# RELIABILITY ANALYSIS OF CONCRETE FILLED STEEL TUBE COLUMNS BY FOSM AND SUBSET SIMULATION TECHNIQUE

**Naveen Kumar. S[1], Khalid Nayaz Khan[2], N.S.Kumar[3]**

*[1]Final Year Student, Department of Civil Engineering, Ghousia college of Engineering, Karnataka, India*
*[2]Associate Professor, Department of Civil Engineering, Ghousia college of Engineering, Karnataka, India*
*[3]Professor and Director (R&D-Civil Engineering), Department of Civil Engineering, Ghousia college of Engineering, Karnataka, India*

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**Abstract** - *In this study, controlled, deterministic and reliability found optimal design of concrete filled with circular composite columns is entrusted. The main design work is to attain the nominal load taking ability with the less deflection. Analytical Study and Reliability analysis of Steel Tube with concrete filled under monotonic loading is obtained in this study. Analytical results are fetched by the Finite element software NASTRAN are verified using ACI-318-1999 code. Variation may be found to be 20% range accordingly to the above code.*

*The reliability technique is directed under the probabilistic variables such as diameters, thickness, length and grades of concrete with percentage of glass fibers. FOSM method is used for the analysis of the results gained. Subset simulation was adopted for the analysis.*

***KeyWords*: CFST, FOSM, SubsetsimulationTechnique, Reliability.**

## 1. INTRODUCTION

Concrete-filled steel tube (CFST) sections comprise of a steel tube in filled with concrete. The solid in fill enhances compressive properties of the composite section and decreases the potential for local buckling. Conversely, the steel tube acts as longitudinal and horizontal support for the concrete infill helping it to resist shear, tension, bending moment and providing confinement to the concrete.

The steel tube in a concrete filled tubular section (CFST) offers both longitudinal and lateral support and as a result, it is subjected to biaxial stresses whereas, concrete is stressed tri-axially. Concrete filled tubular columns have found their application as a part of structures and scaffolds. Research on CFST is being carried out in China since 1970s. CFST has emerged as a popular structural member because of its highly desirable structural properties, which include high strength, stiffness and high ductility. The advantages of the CFST over other composite members are that the steel tube gives formwork to the concrete; the in-filled concrete restrains local buckling of the steel tube.

Reliability is hypothetically characterized as the probability of achievement as the recurrence of failures or regarding accessibility, as a probability got from reliability, testability and maintainability. Testability, maintainability, and maintenance are regularly characterized as a piece of "reliability engineering" in Reliability Programs. Reliability assumes a key part in the cost-viability of systems.

{1-probability failure} = Reliability

### ➢ First order second moment method

In this method, the arbitrary factors are described by their first and second moments. In assessing the first and second moments of the disappointment work, the first order estimation is utilized. Therefore this method is called as FOSM. The FOSM is gotten from Taylors formula for the extension of a capacity f(x) about a point x.

### ➢ Subset simulation technique

Subset simulation technique is a strategy utilized as a part of reliability models to registering little (i.e., uncommon occasion) disappointment probabilities experienced in designing frameworks.

The Monte Carlo simulation (MCS) can give high-reliability assessment exactness. Be that as it may, the effectiveness of the unrefined MCS is very low, in substantial part since it is computationally costly to assess a little disappointment likelihood. In this paper, subset simulation-based reliability analysis (SSRA) ways to deal with enhance the computational effectiveness in reliability-based Optimization (RBO) issues.

## 2. EXPERIMENTAL RESULTS

**Table -1:** Result

| Sl no | D mm | T mm | L mm | $f_{ck}$ | $f_y$ | P |
|---|---|---|---|---|---|---|
| 1 | 33.7 | 2.6 | 300 | 23.93 | 310 | 118 |
| 2 | 33.7 | 2.6 | 300 | 28.06 | 310 | 121 |
| 3 | 33.7 | 2.6 | 300 | 29.01 | 310 | 122 |
| 4 | 33.7 | 3.2 | 300 | 23.93 | 310 | 132 |
| 5 | 33.7 | 3.2 | 300 | 28.06 | 310 | 136 |
| 6 | 33.7 | 3.2 | 300 | 29.01 | 310 | 136 |
| 7 | 33.7 | 4 | 300 | 23.93 | 310 | 152 |
| 8 | 33.7 | 4 | 300 | 28.06 | 310 | 154 |
| 9 | 33.7 | 4 | 300 | 29.01 | 310 | 154 |
| 10 | 33.7 | 5 | 300 | 23.93 | 310 | 173 |
| 11 | 33.7 | 5 | 300 | 28.06 | 310 | 175 |
| 12 | 33.7 | 5 | 300 | 29.01 | 310 | 175 |
| 13 | 33.7 | 6.2 | 300 | 23.93 | 310 | 176 |
| 14 | 33.7 | 6.2 | 300 | 28.06 | 310 | 198 |
| 15 | 33.7 | 6.2 | 300 | 29.01 | 310 | 198 |
| 16 | 33.7 | 7.6 | 300 | 23.93 | 310 | 220 |
| 17 | 33.7 | 7.6 | 300 | 28.06 | 310 | 221 |
| 18 | 33.7 | 7.6 | 300 | 29.01 | 310 | 223 |
| 19 | 33.7 | 9.4 | 300 | 23.93 | 310 | 246 |
| 20 | 33.7 | 9.4 | 300 | 28.06 | 310 | 248 |
| 21 | 33.7 | 9.4 | 300 | 29.01 | 310 | 250 |
| 22 | 33.7 | 11.4 | 300 | 23.93 | 310 | 269 |
| 23 | 33.7 | 11.4 | 300 | 28.06 | 310 | 270 |
| 24 | 33.7 | 11.4 | 300 | 29.01 | 310 | 271 |
| 25 | 33.7 | 13.6 | 300 | 23.93 | 310 | 285 |
| 26 | 33.7 | 13.6 | 300 | 28.06 | 310 | 285 |
| 27 | 33.7 | 13.6 | 300 | 29.01 | 310 | 288 |

## 3. RELIABILITY ANALYSIS

Limit state function

M = R – S

Where R and S are statistically independent

They are assumed to be regularly disseminated

$\mu_m = \mu_{R} - \mu_S$

$\sigma_M^2 = \sigma_R^2 + \sigma_S^2$

$P_f = P\,(M < 0)$

$\quad = P\,[(R - S) < 0]$

Where $P_f$ = probability of failure

If M= Ordinary variant, then

$P_f = 1 - \emptyset(\mu_m/\sigma M)$

Reliability index $\beta = \mu_m / \sigma M$

Ø = Cumulative distribution function of the standard ordinary variant.

### 3.1 Sample study

The reliability analysis of a CFST column member having D*t=33.7mm*2.6mm and length of 300mm has been examined. The material properties are as follows in the in the employing of the reliability analysis. Compressive strength of the unconfined concrete ($f_{ck}$) is 28.06N/mm$^2$, elastic modulus of steel (E) is 2000Gpa and yield strength of steel ($f_y$) 310N/mm$^2$.

Solving the above parameters by Subset simulation technique using the COMREL 9 method the reliability index (β) is -1.522.Their respective probability of failure is found to be $P_f$=-0.06426,as we know that reliability for any structural member subjected to the axial load is R=1-$P_f$ =93.574%.

**Table -2:** Reliability Analysis

| Sl no | $P_u$ | SST(β) | $P_f$ | R | R in% |
|---|---|---|---|---|---|
| 1 | 118 | -1.405 | 0.0871 | 0.9129 | 91.29 |
| 2 | 121 | -1.522 | 0.0643 | 0.9357 | 93.57 |
| 3 | 122 | -1.522 | 0.0643 | 0.9357 | 93.57 |
| 4 | 132 | -1.504 | 0.1492 | 0.8508 | 85.08 |
| 5 | 136 | -1.136 | 0.1292 | 0.8707 | 87.07 |
| 6 | 136 | -1.136 | 0.1292 | 0.8707 | 87.07 |
| 7 | 152 | -0.900 | 0.1706 | 0.8294 | 82.94 |
| 8 | 154 | -0.915 | 0.1685 | 0.8314 | 83.14 |
| 9 | 154 | -0.915 | 0.1685 | 0.8314 | 83.14 |
| 10 | 173 | -0.619 | 0.2743 | 0.7257 | 72.57 |
| 11 | 175 | -0.643 | 0.2611 | 0.7389 | 73.89 |
| 12 | 175 | -0.650 | 0.2547 | 0.7452 | 74.52 |
| 13 | 176 | -0.559 | 0.2915 | 0.7085 | 70.85 |
| 14 | 198 | -0.577 | 0.2843 | 0.7156 | 71.56 |
| 15 | 198 | -0.577 | 0.2843 | 0.7156 | 71.56 |
| 16 | 220 | -0.429 | 0.3372 | 0.6627 | 66.27 |
| 17 | 221 | -0.451 | 03264 | 0.6736 | 67.36 |
| 18 | 223 | -0.473 | 0.3192 | 0.6808 | 68.08 |
| 19 | 246 | -0.300 | 0.3821 | 0.6197 | 61.97 |

| | | | | | |
|---|---|---|---|---|---|
| 20 | 248 | -0.348 | 0.3669 | 0.6330 | 63.30 |
| 21 | 250 | -0.369 | 0.3590 | 0.6409 | 64.09 |
| 22 | 269 | -0.248 | 0.0871 | 0.5948 | 59.48 |
| 23 | 270 | -0.269 | 0.0643 | 0.6025 | 60.25 |
| 24 | 271 | -0.279 | 0.0643 | 0.6125 | 61.25 |
| 25 | 285 | -0.197 | 0.1492 | 0.5753 | 57.53 |
| 26 | 285 | -0.212 | 0.1292 | 0.5831 | 58.31 |
| 27 | 288 | -1.019 | 0.1292 | 0.5753 | 57.53 |

## 4. RESULTS

Following are the results obtained from the L9 taguchi's approach with the varying diameters, constant length and grade of concrete and steel is as per the taguchi's level-3 approach (TABLE-4) with the 3-factors.

**Table: 4** Taguchi's L 9 Orthogonal array approach

| Sl no | Pu | β(subset simulation) | $P_f$ | Reliability | R% |
|---|---|---|---|---|---|
| 1 | 118 | -1.405 | 0.087 | 0.912 | 91.2 |
| 5 | 136 | -1.136 | 0.129 | 0.870 | 87 |
| 9 | 154 | -1.136 | 0.129 | 0.870 | 87 |
| 11 | 152 | -1.019 | 0.137 | 0.866 | 86.6 |
| 15 | 177 | -1.003 | 0.158 | 0.741 | 74.1 |
| 16 | 190 | -0.565 | 0.187 | 0.712 | 71.2 |
| 21 | 250 | -0.369 | 0.360 | 0.640 | 64 |
| 22 | 269 | -0.248 | 0.406 | 0.594 | 59.4 |
| 26 | 285 | -0.212 | 0.417 | 0.583 | 58.3 |

**Table: 5** strength/weight ratio obtained from Taguchi's method

| Sl no | D mm | T mm | Pu | Weight | Strength /weight |
|---|---|---|---|---|---|
| 1 | 33.7 | 2.6 | 118 | 6.8 | 17.49 |
| 5 | 33.7 | 2.6 | 136 | 6.8 | 20.02 |
| 9 | 33.7 | 2.6 | 154 | 6.8 | 22.73 |
| 11 | 42.4 | 3.2 | 152 | 13.8 | 11.07 |
| 15 | 42.4 | 3.2 | 177 | 13.8 | 12.84 |
| 16 | 42.4 | 3.2 | 190 | 13.8 | 13.79 |
| 21 | 48.3 | 4 | 250 | 22.25 | 7.93 |
| 22 | 48.3 | 4 | 269 | 22.25 | 8.65 |
| 26 | 48.3 | 4 | 285 | 22.25 | 10.11 |

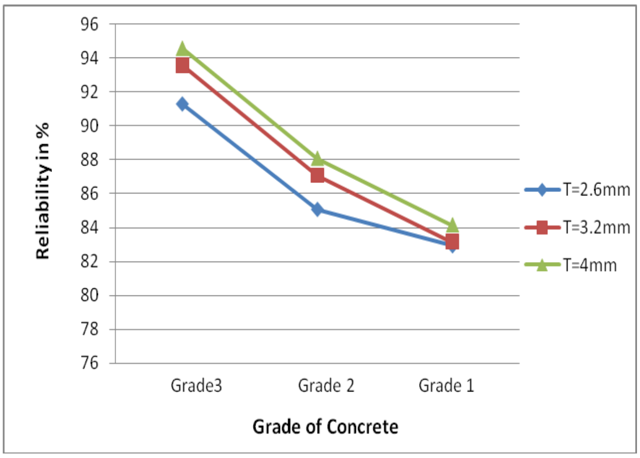


**Fig: 1 Grade of concrete vs Reliability (Dia-33.7mm)**

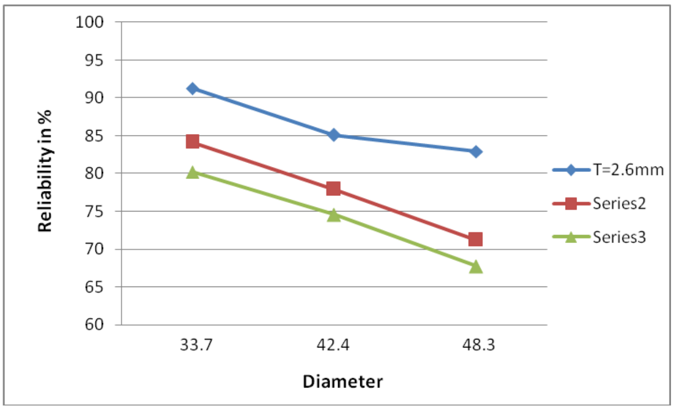


**Fig: 2 Diameter vs Reliability**

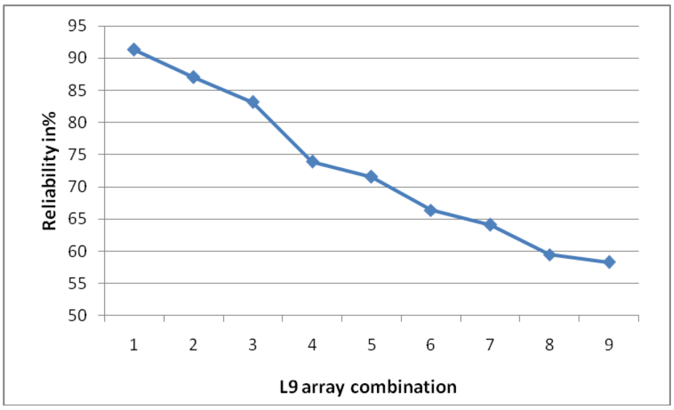


**Fig: 3 Taguchi's method vs Reliability**

## 5. CONCLUSIONS

- The Reliability of member increases with increases in diameter (Fig:2).
- Because of the load carrying ability mainly depends upon the strength of the concrete as the grade of concrete increases the reliability also increases (Fig:1).

- It can be observed from the Fig:3, the maximum reliability obtained is 93.57% for the T1,G2 and D2 Taguchi's L9 array combination.

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