Analysis of Concrete Filled Double Skinned Tubular Columns Infilled With SCC by Using ANSYS

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Abstract: ***The main components of Concrete Filled Double Skinned Tubular (CFDST) Column consist of both Steel and Concrete. In the present study carried out on Concrete Filled Double Skinned Tubular (CFDST) Column with an infill of Selficompacting Concrete (SCC) to determine maximum load carrying capacity that can be taken by the CFDST columns. The Validation is carried out to determine the load carrying capacity of the CFDST columns in which grades of MS steel i.e. Fe 250 with the Selficompacting Concrete (SCC) of various grades such as M30, M35, M40, M45, M50, M55, M60, M65, and M70 by using Ansys software. The complex behavior of CFDST columns plays a dominant role in the seismic design. Results are obtained for various slenderness ratios, i.e. (L/D) of CFDST columns varying 8, 9.2, 10.4, 11.6 to 12.8 of the Diameter for column where 50mm as the diameter of external skin with the internal skin of 20mm in Diameter. Length of specimen varying 400mm, 460mm, 520mm, 580mm, and 640mm. Similarly for various slenderness ratios, i.e. (L/D) of CFDST columns varying from 10, 11.5, 13, 14.5, and 16, of Diameter for column where 40mm as the diameter of external skin with the internal skin of 20mm in Diameter. Varying length from 400mm, 460mm, 520mm, 580mm, and 640mm i.e., both short and long CFDST columns filled with CC were considered for carrying this study. Diameter of the column varying from 50mm to 40mm and length from 400mm to 640mm were considered. As partial experimental results are available. "From different national and inter-national 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. Percentage error between obtained experimental values and Ansys output will be studied in depth along with effect of slenderness ratio"(ovais, 2018). Further Obtained results are also compared with available codes.***

Keywords: CFDST columns, Ansys(16.0), SCC infill, Nonlinear Analysis, self-compacting Concrete

1. Introduction

Concrete Filled Double Skinned Tubular Columns originated into being in wearly 1960. Significant research has been made to appreciate the activities in the mean time. The advantage of using the set CFDST Columns has been origina-tedt by Japane set first and hired in a the, construction of multi-storied buildings successfully. The investigation and design of the set q CFDST Columns have found habitation event in Codes and Specifications. It has been prophesied to study strength, stiffness, and buckling features by providing flutes to steel pipe of columns, which augments aesthesist of columns. Based on the experimental methodologies on a number of construction approaches for the columns in tall structures, it is set up that the concrete filled steel pipe is at precise, constructable and reasonable clarification fort, multistorey, building. At principal factort is the capability to, condense the cost stand the on site period ofthe construction.

1.1. Benefits of using CFDST columns

The composite column has higher ductility than the concrete column and connections may be constructed following the experience of steel constructions. The concrete filling not only leads to a bearing capacity which is much higher than that of steel columns but it also promotes resistance against fire. As far as ductility and rotation capacity are concerned, concrete filled steel tubular columns show the best seismic behavior compared to other types of composite columns. The concrete is held by the steel profile and cannot split away even if the ultimate concrete strength is reached.

1.2. Software Description used for analysis

Finite element method is considered to be the best tool for analyzing the structures,. Numerous software's are used this technique for creating, analyzing and designing. In this research, the software used here is Ansys. Here, the experimental, as well as codal provisions carry out for the validation of the load carrying capacity of the composite steel columns. the results are obtained for various slenderness ratios, as well as various grades of concrete as well steel and also various diameter of the columns.

1.3. Modeling in Finite element tool

Ansys is used for the accurate modelling of Selficompacting concrete filled in the CFST column in finite element software. Results were compared with experimental results and available codes of BS and ASCI.

2. Material Properties w.r.t governing Constitutes of Models

2.1. Steel

Modelling of the MS Steel tube is done as elastic-perfectly plastic with von mises yield criterion. As the steel tube is subjected to multiple stresses and hence the stress-strain curve crosses elastic limit and reaches in plastic region. The steel tube's nonlinear behavior is obtained from uniaxial tension test and used in steel modeling. Material = Structural steel Fe 210Mpa, 230Mpa, 240Mpa, 250Mpa & 310Mpa.
Young's modulus = 210Gpa
Poison's ratio = 0.3
Density = 7800kg/m^3

2.2. Self Compacting Concrete

Grade of concrete
M30, Young's modulus = 27386.12Mpa
M35, Young's modulus = 29580.39892Mpa
M40, Young's modulus = 31622.7766Mpa
M45, Young's modulus = 33541.01966Mpa
M50, Young's modulus = 35355.33906Mpa
M55, Young's modulus = 37080.99Mpa
M60, Young's modulus = 38729.83346Mpa
M65, Young's modulus = 40311.2887Mpa
M70, Young's modulus = 41833Mpa
Poison's ratio = 0.18
Density = 2400 kg/m^3

2.3. Material Model of Concrete

To understand the 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 is depicted in Figure 1. This is used in proposed finite element model. The stress-strain curve is divided into 3 parts namely elastic part (Linear), Elasto-Plastic part and Perfectly Plastic part (nonlinear).

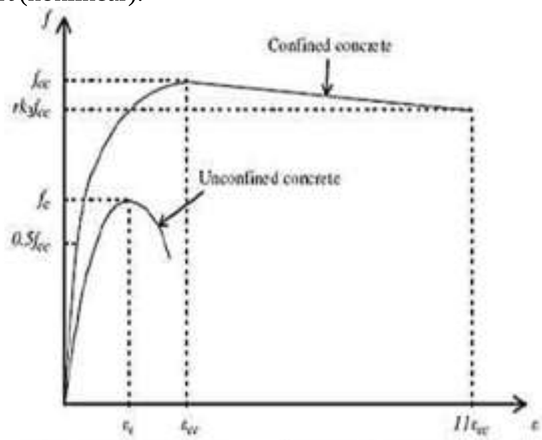


Figure 1: Equivalent stress-strain curve for confined and unconfined concrete

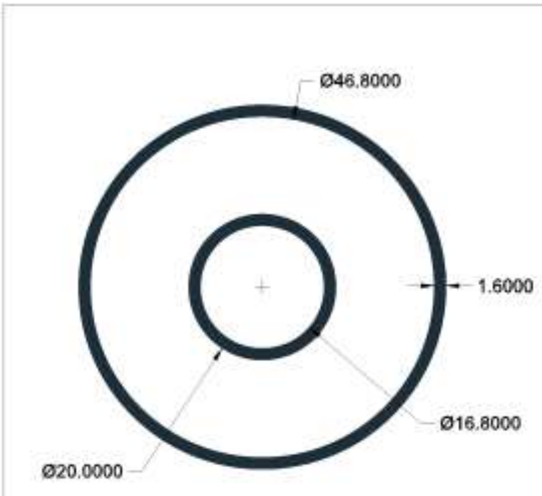
3. Details of the Specimens and Solution Procedure

3.1 Specimen Geometry

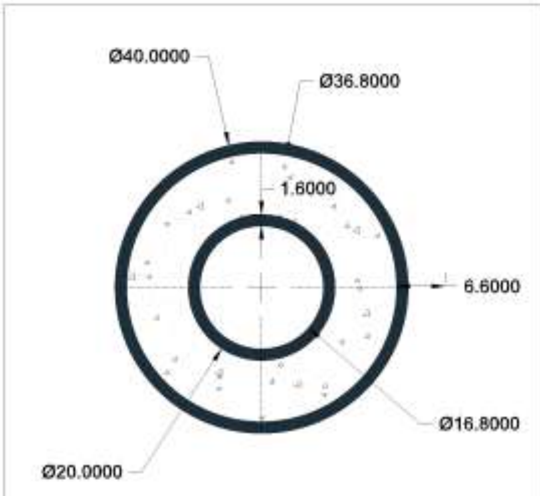
All modeling is done using ANSYS 16.0 finite element software. The project proceeded in several stage of modeling: hollow specimen is modeled as SOLID SHELL ELEMENT and concrete specimen is modeled as CONCRETE65/SOLID65 element with identical geometry. The dimension of section is chosen to match those being used in the experimental testing of experiment.

3.2 Cross sectional details

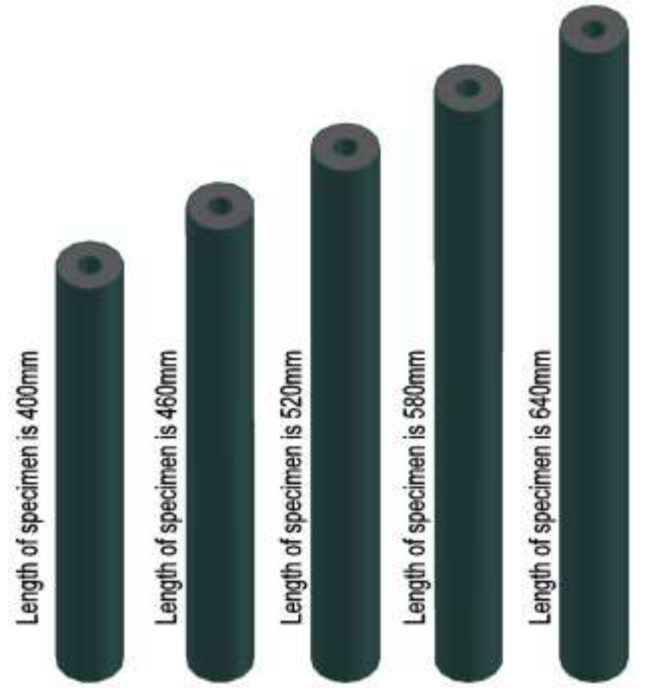
The experimental loads and other specimen details considered for carrying out the investigations is given below



External tube of 50mm and Internal Tube of 20mm in Diameter with thickness of 1.6mm



External tube of 40mm and Internal Tube of 20mm in Diameter with thickness of 1.6mm



According to the earlier theoretical modifications and the analytical study, the present investigation anxieties the follo-wing extents:

- Analyticalt studies for exploration of the, load carrying capability of circular hollow section filled with higher strength, concrete, when the load is functional on the steel pipe only.
- Accounting for interface of mild steel and concrete. The outcomes obtained by theoretical calculation are authen-ticated using ANSYSy (16.0).
- Analytical, relative and arithmetic studies on the ultimate load, carrying capability of at circular hollow section filled with higher strength concrete.
- Theoretical and uanalytical study on the ultimate load capability of a composite circular hollow section filled with higher strength concrete after the axial load is functional eccentrically.
- To conclude the compressive strength of the double skin composite concrete filled steel tubular members in filled concrete, imperiled to axial loading.
- To converse the conclusion of variations in the volume fractions of steel pipes castr off in the concrete.
- Antanalytical study of performance to Concrete Filled Steel Pipes column and at theoretical design technique rendering to ACI method.
- Antanalytical study of, actions of Concrete Filled, Steel Pipes column and a theoretical design process, permitti-ng to BS5400 method.
- Antanalytical examination of activities of Concrete Filled Steel Pipes column and at theoretical design method permitting to EN1994-1-1 Euro Code-4.
- An analytical study of performance of Concrete Filled Steel Pipes column and attheoretical design technique rendering to AISC method.

3.3 Modelling and Meshing

Modeling & meshing of 3D hollow & light weight concrete filled steel tube columns is done Using ANSYS 16.0.

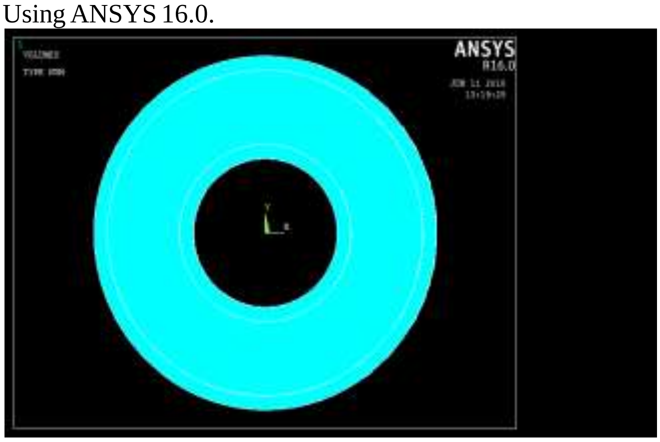


Figure 1: Cross section of Concrete & Steel element

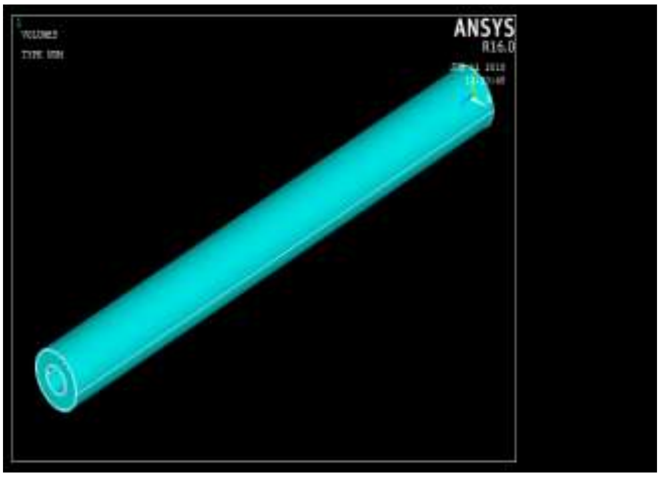


Figure 2: Modeling of CFST

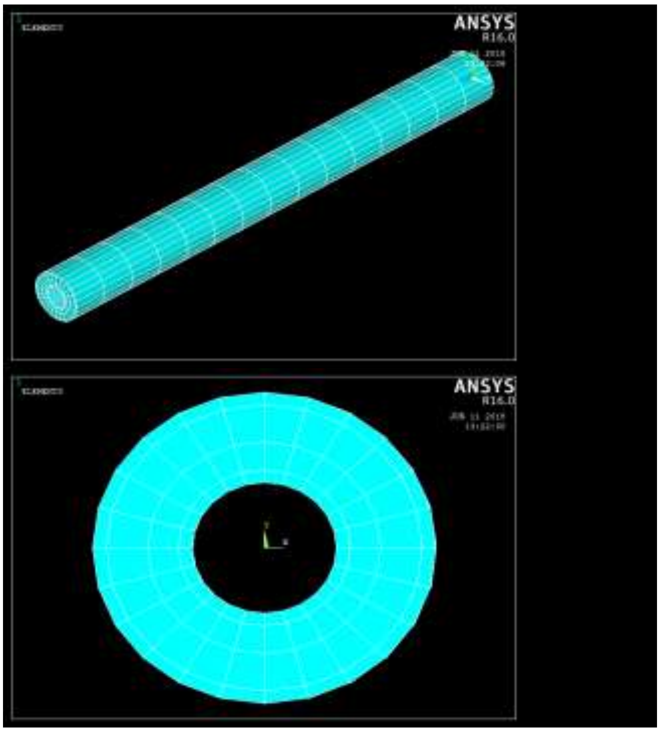
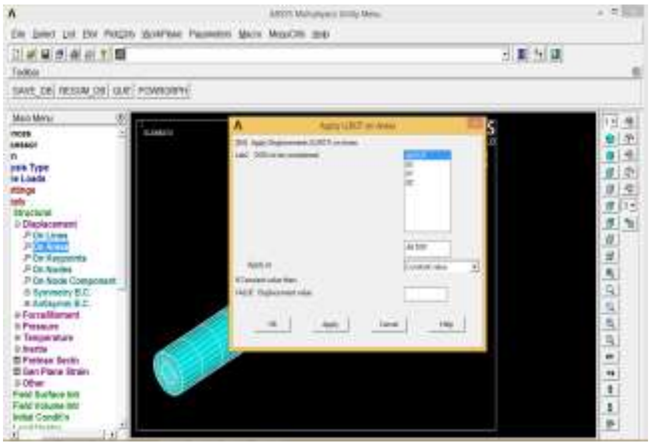


Figure 3: Meshing of CFST

3.4 Boundary conditions

The bottom ends were fixed & top ends were considered to be hinged for modeling. Bottom end, displacement degree of freedom in x, y & z direction (U_X U_Y & U_Z) are restrained and top end displacement degree of freedom x, y directions are restrained.



3.5 Pressure application

A compressive load is uniformly distributed over the top surface of column nodes as shown in fig below. Pressure is applied in Z direction from top.

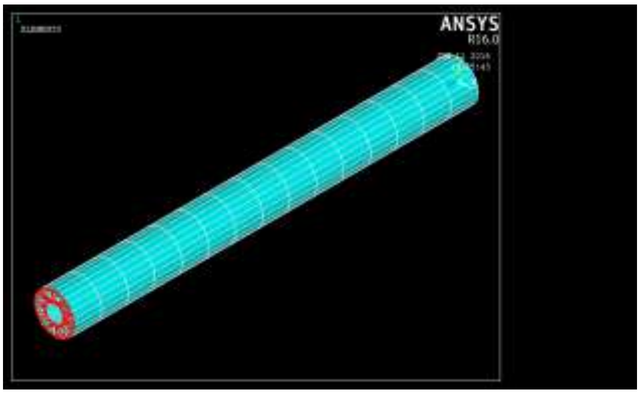


Figure 4: Application of pressure & Boundary conditions

4. Validation of Finite Element Model

4.1 Experimental results

To check the accuracy of results, the numerical results obtained from ANSYS were compared with experimental results obtained by previous postgraduate students of Ghousia college of Engineering. It is found that the result obtained from ANSYS is in good agreement with experimental results.

4.2 Euro code 4

According to EC4: Design of composite steel and concrete structures, the ultimate load carrying capacity of concrete filled steel tubular columns is given by

$$Pu = Ac * Fc + As * Fy$$

4.3 ACI 318

According to American concrete institute, the ultimate load carrying capacity of concrete filled steel tubular column is given by

$$Pu = 0.85 * Ac * Fc + As * Fy$$

4.4 BS 400 : According to British standard code, the ultimate load carrying capacity of concrete filled steel tubular column is given by

$$Pu = 0.675 * Ac * Fc + As * Fy$$

4.5 Load & Resistance Factor Design Method(AISC 360 10 & ACI 318 14)

According to American institute of steel construction, the theoretical load carrying capacity of CFST column is given by

$$Pu = Po\,(0.658^{Po/Pe})$$

Where, Ac = Area of concrete infill.
As = Area of steel tube.
F'c = Characteristic strength of concrete(30Mpa)
Fy = Yield strength of steel tube(250Mpa).
E_s = 2.1Gpa (Steel Modulus of Elasticity)
$E_c = 0.043(Wc)^{1.5}$ X $F'c^{0.5}$
Wc = 2400 Kg/m^3
Length (L)= 400mm
Thickness of both outer (t_o) and inner skin(t) = 1.6mm
Do_{ext} = 50mm & Do_{nt} = 46.80mm
Ro_{ext} = 25mm & Ro_{nt} = 23.4mm
Di_{ext} = 20mm & Di_{nt} = 16.8mm
Ri_{ext} = 10mm & Ri_{nt} = 8.4mm
$0.15\ E_s/f_y = 120$
$D_o/t_o = 31.25$

4.5.1 Steel

1. Moment of inertia for steel

$$Is_{out} = \frac{\pi\ (Do_{ext}{}^4\ Do_{int}{}^4)}{64}$$

= 71316.54581mm^4

$$Is_{int} = \frac{\pi\ (Di_{ext}{}^4\ Di_{int}{}^4)}{64}$$

= 3943.709116mm^4
Total MOI = 75260.25499mm^4
Similarly for Area
Area of outer tube = 243.162mm^2
Area of inner tube = 92.4416mm^2
Total area = 372.40320mm^2
Radius of gyration = $r_s = (I/A)^{0.5}$
= 14.215958

4.5.2Concrete

2. Moment of inertia for Concrete

$$Ic_{out} = \frac{\pi\ (Do_{ext}{}^4\ Do_{int}{}^4)}{64}$$

= 227625.6301mm^4
Similarly for Area
Considering both end are fixed
Area of outer tube = 1405.338mm^2
Radius of gyration = $r_s = (I/A)^{0.5}$
= 14.215958
Therefore K= 0.5
Column effective length = KL = 0.5 x 400 = 200mm
Slenderness Ratio = KL/r = 14.069 < 40
Hence it is short column

$P_{no} = P_p = f_y * As + C_2 * F_c * A_c$

From AISC 360 10 C2 = 0.95 for round sections

$P_{no} = P_p = 133152.705$ N

$$Pe = \frac{\pi^2 EI_{effi}}{(kl)^2}$$

$EI_{eff} = E_s * I_s + C_3 * E_c * I_c$

$EI_{eff} = 1.5052*10^{10}$

$Pe = 3713932.136$

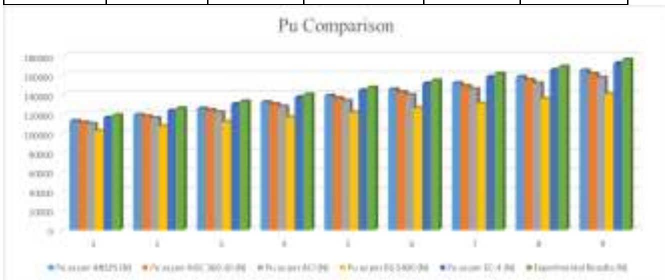
Pu =131169.53 N

5. Results and Discussions

Pu as per ANSYS (N)	Pu as per AISC 360-10 (N)	Pu as per ACI (N)	Pu as per BS 5400 (N)	Pu as per EC-4 (N)	Exp. Results (N)
145443	129212	128937	121559	135261	138150
148833	135485	134910	126302	142288	145327
151983	141739	140882	131045	149314	152504
154956	147975	146855	135788	156341	159680
157752	154191	152828	140531	163368	166857
160418	160388	158800	145274	170394	174034
162977	166566	164773	150017	177421	181211
165414	172725	170746	154760	184448	188387
167774	178865	176718	159503	191474	195564

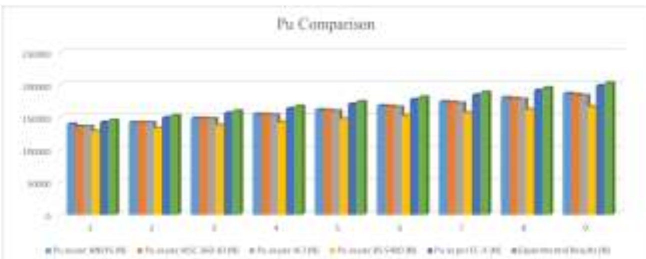
Pu as per ANSYS (N)	Pu as per AISC 360-10 (N)	Pu as per ACI (N)	Pu as per BS 5400 (N)	Pu as per EC-4 (N)	Exp. Results (N)
127230	125703	125213	117835	131537	134346
132505	131988	131186	122578	138564	141523
139098	138253	137158	127321	145590	148700
145651	144498	143131	132064	152617	155877
152165	150725	149104	136807	159644	163054
158640	156933	155076	141550	166670	170230
165074	163122	161049	146293	173697	177407
171470	169291	167022	151036	180724	184584
177826	175442	172994	155779	187750	191761

Pu as per ANSYS (N)	Pu as per AISC (N)	Pu as per ACI (N)	Pu as per BS 5400 (N)	Pu as per EC-4 (N)	Exp. Results (N)
112821	111247	109934	102556	116258	118741
118980	117575	115906	107299	123284	125918
125668	123884	121879	112042	130311	133094
132316	130174	127852	116785	137338	140271
138923	136445	133824	121528	144364	147448
145490	142696	139797	126271	151391	154625
152017	148928	145770	131014	158418	161801
158503	155141	151742	135757	165445	168978
164949	161336	157715	140500	172471	176155

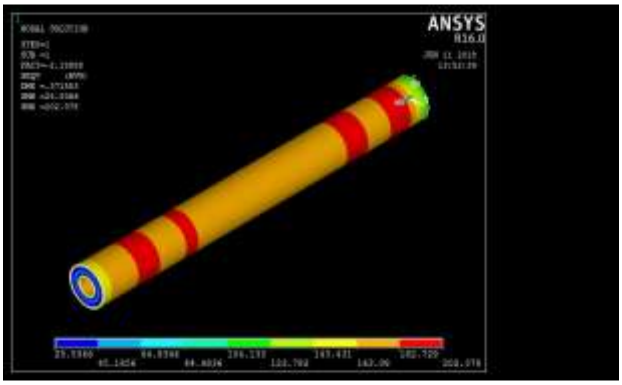


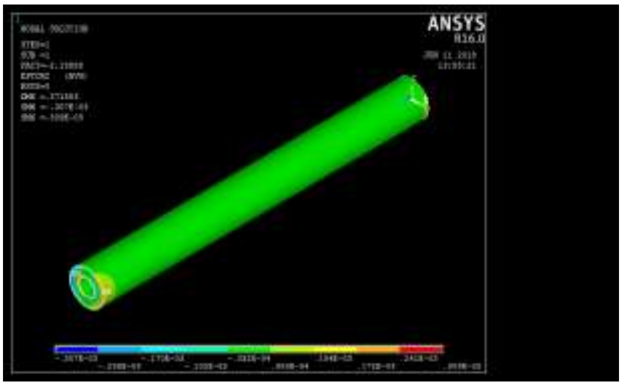
Pu as per ANSYS (N)	Pu as per AISC (N)	Pu as per ACI (N)	Pu as per BS 5400 (N)	Pu as per EC-4 (N)	Exp. Results (N)
107533	105120	103490	96112	109814	112160
113223	111467	109463	100855	116841	119337
119951	117795	115436	105598	123868	126514
126639	124103	121408	110341	130895	133690
133287	130392	127381	115084	137921	140867
139893	136662	133354	119827	144948	148044
146459	142913	139327	124570	151975	155221
152984	149145	145299	129313	159001	162397
159469	155357	151272	134057	166028	169574

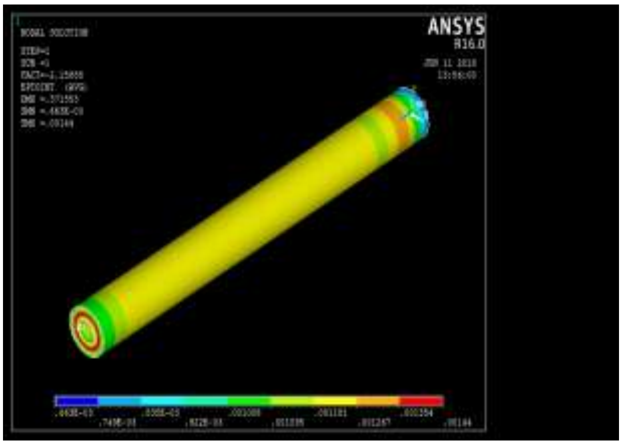
Pu as per ANSYS (N)	Pu as per AISC (N)	Pu as per ACI (N)	Pu as per BS 5400 (N)	Pu as per EC-4 (N)	Exp. Results (N)
139235	135574	135707	128329	142031	145064
141689	141828	141679	133072	149057	152241
148218	148063	147652	137815	156084	159418
154707	154278	153625	142558	163111	166595
161158	160475	159597	147301	170138	173771
167570	166653	165570	152044	177164	180948
173942	172812	171543	156787	184191	188125
180276	178952	177516	161530	191218	195302
186570	185073	183488	166273	198244	202479

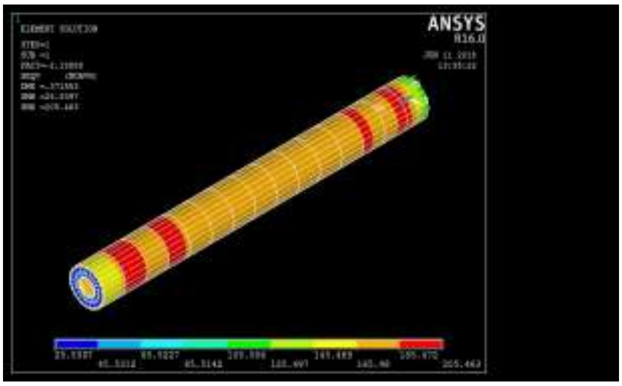


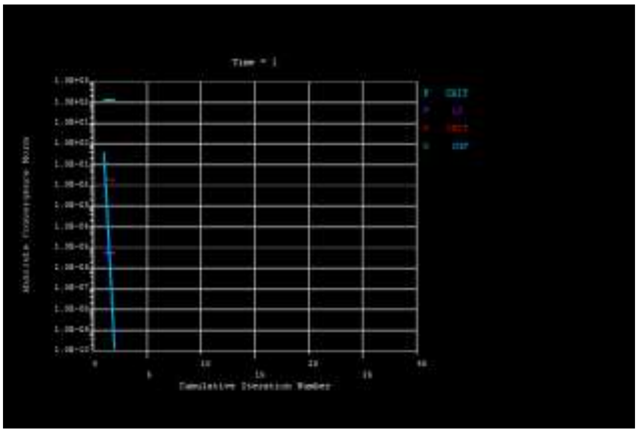
Elemental and Nodal results:

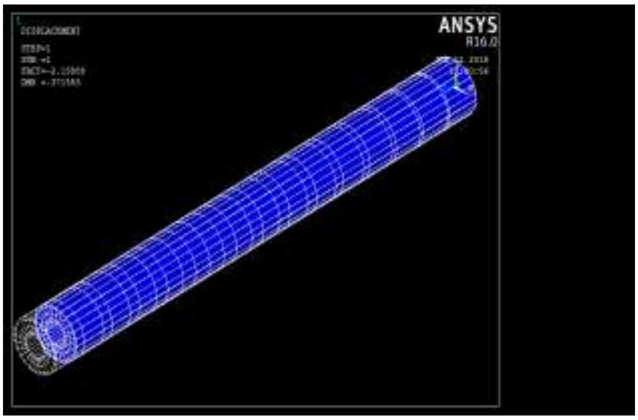












6. Conclusions

1) From Time Series plot we observe that Ultimate Axial load carrying capacity of column can be well predicted.
2) From this Research work parametric optimization and Factors like Thickness, length and Grade of concrete influencing the response can be well predicted.
3) Results obtained from ANSYS software varied from 5% to 10% when compared with experimental results.
4) Results obtained from EC4 code of practice varied from 2% to 15% when compared with experimental results.
5) Results obtained from ACI code of practice varied from 6% to 25% when compared with experimental results.
6) Results obtained from BS400 code of practice varied from 5% to 15% when compared with experimental results.
7) Results obtained from AISC 360-10 code of practice varied from 5% to 15% when compared with experimental results.
8) For M30 grade of concrete (constant diameter, constant thickness) for varying L/D ratio, load carrying capacity decreased by 4% to 8%.
9) For M40 grade of concrete (constant diameter, constant thickness) for varying L/D ratio, load carrying capacity decreased by 5% to 10%.
10) For Hollow CFST (constant diameter, constant thickness) for varying L/D ratio, the load carrying capacity decreased by 2% to 5%.
11) It is observed that results obtained from ANSYS software almost coincides with experimental results than results obtained from EC4, ACI, BS400, AISC 360-10 Codes.

7. Scope of the Project

- Cyclic loading can be tried for hybrid double skin composite steel columns to obtain ultimate axial load.
- Cyclic loading can be tried for double skin composite steel columns to obtain ultimate axial load with stiffener.
- Different shapes and its combination of composite columns can be tried under various loading condition.
- The cross section area of the composite columns above 50mm can be used.
- The thickness and length for the hybrid double skin composite column can be greater than before.
- Higher grade of concrete above M70 can be studied.
- Double skin composite columns can be modelled with ABAQUS, MIDAS and Other software's.

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