

Buckling Analysis and Mode Shapes of Composite Columns with Self Compacting Concrete Infill (SCC) using MIDAS CIVIL

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Abstract: *This Research focuses on validation of Ultimate axial load carrying capacity of CFST column filled with self-compacting concrete using MIDAS CIVIL finite element software. Three-dimensional nonlinear finite element model 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). Diameter of column varying from 337mm to 483mm and length from 200mm to 680mm is considered as experimental results are available from different national and international research works including R&D works carried out at Civil Engineering research laboratory at Ghousia College of Engineering by previous UG, PG and research scholars since 2010 till date.*

Keywords: Nonlinear Analysis, Buckling Analysis, Mode Shapes, Self-compacting Concrete, Filled Steel Tubes, Midas Civil.

1. 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 tubes 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 owing 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. MIDAS CIVIL. It was developed in KOREA as a structural design software for bridges and other civil structures. The 3D hollow and concrete filled steel conduit columns are created in the software and then analysed for buckling and mode shapes under failure are generated.

C. Finite Element Modeling

Self weight concrete filled in the CFST column are accurately model in finite element software MIDAS CIVIL and compred with experimental results and codes of practice.

2. 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 $\mu=0.3$, $\rho=7860\text{kg/m}^3$ and $E_s=210000\text{MPa}$, 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.

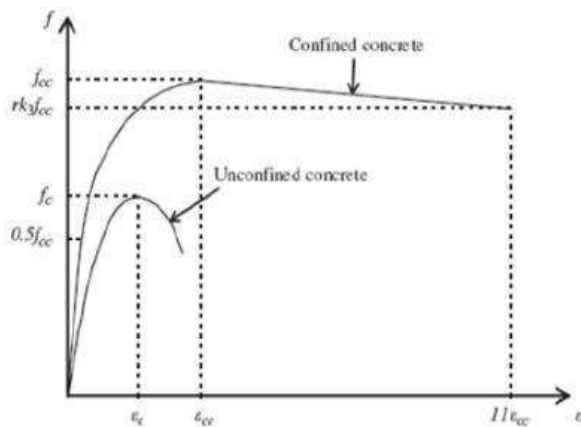


Fig .2 Equivalent stress-strain curves for confined and unconfined concrete

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 established. 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).

D. Properties of Materials: Table I Properties of Materials

Properties steel	Steel	Self-compacting concrete
Density(ρ)	7860 kg/m ³	2400 kg/m ³
Poison ratio (ν)	0.3	0.16
Young's modulus (E)	210000MPa	22360.70000 (M20), 27386.12(M30), and 31622.78(M40)MPa

3. Specimen Details and Experimental Loads

Experimental Loads & Other Data					
Sl No.	Length (mm)	Diameter (mm)	Load P (kN)	Weight (kg)	Grades
1	678.4	48.3	142.8	3.054	M20
			146.8	3.126	M30
			150.2	3.25	M40
			131.3	2.402	H
2	594.6	42.4	118.9	2.934	M20
			121.8	2.886	M30
			124.2	2.986	M40
			109.3	1.732	H
3	508.8	42.4	162.2	2.38	M20
			166.1	2.416	M30
			169.2	2.52	M40
			121.8	1.512	H

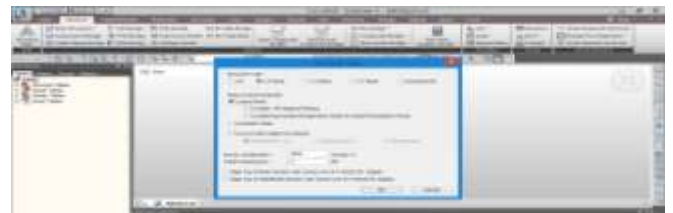
4	424	42.4	233.5	2.112	M20
			239.1	2.215	M30
			243.9	2.022	M40
			180.6	1.22	H
5	339.2	42.4	323.24	1.154	M20
			331.31	1.182	M30
			379.9	1.088	M40
			334.2	0.714	H
6	254.4	42.4	220	1.208	M20
			227	1.118	M30
			238	1.156	M40
			200	0.627	H
7	202.2	33.7	170	0.658	M20
			178	0.698	M30
			184	0.69	M40
			145	0.462	H

4. Modeling Procedure and Analysis in Midas Civil

1. Set the units to KN and MM in the bottom most bar.



2. From STRUCTURE tab, click STRUCTURE TYPE and select X-Z Plane. i.e, the structure is to be modelled in only 2D plane.



3. Select BASE STRUCTURES and select COLUMN. Suppose a cfst column of 678.4mm length is modelled, enter the distance as 6.784 mm and repeat as 100. This implies that the given length of column is divided into 100 equal finite elements to get more accurate results. Also, select the boundary condition as FIXED. Therefore a restraint will be applied on one end of the column. Click Apply.



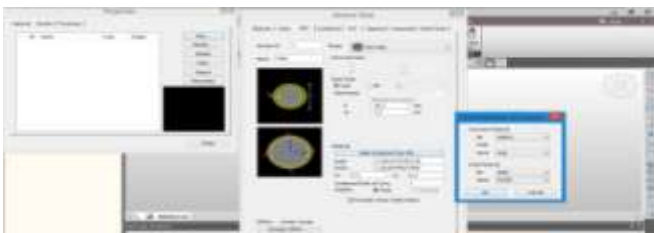
4. Goto BOUNDARY tab and select DEFINE SUPPORTS. Check D-ALL and R-ALL. This implies that to provide fixed end restraint for the other end of the column, the displacements and rotations in all directions have been restrained.



5. Goto PROPERTIES tab and select MATERIAL PROPERTIES. Provide a name to the material like “Composite” and choose SRC (Steel Reinforced Concrete) for modelling a composite column. Likewise, for modelling a hollow steel pipe, select type of design as STEEL. Select the code of design and specify the strength of the steel and concrete and apply.



6. In the section tab, expand the SRC tab and provide a name to the section like “Pipe”. Choose the shape as SRC-Pipe and enter the diameter, thickness and other properties of the column as shown in the figure below.



7. Goto LOAD tab, and select STATIC LOAD CASES. Enter a name and select type of load as User Defined Load (USER) and add. In this step, the load case is defined.



8. Select NODAL LOADS. Since a vertical downward load is to be applied on the model, enter a nominal load of -10KN (this load will later be multiplied by the critical load factor to obtain the actual failure load) in the FZ direction. Select the specimen and apply the load.



9. For analyzing, goto ANALYSIS tab and select BUCKLING. Enter the number of modes required. Here, 4 modes have been selected. Check OK “Consider axial force only”. Add the load case P specified in the earlier steps.

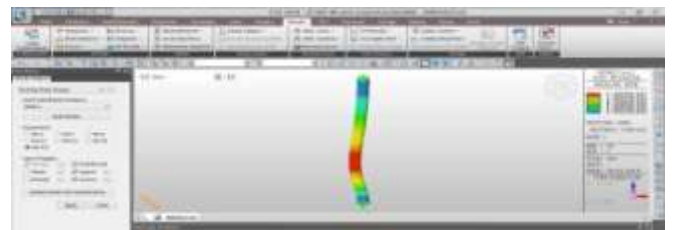


10. Click PERFORM ANALYSIS and the Buckling analysis will be done on the model.



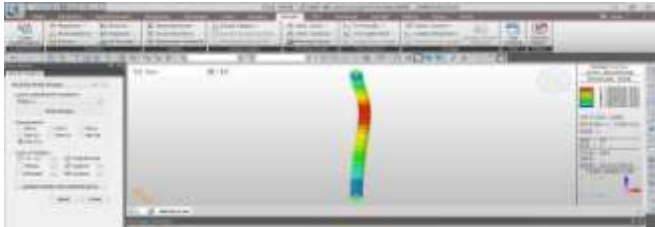
5. Obtaining Results, Mode Shapes and Load Calculation

1. Click on **Results>Mode Shapes>Buckling Mode Shapes**. Select Mode 1,2 and 3 one by one. Check on Undeformed, Legend and Contour and click on Apply to see different mode shapes graphically. You can also view multiple buckling mode shapes at the same time by clicking on Multi Modes option.



The Critical Load Factor obtained for 1st mode is 1.740E+001. Therefore the load for this mode is nominal load applied multiplies by the critical load factor. That is, Maximum Compressive Force for Buckling, $P_{cr} = 10 \times 17.40 = 174 \text{ KN}$.

2. For 2nd mode, critical load factor is 1.740E+001. $P_{cr} = 10 \times 17.40 = 174 \text{ KN}$.



3. For 3rd mode, critical load factor is 3.024E+001. Pcr = 10 X 30.24 = 302.4 KN.



4. For 4th mode, critical load factor is 3.024E+001. Pcr = 10 X 30.24 = 302.4 KN.



6. Results

EXPERIMENTAL LOADS & OTHER DATA						LOADS FROM MIDAS CIVIL (kN)			
sl no.	Length (mm)	Diameter (mm)	Load P (kN)	Weight (kg)	Grades	MODE 1	MODE 2	MODE 3	MODE 4
1	678.4	48.3	142.8	3.054	M20	174	174	302.4	302.4
			146.8	3.126	M30	180.6	180.6	318.3	318.4
			150.2	3.25	M40	186.1	186.1	331.3	331.3
			131.3	2.402	H	141.1	141.1	221.7	221.7
2	594.6	42.4	118.9	2.934	M20	145.2	145.2	250.7	250.7
			121.8	2.886	M30	149.6	149.6	262	262
			124.2	2.986	M40	154	154	272.2	272.2
			109.3	1.732	H	121.3	121.3	191.4	191.4
3	508.8	42.4	162.2	2.38	M20	185.8	185.8	294.5	294.5
			166.1	2.416	M30	192.6	192.6	310.1	310.1
			169.2	2.52	M40	198.2	198.2	322.9	322.9
			121.8	1.512	H	151.8	151.8	216.7	216.7
4	424	42.4	233.5	2.112	M20	241.3	241.3	340.1	340.1
			239.1	2.215	M30	251.4	251.4	360.7	360.7
			243.9	2.022	M40	259.6	259.6	377.6	377.6
			180.6	1.22	H	190.5	190.5	239.6	239.6
5	339.2	42.4	323.24	1.154	M20	314.9	314.9	379.7	379.7
			331.31	1.182	M30	330.6	330.6	406.1	406.1
			379.9	1.088	M40	343.4	343.4	427.9	427.9
			334.2	0.714	H	235.2	235.2	255	255
6	254.4	42.4	220	1.208	M20	393.3	393.3	400.9	400.9
			227	1.118	M30	419.1	419.1	431.7	431.7
			238	1.156	M40	440.2	440.2	457.6	457.6
			200	0.627	H	259.9	259.9	264.6	264.6
7	202.2	33.7	170	0.658	M20	279.3	279.3	283.5	283.5
			178	0.698	M30	294.4	294.4	301.2	301.2
			184	0.69	M40	306.9	306.9	316.1	316.1
			145	0.462	H	202.1	202.1	205.7	205.7

7. Conclusions

- 1) Increase in thickness of steel tube, enhance the capacity (Pu) of both Hollow and composite column as confinement pressure increases with increase in thickness of steel tube
- 2) Ultimate load obtained from MIDAS CIVIL non-linear Modeling varied by 2% to 11% when compared with experimental values.

- 3) Ultimate load values obtained were found to be slightly higher in magnitude when compared with experimental values.
- 4) Finite element model results obtained from MIDAS CIVIL compared with Experimental results of the hollow and composite columns with different grades including different thickness varied very less.
- 5) The critical load factor and the load value for a given specimen is found to be same for 1st and 2nd mode and 3rd and 4th mode respectively.

6) 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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Dr. N.S Kumar, Prof. & Director (R&D), is involved in this Research field related to behavior of Composite Steel Column since a Decade. He has guided One Ph.D Thesis (under VTU, Belgaum), more than 25M.tech projects including one M.Sc. Engineering (by Research under VTU, Belgaum). Presently guiding Six Ph.D Scholars under VTU Belgaum. Has more than 29 years of teaching & 6 years of Research experience at Ghousia College of Engineering, Ramanagaram. To his credit, he has 130 International /National research publications as on date.