Numerical studies on Non-linear behavior of Composite Steel Tubes using ABAQUS v6.10-1*

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Abstract

In steel and concrete composite construction, the two materials are integrated in structural members to combine the advantages of both materials steel has high strength and ductility and facilitates connections with steel girders and braces in a steel framing system. Concrete is economical, durable and fire resistant. In composite columns, steel tube confines the concrete core leading to an increase in both strength and ductility of the concrete. The concrete core restricts inward local buckling of steel tube. composite columns have been shown to shown to have high strength, stiffness and ductility. As little data is available to justify the structural response, accurate Non-linear static and dynamic computational formulations are required for developing rational system response factors. For developing rational system response factors. Non-linear FEM analysis is performed to quantify demand, optimize design among other purposes. In this dissertation, ABAQUS 6.10-1 and Hyper Mesh is used to study non-linear behavior of composite tubes. At the outset, Validation for the work done by previous researchers(G.Giakoumelias, D.Lam/ Journal of Constructional Steel Research 60(2004)1049-1068) is carried out using non-linear FEM and is further extendented for experimental work done at the Department of Civil Engineering., R & D laboratory of Ghousia College of Engineering, Ramanagara. Experiments are carried out on columns for different tube thickness, diameter and length, obtained experimental values of ultimate load is compared with EC-4 including ABAQUS results. Frequency in Hz and time period in Sec are also evaluated for different tube sizes, lengths and thickness.

Keywords : *Composite, Steel Tubes, Hollow, Circular, Hyper Mesh, FEM, Abaqus, Fundamental Frequencies, Time Period,*

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1. INTRODUCTION

CFST or concrete filled steel tube comprise both steel and concrete adding to the advantage of it. The hallow steel tube of circular shape with infill either plain or reinforced concrete. It is main used for high rise building.

There are more number of benefit in structural systems both in performance and easy construction pattern. Problems of buckling is constrained or delayed because of the presence of concrete presence as infill, the performance of concrete is increased from confinement effect from the outer steel cover.

Concrete infill steel tubes in high raise structures has seen its raise nowadays, mainly due to its easy executing procedure, apart from its superior structural performance.

Hollow tubes are alone designed in such a way that they are capable of supporting the floor load up to three or four storey height. Once the upper floors were completed, the concrete will be pumped into the tubes from the bottom. To facilitate easy pumping the tubes are to be placed continuous at the floor level. Modern pumping facility and high performance concrete make pumping three or four storey readily achievable.

2. FINITE ELEMENT MODEL

Hollow steel tube column and Concrete filled steel tube column accurately model in finite element software ABAQUS and verified with experimental results and codes of practice.

2.1 MATERIAL PROPERTIES

Steel, concrete and contact between them are the main materials used in the numerical analysis of the columns which their properties

2.2 MATERIAL MODEL

2.2.1 CONCRETE PROPERTIES

30 and 60 N/mm^2 grade concrete were produced using only commercially available materials with normal mixing and curing techniques. Three trial mix designs had been prepared before the start of experiments.

2.2.2 STEEL PROPERTIES

To determine the strength of the steel tubes, tests on the steel sections were carried out for each wall thickness. The strength of the steel specimens f_y can be obtained.

2.3 MODELING AND MESHING

The 3D hollow and concrete filled steel tube columns with and without stiffener is created in Hypermesh-11.0 software and then exported to ABAQUS. Because creating stiffener is difficult in ABAQUS. The element library of finite element software ABAQUS-6.10.1 is used to select different types of elements. This library provides 1D element(Beam element, Truss Element), 2D element (Shell element) and 3D elements (solid elements).solid elements were found to be more efficient in modeling of concrete and steel tube because it gives better capturing of stiffness and mass. The three dimensional incompatable eight noded solid element(C3D8I) is used for meshing and is illustrated in figure 2.

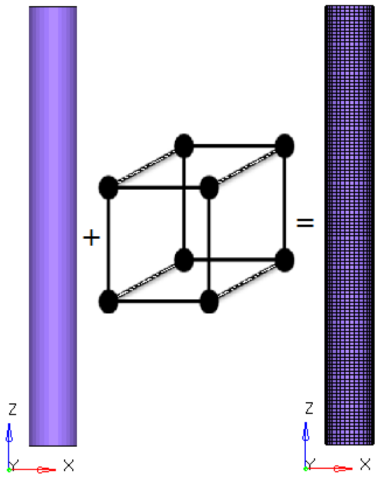


Figure-2 Descritisation of Column by using C3D8I

2.4 LOAD APPLICATION

A compressive load is uniformly distributed over the top surface of column nodes as shown in figure 3. The load is applied in Z-direction and is allow to move freely in Z-direction but restrained in X and Y-direction.

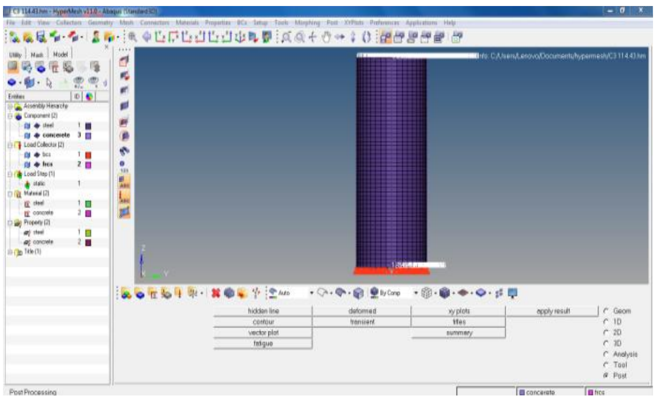


Figure-3 Load applied on each node of top surface

2.5 BOUNDARY CONDITIONS

Bottom end of the column is fixed in all directions that is $\Delta x=0$, $\Delta y=0$, $\Delta z=0$. Top surface of the column is restrained in X and Y-direction ($\Delta x=0$, $\Delta y=0$) and allowing displacement in Z-direction as shown in figure 4.

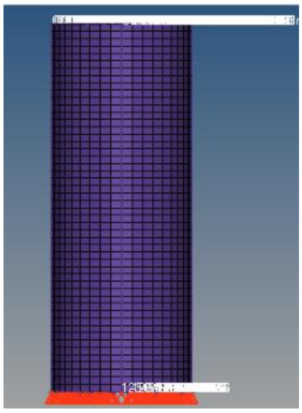


Figure-4 Fixed at Bottom

3. ANALYTICAL STUDY

3.1 Euro code 4(EC-4)

EC-4 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

$$Pu=Acfc + Asfs$$

Where
Ac and As are the Area of concrete and steel respectively, and fc and fs are the yield strength of concrete and steel respectively. For circular columns, confinement effect has to be consider if the relative slenderness ratio λ is less than 0.5. Where λ is given by Ncr

5.2 AMERICAN CONCRETE INSTITUTE

The American concrete institute ACI 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

$$Pu=0.85Acfc + Asfs$$

A modification for above equation is proposed by Giakoumelis and Lam. A co efficient is proposed for above ACI equation to take into account the effect of confinement on axial load capacity of CFST column and for 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

6. PARAMETRIC STUDY

6.1 General

The ultimate load capacity of different hollow and CFST columns based on their thickness were found by using codes of practice (Eurcode 4 , ACI/AS and Giakoumelis and lam). The numerical and theoretical results obtained by using above codes which denotes that with increase in thickness, enhances the capacity which is due to increase in confinement pressure.

6.2 EFFECT OF HOLLOW AND CONCRETE FILLED COLUMN

The strength of hollow column is less than concrete filled column. The hollow column fails due to inward buckling at lower load. Where as in concrete filled steel tube, concrete try to bulge and steel tube try to buckle therefore due this opposite forces failure takes place after a long time results in increasing the capacity of column.

6.3 GRADE OF CONCRETE

The stiffness of CFST column is depends on strength of concrete. With increase in strength of concrete stiffness of CFST column can be increased. Since concrete is a brittle material, the concrete fails due to crushing. This brittleness is increased with increase in grade of concrete. However this concrete core is covered with steel tube which minimizes the crushing of concrete.

7.RESULTS

Validation for the work done Journal of Constructional Steel Research 60(2004)1049-1068 by G.Giakoumelias, D.Lam

Table 1: Specimen Properties

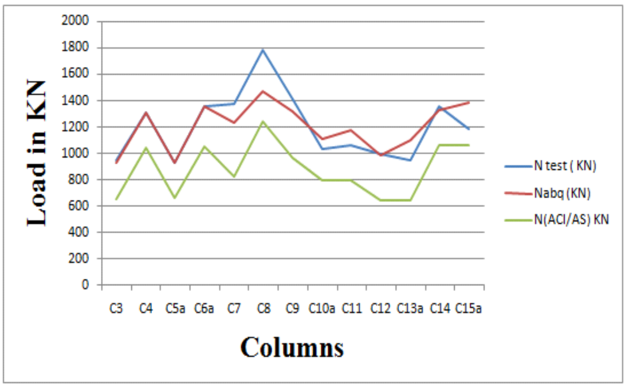
Ref	Dia D(mm)	Thick T(mm)	D/t	Len L(mm)	L/D	Fy Mpa	Fcu Mpa
C1	114.00	3.87	29.45	298.9	2.62	343	N/A
C2	115.04	5.02	22.91	300	2.60	365	N/A
C3	114.43	3.98	28.75	300	2.62	343	31.4
C4	114.57	3.99	28.71	300	2.61	343	93.6
C5[a]	114.43	3.82	29.95	300	2.62	343	34.7
C6[a]	114.26	3.93	29.07	300	2.61	343	97.2
C7[a]	114.88	4.91	23.39	300.5	2.60	365	34.7
C8	115.04	4.92	23.38	300	2.61	365	104.9
C9	114.02	5.02	22.91	300.5	2.61	365	57.6
C10[a]	114.49	3.75	30.53	299.3	2.62	343	57.6
C11	114.29	3.75	30.47	300	2.62	343	57.6
C12	114.30	3.85	29.68	300	2.63	343	31.9
C13	114.09	3.85	29.63	300.5	2.61	343	31.9
C14	114.54	3.84	29.82	300	2.61	343	98.9
C15[a]	114.37	3.85	29.70	299.5	2.61	343	98.9

Table 2: comparsion between experimental results , eurocode-4 and Abaqus results

Ref	N_{EC-4} KN	N_{TEST} KN	N_{TEST}/N_{EC-4}	N_{ABQ} KN	N_{ABQ}/N_{EC-4}
C3	911.3	948	1.04	925.87	1.05
C4	1325.7	1308	0.987	1307.2	1.04
C5[a]	912.9	929	1.018	945.3	1.03
C6[a]	1335.3	1359	1.018	1421.9	1.06
C7[a]	1134.2	1380	1.217	1493.2	1.31
C8	1584.2	1787	1.128	1877.0	1.18
C9	1294.8	1413	1.091	1543.8	1.19
C10[a]	1055.8	1038	0.983	1102.2	1.04
C11	1052.8	1067	1.013	1167.8	1.10
C12	898.3	998	1.111	1098.3	1.22
C13[a]	896.3	948	1.058	1096.3	1.23
C14	1342.9	1359	1.012	1442.9	1.07
C15[a]	1341.0	1182	0.881	1382.0	1.03

Table 3: comparsion between experimental results , ACI/AS code and Abaqus results

Ref	$N_{ACI/AS}$ KN	N_{TEST} KN	$N_{TEST}/N_{ACI/AS}$	N_{ABQ} KN	$N_{ABQ}/N_{ACI/AS}$
C3	659.5	948	1.43	925.87	1.40
C4	1043.0	1308	1.25	1307.2	1.25
C5[a]	665.8	929	1.39	945.3	1.38
C6[a]	1054.7	1359	1.28	1421.9	1.28
C7[a]	823.6	1380	1.67	1493.2	1.49
C8	1240.5	1787	1.44	1877.0	1.18
C9	971.9	1413	1.45	1543.8	1.35
C10[a]	799.3	1038	1.29	1102.2	1.37
C11	797.2	1067	1.33	1167.8	1.46
C12	651.3	998	1.53	1098.3	1.50
C13[a]	649.7	948	1.45	1096.3	1.68
C14	1060.5	1359	1.28	1442.9	1.25
C15[a]	1058.8	1182	1.11	1382.0	1.30



Graph 1: Comparison between experimental results ACI/AS code and ABAQUS results

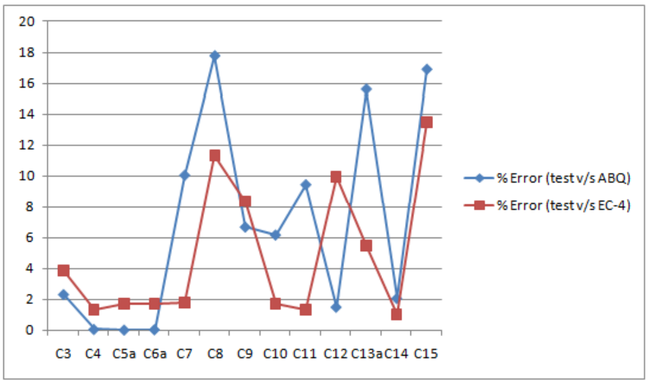
7.1 CALCULATION OF %ERROR

Table 4: Calculation of percentage error(Ntest v/s NACI/AS)

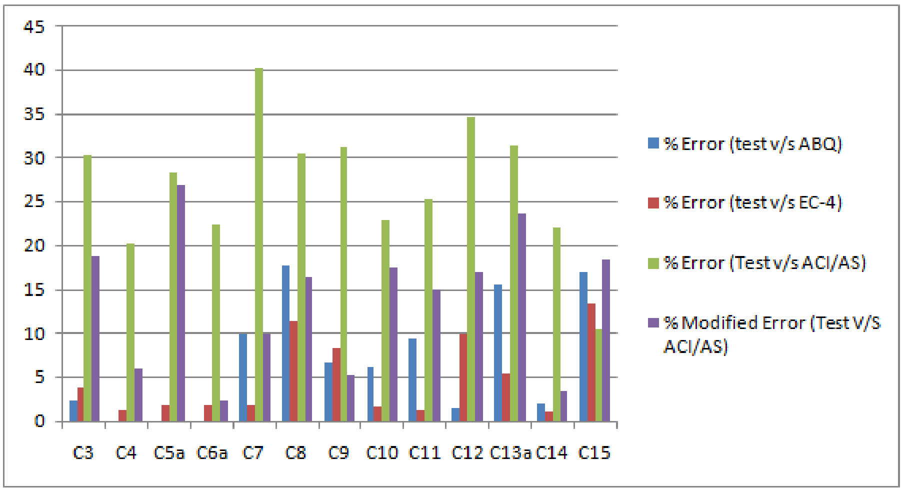
Ref	N_{test} KN	$N_{ACI/AS}$ KN	% Error (Test v/s ACI/AS)	Modified $N_{ACI?AS}$ KN	% Modified Error (Test v/s ACI/AS)
C_3	948	659.5	30.43	1167.14	18.77
C_4	1308	1043.0	20.25	1386.17	5.97
C_5^a	929	665.8	28.33	1179.36	26.94
C_6^a	1359	1054.7	22.39	1391.38	2.38
C_7	1380	823.6	40.31	1254.12	10.03
C_8	1787	1240.5	30.58	1493.58	16.41
C_9	1413	971.9	31.21	1338.67	5.26
C_{10}	1038	799.3	22.99	1258.21	17.50
C_{11}	1067	797.2	25.28	1256.61	15.08
C_{12}	998	651.3	34.73	1166.76	16.90
C_{13}^a	948	649.7	31.46	1172.49	23.68
C_{14}	1359	1060.5	21.96	1406.06	3.46
C_{15}	1182	1058.8	10.42	1399.12	18.36

Table 5: calculation of percentage error(Ntest and NEC-4)

Ref	N_{test} KN	N_{abq} (KN)	% Error (test v/s ABQ)	$N_{(EC-4)}$ KN	% Error (test v/s EC-4)
C_3	948	925.87	2.33	911.3	3.87
C_4	1308	1307.2	0.07	1325.7	1.35
C_5^a	929	925.3	0.03	912.9	1.73
C_6^a	1359	1350.9	0.05	1335.3	1.74
C_7	1380	1234	10.05	1134.2	1.78
C_8	1787	1467.3	17.79	1584.2	11.34
C_9	1413	1318.3	6.70	1294.8	8.36
C_{10}	1038	1102.2	6.18	1055.8	1.71
C_{11}	1067	1167.8	9.44	1052.8	1.33
C_{12}	998	982.9	1.51	895.3	9.98
C_{13}^a	948	1096.3	15.64	896.3	5.45
C_{14}	1359	1328.9	2.07	1342.9	1.03
C_{15}	1182	1382	16.92	1341	13.45



Graph 2: calculation of percentage error(Ntest,NEC-4 and NABQ)

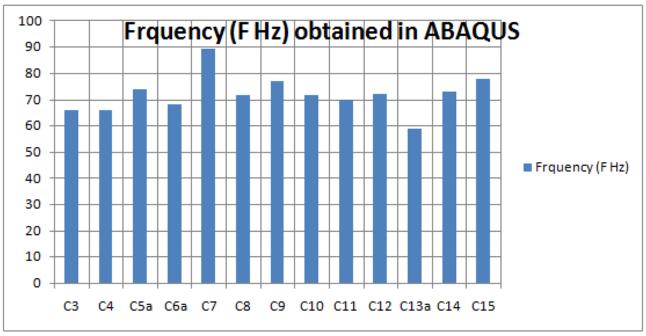


Graph 3: calculation of percentage error(Ntest, NACI/AS, NEC-4 and NABQ)

7.2 FREQUENCY CALCULATION

Table 6: Frequency obtained in abaqus

Ref	Nabq KN	Frequency(F)			Fundamental frequency (F)	Frequency F (Hz)	MEAN TIME (T) SEC
		F1	F2	F3			T
C3	925.87	1.26E[5]	1.05E[6]	3.91E[6]	1.05 E[5]	66.19	0.015
C4	1307.2	1.05E[5]	2.11E[6]	2.85E[5]	1.05E[5]	66.19	0.015
C5[a]	925.7	1.87E[5]	1.93E[5]	4.96E[6]	1.87E[5]	74.16	0.013
C6[a]	1350.9	1.26E[5]	2.11E[6]	4.93E[6]	1.26E[5]	68.23	0.014
C7	1234.0	4.74E[5]	3.99E[5]	3.96E[6]	3.96E[5]	89.56	0.011
C8	1467.3	1.96E[5]	1.61 E[6]	4.03 E[6]	1.61E[5]	72.13	0.013
C9	1318.3	2.06E[6]	2.01 E[5]	5.03 E[5]	2.01E[5]	77.38	0.012
C10	1102.2	1.63 E[5]	1.82 E[6]	5.08 E[6]	1.63E[5]	72.22	0.013
C11	1167.8	1.58 E[5]	1.88 E[5]	2.36 E[5]	1.58E[5]	70.19	0.014
C12	982.9	1.97 E[6]	1.64 E[6]	5.08 E[5]	1.64E[5]	72.56	0.013
C13[a]	1096.3	1.48 E[6]	1.66 E[5]	4.11 E[5]	1.48E[5]	59.23	0.016
C14	1328.9	1.66 E[6]	1.82 E[6]	2.36 E[5]	1.66E[5]	73.21	0.013
C15[a]	1328.0	2.06 E[6]	2.62 E[5]	4.09 E[5]	2.06E[5]	78.25	0.012



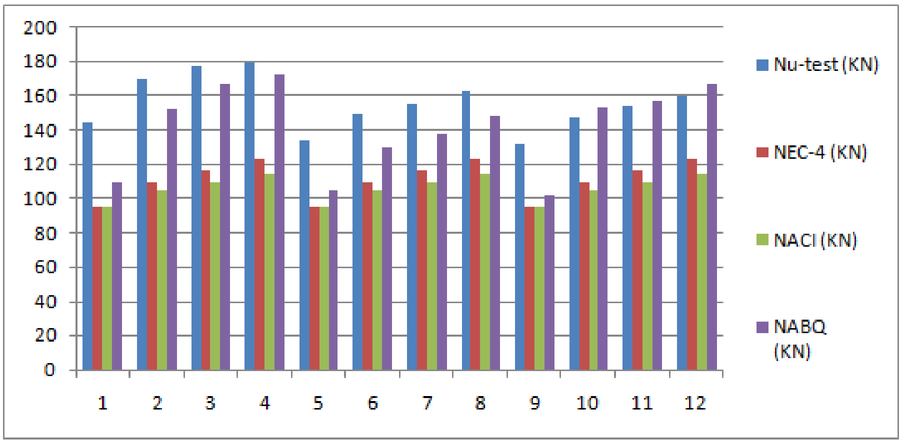
Graph 4: Frequency obtained in ABAQUS

8. EXPERIMENT CONDUCTED AT R&D LAB,GCE, RAMANAGARA

Experiment was carried out for hollow steel tube, M20,M30,M40 grade concrete as infill for different thickness, diameter and length the experiment results obtained were compared with EC-4, ACI and ABAQUS 6.10-1* values

Table 7: Specimen properties and Ulimate load obtained

DIA D(mm)	LEN L(mm)	THICK T(mm)	L/D	D/T	GRADE	N_{u-test} (KN)	N_{EC-4} (KN)	N_{ACI} (KN)	N_{ABQ} (KN)
33.7	202.2	3.20	6	10.5	Hollow	145	95.05	95.05	110.03
33.7	202.2	3.20	6	10.5	M20	170	109.33	104.69	152.69
33.7	202.2	3.20	6	10.5	M30	178	116.69	109.65	166.65
33.7	202.2	3.20	6	10.5	M40	180	123.41	114.19	172.41
33.7	404.4	2.50	12	13.3	Hollow	134	95.05	95.05	105.02
33.7	404.4	2.50	12	13.3	M20	150	109.33	104.69	130.33
33.7	404.4	2.50	12	13.3	M30	155	116.69	109.65	137.65
33.7	404.4	2.50	12	13.3	M40	163	123.41	114.19	148.19
33.7	539.2	2.20	16	15.1	HOLLOW	132	95.05	95.05	102.10
33.7	539.2	2.20	16	15.1	M20	148	109.33	104.69	153.65
33.7	539.2	2.20	16	15.1	M30	154	116.69	109.65	157.33
33.7	539.2	2.20	16	15.1	M40	160	123.41	114.19	166.65



Graph 5 : Ultimate load obtained

8.1 PERCENTAGE ERROR

For Dia 33.7mm

Table 8: %error (Ntest v/s NEC-4)

DIA	LEN (mm)	THICK (mm)	L/D	D/T	GRADE	N_{u-test} (KN)	N_{EC-4} (KN)	%ERROR
33.7	202.2	3.20	6	10.5	HOLLOW	145	95.05	34.4
33.7	202.2	3.20	6	10.5	M20	170	109.33	35.6
33.7	202.2	3.20	6	10.5	M30	178	116.69	34.4
33.7	202.2	3.20	6	10.5	M40	180	123.41	31.4
33.7	404.4	2.50	12	13.3	HOLLOW	134	95.05	29.0
33.7	404.4	2.50	12	13.3	M20	150	109.33	27.1
33.7	404.4	2.50	12	13.3	M30	155	116.69	24.7
33.7	404.4	2.50	12	13.3	M40	163	123.41	24.2
33.7	539.2	2.20	16	15.1	HOLLOW	132	95.05	27.9
33.7	539.2	2.20	16	15.1	M20	148	109.33	26.1
33.7	539.2	2.20	16	15.1	M30	154	116.69	24.2
33.7	539.2	2.20	16	15.1	M40	160	123.41	22.8

Table 9: %error (Ntest v/s NACI)

DIA	LEN (mm)	THICK (mm)	L/D	D/T	GRADE	N_{u-test} (KN)	N_{ACI} (KN)	%ERROR
33.7	202.2	3.20	6	10.5	HOLLOW	145	95.05	34.4
33.7	202.2	3.20	6	10.5	M20	170	104.69	38.4
33.7	202.2	3.20	6	10.5	M30	178	109.65	38.3
33.7	202.2	3.20	6	10.5	M40	180	114.19	36.5
33.7	404.4	2.50	12	13.3	HOLLOW	134	95.05	29.0
33.7	404.4	2.50	12	13.3	M20	150	104.69	30.2
33.7	404.4	2.50	12	13.3	M30	155	109.65	29.9
33.7	404.4	2.50	12	13.3	M40	163	114.19	29.2
33.7	539.2	2.20	16	15.1	HOLLOW	132	95.05	27.9
33.7	539.2	2.20	16	15.1	M20	148	104.69	29.2
33.7	539.2	2.20	16	15.1	M30	154	109.65	28.7
33.7	539.2	2.20	16	15.1	M40	160	114.19	28.6

Table 10: %error (Ntest v/s NABQ)

DIA	LEN (mm)	THICK (mm)	L/D	D/T	GRADE	N_{u-test} (KN)	N_{ABQ} (KN)	%ERROR
33.7	202.2	3.20	6	10.5	HOLLOW	145	110.03	24.11
33.7	202.2	3.20	6	10.5	M20	170	152.69	10.18
33.7	202.2	3.20	6	10.5	M30	178	166.65	6.37
33.7	202.2	3.20	6	10.5	M40	180	172.41	4.21
33.7	404.4	2.50	12	13.3	HOLLOW	134	105.02	21.62
33.7	404.4	2.50	12	13.3	M20	150	130.33	13.11
33.7	404.4	2.50	12	13.3	M30	155	137.65	11.19
33.7	404.4	2.50	12	13.3	M40	163	148.19	9.08
33.7	539.2	2.20	16	15.1	HOLLOW	132	102.10	22.65
33.7	539.2	2.20	16	15.1	M20	148	153.65	3.81
33.7	539.2	2.20	16	15.1	M30	154	157.33	2.16
33.7	539.2	2.20	16	15.1	M40	160	166.65	4.15

For diameter 42.4mm

Table 11: %error (Ntest v/s NEC-4)

DIA	LEN (mm)	THICK	L/D	D/T	GRADE	N_{u-test} (KN)	N_{EC-4} KN	%ERROR
42.4	254.4	3.2	6	13.3	HOLLOW	200	122.16	38.92
42.4	254.4	3.2	6	13.3	M20	211	147.00	30.33
42.4	254.4	3.2	6	13.3	M30	226	159.79	29.29
42.4	254.4	3.2	6	13.3	M40	235	171.48	27.03
42.4	508.8	2.8	12	15.1	HOLLOW	174	122.16	29.79
42.4	508.8	2.8	12	15.1	M20	209	147.00	29.66
42.4	508.8	2.8	12	15.1	M30	215	159.79	25.67
42.4	508.8	2.8	12	15.1	M40	225	171.48	23.78
42.4	678.4	4.0	16	10.5	HOLLOW	158	122.16	22.68
42.4	678.4	4.0	16	10.5	M20	162	147.00	09.25
42.4	678.4	4.0	16	10.5	M30	171	159.79	06.55
42.4	678.4	4.0	16	10.5	M40	175	171.48	02.01

Table 12: %error (Ntest v/s NACI)

DIA	LEN (mm)	THICK (mm)	L/D	D/T	GRADE	$N_{u\text{-}test}$ (KN)	N_{ACI} (KN)	%ERROR
42.4	254.4	3.2	6	13.3	HOLLOW	200	122.16	38.92
42.4	254.4	3.2	6	13.3	M20	211	138.92	34.16
42.4	254.4	3.2	6	13.3	M30	226	147.56	34.70
42.4	254.4	3.2	6	13.3	M40	235	155.45	33.85
42.4	508.8	2.8	12	15.1	HOLLOW	174	122.16	29.79
42.4	508.8	2.8	12	15.1	M20	209	138.92	33.53
42.4	508.8	2.8	12	15.1	M30	215	147.56	31.36
42.4	508.8	2.8	12	15.1	M40	225	155.45	30.91
42.4	678.4	4.0	16	10.5	HOLLOW	158	122.16	22.68
42.4	678.4	4.0	16	10.5	M20	162	138.92	14.24
42.4	678.4	4.0	16	10.5	M30	171	147.56	13.70
42.4	678.4	4.0	16	10.5	M40	175	155.45	11.17

Table 13: %error (Ntest v/s NABQ)

DIA	LEN mm	THICK mm	L/D	D/T	GRADE	$N_{u\text{-}test}$ (KN)	N_{ABQ} (KN)	%ERROR
42.4	254.4	3.2	6	13.3	HOLLOW	200	184.61	07.69
42.4	254.4	3.2	6	13.3	M20	211	213.83	01.34
42.4	254.4	3.2	6	13.3	M30	226	222.59	01.50
42.4	254.4	3.2	6	13.3	M40	235	226.58	03.58
42.4	508.8	2.8	12	15.1	HOLLOW	174	163.65	05.94
42.4	508.8	2.8	12	15.1	M20	209	192.29	07.99
42.4	508.8	2.8	12	15.1	M30	215	207.69	03.40
42.4	508.8	2.8	12	15.1	M40	225	219.58	02.40
42.4	678.4	4.0	16	10.5	HOLLOW	158	142.16	10.02
42.4	678.4	4.0	16	10.5	M20	162	151.29	06.61
42.4	678.4	4.0	16	10.5	M30	171	162.75	04.82
42.4	678.4	4.0	16	10.5	M40	175	169.48	03.15

For diameter 48.3

Table 14: %error (Ntest v/s NEC-4)

DIA	LEN (mm)	THI (mm)	L/D	D/T	GRADE	$N_{u\text{-}test}$ (KN)	$N_{EC\text{-}4}$ (KN)	%ERROR
48.3	289.8	4.6	6	10.5	HOLLOW	242	140.55	41.92
48.3	289.8	4.6	6	10.5	M20	268	174.21	34.99
48.3	289.8	4.6	6	10.5	M30	270	191.56	29.05
48.3	289.8	4.6	6	10.5	M40	274	207.40	24.30
48.3	579.6	3.6	12	13.3	HOLLOW	212	140.55	33.70
48.3	579.6	3.6	12	13.3	M20	225	174.21	22.57
48.3	579.6	3.6	12	13.3	M30	265	191.56	27.71
48.3	579.6	3.6	12	13.3	M40	289	207.40	28.23
48.3	772.8	3.2	16	15.1	HOLLOW	192	140.55	26.79
48.3	772.8	3.2	16	15.1	M20	222	174.21	21.52
48.3	772.8	3.2	16	15.1	M30	225	191.56	14.86
48.3	772.8	3.2	16	15.1	M40	230	207.40	09.82

Table 15: %error (Ntest v/s ACI)

DIA	LEN (mm)	THICK (mm)	L/D	D/T	GRADE	N_{u-test} (KN)	N_{ACI} (KN)	%ERROR
48.3	289.8	4.6	6	10.5	HOLLOW	242	140.55	41.92
48.3	289.8	4.6	6	10.5	M20	268	163.27	39.07
48.3	289.8	4.6	6	10.5	M30	270	174.98	35.19
48.3	289.8	4.6	6	10.5	M40	274	185.67	32.23
48.3	579.6	3.6	12	13.3	HOLLOW	212	140.55	33.70
48.3	579.6	3.6	12	13.3	M20	225	163.27	27.43
48.3	579.6	3.6	12	13.3	M30	265	174.98	33.97
48.3	579.6	3.6	12	13.3	M40	289	185.67	35.75
48.3	772.8	3.2	16	15.1	HOLLOW	192	140.55	26.79
48.3	772.8	3.2	16	15.1	M20	222	163.27	26.45
48.3	772.8	3.2	16	15.1	M30	225	174.98	22.23
48.3	772.8	3.2	16	15.1	M40	230	185.67	19.27

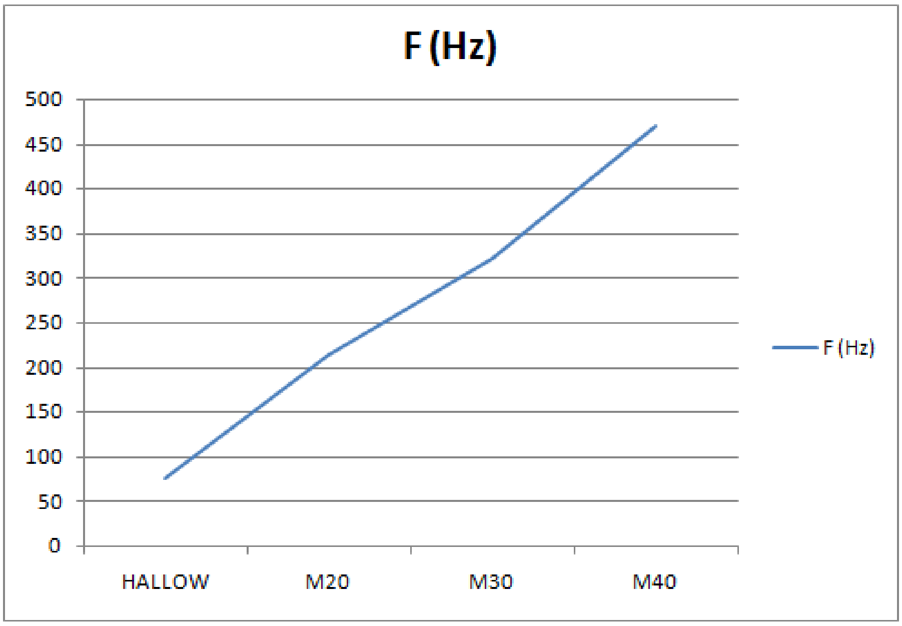
Table 16: %error (Ntest v/s NABQ)

DIA	LEN mm	THICK (mm)	L/D	D/T	GRADE	N_{u-test} (KN)	N_{ABQ} (KN)	%ERROR
48.3	289.8	4.6	6	10.5	HOLLOW	242	210.57	12.98
48.3	289.8	4.6	6	10.5	M20	268	245.42	08.42
48.3	289.8	4.6	6	10.5	M30	270	264.48	02.04
48.3	289.8	4.6	6	10.5	M40	274	269.55	01.62
48.3	579.6	3.6	12	13.3	HOLLOW	212	195.65	07.71
48.3	579.6	3.6	12	13.3	M20	225	206.73	08.12
48.3	579.6	3.6	12	13.3	M30	265	245.25	07.45
48.3	579.6	3.6	12	13.3	M40	289	275.54	04.65
48.3	772.8	3.2	16	15.1	HOLLOW	192	183.12	04.62
48.3	772.8	3.2	16	15.1	M20	222	198.71	10.49
48.3	772.8	3.2	16	15.1	M30	225	206.68	08.14
48.3	772.8	3.2	16	15.1	M40	230	221.74	03.59

8.1 Frequency

Table 17: Frequency for dia 33.7mm

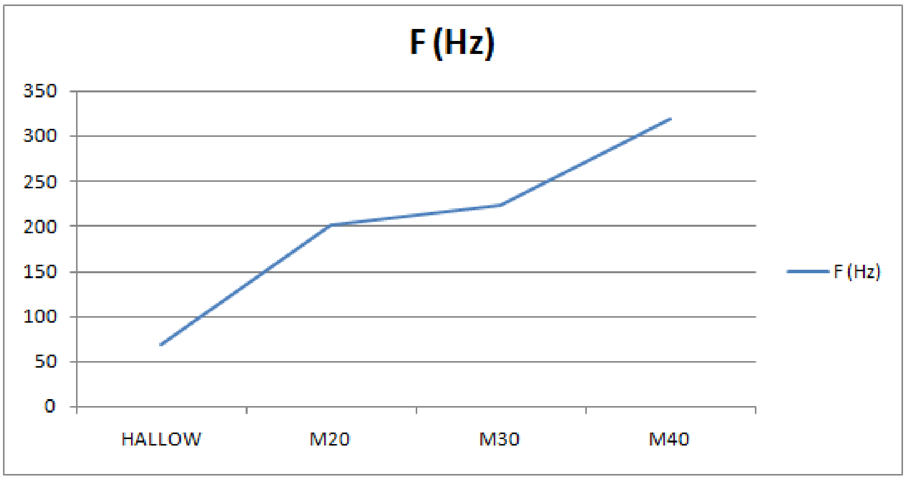
CASE	DIAMETER (mm)	λ^2	ώ (rps)	F (Hz)	T(SEC)
HOLLOW	33.7	$2.35E^5$	484.59	77.164	0.012
M20	33.7	$1.86E^6$	215.28	215.28	0.004
M30	33.7	$4.09E^6$	321.86	321.86	0.003
M40	33.7	$1.99E^6$	71.06	71.065	0.014



Graph 6 : frequency for dia 33.7mm

Table 18: Frequency for dia 42.4mm

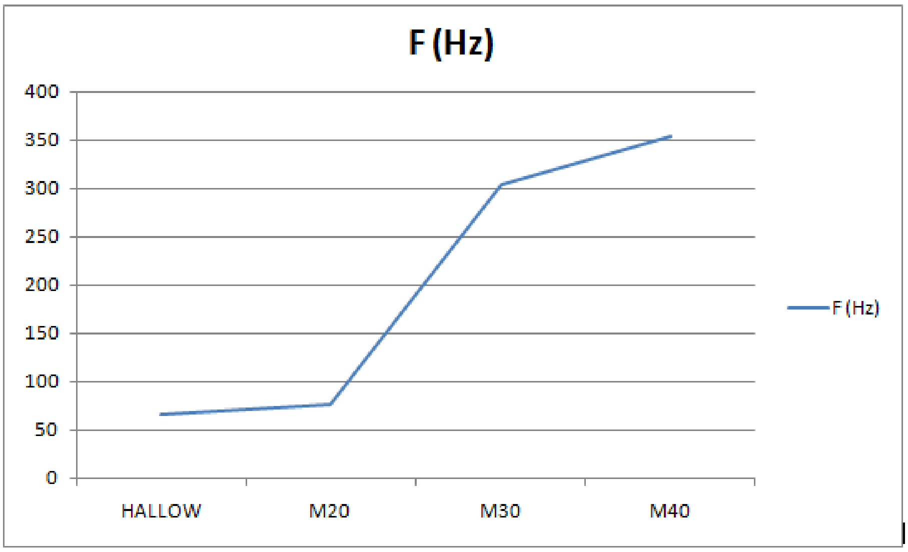
CASE	DIAMETER (mm)	$ʎ^2$	ώ (rps)	F (Hz)	T(SEC)
HOLLOW	42.4	$1.90E^5$	436.13	69.44	0.014
M20	42.4	$1.61E^6$	1270.3	202.27	0.004
M30	42.4	$1.99E^6$	441.14	224.74	0.004
M40	42.4	$4.03E^6$	2006.4	319.49	0.003



Graph 7: frequency for dia 42.4mm

Table 19: Frequency for dia 48.3 mm

CASE	DIAMETER (mm)	$ʎ^2$	ώ (rps)	F (Hz)	T(SEC)
HOLLOW	48.3	$1.74E^5$	417.69	66.51	0.015
M20	48.3	$2.35E^6$	484.59	77.16	0.012
M30	48.3	$3.69E^6$	920.25	305.72	0.003
M40	48.3	$4.97E^6$	2229.44	355.00	0.002



Graph 8: frequency for dia 48.3 mm

8. CONCLUSION

Validation for the paper entitled "Axial Capacity of circular concrete filled tube columns, by G.Giakoumelis, D.Lam / journal of constructional steel research 60(2004), 1049-1068"

- Percentage error obtained for ultimate load for the above mentioned paper when compared with the developed ABAQUS 6.10-1 model was found to be 15%- 18%
- Percentage error for paper mentioned above the ultimate load when compared with ACI/AS code were found to be less than 35% than the results obtained from experiments
- Percentage error obtained with EC-4 was found to be 10%-14%
- Percentage error obtained for the above mentioned paper, for the Modified ACI/AS with test results obtained to be 27%, which is lesser then un-modified values
- As diameter increases frequency in Hz decrease and time in seconds increase

For work done at R & D Lab, CIVIL DEPT., GCE, Ramanagara

- Percentage error obtained for ultimate load when compared with ABAQUS 6.10- was found to be 24.11% was the higher difference obtained
- Percentage error for journal ultimate load when compared with ACI/AS code were found to be less than 39% than the results obtained from experiments
- Percentage error when compared with EC-4 was found to be 34% with largest difference obtained
- As diameter increases frequency in Hz decrease and time in seconds increase
- As grade of concrete increases frequency increase and time period decreases
- As the D/t ratio increses the load carrying capacity increases

9. REFERENCE

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