

Analytical Investigation for Buckling Capacity of Composite Steel Tubes under Compression – Taguchi’s Approach using Minitab-16

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ABSTRACT: Due to the severe impact of seismic activity in the late 20th century, the adversity from damage or failure of buildings is inescapable. Moreover, the trend now in construction industry is to utilize the Composite Steel Tubes concept as prime for lateral load resisting frames. The concrete used for enfolded the structural steel segment not only enhances its strength & stiffness, but also it prevents the steel from buckling. Experimental Investigation on Composite Circular Steel Tubes infilled with concrete is tested for ultimate load carrying capacity & % of failure. The experiments were carried out for different Diameter, Thickness & L/D ratio implemented by Taguchi’s L9 orthogonal array approach. Results were obtained for different combinations by performing the experiments. The obtained results were analyzed for Signal/Noise ratio, Main effects & Analysis of Variance (ANOVA) using Minitab-16. The equations of regression were developed.

KEYWORDS: Taguchi’s Approach, Minitab, ANOVA, Regression, Composite Steel Tubes.

I. INTRODUCTION

Columns play a vital role in the structural system. Failure of a column leads to the failure of the entire structure. Strength & ductility of the columns need to be safeguarded through ample strengthening, repair & rehabilitation techniques to uphold adequate structural presentation. Based on the experimental methodologies on a figure of erection methods for the columns in high rise buildings, it is initiated that the concrete filled steel tubes is a very constructible and reasonably priced elucidation for multi storey building. A key issue is the capability to reduce the charges and the onsite interval of construction. From the interpretation point of the structural physiognomies, the most vital reason for the budget of this caring of column, is the confinement of concrete by the tube, which further pep talk the ability of the concrete. This is not probable with any other composite column arrangement. On the other hand, a generous section of the axial load is taken on the high power concrete, which is the most inexpensive way to counterattack the compressive force. In count, the constructability of the unreinforced filled tube is its prime lead. The absenteeism of reinforcement has far reaching aids in the dipping carnage, treatment, and site labour, as well as critically makes simpler fabrication and gathering of the columns. Moreover, the solidity of the steel tube will be upgraded against the indigenous do up. In order to reveal the performance of composite steel tubes, 81 specimens will be designed for axial compression loading experiment. The type of concrete infilled is conventional.

Based on these factors failure pattern and slenderness ratio to axial compression load capacity are analysed.

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II. RELATED WORK

In this research, Circular steel tubes with three different Diameters (33.7mm, 42.4mm, 48.3mm) each with different Thickness (3.2mm, 3.6mm, 4mm) & different L/D ratio (4, 8, 12) are selected for testing. Suitable factors and levels are considered as per Taguchi’s Method of Design of experiments.

Steel tubes were cut to different lengths as per Taguchi’s L9 orthogonal array combination considering respective L/D ratio are tested for ultimate axial load under monotonic loading as per Taguchi’s level – 3 design with 3 factors as shown in Table no: 1. Tubes are placed upright for compression loading with proper end conditions after curing the infilled tubes for 28 days.

Table 1: Taguchi’s L9 design with 3-levels and 3-factors

A	B	C
1	1	1
1	2	2
1	3	3
2	1	2
2	2	3
2	3	1
3	1	3
3	2	1
3	3	2

III. PREPARATION OF SPECIMEN

In order to save time & material cost involved in experimentation, lesser number of experiment are desired. Therefore Taguchi’s method is adopted. Proper factors and levels are considered for each type of infill as per Taguchi’s Method of design of experiments. Steel tubes are of different lengths, diameters, and thickness as per Taguchi’s L9 combination considering L/D ratio were tested for ultimate axial load and axial shortening under monotonic loading circumstances as shown below in Table no 2.

Table 2: Levels & factors used in Taguchi’s design

Thickness	Diameter	L/D ratio
3.2	33.7	4
3.2	42.4	8
3.2	48.3	12
3.6	33.7	8
3.6	42.4	12
3.6	48.3	4
4	33.7	12
4	42.4	4
4	48.3	8

Table 3: Material properties

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Density kg/m ³		Poisson's ratio		Elastic Modulus N/mm ²		Yield/Compressive strength N/mm ²	
Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete
7850	2400	0.3	0.2	2 x 10 ⁵	27386	310	30

IV. ANALYSIS OF EXPERIMENTAL RESULTS*

4.1 Design of experiment using Taguchi's approach

In effect to save the time & material cost involved in experimentation, lesser number of experiments are desired. Therefore Taguchi's method is adopted. Experiments are carried out according to combination levels indicated by L9 orthogonal array for three Diameters, Thickness & L/D ratios. An orthogonal array helps in determining the number of trials that are necessary and factor levels for each parameter. A general L9 orthogonal array consists of combination of experiments with three factors at three levels as shown in Table no: 4 below.

Table 4: Results from experiment

Thickness	Diameter	L/D ratio	Pu KN	% of failure
3.2	33.7	4	136.23	17.1
3.2	42.4	8	168.25	45.2
3.2	48.3	12	189.24	38.6
3.6	33.7	8	129.30	27.4
3.6	42.4	12	176.06	45.2
3.6	48.3	4	234.37	17.1
4	33.7	12	144.66	1.8
4	42.4	4	229.19	45.2
4	48.3	8	235.87	38.6

* Results were obtained from experimentation performed by Syed Aqeeb Javeed Pasha under the guidance of Dr N.S Kumar at R&D laboratory, GCE, Ramanagaram

4.2 Main effect plots

After performing the experiment as per Taguchi's experiment design, main effect plots for Ultimate load & % of Failure were plotted. A main effect is a direct effect of parameters on response and dependent variables. Typical main effect plots of parameters with respect to Ultimate load & % of failure are shown in below figures 1 & 2. The plots are obtained by considering mean of response at each level of parameters as shown below. Maximum Ultimate load was obtained for Diameter 48.3mm, Thickness 4mm & L/D ratio 4 and min % of Failure was obtained for Diameter 42.4mm, Thickness 3.2mm & L/D ratio 8.

From Minitab, it can be concluded that **Diameter** is the main parameter for Maximum Ultimate load as it has ranked 1 out of 3 parameters considered for experimentation. A typical response from Minitab is shown below.

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Response Table for Means

Level	Thickness	Diameter	L/D ratio
1	164.6	136.7	199.9
2	179.9	191.2	177.8
3	203.2	219.8	170.0
Delta	38.7	83.1	30.0
Rank	2	1	3

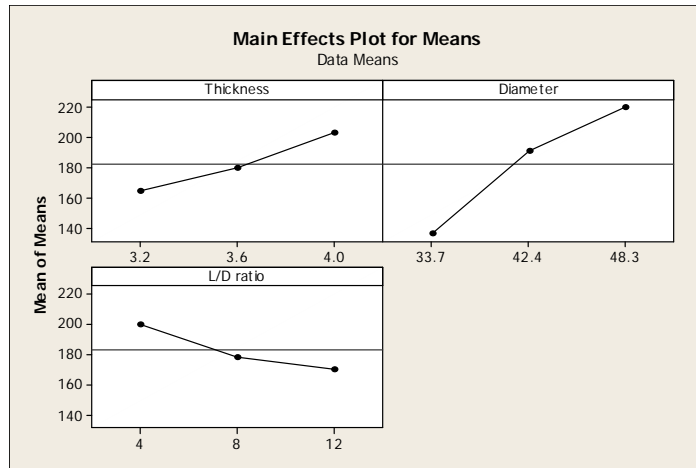


Figure 1: Main effect plots for means for Pu

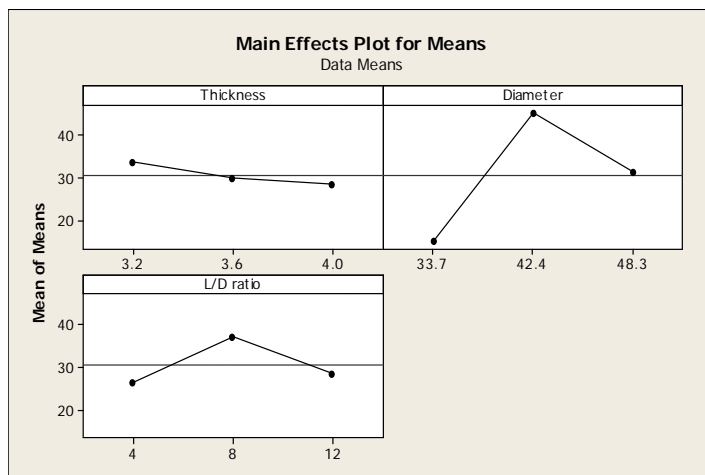


Figure 2: Main effect plots for means for % of failure

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4.3 Signal to Noise ratio

S/N ratio is used as measurable value instead of standard deviation due to the fact that as the mean decreases, the standard deviation also decreases and vice versa. In other words, the standard deviation cannot be minimized first and the mean brought to the target. In practise, the target mean value may change during the process development. Two of the applications in which the concept of S/S ratio is useful are the improvement of quality through variability ant the improvement of measurement. The S /N ratios characteristics can be divided into three categories.

- Nominal is best Characteristic
- Smaller is best Characteristic
- Larger is best Characteristic

Larger is best is adopted for Ultimate Axial load & smaller is best is adopted for % of failure for the Taguchi's analysis as shown in figures 3 & 4 below. From the Response table of S/N ratio, it can be clearly seen that Diameter is the main parameter ranked 1 among 3 of the parameters.

Response Table for Signal to Noise Ratios
Larger is better

Level	Thickness	Diameter	L/D ratio
1	44.25	42.71	45.76
2	44.85	45.55	44.73
3	45.95	46.80	44.55
Delta	1.71	4.09	1.21
Rank	2	1	3

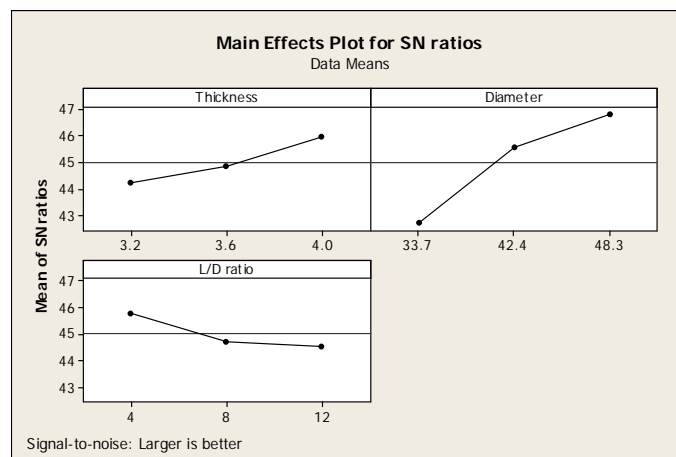


Figure 3: Main effect plots for S/N ratios for Pu

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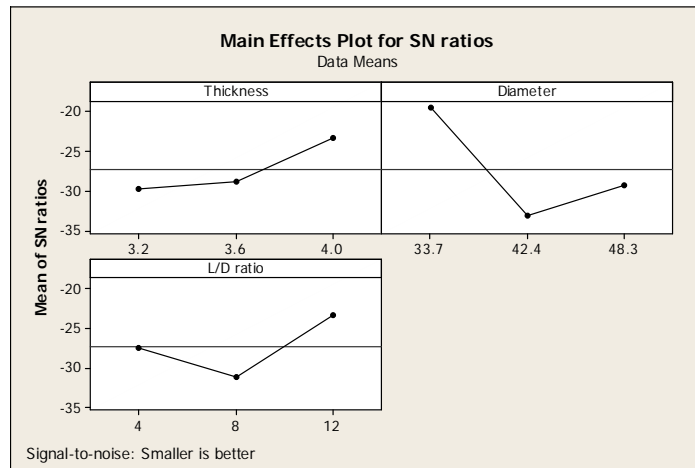


Figure 4: Main effect plots for S/N ratios for % of failure

V. ANALYSIS OF VARIANCE (ANOVA)

ANOVA is a statistical tool which helps to minimize the errors of variance and quantifies the dominance of control factor. This analysis aids in justifying the effects of input changes on the responses in experiment.

5.1 Regression Analysis

After conducting the initial nine experiments (each in triplicate trial), linear regression model were developed for all Diameters, Thickness & L/D ratio to predict the ultimate axial load and % of failure for all circular composite steel tubes. The REGRESSION equation is developed. The equation can be used to predict the ultimate axial load carrying capacity of the remaining samples used in the experimental program. To verify the accuracy of such prediction of load carrying capacity of samples the remaining experiments are conducted and a comparison of experimental values is made with the predicted values. It is observed that regression model based on initial nine experiments were reasonably well. The residual plots for regression were obtained from Minitab as shown in Figures 5 & 6.

The regression equations are

$$Pu\ KN = - 196 + 48.0\ Thickness + 5.70\ Diameter - 3.72\ L/D\ ratio$$

$$\% \text{ of failure} = - 1.1 - 6.4\ Thickness + 1.27\ Diameter + 0.26\ L/D\ ratio$$

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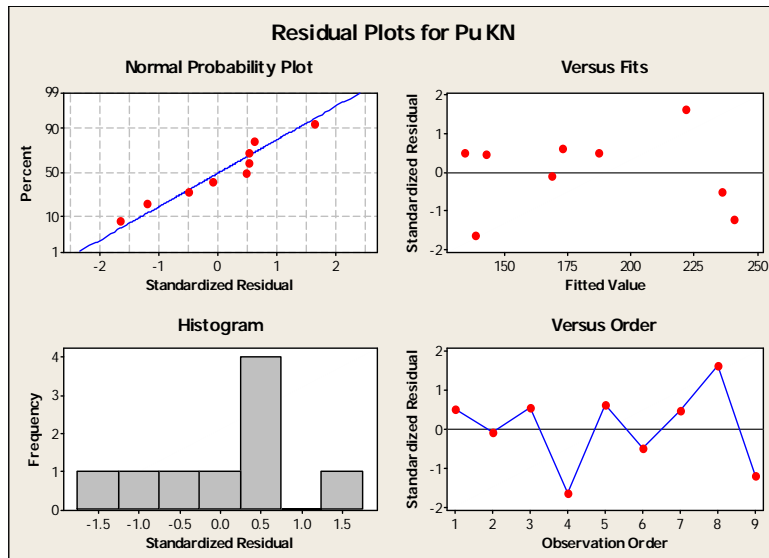


Figure 5: Residual plots for Pu

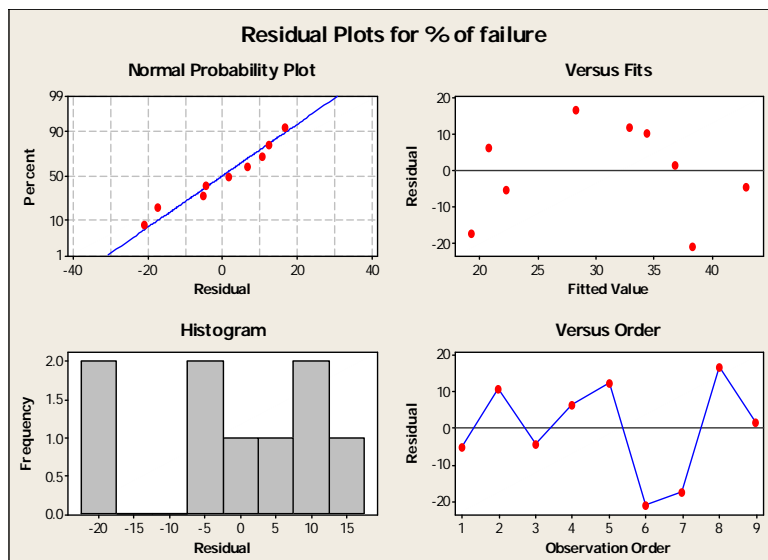


Figure 6: Residual plots for % of failure

A time series plot is a graph that you can use to evaluate patterns and behavior in data over time. A time series plot displays observations on the y-axis against equally spaced time intervals on the x-axis. Time series plots are often used to examine daily, weekly, seasonal or annual variations, or before-and-after effects of a process change. Time series plots are especially useful for comparing data patterns of different groups. A plot of experimental values is plotted for all three levels of steel tube. The time series plot is shown in the Figure 7 below as obtained from Minitab – 16.

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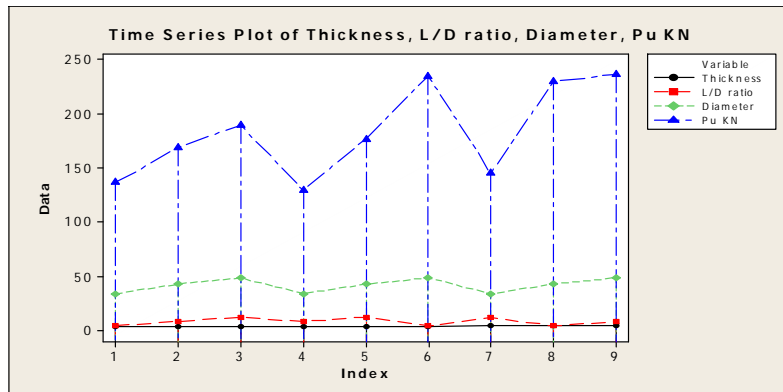


Figure 7: Time series plot for experimental values

5.3 Comparison of Predicted values with Experimental Values

To verify the results obtained from REGRESSION a set of data is taken for experiment and performed the experiment. Later it is compared with the results obtained from REGRESSION equation. It can be said that the equation can be used to predict the results were reasonably well. It is as indicated in the Table no: 5 below.

Table 5: Comparison of predicted results with experimental results

Thickness	Diameter	L/D ratio	Pu Exp	Pu Regression	Error
3.2	48.3	4	269.1	218.03	18.97
3.2	60.3	8	346.78	271.55	21.69

5.4 Interaction plot

Contour plots are plotted for Ultimate axial load & % of failure of all three levels of steel tubes which are plotted for thickness, diameter & L/D ratio using Minitab – 16. The plots explain that for different diameter range of 35 – 47.5 mm is varying with different combination in range which can be referred by the contour plot given in Figure 8.

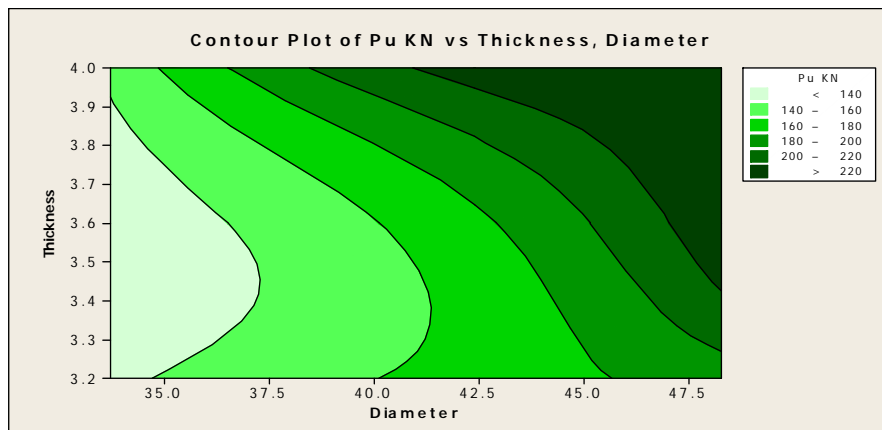


Figure 8: Contour plot for experimental values

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VI. CONCLUSION

- The important parameters affecting the load-deformation behaviour are member size, thickness of steel tube, slenderness ratio (L/D) ratio, D/t ratio, etc.
- As grade of concrete increased, load carrying capacity increases by 5-10%
- From regression analysis, the Ultimate load carrying capacity can be well predicted
- From Taguchi's analysis, for maximum axial load carrying capacity using the response of means and response of S./N ratios, the predominate factor for Ultimate load carrying capacity is **Diameter** of the composite steel tube
- Maximum load carrying capacity can be obtained for Thickness 4mm, Diameter 48.3mm & L/D ratio 4
- Minimum % of failure can be obtained for Thickness 3.2mm, Diameter 42.4mm & L/D ratio 8
- Huge amount of money can be saved for experimental works-about 80%

VII. ACKNOWLEDGEMENT

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