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Non-Linear Behaviour of CFST Columns at Elevated Temperature Under Monotonic Loading using Hyper Mesh & Abaqus Software's (Conventional Concrete & LWC infill)

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Abstract: ***In the present research, Behaviour of Conventional & Lightweight Concrete Filled Steel Tube (CFST) under monotonic loading at elevated temperature is investigated using finite element method (Abaqus version 6.13.0.0). The parameters chosen for the study are geometry of the specimen – circular section, different L/D ratios, different grades of conventional & lightweight concrete infill and different temperatures (30^{o}C, 60^{o}C, 90^{o}C and 120^{o}C). The study includes analytical investigation on a total of 84 specimens that includes twelve hollow and seventy-two specimens filled with conventional & lightweight concrete of grades M20, M25, and M30. The specimens including three L/D ratio and having a common thickness, which are subjected to different elevated temperature (30°C, 60°C, 90°C & 120°C) were tested the experimental column strengths are compared with values of the analytical results obtained by conducting nonlinear analysis using ABAQUS software. The analytical results indicated that with increase in the temperature the load carrying capacity of CFST decreases. The ultimate load carrying capacity is higher for conventional than lightweight concrete filled tubes.***

Keywords: Nonlinear Analysis, Buckling Analysis, Mode Shapes, Conventional Concrete, Light weight Concrete, Filled Steel Tubes, Hollow tubes, Hyper Mesh Software version 13.0, Abaqus Software version 6.13.0.0.

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 favorable 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.

Benefits of using CFST columns:

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.

Brief Description of Software's 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. ALTAIR HYPERMESH was found in 1985 by James R Scapa, George Christ & Mark Kistner, SIMULIA ABAQUS was founded in 1978 by Dr. Paul Sorensen & Dr. Bengt Karlsson as 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 analyzed for buckling and mode shapes under failure are generated.

Finite Element Modeling:

Conventional & Lightweight concrete filled in the CFST column are accurately model in finite element software Hyper mesh & exported to Abaqus for analysis and compared with experimental results and codes of practice.

2. Material Properties and Constitutive Models

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, ʃ=7860kg/m3 and Es=210000MPa, respectively.

Conventional Concrete: A rational mix design method of Conventional 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.

Light weight Concrete: A rational mix design method of Lightweight 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.

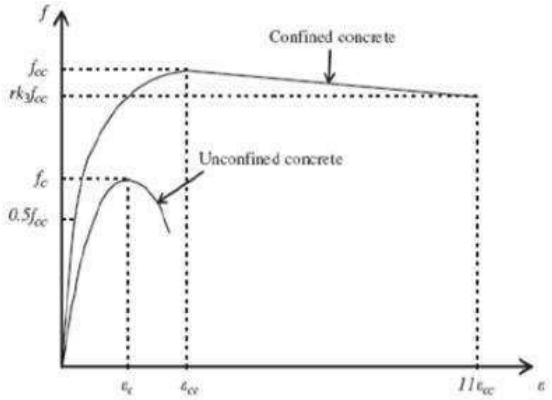


Figure 1: Equivalent stress-strain curves for confined and unconfined concrete

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).

Table 1: Properties of Material

Properties	*Steel*	*Conventional Concrete*	*Light Weight Concrete*
Density (ʃ)	7860 kg/m3	2200 to 2600 kg/m3	300 to 1850 kg/m3
Poison ratio (v)	0.3	0.1	0.2
Young's modules (E)	210000MPa	22360.70000 (M20),25386.12(M25) and 27386.12(M30) MPA	22360.70000 (M20),25386.12(M25 and 27386.12(M30) MPA

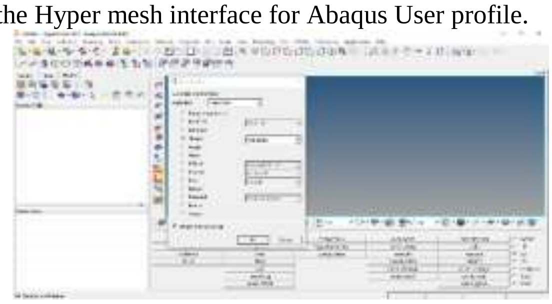
3. Specimen Details and Geometric Properties

Table 2: Geometric Properties of CC & LWC

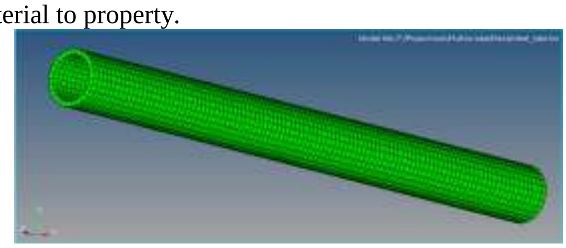
Case	*L (mm)*	*D (mm)*	*t (mm)*	*L/D*	*D/t*
Hollow Tube	215.8	26.9	3.2	8	8.40
	404.4	33.7	3.2	12	10.53
	678.4	42.4	3.2	16	13.25
M20 Grade	215.8	26.9	3.2	8	8.40
	404.4	33.7	3.2	12	10.53
	678.4	42.4	3.2	16	13.25
M25 Grade	215.8	26.9	3.2	8	8.40
	404.4	33.7	3.2	12	10.53
	678.4	42.4	3.2	16	13.25
M30 Grade	215.8	26.9	3.2	8	8.40
	404.4	33.7	3.2	12	10.53
	678.4	42.4	3.2	16	13.25

4. Modeling procedure and analysis in Hyper Mesh and Abaqus

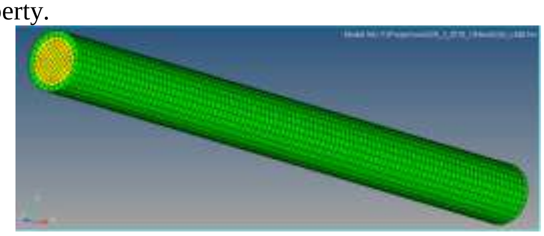
Set the Hyper mesh interface for Abaqus User profile.



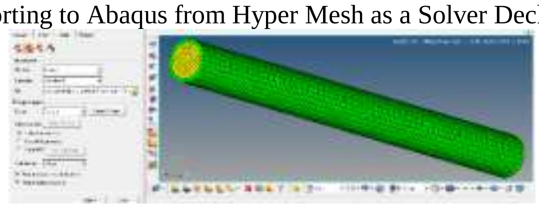
Hollow tube meshing by creating component, property & material and by assigning property to component and material to property.



CFST meshing by creating component, property & material and by assigning property to component and material to property.



Exporting to Abaqus from Hyper Mesh as a Solver Deck



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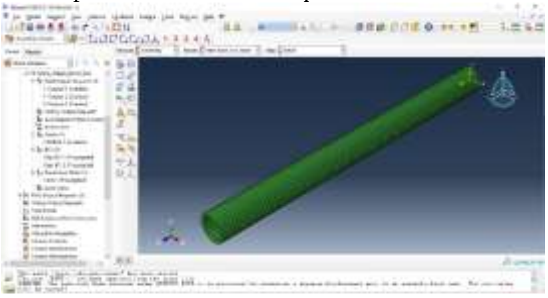
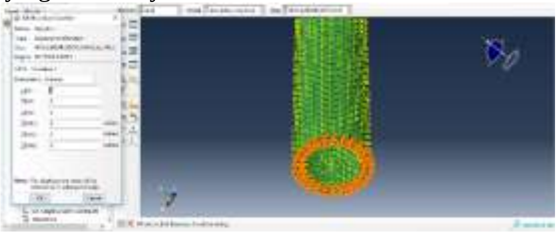
Solution steps carried out in Abaqus.

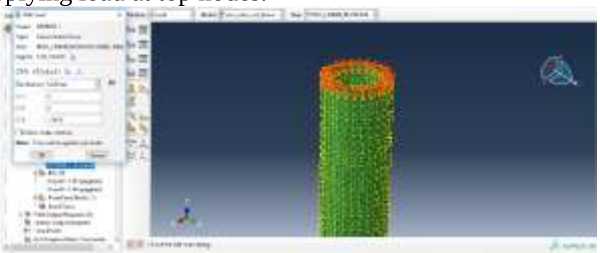


Applying Boundary Condition at Bottom Nodes.

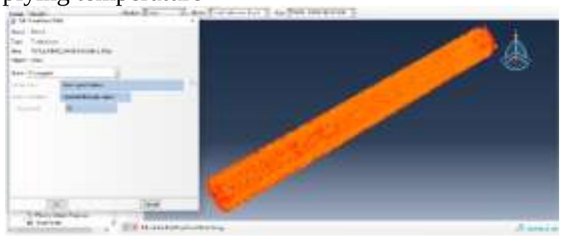


Applying Boundary Conditions at Top Nodes.

Applying load at top nodes.

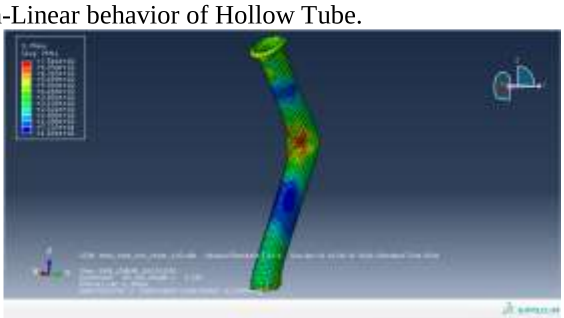


Applying temperature

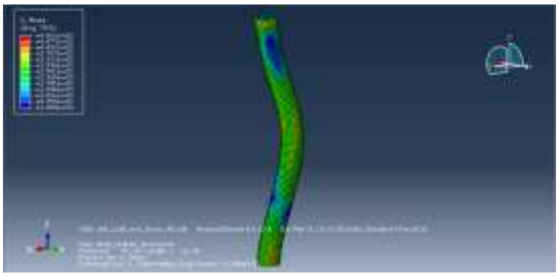


5. Obtaining Results, Modes shapes and Load calculation

Non-Linear behavior of Hollow Tube.



Non-Linear behavior of CFST Column.



Symmetrical view of CFST column

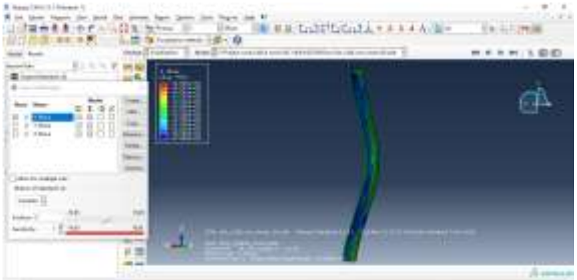


Table 3: Result obtained from analytical investigation for L=215.8mm

L (mm)	*D (mm)*	*t (mm)*	*L/D*	*D/t*	*Case*	*Temp. (˚C)*	*Pu (kN)*
215.8	26.9	3.2	8	8.40	Hollow	30	110
						60	91
						90	83
						120	75

L (mm)	*D (mm)*	*t (mm)*	*L/D*	*D/t*	*Case*	*Temp. (˚C)*	*Pu (kN) CC*	*Pu (kN) LWC*
215.8	26.9	3.2	8	8.40	M20	30	152	149
					M25		174	169
					M30		187	176
215.8	26.9	3.2	8	8.40	M20	60	143	140
					M25		158	149
					M30		165	157
215.8	26.9	3.2	8	8.40	M20	90	136	133
					M25		150	140
					M30		155	151
215.8	26.9	3.2	8	8.40	M20	120	128	127
					M25		141	132
					M30		147	138

Table 4: Result obtained from analytical investigation for L=404.4mm

L (mm)	D (mm)	t (mm)	L/D	D/t	Case	Temp. (˚C)	Pu (kN) CC	Pu (kN) LWC
404.4	33.7	3.2	12	10.53	M20	30	147	144
					M25		167	166
					M30		180	173
404.4	33.7	3.2	12	10.53	M20	60	135	134
					M25		145	139
					M30		154	144
404.4	33.7	3.2	12	10.53	M20	90	131	126
					M25		140	131
					M30		146	135
404.4	33.7	3.2	12	10.53	M20	120	124	120
					M25		133	124
					M30		141	131

L (mm)	D (mm)	t (mm)	L/D	D/t	Case	Temp. (˚C)	Pu (kN)
404.4	33.7	3.2	12	10.53	Hollow	30	102
						60	82
						90	78
						120	74

Table 5: Result obtained from analytical investigation for L=678.4mm

L (mm)	D (mm)	t (mm)	L/D	D/t	Case	Temp. (˚C)	Pu (kN)
678.4	42.4	3.2	16	13.25	Hollow	30	92
						60	79
						90	71
						120	66

L (mm)	*D (mm)*	*t (mm)*	*L/D*	*D/t*	*Case*	*Temp. (˚C)*	*Pu (kN) CC*	*Pu (kN) LWC*
678.4	42.4	3.2	16	13.25	M20	30	140	138
					M25		159	156
					M30		168	162
678.4	42.4	3.2	16	13.25	M20	60	128	127
					M25		140	136
					M30		149	140
678.4	42.4	3.2	16	13.25	M20	90	123	121
					M25		129	126
					M30		136	129
678.4	42.4	3.2	16	13.25	M20	120	117	114
					M25		121	118
					M30		127	121

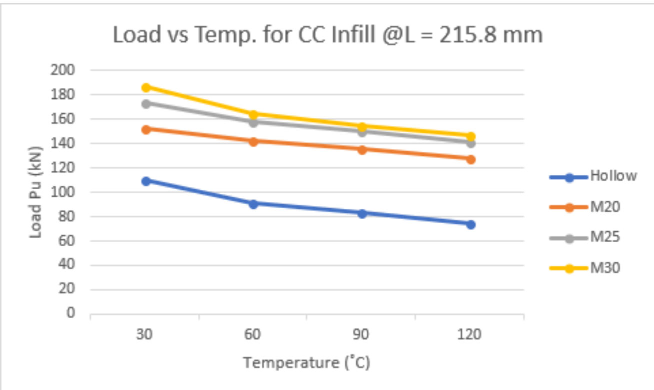


Figure 2: Load vs Temperature

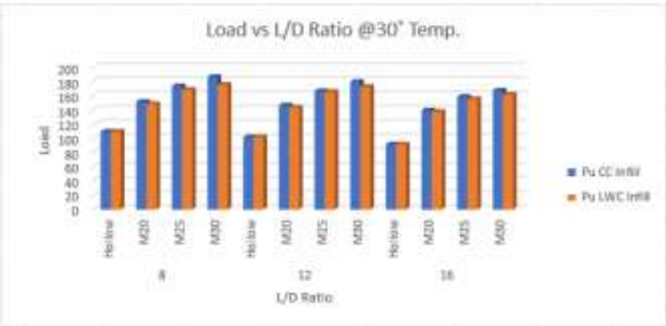


Figure 3: Load vs L/D Ratio

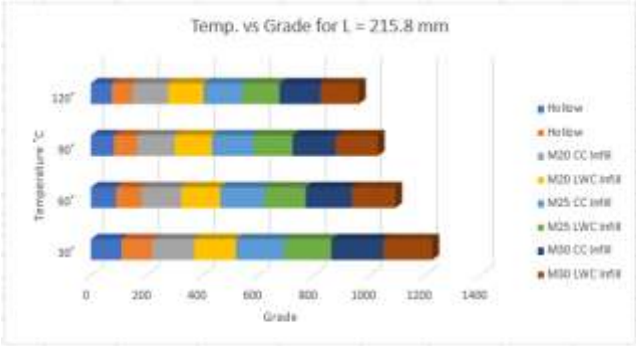


Figure 4: Temperature vs Grade

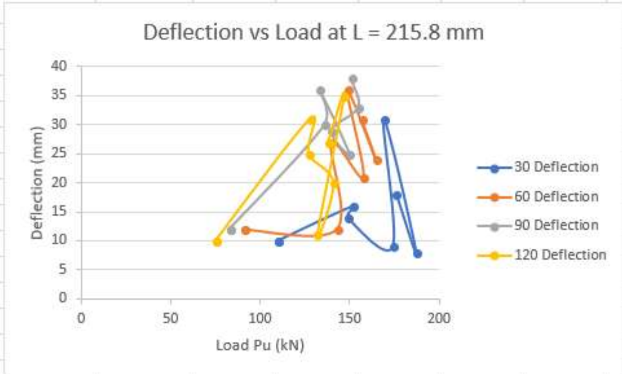


Figure 5: Deflection vs Load

6. Conclusions

1) The ultimate load carrying capacity of CFST is higher at room temperature than at elevated temperature (60° C, 90° C, 120° C).
2) For every increment in temperature, the ultimate load carrying capacity of concrete filled tubes decreases by 5-10% and for hollow tubes by 10-15%.
3) CC and LWC filled steel tubes carry higher ultimate load than the hollow tubes when subjected to elevated temperature. The ultimate load for CC & LWC filled steel tube is about 13-20% higher than the hollow steel tubes.
4) The local buckling is delayed in CFST compared to the hollow steel tubes.
5) With increase in grade of concrete, the ultimate load also increases marginally by 4-5%. Thus, the load verses deflection curve is shifted higher for higher grades of CC & LWC
6) As L/D ratio increases, the load carrying capacity of the composite tube decreases by 4%-10%.

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Author Profile

Mr. Shreyas N Obtained B.E degree in Civil Engineering from Govt. Engineering College, Ramanagaram, Affiliated to VTU Belgaum. Presently pursuing Master of Technology in Structural Engineering at Ghousia College of Engineering, Ramanagaram. Also working on this topic for the dissertation under the guidance of Mr. Athiq Ulla Khan.

Mr. Athiq Ulla Khan, Assistant Professor in Dept. of Civil Engineering, obtained his B.E & M. Tech from VTU with Distinction. Since 3 years he is involved in teaching. Also, he has registered for his Ph. D in VTU since 2017 under the guidance of Dr. N. S. Kumar, Professor & Director.

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 25 M. 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.