{-(\frac{fc'}{3.55})}$$

$$B = -32.517 + \frac{510}{fc'}$$

Hence un confined concrete's strength (fc') in ksi .

1.4 Concrete's stress-strain curve :

Mander et al. (1988) : Mander et al. made a model based on on an earlier model proposed by Popovics (1973) , it differs than shah and fafitis model by the stress-strain been created by a continuous function , Derivation of the following equations incorporates the peak stress and strain,confining pressure and Elastic Secant Modulus of the concrete :

$$fc = \frac{fcc' * X * r}{r - 1 + X^{r}}$$

$$fcc' = fc'(-1.254 + 2.254\sqrt{1+\frac{7.94 * f1}{fc'}} - 2 * \frac{f1}{fc'})$$

$$X = \frac{\varepsilon}{\varepsilon_o}$$

$$\varepsilon_o = \varepsilon_{co}\left(1+5\left(\frac{fcc'}{fc'}-1\right)\right)$$

ε_{co} taken as 0.003 and some cases as 0.002 , in this paper an amount of 0.003 were adopted .

$$r = \frac{E_c}{E_c - E_{seq}}$$

$$E_{seq} = \frac{fcc'}{\varepsilon_o}$$

1.5 Finite element model :

Finite element method consider to be the best tool for analyzing the structures recently , many soft wares uses this method for analyzing and designing , such as : Abaqus , ADINA , ANSA, COMSOL Multiphysics , LS-DYNA , Nastran , SAP2000 , ansys , …. Etc .
The most popular and the easiest to learn is ansys software , ansys is an engineering simulation software (computer-aided engineering, or CAE) developer that is headquartered south of Pittsburgh in the Southpointe business park in Cecil Township, Pennsylvania, United States . its widely used especially for the industrially works . the figure shown below is the first front of the program :

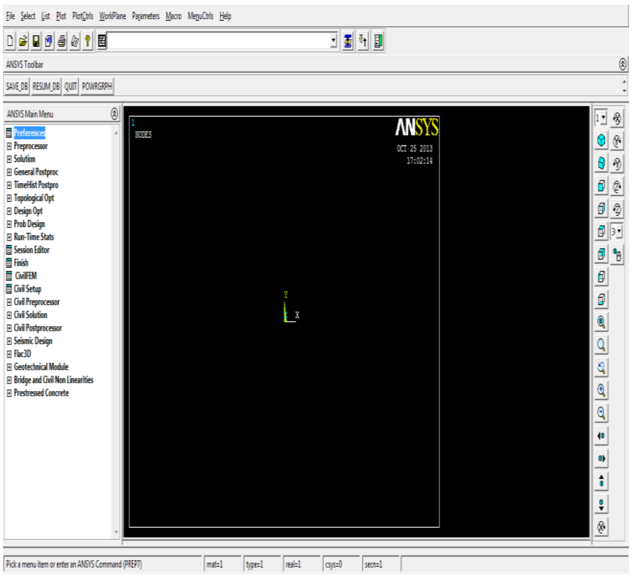

Fig. 1 : front page of the ANSYS software .

1.5.1Choosing Element types :

1-Concrete : for concrete simulation , it's been used the element solid 65 , SOLID65 is used for the three-dimensional modeling of solids with or without reinforcing bars (rebars). The solid is capable of cracking in tension and crushing in compression. In concrete applications, for example, the solid capability of the element may be used to model the concrete while the rebar capability is available for modeling reinforcement behavior. Other cases for which the element is also applicable would be reinforced composites (such as fiberglass), and geological materials (such as rock).

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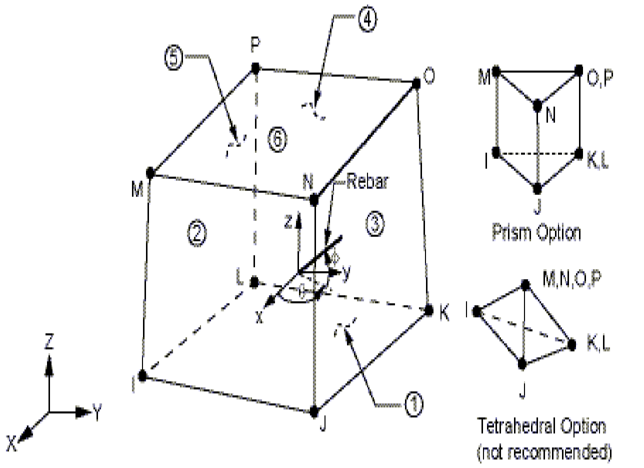
The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. Up to three different rebar specifications may be defined.



Fg. 2 : solid 65 element

2- Steel : For steel tubes simulation element shell181 been used for that purpose , SHELL181 is suitable for analyzing thin to moderately-thick shell structures. It is a four-noded element with six degrees of freedom at each node: translations in the x, y, and z directions, and rotations about the x, y, and z axes. The degenerate triangular option should only be used as filler elements in mesh generation.

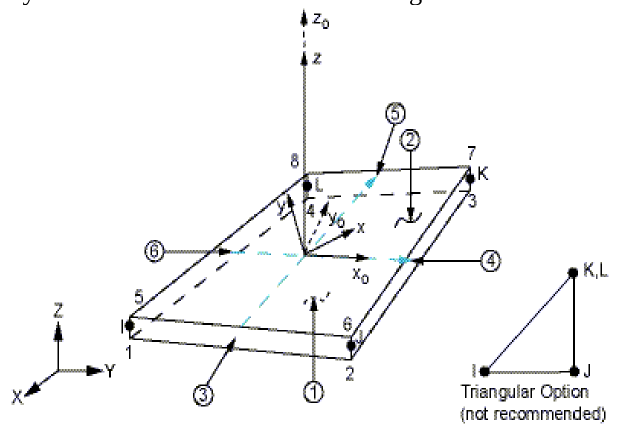


Fig. 3 : shell 181 element .

1.5.2Modeling :

The modeling is consists of creating key points , lines , volumes and areas , with same dimension given in the experimental data .

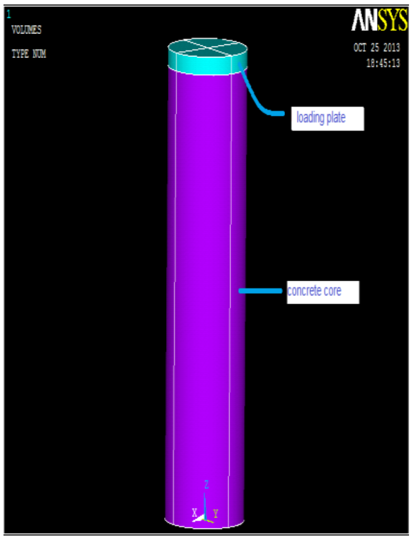


Fig. 4 : loading plate and the concrete core .

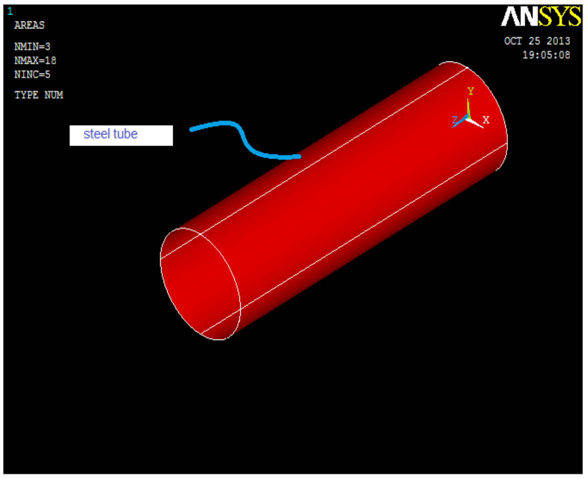


Fig. 5 : steel tube .

Table 1 : the specimens properties .

No.	D mm	T mm	FC' mpa	FY mpa	L mm	D/T	L/D	P kn	tester
1	630	7.0	36.0	291.4	1890	90.0	3.0	16650	C.D. Goode (2005)
2	630	7.6	35.0	349.5	1890	82.8	3.0	18000	C.D. Goode (2005)
3	630.0	8.4	34.5	350.0	1890	74.6	3.0	18600	C.D. Goode (2005)
4	630.0	10.2	38.4	323.3	1890	61.7	3.0	20500	C.D. Goode (2005)
5	630.0	11.6	46.0	347.2	1890	54.3	3.0	24400	C.D. Goode (2005)
6	720.0	8.3	15.0	312.0	2160	86.7	3.0	15000	C.D. Goode (2005)

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7	820.0	8.9	45.0	331.0	2460	91.8	3.0	33600	C.D. Goode (2005)
8	1020.0	9.6	16.9	336.0	3060	105.8	3.0	30000	C.D. Goode (2005)
9	1020	13.3	28.9	368.7	3060	77.0	3.0	46000	C.D. Goode (2005)
10	89.3	4.0	30.2	226.7	270.0	22.3	3.0	491.0	C.D. Goode (2005)
11	86.5	2.8	48.0	226.7	270.0	31.0	3.1	489.0	C.D. Goode (2005)

2. Results and discussion :

The results of the finite element simulation showed good agreement with the experimental results .
For all of the 11 tested specimens , neither one of them exceeded the ± 10% .

The least value from the test to finite element ratio was for the specimen no. 11 equal (0.919914), and the highest was (1.044666) .

Table 2 : the tested specimens results .

No.	P test kn	P fem kn	P fem / p test
1	16650	16623.17	0.998388
2	18000	17649.44	0.980525
3	18600	18156.39	0.97615
4	20500	19732.07	0.96254
5	24400	22799.28	0.934397
6	15000	15669.99	1.044666
7	33600	32483.62	0.966774
8	30000	31199.25	1.039975
9	46000	44632.41	0.97027
10	491	465.7391	0.948552
11	489	449.8381	0.919914

The sum of the experimental results to the fem results ratio was equal to (10.742151) And the average was therefore equal to (0.976559).
As a result from this comparison , it's obvious that the simulation using ANSYS software gives the most safe and accurate results , so it can be used for predicting the axial load capacity for this type of columns .

III. CONCLUSION

Based on the simulation work done by the help of ansys program , number of observations been noticed :

1- Results of the experimental test and the simulation showed good agreement .
2- Concrete filled steel tubular columns axial capacity significantly affected with the cross-section of the column , concrete's compressive strength and yield strength of the steel tubes.

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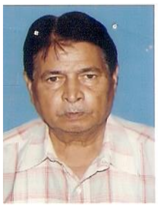

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