https://doi.org/10.15623/ijret.2018.0703004 Received: 12-01-2018, Accepted: 23-02-2018, Published: 15-03-2018

EXPERIMENTAL INVESTIGATION ON CFST COLUMNS WITH LIGHT WEIGHT CONCRETE AS INFILL UNDER CYCLIC LOADING

Eadara Ramesh Babu[1], N S Kumar[2]

[1]*Research scholar, Dept. of Civil Engineering, Ghousia College of Engineering, Ramanagara, Affiliated to VTU, Belgaum,*

[2]*Professor, Director of R&D, Dept. of Civil Engineering, Ghousia College of Engineering, Ramanagara, Affiliated to VTU, Belgaum,*

Abstract

Experimental investigation has been carried out to study the behavior of Concrete Filled Steel Tube (CFST) columns under cyclic loading with different Length to Diameter (L/D) ratios. Generally cyclic loading is the application of fluctuating stresses and strains on structural elements. The fatigue degradation that occurs at particular locations of the tested specimens have been examined. In this study, effect on the buckling load capacity of CFST columns have been studied. Totally 72 specimens of different dimensions are prepared and three grades of concrete is used such as M20, M30 and M40 and models are developed using software ABAQUS 10.1 for the same parameters. Experimental results are verified and checked with ABAQUS results. It is found that buckling/ultimate load increases as the grade of concrete increases and decreases with the increase in L/D ratios.

Keywords: *CFST, Ultimate load, Buckling, L/D ratios, cyclic loading.*

---***---

1. INTRODUCTION

CFST technology deals with the returns of the combination of concrete and steel. This method include a steel empty area with circular or square shaped members, loaded with plain concrete or Reinforced concrete (RCC) [1, 2]. Presently this technology is used in the construction of skyscrapers and multistory structures, and also as supporting members in low-rise mechanical structures, as the technology provides a strong and effective basic framework [2].

It is found that, CFST is advantageous over the conventional method of frameworks both in terms of basic execution and also at development stages. The important parameter i.e. the buckling has been identified with thin walled steel tubes is either avoided or delayed because of the inner empty concrete areas. Also, the presence of the concrete in the interior space, which further enhances the confinement impact to the steel shells [3]. The spreading of materials in the cross segments which makes the framework extremely capable in term of its secondary execution. The steel lies at the outer boundary which helps to perform better in tension as well as buckling. This mechanism contributes the best strength as the materials are distributed to the outermost from the mass center. This, combination with the steel gives rise to much more worthy young's modulus, this finally reflects in getting the best moment of inertia [2]. This confinement provides the best stability even for the axial members which normally exists in the service life of the compression member [4].

1.1 Mechanism of CFST

Numerous studies have demonstrated that the execution of a square CFST is not as great contrast with its circular CFST. This is because of the way that a square steel tube could just give less confinement force to concrete infill, and it's probably to result local buckling. This has now been generally reflected in various design codes of composite structures. Such strengthening measure will make circular CFST an efficient development material; hence it is that circular CFST is more advantageous compared to square CFST [5].

The structural conduct of CFST components are impressively influenced by the difference between the Poisson's ratio of the steel and that of infill material. The Poisson's ratio of the infill material will be lower than that of steel tube [6]. This leads to the steel tube to give no containment impact on the infill material [7, 8]. As the strain builds in the direction of the load, the parallel development of concrete bit by bit gets to be greater than extension of steel tube. During this stage, the infill material turns out to be triaxially and steel tube biaxially pushed. The steel tube under such state normally cannot support the typical yield stress, bringing about an exchange of stress from tube to infill [9].

1.2 Background of Light Weight Concrete

It is known that, the conventional concrete will have density of the range 2300 kg/m^3 2400 kg/m^3 which is consider to be very higher when structures are to be built for lighter weight [2]. In order to have less dead load on structure a lighter concrete is preferred which assumes greater importance in

https://doi.org/10.15623/ijret.2018.0703004 Received: 12-01-2018, Accepted: 23-02-2018, Published: 15-03-2018

the structural field. So, the concrete that has lighter weight is called as light weight concrete (LWC). LWC density will be normally varies from lower side 600 kg/m3 to a most extreme of 1850 kg/m3 when compared with ordinary concrete its density will be ranging from 2240 kg/m3 to 2400 kg/m³ [2, 10].

LWC has strength equivalent with ordinary weight concrete, yet is normally 25% to 35% lighter. The basic ingredients of LWC are same as that of ordinary concretes but the admixtures will be added which introduces entrainment of air. Light weight aggregates are mainly used in earthquake resistant structures [2, 11, 12].

1.3 Transverse Loading on CFST

The shear span is the governing factor when CFST is subjected to transverse loading. Shear stress occurs throughout the CFST during the application of transverse load.

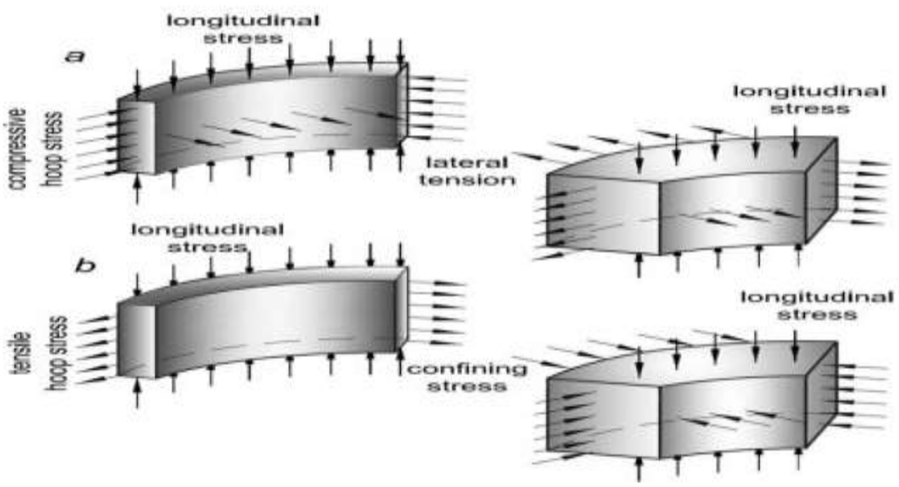

Fig 1: Stress Condition in CFST

2. OBJECTIVES OF THE STUDY

I. To understand the effects of steel tubes with different L/D ratios with different grades of Light Weight Concrete (LWC) infill.

II. To study the behavior of strength and deflection for different steel tubes filled with LWC under cyclic loading.

III. To know the failure mechanism of composite steel and hollow steel tubes.

3. METHODOLOGY

In order to find the ultimate load and the corresponding deformations of the various specimens, cyclic loading compressive testing machine was used. The different sections, lengths and grades of concretes are separately tabulated while carrying out the experimentation. After doing the basic tests on the materials a suitable design for light weight concrete is done according to the ACI and European standards. Then the basic tests on the fresh concrete are done before casted in to the steel tubes. The filling material which is LWC concrete is tested for 7 and 28 days respectively where the aggregates used is 6 mm to 10 mm in range.

Total of 72 specimens where prepared according to aim of the project and these steel tubes where cut to required dimensions and cleaned to remove it from dirt and any type of grease and the corners are leveled in order to maintain the even leveled surface. A plate is welded one side in order to seize expel of fresh concrete while filling in steel tubes. After filling the concrete it is compacted well and the top of the surface is leveled. Light weight concrete is used in order to decrease the total weight of the composite structure.

3.1 Cinder as Coarse Aggregate

The main use of cinders as coarse aggregates is to reduce the density which means the dead weight of the concrete from which in practical the total weight of the structure decrease and the load carrying capacity maintained satisfactorily. It is necessary to the properties of the cinder before it is used in concrete hence the required properties of the cinder are calculated by using the procedures of American code ACI211.2-98 respectively. The properties of the cinder used is presented in Table 1.

Table 1: Cinder properties

Sl.No.	Property	Value obtained
1	Specific Gravity (G)	1.9
2	Fineness modulus (S)	2.4
3	Bulk density (w_b) (kg/m3)	1850

3.2 Steel Tubes

https://doi.org/10.15623/ijret.2018.0703004 Received: 12-01-2018, Accepted: 23-02-2018, Published: 15-03-2018

Steel tubes are the outer casing for the composite element where it holds the concrete still and strong in its place. In this experiment total of 36 specimens where prepared and those dimensions and properties are given in Table 2.

Table 2: Steel properties

Sl. No.	Description	Value
1	Yield strength (F_y)	310 Mpa
2	Young's modulus (Es)	200 Gpa
3	Poisson ratio (μ)	0.3
4	Density (ρ)	7800 Kg/m^3

4. MIX DESIGN

The mix design for the light weight concrete used to fill in the prepared specimens is done using ACI standards along with referring some European journals. For this light weight concrete the coarse aggregates are completely replaced by cinders. The cinders used are in between 6 mm to 10 mm in size because of small diameter of availability of steel tubes. The aim of mix design is to select suitable ingredients and to determine the relative proportions of the ingredients, so that the required workability, durability and strengths are obtained with a less cost. The mix design can be performed in two ways, nominal mix design and the design mix.

4.1 Requirement for Mix Design

a) The minimum limit of required compressive strength of light weight concrete in the structural element.
b) The requirement of degree of workability of LWC such as for pumping concrete workability should be more.
c) Degree of compaction required.
d) Limitations such as the allowable maximum water content, condition for which concrete is exposed, w/c ratio according to that required condition.
e) To avoid the failure of concrete such as by shrinkage or any other property such as
f) Durability the maximum cement content which can be used.

4.2 Mix Design Prepared for Different Grades

Several numbers of trails have been done after designing of concrete and the fresh concrete of mixture satisfying all workability properties are selected and casted for test of harden concrete properties. Carefully selecting and proportioning of the basic ingredients of LWC with a objective of obtaining a required workability is the key element of any concrete. It is known that the compressive strength of the hardened concrete which is considered to be an index of its other all properties. The compressive strength of the hardened concrete mainly depends on quality and quantity of cement, water, aggregates, batching and mixing, placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labor. The cost of concrete also depends on the same factors.

Table 3: Dimensions of specimens

Diameter in mm	Thickness in mm	L/D ratio	length in mm	Number specimens
33.7	3.2	6	202.2	4
		8	269.6	4
		10	337	4
		12	404.4	4
		14	471.8	4
		16	539.2	4
42.4	3.2	6	254.4	4
		8	339.2	4
		10	424	4
		12	508.8	4
		14	594.6	4
		16	678.4	4
48.3	3.2	6	289.8	4
		8	386.4	4
		10	483	4
		12	579.6	4
		14	676.2	4
		16	772.8	4

5. MODELING –ABAQUS6.10-1

Modeling of column sections done using the ABAQUS6.10-1 software. The specimens are modelled using the hyper-mesh software for different sectional dimensions with different L/D rations, light weight concrete as in fill, and different grades of concretes. Figure 2 shows the cross section the specimen. The model developed is imported in the ABAQUS software and analyzed. Figure 3 shows the deformed shape of column section and buckling load or

https://doi.org/10.15623/ijret.2018.0703004 Received: 12-01-2018, Accepted: 23-02-2018, Published: 15-03-2018

ultimate load tabulated obtained by analyzing using ABAQUS software and are denoted as $Pu_{ABQ.}$

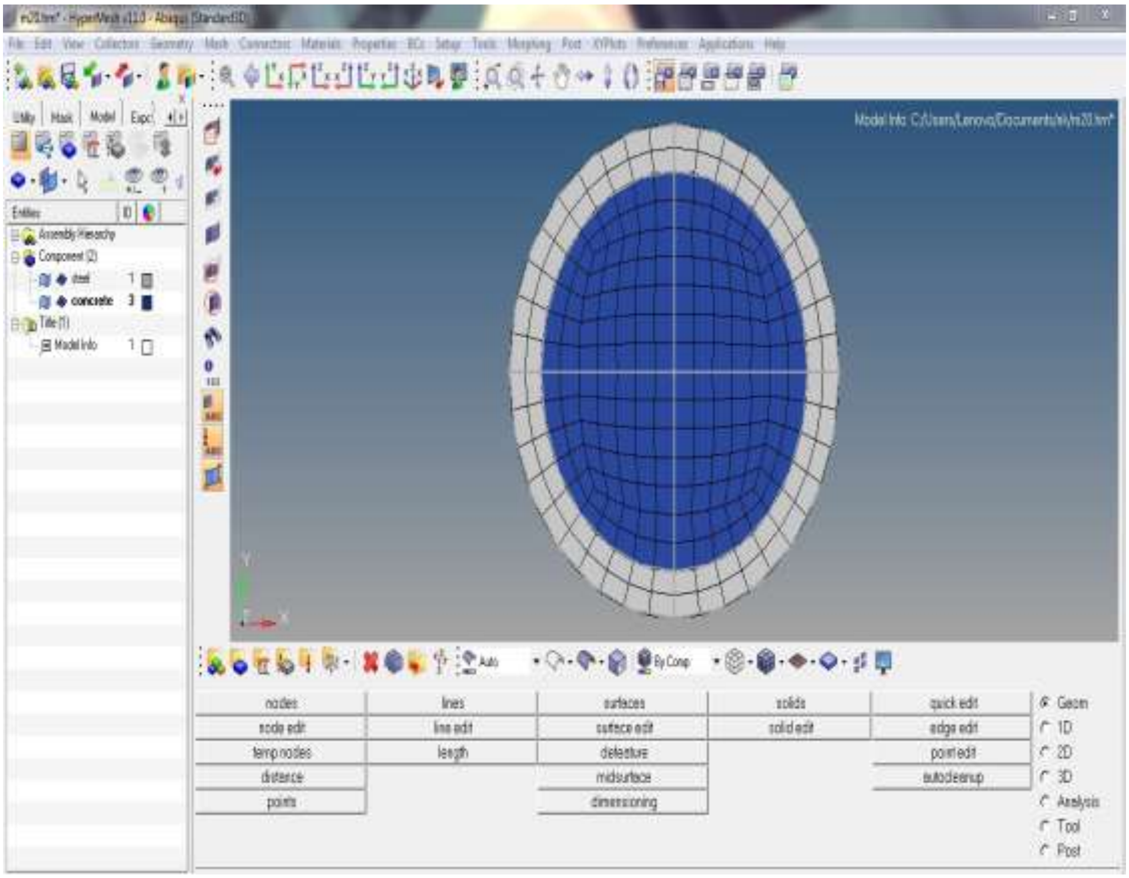

Fig 2: Components of the specimen

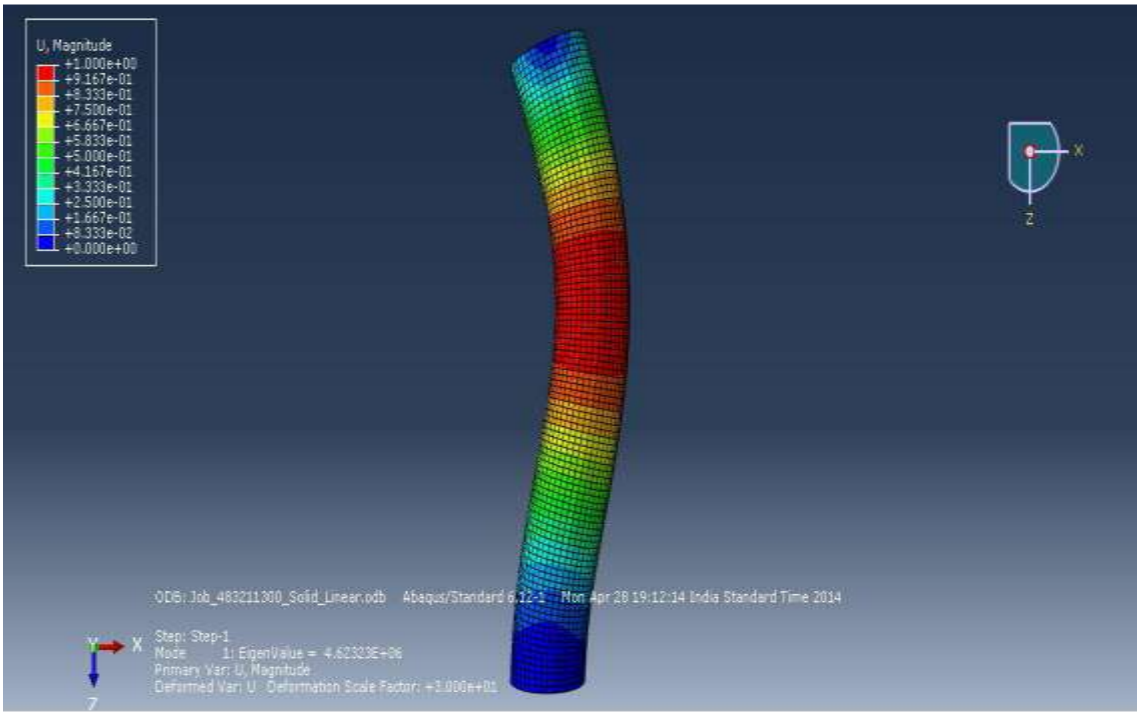

Fig 3: Deformed shape of column section

6. EXPERIMENTAL RESULTS OF ULTIMATE LOAD CARRYING CAPACITY

https://doi.org/10.15623/ijret.2018.0703004 Received: 12-01-2018, Accepted: 23-02-2018, Published: 15-03-2018

Table 4: Hollow steel tube

Outer dia = 33.7mm, thickness 3.2 mm and length = 404.4 mm at room temperature (L/D=12)			
Load (KN)	**Deformation (mm)**	**Stress KN/sq.mm**	**Strain**
0	0	0	0
10	0.05	32.6136586	0.00012364
30	0.16	97.8409758	0.000395648
50	0.245	163.068293	0.000605836
62	0.324	202.204683	0.000801187
50	0.296	163.068293	0.000731949
75	0.376	244.60244	0.000929773
87	0.44	283.73883	0.001088032
95	0.6	309.829757	0.00148368
110	0.74	358.750245	0.001829871
85	0.69	277.216098	0.001706231
76	0.65	247.863805	0.001607319
107	0.89	348.966147	0.002200791
119	1.45	388.102537	0.003585559
120	1.95	391.363903	0.004821958
85	1.47	277.216098	0.003635015
112	1.75	365.272976	0.004327399
126	2.05	410.932098	0.005069238

Table 5: Steel tube infill with M20 (LWC)

Outer dia = 33.7 mm, thickness 3.2 mm and length = 404.4 mm at room temperature. (L/D=12)			
Load (KN)	**Deformation (mm)**	**Stress N/sq.mm**	**Strain**
0	0	0	0
20	0.095	56.8763508	0.000234916
44	0.198	125.127972	0.000489614
64	0.3	182.004323	0.00074184
40	0.24	113.752702	0.000593472
68	0.34	193.379593	0.000840752
87	0.415	247.412126	0.001026212
115	0.6	327.039017	0.00148368
80	0.5	227.505403	0.0012364
101	0.65	287.225572	0.001607319
123	0.86	349.789558	0.002126607
128	0.95	364.008645	0.002349159
119	0.92	338.414287	0.002274975
74	0.86	210.442498	0.002126607
118	0.92	335.57047	0.002274975
123	1.14	349.789558	0.002818991
134	1.5	381.07155	0.003709199
142	1.98	403.822091	0.004896142

Table 6: Steel tube infill with M30 (LWC)

https://doi.org/10.15623/ijret.2018.0703004 Received: 12-01-2018, Accepted: 23-02-2018, Published: 15-03-2018

Outer dia = 33.7 mm, thickness = 3.2 mm and length = 404.4 mm at room temperature. (L/D=12)			
Load (KN)	**Deformation (mm)**	**Stress N/sq.mm**	**Strain**
0	0	0	0
25	0.08	71.0954385	0.000197824
50	161	142.190877	0.398120673
67	0.26	190.535775	0.000642928
83	0.34	236.036856	0.000840752
62	0.25	176.316688	0.0006182
109	0.5	309.976112	0.0012364
120	0.62	341.258105	0.001533136
99	0.6	281.537937	0.00148368
85	0.575	241.724491	0.00142186
115	0.8	327.039017	0.001978239
124	1.05	352.633375	0.002596439
135	1.87	383.915368	0.004624135
123	1.5	349.789558	0.003709199
95	1.65	270.162666	0.004080119
115	1.8	327.039017	0.004451039
124	1.94	352.633375	0.00479723
135	2.24	383.915368	0.00553907
150	2.67	426.572631	0.006602374
125	2.36	355.477193	0.005835806
115	2.3	327.039017	0.005687438
160	2.88	455.010807	0.007121662

Table 7: Steel tube infill with M40 (LWC)

Outer dia = 33.7 mm, thickness = 3.2mm and length = 404.4 mm at room temperature. (L/D=12)			
Load (KN)	**Deformation (mm)**	**Stress N/sq.mm**	**Strain**
0	0	0	0
20	0.06	56.8763508	0.000148368
45	0.12	127.971789	0.000296736
70	0.19	199.067228	0.000469832
92	0.3	261.631214	0.00074184
62	0.21	176.316688	0.000519288
87	0.36	247.412126	0.000890208
115	0.46	327.039017	0.001137488
127	0.54	361.164828	0.001335312
119	0.5	338.414287	0.0012364
89	0.47	253.099761	0.001162216
117	0.86	332.726652	0.002126607
129	1.5	366.852463	0.003709199
147	1.9	418.041178	0.004698318
135	1.86	383.915368	0.004599407
122	1.8	346.94574	0.004451039
113	1.78	321.351382	0.004401583
125	1.9	355.477193	0.004698318
149	2.25	423.728814	0.005563798
156	2.47	443.635536	0.006107814
166	2.75	472.073712	0.006800198

IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308
https://doi.org/10.15623/ijret.2018.0703004 Received: 12-01-2018, Accepted: 23-02-2018, Published: 15-03-2018

170	2.93	483.448982	0.007245302

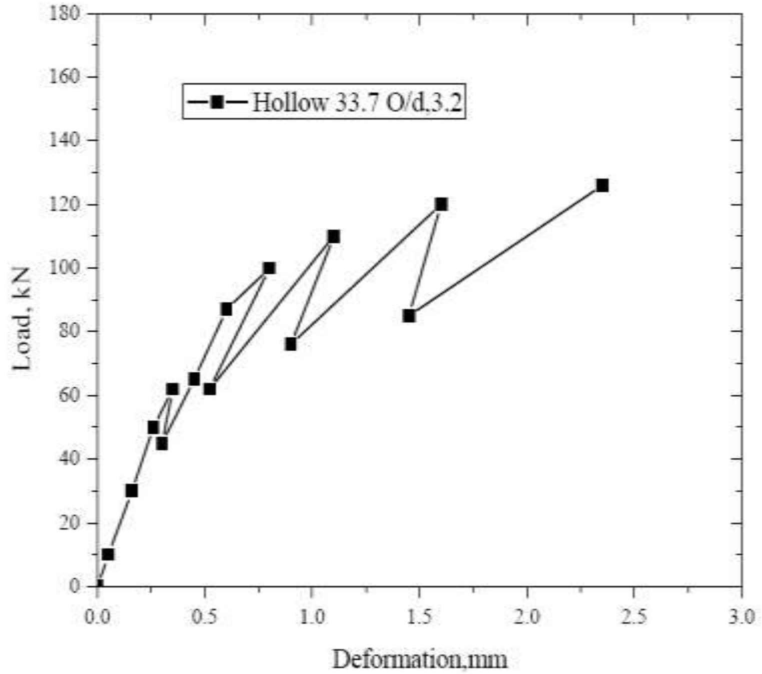

Fig 2: Hollow section, deflection vs. load curve

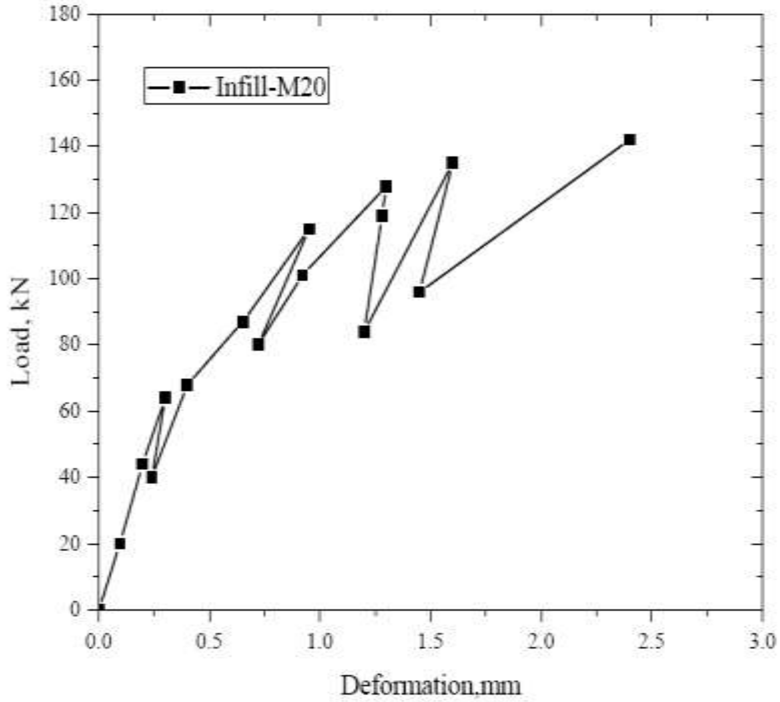

Fig 3: Section infill with M20, deflection vs. load curve

https://doi.org/10.15623/ijret.2018.0703004 Received: 12-01-2018, Accepted: 23-02-2018, Published: 15-03-2018

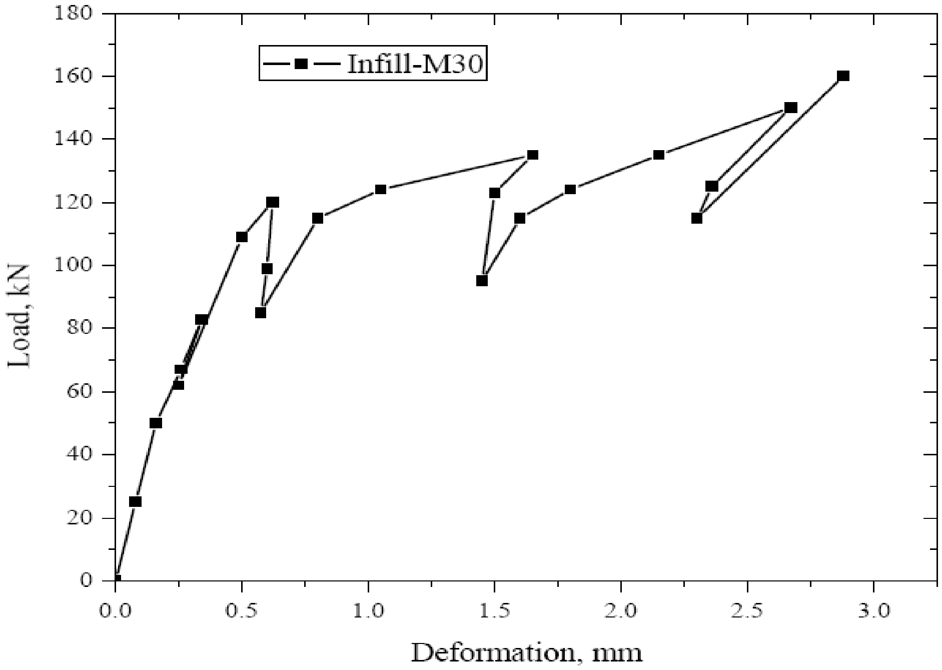

Fig 4: Section infill with M30, deflection vs. load curve

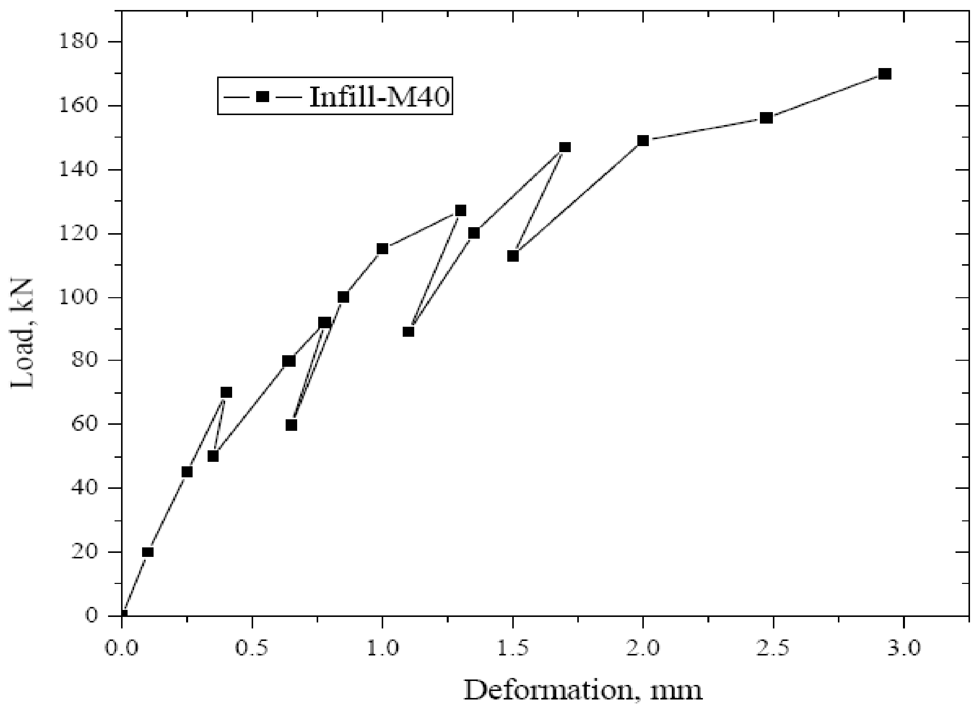

Fig 5: Section infill with M40, deflection vs. load curve

https://doi.org/10.15623/ijret.2018.0703004 Received: 12-01-2018, Accepted: 23-02-2018, Published: 15-03-2018

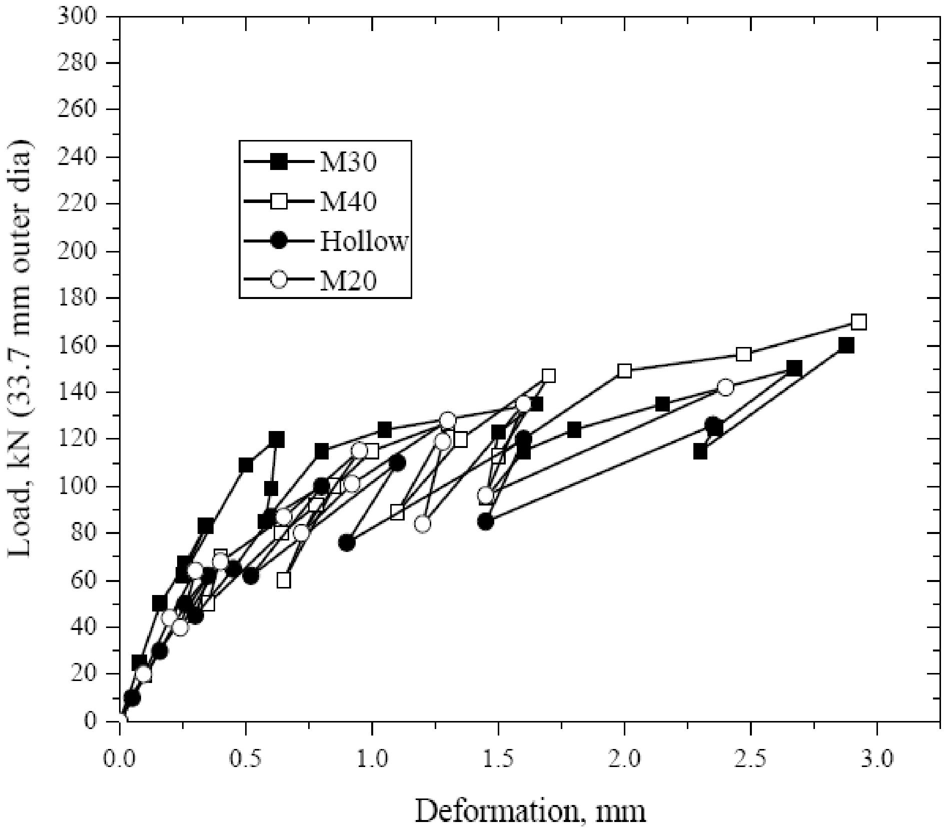

Fig 6: Buckling load vs. deflection for 33.7 O/D sections for different L/D ratios

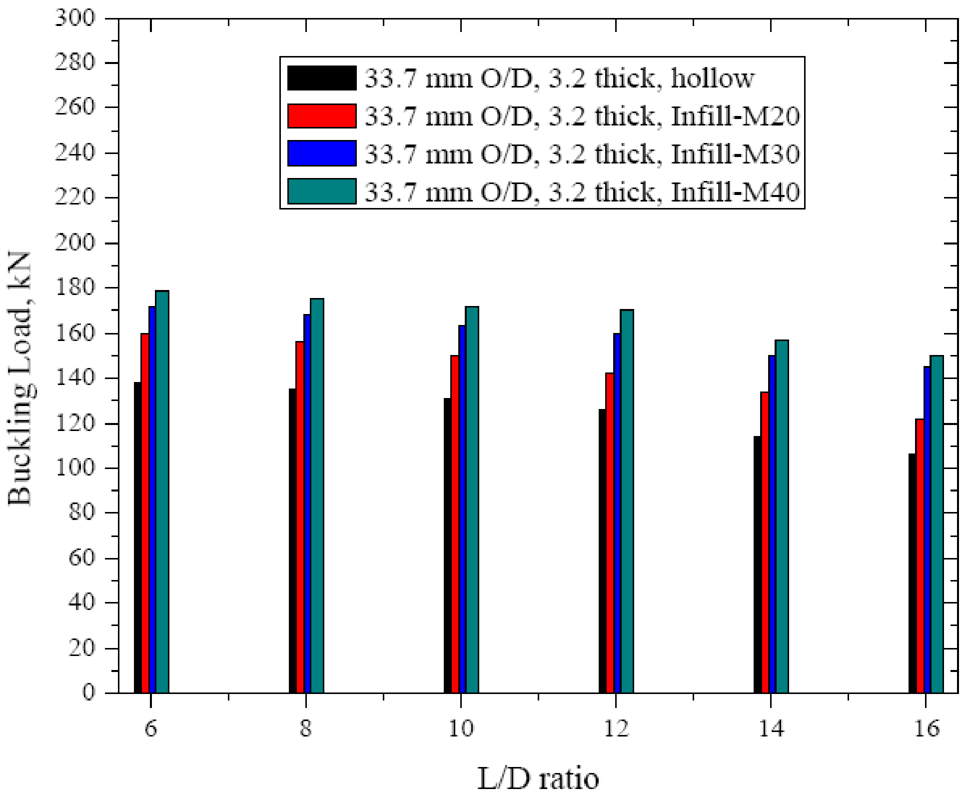

Fig 7: Buckling load for 33.7 O/D sections for different L/D ratios

https://doi.org/10.15623/ijret.2018.0703004 Received: 12-01-2018, Accepted: 23-02-2018, Published: 15-03-2018

7. CONCLUSION

- Ultimate load carrying capacity of tested specimen is inversely proportional to the length of the specimen.
- With increase in concrete grade the strength of CFST also increases, i.e. for M20 to M30 it varied about 8.5% and for M30 to M40 only 4%.
- As the L/D ratio increases the buckling or ultimate load decreases, about 2.5% to 8% from L/D ratio 6 to 12, 17% for L/D 14 and 22% for L/d=16.
- As the grade of concrete increases the increase of the load is not proportional but it observed to be marginal.
- It is found that the ultimate load varies between experimental work and ABAQUS Program about 3% to 8 %.

REFERENCES

[1] Artiomas Kuranovas, Douglas Goode, Audronis Kazimtreas, and Shantong Zhong, "Load bearing capacity of concrete filled steel columns," Journal of Civil Engineering and Management vol. 15, pp. 21-33, 2009.

[2] Silpa C. K, Ramesh Babu E, and Kumar N.S, "Expermental investigation on Composite Column Subjected to Cyclic loading," International Journal of Research in Engineering and Technology, vol. 5, pp. 293-298, 2016.

[3] P. Gajalakshmi, H. Jane Helena, and Srinivasa Raghavanm, "Experimental investigation on the behaviour of concrete-filled steel columns," Asian journal of civil engineering (building and housing), vol. 11, pp. 691-701., 2011.

[4] N. Tamilselvan, V. Chandrikka, L. Krishnan, and S. Narmadha, "Analytical Study on Behaviour of Concrete Filled Steel Tubular Columns " Advances in Natural and

[5] H. Ravi Kumar, K. U. Muthu, and N. S. Kumar, "Experimental Behavior of Circular HSSCFRC filled steel tubular columns under axial compression," International Journal of Research in Engineering and Technology, pp. 111-115, 2013.

[6] Shilpa Sara Kurian, D. Paulose, and Sreepriya mohan, "Study On Concrete Filled Steel Tube," IOSR Journal of Mechanical and Civil Engineering, pp. 25-33, 2016.

[7] H. Ravi Kumar, K. U. Muthu, and N. S. Kumar, "Concrete filled steel tubular columns-a critical review," International journal of Elixir 250 Cement & Con. Com vol. 48, pp. 9656-9662, 2012.

[8] S. P. Schneider, "Axially loaded concrete-filled steel tubes," Journal of structural Engineering, ASCE, vol. 124, pp. 1125-38, 1998.

[9] S. Schnabl, G. Jelenić , and I. Planinc, "Analytical buckling of slender circular concrete-filled steel tubular columns with compliant interfaces," Journal of Constructional Steel Research, vol. 115, pp. 252–262, 2015.

[10] Fu Zhong-qiu, Jib Bo-hai, Lv Lei, and Zhou Wen-jie, "Behavior of lightweight aggregate concrete filled steel tubular slender columns under axial compression," Advanced Steel Construction vol. 7, pp. 144-156, 2011.

[11] E. E.Hanuman Sai Gupta and V. Giridhar umar, "Investigations on Properties of Light Weight Cinder Aggregate Concrete," International Journal of Engineering Research and Development vol. 11, pp. 50-59, 2015.

[12] Shehdeh Ghannam , Orabi Al-Rawi , and Moh'd El-Khatieb, "Experimental Study on Light Weight Concrete-Filled Steel Tubes," Jordan Journal of Civil Engineering, vol. 5, pp. 521-529, 2011.