"Bi-AXIAL LOAD CAPABILITY OF CFST COLUMNS WITH AND WITHOUT SHEAR CONNECTORS UNDER CYCLIC LOADING"

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Abstract – The concrete-filled steel tube (CFST) Structure offer numerous structural benefits, including high strength and fire resistance, favourable ductility and large energy absorption capacities. There is also no need for use of shuttering during concrete construction; hence, the construction cost and time are reduced. These advantage have been widely exploited and have led to extensive use of concrete filled tabular structure in civil engineering .some code of practice and local specification were developed to provide design guidance an experimental study on the behavior of concrete filled steel tubular columns (CEST) axially loaded in compression to failure. A Total 48 Specimens (24circular and 24 square) with difference in concrete grade of M20, M30 and M40 with and without shear connector (SC) were tested to investigate the load capacity and Connection under reversed Cyclic Loading. The chosen shear connector is of nominal diameter 6 mm and a length of 60mm. The results show that the use of high strength infill concrete is much more effective to get extra strength with same size of CFST column and use of shear connector increases the strength of column with the same size of column dimensions give a D/T ratio 19.33(circular) and 16.66(square) to avoid local buckling effect.24 specimens of the concrete filled columns are provided with shear connectors. High strength bolts (10.9) with smooth shank were used as shear connector.

KEYWORDS: Concrete filled Steel tube, shear connector, shear bearing capacity, reversed cyclic loading, and axial compression test.

1. INTRODUCTION

Composite member:

A steal-concrete composite column is a compression member, comprising either a concrete encased hot-rolled steel section or a concrete filled tubular section of hot-rolled and is generally used as a load-bearing member in composite framed hot-rolled steel and is generally used as a load e is no requirement to provide additional reinforcing steel for composite structure. There is no requirement to provide additional reinforcing steel for composite concrete Tubular sections, except for requirements of fire resistance where a composite column both the steel and concrete would resist the of interacting together by bond and friction. Supplementary external loading by interacting together by bonds reinforcement in the concrete encasement prevents excessive spelling of concrete both under normal load and fire conditions. In composite cost and fire conditions. In composite construction, the bare steel sections support the initial construction loads, including the weight of structure during construction. The Concrete is later cast around the steel section, or filled inside the tubular sections. The concrete and steel are combined in such a fashion that the advantages of both the materials are utilized effectively in composite column. The lighter weight and higher strength of steel permit the use of smaller and lighter foundations. The subsequent concrete addition enables the building frame to easily limit the sway and lateral deflections. With the use of composite columns along with composite decking and composite beams it is possible to erect high rise structures in an extremely efficient manner.There is quite a vertical spread of construction activity carried out simultaneously at any one time, with numerous trades working simultaneously

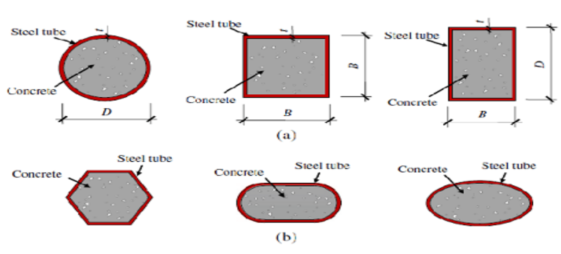


Fig No.1 Typical concrete filled steel tubes

BEHAVIOR OF CONCRETE FILLED STEEL TUBE CFST

Many studies have shown that the performance of a square concrete filled steel tube CFST is not good compare to its circular counterpart. This due to fact that a square steel tube could only provided less confining pressure to the concrete core **,**and its local buckling is more likely to occur.This fact has now been widely reflected in modern design code such as manual of steel construction .load and resistance factor design(LRFD),(AISC1984) and seismic provision for structural steel building (SISC1997).Design of composite steel and concrete structures.Eurocode4,ENV 1994-1-1(BSI1994),and recommendation for design and construction of concrete filled steel tube tabular structure (AIJ1997).Allowable width to thickness ratio for steel tube with square cross section is more restricted than that for circular one .an adequate stiffening measure for square CFST is highly desirable,such stiffening measure will make square CFST an economical construction material too,and consequently the barrier to promote construction using square CFST could be overcome

In first stage of loading the steel tube sustains most of the load until it yields shown in fig .At this point (a) there is a load transfer from steel tube to the concrete core. The steel tube exhibits a gradual decrease in load sharing until the concrete reaches its maximum compreessive strength (a to b) after this stage of loading (point b) there is redistribution of load from concrete core to the steel tube .At this point (b) the steel exhibits a hardening behavior with almost the same slope as uni -axial stress- strain hardening relationship.

The advantages of CFT columns over other steel concrete composite called either mixed or hybrid system there used as been limited due to complexity beam to columns connection the verified modal as used investigate effect of geometric dimensions as well connection configuring on connection behavior including moment drift curves hysteresis curves ,displacement ductility ultimate load and initial stiffness

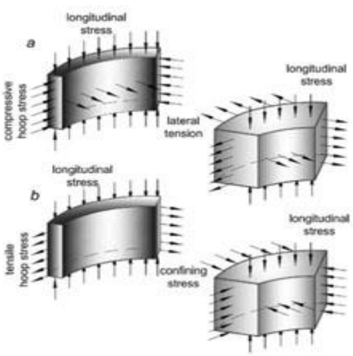


Fig. 27. Stress condition in steel tube and concrete core at different stages of loading: $v_a > v_c$ (a). $v_a < v_c$ (b)

Fig No.2 Stress Condition in Steel Tube and Concrete Core at Different Stages of Loading

Experimental work: For experimental investigation axial load is applied on HST & CFST Specimen .while testing care taken that end surface on which concrete filled steel tube keeping for testing should be the plane. All specimen were tested in universal testing machine and simple supported at the both the end.

1. **Detail of column specimen:**

1. All steel tube have same cross section as circular (58mm) and square (50x50)mm & 3mm thickness

2.A total of 48 column were tested (12 only HST& 36 CFST)

3.**3HST AND 3CFST** Column of height 0.7 m were tested for axial carrying capacity without share connector.

4.**3HST AND 3CFST** Column of height 0.7 m were tested for universal compression loading with share connector

2. PRESENT SCOPE OF THE WORK:-

The behavior of circular and square concrete filled steel tubes with and without shear connector having concert M20, M30, M40 under axial compressive load is to be determine. The steel tube

Having tube thickness 3mm and measured the columns compression strength is to be compare the value of predicted by Eurocode4,ACI318,AISC-LRFD and Finite element ABAQUS software has been used for analyzing connection effects on CFTs.

3. OBJECT OF THE STUDY:

1) To determine the axial load capacity of circular and square concrete filled steel tube column having concrete grade M20, M30 and M40 without shear connector.

2) To determine compressive strength of circular and square concrete filled steel column having concrete grade M20, M30 and M40 with shear connector

3) To compare the experimental values with the values predicted by Eurocode4, ACI318, AISC-LRFD AND Finite element ABAQUS software.

1.1 LITERATURE SURVEY :

Bhushan H. Patil, P. M. Mohite, et.al (August 2014) The Concrete Filled Steel Tube (CFST) member has many advantages compared with the conventional concrete structural member. This study presents on the behaviour of concrete-filled steel tube (CFST) columns under axial load by changing parameters. The parameters are thickness of steel tube, Grade of concrete and length of column. The study was conducted using ANSYS 13 finite element software. All the columns are 60 X 60 mm in size. The thickness of the tube is taken as 2, 3, 4, 5 and 6 mm for thickness variation. The grades of concrete infill are M25, M30, M40, M50, M60 and M70 used for grade variation. Lengths of columns are taken as 900, 1200, 1500, 1800, 2100, and 2400 mm for length variation. Buckling load is compared with Euro code 4 (1994).

Vishwajeet Patel, *P. S. Lande* et.al(27-28 Feb. 2016) Steel-concrete composite *columns are used extensively in high* high rise building and bridges as a type of hybrid system *concrete, the concrete prevents local capacity and behavior in comp concrete. An analytical invested* extensively in

this approach is a relatively new concept for construction industry. pirate-filled steel tube (CFST) columns, the steel tube provides form work for the e concrete prevents local buckling of the steel tube wall. The load carrying nd behavior in compression, bending and shear are all superior to reinforced

An analytical investigation of behavior of Concrete Filled Steel Tubes column and a theoretical design procedure according to EN 1994-1-1 Euro Code-4 are canted. The investigation has been carried out for rectangular and circular CFST columns under axial compression. The analytical model is developed to predict the capacity of CFST accounting for interaction between steel and concrete. The results obtained by theoretical calculation are validated using ANSYS 11.0 Multi physics utility tool. The results are illustrated by load carrying capacity table and modes of failure.

1.2 CONCLUSION FROM LITERATURE SURVEY:

Considerable progress has been made during the two last decade in the investigation of steel-concrete composite columns, and information available is summarized in this paper. Fundamental knowledge on composite construction system such as seismic behavior, bond strength has already been obtained by the research carried out so far.

The details of experimental works available are given in research paper. The research provide information such as number of tests, section shape, loading type, variables considered in the study and the origin of work, etc. Fundamental knowledge on composite construction system such as ultimate strength has already been obtained by the research carried out so far. Intensive research is required on the interaction between steel and concrete, the effect of concrete restraining local buckling of steel plate elements, effect of steel section, confining concrete, effect of shear connector, theoretical capacity of concrete filled steel tube etc.

1.3 MATERIAL :-

Material used are:

1 Cement

2.Aggregate A) Fine Aggregate B) Coarse Aggregate

3. Water chemical admixture (super plasticizer)

4. Steel Tube Circular and Square

5 curing compound

Properties of the basic material;

1. Cement;PPC53 Grade cement confirming to IS12269;1987 is used in the current investigation.

Table no1 properties of cement

Sr. no.	Characteristics or Description of test	Result	Requirements as per IS 12269-1987
1	Fineness of cement on (IS sieve no 9)	2% or 340 m2/kg	Should be more than 225 m2/kg
2	Specific gravity	3.15	…………………………….
3	Soundness test of cement (with Le-chatelier' s	3mm	Should be less than or equal to 10mm

	mould			
4	Setting Time	Initial	86 minutes	Should be more than 30 minutes
		Final	586 minutes	Should be less than or equal to 600 minutes
5	Standard consistency of cement		29%	……………………

2. **Fine aggregate sand** confirming IS 383-1983 belonging to zone II is used in the current investigation

Table no 2 properties of sand

Serial no	property	Result
1	Particle shape and size	Rounded below 4.75mm
2	Fineness of modulus	3.61
3	Silt content	Nil
4	Specific gravity	2.71
5	Bulk density(kg/m3)	1540
6	Water absorption	4.5%

3. **Coarse aggregate** :Crushed stone aggregate confirming to IS 383-1970 Were used as coarse aggregate. The maximum size of crushed stone dust was 12.5mm .The specific gravity of crushed stone aggregate used as found to be 2.80 and fineness of modulus 4.58 and water absorption was found to be 0.73%

4.**Chemical admixture**: chemical admixture basically used in the concrete for current experimental investigation is a high performance super plasticize r which is derived from carboxylic ether.

5. Hollow steel tube: it confirms to IS 4923:1997 A Grade fy210 steel tube considered.The dimensions of tube cross sections were selected on the basis of their nominal wall slenderness (D/t) machining characteristics and maximum capacity of the compression testing apparatus used for CFST test (1000KN- Universal testing apparatus) the steel tube are manufactured from rolled flat plate with nominal external diameter and wall thickness of 58mm and 3mm circular respectively .The square section is having corresponding dimensions of 50x50mm and 3mm.

Table no 5

GRADE OF STEEL	Minimum yield stress(MPa)	Minimum tensile stress(MPa)	Percentage elongation ,mini for sizes (%)	
			Less than or equal to 25.4 mm	Greater than 25.4mm
210	210	330	8	10

Material properties :

1.STEEL ; Square tube

Table no 6 strength properties of square steel tube.

DXB	Thickness	Area	Moment of inertia	Radius of gyration	Elastic modulus	fy	fu	Poisson's ratio
Mm	mm	Mm2	Mm2	mm	N/mm2	MPA	MPA	
50X50	3	2500	16.91X10 ^4	19	2X10^6	210	330	0.3

2. Circular tube

Table no 7 strength properties of circular steel tubes

DIAMETE R (outer)	Thickness	Area	Moment of inertia	Elastic modulus	fy	fu	Poisson's ratio
Mm	Mm	Mm2	Mm2	N/mm2	Mpa	mpa	
58	3	2642.07	196.589x1 0^3	2x10^5	210	330	0.3

Concrete: The concrete used in the current experimental investigation was produced in the ready

mix concrete (RMC) plant. 3 grade of concrete M20, M30 ,M40 were used Both the concrete had collapsible slump so that concrete can easily flow into the steel tube by its own .

6. **Curing compound:** The curing compound used in the current experimental investigation was basically based the membrane curing theory. The curing compound used in master kure 181which is a non degrading .membrane forming liquid basically derived from the acrylic resin.

Table no.6 characteristics of master kure181

Sr no	Properties	values
1	Specific gravity	0.82 at 25 C
2	Flash point	30 C
3	Drying time	45 minutes

Fig No.3 CFST Column BeFor After Application of Curing Compound

MIX DESIGN:

Design mix stipulation according to IS 10262-2009

Grade Designation =M-20,M-30,M-40

Fine Aggregate =Zone-II

Specific gravity of cement=3.13

Fine Aggregate =2.678

Coarse Aggregate (20mm)=2.76

Coarse Aggregate (10mm)=2.66

Minimum cement (As per contract)=400kg/m3

Minimum Water cement ratio(as per the contract)=0.4

Mix proportion :

Water :Cement : F.A:C.A=0.4:1:1.39:2.39

METHODOLOGY:

The steel specimen were cut for the obliged L/D ratio ,and edges were flattened well to obtain a level surface for uniform loading .Bolt of high strength with grade 8.8 according to IS 1364 Part l

(2002) Of length 60mm was placed as demonstrated in fig. 1 and utilized as a "shear connector".The bolt shear connector was external steel surface .The connector placing and position were adopted as per the particulars given for steel Concrete composite bars in Euro- code-4 (2004).minimum spacing of shear connectors in the direction of shear is 5d .(here5x12=60 .provided spacing is 75mm hence safe. minimum spacing in transverse direction of shear force is 2.5d (here 2.5x12=30) .provided spacing 43mm . hence safe were maximum 800mm an be used .in the course of preparation of the test specimen ,the strategic distance from air voids in concrete and also performing push out test for finding bond stress, before casting of specimen a gap of 50mm left not filled at the top for enabling the movement of concrete

SPECIMENS AREGMENT:-

Fig No .4 Share connector

Fig No .5 without Share connector

Fig .4 concrete material filling CFST

Experimental Test Setup:

The concrete filled steel tube specimens of different cross section are tested for their load carrying capacity an universal testing machine with a maximum compressive load capacity of 1000KN was used to test the specimens as shown in fig. The specimen were placed between the base and the head of universal testing machine and centered with applied gradually. The load application was continued till specimens failure. A1000 KN load cell was attached to the machine head to measure the load during testing .All the instrumentation were connected to data acquisition system to record different measurement with a rate of 2 reading per second.

Fig No.7 Experimental setup CFST column for axial loading

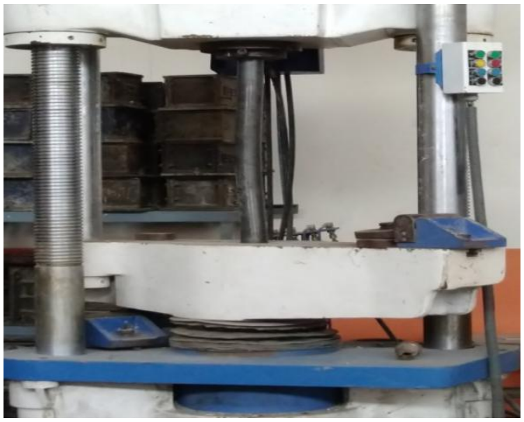


Fig No.8 Experimental setup CFST column for axial compression test

RESULT AND ANYALYSIS

A) Circular **CFST Specimen**

Specimen type	Load (KN)		Deflection (mm)	
	Without SC	SC	Without SC	SC
Hollow steel tube	162.1	221.1	3.8	5.8
CFST M20	283.1	340	8.4	8.9
CFST M30	331.6	386.9	7.3	7.8
CFST M40	391.2	436.5	8.1	9

B) Square CFST Specimen

Specimen type	Load (KN)		Deflection (mm)	
	Without SC	SC	Without SC	SC
Hollow steel tube	162.1	221.1	3.8	5.8
CFST M20	283.1	340	8.4	8.9
CFST M30	331.6	386.9	7.3	7.8
CFST M40	391.2	436.5	8.1	9

C) **Circular CFST Specimen**

Specimen type	Expt.Load (KN)		ACI-318 LOAD (KN)	AISC LRFD LOAD (KN)		EUROCODE 4 LOAD (KN)
	Without SC	SC	Without SC	Without SC	SC	Without SC
CFST M20	283.1	240	144.95	145.59	149	151.32
CFST M30	331.6	386.9	170.71	172.59	174.58	177.30
CFST M40	391.2	436.5	201.6	204.59	206.98	209.17

D**) Square CFST Specimen Result obtain with different code**

Specimen type	Expt.Load (KN)		ACI-318 LOAD (KN)	AISC LRFD LOAD (KN)		EUROCODE 4 LOAD (KN)
	Without SC	SC	Without SC	Without SC	SC	Without SC
CFST M20	276.2	344.1	145.41	141.53	181.16	147.68
CFST M30	344.3	380.3	181.5	175.59	200.23	183.85
CFST M40	181.3	420.22	200.56	199.27	221.18	203.61

COMPARISION OF TEST RESULT AND CODES.

In this research, calculation of ultimate load with the Eurocode4, ACI, AISC-LRFD

ACI-318(American concrete Institute-318)

A) Load carrying capacity of CFST with M20 Grade concrete without shear connector(circular)

$Pn=0.85Ac.Fc+ AsFy$

Ac= Area of concrete.

Fc=characteristics strength of concrete.

As= area of steel

Fy= yield strength of steel.

$Ac=\pi/4xD2$

$Ac=\pi/4x(52)2=2123.71mm2$

Fc=20N/mm2.Fy=210 N/mm2

$As=\pi/4(D2-d2)$

As=/4x(58^2-52^2)=518.36mm2

Pn=144.95KN

Pexp/Pn=283.1/144.95=1.9

B) By AISC -LRFD(2010)

Po=C2.Ac.Fc+As.Fy

C2=0.99 for circular section

$Pe=\pi/(KL^2)$ XEleff.

K=1 For CFST-AISC LRFD

Eleff= EsIs+C1.Ec.Ic

C1=0.6+2(As/Ac+As)< or=0.9

Ec=22xfc/10)0.3=27.085x103 mpa

C1=0.9

Eleff={2x10^5x196.58x10^3}+{0.9x27.08x10^3x358.90x10^3]

=4.80x10^10

$Pe=(\pi^2.480x10^{10}/440^2$

=2.44X10^6

Po=(0.95x2113.71x20)+(518.36x210)=149.20x10^3

0.44p=65.65x10^3

Pn=Po(0.658)

Po/Pe=0.060

Pe=145.499x10^3

Pexp=283.1kn

Pexp/Pn=283.1/145.49=1.9

C) Eurocode4

Pn=Ac.Fc+As.Fy

=151.32kn

Pexp/Pn=283.1/151.32

=1.87

Ultimate axial load capacities of all CFST Specimen are find out in the same way as above state.

DISCUSSIONS:

1. The graph shows that the result of axial load carrying of group I and Group II .The representative of load carrying capacity is taken for further studies.

2. The graph shows the result of axial load capacity of group III TO VIII.The representative of load carrying capacity of each group is taken for studies

3. In both circular and square columns it is seen that,the axial load carrying of columns increase the strength of concrete increase .from above result it is concluded that use use of high strength infill concrete is much more effective to get extra strength with same size of CFST Columns.

4. The specimen shows that, adding shear connector inside the columns increased the load carrying capacity of columns so that of shear connector can help to increase to strength columns with same size of columns.

5. Eurocode4 gives the better prediction about axial capacity of CFST without shear connector

6. The only AISC-LRFD code can be used to predict the axial load capacity off CFST with shear connector.

7. There is need to develop an expression for axial load capacity of CFST with shear connector and its distribution.

8. The high strength of concrete in CFST can be achived with shear connector with appropriate spacing and material properties.

Graph draw following schedule please note

1. Load and deflection of hollow square column With SC and Without SC

2. Load and deflection of hollow circular column With SC and without SC

3. Load and deflection of M20 grade circular CFST With SC and without SC

4. Load and deflection of M30 grade circular CFST with SC and without SC

5. Load and deflection of M40 grade square CFST with SC and without SC

6. Axial load of M20, M30, M40 grade circular CFST with SC and without SC

7. Axial load of M20, M30, M40 grade circular CFST with SC and without SC

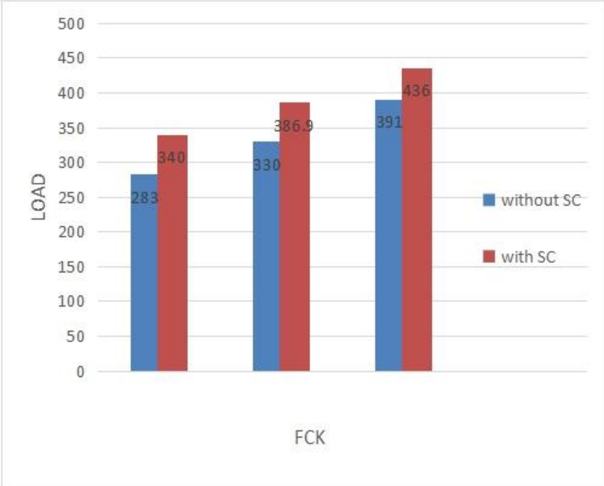


Fig.Axial Load of M20,M30, M40 grade circularCFST with SC and without SC

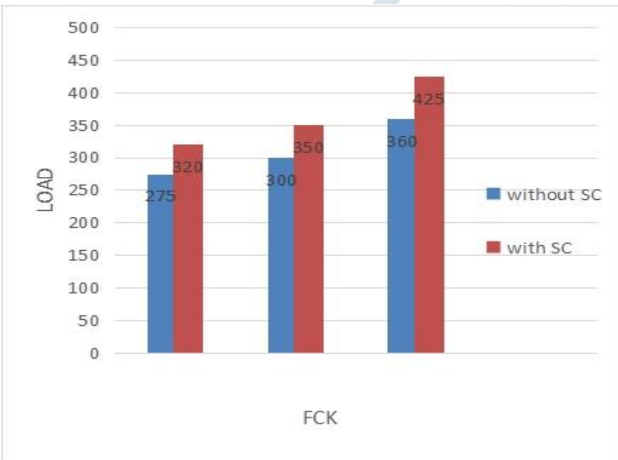
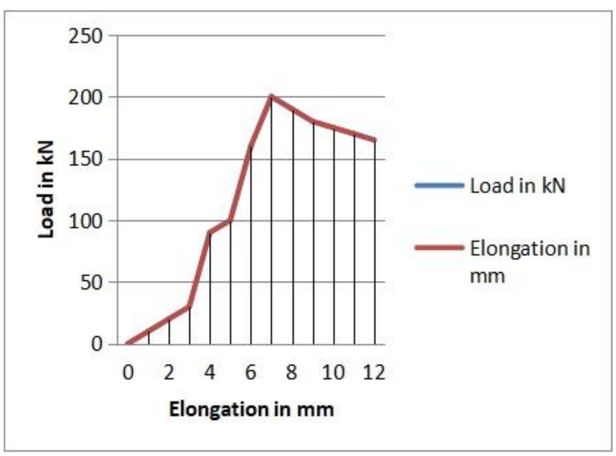
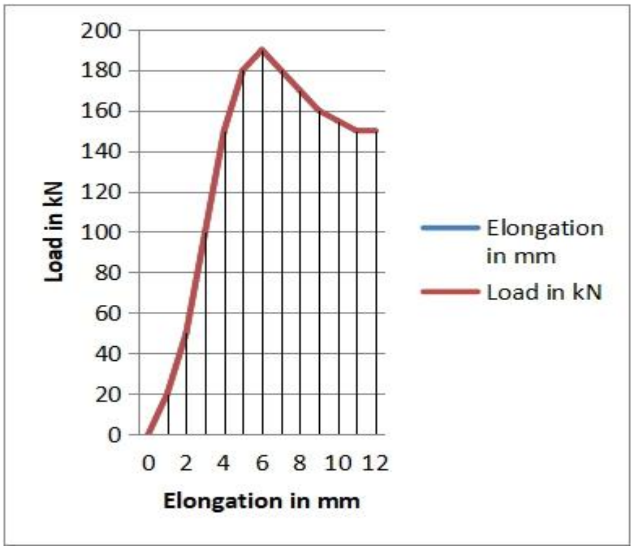


Fig.Axial Load of M20,M30, M40 grade Squar CFST with SC and without SC

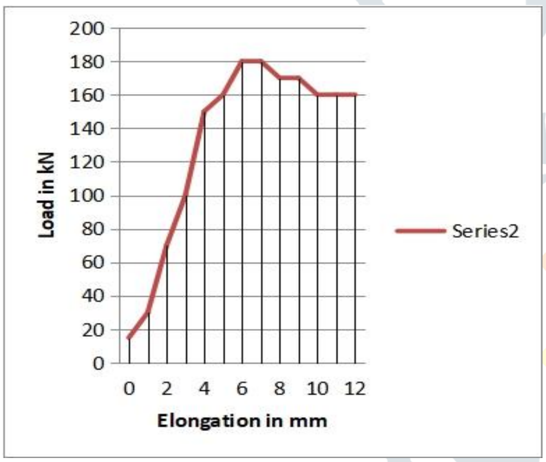
2. Load and deflection of hollow square column With SC and Without SC

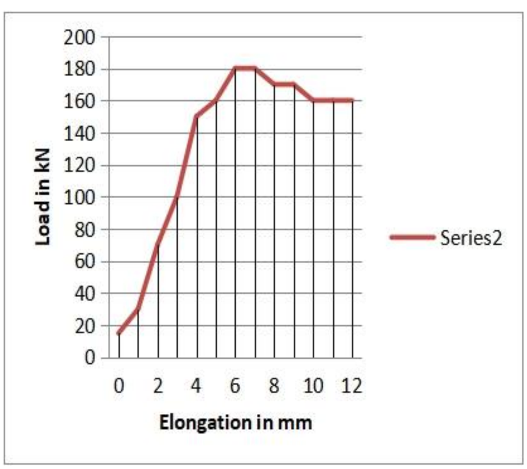


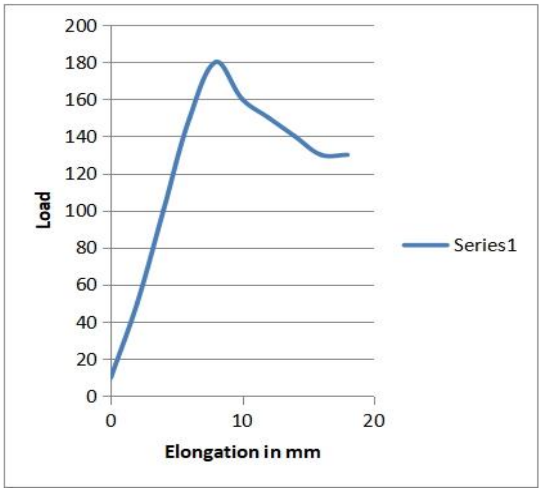
50 X 50 hollow square column with shear connector



50 X 50 hollow square column without shear connector







2. CONCLUSION

From the extensive study of CFST and the experimentation carried out following conclusion were made

1) Comparing the graphs from graph 5.29 to 5.32 it is concluded that the presence of shear connector increases the strength and such enhancement in strength reaches up to 25% to 30% in specimens of groups ii ,iv,vi and viii respectively.
2) The deflection is increased as shear connector is provided. That is due to shear connector CFST behaves more ductile.
3) The most optimal ductility in the connections related to the beam with a depth 700mm the ductility of which was increased by 14% than other CFT connections.
4) An increase in the flange thickness in specimens could reduce connection ductility by 18% which touched 26% in the hollow steel column connection the parameters of resistance ductility ultimate strength energy dissipation s and stiffness have been obtain from hysteresis curves.
5) The experimental results compared with all stated code of practices which shows EC4 Gives the better prediction as compared other two code.
6) Comparing the graphs from code AISC-LRFD,ACI AND Eurocode4 gives a ratio of Nexp/Nu1.95,1.89,1.87
7) The graph shows that AISC-LRFD Gives the ratio of Nexp/Nu of 1.89
8) The AISC-LRFD,ACI AND Eurocode4 gives conservative result.
9) The axial load carrying capacity of CFST columns was increased by 19.35% to 38% m20 ,m30 and 17.3% and 22.04 % m20 and m40
10) The average strength ultimate load carrying capacity of concrete filled steel tube frame was increased by 22.50%48.08% M30.M40
11) The theoretical axial load carrying capacity of concrete filled steel tube columns evaluated in accordance with AISC-LRFD2005,AND Eurocode4 were found to be in best agreement.
12) The maximum percentage variation for experimental result and theoretical result of axial load AISC-LRFD 2005 Was around 21%and Eurocode4was fund by16%
13) The failure of the CFST Column of height 0.7m basically due to local buckling near the mid height compare to the failure of hollow steel tube columns which failed due to in ward local buckling near the ends.
14) The failure of CFST columns of height 0.7m were basically due to to the ovrall buckling which was very much similar in case of hollow steel tube column.

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