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Experimental Investigation on Bond Strength in Self-Compacting Concrete Filled Steel Tube

Shivadarshan S[1], Chethan Kumar S[2], Dr. N. S. Kumar[3]

[1]Student, Dept. of Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru, 560078, India
[2]Assistant Professor, Dept. of Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru, 560078, India
[3]Professor and Director R&D, Ghousia College of Engineering, Ramanagara, 562159, India

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Abstract - *In this paper, the bond behavior between the steel tube and the self-compacting concrete in concrete-filled steel tubes (CFST) is investigated. A series of push-out tests on 27 circular CFST specimens going to be conducted, and the main parameters considered in the test program were: (a) cross-sectional dimension; (b) steel type (galvanized steel); (c) concrete type (normal and self-compacting concrete); (d) concrete age (28 days); and (e) L/D ratio. To conduct the following push out test to find out the bond strength of self-compacting concrete filled steel tube the review on the following paper is carried out in this paper.*

***Key Words*: Bond strength, Concrete filled steel tubes, Push out test**

1. INTRODUCTION

A Concrete filled steel tube (CFST) column is a structural system with excellent structural characteristics, which is the result of combining the advantages of a steel tube and those of concrete. A CFST column is constructed by filling a hollow rectangular or circular structural steel tube with concrete. As a structural system, a CFST column has a high load bearing capacity, excellent earthquake-resistance, good ductility, high fire resistance and its higher stiffness which delays the onset of local buckling. Besides that, the steel tube can function as a permanent formwork as well as reinforcement, thus more economical to be utilized. The increasing costs and project work delay in construction industries in our country require certain measures to be taken as to reduce the costs and increase the speed of construction. One of the solutions worth considering is by applying the Industrialized Building System, where concrete filled steel columns can be considered as one of the structural elements.

The promising features of a CFST column as an excellent earthquake resistance might be of interest for structural engineers or designers in finding a solution to the increasing threat of earthquake in our country. Composite columns of this type have a very good potential to be used in a structural application.

In current international practice, concrete-filled steel tube columns are used in the primary lateral resistance systems of both braced and un-braced building structures. There exist applications in Japan and Europe where CFST are also used as bridge piers. Moreover, CFST may be utilized for retrofitting purposes for strengthening concrete columns in earthquake zones. Due the above advantages of CFST columns the use of this types of columns as a primary column in different structures made necessary to understanding the behaviour of CFST columns.

The interaction between the steel tube and the concrete core is the key issue for understanding the behaviour of concrete-filled steel tube columns. So, it can be understood by knowing the bond strength between concrete and steel tube. Number of experimental investigation were carried out all around the world to understand the behaviour of CFST columns by means of bond strength and this studies have shown the effect of different parameters like dimensions of steel tubes, concrete strength, temperature effects, different interfaces of steel tube and by means of expansive concrete has been carried out but there were no attempts were mad on the study of bond strength in self-compacted concrete filled steel tube column (SCCFST) so in this study the bond strength in self-compacted concrete filled steel tube columns and the effects of concrete strength and dimensions of steel tubes and also the bond strength in SCCFST were compared with conventional concrete filled steel tube column

1.1 OBJECTIVES OF PRESENT WORK

1. To use self-compacting concrete in CFST columns
2. To find the bond strength of SCCFST for different L/d ratio and D/T ratio
3. To assess the effects of C/S of steel tube on bond strength
4. To assess the effects of concrete compressive strength on bond strength
5. To model artificial neural network in matlab for the prediction of bond strength in SCCFST columns

1.2 LITERATURE

a) Zhong Tao (2016): This paper deals with the bond behaviour between the steel tube and the concrete in CFST column. Number of push-out test on circular and squire CFST columns were conducted and in this paper the parameters considered were cross-sectional dimension, to different steel tubes like carbon and stainless steel, concrete type like normal and expansive concrete, concrete age and interface types such as normal interface, interface with shear studs and interface with an internal ring. From this study the author had seen that the stainless steel CFST columns have less bond strength when compared to carbon steel columns, and the bond strength decreases remarkably with increase in cross-sectional dimension

b) Yu Chen (2016): This paper repeated push-out tests on concrete-filled stainless-steel tubes columns were made. The tubes with different values of height-to-diameter ratio, diameter-to-thickness ratio and concrete strengths were considered in the present study It been absorbed that the height-to-diameter ratio and the diameter-to-thickness ratio of the stainless-steel tube as well as the concrete strength have insignificant influence on the shear resistance of the bonding strength of the interface elements. It was also shown from the comparison that the current design rules of concrete-filled carbon steel tubes are inapplicable to the shear resistance of the bonding strength of concrete-filled stainless-steel tubes

c) Ran Feng (1), Yu Chen (2) (2018): In this paper total of 32 push-out tests were carried out on concrete filled stainless-steel square tubes with different values of height to width ratio, width to thickness ratio and concrete strength. The bond-slip behaviour of all specimens and the strain distribution on the exterior of stainless-steel tubes along the longitudinal height direction were carefully investigated. It been absorbed that shear failure loads of bonding slip and the interface friction resistance generally decreased with more loading cycles of the repeated push-out test employed in the same direction. In this paper the author had concluded that 70% of the bonding strength at the interface was taken by the friction force of the interface elements, while the remaining 30% of the bonding strength at the interface was sustained by the chemical adhesive force and the mechanical interlock force.

d) Tian-Yi Song (1), Zhong Tao (2) (2017): In this paper studies have been conducted into the bond behaviour in concrete filled steel tubes at ambient temperature. A total of 24 push-out tests were conducted to investigate the bond strength of CFST columns at elevated temperatures, and 12 reference specimens at ambient temperature, and 16 postfire specimens were tested for comparison. The parameters considered in the experimental investigation are steel type of carbon and stainless steels, concrete types of normal and expansive concretes, cross section type circular and square sections interface types like normal interface, interface with shear studs and interface with an internal ring, temperature level considered in this study is 20, 200, 400, 600, and 800◦C and holding time were 45, 90, 135 and 180 min In this paper the conclusions made were. The bond strength of a stainless-steel specimen was usually lower than that of a reference specimen with carbon steel at ambient temperature or after fire. However, It shod that when the concrete age was relatively long, the influence of steel type on the bond strength was minimized due to the significant concrete shrinkage. Also shod Expansive concrete is effective in enhancing the room temperature bond strength in circular CFST columns

e) Xiushu Qu (1), Zhihua Chen (2) (2015): In this paper push-out tests have been conducted on 18 rectangular concrete-filled steel tube columns with the aim of studying the bond behaviour between the steel tube and the concrete infill. the obtained load-slip response and the distribution of the interface bond stress along the member length and around the cross-section for various load levels, as derived from measured axial strain gradients in the steel tube, are reported. Concrete compressive strength, interface length, cross-sectional dimensions and different interface conditions were varied to assess their effect on the ultimate bond stress. The test results indicate that lubricating the steel-concrete interface always had a significant adverse effect on the interface bond strength. Among the other variables considered, concrete compressive strength and cross-section size was found to have a pronounced effect on the bond strength of non-lubricated

f) Lihue Chen (1), Zhihua Chen (2) (2014): In this paper 9 push out test specimens of concrete filled checkered steel tube have been done to investigate the bond performance between checked steel tube and concrete. According to the experimental results of bond–slip curves, a basic bond–slip constitutive model is established. Considering the varying influential parameters of height of checkered pattern and concrete strength, the changing trends of the ultimate average bond strength are analysed. the distribution regularities of checkered steel tube strains, bond strengths and slippages along the longitudinal length, and bond–slip curves in different longitudinal positions are obtained. Based on the basic bond–slip constitutive model, two position functions are introduced to establish the bond–slip constitutive relationship. The experimental results show that the height of checkered pattern has a significant influence on ultimate average bond strength and that the basic bond–slip constitutive model matches well with our test curves. The introduction of the position functions laid the foundation for further finite element analysis of CFCST.

g) Xiushu Qu (1), Zhihua Chen (2) (2012):
In this paper load reversed push-out tests are cared out by the author on 6 rectangular CFST column to investigate the nature of the bond between the infill concrete and the steel tube. Each specimen was subjected to four half-cycles of loading The Bond stress versus slip curves were obtained for each specimen. The axial bond strain distribution in the narrow and wide faces of the steel tube, and along the entire length of the specimen at the point of the interface reaching its ultimate load carrying capacity and the development of macro locking within four half-cycles of loading. The contribution of micro locking to the total bond strength was obtained from the comparison between the ultimate strength of normal specimens and lubricated specimens the

macro locking contribution was obtained from the comparison between the ultimate strength achieved in the first half-cycle of loading and the ultimate strength achieved in the third half-cycle of loading of the non-lubricated specimens. The developed bond mechanisms were explained and details of the interface bond stress distribution were obtained from the recorded axial strain gradients in the steel tube. Also, the concept of a critical shear force transfer length was introduced, and its implications on practical design discussed in this paper

h) Zhong Tao (2010): In this study the experimental program of bond characteristics between the steel tube and in-filled concrete is carried out. The following conclusions were made by the study. Bond strength generally decreased for specimens after 90 min fire exposure, and a strength recovery was found when the fire exposure time was extended to 180 min. Circular columns generally had much higher bond strength than square columns. Within the limitations of the current tests, 0.4 and 0.15 MPa are recommended as design bond strength for circular and square CFST columns, respectively. In this regard, the influence of fire exposure may be ignored. He said that Due to concrete shrinkage bond strength of CFST columns was very sensitive to their cross-sectional dimension.

Fly ash type, water-binder ratio and cement replacement ratio have impact on the bond strength of SCC. In general, the bond strength of SCC is comparable to that of normal concrete. Based on the results in this paper, it seems that fire exposure has significant influence on the initial slope, ultimate strength, and curve shape of the bond stress-slip curves for CFST columns. To carry out accurate nonlinear analysis for fire-damaged structures

i) Chang Xu (1) (2007): In this paper the expansion/shrinkage behaviours and bond carrying capacities of 17 short, pre-stressing concrete filled circular steel tube columns by means of expansive cement and three short, conventional concrete filled circular steel tube columns are experimentally investigated. This study indicated that both concrete mixes and dimensions of the steel tube have important influence on expansive behaviours of pre-stressing concrete filled circular steel tube columns. The pre-stress in concrete core is a sensitive parameter to the bond strength as well as the load–slip relationship. also indicates that PCFST columns have much higher bond strength than conventional concrete filled circular steel tube columns and this recommends a new method to improve the bond strength of composite structures. Finally, an empirical equation for predicting the bond strengths of pre-stressing concrete filled circular steel tube columns is proposed.

j) Charles W. Roeder (1). (2007): This paper studies composite action in concrete filled tubes that have dimensions and proportions like those used in U.S. practice. concrete filled tubes applications in buildings and the importance of bond stress and interface conditions to behaviour are noted, past research is summarized.

2. METHODOLOGY

2.1 Taguchi's method: -

The Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. The Taguchi method was developed by Dr. Genichi Taguchi of Japan who maintained that variation. Taguchi developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varies.

2.2 Steps involved in Taguchi's Design: -

1. A Taguchi's design or an orthogonal array is a method of designing experiment that usually requires only a fraction of full factorial combinations

2. An orthogonal array means the design is balanced so that factor levels are weighted equally. Because of this, each factor can be evaluated independently of all the other factors, so the effect of one factor does not influence the estimation of the other factor

2. In robust parameter deign you first choose factors & their levels & choose an orthogonal array appropriate for these control factors. The factors comprise the inner array

3. The experiment is carried out by running the complete set of noise factor setting at each combinations of control factors (at each run)

4. The response data from each run of the noise factor in the outer array are usually aligned in a row

5. Each column in the orthogonal array represent a specific factor with two or more levels

6. The following table displays the L9 (2**7) Taguchi's design. L9 means 9runs (2**7) means 7 factors with 2 levels each

7. This array is orthogonal factor levels are weighted equally across the entire design. The table columns represent the control factors the table rows represent the runs & each table cell represent the factor levels for that run

3. EXPERIMENTAL PROGRAM

3.1 Material properties

1. Galvanized steel tubes: Galvanized steel is defined as a carbon steel sheet coated with zinc on both sides. There are two main processes used to produce galvanized steel continuous hot dipping and electro-galvanizing. The hot dipping process consists of passing the steel through a bath of molten zinc, while the electro-galvanizing process consists of the application of zinc through electrolytic disposition. The result is a layer of zinc tightly adhering to the base metal through an iron-zinc bonding layer. The hot dipped galvanized products are manufactured to ASTM A653 specifications and electro galvanized products are conforming to ASTM A879 specifications

Table -1: Physical & Mechanical Properties of Galvanized Steel

Density (×1000 kg/m3)	7.8
Poisson's Ratio	0.27-0.30
Elastic Modulus (GPa)	210
Tensile Strength (Mpa)	310
Yield Strength (Mpa)	445
Elongation (%)	20

2. Concrete: Three self-compacting concrete strengths – M30, M50, and M70 is used and one normal concrete strength- M30 is used this concrete was produced using commercially available materials with normal mixing and curing techniques. The strength development of the concrete was monitored over a duration of 7 & 28 days by conducting periodic cube and cylinder tests

Table -2: concrete properties and mix proportions

Mix	M30	SCCM30	SCCM50	SCCM70
Concrete properties				
Weight per unit volume kn/m3	24	25	25	25
Modulus of Elasticity N/mm2	27386.12	27386.12	35355.33	41833
Poisson's Ratio	0.2	0.2	0.2	0.2
Mix proportions				
Cement (Kg/m3)	400	300	385	490
Fly ash (Kg/m3)	-	123	180	160
Water(L/m3)	209	180	197	220
CA (10 mm down) (Kg/m3)	984	781	810	700
FA (Kg/m3)	774	865	820	790
SP (L)	-	3.2	3.6	3.8
VMA (L)	-	0.65	0.58	0.32

3.2 Loading set up of push out test and loading scheme:

In this study all 27 specimens of SCCFST and 3 CFST columns were tested in UTM for push out test were the specimen placements in to the UTM for the push out test for column were showed in the Fig 1 the testing set up is similar to the axial testing of CFST columns but the loaning will be applied on the concrete portion only with will leads to the bonds failure also non as shear failure due to the initial air gape provided in SCCFST and CFST specimens as to allow slip shone in Fig 1. the dial gauge is used to find the slip of concrete in fill with respect to the steel tube is found out and also the load by sleep curve is drown from the results obtained to understand the bonding behavior the experimental.

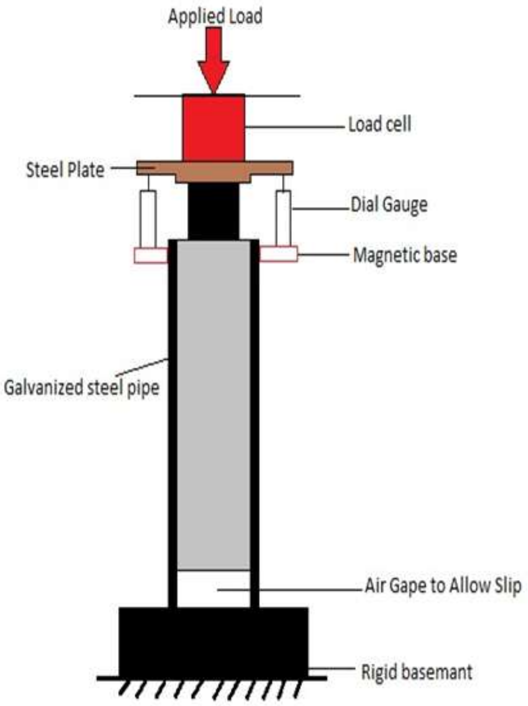

Fig -1: load scheme diagram

3.2 Procedure for push-out test:

The procedure of push out test carried out to find the bond strength in this study the total of 30 specimens were test under push-out test using UTM under controlled loading of 0.2 KN/sec. its procedure is given below

1. Investigation is to be carried out initially to chuck the proper working of UTM, dile gauge and also the CFST specimens were also chucked for the loading surface horizontality and it is prepared loading surface horizontal if any undulation were there

2. If the loading surface of CFST surface is un even the surface is made horizontal by speeding sand on the surface

3. After the surface is made horizontal the specimen will be fitted in to the UTMs compression loading frame proton as showed in fig 1 by using controlling panel

4. The solid steel cylinder is fixed between loading frame and CFST column specimen only on the concrete to make Shure the loading head is applying the load only on the concrete proton as shown in fig 2.

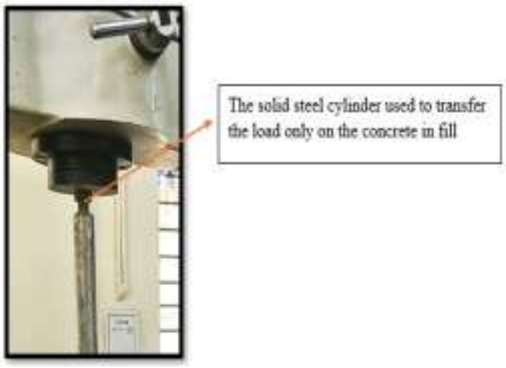

Fig -2: Solid cylinder arrangement to push-out test

5. After the specimen is fitted in to the UTM has explained above manner the initial load of 5 KN is applied on the CFST column to make the loose concrete on the top of the column to consolidate to prevent the initial false settlement reading

6. Ones after initial load is applied on the concrete infill the load point is taken as zero and the deal gauge of accuracy of 0.01 is used to measure the slip of concert core and it is fixed on the loading head properly as showed in the Fig 3

Fig -3: Arrangement of dile gauge

7. Ones after the dile gauge is fixed to the loading head the constantly increasing load of 0.2 KN/sec is applied on the concrete

8. So, to record the slip of concrete with respect to applied load on the CFST columns two camera were used to record the slip with an accuracy of 0.01 mm and loading with an accuracy of 0.2 KN/sec

9. And ones after the CFST column fails under bond the loading rate is increase to 2 KN/min un till the settlement reaches 10 mm

10. The readings obtained from the results were used to drown the load-slip response curve to no the behavior of SCCFST column is drown

The bond strength from push-out test is defined by the following equation:

$$\tau=Ps/\pi DL \qquad \rightarrow \text{Eq (1)}$$

where Ps is the applied load at which initial rigid body slip of the concrete core relative to the steel tube occurs, and in this paper, Ps is called the failure load. D and L are the inside diameter of the steel tube and the length of the concrete–steel interface, respectively. Ps of the CFST column can be found out by means of push out test which is carried out in the current study

Fig -4: SCCFST column specimen after push-out test

the concrete which will leads to the bond failure due to push out test also non-as shear failure due to the initial air gape provided in SCCFST and CFST specimens as to allow slip shone in Fig 1. the dial gauge is used to find the slip of concrete in fill with respect to the steel tube is found out and also the load by sleep curve is drown from the results obtained to understand the bonding behavior the CFST column specimen after push-out test is shown in Fig 4

Table -3: Experimental Results

Test group	Specimen label	D(mm)	t(mm)	L/D	C(Mpa)	Pu(N)	Tu(Mpa)
1	D33-L12-SCC30	33	2	12	35.4	92	3.162
	D33-L14-SCC30	33	4	14	35.4	108	3.271
	D33-L14-SCC30	33	3	16	35.4	122	3.283
2	D42-L12-SCC30	42	2	12	35.4	156	3.156
	D42-L14-SCC30	42	3	14	35.4	192	3.236
	D42-L16-SCC30	42	4	16	35.4	198	3.267
3	D48-L12-SCC30	48	4	12	35.4	192	3.133
	D48-L14-SCC30	48	3	14	35.4	248	3.216
	D48-L16-SCC30	48	2	16	35.4	300	3.221
4	D33-L12-SCC50	33	2	12	53.2	90	3.099
	D33-L14-SCC50	33	4	14	53.2	102	3.083
	D33-L16-SCC50	33	3	16	53.2	118	3.192
5	D42-L12-SCC50	42	2	12	53.2	139	2.862
	D42-L14-SCC50	42	3	14	53.2	174	2.911
	D42-L16-SCC50	42	4	16	53.2	190	3.153
6	D48-L12-SCC50	48	4	12	53.2	166	2.713
	D48-L14-SCC50	48	3	14	53.2	220	2.841
	D48-L16-SCC50	48	2	16	53.2	284	3.047
7	D48-L12-SCC70	33	2	12	71.8	86	2.941
	D48-L14-SCC70	33	4	14	71.8	98	2.994
	D48-L16-SCC70	33	3	16	71.8	100	3.11
8	D48-L12-SCC70	42	2	12	71.8	143	2.853
	D48-L14-SCC70	42	3	14	71.8	168	2.876
	D48-L16-SCC70	42	4	16	71.8	176	2.934
9	D48-L12-SCC70	48	4	12	71.8	164	2.681
	D48-L14-SCC70	48	3	14	71.8	208	2.719
	D48-L16-SCC70	48	2	16	71.8	272	2.915
10	D33-L12-SCC30	33	2	12	36.7	70	1.847
	D42-L16-SCC30	42	4	16	36.7	162	2.187
	D48-L14-SCC30	48	3	14	36.7	132	1.517

Were: -

D= Internal diameter of steel tubes in mm

t= Thickness of the steel tubes in mm

C= Characteristic compressive strength of concrete at 28 days in N/mm2

Pu= Max shear failure loads

Tu= τ= bond strength in N/mm2 as given in Eq (1)

4. RESULTS & DISCUSSION

The results obtained from the experimental are tabulated in the table 3 and following discussions were made

1. load-slip curve drowns from the push out test is showing the behavior of bonding between concrete and steel tube from which can be point out that the bond strength of CFST columns well be due to

-chemical adessive force

-frictional force in steel and concrete interface

The load slip curve for SCCFST columns from push-out test is given in the chart-1

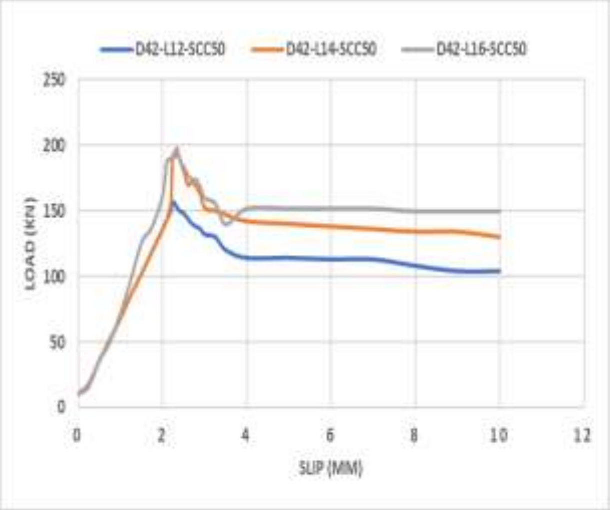

Chart -1: load-slip curve

2. Comparison of bond strength in CFST columns of different L/D ratio of same diameter is made from the obtained results in table 3 and the graph were drowned as fallow

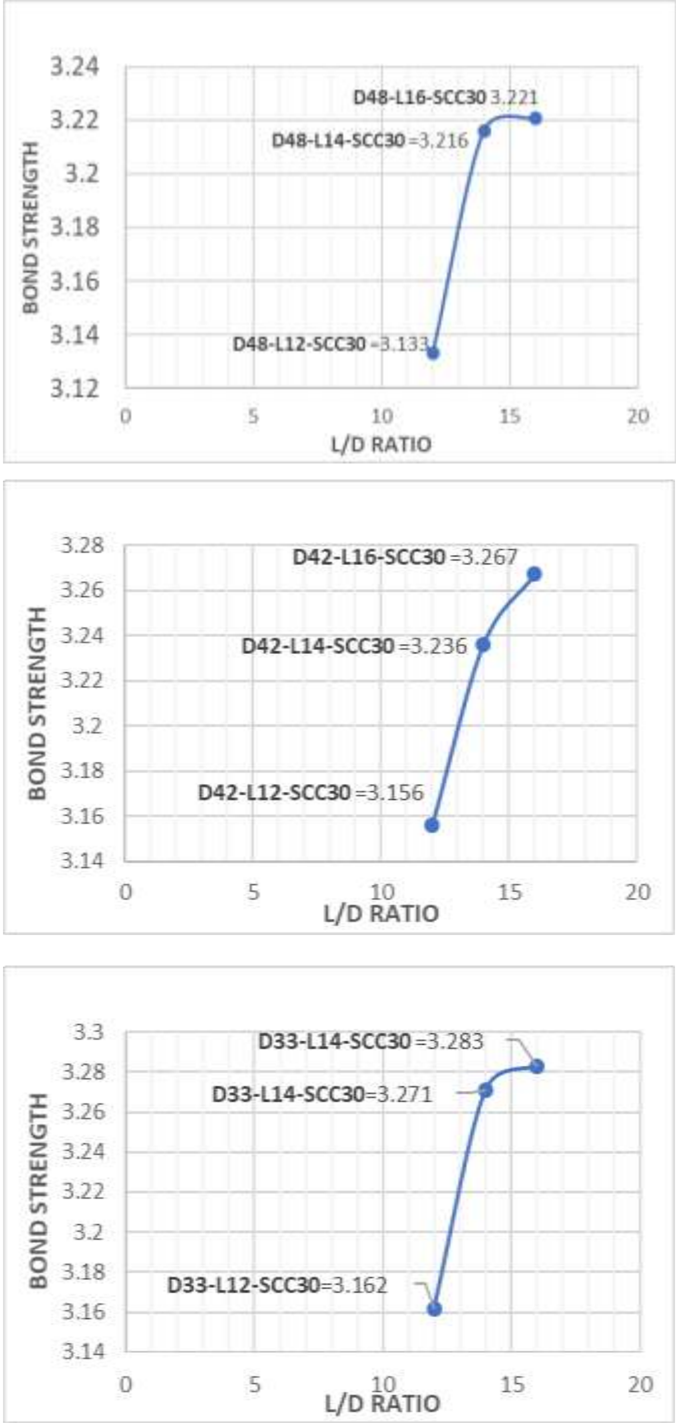

Chart -2: Bond strength vs L/d ratio curve

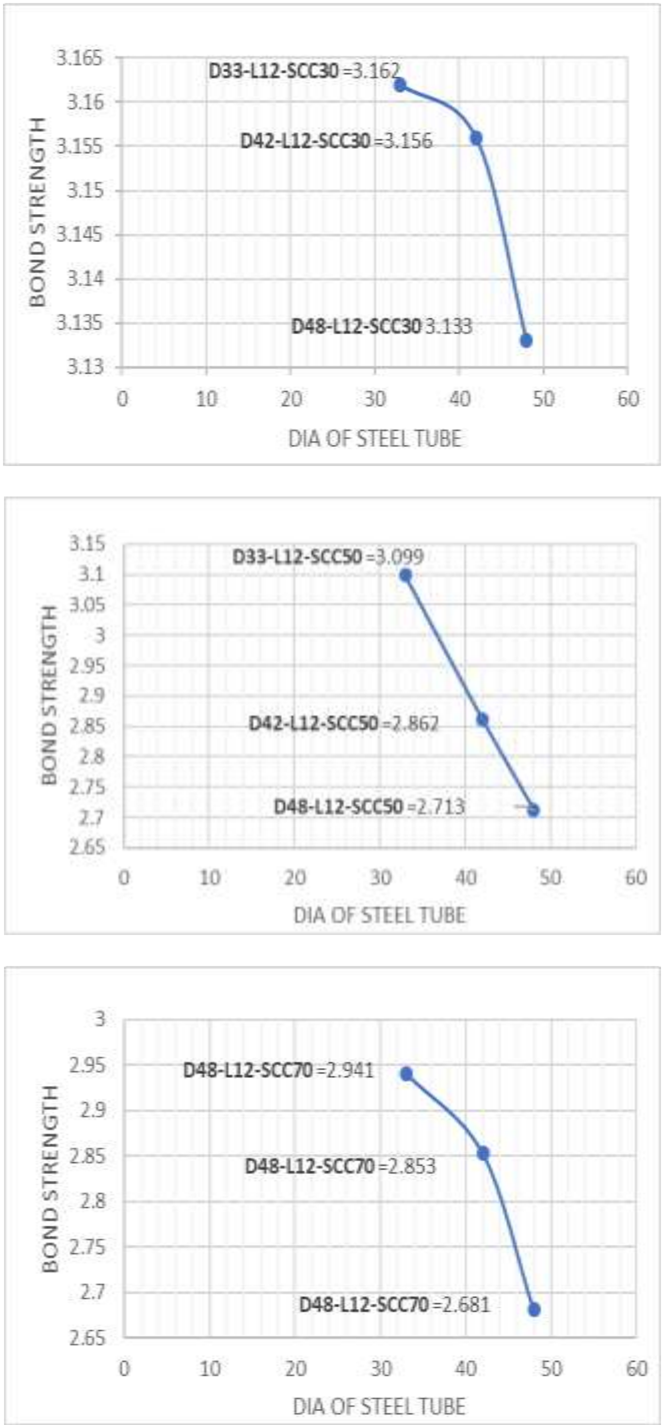

Chart -3: Bond strength vs diameter

From the above chart 2 it can be seen that Increase in L/d ratio of columns showed the increase in bond strength

3. Comparison of bond strength in CFST columns of different L/D ratio of same diameter is carried out from the obtained results and the grapes were drown to represent the vernation in bond strength in SCCFST column

By the above bond strength vs diameter curve It can be seen that the Increase in diameter of SCCFST columns has showed the decrees in bond strength so it can be non by this that the bigger diameter concrete columns may have lesser bond strength when camper to smaller diameter specimen so in this paper the bond strength in smaller diameter were tested so still the experiment need to be carried out on bigger diameter to obtain the proper results

4. Comparison of bond strength in SCCFST Columns of different concrete characteristic compressive strength is made by the obtained results and it is represented in the following chart

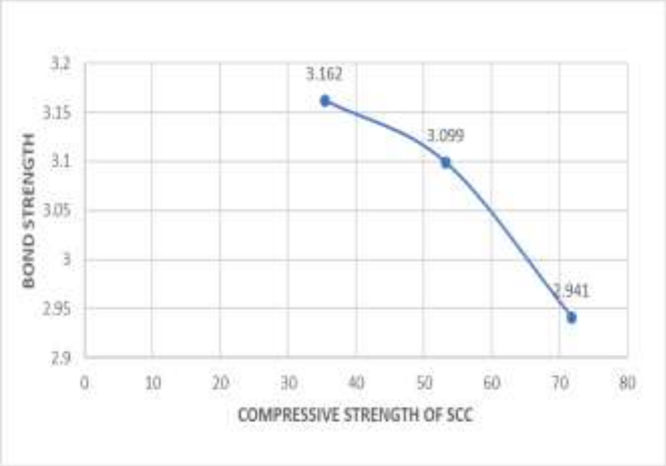

Chart 4 -: Bond strength vs compressive strength of SCC

From the chart 4 it can be seen that the bond strength in concrete filled steel tube columns will decrease with increase in concrete compressive strength by this it cane be proved that as the concrete strength increases the fines used in the concrete will be more so it will also increases the shrinkage of the concrete so the bond strength of the CFST columns will also depend on the compressive strength

5. Finely the comparison of bond strength in SCCFST Columns and conventional CFST Columns were carried out for this comparison three conventional concrete filled columns were casted separately of same geometry as three self-compacted concrete filled steel tubes columns and there compression is shown in the blackheart

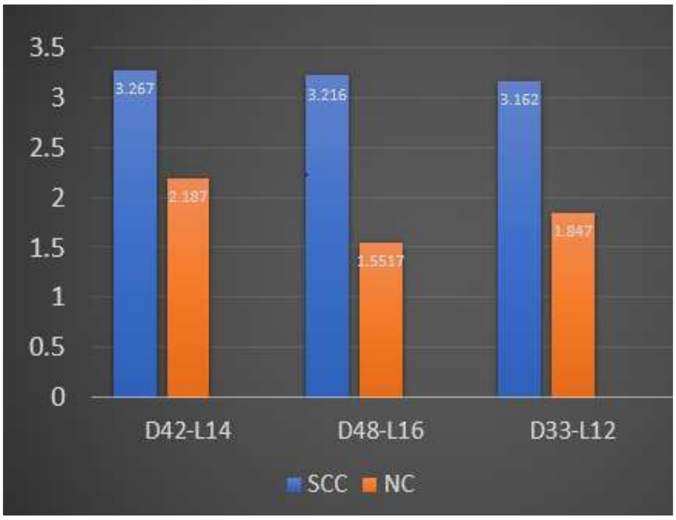

Chart 5 -: compression of SCC and NC

From this comparison it is seen that the bond strength in self-compacting column have more bond strength then the normal concrete (NC) filled steel tube column.

3. CONCLUSIONS

Based on the investigations conducted, the following conclusions can be derived: -

1. Use of SCC in CFST columns has showed the increase on bond strength when campier to conventional CFST column.

2. From this experimental work it is found that the dimensions and compressive strength of the CFST columns have also affect the bond strength were the bond strength will decree with increase in diameter of steel tube and increase in concrete compressive strength

3. The use of SCC in CFST Columns is more advantageous then the conventional CFST Columns because of its high bond strength and no compaction is required so it economize construction cost and increase the speed of the construction

4. Due to it high bond strength the SCCFST columns act as a homogenous and isotropic member which make the design of CFST columns easy

REFERENCES

[1] M. Hunaiti, "Bond Strength in Battened Composite Columns" publication ASCE Journal of Structural Engineering, Vol. 117, No. 3, March 1991

[2] Charles W. Roeder, "Composite Action in Concrete Filled Tubes" publication ASCE Journal of Structural Engineering, Vol. 125, No. 5, May, 1999

[3] Chang Xu, "Push-Out Test of Pre-Stressing Concrete Filled Circular Steel Tube Columns by Means of Expansive Cement" publication Elsevier, 24 October 2007, doi: 10.1016/j.conbuildmat

[4] T. Aly, "Incremental Collapse Threshold for Pushout Resistance of Circular Concrete Filled Steel Tubular Columns" publication Elsevier Journal of Constructional Steel Research, 1 August 2009, doi: 10.1016/j.jcsr.2009.08.002

[5] Zhong Tao, "Post-Fire Bond Between the Steel Tube and Concrete in Concrete-Filled Steel Tubular Columns" publication Elsevier Journal of Constructional Steel Research, 17 September 2010, doi: 10.1016/j.jcsr.2010.09.006

[6] Xiushu Qu, "Load-reversed push-out tests on rectangular CFST columns" publication Elsevier Journal of Constructional Steel Research, 29 November 2012, http://dx.doi.org/10.1016/j.jcsr.2012.11.003

[7] Lihua Chen,, "Refining bond–slip constitutive relationship between checkered steel tube and concrete"

publication Elsevier Journal of Construction and Building Materials, 22 January 2015, http://dx.doi.org/10.1016/j.conbuildmat.2014.12.058

[8] Xiushu Qu, "Push-out tests and bond strength of rectangular CFST columns" publication ASCE, 2015

[9] Zhong Tao, "Bond behavior in concrete-filled steel tubes" publication Elsevier Journal of Constructional Steel Research, 12 January 2016, http://dx.doi.org/10.1016/j.jcsr.2015.12.030

[10] Yu Chen, "Bond-slip behavior of concrete-filled stainless steel circular hollow section tubes" publication Elsevier Journal of Constructional Steel Research, 22 December 2016, http://dx.doi.org/10.1016/j.jcsr.2016.12.012

[11] Tian-Yi Song, "Bond Behavior of Concrete-Filled Steel Tubes at Elevated Temperatures" publication ASCE Journal of Structural Engineering,12 May 2017 DOI: 10.1061/(ASCE)ST.1943-541X.0001890

[12] Xiushu Qu, "Bond strength between steel and self-compacting lower expansion concrete in composite columns" publication Elsevier Journal of Constructional Steel Research, 28 September 2017, https://doi.org/10.1016/j.jcsr.2017.09.017

[13] Ran Feng, "Push-out tests of concrete-filled stainless steel SHS tubes" publication Elsevier Journal of Constructional Steel Research, 16 February 2018, https://doi.org/10.1016/j.jcsr.2018.02.016