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DYNAMIC ANALYSIS OF COMPOSITE STEEL COLUMNS INFILLED WITH LIGHT WEIGHT CONCRETE (LWC) USING MATLAB $_{\text{(R2013a)}}$

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Abstract

The Composite Steel Column consists of both Steel and Concrete as main components. In this study, the load carrying capacity of CFST will be determined for Light Weight Concrete by developing programs using MATLAB software. The behavior of CFST plays an important role in Seismic design. In this study, the Light Weight Concrete is used as infilled materials of different grades of concrete like M20, M30, and M40. The required data of CFST columns like length, diameter, and weight are taken from different National & International research works, including R&D works carried out at Civil Engineering Research Laboratory at Ghousia College of Engineering, Ramanagaram by previous UG, PG & Research Scholars since 2010 till date. In this study, both Long and Short columns are considered. Percentage errors between Experimental, Analytical values and MATLAB results are studied in detail according to Slenderness Ratio of CFST columns. Results are compared with available codes like EUROCODE 4, ACI, BS5400 and suitable conclusions are drawn.

***Keywords:** Light Weight Concrete, Filled steel tubes, Hollow CFST, MATLAB R2013a etc…*

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1. INTRODUCTION

The Composite Steel Columns are composed of both Steel and Concrete components. The solid filled steel tubes has been utilized as a part of numerous zones which is principally similar to segment supporting structures like multi-storey buildings, roof of oil stockpiling tanks, columns for vast modern workshops. Because of its basically proficient load bearing limit the solid filled steel tubes utilizes as segments in multi storied structures which is expanded in late decades.

The concrete filled steel tubes were developed during 19th century. And the composite steel columns have a many excellent structural properties such as high compressive strength, large ductility and large energy absorption capacity. Concrete steel tubes are used for both unbraced and propped gathering structures.

The typical figures of CFST sections are as shown in below figure.

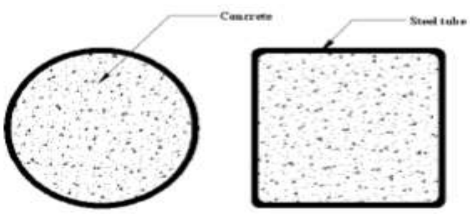

Fig 1: Typical Cross Section of CFST

1.1 Description of Software Used

The name of the software MATLAB stands for matrix laboratory. The MATLAB is a high performance language for technical computing. The 3D modeling of CFST columns infilled with LWC and also hollow CFST columns are modeled by developing MATLAB programs.

Light Weight Concrete filled in CFST columns and hollow columns are accurately modeled in MATLAB R2013a software. The results are verified with available codes.

2. FINITE ELEMENT MODELING

The finite element modeling of CFST columns are done using MATLAB (R2013a) software by developing the programs,

2.1 Material Properties

The properties of Steel and Concrete are considered as follows
Steel properties:
Young's modulus of steel (E_s)=200GPA
Poisons ratio=0.3
Density of steel=7860Kg/m^3
Concrete Properties:
Young's modulus of concrete (E_c) =0.0095(f_{cyl}+8)$^{0.3}$ (by referring the journals by the Author of ARTIOMAS KURANOVAS')
Poisons ratio=0.2
Density of concrete=2200Kg/m^3

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2.2 Modeling of CFST Columns

The 3D modeling of CFST columns of LWC as an infilled material and hollow CSFT columns for above properties are created by developing the MATLAB programs. The MATLAB programs is as shown in below

```
%% PRAMETER DECLARATION SECTION
LENGTH=202.2;% Length in mm
Outer_Dia=33.7;% Outer Diameter in mm
Inner_Dia=27.3;% Inner Diameter in mm
Weight_in_gram=540;% Weight in Grams
Grades=20;%
Load=182450;%
E_s=20000;%
g=9.81%
Mass=Weight_in_gram/g;%
%% Moment of Inertia, I = Is + Ic (mm4)
I_s= 3.14*((Outer_Dia^4)-(Inner_Dia^4))/64;
I_c=3.14*(Inner_Dia^4)/64;
I=I_s+I_c;
%% (EI)eff = Es Is + C3 Ec Ic (Nmm2)
A_s=3.14*((Outer_Dia^2)-(Inner_Dia^2))/4;
A_c=3.14*(Inner_Dia^2)/4;
C3_C3_0_9=0.6+2*(A_s/(A_c+A_s));
E_c=(5000*(sqrt(Grades)))*(2.3544*10^-5);
E_I_eff=(E_s*I_s)+(0.8*E_c*I_c);
%% TO FIND STIFFNESS AND NATURAL FREQUENCY
eff_Length=0.65*LENGTH;
Stiffness=(12*E_I_eff)/eff_Length^3;
disp('Stiffness');
disp(Stiffness);
Natural_Frequency=sqrt(Stiffness/Mass);
disp('Natural_Frequency');
disp(Natural_Frequency);
%% TO FIND FOR COLUMN VIBRATION AND FOR COLUMN BUCKLING
COLUMN_VIBRATION_Lambda1=((Load+((Load^2)+(4*78000000*((3.14*Outer_Dia^2)/4)*E_I_eff*Natural_Frequency^2))^0.5)/(2*E_I_eff))^0.5;
disp('COLUMN_VIBRATION_Lambda1');
disp(COLUMN_VIBRATION_Lambda1);
COLUMN_VIBRATION_Lambda2=((-Load+((Load^2)+(4*78000000*((3.14*Outer_Dia^2)/4)*E_I_eff*Natural_Frequency^2))^0.5)/(2*E_I_eff))^0.5;
disp('COLUMN_VIBRATION_Lambda2');
disp(COLUMN_VIBRATION_Lambda2);
COLUMN_BUCKLING_Lambda1=(Load/E_I_eff)^0.5;
disp('COLUMN_BUCKLING_Lambda1');
disp(COLUMN_BUCKLING_Lambda1);
%% TO FIND THE CRITICAL LOADING FOR INFILLED
critical_loading= ((pi^2)*E_I_eff)/LENGTH^2;
disp('CRITICAL LOADING');
disp(critical_loading);
%% 3-D CFST COLUMN INFILLED LWC
t = linspace(0,2*pi);
rin = 0.27;
rout = 0.3;
center = [0, 0];
zin = rin*cos(t);
zout = rout*cos(t);
yin = rin*sin(t);
yout = rout*sin(t);
x1 = 0;
x2 = 1;
figure(1);
```

After developing the above programme, the 3D modelling of CFST columns will be as shown in below figure.

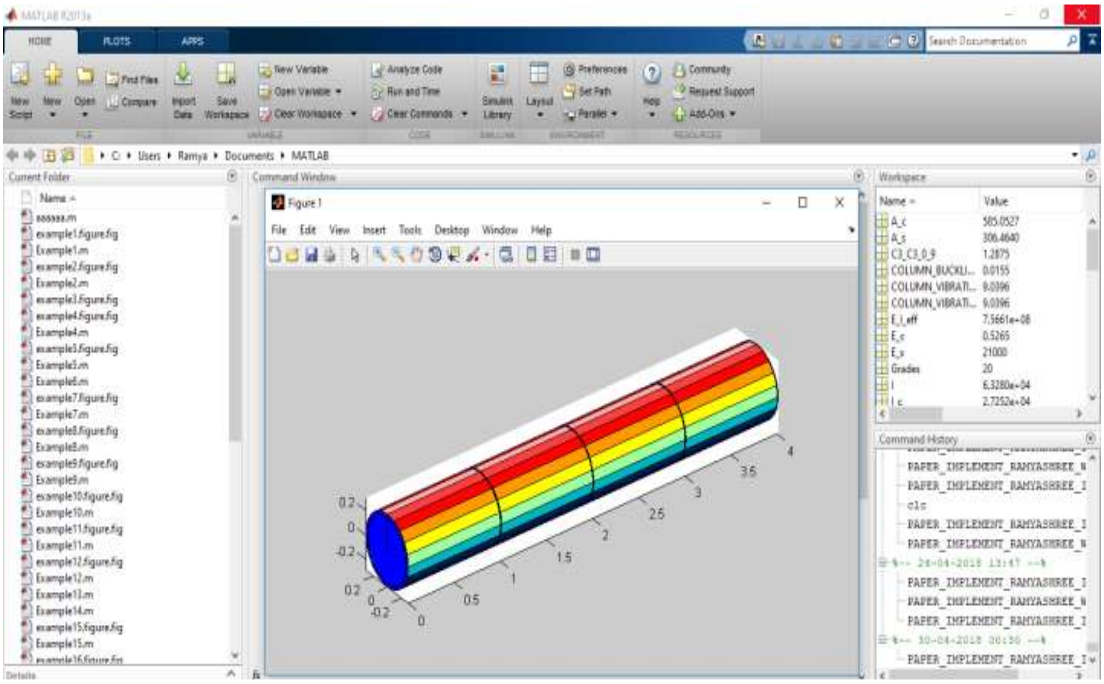

Fig 2: 3D Modelling of CFST column

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The Natural Frequencies, Modal Frequencies and also Critical load of CFSTs are generated by using MATLAB programme. The output results are as shown in figure3, 4.

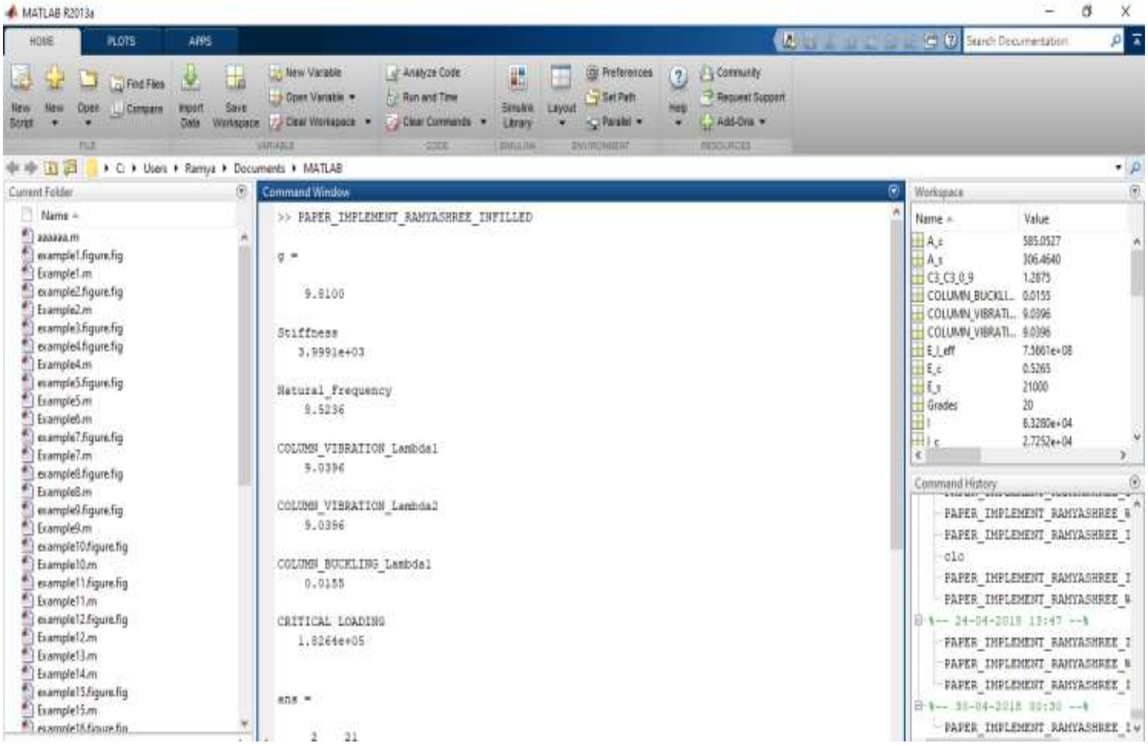

Fig 3: Output results of MATLAB

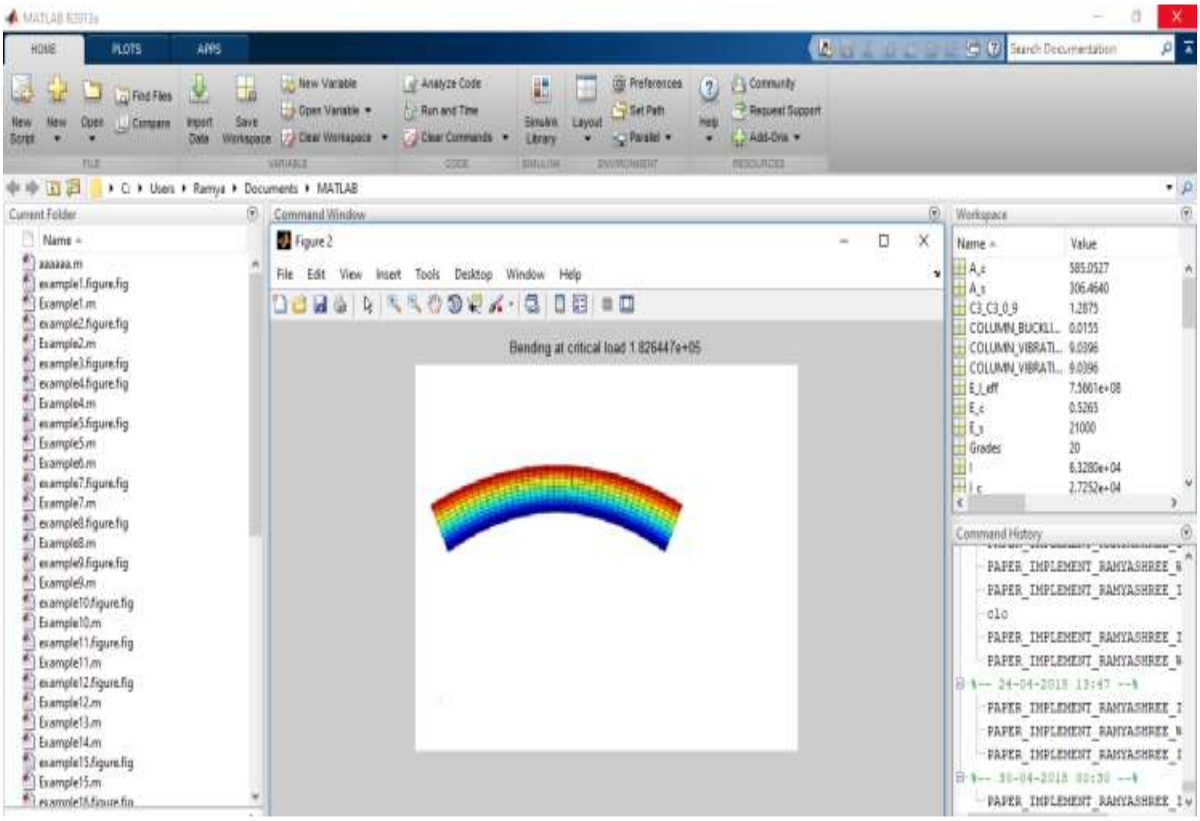

Fig 4: Buckling of CFST column

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3. SOLUTION PROCEDURES

The results of Natural Frequencies and Modal Frequencies of CFST columns and also Critical load of CFST columns (for both infilled LWC and hollow CFST) for different L/D ratios and also for different grades of concrete like M20, M30, M40 are calculated by using below procedures.

3.1 Natural frequency

The natural frequency of CFST columns are calculated by using below formula

$$w_{(rsd)}=(k/m)^{0.5}$$

Where, w=Natural frequency in rad
k= stiffness of CFST in N/mm
m=mass of CFST in N-sec^2/mm

3.2 Modal Frequencies

The Modal Frequency for CFST is calculated by using the following formula

For column vibration:

$$\lambda_{1=}\text{sqrt}\ (P+P^2+4\rho*\text{sqrt}\ ((\pi*D^2/4)*EI*w_n^2))/\ (2*EI))$$

$$\lambda_2=\text{sqrt}\ (-P+P^2+4\rho*\text{sqrt}\ ((\pi*D^2/4)*EI*w_n^2))/\ (2*EI))$$

Where, P=crippling load in N
D=Outer diameter in mm
W_n=Natural frequency in rad

For column buckling:

$$\lambda_1=\text{sqrt}\ (P/EI)$$

3.3 Critical Load

To check the accuracy of Critical loading obtained from MATLAB are compared with available codes. The Critical loading of CFST columns are calculated by using the formula as mentioned in below.

$$N_{cr}=(\pi^2\ (EI)_{eff})/L^2$$

Where $(EI)_{eff}$=effective elastic flexural stiffness of concrete sections, and L is the buckling length of column.

$$(EI)_{eff}=E_aI_a+0.8E_{cd}I_c \text{ for short columns}$$

$$(EI)_{eff}=E_aI_a+0.6E_cI_c \text{ for short columns}$$

Where I_a and I_c are the moment of inertia of steel and concrete.
E_a= elastic modulus of steel structures.
$E_{cd}=E_{cm}/\gamma_c$
E_{cm}= mean value of concrete elasticity modulus
γ_c=partial safety factor of concrete which is reduced to 1.35

The results are compared with following codes:

3.3.1 Euro Code 4

The Critical load of CFST columns are calculated by using below formula according to Euro code 4

$$N_{cr}=A_sf_s+A_cf_c$$

3.3.2 ACI Code

The Critical load of CFST columns are calculated by using the below formula according to American Concrete Institute $N_{cr}=A_sf_s+0.85A_cf_c$

3.3.3 BS5400 Code

The Critical load of CFST columns are calculated by using the below formula according to British Standards 5400
$N_{cr}=A_sf_s+0.675A_cf_c$
Where, A_s= area of steel in mm^2
f_s= yield strength of steel in N/mm^2
A_c=area of concrete in mm^2
f_c=characteristic strength of concrete in N/mm2

4. VERIFICATIONS OF RESULTS

The Experimental, Analytical, MATLAB results of Natural frequencies and Modal Frequencies and also Critical loading of CFST columns (for both infilled LWC and hollow) of different L/D ratio and also different grades of concrete are compared with codes is as shown in below

Table 1: Comparison of Natural Frequency with MATLAB

Length	Grades	Natural frequency(Analytic)	Natural frequency(MATLAB)
L (mm)	M	w(rad)	w(rad)
202.2	M20	8.318144571	8.5236
	M30	7.738045	7.9291
	M40	7.54695	7.7333
	Hollow	8.99288	9.234
254.4	M20	6.0263477	6.186
	M30	5.939948	6.053
	M40	5.877537	6.034
	Hollow	7.952923	8.152
339.2	M20	3.963534	4.1254
	M30	3.91782	4.0012
	M40	3.71541	3.8081
	Hollow	4.8406466	4.9821
424	M20	2.089496	2.1542
	M30	1.96344787	2.01325
	M40	1.9357695	2.0124
	Hollo	2.649766192	2.7235

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	w		
508.8	M20	1.516685	1.5683
	M30	1.46175	1.4978
	M40	1.41381	1.4512
	Hollow	1.81067166	1.8592
594.6	M20	1.058918	1.1534
	M30	1.042125001	1.0684
	M40	1.0278495	1.0546
	Hollow	1.33913	1.3856
678.4	M20	1.014745	1.3845
	M30	1.0114761	1.0364
	M40	1.011247	1.01145
	Hollow	1.150548	1.1834

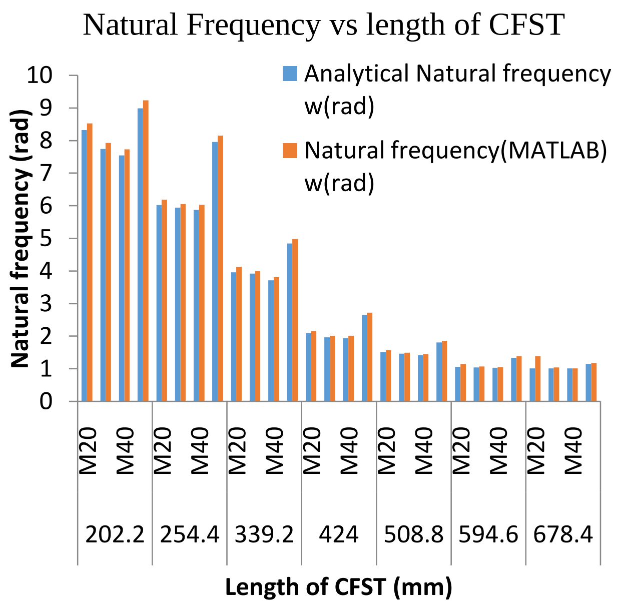

Chart 1: Natural Frequency v/s length of CFST

Table 2: comparison of modal frequencies for 202.2mm length

L	Grades	Modal Frequency(Analy)			Modal Frequency(MATLAB)		
	M	λ1	λ2	λ3	λ1	λ2	λ3
202.2	20	9.03	9.03	0.01	9.03	9.03	0.01
	30	8.71	8.71	0.01	8.71	8.71	0.01
	40	8.61	8.61	0.01	8.61	8.61	0.01
	Hollow	9.39	9.39	0.01	9.41	9.41	0.01

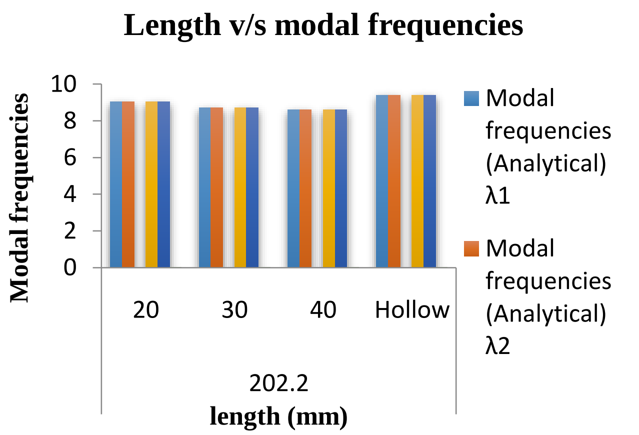

Chart 2: modal frequencies for a length of 202.2mm

Table 3: comparison of modal frequency for 254.2mm length

L	Grades	Modal frequency(Analyt)			Modal frequency(MATLAB)		
	M	λ1	λ2	λ3	λ1	λ2	λ3
254.2	20	7.15	7.15	0.01	7.15	7.15	0.01
	30	7.10	7.10	0.01	7.12	7.12	0.01
	40	7.06	7.06	0.01	7.06	7.06	0.01
	Hollow	8.22	8.22	0.01	8.22	8.22	0.01

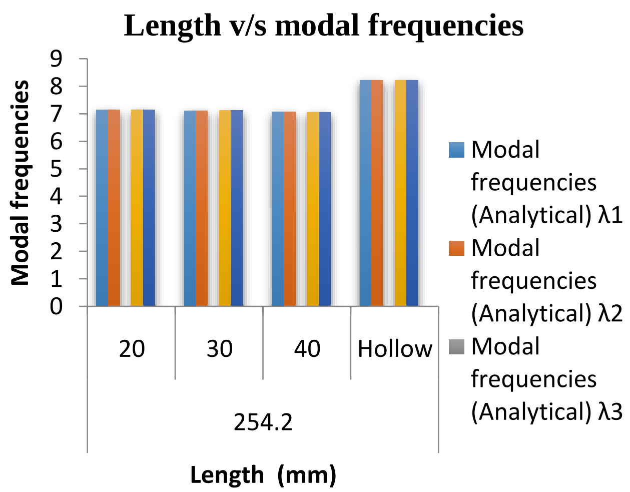

Chart 3: Modal frequency for 254.2mm length

Table 4: Comparison of modal frequencies for 392.2mm length

L	Grades	Modal frequency (Analytical)			Modal frequency(MATLAB)		
	M	λ1	λ2	λ3	λ1	λ2	λ3
392.2	20	5.80	5.80	0.01	5.80	5.80	0.01
	30	5.77	5.77	0.01	5.77	5.77	0.01
	40	5.61	5.61	0.01	5.61	5.62	0.01
	Hollow	6.41	6.41	0.01	6.41	6.41	0.01

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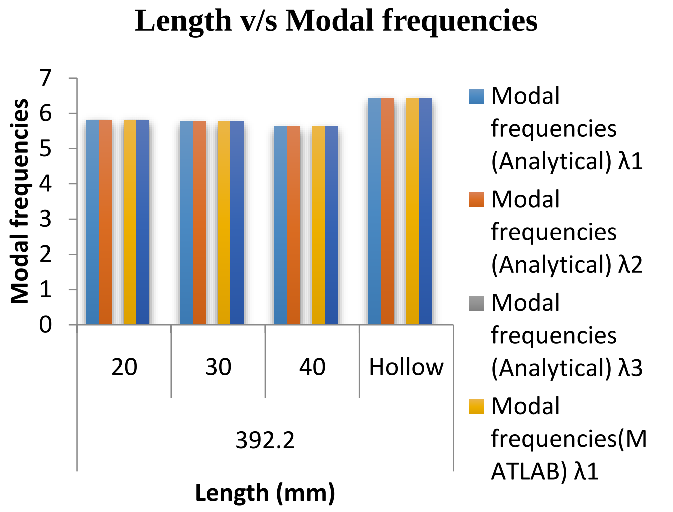

Chart 4: Modal frequencies for length of 392.2mm

Table 5: comparison of modal frequencies for 424mm length

L	Grades	Modal frequency(Analytical)			Modal frequency(MATLAB)		
	M	λ1	λ2	λ3	λ1	λ2	λ3
424	20	4.21	4.21	0.01	4.21	4.21	0.01
	30	4.08	4.08	0.01	4.08	4.08	0.01
	40	4.05	4.05	0.01	4.05	4.05	0.01
	Hollow	4.74	4.74	0.01	4.74	4.74	0.01

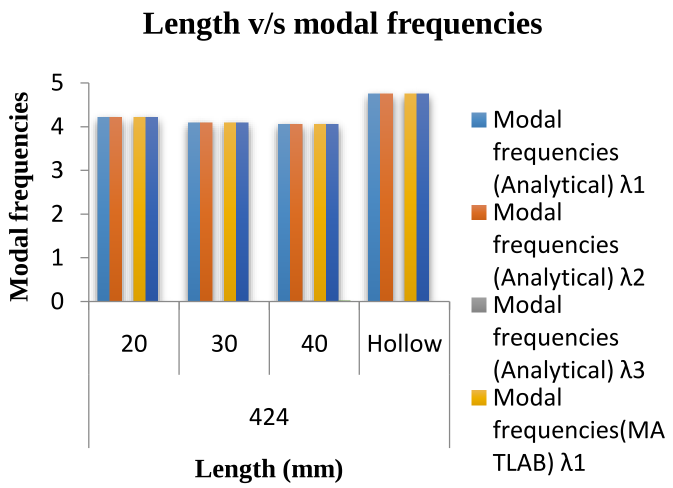

Chart 5: Modal frequency for 424mm length

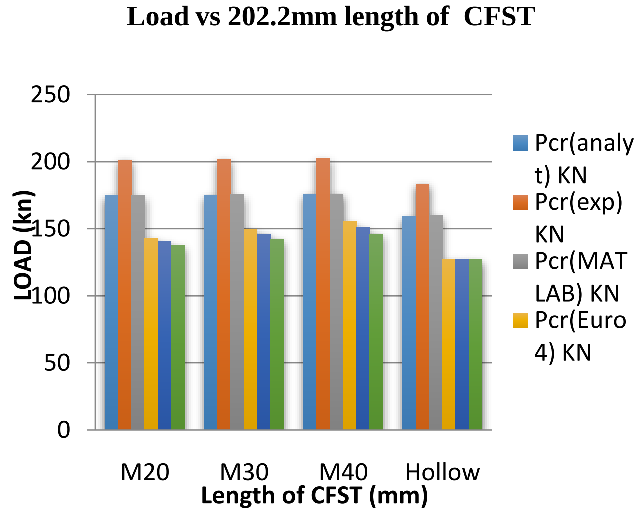

Chart 6: comparison of loads for 202.2mm length

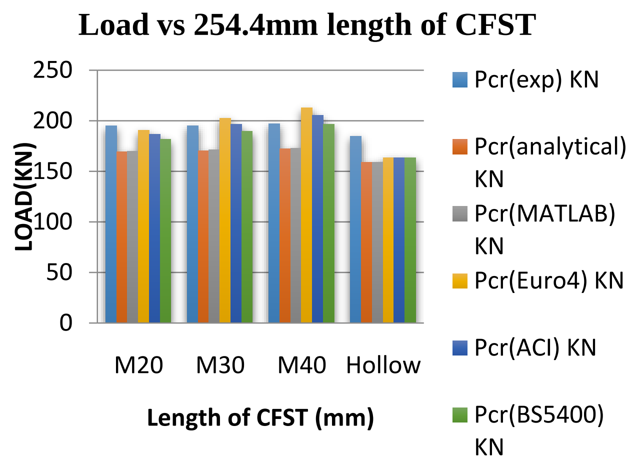

Chart 7: Comparison of loads for 254.4mm length

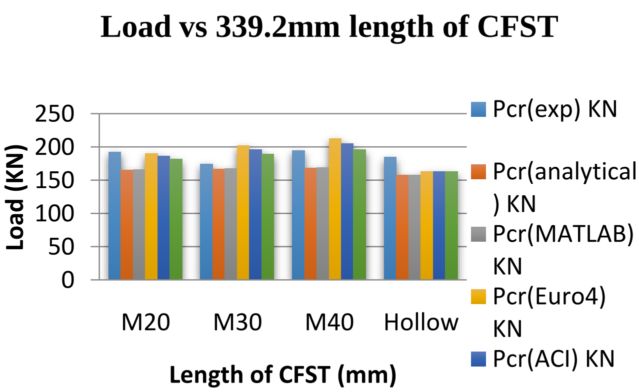

Chart 8: Comparison of loads for 339.2mm length

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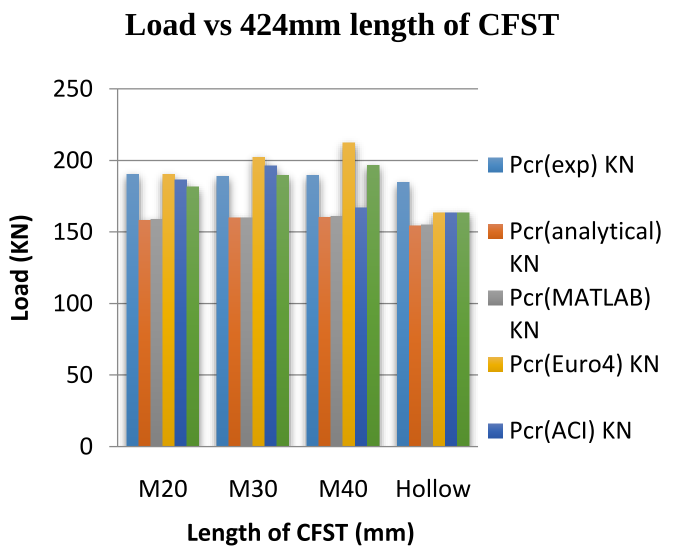

Chart 9: Comparison of loads for 424mm length

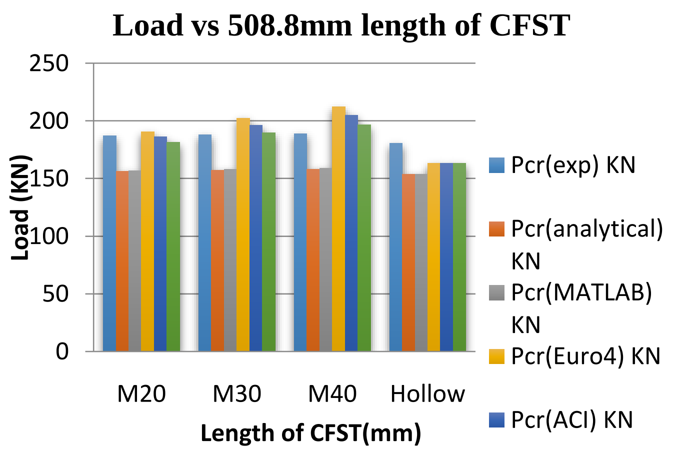

Chart 10: Comparison of loads for 508.8mm length

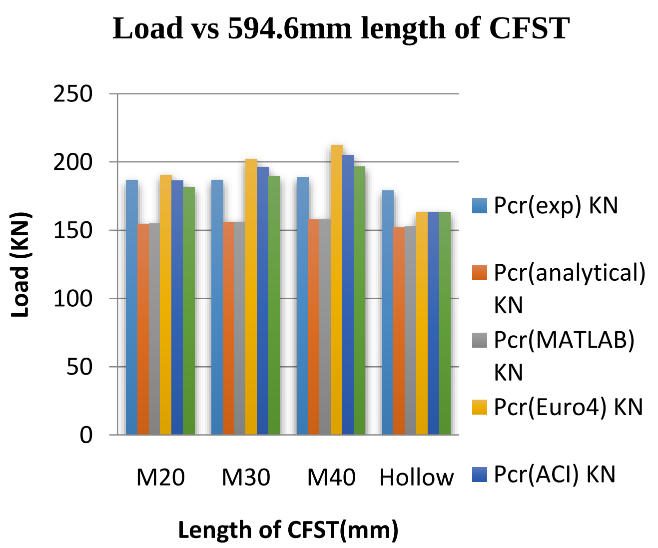

Chart 11: Comparison of loads for 594.6mm length

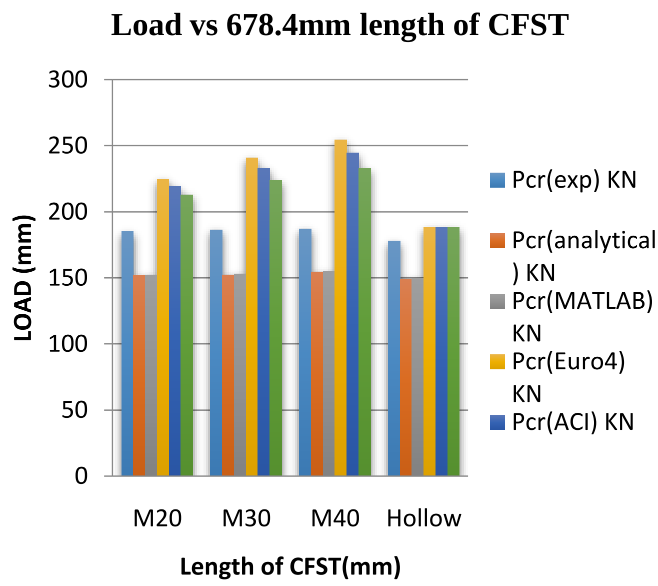

Chart 12: Comparison of loads for 678.4mm length

5. CONCLUSION

In this study the following conclusions are drawn,

[1]. As the Column Length increases, the Load Carrying Capacity of CFST is decreased by 2.36%.

[2]. As Slenderness Ratio (L/D) increases, Load Carrying Capacity of CFST is decreased by 2.36%.

[3]. As Grades of Light Weight Concrete increases (i.e. M20, M30, and M40), Load Carrying Capacity of CFST column increased by 0.651% for a Column of Constant Length.

[4]. For Particular Grade of Concrete Load Carrying Capacity increased by 2 to 5% for 15 to 16% increased in Column Length.

[5]. For 15 to 16% increased in Column Length, Load Carrying Capacity is decreased by 1.5 to 5%.

[6]. As Grades of Concrete increases and for 15 to 16% Column Length increases, then percentage increases in Load Carrying Capacity was found to be very nominal 0.5 to 1%.

[7]. For Short Columns ($\lambda<12$), Ultimate Load obtained from developing MATLAB programming varying by 0.45% when compared with Analytical Results by referring the Journals of Load Bearing Capacity of Concrete Filled Steel Columns by the ARTIOMAS KURANOVAS' for M20 Grades of Concrete.

[8]. For Long Columns ($\lambda>12$), Ultimate Load obtained from developing MATLAB programming varying by 0.419% when compared with Analytical Results by referring the Journals Of Load Bearing Capacity Of Concrete Filled Steel Columns by the ARTIOMAS KURANOVAS' for M20 Grades of Concrete.

[9]. For Short Columns ($\lambda<12$), Ultimate Load obtained from developing MATLAB programming varying by 0.534% when compared with Analytical Results by referring the Journals Of Load Bearing Capacity Of Concrete Filled Steel Columns by the ARTIOMAS KURANOVAS' for M30 Grades Of Concrete.

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[10]. For Long Columns (λ>12), Ultimate Load obtained from developing MATLAB programming varying by 0.39% when compared with Analytical Results by referring the Journals Of Load Bearing Capacity Of Concrete Filled Steel Columns by the ARTIOMAS KURANOVAS' for M30 Grades Of Concrete.
[11]. For Short Columns (λ<12), Ultimate Load obtained from developing MATLAB programming varying by 0.618% when compared with Analytical Results by referring the Journals Of Load Bearing Capacity Of Concrete Filled Steel Columns by the ARTIOMAS KURANOVAS' for M40 grades of concrete.
[12]. For Long Columns (λ>12), Ultimate Load obtained from developing MATLAB programming varying by 0.361% when compared with Analytical Results by referring the Journals Of Load Bearing Capacity Of Concrete Filled Steel Columns by the ARTIOMAS KURANOVAS' for M40 Grades Of Concrete.
[13]. For Short Columns (λ<12), Ultimate Load obtained from developing MATLAB programming varying by 0.447% when compared with Analytical Results by referring the Journals Of Load Bearing Capacity Of Concrete Filled Steel Columns by the ARTIOMAS KURANOVAS' for Hollow CFST.
[14]. For Long Columns (λ>12), Ultimate Load obtained from developing MATLAB programming varying by 0.433% when compared with Analytical Results by referring the Journals Of Load Bearing Capacity Of Concrete Filled Steel Columns by the ARTIOMAS KURANOVAS' for Hollow CFST.
[15]. Results obtained by developing MATLAB programming is compared with 3 different codes i.e. EUROCODE 4, ACI, BS5400, in which EUROCODE4 gives better results in comparison with Analytical, Experimental and MATLAB results.
[16]. As Length of Column increases, the Natural Frequency of column decreases by 20% to 25%.
[17]. For Particular Grade of concrete, the Natural Frequency decreased by 20% to 25% (for 15% to 16% length increase)
[18]. As Grade of Concrete increases, the Natural Frequency found to decrease by 4 %to 6%. (Length being constant)
[19]. For Change in Length of Column, the Natural Frequency obtained from developing MATLAB programming varied between 2% to 2.5% when compared with Analytical results.
[20]. As Column Length increases, the Modal Frequencies were observed to decrease.
[21]. For Particular Grade of Concrete (for 12% to 16 %of increased length), the Modal Frequencies decreased by 8% to 12%.
[22]. For Constant Length and for increased grade of concrete, Modal Frequencies decreased by 3.5% to 5%.

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BIOGRAPHIES

Graduated in the year 2016 from VTU, Belgaum. Presently perusing Master of Technology in Structural Engineering at Ghousia College of Engineering, Ramanagaram Also working on this topic for the dissertation under the guidance of Dr. N S Kumar.

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