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Experimental Study on Flexural Behavior of Concrete Filled Steel Tube Beam

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***Abstract*— Concrete filled steel tubes (CFST) member have many advantages compared with the ordinary structural member made of steel or reinforced concrete. One of the main advantages is the interaction between the steel tube and concrete. Concrete delays the steel tube's local buckling, whereas the steel tube confines the concrete and thereby increases the concrete's strength. CFSTs are economical and permit rapid construction because the steel tube serves as formwork and reinforcement to the concrete fill, negating the need for either. The deformation capacity of the system is increased by the combined action of the concrete fill with the thin, ductile steel tube. The concrete fill significantly increases inelastic deformation capacity and the compressive stiffness and load capacity of the CFST member. In building construction concrete filled steel tubes are very widely used for columns in combination with steel or reinforced concrete beam. In this work totally 9 specimens will tested out of which 3 specimens were empty steel tubes and remaining 6 specimens were concrete filled with different bonding techniques. Comparison of experimental flexural stiffness with existing codes, such as AIJ-1997, BS5400-1979, EC4-1994, and LRFD-AISC-1999.**

Keywords*— *Concrete fill Steel Section, flexural Behavior, different bonding techniques.)

I. INTRODUCTION

Concrete-filled steel hollow section (CFSHS) columns are widely used in the construction industry for the past few years owing to advantages of combining two constituent materials. The steel hollow section in-filled with concrete has higher strength and larger stiffness than the conventional structural steel section and reinforced concrete. It can be more economical to use CFSHS columns for the construction of building structures because of the ease of fabrication and lightweight [1]. Concrete-filed steel tubes -CFSTs are used in many structural applications including columns, supporting platforms of offshore structures, roofs of storage tanks, bridge piers, piles, and columns in seismic zones. Concrete-filed steel box columns offer excellent structural performance, such as high strength, high ductility and large energy absorption capacity and have been widely used as primary axial load carrying members in high-rise buildings, bridges and offshore structures. Application of the CFST concept can lead to overall savings of steel in comparison with conventional structural steel systems. In CFST composite construction steel tubes are also used as permanent formwork and to provide well-distributed reinforcement [2] Composite members consisting of circular steel tubes filled with concrete are extensively used in structures involving very large applied moments, particularly in zones of high seismicity. Composite circular concrete filled tubes (CFT) have been used increasingly as columns and beam-columns in braced and unbraced frame structures. Their use worldwide has ranged from compression members in low-rise, open floor plan construction using cold-formed steel circular or rectangular tubes filled with precast or cast-in-place concrete, to large diameter cast-in-place members used as the primary lateral resistance columns in multi-story buildings. In addition, concrete filling is widely used in retrofitting of damaged steel bridge piers after the earthquake in Japan and the Northridge earthquake in the USA. The CFT structural members have a number of distinctive advantages over conventional steel reinforced concrete members. CFT members provide excellent seismic resistance in two orthogonal directions as well as good damping characteristics. These members also have excellent hysteresis behavior under cyclic loading, compared with hollow tubes [5]

II. OBJECTIVES

The objectives of present study are:

•To find out the ultimate flexural strengths of empty and concrete filled steel tube beam.

•To check effect of different bonding technique on flexural strength of concrete filled steel tube beam.

•To check the behavior, failure and crack pattern of in filled concrete.

•Validate experiment result with AIJ-1997, BS5400-1979, EC4-1994, LRFD-AISC-1999.

III. LITERATURE REVIEW

1] wie-Min Gho et.al. (2004) :-

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 behaviour 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.

2] Arivalagan et.al. (2009):-

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 behaviour 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, momentstrain 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 was 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] Andrew Wheeler et.al. (2015) –

Andrew Wheeler et.al. (2015) present Flexure Behavior of Concrete Filled Thin-Walled Steel Tubes with Longitudinal Reinforcement. Tests were carried on the tube specimens and the flexural stiffness of specimens were measured. Additionally in the experimental work, the change in flexural stiffness decreases with increase in diameter of the section. 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 emphasises that size of the specimens effect on flexural behaviour of concrete filled tubular members.

4] Manojkumar V. Chitawadagi et.al. (2009) -

Manojkumar V. Chitawadagi et.al. (2009) - The strength deformation behaviour 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 in-filled concrete for a given wall thickness of a CFT specimen, does not help in increasing the moment carrying capacity to a great extent.

5] M. Elchalakani et.al. (2001) -

M. Elchalakani et.al. (2001) presents an experimental investigation of the flexural behaviour of circular CFT subjected to large deformation pure bending. In general, void filling of the steel tube enhances strength, ductility and energy absorption especially for thinner sections.

6] Lin-Hai Han et.al. (2003) –

Lin-Hai Han (2003) develop a mechanics model that can predict the behaviour of concrete-filled hollow structural section beams. To develop formulas for the calculation of the moment capacity of the concrete-filled HSS beams, such formulas should be suitable for incorporation into building codes.

7] Naveena Treesa et.al. (2016) –

Naveena Treesa (2016) From the studies conducted on three different beams it can be seen that a concrete filled steel tubular section with reinforcement resists tension, bending moments and also increases load carrying capacity when compared to a normal reinforced concrete and steel section of similar dimensions.

IV. MATERIALS AND METHODS

This experimental work was conducted to check the flexural behaviour of empty steel tube and concrete filled steel tube beams. Main objective was to find out the ultimate flexural strengths of empty and concrete filled steel tube beams. All specimens were of uniform cross section 96mmx48mm of thickness 3.2mm and of length 1000mm. Steel tubes were confirming to Indian Standard code IS 4923 : 1997. All specimens were tested under two point loading with simple supports in Universal Testing Machine (UTM) of capacity 200 tonnes.

The material required for concrete are tested in laboratory before use it for making concrete. In this experiment work M25 grade concrete is used.

A. *Material Used and Material Properties*

Cement:

The cement used in this experimental work is "53 grade Ordinary Portland Cement". No doubt the laboratory test have been done at the factory before production come from factory. But cement may go bad during transportation and storage prior to it's use in Work. All properties of cement are tested by referring IS 12269 - 1987 Specification for 53 Grade Ordinary Portland Cement. List of Laboratory test conducted on cement are listed below;

1. Fineness of cement (residue on IS sieve No. 9)
2. Standard consistency of cement
3. Setting time of cement (Initial & Final setting time)
4. Compressive strength of cement (7 & 28 days)
5. Specific Gravity

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Aggregate:

Aggregates influence the properties of concrete/mortar such as water requirement, cohesiveness and workability of the concrete in plastic stage, while they influence strength, density, durability and permeability, surface finish and colour in hardened stage. Natural sand from Banganga River confirming to IS 383-1970 is used. Crushed black trap basalt rock of aggregate size 12mm down was used confirming to IS 383-1970.

The properties of aggregate are tested by referring IS 383-1970 Specification for Coarse and Fine Aggregates from Natural Sources for Concrete. List of test conducted on aggregate are listed below;

1. Specific Gravity
2. Surface Moisture Content & water Absorption
3. Sieve Analysis
4. Fineness Modulus

Hallow Section:

Steel hallow section of size 96mm X 48mm X 3.2mm of 1m length is used for this experimental work. Steel tube confining to Indian Standard code IS 4923 : 1997. Steel tube available in 6m length in local market. It cut into 1m piece, from retailer following data will available;

Yield stress fy = 270 N/mm^2

Ultimate stress fu = 410 N/mm^2

Modulus of Elasticity E = 2.05×10^5 N/mm^2.

Fig. 1 Hallow Steel Section

V. RESULT AND DISCUSSION

Preparation of Specimen & Testing:

This experimental work was conducted to check the flexural behavior of empty steel tube and concrete filled steel tube beams. Main objective was to find out the ultimate flexural strengths of empty and concrete filled steel tube beams. Total 12 number of specimen used in this work. All specimen were of uniform cross section of size 96mm X 48mm X 3.2mm and length 1000mm are used.

The specimen detail are as follow;

1. Empty Steel Tube (EST) - 03 Number
2. Concrete Filled Steel Tube Beam (CFSTB) - 03 Number.
3. Concrete Filled Steel Tube Beam with Sand Blasting inner surface (CFSTBWSB) - 03 Number.
4. Concrete Filled Steel Tube Beam With 10mm HYSD bar as Diagonal Shear Connection (CFSTBWDSC) - 03 Number.

Sand Blasting of Specimen:

For 3 number of specimens, inner surface of tube were roughed to develop bond between bond between steel and concrete with epoxy resin araldite and sand particles of grain size retaining on 4.75mm sieve. First inner surface was cleaned for dust and corrosion particles then a layer of Araldite was applied on inner surface and then sand particles were sprinkled on that surface. Then the steel tube was left for 24 hours undisturbed.

Welding of Shear Connectors:

For 3 numbers of specimens, 2 numbers of 10mm diameter HYSD bars were welded at the ends of tubes diagonally as shear connector. End plugs were provided at one end of steel tubes to fill concrete from other side. Polythene sheet was used with araldite.

Fig. 2 Welding of Shear Connection

Concreting of Specimens:

Totally 9 specimens were filled with M25 grade of concrete. Concrete filled tubes were cured by immersing the tube in water for 28days.

Fig. 3 Concreting of Specimens

Test Setup:

All specimens were tested under two point static loading as simply supported condition with a span of 900 mm. All specimens were tested in Universal Testing machine (UTM) of capacity 200 tonnes. The load was introduced at the rate of 2 KN/minute. Deflections were noted down at every 2 KN interval. Load was applied up to a point when the needle comes back and final load was noted down as ultimate load of the beam. To compare all specimens, ultimate load, ultimate deflection and allowable deflection is tabulated and presented graphically.

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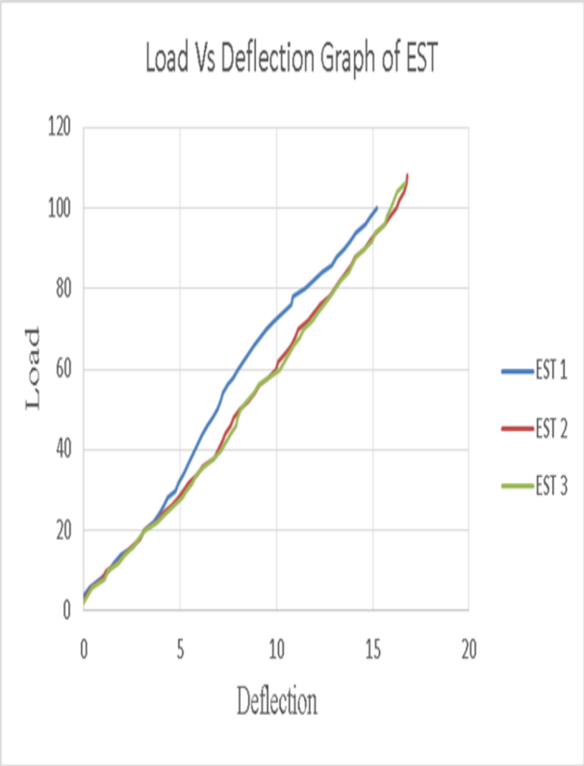

Fig. 4 Load Vs Deflection Graph of EST

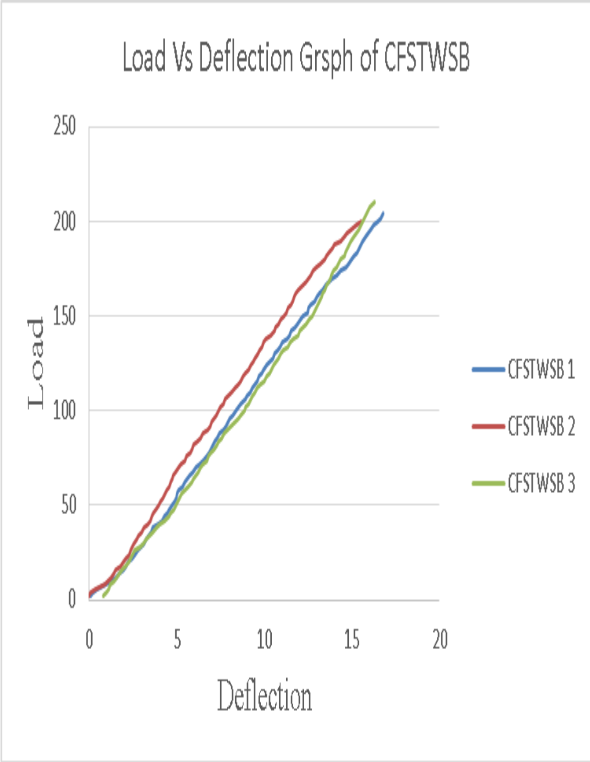

Fig. 6 Load Vs Deflection Graph of CFSTWSB

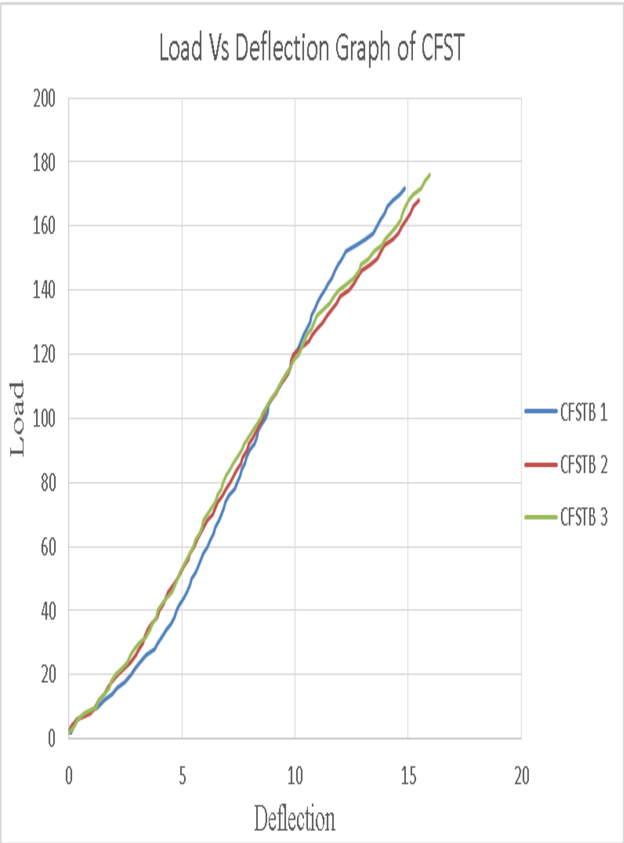

Fig. 5 Load Vs Deflection Graph of CFST

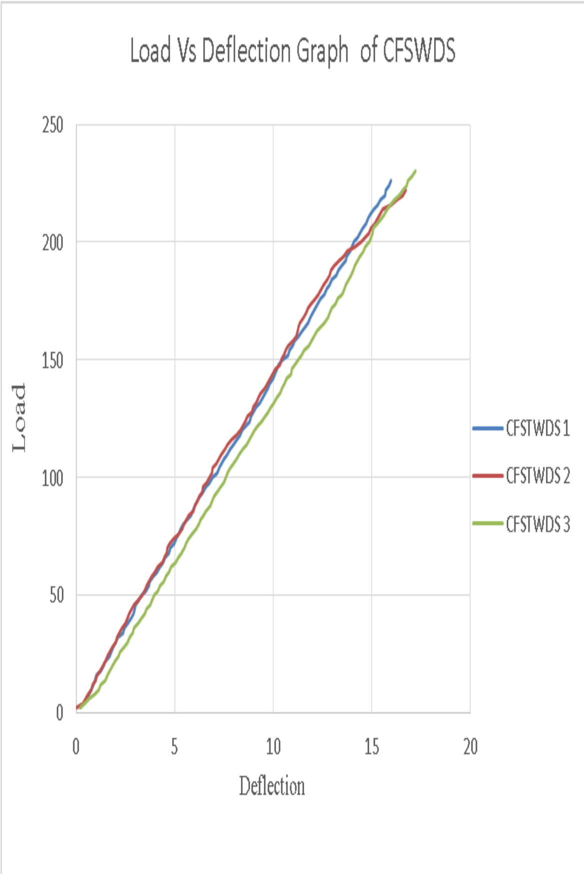

Fig. 7 Load Vs Deflection Graph of CFSTWDS

Summary of results obtained from experimental investigation sown in following table;

Sr.No.	Beam type	Ultimate load (KN)	Average ultimate load (KN)	Percentage of strength increase (%)	Ultimate experimental moment (KN-M)	Ultimate deflection (mm)
1	EST-1	100	104.67	-----	13.33	15.20
2	EST-2	108			14.4	16.80
3	EST-3	106			14.30	16.66
4	CFST-1	172	172.00	64.33	22.93	14.83
5	CFST-2	168			22.40	15.47
6	CFST-3	176			23.46	15.94
7	CFSTWSB-1	204	204.67	100	27.20	16.80
8	CFSTWSB-2	200			26.67	15.52
9	CFSTWSB-3	210			28.00	16.3
10	CFSTWDS-1	226	226.00	115.92	30.13	15.97
11	CFSTWDS-2	222			29.60	16.74
12	CFSTWDS-3	230			30.67	17.2

VALIDATION OF RESULT:

The experimental flexural stiffness (Kee) determined for the tested beams are compared with the flexural stiffness's (Ke) calculated from the expressions given in the codes and are listed.

AIJ-1997

Flexural Stiffness $K_e = E_s.\ I_s + 0.20\ E_c.\ I_c$

where E_s = 205,800 Mpa; $E_c = 21{,}000\ (f_c'/19.60)^{1/2}$ Mpa

BS 5400-1979

Flexural Stiffness $K_e = E_s.\ I_s + E_c.\ I_c$

where E_s = 206,000 Mpa; $E_c = 450.\ F_{cu}$ Mpa

EC 4-1994

Flexural Stiffness $K_e = E_s.\ I_s + 0.60\ E_c.\ I_c$

where E_s = 206,000 Mpa; $E_c = 9500\ (f_{ck} + 8)^{1/3}$ Mpa

AISC-LRFD-1999

Flexural Stiffness $K_e = E_s.\ I_s + 0.80\ E_c.\ I_c$

where E_s = 199,000 Mpa; $E_c = 4733\ (f_c')^{1/2}$ Mpa

CONCLUSIONS:

Flexural load carrying capacity of concrete filled steel tubes nearly doubled when compared to empty steel tubes.

Much difference between different bonding techniques was not seen in any of the specimen.

The maximum load was taken by the specimen CFSTBWDSC, it may be because of presence of diagonal shear connector inside the tube.

As concrete is confined by steel tube all around, sudden failure of beams may not occur.

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