EXPERIMENTAL INVESTIGATION ON FLEXURAL BEHAVIOUR OF HOLLOW STEEL TUBE BEAMS AND CONCRETE FILLED STEEL TUBE BEAMS

Mr. Nikhil B. Khandge[1], Dr. S. B. Kandekar[2]

[1] *PG Student, Department of Civil Engineering, Amrutvahini College Of Engineering, Sangamner, Maharashtra, India*
[2] *Associate Professor, Department of Civil Engineering, Amrutvahini College Of Engineering, Sangamner, Maharashtra, India*

ABSTRACT

Concrete filled steel tubular (CFST) members have several benefits compared with the normal structural member manufactured of steel or concrete. One in all the most beneficial is the combination between the steel tube and concrete. Concrete slow down the steel tube's buckling, other benefits of the concrete filled steel tubular sections is having high strength having less cross sectional area compared with reinforced concrete system also having excellent seismic resistant properties and it improved fire resistance of the structure. Whereas the steel tube reach the concrete and thereby will increases the concrete's strength. CFSTs are economical compared to reinforced concrete and allow fast construction as a result of the steel tube is formwork and reinforcement to the concrete fill, negating the requirement for either. The deformation capability of the system is enhanced by the combined action of the concrete fill with the hollow, ductile steel tube. The concrete fill considerably will increase inelastic deformation capacity and also the compressive stiffness and cargo capability of the CFST member. In building construction concrete poured steel tubes are very largely used for columns in together with steel or RC beam. during this work totally six specimens were tested out of that a pair of specimens were empty and remaining four specimens were concrete filled with totally different bonding techniques. As it is cast-in-situ and prefab time consumption are less in construction observe and because of confinement a lot of malleability is anticipated that is extremely helpful in earthquake resistant structures. Load carrying capability of concrete filled steel tubular sections nearly doubled compared with empty steel tubular sections. The maximum load was taken by the specimen CFSTBWDSC – CH that was 165 KN, it's going to be owing to presence of diagonal shear connection within the tube.

Keyword: - *CFST Members, Flexural Strength, Composite Beams, Various Bonding Methods.*

---

1. INTRODUCTION

Concrete-filled steel hollow sections (CFSHS) area unit wide utilized within the development trade for the past few years because of edges of blending 2 constituent materials. The steel hollow section in-filled with concrete has higher strength and bigger stiffness than the quality steel section and steel RC system. It are often additional economical to use CFSHS columns for the development of building structures as a result of the convenience of fabrication and light-weight [1] Concrete-filed steel tubes -CFSTs area unit utilized in several structural applications together with columns, supporting platforms of offshore structures, roofs of storage tanks, bridge piers, piles, and columns in seismic zones. Concrete-filed steel box columns provide wonderful structural performance, like high strength, high plasticity and enormous energy absorption capability and are wide used as primary axial load carrying members in high-rise buildings, bridges and offshore structures. Application of the CFST conception will result in overall savings of steel compared with standard steel systems. In CFST composite construction steel tubes also are used as permanent formwork and to produce well-distributed reinforcement. [2] Composite members consisting of circular steel tubes full of concrete area unit extensively utilized in structures involving terribly giant applied moments, notably in zones of high seismicity.

Composite circular concrete crammed tubes are used progressively as columns and beam-columns in braced and unsupported frame structures additionally; concrete filling is wide utilized in retrofitting of broken steel bridge piers once the earthquake in Japan and also the Northridge earthquake within the USA. The CFT structural members have variety of distinctive benefits over standard steel RC members. CFT members give wonderful seismic resistance in 2 orthogonal directions further pretty much as good damping characteristics. These members even have wonderful physical phenomenon behavior underneath cyclic loading, compared with hollow tubes. The 2 main kinds of composite column area unit the steel-reinforcement concrete beam, that consists of a steel section cased in strengthened or unreinforced concrete, and also the concrete-filled steel hollow (CFST) beams, that consists of a steel tube full of concrete.

CFST beams have several benefits over steel reinforcement concrete beams. The most important edges of concrete filled beams are as follows:

- Steel beam acts as permanent and integral formwork.
- The steel beam provides external reinforcement.

1.1 Types of CFT Configuration

Following Sections are easily available on construction site or in market:

1. Circular concrete filled tubes (CCFT)
2. Rectangular concrete filled tubes (SRC)
3. Structural hollow section (SHS)
4. Rectangular hollow section (RHS)
5. Concrete filled steel section (CHS)

1.2 Objectives

- To determine the Flexural Strength of empty steel sections and concrete poured steel sections.
- To check result of various bonding techniques on flexural strength of concrete poured steel sections.
- To check the behavior, failure and crack pattern of in poured concrete.

2. LITERATURE RIVIEW

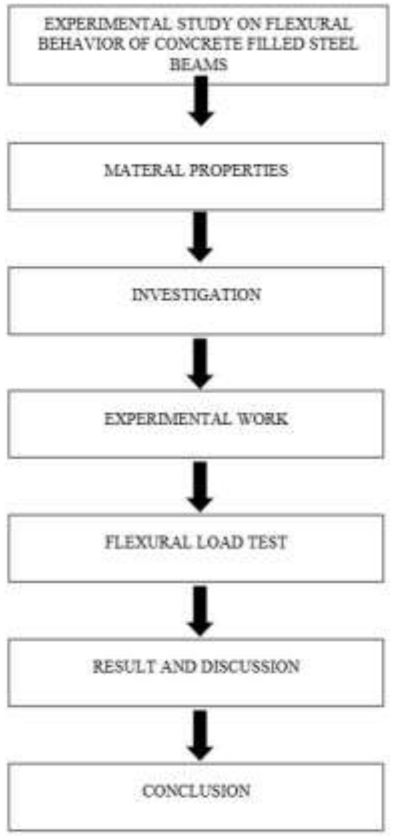
1] Manojkumar V. Chitawadagi et.al. (2009), Studied the strength deformation behavior of circular steel tubes filled with different grades of concrete under flexure is presented. The effects of steel tube thickness, the cross sectional area of concrete, strength of in-filled concrete and the confinement of concrete on moment capacity and curvature of Concrete Filled steel Tubes (CFTs) are examined he conclude that A substantial increase in the moment of resistance and the corresponding curvature of all the hollow sections used in the experimental investigation are observed due to concrete filling and the CFT specimens exhibited a higher ductility than the hollow sections. An increase in the wall thickness of the steel tube increases the moment of resistance and ductility of both the hollow and CFT samples. An increase in strength of infilled concrete for a given wall thickness of a CFT specimen, does not help in increasing the moment carrying capacity to a great extent.

2] Arivalagan et.al. (2009), Presented the study of 'Energy Absorption Capacity of Composite Beams Ultimate strength capacity of a square hollow section filled with fibrous foamed concrete'. A brief experimental research was conducted in the experimental work; the moment capacity and the behavior of unfilled and concrete filled hollow sections were noted down. The sections were subjected to cyclic reversible loading. Here the filler materials were of two types, normal concrete and fly ash concrete. The effect of filler materials used, slenderness of section, load vs deflection, moment strain curve, ductility, stiffness degradation and energy absorption of concrete –filled RHS beams were studied. Totally 9 specimens were considered. 3 were rectangular hollow sections, 3 were concrete filled steel tubes and the other six were fly ash filled steel tubes. The sizes of RHS section were 100x50x3.2 mm. They concluded that the increase in ultimate moment capacity was due to the filler material strength. The ultimate moment capacity for concrete-filled RHS members based on CIDECT standard was found to be in good agreement with the experimental moment capacity of Rectangular hollow steel beams filled with normal concrete and fly ash concrete. Experimental results prove that void filling increases energy absorption capacity of the section and also reduces the stiffness degradation. It also increases the ductility factor. The study showed that fly ash concrete could be used as infill material for a satisfactory mechanism.

3] wie-Min Gho et.al. (2004), Presented ‘Flexural behavior of high-strength rectangular concrete-filled steel hollow sections. In this experimental work the behavior of concrete filled steel tubes under pure bending was studied. Twelve rectangular hollow tubes with different sizes 150x150; 200x150 and 250x150 mm were used. High strength concrete (56.3MPa to 90.9MPa) was used as infill for the hollow tubes for composite action. Yield stresses of hollow tubes were 438Mpa, 495Mpa and 409Mpa respectively. They concluded that the post yielding behavior was good enough with ductility performance. A comparison of the experimental values and values calculated from design formulas in EC4, ACI and AISC were made. The codes underrated moment capacities of the specimens considered. EC4 provides better moment carrying capacity than ACI and AISC and the difference is about 11%. THE ACI and AISC codes underrated the flexural strength of the specimens by 15 and 18%, respectively. On evaluating the codes with the collected data, test results show an increase in flexural strengths by 9, 12 and 15%, respectively.

4] Wheeler and Bridge (2003), in the experimental work, the change in flexural stiffness decreases with increase in diameter of the section. In the experimental work by Shawkat et al the concrete filled tubes which had larger depth to span ratios, there was cracking on tension side of the specimens and multiple cracks at the mid span. This effect was noted down by Wheeler and Bridge in their work. Both the issues emphasizes that size of the specimen’s effect on flexural behavior of concrete filled tubular members [1]. In the experimental work carried out, the moment capacity and the behavior of unfilled and concrete filled hollow sections were noted down. The sections were subjected to cyclic reversible loading. Here the filler materials were of two types, normal concrete and fly ash concrete. The effect of filler materials used, slenderness of section, load vs deflection, moment strain curve, ductility, stiffness degradation and energy absorption of concrete –filled RHS beams were studied. Totally 9 specimens were considered. 3 were rectangular hollow sections, 3 were concrete filled steel tubes and the other six were fly ash filled steel tubes. The sizes of RHS section were 100x50x3.2 mm. They concluded that the increase in ultimate moment capacity was due to the filler material strength. The ultimate moment capacity for concrete-filled RHS members based on CIDECT standard was found to be in good agreement with the experimental moment capacity of Rectangular hollow steel beams filled with normal concrete and fly ash concrete. Experimental results prove that void filling increases energy absorption capacity of the section and also reduces the stiffness degradation. It also increases the ductility factor. The study showed that fly ash concrete could be used as infill material for a satisfactory mechanism [2]. In this experimental work the behavior of concrete filled steel tubes under pure bending was studied. Twelve rectangular hollow tubes with different sizes 150x150; 200x150 and 250x150 mm were used. High strength concrete (56.3MPa to 90.9MPa) was used as infill for the hollow tubes for composite action. Yield stresses of hollow tubes were 438Mpa, 495Mpa and 409Mpa respectively. They concluded that the post yielding behavior was good enough with ductility performance. A comparison of the experimental values and values calculated from design formulas in EC4, ACI and AISC were made. The codes underrated moment capacities of the specimens considered. EC4 provides better moment carrying capacity than ACI and AISC and the difference is about 11%. THE ACI and AISC codes underrated the flexural strength of the specimens by 15 and 18%, respectively. On evaluating the codes with the collected data, test results show an increase in flexural strengths by 9, 12 and 15%, respectively [3]. In this experimental work the behavior of concrete filled steel tubes under pure bending was studied. Twelve rectangular hollow tubes with different sizes 150x150; 200x150 and 250x150 mm were used. High strength concrete (56.3MPa to 90.9MPa) was used as infill for the hollow tubes for composite action. Yield stresses of hollow tubes were 438Mpa, 495Mpa and 409Mpa respectively. They concluded that the post yielding behavior was good enough with ductility performance. A comparison of the experimental values and values calculated from design formulas in EC4, ACI and AISC were made. The codes underrated moment capacities of the specimens considered. EC4 provides better moment carrying capacity than ACI and AISC and the difference is about 11%. THE ACI and AISC codes underrated the flexural strength of the specimens by 15 and 18%, respectively. On evaluating the codes with the collected data, test results show an increase in flexural strengths by 9, 12 and 15%, respectively.

3. RESEARCH METHODOLOGY



3.1 Experimental Investigation

The main aim of this project is to find out the flexural strength of empty steel sections and concrete poured steel sections with varied bonding ways Subjected to the flexural loading. The materials utilized in this investigation and their properties square measure in brief mentioned below.

3.2 Mix Design

Mix Design for M20 grade concrete by Indian Standard recommended of concrete mix design as per design code 10262-2009.

Description	Cement	Fine Aggregate	Coarse Aggregate	Water
Mix proportion (by weight)	1	2.51	3.53	0.50
Quantities of materials (in kg/m^3)	300	754	1059	150

4. EXPERIMENTAL WORK

4.1 Preparation

This experiment was carried to look at the flexural behavior of empty steel beams and concrete poured steel beams. Main objective was to search out the flexural strengths of empty and concrete poured steel beams. Total VI range of specimens used in this work. (III circular and III C Channel Sections connected face to face to make a square section (100mmX100mm) all specimens were of uniform length 1200mm area unit used. CR denoted for Circular section and CH denoted for Channel Sections connected face to face to make a square section.

4.1.1 Specimen Details

Empty Steel Tube (EST) - 02 Number (1 Circular and 1 Square section) (C Channel Sections connected face to face to make a square section)
Concrete Filled Steel Tube Beam with Sand Blasting inner surface (CFSTBWSB) - 02 Number. (1 Circular and 1 Square section)
Concrete Filled Steel Tube Beam With 10mm HYSD bar as Diagonal Shear Connection (CFSTBWDSC) - 02 Number. (1 Circular and 1 Square section)

4.1.2 Shear Connectors

Basically for two numbers of specimens, two numbers of 10mm diameter bars were welded at the both ends of tubes diagonally to make a shear connector.

Figure: Welding of steel bars.

4.1.3 Sand Blasting

In sand blasting, we have totally six numbers of specimens from that two specimens are used for sand blasting, first one is square section (Two channel sections connected face to face to make square section) & second one is circular section. For sand blasting inner surface were chapped to develop bond between steel & concrete with epoxy adhesive (araldite) & sand particles of grain size holding on 4.75mm sieve. Initially inner surface was clean from dirt & corrosion particles then later of araldite was applied on inner surface then sand articles were trickle on surface. Then steel sections were left for 24 hours undisturbed.

Figure: Sand Blasting of Specimen.

4.1.4 Curing

Concrete poured tubes were cured by immersing one finish of the tube in water and constant application of water at the opposite finish. Curing is done on construction site for 28 days.

4.1.5 Concreting

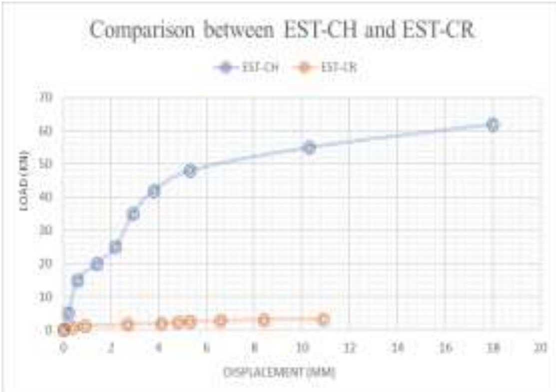
Out of six specimens, four specimens were poured with M20 Grade of concrete on the construction site.

4.2 Test Setup

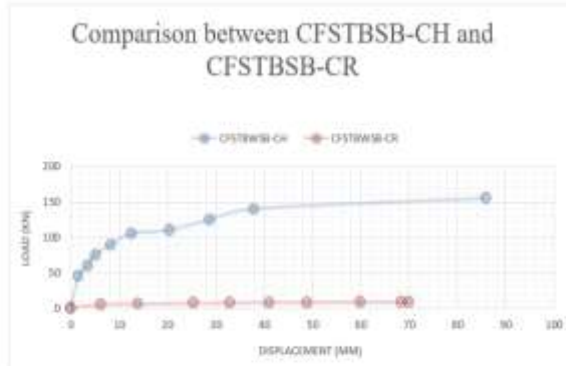
All specimens were tested under single point static loading as simply supported condition with a span of 1200 mm. All specimens were tested in Universal Testing machine (UTM) of capacity 1000KN. The load was applied at the rate of 1KN/minute. Deflections were noted down at every 1 KN intervals. Load was applied up to a point when the needle comes back and final load was noted down as load of the beam. To compare all specimens, load, deflection and allowable deflection is tabulated and presented graphically. Dial gauge was used to measure the deflection at mid span of the beam.

5. RESULT AND DISCUSSION

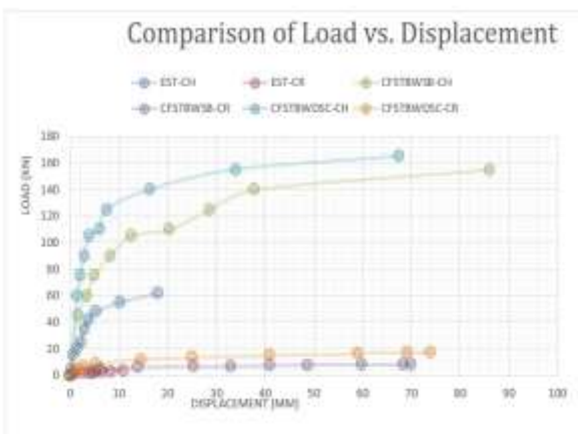
This experimental work was conducted under the universal testing machine to ascertain flexural behavior of empty steel tube beams and concrete poured steel tube beams. The main objective of the experiment was to check the flexural strength of different steel beam sections with and without concrete poured and also for the study of different bonding techniques of composite beams under flexural loading condition. Total six specimens used in this work. All specimens were of uniform length of 1200mm. during this work we tend to endure flexural strength check on three circular sections and three square sections fashioned by connecting six numbers of C form channel sections face to face. Behavior of the CFST's beams has been studied with reference to displacement characteristics within the flexural direction. The load carrying capability because of the steel confinement with steel shear connector, impact was analyzed. M20 grade of concrete is employed for four specimen of length 1200mm with constant diameter 75 mm for Circular section and 100mmX100mm for square section were tested. Table represents the test results of load and corresponding displacement of the CFST specimens severally. The results are noted down in table format and from the table graph was plotted. it shows load vs. displacement. Within the graph load is shown on y axis and displacement is shown on x axis. All graphs provide a linear and parabolic nature of line. Table represents comparison of load and displacement for various CFST's sample specimens. Graph shows load vs. displacement curve for various CFST's sample specimens.



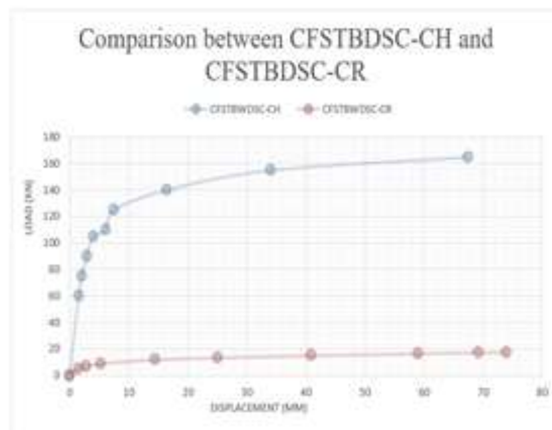
Graph: Comparison between EST-CH and EST-CR



Graph: Comparison between CFSTBSB-CH and CFSTBSB-CR



Graph: Comparison of Load vs. Displacement.



Graph: Comparison between CFSTBDSC-CH and CFSTBDSC-CR

Displacement (mm)	Load (KN)					
	EST-CH	EST-CR	CFSTBWSB-CH	CFSTBWSB-CR	CFSTBWDSC-CH	CFSTBWDSC-CR
0-10	48	3	90	5	125	9
10-20	62	3.2	105	6.10	140	12
20-30	-	-	125	6.80	150	13.5
30-40	-	-	140	7.20	155	14.5
40-50	-	-	148	7.80	160	15
50-100	-	-	155	8.60	165	17.50

6. CONCLUSION

- Load carrying capacity of CFSTBWSB-CH to bear permissible displacement is 58.12% larger than EST-CH.
- Load carrying capacity of CFSTBWDSC-CH to bear permissible displacement is 60% larger than EST-CH.
- Load carrying capacity CFSTBWSB-CR to bear permissible displacement is 54% larger than EST-CR
- Load carrying capacity of CFSTBWDSC-CR to bear permissible displacement is 71.50% greater than EST-CR.
- CFSTBWDSC takes maximum range of load as compared with the other specimens; it's going to be due to presence of diagonal shear connector (welded bars) inside the tube.
- No crack pattern found at the edges of the beams and also there was no slip of concrete at ends of beams. From the experiment it shows bonding between steel and concrete is strong.
- From the above experiment we can conclude that the concrete filled steel beams having almost double capacity to take a load under flexural loading compared to empty steel tube beams.

7. REFERENCES

[1] Dr. Andrew Wheeler, Prof. Russell Bridge, “Flexure Behaviour of Concrete Filled Thin-Walled Steel Tubes with Longitudinal Reinforcement”, School of Engineering; University of Western Sydney Locked Bag (2003), 99-130.
[2] Arivalagan and Kandasamy, “Energy Absorption Capacity of Composite Beams, Journal of Engineering Science and Technology Review”, 2 (1), (2009), pp145-150.
[3] Aoyu Jiang, JuChen, Wei-liangJin, “Experimental Investigation and Design of Thin Walled Concrete Filled Steel Tubes subject To Bending”, Thin-Walled Structures, 63, (2013), 44–50.
[4] M. Elchalakani, X.L. Zhao, R.H. Grzebieta, “Concrete-filled circular steel tubes subjected to pure bending” Journal of Constructional Steel Research 57 (2001) 1141–1168.
[5] Manojkumar V. Chitawadagi, Mattur C. Narasimhan, “Strength Deformation Behaviour of Circular Concrete Filled Steel Tubes Subjected To Pure Bending”, Journal of Constructional Steel Research, 65, (2009), 1836 – 1845.
[6] Wie-Min Gho, Dalin Liu, “Flexural Behaviour of High-Strength Rectangular Concrete-Filled Steel Hollow Sections”, Journal of Constructional Steel Research, 60, (2004), 1681–1696.
[7] LRFD-AISC 1999 – Load and Resistance Factor Design specification for structural steel buildings. Chicago: American Institute of Steel Construction 1999.
[8] Mohamed Elchalakani, Xiao-Ling Zhao, Raphael Grzebieta, “Concrete-Filled Steel Circular Tubes Subjected To Constant Amplitude Cyclic Pure Bending”, Engineering Structures, 26, (2004), 2125–2135
[9] Ali I. Tayeh “Flexural Behavior of Concrete-Filled Steel Hollow Sections Beams” Dean of College of Applied Engineering and Urban Planning.
[10] Arivalagan Soundararajan, “Flexural behaviour of concrete -filled steel hollow sections beams” Journal of Civil Engineering and Management ISSN: 1392-3730 (Print) 1822-3605 (Online) Journal homepage: http://www.tandfonline.com/loi/tcem20
[11] E K Mohanraj, “SEISMIC BEHAVIOUR OF CONCRETE FILLED STEEL TUBULAR BEAMS” 35th Conference on OUR WORLD IN CONCRETE & STRUCTURES: 25 - 27 August 2010, Singapore Article Online Id: 100035039.
[12] IS 4923:1997 – Code of Hollow steel sections for structural use – Specification. Second revision.
[13] BS5400-1979 – British Standard Institute: BS5400. Part 5, Concrete and composite bridges, 1979.
[14] IS 456:2000 – Plain and Reinforced Concrete Code of Practice.
[15] IS 1161:1998 – Code of Steel tubes for structural purposes – Specification. Fourth Revision.