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STUDY ON BOND STRENGTH IN COMPOSITE COLUMNS

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Abstract: The Bond strength of the composite columns with lightweight concrete is presented . The effect of the Diameter, L/D ratio, thickness of the steel tube and variation of cinders in light weight concrete is examined here. Taguchi's approach with an L9 orthogonal array is used to reduce the number of experiments. Measured bond strength are compared with the linear regression model. Based on the experimental results, and interaction model was developed. The experimental results are analyzed using Analysis Of Variance to investigate the most influencing factor on bond strength of the CFST Column.

***Index Terms* – Bond Strength, DoE, Liner Regression, Composite Columns.**

I. INTRODUCTION

Composite Columns are widely used in the construction industry due to outstanding composite action of the columns under static and dynamic loading conditions. The construction time can be reduced due to the steel tube act as formwork and it can sustain the load before the setting time of the concrete. These tubes resist the load acting on it, acts as longitudinal and transverse reinforcement. The compressive nature of the concrete and ductility nature of the steel effectively complements each other. The concrete in-filled in the composite column reduces that the local buckling of the steel tube, similarly the outer perimeter of the steel tube reduces the confinement of the concrete. With the demand in the industry, from several years the researchers has carried out studies on the axial load and different loading conditions on the columns. The bond strength in the composite columns plays a predominant role in the construction. The researchers also significantly carried in this arena. From the previous research it can be observed the studies are mainly concentrated on the mild steel and specific type of concrete. In this study the galvanized steel tubes are considered and light weight concrete with cinders are used as infill material. The Design of Experiments (DoE) with Taguchi's approach is considered for deciding the experimental parameters. The adoption of DoE leads to the reduction in the number of experiments and higher number of parameters can be considered for the analysis.

II. Experimental Program

2.1 Concrete

In the present study M40 grades of concrete are prepared according to IS 10262-1978 [1]. Locally available OPC cement, crushed jelly, cinders and M Sand are used in the preparation. The three different percentages of cinder variation are adopted such as 0%, 20% and 40%. The test results are tabulated in Table.1

Table: 1 The properties of the concrete

M40 Grade of Concrete				
Cinder %	Slump in mm	Compaction factor	Vee-Bee Degree, secs	Average Cube Compression Strength, MPa in N/mm^2
0	30	0.95	11	46.4
20	36	0.90	13	43.2
40	48	0.8	15	41.5

2.2 Steel

Galvanized steel tubes of yield strength 31 MPa and with different L/D ratios are used in the current study. These tubes are welded and edges are smooth finished. The 10 mm of air gaps are provided at the bottom of the tube to perform push out test to evaluate the bond strength. The tubes are brushed to remove the excess debris and cleaned.

2.3 Preparation of Specimen

The bottom of the steel tubes was filled with thermocol to provide the air gap for the movement of concrete during pushout test. Steel tubes are kept in an upright position in the stand specially prepared for the casting of the specimen. Concrete prepared were filled in the steel tube in equal layers and compacted with 25 blows in each layer. After 24 hours of casting the specimen kept for curing.

2.4 Taguchi's Approach

A smaller number of tests is desired to decrease time and material costs associated with experimentation. As a result, the Taguchi technique was established as a valuable engineering methodology for determining the optimal combination of structural characteristics and doing the analysis with the fewest possible experiments. Nine trials are carried out according to the combination levels predicted by a L9 orthogonal array . An orthogonal array aids in the determination of the minimal number of trials required, as well as the factor values for each parameter in each trial. A standard L9 (Table 2) orthogonal array has three factor levels, each of which has three levels. Three replicates of each sample were evaluated.

Table 2 : L9 Array

Run	Columns			
	1	2	3	4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table 3: Different parameters considered in the experimentation

1.	L/D ratio (L)	Three different L/D ratio	L1 L2 L3	12 14 16
2.	Diameter (D)	Three different Dia of steel tubes	D1 D2 D3	32.7mm 42.4mm 48.3mm
3.	Thickness (T)	Three different thickness	T1 T2 T3	2.6mm 3.2mm 4.0mm
4.	% replacement	Three % replacements		0% 20% 40%
5.	Grade of Concrete	One nominal mix	M40	40 N/mm2

Therefore nine experiments are initially conducted according to a combination level and the corresponding experimental results are shown in Table 4.

Table:4 Experimental Results

Sl No	D	T	L/D	%age of cinder	Pt	Cu
1	32.7	2.6	12	0	85	2.11
2	32.7	3.2	14	20	130	2.42
3	32.7	4	16	40	121	2.25
4	42.4	2.6	14	40	123	1.82
5	42.4	3.2	16	0	176	2.23
6	42.4	4	12	20	214	2.37
7	48.3	2.6	16	20	172	1.96
8	48.3	3.2	12	40	209	2.04
9	48.3	4	14	0	272	2.32

II. Results and Discussion

The main effect graphs for bond strength are plotted after performing experiments using the L9-orthogonal array. The direct effect of parameters on the response or dependent variable is known as a main effect. Fig 1 shows the main effect plots of parameters with respect to bond strength. The direct effect of parameters on the response or dependent variable is known as a main effect, as shown in table 5. The Analysis Of Variance (ANOVA) approach is also used to analyse the experimental outcomes. From the fig 1 it can be concluded that increase in diameter results in decrease in bond strength. Also, increase in thickness the bond strength increases. It is evident that the L/D ration 14 and 20% cinder will provide the higher bond strength.

Table: 5 Response Table for Means

Level	Diameter	Thickness	L/D	Cinder in %
1	2.26	1.963	2.173	2.22
2	2.14	2.23	2.187	2.25
3	2.107	2.313	2.147	2.037
Delta	0.153	0.35	0.04	0.213
Rank	3	1	4	2

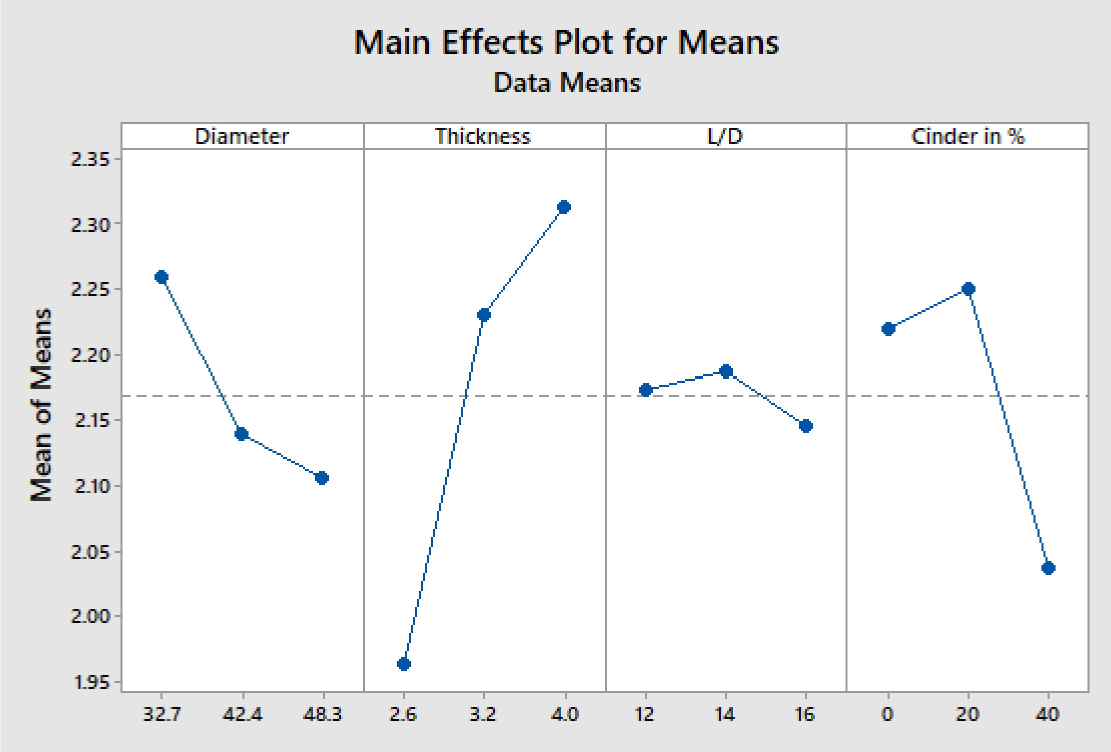

Fig: 1 Main effect Plot

IV Linear regression model to predict the Bond Strength

Plots of predicted values against experimental results are shown in Fig. 2, where again it can be seen that predictions are satisfactory.

$$Cu = 1.978 - 0.01008 \text{ Diameter} + 0.2421 \text{ Thickness} - 0.0067 \text{ L/D} - 0.00458 \text{ Cinder in \%}$$

Table: 6 Analysis of Variance Response

Source	DF	Adj SS	Adj MS	F-Value
Regression	4	0.031175	0.007794	4.58
Diameter	1	0.004426	0.004426	2.6
Thickness	1	0.020502	0.020502	12.05
L/D	1	0.000122	0.000122	0.07
Cinder in %	1	0.006125	0.006125	3.6
Error	4	0.006807	0.001702	

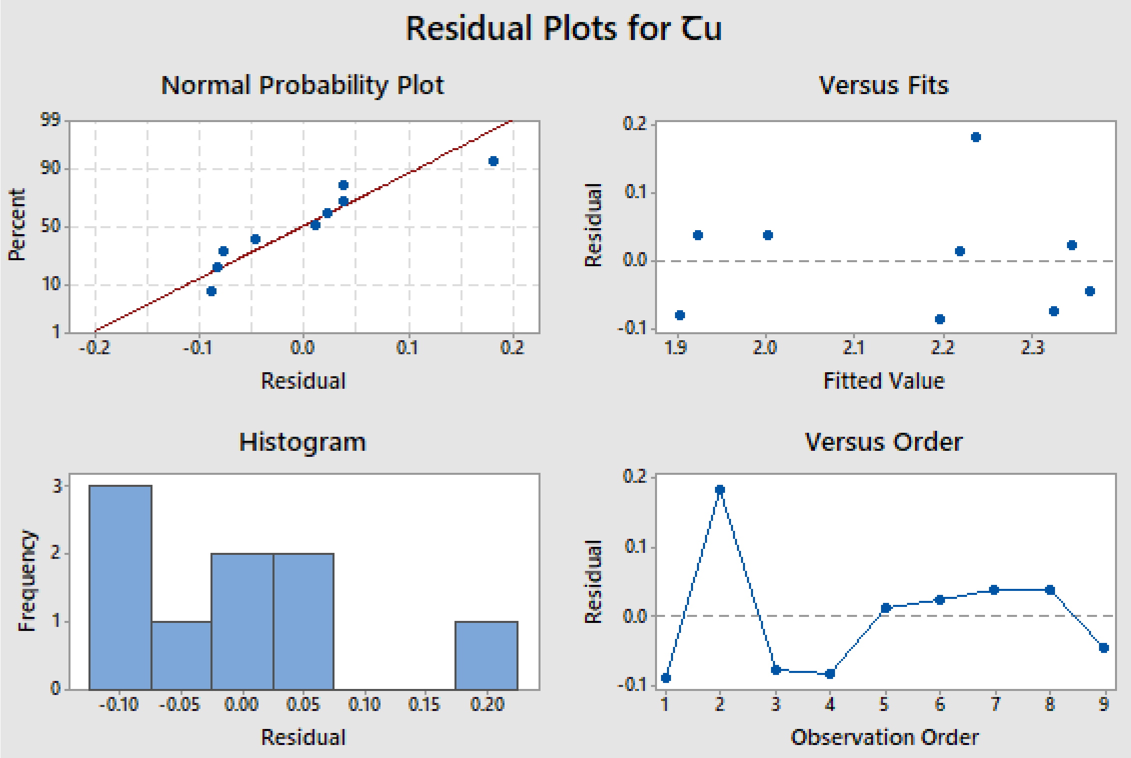

Fig: 2 Residual Plots

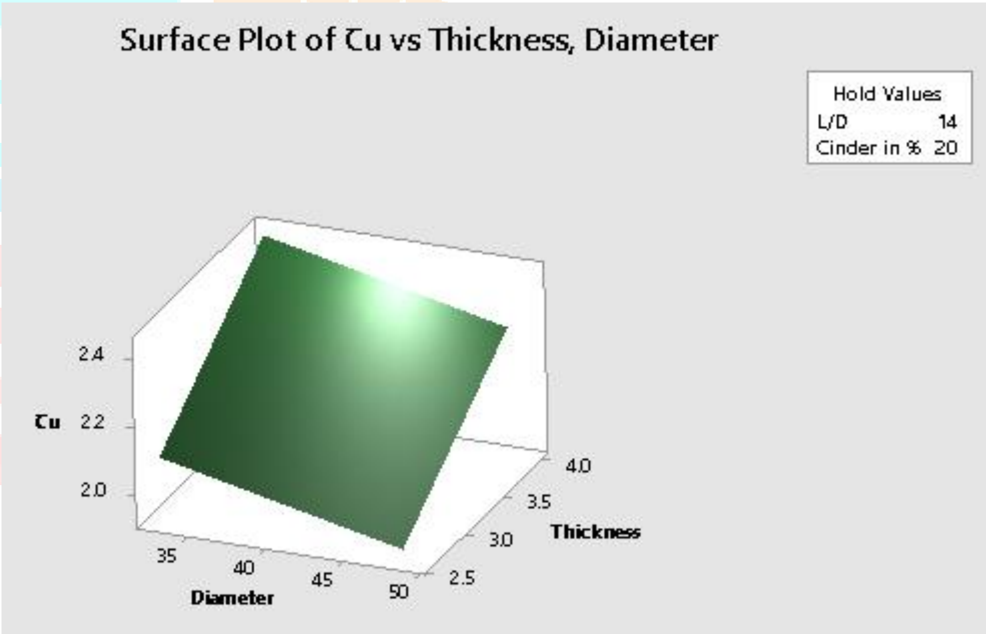

Fig: 3 Surface Plot of Cu

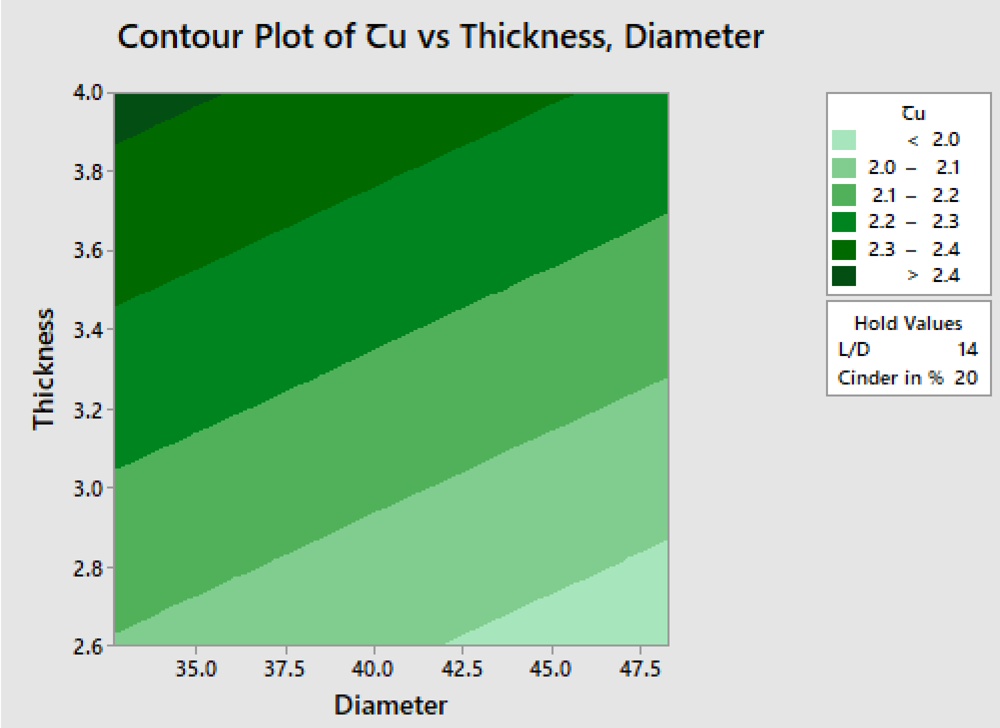

Fig: 4 Contour Plot of Ƭu

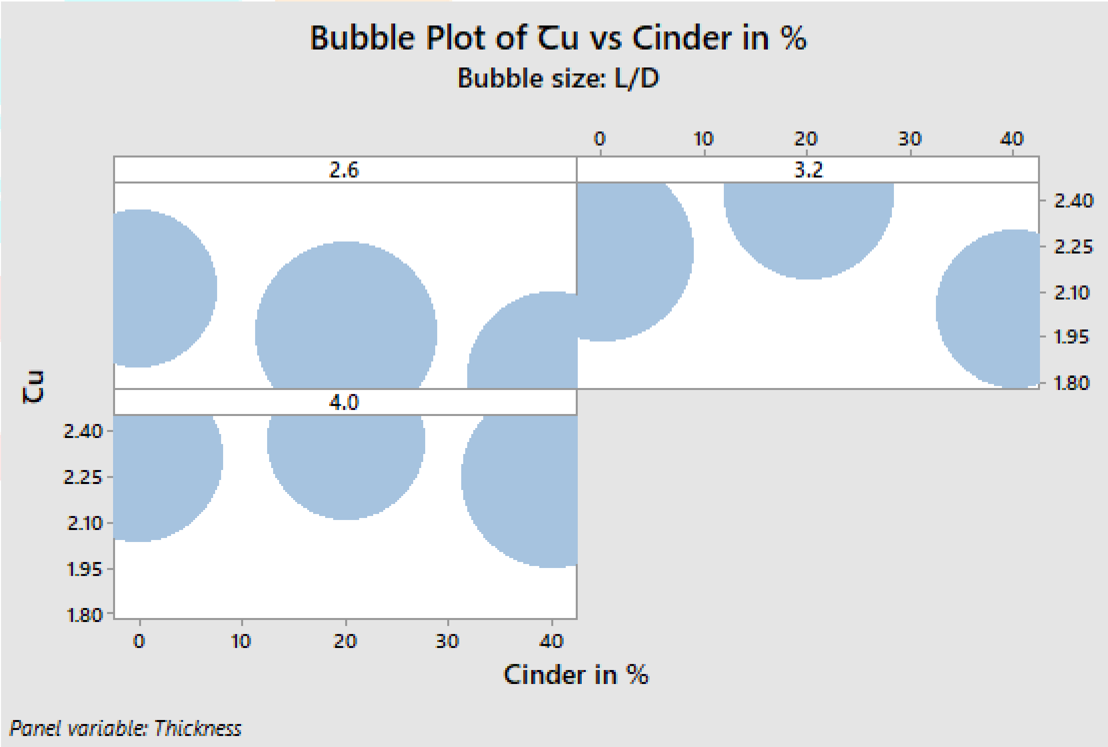

Fig: 5 Bubble plot of Ƭu

Table 6: C̄u Predicted using Liner Regression Model

Sl No	D	T	L/D	%age of cinder	C̄u	C̄u Predicted
1	32.7	2.6	12	0	2.11	2.197444
2	32.7	3.2	14	20	2.42	2.237704
3	32.7	4	16	40	2.25	2.326384
4	42.4	2.6	14	40	1.82	1.903068
5	42.4	3.2	16	0	2.23	2.218128
6	42.4	4	12	20	2.37	2.347008
7	48.3	2.6	16	20	1.96	1.921796
8	48.3	3.2	12	40	2.04	2.002256
9	48.3	4	14	0	2.32	2.365736

V. CONCLUSIONS

1. The push out test conducted on CFST columns showed that bond strength is dependent on the type of concrete as infill material, i.e., conventional concrete containing 0% CIN beads or Light weight Concrete containing 10% or 20% CIN.
2. The results showed that as CIN % increases in concrete in CFST, there is slight decrease in the bond strength compared to CFST columns containing conventional concrete (0% CIN).
3. As Slenderness ratio (L/D ratio) increases, then there is increase in bond strength.
4. As diameter of CFST columns increases, then there is decrease in bond strength.
5. Regression models constructed utilising Taguchi's DOE technique and based on the outcomes of a small number of tests can be used.

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