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Validation of Ultimate Axial Load Carrying Capacity on Composite Steel Tube Column In filled With SCC by Using Nx-Nastron

Madhu B. N
Ghousia College of Engineering, Ramanagara, Karnataka
madhubn.1993@gmail.com

Dr. N. S Kumar
Ghousia College of Engineering, Ramanagara, Karnataka
drkumarns@gmail.com

***Abstract:** This Research focuses on validation of Ultimate axial load carrying capacity of CFST column filled with Lightweight concrete and self-compacting concrete using NASTRON. Three-dimensional nonlinear finite element modal is developed to study the force transfer effect between concrete and hollow steel tube. Model is developed for understanding the complex behavior of conventional composite circular steel tube and self-compacting concrete infilled tube with various grades and different diameters (D), thickness (t) and length (l). Using hyper mesh, the model is meshed and model is used in NASTRON finite element software. The result obtained for M20, M30 Grades of SCC concrete is compared with Analytical Codal relations along with standard results obtained from previous Researchers.*

***Keywords:** Nonlinear Analysis, self-compacting Concrete, Filled Steel Tubes, NX-NASTRON.*

I. INTRODUCTION

Concrete Filled steel tube (CFST) was used in the early 1900s. But till 1960s research on concrete filled steel tube did not begin. Concrete Filled steel tube (CFST) are composite members consists steel tube infilled with concrete materials. Concrete filled column are used in lateral resistance system of both braced and unbraced system of the building, commonly concrete filled steel tube are used in bridges piers. Moreover Concrete filled steel tube column are used for strengthening the structure in earthquake zones. Concrete Filled Steel Tubular (CFST) composite columns represent a class of structural systems, where the best properties of steel and concrete are used to their maximum advantage. When employed under favourable conditions the steel casing confines the core tri-axially creating a confinement for better seismic resistance and the in-filled concrete inhibits the local buckling of the tubular shell.

Moreover when compare with hollow steel tube, core concrete the concrete filled steel tube (CFST) will give more compressive stability enormously concrete filled steel tube (CFST) will give more excellent compressive resistance capacity, ductility and energy dissipation ability owning to be confining effect provided by steel tube

A. 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.

B. 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 programs is suitable i. e. NASTRON. The 3D hollow and concrete filled steel conduit columns are created in Hypermesh-11. 0 software and then exported to NASTRON. Because creating a model is difficult in NASTRON. The factor libraries of specific factor software NASTRON are employed to choose different types of elements.

C. Finite Element Modeling Self weight concrete & light weight concrete filled in the CFST column are accurately model in finite element software NASTRON and verified with experimental results and codes of practice. The above figure shows on the cross section of CFST columns.

II. MATERIAL PROPERTIES AND CONSTITUTIVE MODELS

A. 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 Poisson's ratio, density and young's modulus are taken as μ=0.3, ∫=7860kg/m3 and Es=210000MPa, respectively.

B. 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.

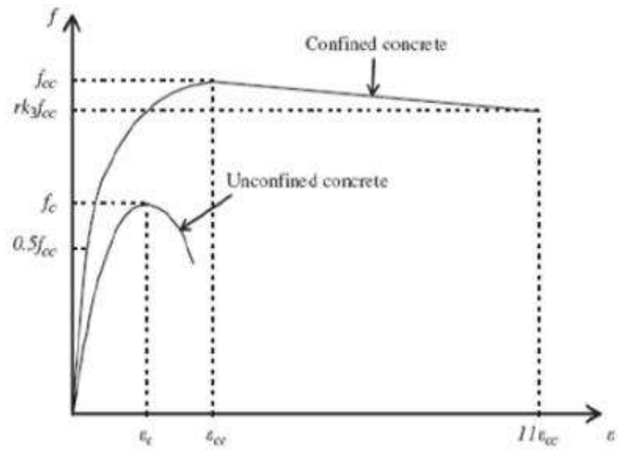


Fig .2 Equivalent stress-strain curves for confined and unconfined concrete

C. 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 (nonlinear).

E. Properties of Materials: Table I Properties of Materials

Properties steel	**Steel**	**Self-compacting concrete**
Density(∫)	7860 kg/m3	2400 kg/m3
Poison ratio (v)	0.3	0.16
Young's modules (E)	210000MPa	22360.70000 (M20),27386.12(M30),and 31622.78(M40)MPA

III. BREIF DESCRIBE OF SOFTWARE'S USED

The following are the software's tools used below are;

CATIAV 5

□□HYPERMESH
□□NASTRON

CATIA V5

CATIA software also used to design the geometry that is modeling this software gives more accurate 3-d modeling. Catia is the present software used for a development solution for all manufactured catiav5 using in the processing of the buildings the globe leading facilities for new research.

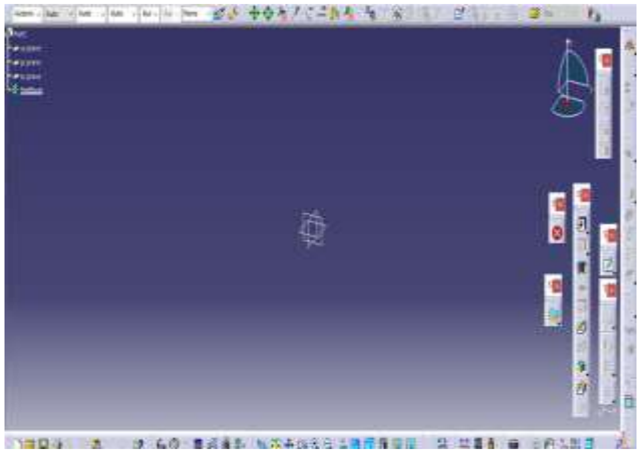


Fig 3 Main menus of CATIA V5

Hypermesh

HYPERMESH: hyper mesh performance and therefore it is a performance finite element pre and posts processor. Used for modeling the specimen and also for the purpose of analysis stands for high and per stands for performance and therefore it is a high

Flow Chart of the FEM Process

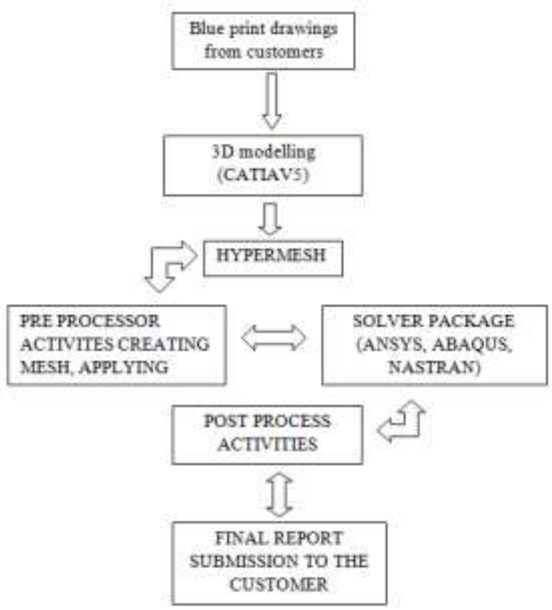


Fig 4 Flowchart of Hyper Mesh

IV. MODELING AND MESHING

The 3D hollow and self-compacting concrete & light weight concrete-filled steel tube columns are created in Hypermesh-11.0 software and then exported to NX-NASTRON. Because creating a model is difficult in NX-NASTRON when compare to the Hypermesh. The element library of finite element software NX-NASTRON is used to select different types of elements

Fig 3: Meshing of the Component

A. ***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.

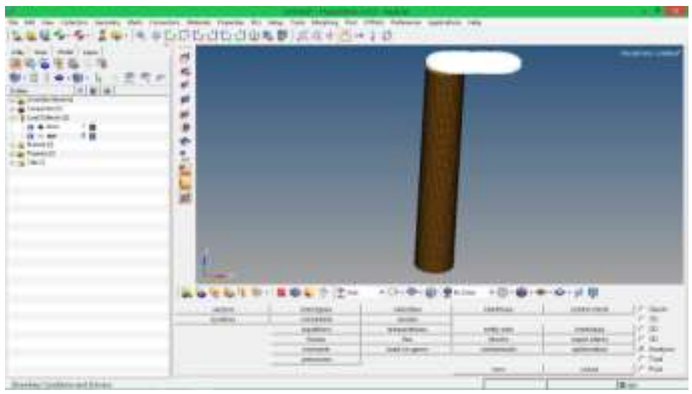


Fig 4: Application of Load

B. ***Boundary Conditions*** Bottom end of the column is fixed in all directions that are 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 5: Boundary Condition

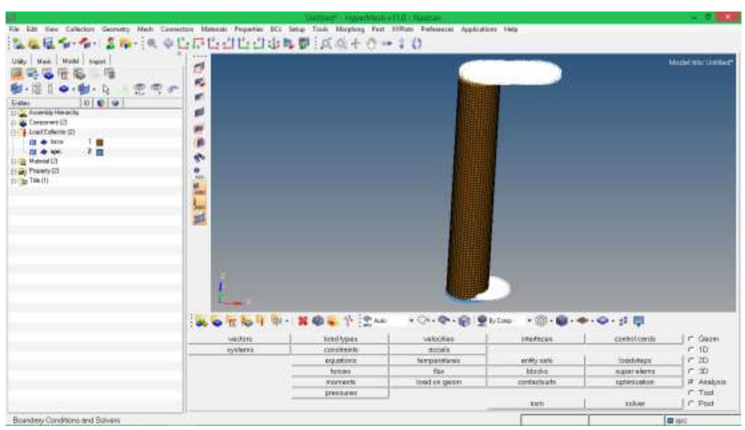


Fig 5: Boundary Condition

The first static analysis is performed and then the procedure is changed to linear buckling analysis, which gives Eigenvalues. The first Eigenvalue is considered as Buckling load factor or critical load for linear analysis. First Eigenvalue 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 NASTRON. Now the job is created and submitted to run the analysis. The Load Prediction Factor LPF value corresponding to the ultimate point is taken from the graph and multiplied with the first Eigenvalue obtained from linear buckling analysis which gives Ultimate load carrying capacity (PU) the output gives a nonlinear graph which is plotted against (LPF) versus Arc length.

V. VERIFICATION OF FINITE ELEMENT MODE

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

B. Analytical Study by using Eurocode 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 a composite column when relative slenderness ratio (λ) has a value less than 0.5. The ultimate axial force for square column is given by

$$Pu=Acfc + Asfs$$

Where; Ac=Area of concrete As= Area of steel, and fc and fs are the yield strength of concrete and steel respectively

American Concrete Institute: Building Code Requirements for Structural Concrete

The American concrete institute ACI [1] use the formula to calculate squash load. This code doesn’t consider the effect of confinement. The squash load for circular column is given by

$$Pu=0.95Acfc + Asfs$$

A modification for above equation is proposed by Giakoumelis and Lam [11]. A coefficient is proposed for above ACI equation to take into account the effect of confinement on the axial load capacity of CFST column and for the hollow first term is zero. A revised equation is given by

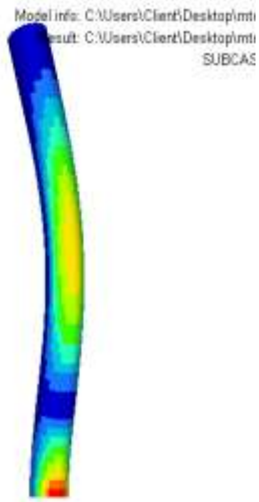
$$Pu=1.3Acfc + Asfs$$

The capacities given by ACI code are too conservative whereas those calculated by using revised equation are more realistic, especially for circular columns.

Specimen Details

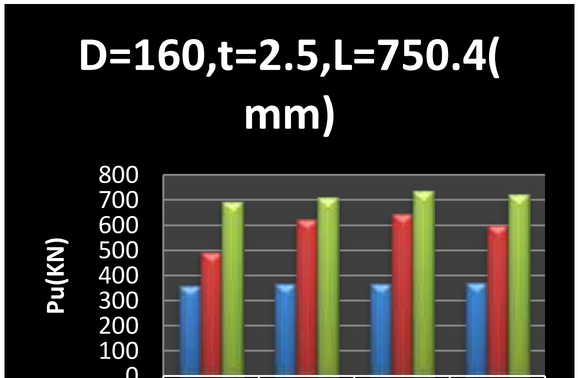
Diameter (mm)	Length (mm)	Thickness (mm)	D/t	L/D)
160	750.4	2.5	64	4.69
139.6	800	4	34.9	5.73
	2000	4	34.9	14.32
111.25	750.4	2.5	44.5	6.75
160	400	2.8	57.14	2.5
	1000	2.8	57.142	6.25
60.3	301.5	2.9	20.79	5
	422.1	3.6	16.75	7
26.9	215.8	3.2	8.4	8
	404.8	3.2	8.4	15
33.7	215.8	3.2	10.53	6.4
	404.8	3.2	1053	12

VII. RESULTS DIFFERENT MODE SHAPES

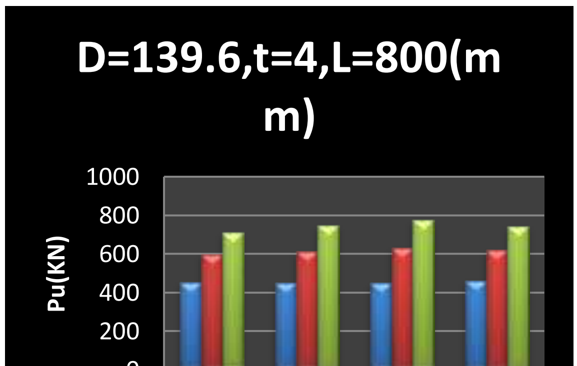


Year	Grade	Diameter	Length	Thickness	D/t	L/D	Pu(expt) KN	Pu(Ec4) KN	Pu(ACI) KN	Pu(nast) KN	Pu(Nast)/ Pu(expt)	Pu(nast) KN
		(mm)	(mm)	(mm)						nonlinear		Linear
2007	Hollow	160	750.4	2.5	64	4.69	361.4	367.275	367.275	371	1.026563	369
2007	M20	160	750.4	2.5	64	4.69	491.3	624.468	646.3244	601	1.223285	648
2007	M30	160	750.4	2.5	64	4.69	693.3	713.1	738.0585	723	1.042839	740
2010	Hollow	139.6	800	4	34.9	5.73	453.3	450.63	450.63	462	1.019193	453
2010	M20	139.6	800	4	34.9	5.73	598.6	612.53	633.9686	621	1.037421	636
2010	M30	139.6	800	4	34.9	5.73	712.4	748.5	774.6975	743	1.042953	778
2010	Hollow	139.6	2000	4	34.9	14.32	470.5	460.63	460.63	524	1.113709	463
2010	M20	139.6	2000	4	34.9	14.32	610.3	612.53	633.9686	621	1.017532	636
2010	M30	139.6	2000	4	34.9	14.32	739	748.478	774.6747	749	1.013532	777
2011	Hollow	111.25	750.4	2.5	44.5	6.75	267.3	270.7	270.7	377	1.4104	273
2011	M20	111.25	750.4	2.5	44.5	6.75	331.3	347.9	360.0765	353	1.0655	362
2011	M30	111.25	750.4	2.5	44.5	6.75	427.3	436.6	451.881	586	1.371402	454
2013	Hollow	160	400	2.8	57.14	2.5	261.3	276.42	276.42	281	1.075392	278
2013	M20	160	400	2.8	57.14	2.5	297.5	302.54	313.1289	309	1.038655	315
2013	M30	160	400	2.8	57.14	2.5	371	398	411.93	411	1.107817	414
2013	Hollow	160	1000	2.8	57.142	6.25	283.3	276.42	276.42	291	1.02718	278
2013	M20	160	1000	2.8	57.142	6.25	643	650.7	673.4745	701	1.090202	675
2013	M30	160	1000	2.8	57.142	6.25	687	707.8	732.573	709	1.032023	735
2014	Hollow	60.3	301.5	2.9	20.79	5	99.5	104.53	104.53	113	1.135678	107
2014	M20	60.3	301.5	2.9	20.79	5	153.7	151.1	156.3885	187	1.216656	158
2014	M30	60.3	301.5	2.9	20.79	5	182.1	174.4	180.504	197	1.081823	183
2014	Hollow	60.3	422.1	3.6	16.75	7	112.6	128.2	128.2	133	1.181172	130
2014	M20	60.3	422.1	3.6	16.75	7	168.2	172.8	178.848	212	1.260404	181
2014	M30	60.3	422.1	3.6	16.75	7	195.6	194.6	201.411	218	1.114519	203
2016	Hollow	26.9	215.8	3.2	8.4	8	70	77.7	77.7	79	1.128571	80
2016	M20	26.9	215.8	3.2	8.4	8	80	84.3	87.2505	103	1.2875	89
2016	M30	26.9	215.8	3.2	8.4	8	90	94.3	97.6005	112	1.244444	100
2016	Hollow	26.9	404.8	3.2	8.4	15	75	77.7	77.7	83	1.106667	80
2016	M20	26.9	404.8	3.2	8.4	15	88.3	84.3	87.2505	101	1.143828	89
2016	M30	26.9	404.8	3.2	8.4	15	93.7	94.3	97.6005	121	1.291355	100
2016	Hollow	33.7	215.8	3.2	10.53	6.4	84	81.3	81.3	93	1.107143	83
2016	M20	33.7	215.8	3.2	10.53	6.4	101.7	103	106.605	123	1.20944	109
2016	M30	33.7	215.8	3.2	10.53	6.4	112.3	109	112.815	129	1.148709	115
2016	Hollow	33.7	404.8	3.2	1053	12	90	81.3	81.3	99	1.1	83
2016	M20	33.7	404.8	3.2	1053	12	110	103	106.605	124	1.127273	109
2016	M30	33.7	404.8	3.2	1053	12	120	109	112.815	136	1.133333	115

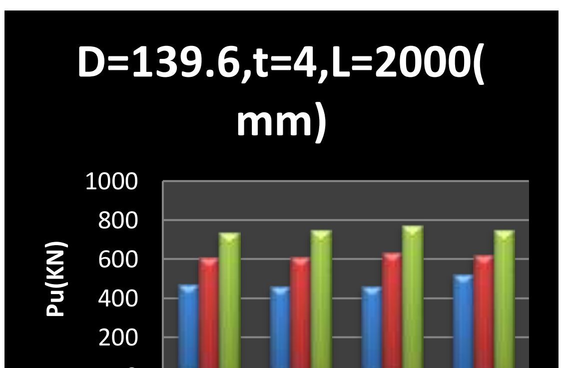
GRAPHICAL REPRESENTATION OF SCC RESULTS



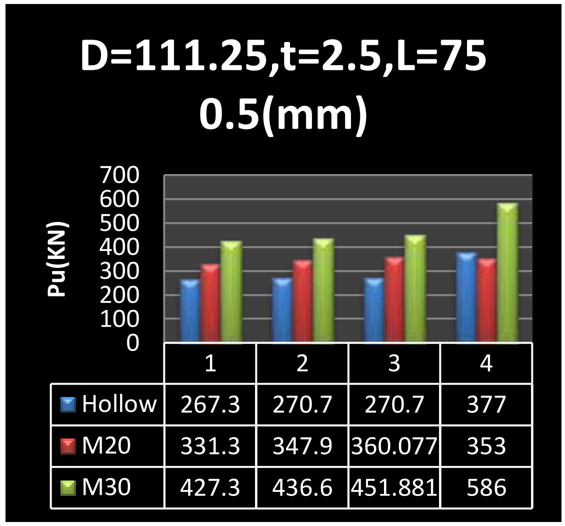
	1	2	3	4
Hollow	361.4	367.275	367.275	371
M20	491.3	624.468	646.324	601
M30	693.3	713.1	738.059	723



	1	2	3	4
Hollow	453.3	450.63	450.63	462
M20	598.6	612.53	633.969	621
M30	712.4	748.5	774.698	743



	1	2	3	4
Hollow	470.5	460.63	460.63	524
M20	610.3	612.53	633.97	621
M30	739	748.48	774.67	749



CONCLUSIONS

1) 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

2) Ultimate load obtained from NASTRON non-linear Modeling varied by 2% to 11% when compared with experimental values.

3) Ultimate load values obtain, eurocode-4 varied by 1% to 2% when compared with NASTRON values.

4) Finite element model results are obtained from NASTRON and compare with Experimental results of the hollow and composite column with different grade, thickness results in predicting the column behavior.

5) Thickness of the tube plays a vital role in load carrying capacity, as the thickness increased i.e., for D/t ratio there is a slight decrease in load carry capacity

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2014-Reliability Analysis of Composite Steel Column Subjected to Monotonic Loading-Pradeep .K

BIOGRAPHIES

Madhu B N Obtained B.E degree in Civil Engineering (First Class with distinction) during the year 2015 from Sampoorna institution of tecnology, Channapatna Affiliated to VTU Belgaum. Presently persuing Master of Technology in Structural Engineering at Ghousia College of Engineering, Ramanagaram. Also working on this topic for the dissertation under the guidance of Dr. N.S Kumar

Dr. N.S Kumar, Involved in the Research field related to behavior of Composite Steel Column since a decade. & He has guided more than 20 M.tech projects including one M.Sc. Engineering (by Research under VTU, Belgaum). Presently guiding four Ph.D Scholars under VTU Belgaum. Has more than 28 years of teaching & 6 years of Research experience at Ghousia College of Engineering, Ramanagaram

