Experimental Investigation on Bond Strength in Concrete Filled Steel Tube(CFST) with Welded Internal Rings

Sanjay H M[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

---***---

Abstract -*Concrete filled steel tube (CFST) is one of the economical way of construction. In CFST both concrete and steel contribute their strength combinedly so strength composite filled steel tube of high strength and here steel acts as permanent framework .And the bond strength between steel tube and concrete is one of the important fact for CFST's strength. In order to improve bond strength various parameters were considered like varying dimension of tube, varying the concrete infill etc. In this experimental work steel tube used is G I pipe and M40 concrete is used as infill, 27 specimens were considered for experiment with varying dimension and in each tube an internal ring is welded to different lengths. To conduct the following push out test to find out the bond strength of concrete filled steel tube with internal ring welded the review on the following paper is carried out in this paper.*

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

1. INTRODUCTION

Concrete filled steel tube is a one in which positive behaviour of both steel and concrete is used in one platform. This includes a hollow steel tube which acts a permanent frame work and normal concrete or reinforced concrete is used as the solid member to fill the hollow section of the steel tube. This elements are majorly in skyscraper and multi story building as sections and bar segments it reduces the self weight of the structure and is also used in the structures where effective frame work is required. And there are many more areas where the effective frame work is very much required. The performance of concrete infilled is improved due to this steel frame and this concrete helped in taking the major compression load so in this way each infill and the outer shell are compensating each other to perform to it's best level. Here outer most layer which should perform in tension and bending is the steel tube and is successful in it. And is also giving firmness to the element. And the solid infill will act as the compression member and the infill used is concrete.

CFST has the higher advantages of bearing limit, higher plasticity and higher strength in structures, advantageous development and greater financial profits. It is a amazing structural element it exploits the connection and cooperative energy among the cylindrical steel and the concrete over the length. As an extremely good structural element, supportive energy between steel cylinder and concrete infill enhances the ability of element on loading. Here the behaviour of load bearing capacity is not same due to change in the properties of both the steel tube and the concrete. As we know that CFST is a composite structural element it is necessary for each concrete in fill and the steel shell to contribute their best by working together under loading in order to work together both of them has to be together and there should be a good bond between them . And this bond between them is called the bond strength. And this bond strength is one of the main property on which the capacity of load bearing is dependent. And this bond strength depends on the properties of both the concrete infill and that of steel pipe, the properties may be the shape, size, texture of the steel shell or the type of concrete.

As bond strength is one of the main property of the CFST to get its maximum strength there are more number of ways to improve the bond strength and some of the ways to improve the bond strength are as follow easy way of getting high bond strength is by using higher grade concrete on using this as infill the bond strength is improved, by using the fibres which improves bond strength between steel tube and the concrete infill. By changing the infill a small improvement in bond strength can be obtained. But on changing the properties of the steel tube higher bond strength can be acquired, changing properties maybe as follow by implanting the stud to the inside surface of the steel tube to certain lengths, by welding the rings on the external surface of the steel tube, by getting the rough internal surface of the steel tube and welding rings to the internal surface of the steel tube enhances the bond strength to its higher level more than that of any other changes made. In this experiment we are considering improvement of bond strength by welding internal rings to the different heights of the steel pipe.

CFST offers numerous basic advantages, for example, high compressive quality and durability, brilliant seismic shock opposition and ready to diminish cost and length of the developments. These focal points have been generally abused and have prompted the broad utilization of CFST in structural designing structures. By observing to the properties and ability of the CFST many investigations and researches have been conducted in this area to get its maximum uses in construction field. Developing countries are working in this field to get its maximum use as this CFST is the best low weight structural elements when compared to that of the normal conventional structural elements like reinforced beams and column this is majorly used in high raise structures where it is reduce the self weight of the structure without compromising with strength. This CFST is also been a major technique used in the areas where it is seismic zone where the structures are frequently get disturbed or even get destroyed and in using the conventional way for construction here the cost of construction gets higher and the time required for construction will also be higher. So in order overcome this problem this CFST can be used it is economical ,light weight, and construction time taken is less so this is the best way for construction and also this is the reason why this construction is in higher trend in the present world. This experimental work deals with giving an idea about location where an internal ring can be welded so that to get its ultimate strength.

2. AIM AND SCOPE OF STUDY

- To improve bond strength in concrete filled steel tube.
- To improve of bond strength in concrete filled steel tube by welding internal rings inside the steel tube.
- To analyze the amount of improved bond strength in concrete filled steel tube with internal rings welded at different levels of the tube.
- To assess the bond strength variation in concrete filled steel tube with varying steel tube cross-section.
- To analyze the bond strength in internal ring welded steel tube filled with different grade of concrete.

2.1 LITERATURE

Tian-Yi Melody et al. (2017) to know the behaviour of CFST at ambient temperature, a total of 24 push out test were done. 12 reference specimen at ambient temperature and 16 postfire specimens were tested for comparison. Different parameters were considered in the experiment. Steel type like carbon and stainless steel, concrete type of nominal concrete, expansive concrete, different cross section like square and rectangular and interface like normal interface, interface with shear studs with an internal ring. Experiment is done at different temperatures like 20,200,400,600 and 800^0 C and holding time considered were 45,90,1350and 180min.

The results were carbon had more bond strength than stainless steel at ambient temperature. Due to concrete shrinkage there is low in bond strength as there is increase in concrete age.

Expansive concrete had more bond strength at ambient temperature than nominal concrete. Welding internal rings or shear studs on internal surface increases the bond strength.

Zhong Tao, Tian-Yi Tune, Brian Uyb, Lin-Hai Han (2016) introduced paper on "Bond conduct in concrete-filled steel tubes", they have done their examination by leading the push out test and this trial paper is introduced on ELSEVIER Diary of Constructional Steel Exploration 120,81–93 .

Zhong Tao et al. (2015) To know about the effect on bond strength of CFST due to obstructions laid internally in the CFST tube, author has done the following experiment. This experiment consists of different shapes. Square and rectangular are the different shapes. Different cross sectional measurements 120-160 mm, Steel types were treated steel and carbon steel, Obstruction like internal rings and solid studs.

The results of this experiments were square CFST of carbon steel with internal rings were showing high bons strength than circular CFST with stainless steel and without internal rings. Bond strength decreased as increase in concrete age due to shrinkage in concrete.

Lin-Hai Han et al. (2014) explored the conduct of cement encased CFST stub sections under hub pressure. A FEA) displaying was created to dissect the conduct of the composite sections. The material nonlinearity and the communication among cement and steel tube were thought of. The heap versus misshapening relations of the solid encased CFST stub sections was introduced. The distinctions of cement encased CFST sections, customary CFST and RC segments were depicted. An equation was proposed to anticipate a definitive quality of the composite stub segments.

Xiushu Qu (2013) did Load switched push-out tests on 6 rectangular CFST segments. The paper researched the idea of the connection between the solid in fill and the steel tube, the commitment of each bond pressure segment (i.e., synthetic attachment, miniature locking and large scale locking) and the improvement of full scale locking inside four half patterns of stacking. The idea of a basic shear power move length was presented, and its suggestions on handy plan talked about. The basic interface length to guarantee full shear move was contemplated, and plan proposals were given.

Vipulkumar Ishvarbhai Patel et al. (2012) completed test and mathematical examination on full-scale high quality flimsy walled rectangular steel thin cylinders loaded up with high quality cement. Exploratory extreme qualities and burden redirection reactions of CFST slim bar sections were tried by autonomous scientists and used to check the precision of the mathematical model. The confirmed mathematical model was then used to explore the impacts of nearby clasping, section thinness proportion, and profundity to-thickness proportion, stacking unconventionality proportion, concrete compressive qualities and steel yield qualities on the conduct of high quality slim walled CFST thin bar segments.

Qing Quan Liang (2011) introduced the check and uses of another mathematical model produced for the nonlinear inelastic investigation of high quality round CFST slim bar sections under hub burden and bowing. The precision of the mathematical model was analyzed by looking at the anticipated extreme qualities and burden redirection reactions of roundabout CFST slim shaft sections with relating test results. Great understanding among computational and exploratory outcomes was gotten. The parametric investigations revealed in this paper gave benchmark mathematical outcomes that are incredibly valuable for approving other nonlinear inelastic examination procedures.

3. METHODOLOGY

3.1 Taguchi's method: -

Taguchi was brought up inside the material town of Tokamachi, in Niigata prefecture. He contemplated material building at Kiryu Specialized School in his underlying days to enter the family kimono business. Notwithstanding, with the blast of war II in 1942, he was enrolled into the Cosmic Branch of the Route Establishment of the Royal Japanese Naval force.

Taguchi's procedures have been broadly used in various fields. Frame work plan is one of the main component in taguchi's process. When there are different parameters in the experiments then to select the optimum number of combination this method is used. To select the best degree of quality trademark with least variety. This method is useful to get the productive strategy for working reliably and ideally over an complex conditions. This method is useful in complex projects which needs to be done economically and with less time and containing high number of parameters which will effect the result of the project.

3.2Steps involved in Taguchi's Design: -

Step1: A Taguchi's design requires only a fraction of full factorial combinations
Step2: An orthogonal array means the design is balanced, this means that factor levels are weighted equally. Due to this, each factor can be evaluated independently, the result of this is the effect of one factor do not influence the other factor.
Step3: In robust parameter deign the procedure is that you first choose factors & their levels & after that choose an orthogonal array which are suitable for certain control factors. The factors comprise the inner array.
Step4: At each run the complete set of noise factors is run to carry out the experiment.
Step5: The alignment of a row is done by the response data which gad obtained by the each run of noise factor.
Step6: Each column in the orthogonal array represent a specific factor with two or more levels
Step7: The following table displays the L9 (2**7) Taguchi's design. L9 means 9runs (2**7) means 7 factors with 2 levels each
Step8: At the entire design the array is orthogonal factor levels are weighted equally. The table columns represent the control factors the table rows represent the runs & each table cell represent the factor levels for that run.

3.3. Different parameters considered in experimentation

This experimental investigation study on bond strength in steel tube with internal rings welded on the internal surface of steel tube and parameters considered in the experiment is given below.

1.	L/D ratio(L)	L1 L2 L3	12 14 16
2.	Diameter(D)	D1 D2 D3	32.70mm 42.40mm 48.30mm
3.	Thickness(T)	T1 T2 T3	2.60mm 3.20mm 4.00mm
4.	Internal rings	TOP MID BOTTOM	L/3mm from top L/2mm L/3mm from bottom
5.	MIX	M40	40N/mm^2

Table 3.3.1 Parameters considered in the experimental work

3.4 Material properties

Galvanised steel tubes

Galvanized steel tubes are the steel tubes which are been covered with zinc. This covering shields steel from corrosion. This GI steel tubes are most usually utilized in development presently. It is even called as galvanized iron cylinder.

To produce galvanized steel tube steel materials are set into a liquid shower of zinc. This cycle is called as hot plunge galvanization. The two materials are artificially attached to each other in this cycle and will subsequently never isolated bringing about enduring execution of steel tube.

And the galvanized steel tube used in this experiment are bought from manufactures "Prakash steel" and the materials properties are provided below

Table 3.4.1 Physical and Mechanical properties of GI steel tube

Density(1000Kg/m^3)	**7.80**
Poission's Ratio	**0.270-0.3000**
Elastic Modulus(Gpa)	**210.0**
Tensile strength(Mpa)	**445.0**
Yield Strength(Mpa)	**310.0**
Elongation(%)	**20.0**

Fig 3.4.2. Galvanized steel tube

3.5 Concrete properties

In preparing of the test samples Concrete filled galvanized steel tube for this experiment concrete is used as the infill material inside the steel tube. And the grade of concrete used in this experiment is M40 and the test results in fresh state, hardened state and mix design of the concrete is given below.

3.6 Tests on fresh concrete

3.6.1 Workability

Functionality is the property deciding the vitality needed to work a newly blended amount of cement in with least loss of homogeneity. It is important to reduced cement to the greatest conceivable thickness. Droop test is the normally utilized technique for estimating consistency of solid which can be utilized either in research center or at site of work. It 73 is utilized advantageously as a control test and gives a sign of the consistency of cement from clump to group. The functionality of cement is tried by a droop cone device according to Seems to be: 1199 – 1959 for M20 evaluation and M40 grade concrete in different substitution extents of characteristic totals by steel slag

Evaluated slump value from experiment is

Concrete	Trial 1	Trial 2	Average
M40	42	44	43

3.7 Tests on hardened concrete

Preparation of specimens and its details

Cube dimension- 150*150mm

Cylinder dimension-150*600mm

Strength parameters	M40
Compressive strength (N/mm^2)	50
Split Tensile strength (N/mm^2)	5.41

Table 3.7.1 Compression and Split tensile strength value

4 Preparation of specimen

4.1 Cutting of galvanized steel tube

Cutting the tubes to the suitable dimension on the basics of L/D ratio and the L/D ratio is considered to be 12,14,16 .The numbers of specimens cut are on the requirement basis of Taguchi method.

Fig 4.1.1 Cutting of galvanized steel tubes and Pruning the edges

4.2 Welding of internal ring

An internal ring is welded inside the GI steel tube and are welded in different positions top, middle and bottom. Washers of suitable diameters are used to weld as the internal rings.

Fig 4.2.1 Internal ring and welded internal ring

4.3 Test arrangement

4.3.1 Equipment's required

1. **Metal cutter machine:** This cutter machine is used to cut the specimen to required length
2. **Grinder machine**: It is used in cutting the extra edges of pipe end.
3. **Weight scale:** It is used to measure the weight of infill materials used.
4. **Mixing trays:** It is used in mixing concrete.
5. **Measuring jug:** It is primarily used to measure the volume of liquid.
6. **Tamping rod**: Tamping rod is used to tamp the concrete and compact it.
7. **Universal Testing Machine (UTM) of 2000 tons:** It is the machine in which specimens undergo push out test.

4.4 Experimental setup

4.4.1 Organizing specimen

Organizing the specimen that is GI steel tube infilled with concrete to undergo push out test for analysing the bond strength. A small gap is left in the specimen so that the infilled concrete can undergo displacement due to pushout test.

Fig 4.4.1.1 Creating of gap in the specimen to undergo push out test at the base of specimen

4.5 Loading setup for pushout test

Fig 4.5.1 Specimen under loading in a UTM

Loading to the specimen is done as shown in the picture above and a metal plate of diameter slightly less than internal diameter of the steel pipe is placed on the surface of the specimen and the hollow section of the specimen is towards the bottom. And a dial gauge is placed to determine the amount of concrete slip from its original position.

4.6 Procedure for Push-out test

In this study to find the bond strength we follow the procedure of push out test. And a total of number 27 specimens were under gone push out testing using the UTM machine with a controlled loading of 0.2 KN/sec. And the following is the procedure

- Firstly checking the working condition of UTM and Dial gauge.
- Dust or other particles on the concrete surface of CFST is cleaned.
- Checking the concrete surface horizontality for horizontality. By speeding sand on the surface to make it even if it is even.
- And to the UTM compression loading frame the specimen is fixed as in figure as shown in Fig 4.6.1

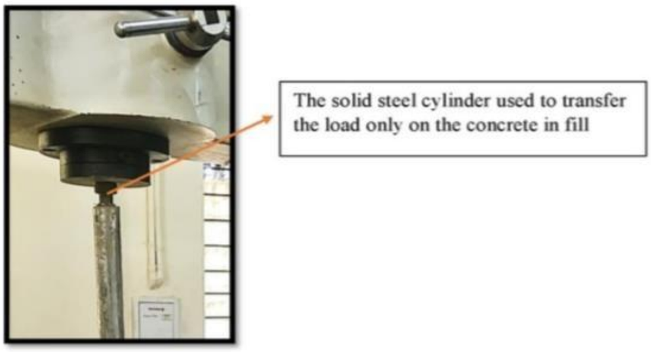


Fig 4.6.1Solid cylinder arrangement to push out test

Fig 4.6.2 Solid cylinders used to transfer load only on concrete infill

- Solid steel cylinder is placed in between loading frame and specimen as shown in Fig 4.6.1 so that the load applied is only on the concrete surface.
- Once the specimen is fixed, a initial load of 5KN is applied so the there is no initial false settlement which is mainly due the loose concrete in the column.
- And to the loading head dial gauge is fixed as shown in figure to record the slip of concrete.

Fig 4.6.3 Arrangement dial gauge

- After that initial loading, load on the concrete infill is considered as zero and dial gauge of accuracy is considered as 0.01 .
- Load is increased constantly and 0.2 KN/s of load is applied on the concrete infill.
- To record the slip of concrete, two cameras are placed to record slip accuracy of 0.01mm and loading with 0.2KN/sec accuracy.
- Once the bond in CFST fails, increased of 2KN/min is applied until a 10mm settlement reached.
- To know the bond behavior of CFST load vs slip graph is drawn.

Fig 4.6.4 Specimen after push out test

5. Tabulation of Results

Test group	Specimen label	D	T	L/D	Pt	Ʈu
1	D33-L12-M40TOP	33.4	2	12	98	3.268
	D33-L14- M40TOP	33.4	3	14	108	3.368
	D33-L16- M40TOP	33.4	4	16	114	3.515
2	D42-L12- M40TOP	42.2	2	12	166	3.216
	D42-L14- M40TOP	42.2	3	14	185	3.281
	D42-L16- M40TOP	42.2	4	16	198	3.369
3	D48-L12- M40TOP	48.3	2	12	225	3.169
	D48-L14- M40TOP	48.3	3	14	248	3.224
	D48-L16- M40TOP	48.3	4	16	271	3.318
4	D33-L12-M40MID	33.4	2	12	115	3.835
	D33-L14- M40MID	33.4	3	14	127	3.960
	D33-L16- M40MID	33.4	4	16	130	4.018
5	D42-L12- M40MID	42.2	2	12	193	3.731
	D42-L14- M40MID	42.2	3	14	217	3.852
	D42-L16- M40MID	42.2	4	16	234	3.982
6	D48-L12- M40MID	48.3	2	12	259	3.712
	D48-L14- M40MID	48.3	3	14	288	3.732
	D48-L16- M40MID	48.3	4	16	314	3.864
7	D33-L12-M40BOTTOM	33.4	2	12	326	4.601
	D33-L14- M40BOTTOM	33.4	3	14	357	4.643
	D33-L16- M40BOTTOM	33.4	4	16	388	4.782
8	D42-L12- M40BOTTOM	42.2	2	12	319	4.481
	D42-L14- M40BOTTOM	42.2	3	14	349	4.517
	D42-L16- M40BOTTOM	42.2	4	16	379	4.631
9	D48-L12- M40BOTTOM	48.3	2	12	307	4.410
	D48-L14- M40BOTTOM	48.3	3	14	349	4.402
	D48-L16- M40BOTTOM	48.3	4	16	369	4.512

Table 5.1 results of bond strength between steel tube and concrete

WHERE

D=Steel tube diameter in mm

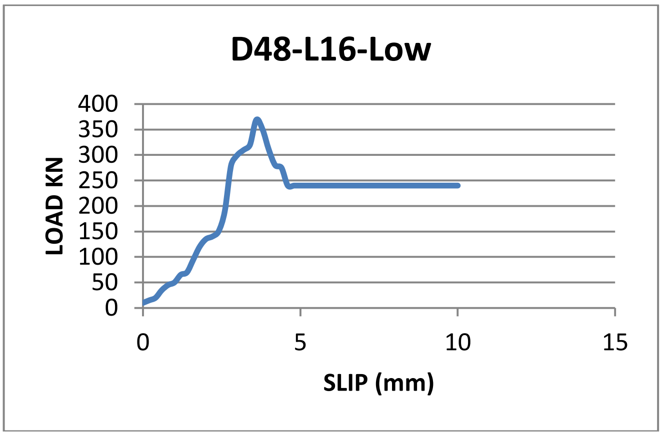
T=Steel tube thickness in mm

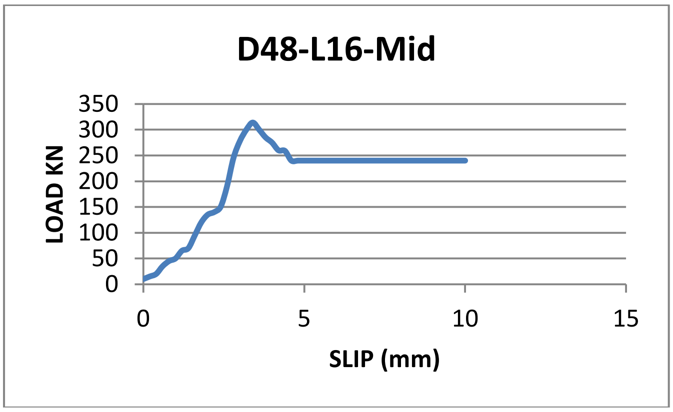
L/D= Ratio of length by depth

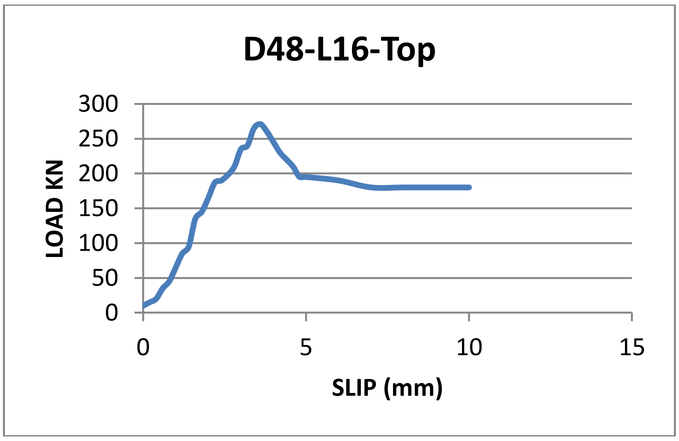
Pt= Shear faiLure load or Ultimate Bond failure or shear failure load

Ʈu =Bond strenGth in N/mm2

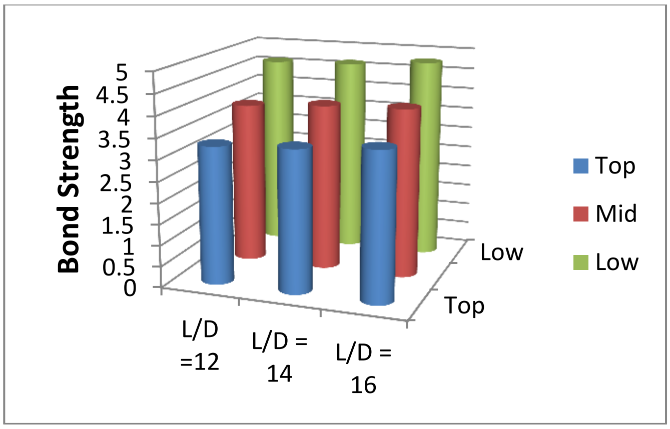
5.2 Load slip curve

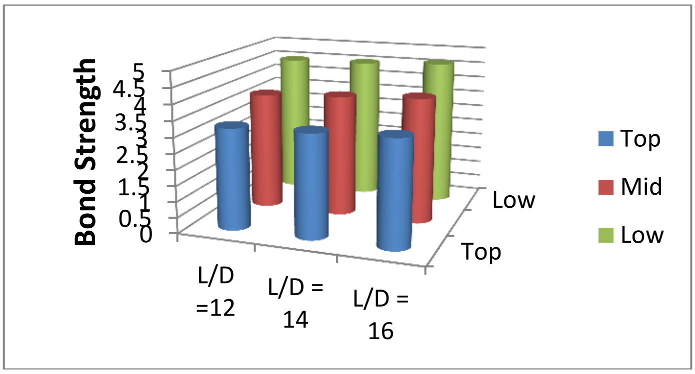


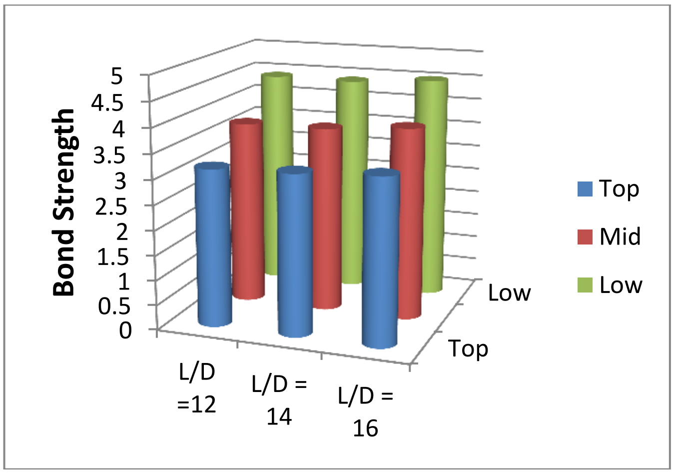




5.3 Comparison of Bond Strength in Internal Ring Welded CFST at Different Positions







By looking into the graphs above we can conclude that CFST with internal rings welded have higher bond strength. And even bond strength varies with positioning of welding internal ring, internal ring welded in the bottom position has higher bond strength than that of positioning rings in middle and top.

CONCLUSIONS

This experimental investigation is conducted on Concrete Filled Steel Tubes (CFST) and the steel tube used is Galvanized Iron (G,I) tube with internal rings welded inside the steel tube in top, middle and bottom position with respect to length of tube. And M40 Concrete is used as the infill material. A total number of 27 specimens were prepared on the basis of "Taguchi's Method" with varying parameters like diameter, thickness, slenderness ratio and positioning of internal rings. By conducting push out test bond behaviour of CFST is studied. And following conclusions were drawn

- Bond strength of the CFST is varying with varying slenderness ratio, bond strength increases with increase in slenderness ratio.
- Galvanized iron pipes were replaced in the place of mild steel tube for preparation of CFST specimens and came to conclusion that bond strength in G.I pipe is less than that of a mild steel because of its smooth internal surface.
- Internal ring is welded inside the G.I tube and with using internal ring bond strength is improved by this results we can conclude that with welding internal rings bond strength is improved.
- Bond strength of internal rings welded CFST varies with varying position of internal ring welded. Bond strength of a CFST with internal ring welded in the middle(L/2) is greater than ring position at top(L/3) and the internal ring position at the bottom(L/3 from bottom) is greater than the ring welded at middle(L/2).
- So by conducting this experiment we conclude that internal ring welded at the bottom position of the CFST has more bond strength than that of positioning rings at top or bottom position of the tube.

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" publicationElsevierJournalofConstructionalSteelResearch,17September2010,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. Xiushu Qu, "Push-out tests and bond strength of rectangular CFST columns" publication ASCE, 2015

8. Zhong Tao, "Bond behavior in concrete-filled steel tubes" publication Elsevier Journal of Constructional SteelResearch,12January2016,http://dx.doi.org/10.1016/j.jcsr.2015.12.030

9. 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

10. 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

11. 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

12. 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