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Reliability Analysis of Concrete Filled Steel Tubes using ANSYS and First Order Reliability Method

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Abstract - *A Concrete filled steel tube column is a structural arrangement with excellent structural behavior, which result in combine advantages of a steel tube and those of concrete. Composite steel columns (CFST) have been utilized in various works since early 1900. Analytical Study and Reliability analysis of Hollow Steel Tube with concrete filled of different grades under monotonic loading is offered in this study. The nonlinear behavior of the columns is perceived by using finite element software ANSYS 16.0. The outcomes from non-linear finite element analyses are attained and are substantiated with AISC-LRFD-1999 code and Reliability analysis. This study was carried out to examine the effect of numerous parameters such as thickness of tube (3.2mm), Diameter of steel tube (26.90mm, 33.70mm & 42.40mm) Slenderness ratio & Reliability and Also to find Ultimate load carrying ability of hollow and composite column on compressive response under axis loading was assessed. The main parameters are: (1) Slenderness ratio (2) Thickness -steel tube (3) compressive strength of concrete.*

***Key Words*: CFST Column, ANSYS, Finite Element Analysis, Taguchi's Method, Reliability Analysis**

1. INTRODUCTION

Concrete filled steel tube column has got many leads associated with the reinforced concrete member. Concrete filled steel tubes are often used for piers, profound foundations, caissons and columns because of its high compressive strength and stiffness. Composite section of Structural Steel has substantial larger stiffness, stability and load sustaining capacity in contrast with lone construction of steel. Concrete-filled steel tubes (CFST) can be made used in numerous structural approaches which includes columns, supporting platforms for offshore structures, storage tank roofs, bridge piers, piles, and in seismic zones of columns Composite columns usage can out-turn in remarkable reduction in the size of a column, which eventually guides to total decrease in the construction cost. The depletion in column size offers number of benefits such as floor space premium and in car parking and office blocks. Along with this, CFT's are also finding their way in applications for retrofitting purposes for strengthening the columns of concrete in areas which are more subjected to earthquakes.

1.1 Types of CFST Columns

There are two sorts of composite segments, those with steel tube with steel segment encased in concrete and those with steel tube in-loaded with concrete are usually utilized as a part of structures. Fundamental types of cross-segments illustrative of composite sections are demonstrated in Figure1.1. Under extreme flexural over-burden, solid encasement splits bringing about diminishment of solidness yet the steel centre gives shear limit and bendable imperviousness to consequent cycles of over-burden. Concrete-filled steel tubular segments have been utilized for quake safe structures; connect wharfs subject to affect from activity, sections to help stockpiling tanks, decks of railroads, segments in elevated structures and as heaps. In view of the expanded utilization of composite segments, a lot of hypothetical and exploratory work has been done.

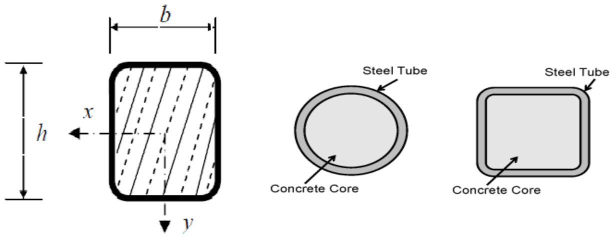


Fig -1: C/S of CFST Tubes

1.2 Failure Mechanism

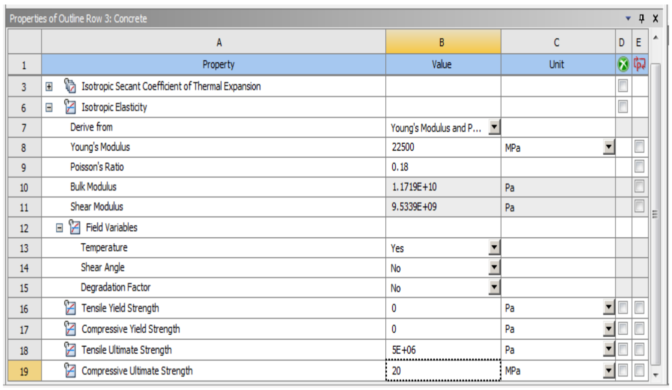
Short sections can be additionally subdivided into two classes in light of the D/t proportion (the proportion of the tube breadth to the tube thickness). Concrete-filled steel tubes with "thick" dividers will display the more standard component of disappointment. The solid winds up plainly kept at a strain of roughly 0.002 and extra pivotal quality is accomplished. Be that as it may, if the quality of the steel surpasses around 55 ksi (the anxiety comparing to a longitudinal strain of roughly 0.002), the solid will probably achieve its compressive quality farthest point and may smash before the steel yields, which is an undesirable method of disappointment (Furlong, 1967). Also, this may cause flexible nearby clasping of the steel tube. SSRC (1979) along these lines indicates a steel yield quality point of confinement of 55 ksi for composite sections. With constraint, the solid can keep on sustaining extra load until the point that the steel tube flops (for the most part by broad neighborhood clasping or full plasticization of the cross-segment) denoting a definitive quality of the segment. The disappointment of roundabout CFTs likewise may occur at the mid-stature with broad neighborhood clasping, and nearby clasping at that point spreads to the closures (Schneider, 1998).

1.3 Concrete Strength

Concrete strength resolves stiffness of CFT tube. Stiffness rises with increase in concrete strength nevertheless columns miscarry due to crushing of concrete. Which exhibit brittle performance when filled with high power concrete. In case stiffness defeat is rapid, traces of axial strain setback occurs for high strength concrete filled in columns, as given by O'Shea and Bridge. But there is statistic that suggests rise in concrete strength increases the strength of composite columns to a greater possibility.

2. Modeling of Columns in ANSYS

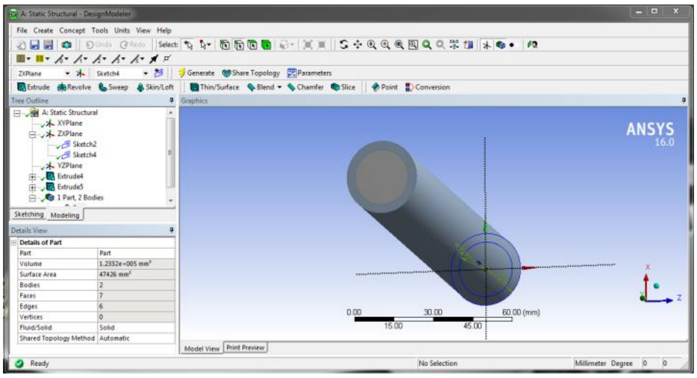
For modeling the CFST columns ANSYS Workbench 16.0 was used. To create a model select static structural template and create model as follows



Properties of Outline Row 3: Concrete

	A	B	C	D	E
1	Property	Value	Unit		
3	Isotropic Secant Coefficient of Thermal Expansion			☐	
6	Isotropic Elasticity			☐	
7	Derive from	Young's Modulus and P...			
8	Young's Modulus	22500	MPa		☐
9	Poisson's Ratio	0.18			☐
10	Bulk Modulus	1.1719E+10	Pa		☐
11	Shear Modulus	9.5339E+09	Pa		☐
12	Field Variables				
13	Temperature	Yes			
14	Shear Angle	No			
15	Degradation Factor	No			
16	Tensile Yield Strength	0	Pa	☐	☐
17	Compressive Yield Strength	0	Pa	☐	☐
18	Tensile Ultimate Strength	5E+06	Pa	☐	☐
19	Compressive Ultimate Strength	20	MPa	☐	☐

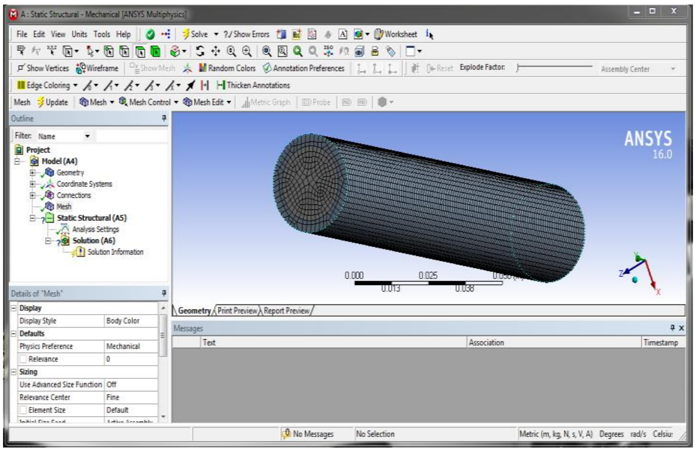
Fig -2: Assigning material properties



Details of Part

Part	Part
Volume	1.2332e+005 mm³
Surface Area	47426 mm²
Bodies	2
Faces	7
Edges	6
Vertices	0
Fluid/Solid	Solid
Shared Topology Method	Automatic

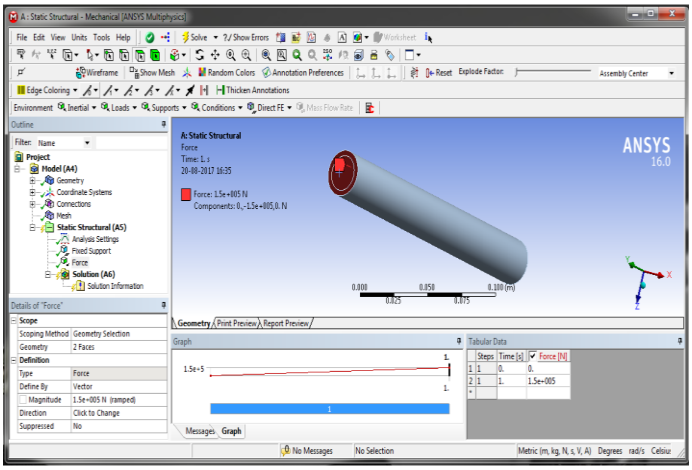
Fig -3: Generating model



Details of "Mesh"

Display	
Display Style	Body Color
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Fine
Element Size	Default

Fig -4: Meshing model



A: Static Structural
Force
Time: 1. s
20-08-2017 16:35

Force: 1.5e+005 N
Components: 0.,-1.5e+005,0. N

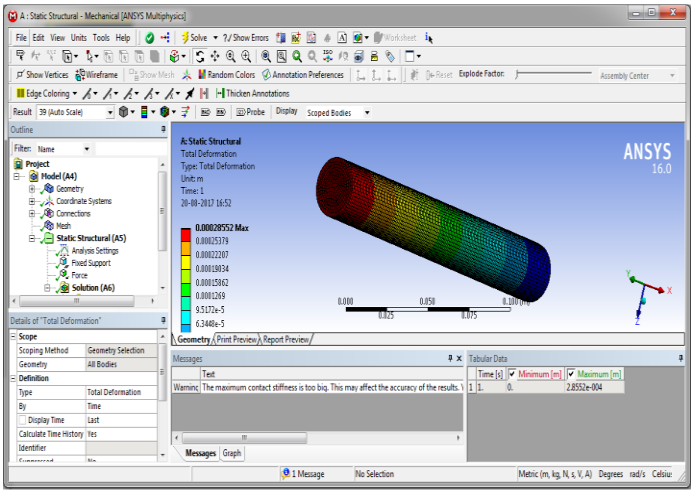
Details of "Force"

Scope	
Scoping Method	Geometry Selection
Geometry	2 Faces
Definition	
Type	Force
Define By	Vector
Magnitude	1.5e+005 N (ramped)
Direction	Click to Change
Suppressed	No

Tabular Data

	Steps	Time [s]	☑ Force [N]
1	1	0.	0.
2	1	1.	1.5e+005
*			

Fig -5: Applying load and end conditions



A: Static Structural
Total Deformation
Type: Total Deformation
Unit: m
Time: 1
20-08-2017 16:52

Details of "Total Deformation"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Total Deformation
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	

Messages

	Text
Warning	The maximum contact stiffness is too big. This may affect the accuracy of the results.

Tabular Data

	Time [s]	☑ Minimum [m]	☑ Maximum [m]
1	1.	0.	2.8552e-004

Fig -6: Deformed shape

3. RESULTS

SL. NO	Dia (mm)	Length (mm)	Thickness (mm)	L/D Ratio	P_u Analytical(kN)
1.	26.9	215.2	3.2	8	105.313
2.		322.8		12	102.161
3.		430.4		16	97.527
4.		269.6		10	105.342
5.		404.4		15	98.325
6.		539.2		20	99.161
7.		339.2		13	101.757
8.		508.2		19	97.181
9.		678.4		25	106.649
10.	33.7	215.2	3.2	8	137.329
11.		322.8		12	131.476
12.		430.4		16	129.755
13.		269.6		10	135.503
14.		404.4		15	128.688
15.		539.2		20	125.920
16.		339.2		13	130.697
17.		508.2		19	126.843
18.		678.4		25	123.95
19.	42.4	215.2	3.2	8	178.639
20.		322.8		12	172.959
21.		430.4		16	167.663
22.		269.6		10	176.736
23.		404.4		15	168.317
24.		539.2		20	164.895
25.		339.2		13	173.113
26		508.2		19	166.596
27.		678.4		25	162.530

Table –1: Analytical results obtained from ANSYS software for M20 infilled CFST tubes.

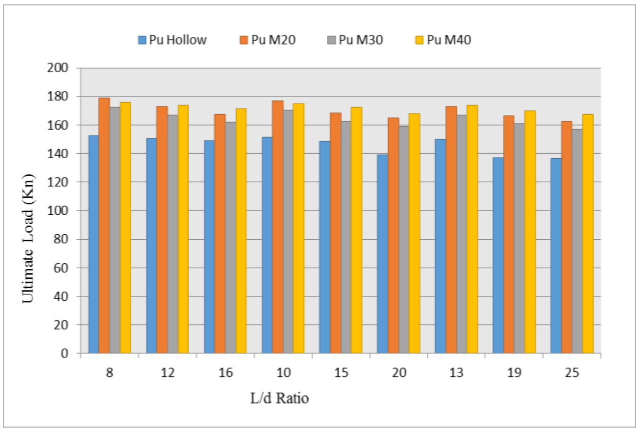


Chart -1: P_u (ANSYS) vs L/D for 26.9 mm dia

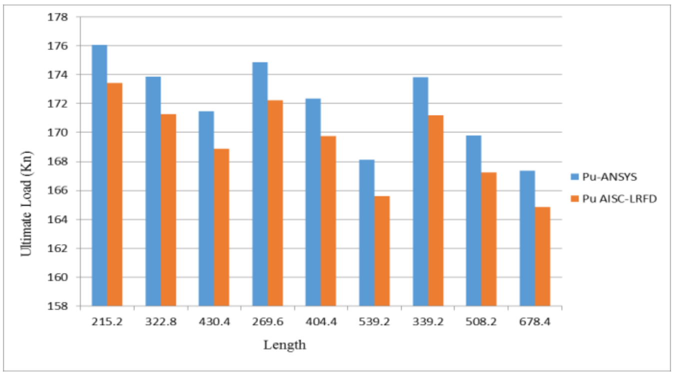


Chart -2: P_u (ansys) vs P_u (code) for M20 26.9 mm dia bar

4. Reliability Analysis

Reliability suggests to the degree to which a scale produces steady outcomes, if the estimations are revised various circumstances. The examination on unwavering quality is called reliability investigation. Unwavering quality examination is dictated by acquiring the extent of precise variety in a scale, which should be possible by deciding the relationship between the scores got from various organizations of the scale. In this way, if the relationship in reliability investigation is high, the scale yields predictable outcomes and is in this way safe.

4.1 Goals of Reliability

1. To apply engineering associate and ideal methods to avoid or to diminish the 7 probabilistic frequency of disasters.
2. To recognise and correct the reasons for failure that arises despite the determinations to forestall.
3. To regulate ways of constrain let-downs, if their causes have-not been adjusted.
4. To apply techniques for valuing the likely reliability of new designs, and for analysing reliability information.

Table –2: % Reliability for M20 26.9 mm dia bar

Sl No.	Length (mm)	L/D Ratio	P_u Analytical (kN)	Reliability Index β	% age of Reliability
1.	215.2	8	105.313	-1.341	90.988
2.	322.8	12	102.161	-0.994	83.891
3.	430.4	16	97.527	-0.878	80.785
4.	269.6	10	105.342	-1.341	90.988
5.	404.4	15	98.325	-0.878	80.785
6.	539.2	20	99.161	-0.915	81.859
7.	339.2	13	101.757	-0.954	82.894
8.	508.2	19	97.181	-0.842	79.955
9.	678.4	25	106.649	-1.405	91.924

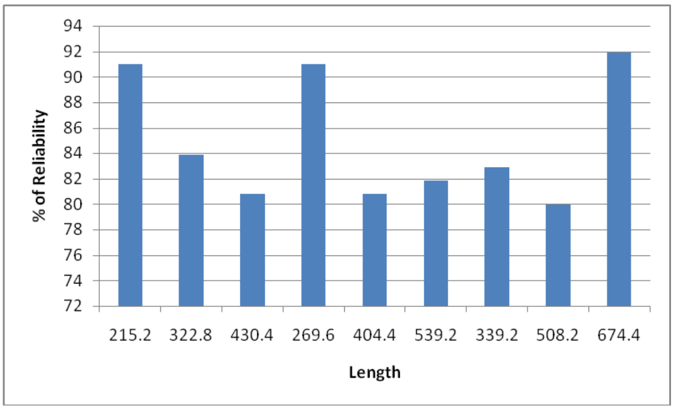


Chart -3: % Reliability vs Length for M20 26.9mm dia bars

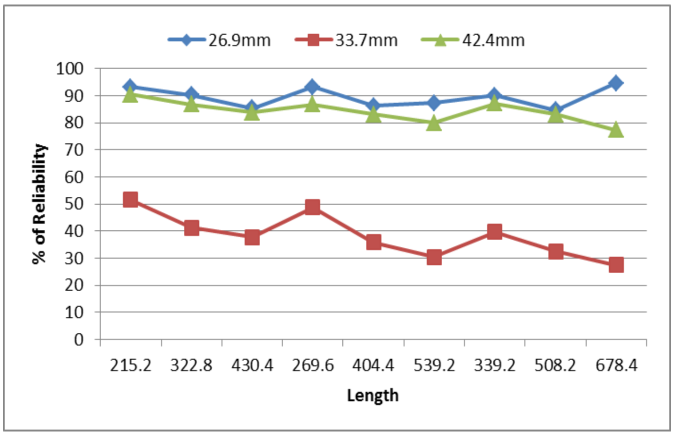


Chart -4: Comparison of Reliability vs Length for M20 sections

Dia (mm)	F_{ck}	Length (mm)	P_u (kN)	Area (mm²)	Weight (kN)	Strength/ eight
26.9	20	215.2	105.313	568.395	5.73	33.642
26.9	30	322.8	99.864	568.395	8.6	21.685
26.9	40	430.4	101.948	568.395	11.46	16.889
33.7	20	322.8	131.476	892.084	12.31	12.456
33.7	30	430.4	129.240	892.084	16.41	9.371
33.7	40	215.2	144.30	892.084	8.2	21.285
42.4	20	430.4	167.663	1412.14	23.84	5.182
42.4	30	215.2	175.12	1412.14	11.92	11.042
42.4	40	322.8	173.873	1412.14	17.88	7.43
26.9	20	269.6	105.342	568.395	7.18	26.856
26.9	30	404.4	98.790	568.395	10.76	17.145
26.9	40	539.2	107.361	568.395	14.36	14.194
33.7	20	404.2	128.668	892.084	15.42	9.733
33.7	30	539.2	127.799	892.084	20.56	7.396
33.7	40	269.6	143.113	892.084	10.28	16.839
42.4	20	539.2	164.895	1412.14	29.85	4.07
42.4	30	269.2	173.237	1412.14	14.91	8.733
42.4	40	404.4	172.353	1412.14	22.39	5.882
26.9	20	339.2	101.757	568.395	9.03	20.627
26.9	30	508.8	94.796	568.395	13.55	13.065
26.9	40	678.4	100.03	568.395	18.06	10.515
33.7	20	508.8	126.843	892.084	19.4	7.625
33.7	30	678.4	132.707	892.084	25.86	6.106
33.7	40	339.2	139.073	892.084	12.94	12.999
42.4	20	678.4	162.53	1412.14	37.56	3.188
42.4	30	339.2	169.685	1412.14	18.78	6.791
42.4	40	508.8	169.805	1412.14	28.17	4.606

Table –3: Taguchi's L-9 Array for Strength/Weight

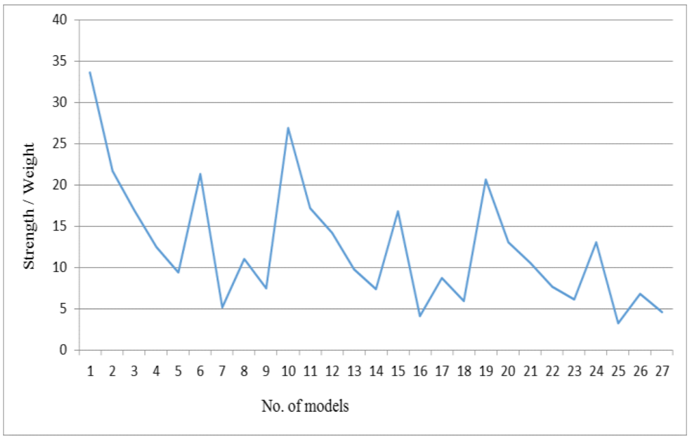


Chart -5: Graphical Representation L9 Array Combinations

3. CONCLUSIONS

1. P_u values obtained by AISC LFRD code formulae and analytical procedure show that the results obtained by analytical method are higher than those of codal values.(Table 5.5 to Table 5.8)
2. The percentage error between P_u analytical and P_u AISC LFRD method is about 12% (Fig 5.2).
3. The load carrying capacity of CFST decreases with increase in L/d ratio. (Table 5.14 to Table 5.22)
4. The load carrying capacity of columns increases with increase in diameter maintaining thickness as constant.
5. The reliability calculation using FORM can be easily done manually whereas Design point sampling requires suitable software.
6. The probability of failure decreases with increase in length of CFST columns. (Table 5.40 to Table 5.41)
7. Reliability Index β values increase with increase in length of CFST columns having constant diameter and thickness. (Fig 5.28 to Fig 5.39).
8. It can be observed from Table-5.40, that the maximum reliability obtained is 93.189 % for D1, T1 combination for a constant length. (Fig 5.37)

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