STUDY ON BEHAVIOR OF CFST COLUMNS UNDER AXIAL COMPRESSION AND ANALYSIS BY ABAQUS

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Abstract -*This study intended to develop a suitable constitutive experimental study of behavior of CFST's. Composite steel tubes with SCC as infill for M30 grade concrete for different thickness and lengths and are tested under for ultimate load carrying capacity under axial load. And also FEA analysis of the same is done through ABAQUS 6.10.1. This paper focuses on study on testing and modeling of CFST column under axial loading.*

Key Words: axial loading, Nonlinear Analysis, self compacting Concrete, Concrete Filled Steel Tubes, Abaqus.6.10.1

1. INTRODUCTION

CFST element utilizes the advantages of both steel and concrete. Utilization of CFST idea can prompt more % of aggregate sparing in contrast with an auxiliary steel framework solid center upgrades higher compressive quality, firmness, damping and elasticity by external steel tube. In addition, high quality CFST segments require a less c /s to withstand load. In cutting edge days, building plan underlines on improving adaptability of the floor space by diminishing the cross area of segment size. CFST's are utilized for both unbraced and propped assembling structures. A CFST segment comprises of steel tube and solid center inside it. The steel tube go about as a perpetual structure work consequently work cost, time utilization is diminished.

1.1 Benefits of Using CFST Column over Reinforced Column

Composite segment joins the benefits of both basic steel and cement, to be specific the pace of development, quality, and light weight steel, and the characteristic mass, firmness, damping, and economy of cement. The steel outline serves as the erection casing to finish the development of whatever remains of the structure. In this way enhancing pliability. Furlong reasons that the solid infill delays the neighborhood clasping of the steel tube. Notwithstanding, no expansion in solid quality because of repression by steel tube was watched.

1.2 Brief Description of Materials Used

CFST columns of two different lengths and two different thicknesses are used and SCC M30 Mortar, and casted and tested after 28days curing, tested under UTM for axial loading.

1.3 Brief Description of Software Used

Finite element method considers being the best tool for analyzing the structures lately, many software's uses this technique for analyzing and creating. For finite factor evaluation and computer aided design field one of the program is suitable i. e. Abaqus. The 3D hollow and concrete filled steel conduit columns are created in Hypermesh-11. 0 software and then exported to ABAQUS. Because creating model is difficult in ABAQUS.

1.4 Finite Element Modeling

Self weight concrete filled in the CFST column are accurately model in finite element software ABAQUS 6.10.1 and verified with experimental results and codes of practice. The above figure shows on cross section of CFST columns.

II. MATERIAL PROPERTIES AND CONSTITUTIVE MODELS

2.1 Steel

Steel tube is modeled as elastic-perfectly plastic with von mises yield criterion. Due to steel tube is subjected to multiple stresses and therefore the stress-strain curve crosses elastic limit and reaches in plastic region. The nonlinear behavior of steel tube is obtained from uniaxial tension test and used in steel modeling. In this analysis poison's ratio, density and young's modulus are taken as μ=0.3, f_s=7860kg/m^3 and E_s=210000MPa, respectively.

2.2 Self compacting concrete

A rational mix design method of self compacting concrete using a variety of materials is necessary. Coarse aggregate, fine aggregate content in concrete is fixed at 50% & 40% percent of the mortar volume

2.3 Material casting of CFST

Fig 2.3.1 CASTING of CFST columns

2.4 Design criteria for CFST – for various codes

Contents		AIJ guide (2008)	ANSI/AISC 360-10 (2010)	DBJ/T 13-51-2010 (2010)	Eurocode 4 (2004)
Cross-sectional type		Circular, Rectangular	Circular, Rectangular	Circular, Rectangular	Circular, Rectangular
Concrete specimen type		Cylinder	Cylinder	Cube	Cylinder, cube
Physical parameters	Concrete strength (N/mm^2)	18–90	21–70 (Normal weight)	C30–C80	C20/25–C60/75 (Normal weight)
	Elastic modulus of concrete, E_c (N/mm^2)	$3.35\times10^4\times\left(\frac{\gamma}{24}\right)^2\times\left(\frac{F_c}{60}\right)^{\frac{1}{3}}$	$4700\sqrt{f'_c}$ (Normal weight)	$10^5/(2.2+34.7/f_{cu,k})$	$22{,}000\,(f_{cm}/10)^{0.3}$ (Normal weight)
	Yield strength of steel, f_y (N/mm^2)	≤590	≤525	235–420	≤460
	Elastic modulus of steel, E_s (N/mm^2)	205,000	200,000	206,000	210,000
	Flexural stiffness, EI	$E_sI_s+E_cI_c$	$E_sI_s+E_sI_{sr}+C_3E_cI_c$	$E_sI_s+\alpha_0E_cI_c$	$E_sI_s+E_aI_a+0.6E_{cm}I_c$
Geometric parameters	D/t (Circular)	Depends on steel type	$\le0.31E_s/f_y$	$\le150\left(\frac{235}{f_y}\right)$	$\le90\left(\frac{235}{f_y}\right)$
	B/t (Square, rectangular)	Depends on steel type	$\le5\sqrt{E_s/f_y}$	$\le60\sqrt{\frac{235}{f_y}}$	$\le52\sqrt{\frac{235}{f_y}}$
	Long column definition	$l_k/D>12$	-	$\lambda>\lambda_0$	-
	Steel ratio, or confinement ratio, or steel contribution ratio	-	$\alpha\ge1\%$ (steel ratio)	$0.3\le\xi\le4$ (confinement ratio)	$0.2\le\delta\le0.9$ (steel contribution ratio)

2.5 Material Model of Concrete

In order to understand concrete behavior in the finite element model, a nonlinear stress-strain diagram for confined concrete should be establish. The equivalent stress-strain curve for confined and unconfined concrete under compressive loading. This is used in proposed FE model.

The properties of material shown in figure 2 are used to define the nonlinear behavior of concrete under confinement. This is defined as follows:

The stress-strain curve is divided into 3 parts namely elastic part (Linear), Elasto-Plastic part and Perfectly Plastic (non linear).

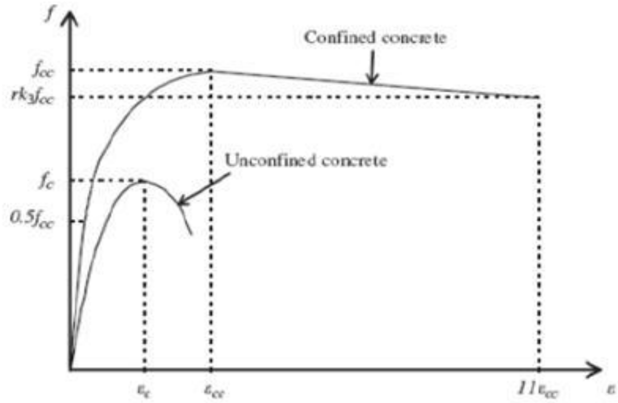


Fig .2 Equivalent stress-strain curves for confined and unconfined concrete

Where f_{cc} = Confined concrete compressive strength.
f_c = Unconfined concrete cylinder compressive strength = $0.8f_{cu}$
f_{cu}= Unconfined concrete cube compressive strength = f_{ck}
f_l = Lateral confining pressure from steel tube = $\frac{2\sigma_\theta t}{D}$

$\sigma_\theta = 0.1f_y$
f_y = Yield strength of steel
t = thickness of steel tube
D = outer dia steel tube
ε_{cc} = confined concrete strain
ε_c = Unconfined concrete strain = 0.002-0.003
ε_c = 0.003, as recommended by the ACI specification [1]
the factor k_1 and k_2 are taken as 4.1 and 20.5 respectively, given by Richart et al.[6]

The first part is linear upto $0.5f_{cc}$ at which stress is proportional to strain energy given by Hu et al.[10] the slope of the linear part gives linear whose elastic young's of confined concrete E_{cc}. According to ACI code [1] the value of E_{cc} is given by

$$E_{cc} = 4700\sqrt{f_{cc}}MPa$$

The poisson's ratio of unconfined concrete is assumed to be μ_{cc}=0.2. The second part is elasto-plastic which is nonlinear whose origin starts from the end of first part that is $0.5f_{cc}$ and ends at confined concrete strength f_{cc} as shown in fig 2. This non linear part can be determined from the following equations, proposed by Saenz [5]

$$f = \frac{E_{cc}\varepsilon}{1 + (R + R_E - 2)\left(\frac{\varepsilon}{\varepsilon_{cc}}\right) - (2R - 1)\left(\frac{\varepsilon}{\varepsilon_{cc}}\right)^2 + R\left(\frac{\varepsilon}{\varepsilon_{cc}}\right)^3}$$

In the above equation R and R_E can be calculated as

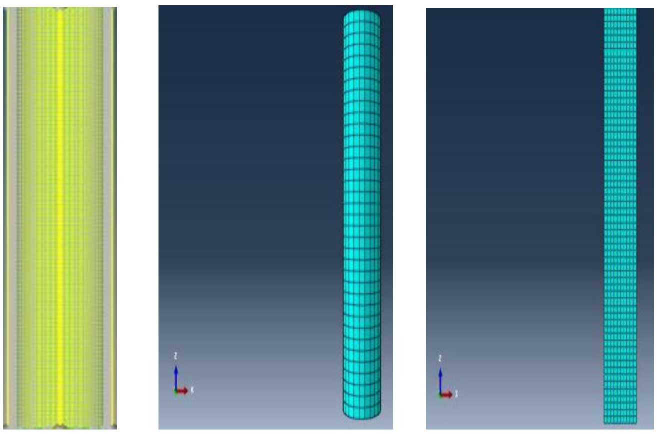
$$R_E = \frac{E_{cc}\varepsilon_{cc}}{f_{cc}}$$

$$R = \frac{R_E(R_\sigma - 1)}{(R_\varepsilon - 1)^2} - \frac{1}{R_\varepsilon}$$

2.6 Properties of Materials

PROPERTIES OF MATERIAL	density	poisons ratio	young modulus (E)
	Kg / m^3		MPa
STEEL	7860	0.3	310000
CONCRETE (SCC)	2400	0.16	25000

III. MODELING AND MESHING



3.1 Load Application

A compressive load is uniformly distributed over the top surface of column nodes as shown in figure 4. The load is applied in Z-direction and is allow to move freely in Z-direction but restrained in X and Y-direction.

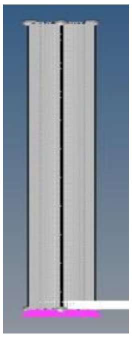


fig 3.1 Application of load

3.2 Boundary Conditions

Bottom end of the column is fixed in all directions that is Δx=0, Δy=0, Δz=0. Top surface of the column is restrained in X and Y-direction (Δx=0, Δy=0) and allowing displacement in Z-direction as shown in figure.

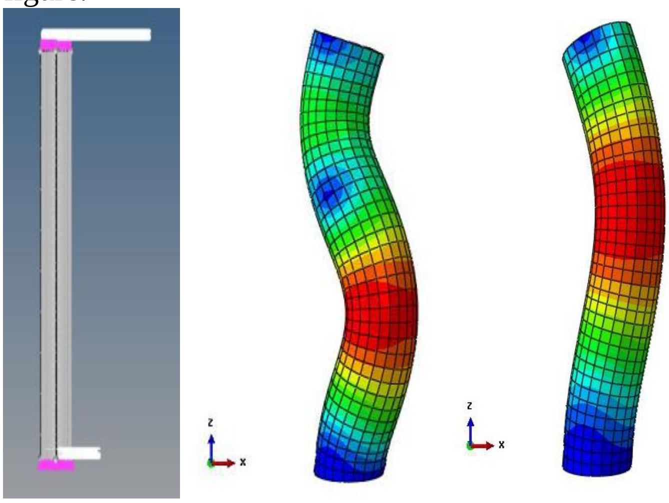


fig 3.2 . Boundary conditions.

IV. SOLUTION PROCEDURE

First static analysis is performed and then procedure is changed to linear buckling analysis, which gives Eigen values. The first Eigen value is considered as Buckling load factor or critical load for linear analysis. First Eigen value because the column will break at first load and there are less chance to go second critical load. But a material reaches to nonlinearity action so therefore nonlinear analysis is performed. There are several nonlinear methods are available in ABAQUS. Now job is created and submitted to run the analysis.

4.1 Analytical Study by using Euro code 4

EC4 [3] is the most recently completed international standard code for composite construction. It covers CFST columns with or without reinforcement. EC4 consider the confinement effect for composite column when relative slenderness ratio(λ) has value less than 0.5. the ultimate axial force for square column is given by

$$P_u = A_c f_c + A_s f_s$$

Where ; A_C=Area of concrete A_S= Area of steel, and f_c and f_s are the yield strength of concrete and steel respectively.

V. VERIFICATION OF FINITE ELEMENT MODEL

5.1 Experimental Results

In order to check the accuracy of the finite element model, the modeling results were compared with experimental tests results which is carried out by using Universal Testing Machine (UTM). The Ultimate loads obtained from finite element analysis is PFE and that for experimental test is P_{expt}. CFST columns obtained Experimentally and numerically using the FEM. It was found that the non linear finite element simulations are in a good agreement with the experimental results

VI.TEST RESULTS:

FOR RECTANGULAR SECTION

size	t	L	Pu (ABA)	Pu (expt)	Pu (EC4)
	mm	mm	KN	KN	KN
38.1x38.1	1.2	400	94.5	90.5	92.5
38.1x38.1	1.6	400	94.5	92	90.5
38.1x38.1	1.2	600	120.3	113.5	115.4
38.1x38.1	1.6	600	122.6	110.5	112.5

size	t	L	Pu (ABA)	Pu (expt)	Pu (EC4)
	mm	mm	KN	KN	KN
50.8x50.8	1.2	400	108.5	102.5	104.2
50.8x50.8	1.6	400	128.5	118	116.2
50.8x50.8	1.2	600	115	108.5	110.5
50.8x50.8	1.6	600	135.2	128	125.3

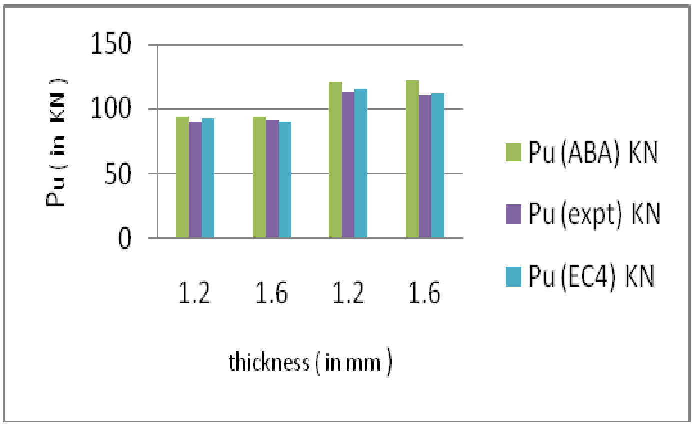
FOR CIRCULAR SECTION

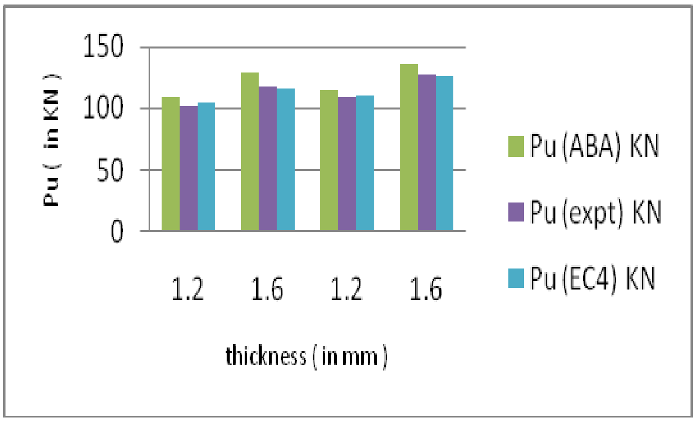
size	t	L	Pu (ABA)	Pu (expt)	Pu (EC4)
mm	mm	mm	KN	KN	KN
38.1	1.2	400	90.6	88.5	84.2
38.1	1.6	400	94.3	92.5	90.5
38.1	1.2	600	118.5	114.5	112.8
38.1	1.6	600	120.3	110.5	112.5

size	t	L	Pu (ABA)	Pu (expt)	Pu (EC4)
mm	mm	mm	KN	KN	KN
50.8	1.2	400	108.5	106	102.5
50.8	1.6	400	125.12	110.5	118.23
50.8	1.2	600	112	108	108.6
50.8	1.6	600	130.5	120	128.76

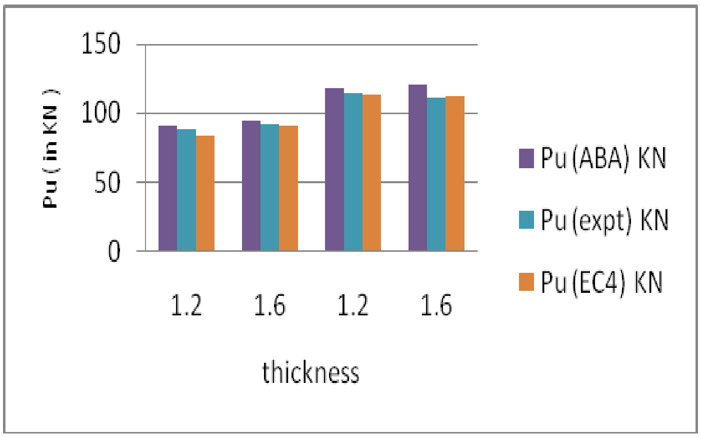
Graphical Representation

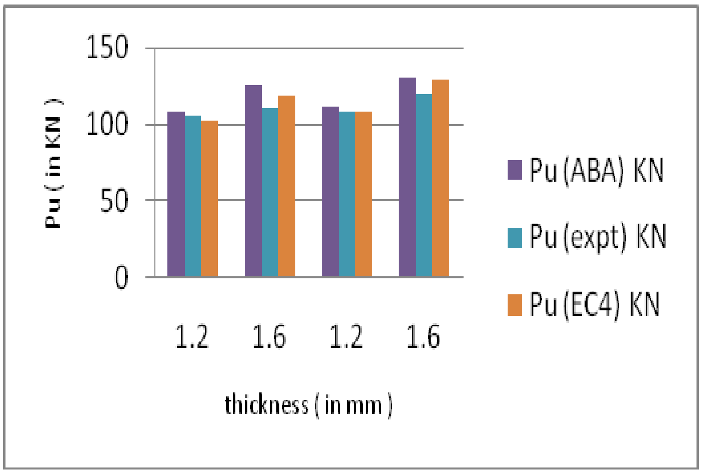
FOR RECTANGULAR SECTION





FOR CIRCULAR SECTION





VII.STATICAL ANALYSIS

STANDARD DEVIATION

OF ALL RESULTS:

FOR RECTANGULAR SECTION :

size	t	L	Pu (ABA)	Pu (expt)	Pu (EC4)
mm	mm	mm			
38.1x38.1	1.2	400	1.414	1.414	0
38.1x38.1	1.2	600	1.58	1.59	0.02
38.1x38.1	1.6	400	2.75	2.05	0.707
38.1x38.1	1.6	600	4.29	4.26	0.021
50.8x50.8	1.2	400	2.42	1.81	0.613
50.8x50.8	1.2	600	5.37	2.05	3.32
50.8x50.8	1.6	400	2.59	2	0.586
50.8x50.8	1.6	600	4.03	1.06	2.96

FOR CIRCULAR SECTION :

size	t	L	Pu (ABA)	Pu (expt)	Pu (EC4)
mm	mm	mm			
38.1	1.2	400	2	0.52	2.51
38.1	1.2	600	1.32	0.049	1.36
38.1	1.6	400	2.29	0.53	1.73
38.1	1.6	600	3.67	3.25	0.424
50.8	1.2	400	2	0.24	2.23
50.8	1.2	600	5.06	5.26	0.197
50.8	1.6	400	1.74	1.08	0.65
50.8	1.6	600	2.88	4.53	1.65

VIII.CONCLUSIONS

A nonlinear finite element analysis was also carried out to study the effects of cross-sectional shape and stiffener on axial stress distribution at a typical cross section. Several interesting points were noted:

1. The stiffness computed by directly superposing the stiffness of the steel tube and the core concrete is significantly overestimated, sometimes by over 40%.
2. Increase in thickness of steel tube enhance the capacity (Pu) of both Hollow and composite column due to confinement pressure increases with increase in thickness of steel tube

3. Ultimate load obtained from ABAQUS non-linear Modelling varied by 4% to 8% when compared with experimental values.

4. Ultimate load values obtain, eurocode-4 varied by 2% to 9% when compared with ABAQUS values.

5. Finite element model results are obtained from ABAQUS 6.10-1 and compare with Experimental results of hollow and composite column with different grade, thickness and number of stiffeners results in predicting the column behaviour.

6. As concrete strength is increase, the stiffness of column increases but column fails due to crushing of concrete which shows brittle failure behaviour when filled with high grade of concrete.

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