BEHAVIOUR OF COMPOSITE CIRCULAR STEEL COLUMN INFILLED WITH FIBRE REINFORCED CONCRETE SUBJECTED TO MONOTONIC LOADING

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ABSTRACT: Many in-fill materials are used to improve ductility of Concrete Filled Steel Tube (CFST). Among the various in-fill materials, fibre is gaining attention in the CFST column. Here an attempt is made to study the effects of the diameter, thickness of steel tube, grade of concrete & volume fractions of glass fibre to Concrete on the behaviour of CFST under Axial Compression. In this research, Taguchi's methodology with DOE (Design of Experiments) is adopted before conducting experiments for selection of combinations. Therefore, 27 experiments have been conducted for M20 grade, 9 experiments for M25 grade & 9 experiment for Hollow Steel Tube. The results indicate that glass fibre reinforced concrete filled steel tube columns appears to have a significant increasing trend in ductility, & have slight increasing trend in load capacity with increase in volume fraction of glass fibre for 0.5% & 1% whereas decreasing beyond 2%. Obtained Experimental results have been verified with different codes-Euro code (EC4-2004), American code (ACI-1999), Japan code (AIJ-1997), Australian code (AS 5100-2004), and British code (BS-5400-2005). The results obtained by experiment, theoretical calculations are validated using ANSYS V.12 model and the errors corresponding to the obtained practical and analytical values are tabulated and concluded. Variation was found to be in the range 5%-20% may be due to quality of steel & micro defects.

Keywords: Glass Fibre Reinforced Concrete (GFRC), Concrete filled steel tube (CFST), 200Ton capacity Monotonic loading Machine, D.O. E approach (Taguchi's approach), and Hollow steel tube (HST), Analysis System (ANSYS).

1. INTRODUCTION

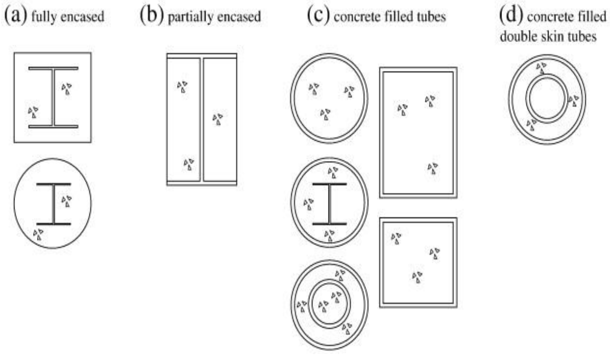
The in-fill material inside steel tubes is required to be of the quality as to increase the ductility, but not the strength of composite columns, many kind of in-fill materials were used to improve ductility of composite columns. Among the various in-fill materials, fibre is gaining attention in the composite columns, due to high flexural strength, tensile strength, lower shrinkage, & better fire resistance. The use of fibre reinforced concrete as filling material has an improvement in the ductility of fibre reinforced concrete filled steel tube, delays the bulge deformation and results in an enhanced energy absorption capacity of fibre reinforced concrete filled steel tube.

In this paper, the effects of the diameter, thickness of steel tube, grade of concrete & volume fractions of glass fibre to concrete on the behaviour of short glass fibre reinforced concrete filled steel tube columns under axial compression are presented. According to the past study on the concentric compression behaviour of the CFT columns, the ultimate axial strength of CFT column is considerably affected by the wall thickness of the steel tube, strength of in-filled concrete and the length of the CFT. The present work is intended to study the parameters affecting the ultimate axial load carrying capacity and corresponding axial shortening of the CFT using Design of Experiments (DOE) approach.

2. ADVANTAGE OF USING CFT OVER ENCASED COLUMNS

Composite column combines the advantages of both structural steel & concrete, namely the speed of construction, strength, & light weight steel, & the inherent mass, stiffness, damping, & economy of concrete. The steel frame serves as the erection frame to complete the construction of the rest of the structure. Thus improving ductility. Furlong concludes that the concrete infill delays the local buckling of the steel tube. However, no increase in concrete strength due to confinement by steel tube was observed.

Fig 1:- Types of Composite Column



3. MATERIAL PROPERTIES

CONCRETE:-Design mixes are prepared using locally available Portland Pozzolana Cement (PPC), crushed granite jelly (12.0mm down) and river sand. Mix designs of these two grades (M20, M25) of concrete are made based on the guidelines of IS 10262-1982. The mix proportions adopted for the two grades of concrete are shown in table below

Table 1:- Mix Proportions

SL NO.	Mix designation	% of Fibre	Binder(B)(Kg/m^3)	Proportions B:FA:CA	W/B ratio	28 days compressive strength (f_{cu} N/mm^2)
			CEMENT			
1	M_{20}	0%	336.42	1:1.6:3.3	0.5	23.33
2		1%				28.06
3		2%				29.01
4	M_{25}	0%	320.00	1:2.35:4.24	0.43	27.95
5		1%				30.54
6		2%				31.28

Fig 2:- Casting, Curing & Testing of Cube for finding 28 days Compressive Strength

STEEL (CIRCULAR HOLLOW STEEL TUBES-CHS):-The steel columns used were hot-rolled CHS sections of diameters (33.7, 42.4, and 48.3). The allowable D/t ratios of the steel hollow sections are less than the limits specified in EC-1994 and thus the premature buckling failure of CFT specimens is avoided.

Table 2:- Slenderness Ratio Table

TO PREVENT LOCAL BUCKLING, λ<(125/(Fy/250))=(125/(310/250))=100.8 for YST 310 GRADE

NOMINAL BORE, mm	OUTSIDE DIAMETER, mm	THICKNESS mm	$\lambda=\frac{(2(sqrt(3))*L)}{D}$	Slenderness value for L=300MM	D/t	L/D for L=300MM
25	33.70	2.60	0.103L	30.84	12.96	8.90
		3.20			10.53	
		4.00			8.43	
32	42.40	2.60	0.082L	24.51	16.31	7.08
		3.20			13.25	
		4.00			10.60	
40	48.30	2.90	0.072L	21.52	16.66	6.21
		3.20			15.09	
		4.00			12.08	

Since all slenderness value is less than 100.8 hence local buckling is prevented

Fig 3:- Cutting & preparation of Specimen to required Length

GLASS FIBER: - In this section the glass fibre-reinforced concrete is examined. It is a cement-based material reinforced with short glass fibres. When glass fibre is added to a concrete mix, they are randomly distributed and act as crack stemmers. Debonding and pulling out of fibres require more energy, giving a considerable increase in resistance and toughness under static or dynamic, monotonic or cyclic loading

Fig 4:- Glass Fibre

PROPERTIES

- High tensile strength, 1020 to 4080 N/mm^2
- Glass Fibre of length 20mm, diameter 13.2µm & aspect ratio of 151 are used
- Improvement in impact strengths, to the tune of 1500%
- Increased flexural strength, ductility and resistance to thermal shock

TEST SETUP:-The column specimens are tested at 28 days of age. The tests are conducted in a 200Ton capacity Monotonic loading machine. The specimen is tightly fixed and then axial load is applied slowly by careful manipulation of the loading-values. The readings of the applied load, Axial shortening are recorded at appropriate load increments.

Fig 5:- Loading Apparatus

Current Design Provisions

- Euro code (EC4-2004)
- American code (ACI-1999)
- Japan code (AIJ-1997)
- Australian code (AS 5100-2004)
- British code (BS-5400-2005).

4. INTRODUCTION TO DOE

DOE (Design of Experiments) is a formal structured technique for studying any situation that involves a response that varies as a function of one or more independent variables.

TYPES OF DOE

- Factorial Design
- Mixture Design
- Response surface Method
- Taguchis Method

Comparison of Taguchi’s Design

For 3 Factors with 3 levels in General Design =3^3X3 (L^F X 3 Levels) = 81

For 3 Factors with 3 levels in Taguchi’s Design=9 Combinations X 3 Levels = 27 therefore, Save =66.66 %

For 4 Factors with 3 levels in General Design =3^4X3 (L^F) X 3 Levels =243

For 3 Factors with 3 levels in Taguchi's Design=9 Combinations X 3 Levels = 27 therefore, Save =88.89%

5. EXPERIMENTAL PROGRAMME

Concrete is filled in the steel tube in approximately four layers and each layer is well compacted. Top of the concrete is trimmed off using a trowel and steel tube is kept undisturbed until it is taken out from the stand after 24hr to keep in water for curing. After curing the in filled tubes for 28days CFST in filled tubes with fibre reinforced concrete of different percentages as per Taguchi level-3 design with 4 -factors are placed upright for compression loading with proper end conditions and are tested for ultimate axial load and axial shortening under a 200 Ton Cyclic and Sustained Loading. The specimen is tightly fixed and then axial load is applied slowly by careful manipulation of the loading-values. The readings of the applied load, Axial shortening are recorded at appropriate load increment

Fig 6:- Experiment Procedure

TAGUCHI L9 ORTHOGONAL ARRAY (Table 3)

EXPERIMENT NOS	A	B	C
1	A1	B1	C1
2	A1	B2	C2
3	A1	B3	C3
4	A2	B1	C2
5	A2	B2	C3
6	A2	B3	C1
7	A3	B1	C3
8	A3	B2	C1
9	A3	B3	C2

(OR)

EX NOS	D	t	% OF GF
1	D1	t1	0%GF
2	D1	t2	1%GF
3	D1	t3	2%GF
4	D2	t1	1%GF
5	D2	t2	2%GF
6	D2	t3	0%GF
7	D3	t1	2%GF
8	D3	t2	0%GF
9	D3	t3	1%GF

6. THEORITICAL FORMULAE & CALCULATION

The design values/capacity of CFST column was calculated using the codes: EC4, ACI (1999), AIJ (1997) & BS5400.

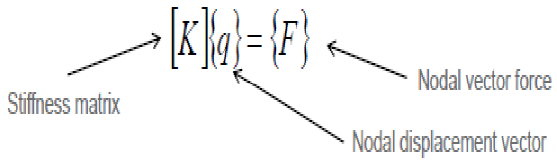
- Eurocode4 (EC4) method,
  $N_{EC4} = (A_S*f_y) + (A_C*f_c)$
- ACI, AIJ & Australian Standards (AS) method,
  $N_{ACI,AIJ,AS} = (A_S*f_y)+0.85\ (A_C*f_c)$
- BS5400 method,
  $N_{BS5400} = (A_S*f_y)+0.675\ (A_C*f_c)$

Where,
Ac = Area of concrete infill,
As = Area of steel tube
f_y= Yield strength of steel tube
f_c= Compressive strength of concrete infill

7. ANALYSIS

Finite Element Method

- For many engineering problems analytical solutions are not suitable because of the complexity of the material properties, the boundary conditions and the structure itself.
- The basis of the finite element method is the representation of a body or a structure by an assemblage of subdivisions called *finite elements.*
- The Finite Element Method translates partial differential equation problems into a set of linear algebraic equations.


$$[K]\{q\}=\{F\}$$

ANSYS

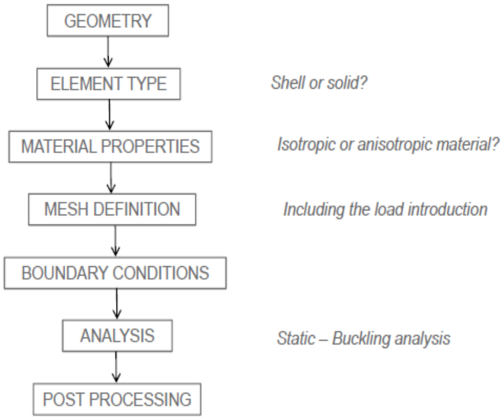
ANSYS is a commercial FEM package having the capabilities ranging from a simple, linear, static analysis to a complex, nonlinear, transient dynamic analysis. It is available in modules. Each module is applicable to specific problem. For example, Ansys/Civil is applicable to Civil structural analysis. Similarly Ansys/Flotran is CFD software applicable to Fluid Flow. The advantage of Ansys compared to other competitive software's is, its availability as bundled software of pre, post and a Processor. Typical Ansys program includes 3 stages.

- Pre-Processing
- Solution
- Post-Processing

MODELING

This is the important step of creating the physical object in the system. They are two types of modeling in Ansys. Direct Modeling & Solid Modeling

Fig 7:- Modeling procedure



MATERIAL SPECIFICATION:

STEEL

- Material : Structural Steel Fe 310Mpa
- Young's Modulus E=200Gpa
- Poison's ratio v=0.3
- Density p=7800kg/m^3.

CONCRETE

- Grade of Concrete:M20
- Grade of Concrete:M25
- Young's Modulus E=22360.7Mpa
- Young's Modulus E =2500Mpa
- Poison's ratio v=0.16-0.3
- Density p=2400kg/m^3

ELEMENTS USED:

SHELL181: SHELL181 is suitable for analyzing thin to moderately-thick shell structures. It is a four-node element with six degrees of freedom at each node: translations in the x, y, and z directions, and rotations about the x, y, and z-axes. The element SHELL181 was used to model the steel tube. All specimens were modeled as 3D structural elements.

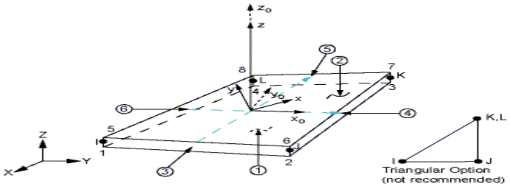


Fig 8:- Shell181 geometry

CONCRETE 65: The element SOLID 65 was used to model the concrete core of the columns. SOLID 65 supports the cracking in tension and crushing in compression properties of concrete. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions.

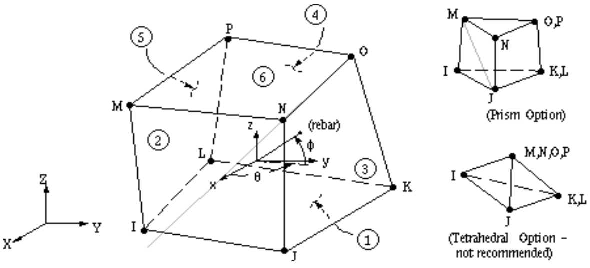


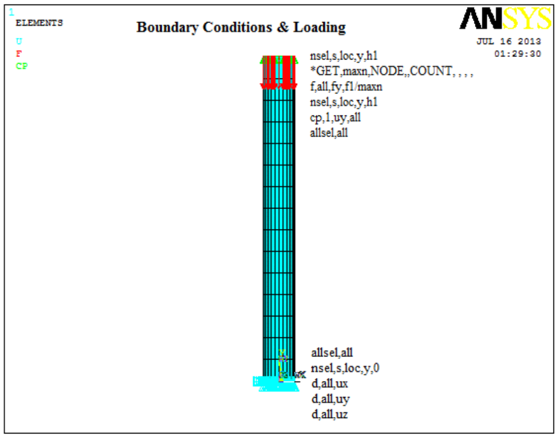
Fig 9:- Solid 65 geometry

ANSYS EIGEN VALUE BUCKLING:

Eigen value buckling analysis predicts the theoretical buckling strength (the bifurcation point) of an ideal linear elastic structure. This method corresponds to the textbook approach to elastic buckling analysis. However, imperfections and nonlinearities prevent most real-world structures from achieving their theoretical elastic buckling strength. Thus, Eigen value buckling analysis often yields un conservative results, and should generally not be used in actual day-to-day engineering analyses.

BOUNDARYCONDITIONS The two ends were considered to be hinged (Fig 10) for modeling. Both the ends, displacement degrees of freedom in x, y directions (U_x, U_y) were restrained and translation U_z as well as rotational degrees of freedom in x, y, z directions (Θ_x, Θ_y, and Θz) was considered to be free.

Fig 10:- Boundary Conditions



```
nsel,s,loc,y,h1
*GET,maxn,NODE,,COUNT, , , ,
f,all,fy,f1/maxn
nsel,s,loc,y,h1
cp,1,uy,all
allsel,all
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allsel,all
nsel,s,loc,y,0
d,all,ux
d,all,uy
d,all,uz
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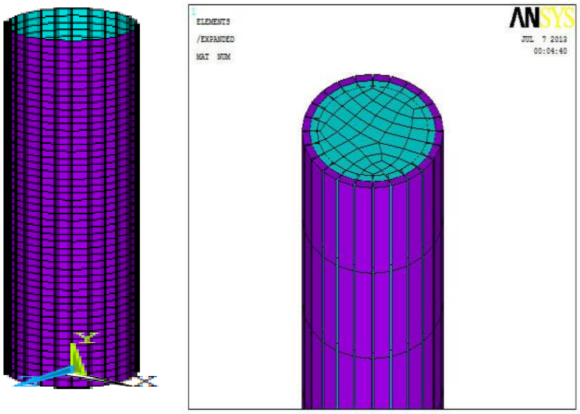
SPECIMEN GEOMETRY

All modeling was conducted using ANSYS 13 finite element software. The project proceeded in several stages of modeling; hollow specimens were modeled as 3D shell181 and concrete specimens were modeled as solid65 element with identical geometry. The dimensions of the sections were chosen to match those being used in the experimental testing of the experiment. A total of 45 specimens were analysis for this study. 9 models were developed for hollow tube section and another 36 models for CFT section both specimen's diameter and thickness varying. **Fig 11** shows the geometry of the sections modeled.

Fig 11:- HST & CFST modeling & meshing



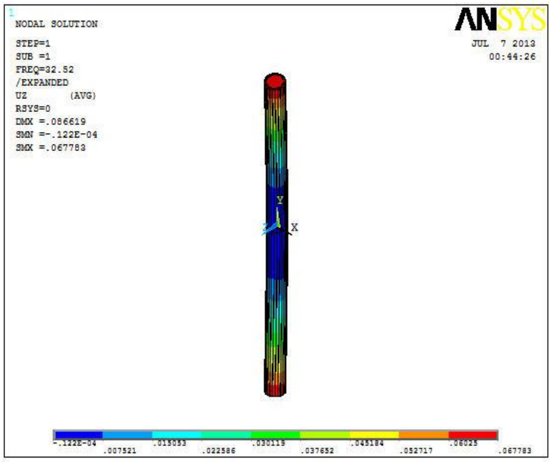


Fig 12:- Global Buckling initial set

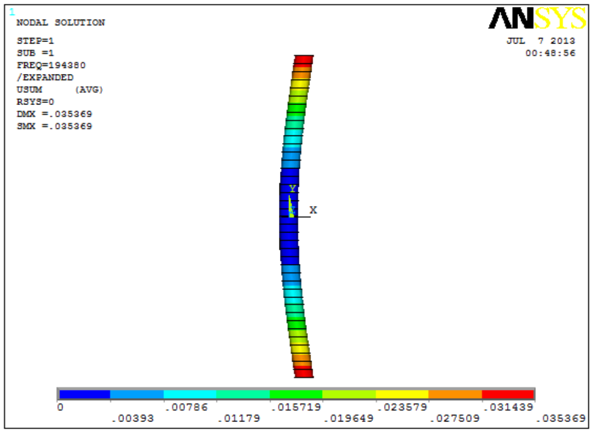


Fig 13:- Global Buckling final set

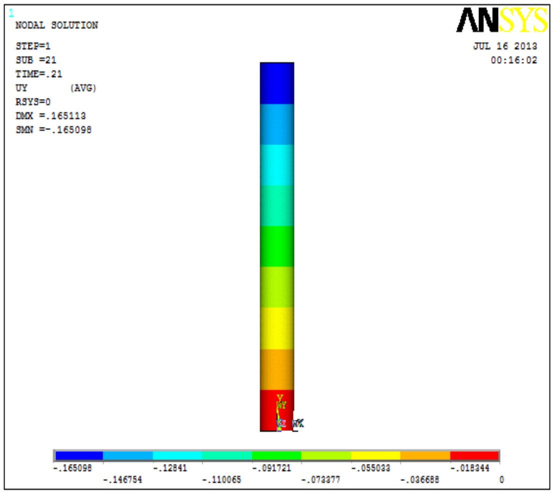


Fig 14:- Displacement of Steel Tube

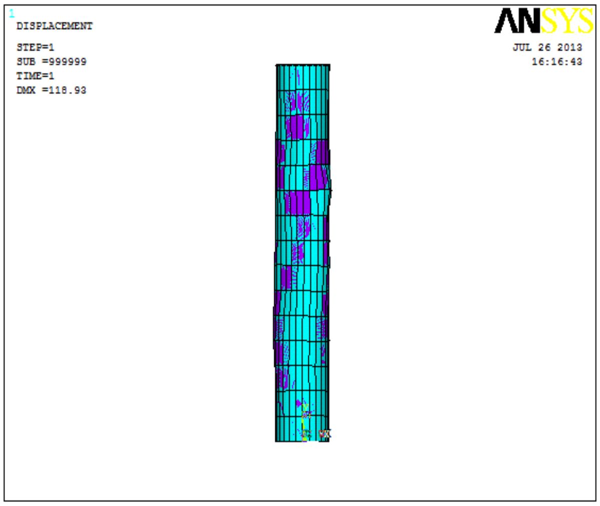


Fig 15:- Buckling deformation of CFST

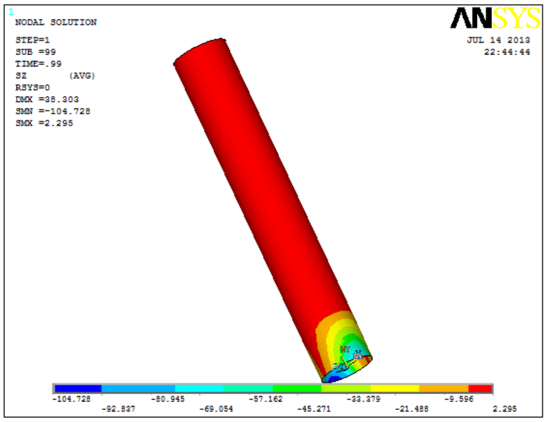


Fig 16:- Stress in Steel Tube

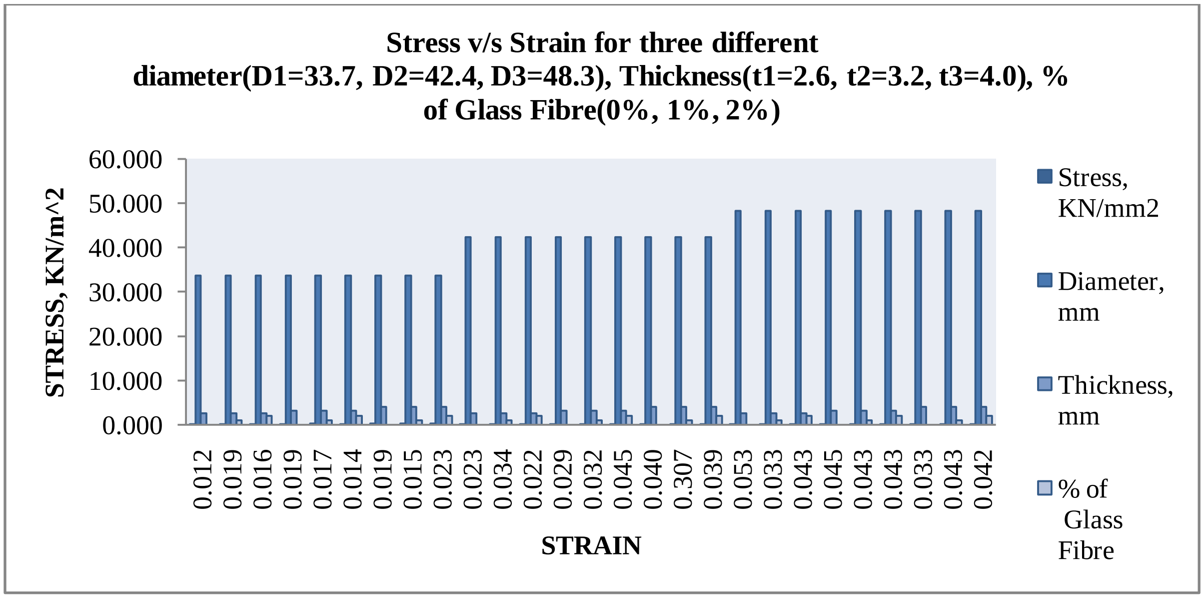
8. LOAD, DEFLECTION, STRESS & STRAIN VALUES OBTAINED FROM EXPERIMENT (Table 4)

Exp no	Diameter, mm	Thickness, mm	% of Glass Fibre	Grade	Length, mm	Area, mm^2	Ultimate Load, P_U KN	Measured length, mm	Change in length, mm	Strain	Stress, KN/mm^2	Young's Modulus, KN/mm^2
1	33.7	2.6	0.0	M20	300.0	891.52	119.0	293.19	6.81	0.023	0.133	5.880
2	33.7	2.6	1.0	M20	300.0	891.52	138.0	289.75	10.25	0.034	0.155	4.531
3	33.7	2.6	2.0	M20	300.0	891.52	135.0	293.55	6.45	0.022	0.151	7.043
4	33.7	3.2	0.0	M20	300.0	891.52	145.0	295.72	4.28	0.014	0.163	11.400
5	33.7	3.2	1.0	M20	300.0	891.52	147.0	294.35	5.65	0.019	0.165	8.755
6	33.7	3.2	2.0	M20	300.0	891.52	143.0	295.27	4.73	0.016	0.160	10.173
7	33.7	4.0	0.0	M20	300.0	891.52	157.0	292.96	7.04	0.023	0.176	7.504
8	33.7	4.0	1.0	M20	300.0	891.52	158.0	294.38	5.62	0.019	0.177	9.460
9	33.7	4.0	2.0	M20	300.0	891.52	151.0	295.39	4.61	0.015	0.169	11.022
10	42.4	2.6	0.0	M20	300.0	1411.24	135.0	291.31	8.69	0.029	0.096	3.302
11	42.4	2.6	1.0	M20	300.0	1411.24	145.0	290.26	9.74	0.032	0.103	3.165
12	42.4	2.6	2.0	M20	300.0	1411.24	132.0	286.45	13.55	0.045	0.094	2.071
13	42.4	3.2	0.0	M20	300.0	1411.24	145.0	296.28	3.72	0.012	0.103	8.286
14	42.4	3.2	1.0	M20	300.0	1411.24	158.0	294.36	5.64	0.019	0.112	5.955
15	42.4	3.2	2.0	M20	300.0	1411.24	137.0	294.80	5.20	0.017	0.097	5.601
16	42.4	4.0	0.0	M20	300.0	1411.24	177.0	287.25	12.75	0.043	0.125	2.951
17	42.4	4.0	1.0	M20	300.0	1411.24	212.0	287.89	12.11	0.040	0.150	3.721
18	42.4	4.0	2.0	M20	300.0	1411.24	209.0	288.38	11.62	0.039	0.148	3.823
19	48.3	2.6	0.0	M20	300.0	1831.32	212.0	284.07	15.93	0.053	0.116	2.180
20	48.3	2.6	1.0	M20	300.0	1831.32	176.0	289.97	10.03	0.033	0.096	2.875
21	48.3	2.6	2.0	M20	300.0	1831.32	171.0	287.25	12.75	0.043	0.093	2.197
22	48.3	3.2	0.0	M20	300.0	1831.32	195.0	290.06	9.94	0.033	0.106	3.214
23	48.3	3.2	1.0	M20	300.0	1831.32	196.0	287.17	12.83	0.043	0.107	2.503
24	48.3	3.2	2.0	M20	300.0	1831.32	169.0	287.44	12.56	0.042	0.092	2.204
25	48.3	4.0	0.0	M20	300.0	1831.32	200.0	287.11	12.89	0.043	0.109	2.542
26	48.3	4.0	1.0	M20	300.0	1831.32	208.0	208.00	92.00	0.307	0.114	0.370
27	48.3	4.0	2.0	M20	300.0	1831.32	202.0	286.40	13.60	0.045	0.110	2.433
28	33.7	2.6	0.0	M25	300.0	891.52	168.0	293.69	6.31	0.021	0.188	8.959
29	33.7	3.2	1.0	M25	300.0	891.52	157.0	293.74	6.26	0.021	0.176	8.440
30	33.7	4.0	2.0	M25	300.0	891.52	155.0	294.42	5.58	0.019	0.174	9.347

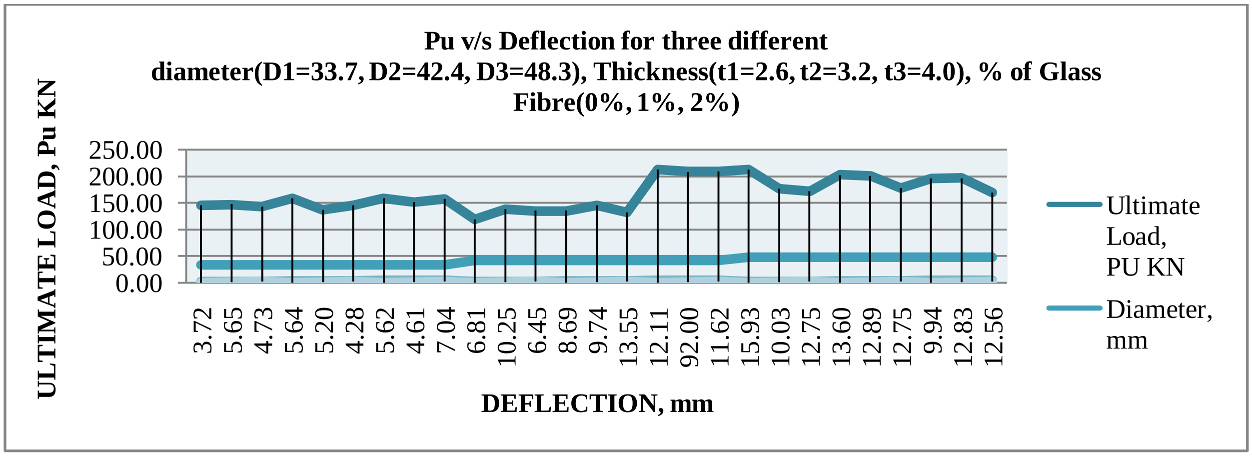
31	42.4	2.6	0.0	M25	300.0	1411.24	169.0	293.44	6.56	0.022	0.120	5.476
32	42.4	3.2	1.0	M25	300.0	1411.24	136.0	292.58	7.42	0.025	0.096	3.896
33	42.4	4.0	2.0	M25	300.0	1411.24	218.0	290.93	9.07	0.030	0.154	5.109
34	48.3	2.6	0.0	M25	300.0	1831.32	243.0	292.57	7.43	0.025	0.133	5.358
35	48.3	3.2	1.0	M25	300.0	1831.32	194.0	284.33	15.67	0.052	0.106	2.028
36	48.3	4.0	2.0	M25	300.0	1831.32	197.0	288.83	11.17	0.037	0.108	2.889
37	33.7	2.6	-	-	300.0	891.52	98.2	284.12	15.88	0.053	0.110	2.081
38	33.7	3.2	-	-	300.0	891.52	112.3	285.23	14.77	0.049	0.126	2.559
39	33.7	4.0	-	-	300.0	891.52	119.3	286.58	13.42	0.045	0.134	2.991
40	42.4	2.6	-	-	300.0	1411.24	100.6	290.56	9.44	0.031	0.071	2.265
41	42.4	3.2	-	-	300.0	1411.24	128.0	291.83	8.17	0.027	0.091	3.330
42	42.4	4.0	-	-	300.0	1411.24	140.3	292.59	7.41	0.025	0.099	4.024
43	48.3	2.6	-	-	300.0	1831.32	120.8	293.59	6.41	0.021	0.066	3.087
44	48.3	3.2	-	-	300.0	1831.32	144.0	294.37	5.63	0.019	0.079	4.190
45	48.3	4.0	-	-	300.0	1831.32	170.9	290.60	9.40	0.031	0.093	2.978

9. GRAPHICAL REPRESENTATION OF LOAD, DEFLECTION, STRESS & STRAIN VALUES OBTAINED FROM EXPERIMENT

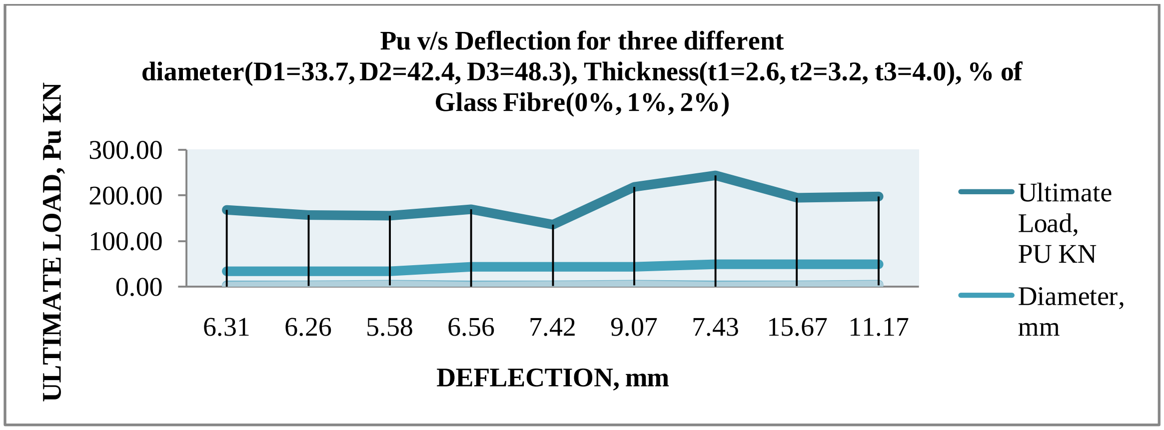
Stress v/s Strain graph for three different Diameter (D1, D2, and D3), Thickness (t1, t2, and t3), and % of Glass Fibre (0%, 1%, 2%) for M20 Grade of Concrete filled CFST.



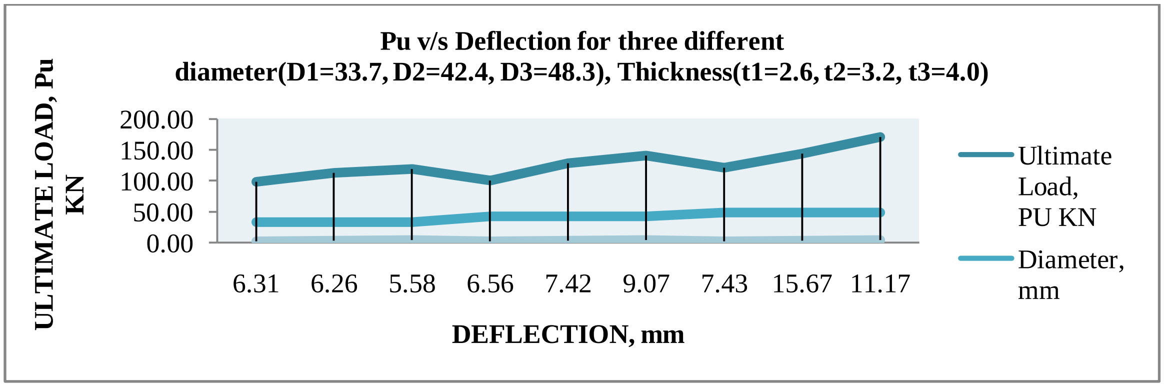
Load v/s Deflection graph for three different Diameter (D1, D2, and D3), Thickness (t1, t2, and t3), and % of Glass Fibre (0%, 1%, 2%) for M20 Grade of Concrete filled CFST.



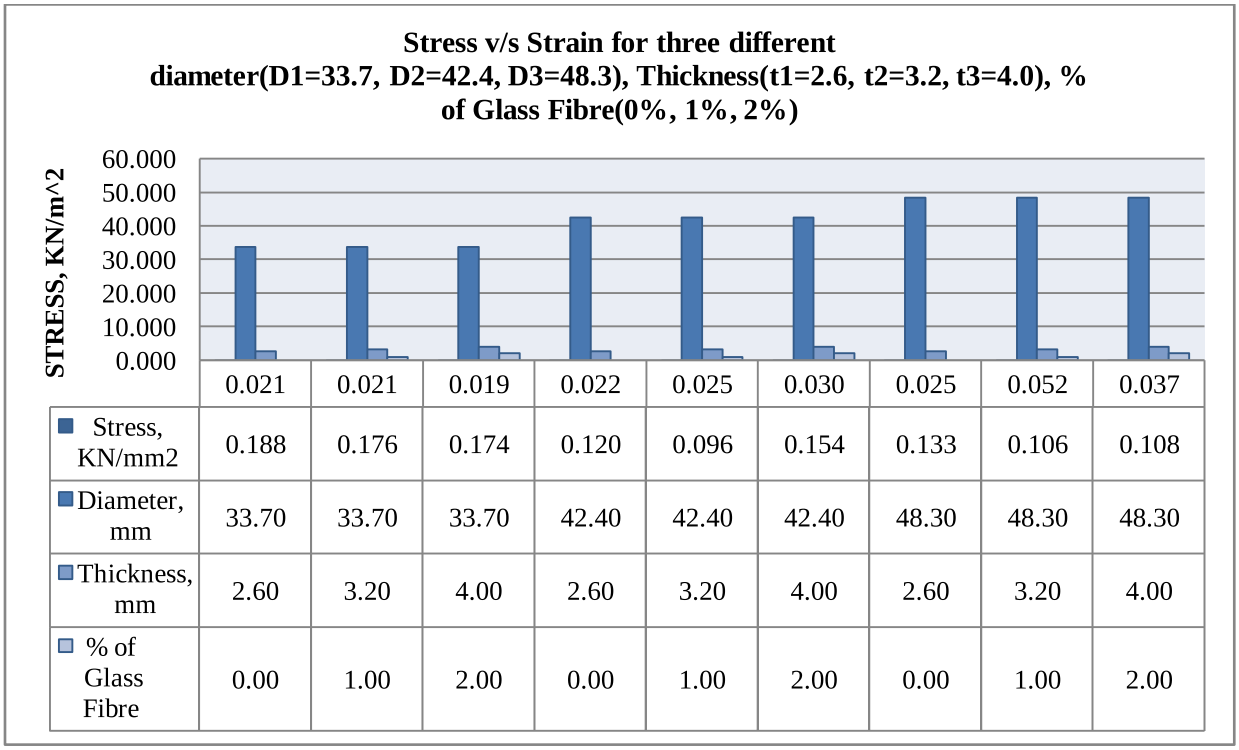
Load v/s Deflection graph for three different Diameter (D1, D2, and D3), Thickness (t1, t2, and t3), and % of Glass Fibre (0%, 1%, 2%) for M25 Grade of Concrete filled CFST.



Load v/s Deflection graph for three different Diameter (D1, D2, and D3), Thickness (t1, t2, and t3), for Hollow Steel Tube

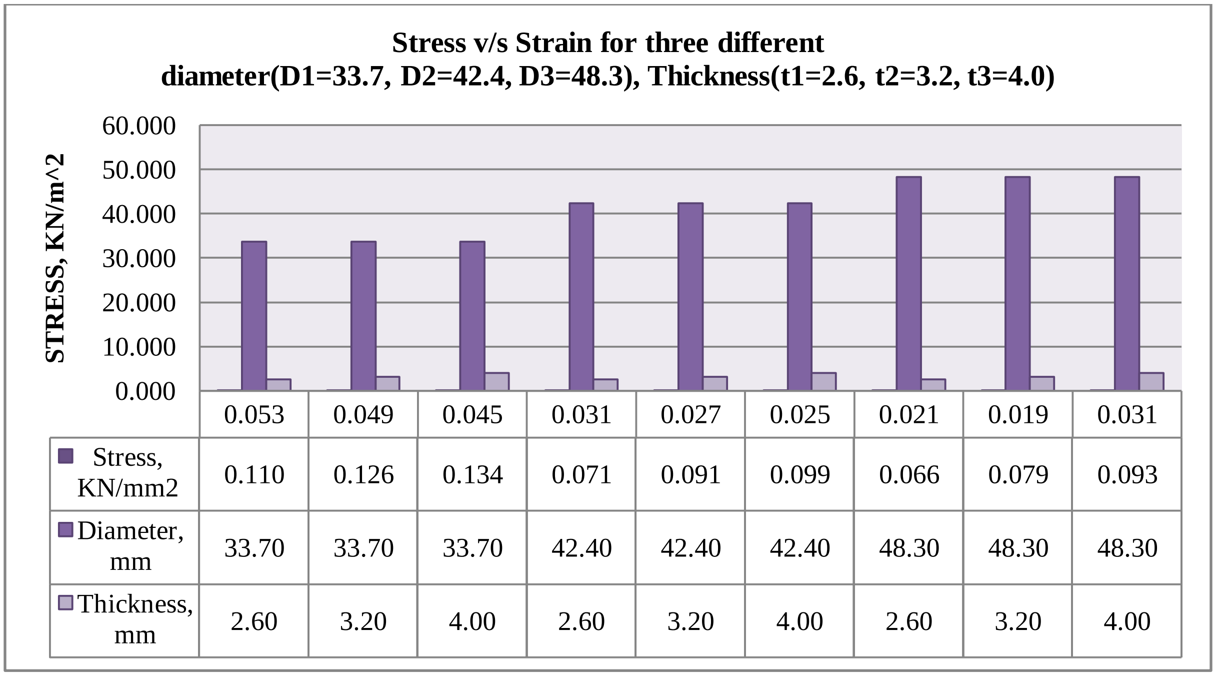


Stress v/s Strain graph for three different Diameter (D1, D2, and D3), Thickness (t1, t2, and t3), and % of Glass Fibre (0%, 1%, 2%) for M25 Grade of Concrete filled CFST.



	0.021	0.021	0.019	0.022	0.025	0.030	0.025	0.052	0.037
■ Stress, KN/mm2	0.188	0.176	0.174	0.120	0.096	0.154	0.133	0.106	0.108
■ Diameter, mm	33.70	33.70	33.70	42.40	42.40	42.40	48.30	48.30	48.30
■ Thickness, mm	2.60	3.20	4.00	2.60	3.20	4.00	2.60	3.20	4.00
□ % of Glass Fibre	0.00	1.00	2.00	0.00	1.00	2.00	0.00	1.00	2.00

Stress v/s Strain graph for three different Diameter (D1, D2, and D3), Thickness (t1, t2, and t3), for Hollow Steel Tube



	0.053	0.049	0.045	0.031	0.027	0.025	0.021	0.019	0.031
■ Stress, KN/mm2	0.110	0.126	0.134	0.071	0.091	0.099	0.066	0.079	0.093
■ Diameter, mm	33.70	33.70	33.70	42.40	42.40	42.40	48.30	48.30	48.30
□ Thickness, mm	2.60	3.20	4.00	2.60	3.20	4.00	2.60	3.20	4.00

10. RESULTS OBTAINED FROM EXPERIMENT, THEORITICAL CALCULATION & ANALYSIS

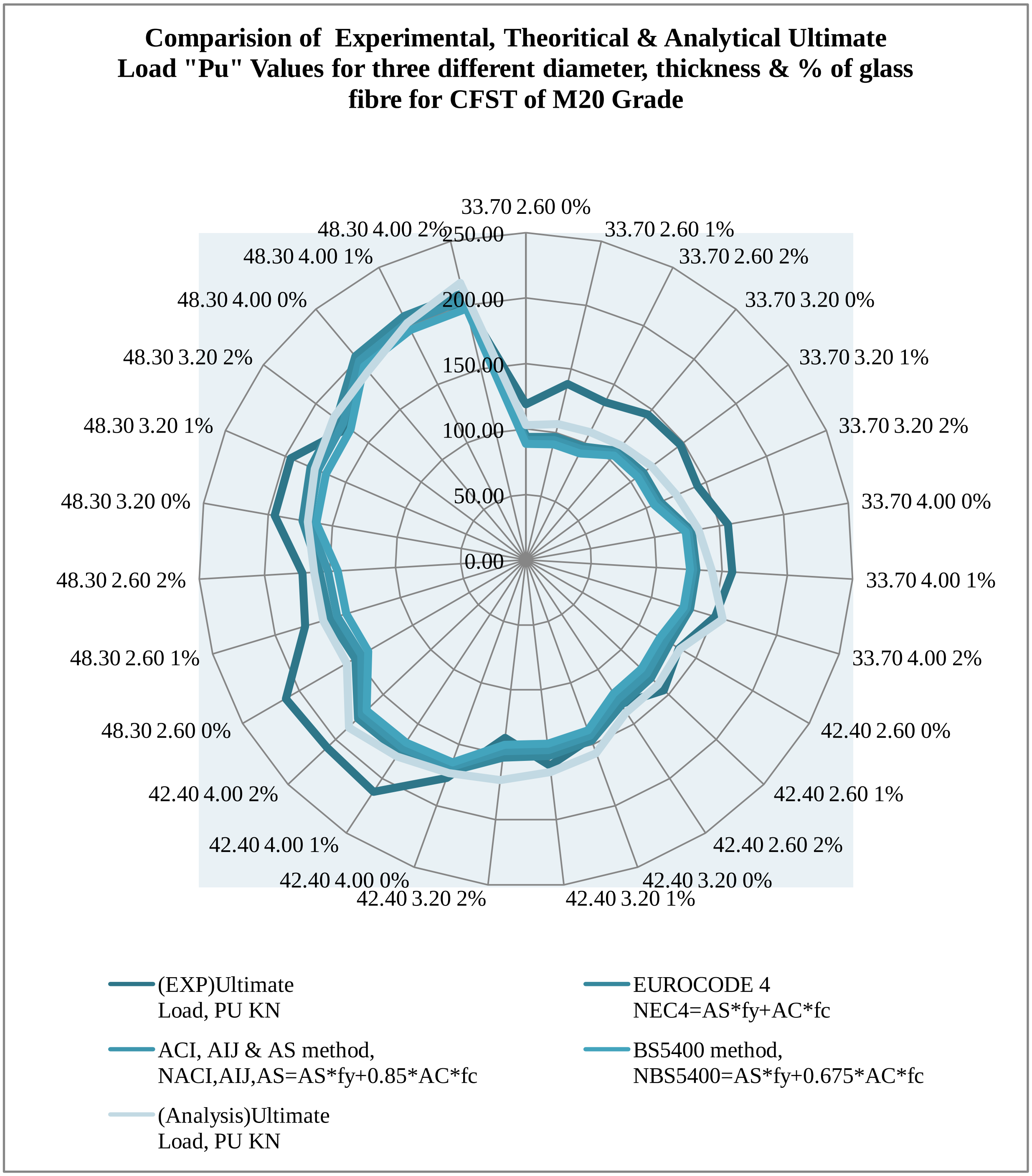
Table 5:- COMPARISION OF ULTIMATE LOAD, P_u OBTAINED FROM EXPERIMENT, THEORITICAL CALCULATION & ANALYSIS

Exp no.	**Diameter, mm**	**Thickness, mm**	**% of Glass Fibre**	**Grade**	**Length, mm**	**Area, mm^2**	**(EXP)Ultimate Load, P_U KN**	**EUROCODE 4 $N_{EC4}=A_S*fy + A_C*fc$**	**ACI, AIJ & AS method, $N_{ACI,AIJ,AS}=A_S*fy + 0.85*A_C*fc$**	**BS5400 method, $N_{BS5400}=A_S*fy + 0.675*A_C*fc$**	**(ANALYSIS)Ultimate Load, P_U KN**	**TYPE**
1	33.70	2.60	0%	M20	300	891.52	119.00	94.01	91.73	89.05	103.07	CONCRETE FILLED STEEL TUBES(CFST)
2	33.70	2.60	1%	M20	300	891.52	138.00	96.65	93.96	90.83	106.69	
3	33.70	2.60	2%	M20	300	891.52	135.00	97.26	94.48	91.24	109.43	
4	33.70	3.20	0%	M20	300	891.52	145.00	109.06	106.96	104.51	114.15	
5	33.70	3.20	1%	M20	300	891.52	147.00	111.48	109.01	106.14	119.83	
6	33.70	3.20	2%	M20	300	891.52	143.00	112.03	109.49	106.51	125.65	
7	33.70	4.00	0%	M20	300	891.52	157.00	128.11	126.25	124.08	134.00	
8	33.70	4.00	1%	M20	300	891.52	158.00	130.25	128.07	125.52	142.61	
9	33.70	4.00	2%	M20	300	891.52	151.00	130.75	128.49	125.86	156.96	
10	42.40	2.60	0%	M20	300	1411.24	135.00	126.79	122.89	118.33	136.00	
11	42.40	2.60	1%	M20	300	1411.24	145.00	131.28	126.70	121.36	138.59	
12	42.40	2.60	2%	M20	300	1411.24	132.00	132.31	127.58	122.06	139.24	
13	42.40	3.20	0%	M20	300	1411.24	145.00	146.52	142.87	138.61	156.78	
14	42.40	3.20	1%	M20	300	1411.24	158.00	150.73	146.44	141.44	162.88	
15	42.40	3.20	2%	M20	300	1411.24	137.00	151.69	147.26	142.10	169.06	
16	42.40	4.00	0%	M20	300	1411.24	177.00	171.83	168.49	164.60	172.91	
17	42.40	4.00	1%	M20	300	1411.24	212.00	175.67	171.76	167.19	179.56	
18	42.40	4.00	2%	M20	300	1411.24	209.00	176.55	172.51	167.79	186.29	
19	48.30	2.60	0%	M20	300	1831.32	212.00	150.63	145.39	139.28	158.13	
20	48.30	2.60	1%	M20	300	1831.32	176.00	156.66	150.52	143.35	161.64	
21	48.30	2.60	2%	M20	300	1831.32	171.00	158.04	151.69	144.29	162.42	

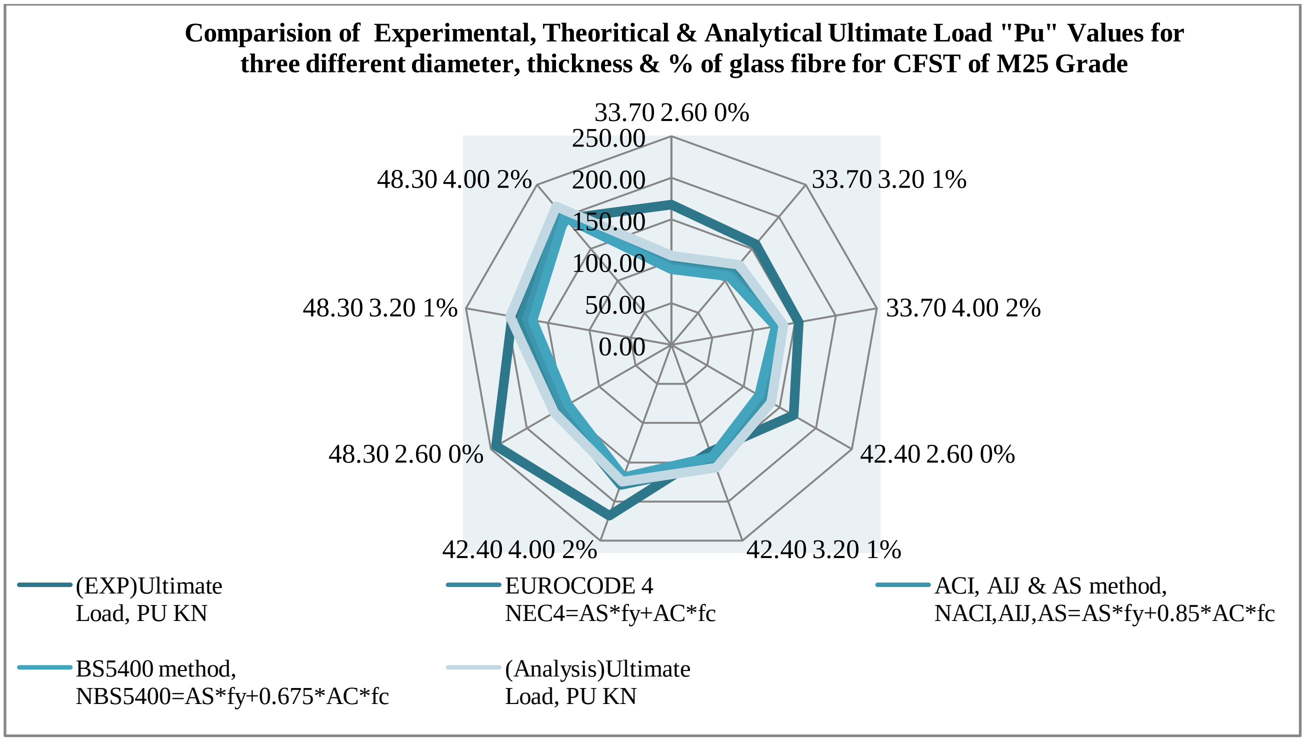
Exp no.	Diameter, mm	Thickness, mm	% of Glass Fibre	Grade	Length, mm	Area, mm^2	(EXP)Ultimate Load, P_U KN	EUROCODE 4 $N_{EC4}=A_S*fy + A_C*fc$	ACI, AIJ & AS method, $N_{ACI,AIJ,AS}=A_S*fy + 0.85*A_C*fc$	BS5400 method, $N_{BS5400}=A_S*fy + 0.675*A_C*fc$	(ANALYSIS)Ultimate Load, P_U KN	TYPE
22	48.30	3.20	0%	M20	300	1831.32	195.00	173.55	168.60	162.82	169.46	CONCRETE FILLED STEEL TUBES
23	48.30	3.20	1%	M20	300	1831.32	196.00	179.24	173.44	166.67	176.10	
24	48.30	3.20	2%	M20	300	1831.32	169.00	180.55	174.55	167.55	182.88	
25	48.30	4.00	0%	M20	300	1831.32	200.00	203.10	198.52	193.18	188.15	
26	48.30	4.00	1%	M20	300	1831.32	208.00	208.37	203.00	196.73	202.60	
27	48.30	4.00	2%	M20	300	1831.32	202.00	209.58	204.03	197.55	217.63	
28	33.70	2.60	0%	M25	300	891.52	168.00	96.58	93.90	90.78	106.49	
29	33.70	3.20	1%	M25	300	891.52	157.00	112.93	110.25	107.12	125.42	
30	33.70	4.00	2%	M25	300	891.52	155.00	131.93	129.49	126.65	135.89	
31	42.40	2.60	0%	M25	300	1411.24	169.00	131.16	126.60	121.28	137.52	
32	42.40	3.20	1%	M25	300	1411.24	136.00	153.25	148.59	143.15	156.45	
33	42.40	4.00	2%	M25	300	1411.24	218.00	178.66	174.30	169.21	174.41	
34	48.30	2.60	0%	M25	300	1831.32	243.00	156.50	150.38	143.24	162.41	
35	48.30	3.20	1%	M25	300	1831.32	194.00	182.66	176.35	168.98	196.83	
36	48.30	4.00	2%	M25	300	1831.32	197.00	212.47	206.49	199.51	216.17	
37	33.70	2.60	-	-	300	891.52	98.20	78.75	78.75	78.75	91.67	HOLLOW
38	33.70	3.20	-	-	300	891.52	112.30	95.05	95.05	95.05	106.91	
39	33.70	4.00	-	-	300	891.52	119.28	115.70	115.70	115.70	124.36	
40	42.40	2.60	-	-	300	1411.24	100.60	100.78	100.78	100.78	112.01	
41	42.40	3.20	-	-	300	1411.24	128.00	122.17	122.17	122.17	132.13	
42	42.40	4.00	-	-	300	1411.24	140.28	149.59	149.59	149.59	144.05	
43	48.30	2.60	-	-	300	1831.32	120.80	115.72	115.72	115.72	129.16	
44	48.30	3.20	-	-	300	1831.32	144.00	140.55	140.55	140.55	153.20	
45	48.30	4.00	-	-	300	1831.32	170.90	172.57	172.57	172.57	182.26	

11. Graphical Representation of Experimental, Theoretical & Analytical results

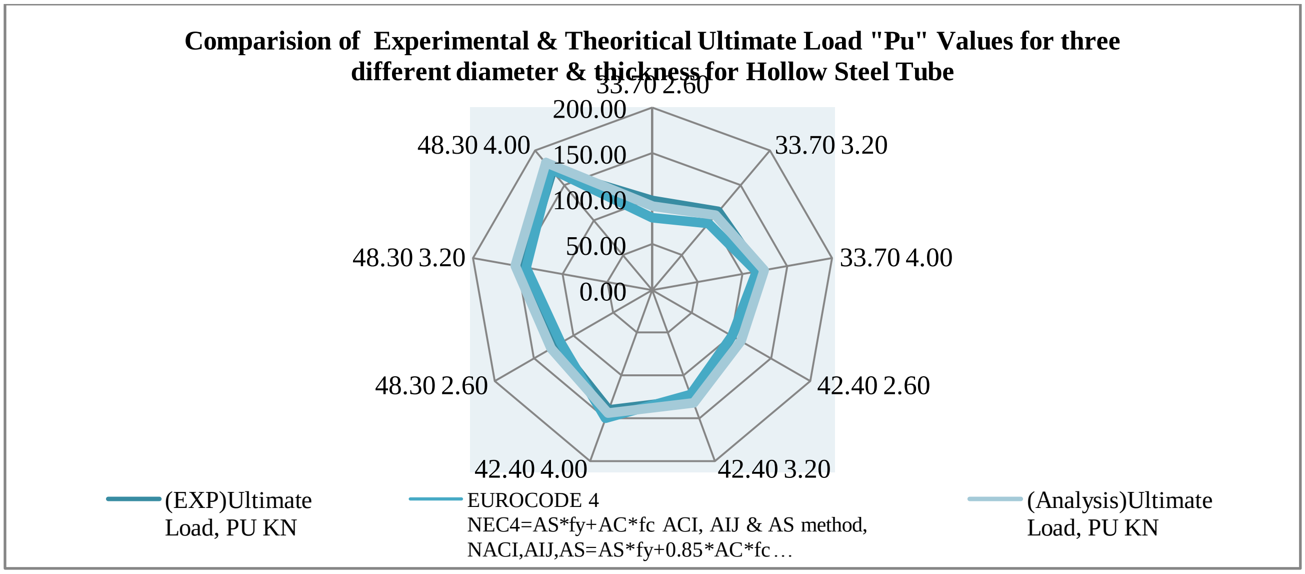
Comparison of Experimental, Theoretical & Analytical Ultimate Load “P_u” values for three different diameter (d1=33.7, d2=42.4, d3=48.3), three different thickness (t1=2.6, t2=3.2, t3=4.0) & three different % of glass fibre (0%, 1%, 2%) for CFST of M20 Grade.



Comparison of Experimental, Theoretical & Analytical Ultimate Load “P_u” values for three different diameter (d1=33.7, d2=42.4, d3=48.3), three different thickness (t1=2.6, t2=3.2, t3=4.0) & three different % of glass fibre (0%, 1%, 2%) for CFST of M25 Grade.



Comparison of Experimental, Theoretical & Analytical Ultimate Load “P_u” values for three different diameter (d1=33.7, d2=42.4, d3=48.3) & three different thickness (t1=2.6, t2=3.2, t3=4.0) for Hollow Steel Tube.



12. CONCLUSION

- From the above experiment it has been observed that the important parameters affecting the load-deformation behaviour are; Geometric parameters like member size, thickness of steel tube, slenderness, D/t ratio of the tube, Grades of concrete, Percentage of fibre added.
- Cross-sectional area of the steel tube has the most significant effect on both the ultimate axial load capacity and corresponding axial shortening of CFST.
- Strength of the in-fill concrete, % of glass fibre & the wall thickness have respectively lesser effects compared to cross-section area of the steel tube.
- Next to cross-sectional area wall thickness has most influence on ultimate axial load carrying capacity of CFST's.
- Results obtained from theoretical calculation & experiment varies between 0-20percent, whereas analytical results & theoretical calculations vary between 0-10percent, experimental & analytical results vary between 0-15percent.
- The results obtained from experiment & analysis matched well with theoretical calculation (with a deviation of not more than 20%)

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