Experimental Study on Hybrid Double Skinned Steel Tubular Columns (SCC in Filled) Subjected to Monotonic Loading

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Abstract

Experimental investigation was carried out on Hybrid double skinned steel tubular columns consisting of an outer and an inner tube made of steel, with space in between filled with the different grades of self-compacting concrete as infill. Analysis was done for the ultimate load carrying capacity of tube subjected to monotonic loading, including the failure pattern up to the ultimate load. In order to save the time and cost of experiment, Taguchi's approach was adopted. Results were generated using Taguchi's method-a new technique to get mean effects plot. Analysis was carried out using ANOVA (Analysis of Variance) technique with the assistance of Mini Tab v15- a statistical soft tool. Results were verified after conducting preliminary nine combination experiments as per L9 orthogonal array and linear regression models were developed. Comparison for predicted and experimental output is obtained from linear regression plots are presented in this paper.

Keywords- *Hybrid double skinned steel tubular columns, Self-compacting concrete, Taguchi's approach, Mini Tab v15, linear regression plots.*

I. INTRODUCTION

Hybrid double skinned composite steel columns have their own distinct advantage related to structural system which enhances aesthesis of column, also enhances strength and stiffness since because surface area of steel sheet and moment of inertia of tube increases. The steel lies at the outer perimeter where it performs good and effectively against buckling and tension. The concrete has a core material which enhances resistance against fire and good resistance in axial compressions. Some of the countries have their own codal provisions and design procedure. Most of researcher's considered the geometric properties like length / diameter (L/D) ratio, thickness / diameter (t/d) ratio with some of boundary condition's and type of loadings. Generally it has been found that Hybrid double skinned composite steel columns fails due to local bucking or yielding failure. It has Found that Europeans codal provisions (Euro code) design method gives more reliable results nearer to experimental values here in this project we are using Minitab ANOVA which helps to reduce the error.

A. About Self Compacting Concrete

In this project we are using self-compacting concrete infill of grade M30,M40 & M50 in Hybrid double skinned composite steel columns since to overcome problems while using conventional concrete such as:-

- Improper filling in small gaps.
- Reduce high shrinkage.
- Reduce bleeding and segregation.
- To obtain good finishing.

Self-Compacting concrete mix design and methods of evaluating the properties of SCC, followed Guidelines (EFNARC)-European Federation of Specialist Construction Chemicals and Concrete Systems.

B. Super Plasticizer

The super plasticizer used in concrete mix makes it highly workable for more time with much lesser water quantity. It is observed that with the use of large quantities of finer material the concrete becomes stiff and requires more water for required workability. Hence, in the present investigation BASF GLENIUM-B233 is used as water reducing admixture, Conforming to the requirement of IS 9103-1999.The dosage of Super Plasticizer used 1%, 1.5% and 2% of total weight of cementitious materials.

II RESEARCH ELABORATIONS

The following are the steps associated with Taguchi method. First step involves identification of the size of the tubes like length, diameter, thickness of the tube and grade of the concrete as infill. This is followed by determination of the number of levels for the Taguchi approach. The next step engages selection of the appropriate orthogonal array as shown in the (Table 1).Further one needs to conduct the experiments according to selected levels and parameters As shown in the (Table 2).After preparing the specimens according to orthogonal array, This must then be subjected to normalize the experiment results of axial loads.

The minimum number of experiments to be conducted is to be fixed based on the formula below.

N Taguchi = 1+ NV (L – 1)

N Taguchi = Number of experiments to be conducted
NV = Number of parameters
L = Number of levels
In this work
NV = 3 and L = 3, Hence
N Taguchi = 1+ 4 (3-1) = 9

TABLE I - Levels Of Process Parameters Used Taguchi L9 Orthogonal Array

No	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table II - Factors And Levels For Selected Steel Tubes

FACTORS	LEVELS		
	LEVEL-1	LEVEL-2	LEVEL-3
Length (mm)-A	400-L1	480- L2	560 -L3
Thickness (mm)-B	1.6 -T1	2 -T2	2.6- T3
Super plasticizers -C	1 -S1	1.5-S2	2- S3

Steel tubes are cut to different lengths of 400 mm, 480 mm and 560 mm and are tested for ultimate axial load under an UTM with empty in filled tubes having outer diameter 40mm and inner diameter of 20mm with Varying thickness of outer Diameter tube of 1.6mm, 2mm and 2.6 mm keeping inner tube thickness 1.6mm constant and filled with concrete of grade (M30, M40&M50) of self-compacting concrete as shown in (Table3). As per Taguchi level-3 design with 3- factors tubes are placed upright for compression loading with proper end conditions after curing the in filled tubes for 28 days. After performing the experiments as per Taguchi experimental design and conducting the initial experiments (each in triplicate trial is 9X3=27), liner regression models and equations are developed for all grade of infill which helps to predict ultimate axial load of all required specimens this can be done using a statically tool called Minitab ANOVA.. The validation process is performed by conducting the experiments with a specific combination of the factors and levels not considered in initial design data.

Table III - Specification Of Specimens

Diameter outer (mm)	L/D	D/T	Thickness mm	Length (mm)	Grade
40	10	25	1.6	400	M30
	12	20	2	480	M40
	14	15.4	2.6	560	M50

Fig 1: Double Skinned Tubes

Fig 2: Specimens Kept for Curing

Fig 3: Monotonic Testing in UTM
(R&D Lab, Department of civil engineering GCE, Ramanagaram)

III. RESULTS AND DISCUSSIONS

In this case we study the behavior of composite column tubes subjected to Monotonic Load in Universal Testing Machine of capacity 200T, connected to system with software PLC SCADA which helps to operate the machine with different loading conditions and helps to obtain all required graphs in it. Such has stress v/s strain, Load v/s Deflections curves. Here experiments were conducted to find the ultimate load bearing capability of tubes having varying thickness of 1.60mm, 2.0mm and 2.6mm, where different grade of self-compacting concrete used M30,M40 and M50 and lengths 400mm 480mm and 560 mm with different percentage of super plasticizer 1.0%, 1.5% and 2%, of total weight of cementitious materials. Where specimens kept for 28 days curing.

Table IV - Experimental Results for M30 GRADE

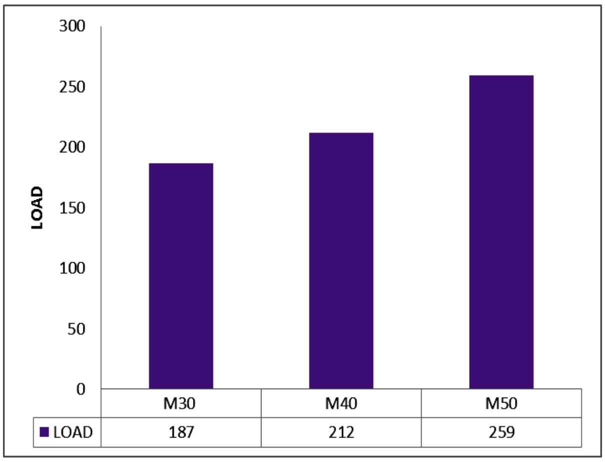
L (MM)	T_0 (MM)	% OF SP	L/D RATIO	P_U M30 EXP (KN)
400	1.6	1.0	10	187
400	2.0	1.5	10	231
400	2.6	2.0	10	286
480	1.6	1.5	12	165
480	2.0	2.0	12	209
480	2.6	1.0	12	267
560	1.6	2.0	14	147
560	2.0	1.0	14	183
560	2.6	1.5	14	239

Table V - Experimental Results For M40 Grade

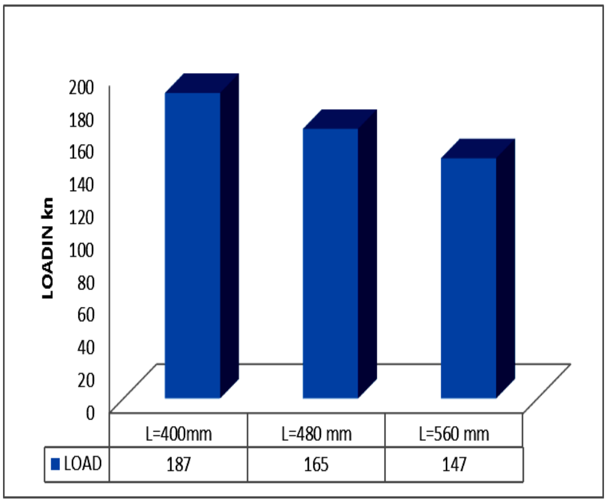
L (MM)	T_0 (MM)	% OF SP	L/D RATIO	P_U M40 EXP (KN) EXP
400	1.6	1.0	10	212
400	2.0	1.5	10	256
400	2.6	2.0	10	301
480	1.6	1.5	12	186
480	2.0	2.0	12	231
480	2.6	1.0	12	280
560	1.6	2.0	14	169
560	2.0	1.0	14	207
560	2.6	1.5	14	253

Table –VI - Experimental results for M50 GRADE

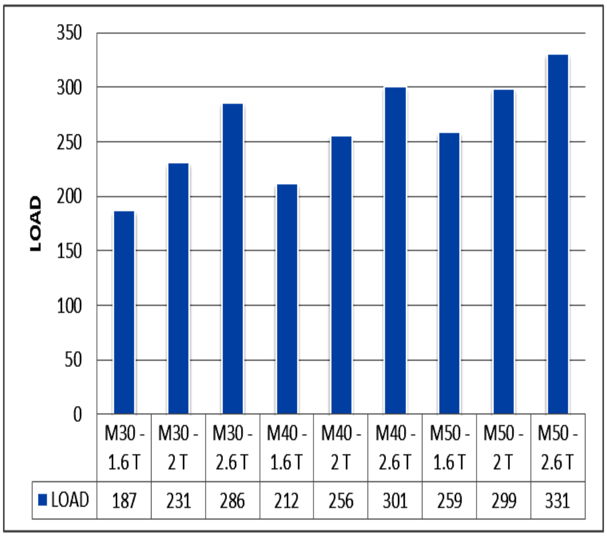
L (MM)	T_0 (MM)	% OF SP	L/D RATIO	P_U M50 EXP (KN) EXP
400	1.6	1.0	10	259
400	2.0	1.5	10	299
400	2.6	2.0	10	331
480	1.6	1.5	12	231
480	2.0	2.0	12	266
480	2.6	1.0	12	309
560	1.6	2.0	14	201
560	2.0	1.0	14	239
560	2.6	1.5	14	284



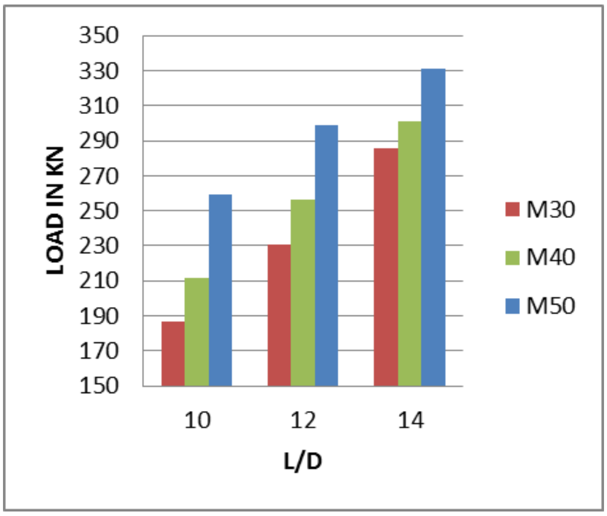
Graph 1: Load V/S Grades of SCC



Graph -2: Load V/S Length



Graph -3: Load V/S Thickness



Graph 4: Load V/S L/D Ratio

After performing the experiments as per Taguchi experimental design, the main effects plots for ultimate axial load for steel tubes with different grades of SCC is entered in the Minitab as shown below

LENGTH	THICKNESS	SP(%)	Pu (M30)	Pu (M40)	Pu(M50)
400	1.6	1.0	187	212	259
400	2.0	1.5	231	256	299
400	2.6	2.0	286	301	331
480	1.6	1.5	165	186	231
480	2.0	2.0	209	231	266
480	2.6	1.0	267	280	309
560	1.6	2.0	147	169	201
560	2.0	1.0	183	207	239
560	2.6	1.5	239	253	284

Fig -4: Values from Minitab

A. Linear Regression Equations

Pu (30) = 143.94 - 0.2813 LENGTH + 97.37 THICKNESS + 1.67 SP(%)

Pu (40) = 189.7 - 0.2917 LENGTH + 88.11 THICKNESS + 0.67 SP(%)

Pu(50) = 279.6 - 0.3438 LENGTH + 76.80 THICKNESS - 3.00 SP(%)

B. Non Linear Regression Equations

Pu(30) NL = 149.7 - 0.2854 LENGTH + 98.68 THICKNESS + 4.67 SP(%)

Pu(40) NL = 190.6 - 0.3204 LENGTH + 94.54 THICKNESS + 10.07 SP(%)

Pu(50) NL = 403.6 - 0.450 LENGTH + 48.7 THICKNESS - 16.9 SP(%)

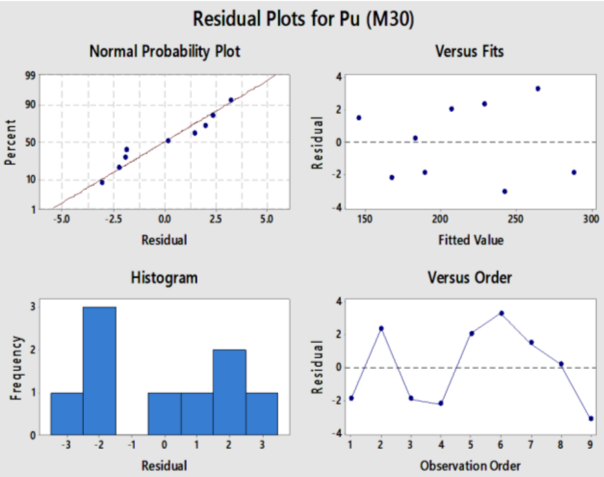
Table VII - Ultimate load values from Regression Analysis

Ultimate load in KN	Linear Regression	Non Linear Regression
Pu (30)	188.90	198.00
Pu (40)	214.67	223.78
Pu(50)	261.96	284.62

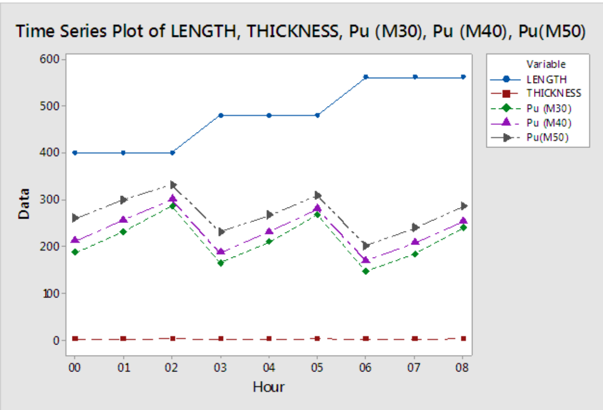
Above Results are shown only for different Grades of concrete M30, M40and M50 keeping Length=400mm, Thickness=1.6mm and Super Plasticizer = 1%.Where has for remaining lengths, Thickness and dosage of A. Super Plasticizer are not shown here.

C. Interaction plots

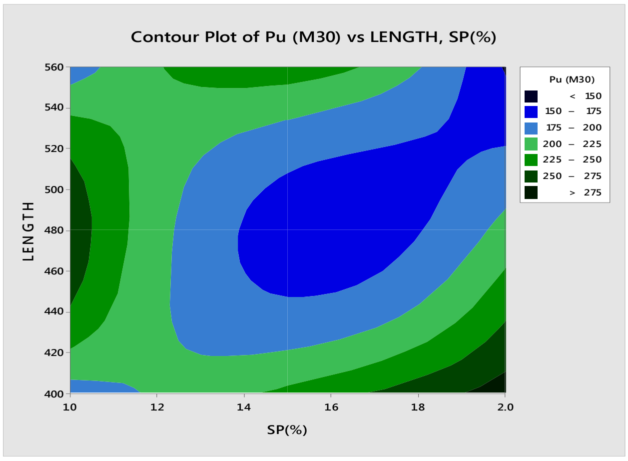
After entering obtained experimental results in Minitab ANOVA Thaguchi analysis done and flowing interaction plots obtained as shown below.



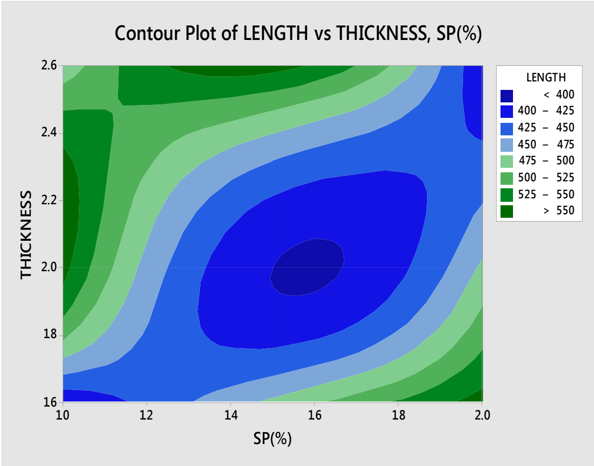
Graph 5: Residual Plots for Pu (M30)



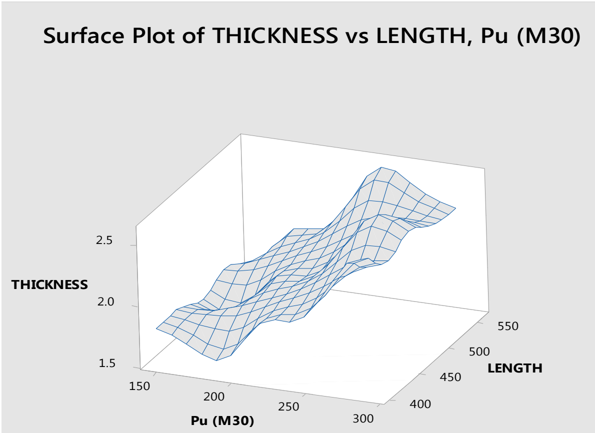
Graph 6: Time Series Plot of Length, Thickness, Pu (M30), Pu (M40), Pu(M50)



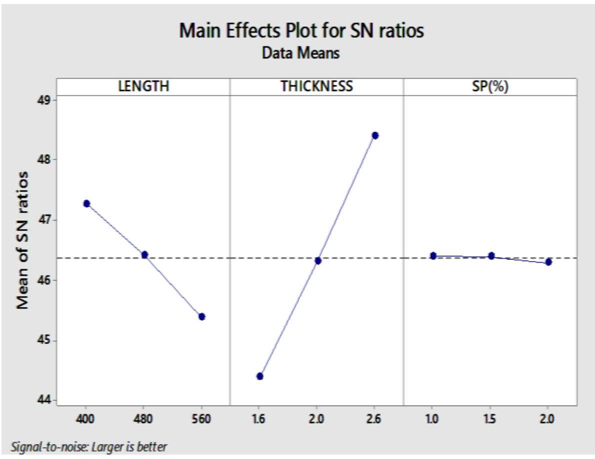
Graph 7: Contour Plot of Pu (M30) V/S Length, Sp(%)



Graph 8: Contour Plot of Length V/S Thickness, SP(%)



Graph 9: Surface Plot of Thickness V/S Length, Pu (M30)



Graph 10: Main Effects Plot for Signal to Noise ratios

Table – VIII - Response Table for Means

LEVEL	LENGTH	THICKNESS	SP(%)
1	234.7	166.3	212.3
2	213.7	207.7	211.7
3	189.7	264.0	214.0
Delta	45.0	97.7	2.3
Rank	2	1	3

IV. CONCLUSION

1. As the column length increases load carrying capacity decreases for a particular grade of concrete has infill.
2. As the Grade of concrete increases, the ultimate axial capacity is found to increase by 10-15%.For length of the column keeping constant.
3. The ultimate axial load carrying capacity decreases as l/d ratio of the HDSCSCs increases.
4. The load carrying capacity increases with higher cross sectional area of the HDSCSCs.
5. From Taguchi Analysis, for maximum Ultimate Axial Load carrying capacity using the response of means and response table of S/N Ratios, The predominate factors for Ultimate Axial load is variation of Thickness of the Composite Colum for all grades.
6. Maximum Load Carrying Capacity can obtained for Length-400 mm, Diameter-40.mm, Thickness-2.6mm and % SP-2%.
7. From Time Series plot we observe that Ultimate Axial load carrying capacity of column can be well predicted.
8. From this Research work parametric optimization and Factors like Thickness, length and Grade of concrete influencing the response can be well predicted.
9. From linear Regression analysis Ultimate load obtained is nearer to experimental values, Non-linear analysis varied by 2% to 9% when compared with experimental values.

REFERENCES

[1] Sameera Simha T.P and.; Dr N. S. Kumar Experimental Investigation on Seismic Resistance of Recycled Concrete in Filled Steel Columns by Taguchi's Approach, Proc. 15 WCEE, Lisboa, 2012.

[2] Kavya M.S,Dr N.S. Kumar and Mohamed Ilyas Anjum; Behavior of Composite Circular Steel Columns in filled with Fiber Reinforced Concrete Subjected to Monotonic Loading, M.Tech dissertation 2013.

[3] Min–Lang Lin and Keh-Chyuan Tsai, (2000), "Mechanical behavior of double-skinned composite steel tubular columns", National Centre for Research on Earthquake Engineering, Taipei, Taiwan

[4] C.X. Dong1and J.C.M. Ho2 "Concrete-filled Double-skin Tubular Columns with External Steel Rings" Australian Earthquake Engineering Society 2012 Conference, Dec 7-9, Gold Coast, Qld.

[5] Shanmugam N.E & Lakshmi. B,(2002), "An analytical model for thin-walled steel box columns with concrete infill", Engineering Structures. Vol. 24. pp 825-38.

[6] Mohanraj E.K & Dr. S. Kandasamy, (2008), " Experimental Behaviour of Axially Loaded Hollow Steel Columns In-filled with Concrete", 2008, IE(I) Journal-CV Vol 88, February 2008 pp 23-29.

[7] IS 10262-1982.India standard recommended guidelines for concrete mix design. Bureau of Indian Standards, New Delhi, India.