FRACTURE ANALYSIS OF RECTANGULAR COMPOSITE STEEL TUBES UNDER AXIAL LOADING USING ABAQUS/CAE 6.10-1

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Abstract

This research paper focuses on Fracture Analysis of Concrete Filled Rectangular Steel Tube Columns under Uniaxial Loading using ABQCUS/CAE 6.10-1 software was used for proper analytical modeling and also damage analysis of CFST columns were carried out. CFST column structure has high ductility , high load bearing capacity hence it has been widely used in civil engineering field. In this dissertation work,' Fracture analysis has been carried out rectangular composite steel tubes under axial loading using ABAQUS. Cracked & uncracked modles have been developed using 8-noded 3Dsoild element for concrete & C3H8 element for steel modelling in ABAQUS 6.10-1 . At the outset, developed model is used to validate the results obtained by " S.D. Bedage , Dr .D.N. Shinde " of " Comparative study of concrete filled steel tubes under axial compression" is the International journal of engineering research , vol.3.,issue.3., 2015. Experimental on rectangular axially loaded composite steel tubes were also carried out for different length , width of varying thickness. Ultimate load values obtained were compared with proposed cracked & uncracked fracture model using CTOD method. Further, all the experimental & ABAQUS results compared with ACI code, Euro code, BS code results. The results obtained by Euro codes were found to be inpar with the experimental & proposed ABAQUS values. For the proposed abaqus fracture model & experimental values, the % of error is in the range of 8-15%.

Keywords: *Finite Element Method, Abaqus, Rectangular CFST Column, Uniaxial Compression, Fracture Process.*

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1. INTRODUCTION

Concrete filled steel tubes has so many advantages, the concrete filled steel tube possess properties such as high ductility, high strength ,resistance against the seismic actions and has a large energy absorption capacity , hence the CFST are widely used in engineering structures which are construction of bridges, ducks of railways, seismic resistance structures and so on. One of the advantage of CFST column compared with other types of structural column where the CFST column is relevant to long span structures & high rise buildings and having a higher of stiffness quality and better in construction efficiency.

Composite column is a member in which the concrete is composite with steel element and act as a structural member and also referred as a compression member. Here the compression member are subjected to axial loading , know a days the composite member are highly used in engineering works.

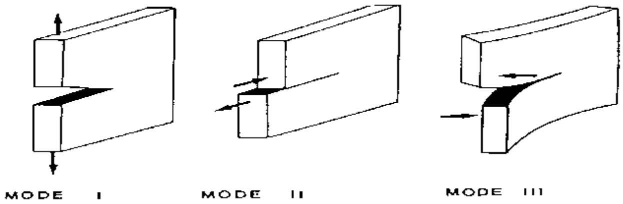
The improvement of CFST column in engineering work is due to composite action between concrete & steel ,here the steel tube itself behave as a transverse reinforcement as well as longitudinal reinforcement and the shell also produce confining pressure to concrete , infill concrete enhance the stuffiness of the column, this property avoids the inward buckling of steel tube , raises the stability & strength of column system, this leads to increase the flexural strength , therefore thinner wall tubes gets local buckling only after reached the yielding stage. During axial compression steel tube confines the concrete this enhance both ductility & axial resistance of CFST members . Rectangular concrete filled steel tubes less confining pressure to concrete core while compare with circular steel tube . local buckling is lore in square CFST member than circular CFST member. three dimensional non linear finite element model are developed to further study the axial load behavior of CFSTs and damages occurred in the CFSTs.

2. FRACTURE MECHANICS

FRACTURE MECHANICS is the type of mechanics in which the study of crack formation & crack propagation in materials were considered. Fracture mechanics plays a best role in the design of critical structural component here durability & reliability are important factor. Fracture mechanics has a valuable tool for engineers to guide their importance as well as effect in developing materials. It is the study of flaws & cracks in materials. The fracture mechanics approaches has 3 important variables such as Stress intensity factor, flow size, fracture toughness & relevant material property

Modes of Fracture

Mode I (opening mode) displacement is normal to the crack surface. Mode II (shearing mode) sliding mode, displacement is in the plane. Mode III denotes (Tearing/Shearing mode) causes sliding motion but the displacement is parallel to the crack surface



3. FINITE ELEMENT METHOD

One of the numerical technique for finding the solutions for partial differential equations and boundary value problems, that technique are called Finite element method. FEM is nothing but its divides the larger one into A smaller ones ,simpler ones and to subparts, those are called finite elements. FEM techniques are assembled into a larger equations FEA ia a good choice for analyzing problems. Some of the benefits of FEM are it good in forms a accurate representation of complex geometry and it is easy representation of the total solution.

that computes the entire problem. The variation methods used by FEM from the calculus of variations to a solution by minimizing the error function.

DETAILS OF SPECIMEN

Size of specimen	Length (mm)	Thickness (mm)	No's of tubes
50*25	300	2	3
		2.6	3
		3.2	3
	325	2	3
		2.6	3
		3.2	3
	350	2	3
		2.6	3
		3.2	3

Dimension in mm	Length in mm	Grdae of concrete	Thickness in mm
38*77.4	300	M20	1.3
38*77.4	300	M30	1.3
38*77.4	300	M40	1.3
43.3*93.3	300	M20	2
43.3*93.3	300	M30	2
43.3*93.3	300	M40	2

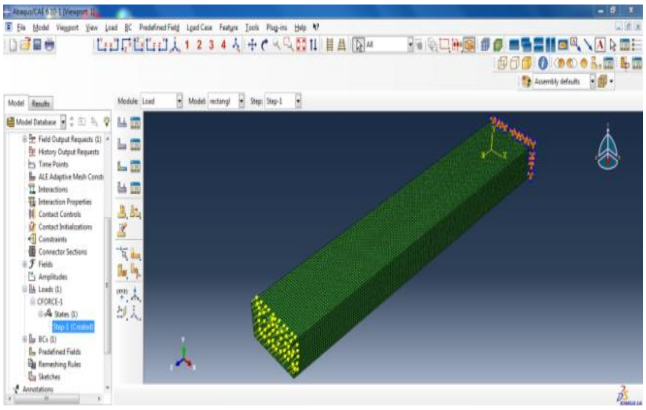
Material Specification
CONCRETE
Grade of concrete :
M20. Young's modulus E=22360 M pa
M25, Young's modulus E=25000 M pa
M30, Young's modulus E=27386.5 M pa
Poison ratio =0.2
Density = 2400 kg/m3

STEEL :
Grade of steel : Fe = 250 M pa
Young's modulus =210000 M pa
Poison ratio = 0.3
Density = 7850 kg/m3

4. MODELLING :

BOUNDNARY CONDITON

The bottom ends are fixed, for fixed condition the degree of freedom is 6 i.e. 3 degree of rotation, 3 degree of displacement



Buckling in FEA

Generally buckling occurs due to instability of the structure , when the structure can no longer support to withstand the heavier loads the structure those withstand the loads they have not forms instability , the smaller structure fails by yielding where as longer span ones fails by buckling or in of instability mode.

Linear Analysis :

Basic form of the buckling process in FEA is linear buckling , this type of buckling process related to Euler type calculation. A small displacement of shape is assumed in each element that a stress, those stress dependent on stiffening effect this adds to form linear static stiffness in the element . the stress dependent stiffness in now subtracting from the liner static stiffness term this causes the buckling effect. In linear analysis her is a Eigen value extraction , for a linear buckling analysis they need to find the scaling factor applied to static load. Here for typical FEA analysis under axial loading ,here an axial load of 1KN is applied at top nodes of cylinder. A linear analysis is carried out than the stress stiffing matrix & linear stiffness matrix are calculated in the first .

The result of analysis are the Eigen values and a set of Eigen vectors. The critical load that will cause the first buckling mode which will calculated from the applied load that is 1KN multiplied but the Eigen value. For example if the obtained Eigen value is 1.9454E5 than the critical load is (1*9454E5) 1.94KN. also get the buckling mode shapes , here the stress and displacements in the nonlinear buckling analysis is meaningful to acceptable than the linear analysis. In order to get critical buckling load and mode shapes linear analysis is adopted

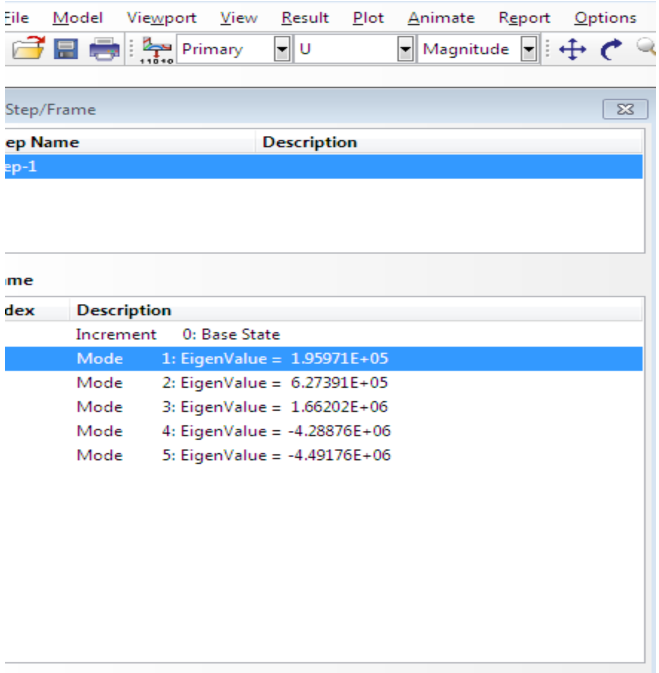


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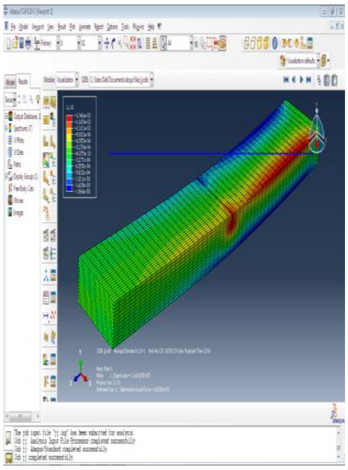
Table 1 : Tabulations of Ultimate load values from ABAQUS for un cracked section& experiment values

Dimension	Length	Thickness	Grade of concrete	Pu(abq)	Pu(expt)	Pu(abq0/Pu9)xpt0	% of error
50*25	300	2	M20	116	97	1.19	16.3
50*25	300	2.6	M20	143	134	1.06	6.29
50*25	300	3.2	M20	162	157	1.031	3.08
50*25	300	2	M25	123.8	101	1.22	18.4
50*25	300	2.6	M25	143.4	134	1.07	6.55
50*25	300	3.2	M25	182	162	1.123	10.9
50*25	300	2	M30	142	126	1.13	11.8
50*25	300	2.6	M30	151	143	1.055	5.2
50*25	300	3.2	M30	179	164	1.09	8.8
50*25	325	2	M20	112	95	1.17	15.1
50*25	325	2.6	M20	129	118	1.09	8.5
50*25	325	3.2	M20	119	107	1.12	10.8
50*25	325	2	M25	121.3	100	1.07	18
50*25	325	2.6	M25	143.8	125	1.213	13.1
50*25	325	3.2	M25	139	110	1.26	20.8
50*25	325	2	M30	135	111	1.216	17.1
50*25	325	2.6	M30	136	129	1.054	5.14
50*25	325	3.2	M30	141.8	113	1.25	20.4
50*25	350	2	M20	116	92	1.26	24.8
50*25	350	2.6	M20	137	103	1.33	16.6
50*25	350	3.2	M20	126	105	1.2	16.6
50*25	350	2	M25	93.6	89	1.08	5
50*25	350	2.6	M25	123	109	1.12	11.3
50*25	350	3.2	M25	141	116	1.21	1707
50*25	350	2	M30	128	95	1.34	257
50*25	350	2.6	M30	165	147	1.12	10.9
50*25	350	3.2	M30	195.4	158	1.23	9.0

FRACTURED MODEL



Stress intensity factor

The tube of centrally located crack or crack located at the edge subjected to stress, the vicinity of crack tip depend on the orientation & factor 'K'. this means that the state of stress at a given point in the vicinity depends completely on the factor K called the stress intensity factor.

However this factor K depends o the nature of loading, the configuration of the body, mode of crack opening .

The stress intensity factor K is given by

$K=\sigma\sqrt{\pi a}$

Crack tip opening displacement(CTOD)

Crack tip opening displacement is another parameter suitable to characterize a crack. The definition of CTOD is based on a model that a beginner may find a bit difficult to accept, because at any location of the crack the opening is called a crack opening displacement. Therefore we will be using CTOD as a parameter. The CTOD parameter has been found more usefull for cracks, the CTOD is another approach to deal with elastic plastic fracture mechanis

From Dugdale approach is used , it can be shown that

$CTOD = KI^{2}/E\sigma$

Table2: Tabulation of CTOD valueS

Dimension	length	thickness	Grdae of concret	Crack length	Ki	CTOD
50*25	300	2	M20	9.7	44.62	0.0379
50*25	300	2.6	M20	11.18	42.45	0.0343
50*25	300	3.2	M20	11.4	47.3	0.0426
50*25	300	2	M25	9.37	42.89	0.050
50*25	300	2.6	M25	11.08	46.64	0.0414
50*25	300	3.2	M25	9.7	45.83	0.04
50*25	300	2	M30	11.08	41.8	0.0332
50*25	300	2.6	M30	9.7	46.95	0.0419
50*25	300	3.2	M30	8.9	47.1	0.0433
50*25	325	2	M20	11.23	39.63	0.0299
50*25	325	2.6	M20	8	40.12	0.036
50*25	325	3.2	M20	11.6	42.29	0.034
50*25	325	2	M25	10.01	39.68	0.029
50*25	325	2.6	M25	9.1	40.61	0.0314
50*25	325	3.2	M25	8.02	43.41	0.0358
50*25	325	2	M30	8.4	41.73	0.0316
50*25	325	2.6	M30	9.6	43.07	0..0356
50*25	325	3.2	M30	8.87	41.7	0.031
50*25	350	2	M20	9.45	43	0.035
50*25	350	2.6	M20	8.03	44.3	0.037
50*25	350	3.2	M20	11.2	41.35	0.032
50*25	350	2	M25	10.12	42.7	0.034
50*25	350	2.6	M25	8.92	41.85	0.033
50*25	350	3.2	M25	9.47	43.12	0.035
50*25	350	2	M30	9.32	44.57	0.0378
50*25	350	2.6	M30	8.7	47.04	0.0421
50*25	350	3.2	M30	10.9	46.26	0.0407

Table 3 : Tabulation of abaqcus values with ACI Euro & BS code for fallowing dimension

Dimension	**length**	**thickness**	**Grdae of concret**	**Pu(abq)**	**Pu(euro)**	**Pu(euro)**	**Pu(BS)**
50*25	300	2	M20	116	111	103	107
50*25	300	2.6	M20	143	134	125	129
50*25	300	3.2	M20	162	157	150	153
50*25	300	2	M25	123.4	116	107	1112
50*25	300	2.6	M25	143.2	135	126	130
50*25	300	3.2	M25	182	162	153	157
50*25	300	2	M30	142.4	126	112	19
50*25	300	2.6	M30	151	143	130	136
50*25	300	3.2	M30	179	164	154	159
50*25	325	2	M20	112	111	103	107
50*25	325	2.6	M20	119	134	126	129
50*25	325	3.2	M20	121	15	130	153
50*25	325	2	M25	143	116	107	118
50*25	325	2.6	M25	139	135	126	130
50*25	325	3.2	M25	135	162	153	136
50*25	325	2	M30	136	126	112	119
50*25	325	2.6	M30	141	143	130	157
50*25	325	3.2	M30	116	164	154	159
50*25	350	2	M20	137	16411	103	107
50*25	350	2.6	M20	126	134	125	129
50*25	350	3.2	M20	93.6	157	150	159
50*25	350	2	M25	123	116	107	112
50*25	350	2.6	M25	141	135	126	130
50*25	350	3.2	M25	128	162	153	157
50*25	350	2	M30	165	126	112	119
50*25	350	2.6	M30	121	143	130	136
50*25	350	3.2	M30	195.4	164	154	139

*****Validation for the workdone by thInternational journal of Comaprative study of concrete filled steel tubes under axial compression

Table 4 : Tabualtion of ultimate load values from abaqus & expermint

Dimension	length	Grade of concrete	Thickness)	Pu(abq)	Pu(expt)	Pu(abq)/Pu(expt)
38*77.4	300	M20	1.3	183.4	153.69	1.19
38*77.4	300	M30	1.3	209.4	183.12	1.14
38*77.4	300	M30	1.3	245.7	209.2	1.17
43.3*93.3	300	M20	2	254	238.71	1.1
43.3*93.3	300	M30	2	313.4	264.87	1.18
43.3*93.3	300	M30	2	334	304.	1.09

Table 5 : Tabulation of CTOD values

Dimension	length	Grade of concrete	Thickness)	Cracklength	Ki	CTOD
38*77.4	300	M20	1.3	12	48.54	0.04
38*77.4	300	M30	1.3	11.4	47.31	0.043
38*77.4	300	M30	1.3	12.8	50.13	0.047
43.3*93.3	300	M20	2	13.1	50.71	0.049
43.3*93.3	300	M30	2	13.34	51.17	0.048
43.3*93.3	300	M30	2	13.03	50.58	0.0487

Table 6 : Tabulation of abaqcus values with Eurocode-4

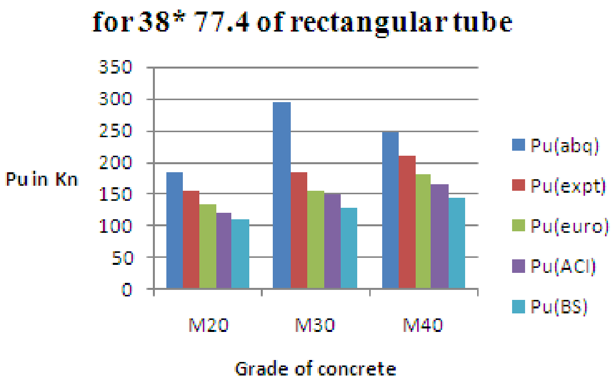
Dimension	length	Grade of concrete	Thickness)	Pu(abq)	Po(euro)	Pu(abq)/Pu(euro)
38*77.4	300	M20	1.3	183.4	132..14	1.3
38*77.4	300	M30	1.3	209.4	152.7	13
38*77.4	300	M30	1.3	245.7	179.23	1.36
43.3*93.3	300	M20	2	254	204.83	1.28
43.3*93.3	300	M30	2	313.4	239.8	1.3
43.3*93.3	300	M30	2	334	274.24	1.21

Table 7 : Tabulation of abaqcus values with ACI code

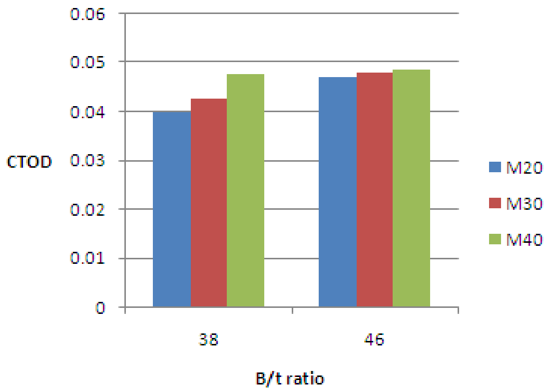
Dimension	length	Grade of concrete	Thickness)	Pu(abq)	Pu(ACI)	Pu(abq)/Pu(ACI)
38*77.4	300	M20	1.3	183.4	118.1	1.5
38*77.4	300	M30	1.3	1.09	148.32	1.41
38*77.4	300	M30	1.3	245.	163.4	1.5
43.3*93.3	300	M20	2	254	195.7	1.36
43.3*93.3	300	M30	2	313.4	224.54	1.39
43.3*93.3	300	M30	2	334	253.84	1.05

Table 8 : Tabulation of abaqcus values with British standard code

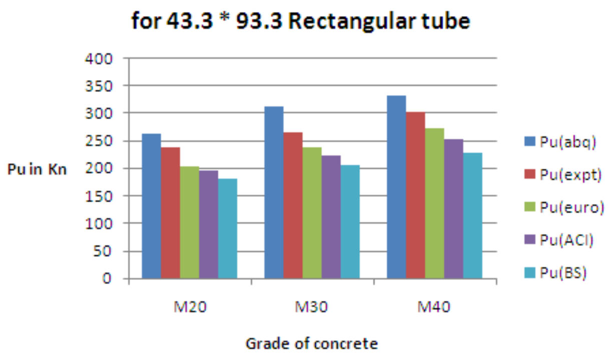
Dimension	length	Grade of concrete	Thickness)	Pu(abq)	PuBS	Pu(abq)/Pu(bs)
38*77.4	300	M20	1.3	183.4	108.8	1.69
38*77.4	300	M30	1.3	1.09	126.54	1.65
38*77.4	300	M30	1.3	245.	144.28	1.7
43.3*93.3	300	M20	2	254	181.73	1.45
43.3*93.3	300	M30	2	313.4	205.18	1.52
43.3*93.3	300	M30	2	334	228.4	1.46



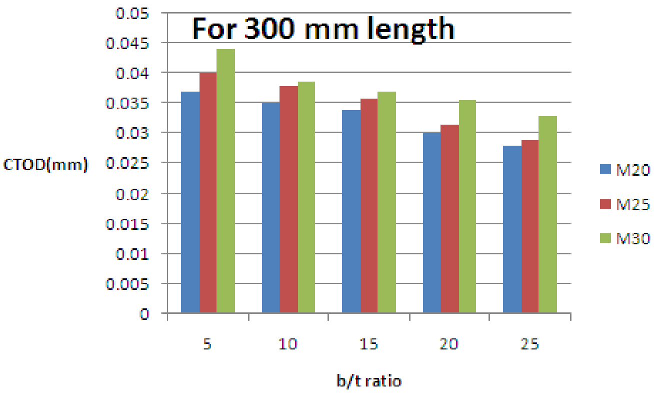
Graph1: Representation of ultimate load values with different grade of concrete for 300 mm length of thickness 1.3 mm for the 38* 77.4 of rectangular tube



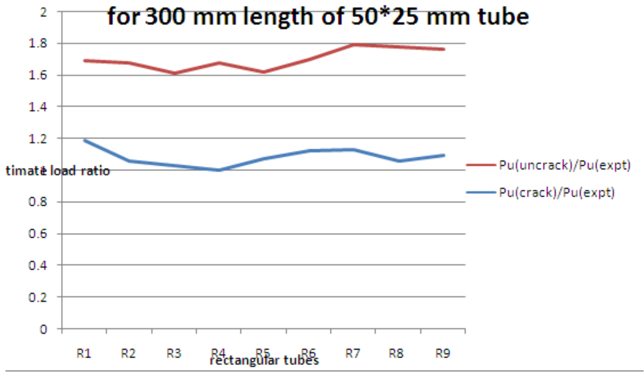
Graph 3 :Representation of CTOD values for 38*77.4 mm tube & 43.3*93.3 mm of rectangular tubes



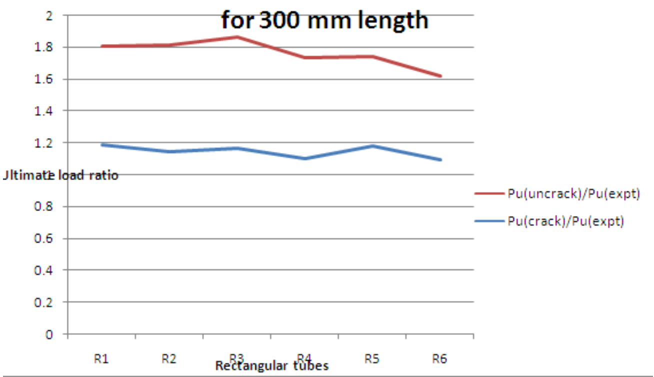
Graph2: Representation of ultimate load values with different grade of concrete for 300 mm length of thickness 2 mm for the 43.3*93.3 of recta8gular tube



Graph 4 :Representation of CTOD values for 300 mm length of the tube for different grade of concrete of 50*25 mm rectangular tube



Graph 5: Representation of ratio of ultimate load values for 300 mm length of 50* 25 mm rectangular tube



Graph 6 : Representation of ratio of ultimate load values for 300 mm length of 38*77.4 & 43.3*93.33 mm rectangular tubes

CONCLUSION

- ✓ The ultimate vaule obtained from un cracked 1.21model is more than the cracked model
- ✓ As tube thickness increases , CTOD value increases by 4-5% which indicates the importance of arriving at optimum tube thickness.
- ✓ For constant thickness & length of the tube, as grade of concrete increases , stress intensity factor along with CTOD meraginally increased by 3-6%.
- ✓ Crack length marginally increased as grade of concrete increased, for M 30 grade , crack length increased by 10 %.
- ✓ The results obtained from the analysis using ABQUS varied by 8% for M20, 15% for M30 than the experimental results
- ✓ The ultimate load carrying capacity increases with increase in the thickness value & grade of concrete , example

Thickness	Grade of concrete	Pu in Kn
2mm	M20	123
2mm	M30	142
2.6mm	M20	146
2.6m	M30	179

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BIOGRAPHIES

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Involved in the Research field related to behavior of Composite Steel Column since a decade. & He has guided more than 15 M.Tech projects including one M.Sc Engineering (by Research under VTU, Belgaum). Presently guiding five Ph.D Scholars under VTU Belgaum. Has more than 26 years of teaching & 6 years of Research experience at Ghousia College of Engineering, Ramanagaram