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Reliability Analysis of CFST Columns by Using Form and Latin Hypercube Method

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Abstract: ***Reliability oriented design techniques have been a powerful technique that is being globally adopting by structural engineers. The concrete filled steel tube column has many advantages compared to reinforced concrete member. This research aims to study the behavior of concrete filled steel tube (CFST) segments under monotonic loading by utilizing the finite element software ANSYS. Modeling accuracy is built up by using outcomes obtained from BS 5400, Eurocode 4 and AS 3600 codes. It is inferred that various parameters have considerable impact on the behavior of concrete filled steel columns, the prime variables are cross sectional area, thickness, and diameter of steel tube etc.., Most of the Researches on concrete filled steel tube is limited to deterministic approach yet in this thesis it also includes the reliability analysis of concrete filled steel tubes using First Order Reliability method and Latin Hypercube method utilizing 2R rel software.***

Keywords: CFST, ANSYS, Reliability, FORM, Latin Hypercube, 2R rel

1. Introduction

Nowadays, in tall buildings, Bridges and other various types of structures the composite components are very much effectively used, because CFST columns have many advantages over the conventional reinforced concrete and structural steel columns. Number one is the concrete infill is confined by the steel tube. The second one is concrete infill delays local buckling of the steel tube. And the last one is the combined capacity of the steel and concrete significantly maximizes the stiffness and ultimate strength of CFST columns which makes them very suitable for columns and other compressive members. Finally, the steel tube serves as longitudinal reinforcement and permanent formwork for the concrete core.

1.1 Concept of Reliability

Reliability engineering is a sub-discipline of system engineering that emphasizes dependability in the lifecycle management of a production. Reliability is the ability to meet specific requirements under a specified period. Reliability is theoretically defined as probability of success.

That is, Probability of failure, Pf = P(R-S< 0)

Reliability = 1-pf

1.2 First order reliability method (FORM)

In 1974 Hosfer st al was first developed FORM method. FORM method is good for handling non linear performance function using Taylor series. FORM utilizes only mean and standard deviation of variables.

Therefore, limit state function is given by Z= R-S

If both R & S are assumed as normal random variables, then Z can also be referred as random variables.

that is $(\mu R - \mu s, \sqrt{\sigma R2 + \sigma s2})$. Then probability of failure can be defined as

pf = P(Z<0)

pf =Φ[0-(μR-μS)/$\sqrt{\sigma R2 + \sigma S2}$]

pf=1− Φ [$\mu R - \mu S / \sqrt{\sigma R2 + \sigma S2}$]

Φ is the CFD of the standard normal variant

Thus, the probability of failure is a function of the mean value of Z to its standard deviation.

$\beta = \mu R - \mu S$/(μR-μS)/$\sqrt{\sigma R2 + \sigma S2}$]

The probability of failure can be expressed in terms of the safety index as follows.

pf= $\Phi(-\beta) = 1 - \varphi(\beta)$

1.3 Latin hypercube method (LHM)

Generally Montecarlo technique is used for simulation method, to increase the efficiency of this simulation technique, a new sampling method is developed called Latin hypercube sampling. Latin hypercube sampling utilizes the stratified sampling scheme to improve the coverage of input space.

2. Experimental Results

The ultimate loads are calculated by using ANSYS software which are shown below table i.e. Table: 2.1

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Table 2.1: ANSYS results

Sl No	D mm	T mm	L mm	f_{ck}	f_y	P_u
1	42.4	2.3	310	23.93	310	124.32
2	42.4	2.3	310	28.06	310	127.63
3	42.4	2.3	310	29.01	310	128.01
4	42.4	2.6	310	23.93	310	137.56
5	42.4	2.6	310	28.06	310	141.32
6	42.4	2.6	310	29.01	310	141.97
7	42.4	2.9	310	23.93	310	149.32
8	42.4	2.9	310	28.06	310	152.56
9	42.4	2.9	310	29.01	310	153.13
10	42.4	3.2	310	23.93	310	162.72
11	42.4	3.2	310	28.06	310	165.34
12	42.4	3.2	310	29.01	310	165.19
13	42.4	3.6	310	23.93	310	173.94
14	42.4	3.6	310	28.06	310	178.56
15	42.4	3.6	310	29.01	310	179.32
16	42.4	4	310	23.93	310	183.62
17	42.4	4	310	28.06	310	186.54
18	42.4	4	310	29.01	310	187.12
19	42.4	4.5	310	23.93	310	194.52
20	42.4	4.5	310	28.06	310	198.77
21	42.4	4.5	310	29.01	310	200.04
22	42.4	4.8	310	23.93	310	208.69
23	42.4	4.8	310	28.06	310	212.54
24	42.4	4.8	310	29.01	310	213.62
25	42.4	5	310	23.93	310	215.54
26	42.4	5	310	28.06	310	221.62
27	42.4	5	310	29.01	310	222.34

2.2 Comparison of Ansys Result with Codal Results

S no.	D mm	T mm	ANSYS Pu (kN)	Eurocode 4 Pu(kN)	Bs5400 Pu(kN)	AS 3600-1999 Pu(kN)
1	42.4	2.3	124.32	116.65	107.93	112.63
2	42.4	2.3	127.63	121.29	111.06	116.57
3	42.4	2.3	128.01	122.35	111.78	117.47
4	42.4	2.6	137.56	126.76	118.31	122.86
5	42.4	2.6	141.32	131.25	121.34	126.68
6	42.4	2.6	141.97	132.28	122.04	127.55
7	42.4	2.9	149.32	136.71	128.53	132.93
8	42.4	2.9	152.56	141.05	131.46	136.63
9	42.4	2.9	153.13	142.05	132.14	137.48
10	42.4	3.2	162.72	146.50	138.58	142.84
11	42.4	3.2	165.34	150.70	141.42	146.41
12	42.4	3.2	165.19	151.67	142.07	147.24
13	42.4	3.6	173.94	159.29	151.72	155.80
14	42.4	3.6	178.56	163.31	154.44	159.21
15	42.4	3.6	179.32	164.23	155.06	160.00
16	42.4	4	183.62	171.80	164.57	168.46
17	42.4	4	186.54	175.64	167.16	171.73
18	42.4	4	187.12	176.52	167.76	172.48
19	42.4	4.5	194.52	187.03	180.22	183.88
20	42.4	4.5	198.77	190.65	182.66	186.96
21	42.4	4.5	200.04	191.48	183.22	187.67
22	42.4	4.8	208.69	195.95	189.38	192.92
23	42.4	4.8	212.54	199.44	191.74	195.88
24	42.4	4.8	213.62	200.24	192.28	196.57
25	42.4	5	215.54	201.81	195.40	198.85
26	42.4	5	221.62	205.21	197.70	201.74
27	42.4	5	222.34	206.00	198.23	202.41

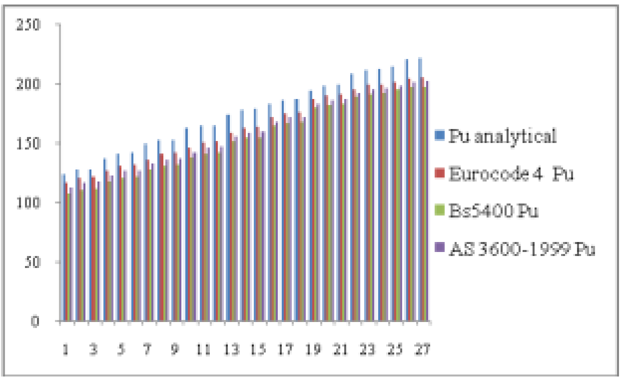

Figure 2.1: Comparison of Ansys Result with Codal Results

The probability of failure and reliability in percentage results are calculated by using 2R rel software which are tabulated in below table i.e. Table 2.2

Limit state function M = R – S
Where R and S are statistically independent

They are assumed to be regularly disseminated
$\mu_m = \mu_R - \mu_S$
$\sigma_M^2 = \sigma_R^2 + \sigma_S^2$
$P_f = P(M < 0) \Rightarrow P[(R - S) < 0]$
Where P_f = probability of failure

If M= Ordinary variant, then
$P_f = 1 - Ø(\mu_m/\sigma M)$ Reliability index $\beta = \mu_m/\sigma M$
Ø = Cumulative distribution function of the standard ordinary variant

Table 2.3: Reliability Results

Sl no	P_u	LHM (β)	P_f	R	R in%
1	124.32	2.4	0.6775	0.322	32.25
2	127.63	2.4	0.665	0.335	33.5
3	128.01	2.3	0.5575	0.442	44.25
4	137.56	1.1	0.7025	0.297	29.75
5	141.32	1.2	0.71	0.29	29.0
6	141.97	1.2	0.687	0.313	31.3
7	149.32	0.8	0.712	0.288	28.8
8	152.56	0.8	0.702	0.298	29.8
9	153.13	0.7	0.717	0.283	28.3
10	162.72	0.9	0.767	0.233	23.3
11	165.34	1.1	0.737	0.263	26.3
12	165.19	1	0.747	0.253	25.3
13	173.94	0.9	0.707	0.293	29.3
14	178.56	1	0.7225	0.277	27.75
15	179.32	1	0.712	0.288	28.8
16	183.62	1	0.685	0.315	31.5
17	186.54	1.1	0.662	0.338	33.8
18	187.12	1.1	0.642	0.358	35.8
19	194.52	1.8	0.622	0.378	37.8
20	198.77	2	0.6225	0.377	37.75
21	200.04	1.9	0.622	0.378	37.8
22	208.69	1.5	0.665	0.335	33.5
23	212.54	1.7	0.66	0.34	34
24	213.62	1.7	0.655	0.345	34.5
25	215.54	1.4	0.6775	0.322	32.25
26	221.62	1.6	0.69	0.31	31.0
27	222.34	1.6	0.692	0.308	30.8

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Following are the results obtained from L9 taguchi's approach

Table 2.4: Taguchi's L 9 Orthogonal array approach

Sl no	Pu	β(LHM)	P_f	Reliability	R%
1	124.32	-0.46	0.6775	0.322	32.2
5	141.32	-0.51	0.71	0.29	29
9	153.13	-0.6	0.717	0.283	28.3
11	165.34	-0.63	0.737	0.263	26.3
15	179.32	-0.6	0.712	0.288	28.8
16	183.62	-0.4	0.685	0.315	31.5
21	200.04	-0.3	0.622	0.378	37.8
22	208.69	-0.4	0.665	0.335	33.5
26	221.62	-0.5	0.69	0.31	31

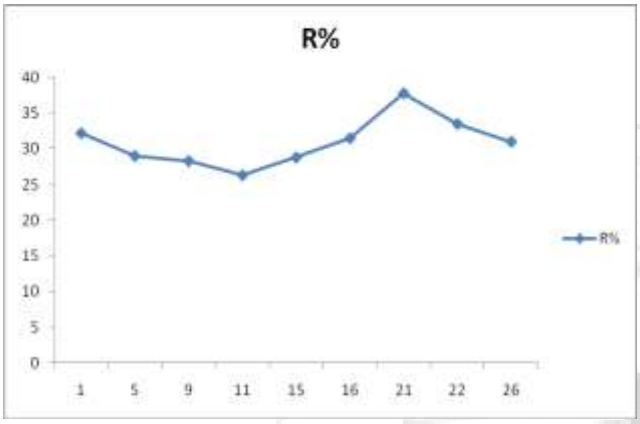

Figure 2.2: Taguchi's method vs Reliability

3. Conclusion

1) The ultimate load Pu obtained from ANSYS result shows that the ultimate load carrying capacity of CFST tubes increases with increase in thickness.
2) The ANSYS results show that the ultimate load carrying capacity of CFST columns increases with decrease in D/t ratio.
3) Ultimate load Pu obtained from ANSYS and various codes like Eurocode, BS 5400 and AC3600-1999 shows that Pu obtained from ANSYS is higher than the Pu obtained from codes.
4) It is observed that as the L/D ratio decreases, ultimate load Pu increases.
5) Maximum reliability of 44.25 % is obtained for model 3 having diameter 42.4mm & thickness 2.3mm

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Author Profile

Prakruthi is graduated in the year 2016 from VTU, Belgaum. Presently perusing Master of Technology in Structural Engineering at Ghousia College of Engineering, Ramanagaram Also working on this topic for the dissertation under the guidance of Khalid Nayaz khan and Dr. N S Kumar.

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