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Numerical Studies on Composite Steel Tubes Subjected To Monotonic Loading using NX-NASTRAN

KEYWORDS NX-NASTRAN, Buckling Analysis, Finite Element, Concrete filled steel tube (CFST).

Mohamed Farhan
PG Student of Structural Engineering, Department of Civil Engineering, Ghousia College of Engineering, Ramanagara, Karnataka, India.

Dr. N.S Kumar
Professor, Director of R&D, Department of Civil Engineering, Ghousia College of Engineering Ramanagara, Karnataka, India .

ABSTRACT *This Research focuses on a numerical model developed for Hollow tube and concrete filled steel tube (CFST) columns under monotonic loading and. The study was conducted using NX-NASTRAN 8.0 finite element software . Three-dimensional nonlinear finite element models developed to study the force transfer between steel tube and concrete core. 8 Noded Hexagonal element is considered for finite element analysis. Analysis was run for both Hollow tubes and Concrete filled steel tube (CFST). Result of Analytical solution were compared with Experimental results and Theoretical formulas. Comparison of hollow and CFST tubes showed that the concrete core delayed the onset of local buckling of the steel tube*

1.0 INTRODUCTION

Concrete Filled Steel Tubes (CFSTs) were used in construction in the early 1900's. However, the research into CFSTs did not begin until the 1960s. From that time onwards, several studies were conducted on the CFSTs to fully understand their behavior with the aim of improving their performance. Concrete-filled steel tubular columns possess excellent earth-quake resistant properties such as highstrength and ductility and large energy absorption capacity

Concrete-filled steel tube (CFT), which combines the advantages of steel and concrete, has been developed as an excellent structural element for building columns, bridge piers, and arch ribs throughout world wide engineering practices. Since the steel tube can serve as a form for casting of core concrete, CFT structures possess economical merits in construction.

Concrete filled steel tubes CFSTs are used in many structural applications including columns, supporting platforms of offshore structures, roofs of storage tanks, bridge piers, piles, and columns in seismic zones (Kilpatrick and Rangan 1995). Concrete filled steel box columns offer excellent structural performance, such as high strength, high ductility and large energy absorption capacity and have been widely used as primary axial load carrying members in high-rise buildings, bridges and offshore structures (Lu and Kennedy, 1994). Application of the CFST concept can lead to overall savings of steel in comparison with conventional structural steel systems.Moreover, compared with hollow steel tube, core concrete can prevent buckling of steel tube, which may improve the compressive stability enormously.

The most attractive advantage of concrete-filled steel tube structures is that the element exhibits an excellent compressive resistance capacity, ductility, and energy dissipation ability owing to the confining effect provided by steel tubes.

Use of composite columns can result in significant savings in column size, which ultimately can lead to considerable economic savings. This reduction in column size provides is particularly beneficial where floor space is at a premium, such as in car parks and office blocks.However if the concrete core and the steel tube areloaded simultaneously the steel tube expands more thant he concrete core under moderate loads since Poisson'sratio is higher for the steel section.

CFT columns have many advantages over SRC columns :
The major benefits of concrete filled columns are:

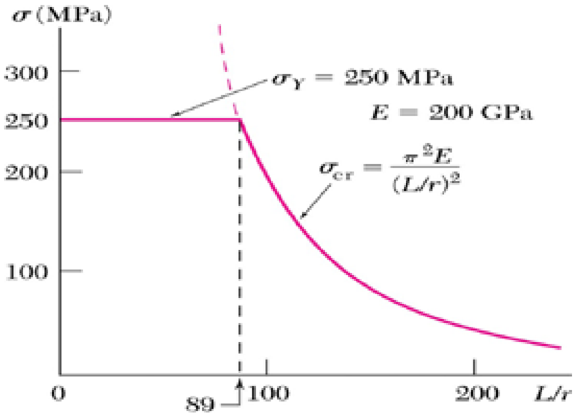
- Steel column acts as permanent and integral formwork
- The steel column provides external reinforcement, and
- The steel column suppot several levels of construction prior to concrete being pumped

1.1 CRITICAL STRESS

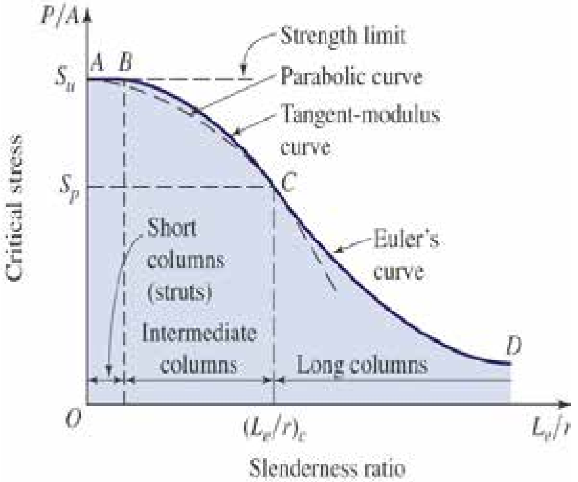
Plot σcr=Pcr/A vs. L/rg
“ Long column:
buckling occurs elastically before the yield stress is reached.

“ Short column:
material failure occurs inelastically beyond the yield stress.

“ A “Johnson Curve” can be used to determine the stress for an intermediate



Volume : 4 | Issue : 7 | July 2014 | ISSN - 2249-555X



Sy = yield strength = σy Su = ultimate strength = σu Sp = proportional limi

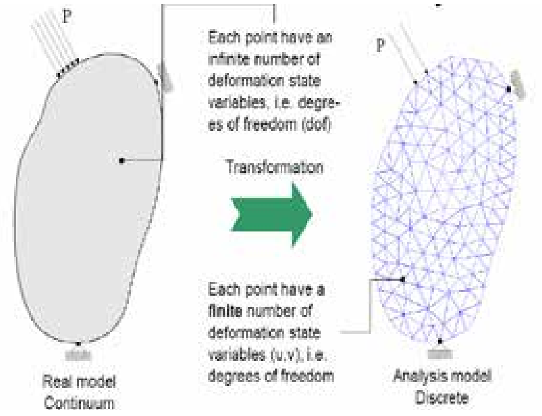
2.0 FINITE ELEMENT METHOD:

INTRODUCTION:

The basic concept of finite element method is discritization of a structure into finite number of elements, connected at finite number of points called nodes. The material properties and the governing relationships are considered over these elements and expressed in terms of nodal displacement at nodes.

An assembly process duly considering the loading and constraints results in a set of equations governing the structural response, which are established through the application of appropriate variation principle.

Solutions of these equations give the response of the structure. Selecting proper elements and subdividing the structure with large number of finite elements or by taking higher order elements can increase the accuracy of solution obtained by finite element method.



ADVANTAGES OF FEM

1. FEM makes piecewise approximation i.e., it ensure the continuity at node points as well as along the side of the element.
2. FEM can handle ultimate number of boundary conditions.
3. FEM needs fewer nodes to get good results
4. FEM can consider the sloping boundaries exactly.If curved elements are used, even the curved boundaries can be handeled easily.
5. FE model can be altered easily and economically
6. Irregular shaped bodies can be easily modelled and.FEM can give values at any point.

3 .0 NX- NASTRAN

NASTRAN is a finite element analysis (FEA) program that was originally developed for NASAin the late 1960s under United States government funding for the Aerospace industry. NASTRAN software was developed by Joe Mule (NASA), Gerald Sandler (NASA)and Stephen J. Burns (currently University of Rochester) .

The NASTRAN system was released to NASA in 1968. It is also used in designing railroad tracks and cars, bridges, power plants, skyscrapers, and aircraft.

The NASTRAN program has evolved over many versions. Each new version contains enhancements in analysis capability and numerical performance. Today, NASTRAN is widely used throughout the world in the aerospace, automotive and maritime industries.

It has been claimed that NASTRAN is the industry standard for basic types of analysis for aerospace structures, e.g. linear elastic static and dynamic analyses

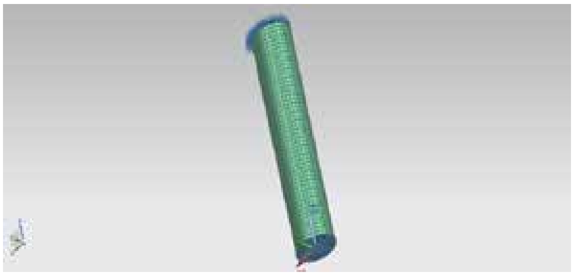
4.0 ELEMENTS USED

HEXAGONAL 8 NODED

HEXAGONAL 8 NODED element is used to model both hollow and concret filled steel tube columns because it gies accurate results is suitable for analyzing translations in the x, y, and z directions, and rotations about the x, y, and z-axes. The element HEXA 8 was used to model the steel tube as well as concrete filled steel tube . All specimens were modeled as 3D structural elements.

4.1 BOUNDARY CONDITIONS

For each of the two ends, two different types of boundary conditions (Figure.4) were used. At the bottom end fixed, displacement degrees of freedom in 1, 2, 3 directions (U1, U2, U3) as well as rotational degrees of freedom in 1, 2, 3 directions were restrained to be zero. At the top end is roller support movable end rotational degrees of freedom are free and translation U2 is free remaining U1, U2 are restrained



4.2 MATERIAL SPECIFICATION:

STEEL

- Material : Structural Steel Fe 250 Mpa
- Young's Modulus E=210000Mpa
- Poison's ratio v=0.3
- Density p=7850kg/m3.

CONCRETE

- Grade of Concrete:M20,M30,and M40
- Young's Modulus E=22360.7Mpa (M20), 27386.12Mpa (M30),and 31622.78 Mpa(M40)
- Poison's ratio v= 0.2
- Density p=2400 kg/m3.

4.3 THEORETICAL BUCKLING ANALYSIS

Steel tube or columns are usually thought of as straight vertical members whose lengths are considerably greater than their cross-sectional dimensions. An initially straight tube or column, compressed by gradually increasing equal and opposite axial forces at the ends is considered first. When the applied loading is increased, the buckling deformation also increases. Buckling occurs mainly in members

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subjected to compressive forces. If the member has high bending stiffness, its buckling resistance is high. Also, when the member length is increased, the buckling resistance is decreased.

4.4 BUCKLING OF AN IDEAL COLUMN OR TUBE

The classical Euler analysis of this problem makes the following assumptions.

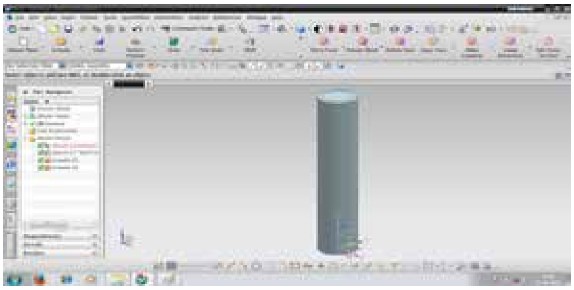
- The material of which the strut is made is homogeneous and linearly elastic (i.e. it obeys Hooke's Law)
- The column is perfectly straight and there are no imperfections.
- The loading is applied at the centroid of the cross section at the ends.

4.5 EULER FORMULA:

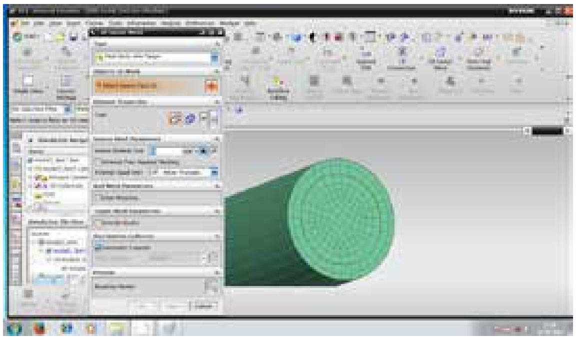
Pcr=$\pi 2EI/Le2$

Using buckling value of FEM model was verified with the theoretical Euler critical buckling load formula

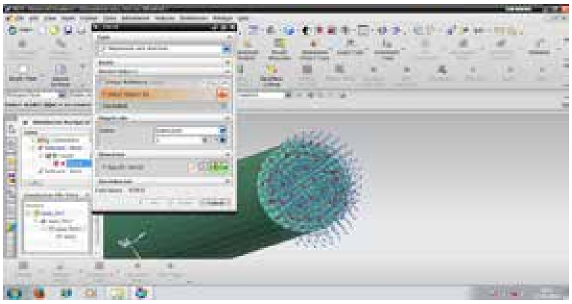
MODEL OF CONCRETE FILLED STEEL TUBE USING NX-NASTRAN



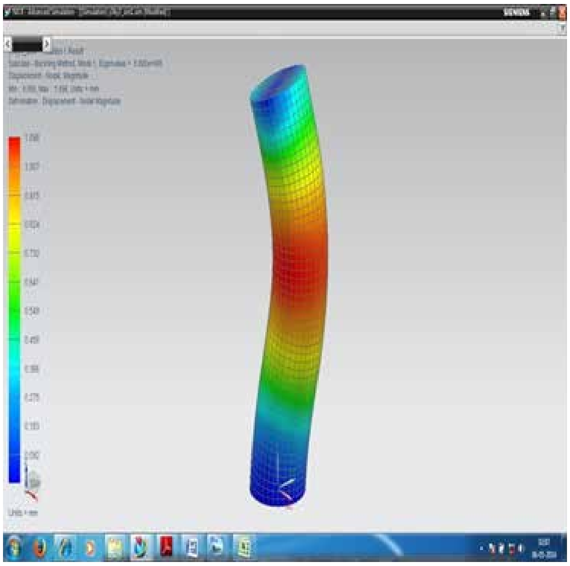
MESHING OF CONCRETE FILLED STEEL TUBE (3mm size of mesh)

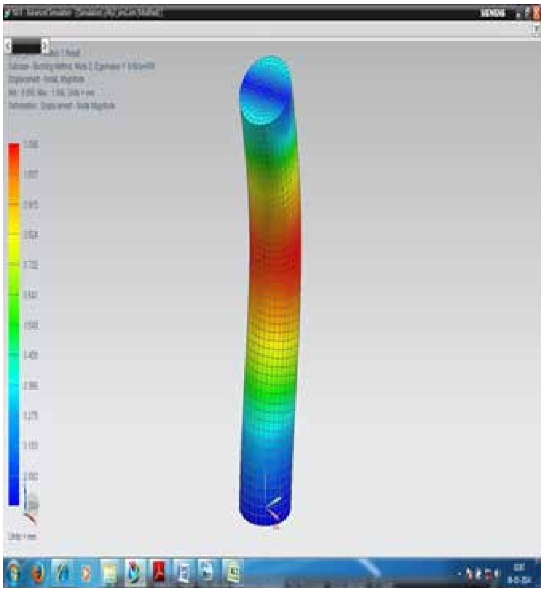


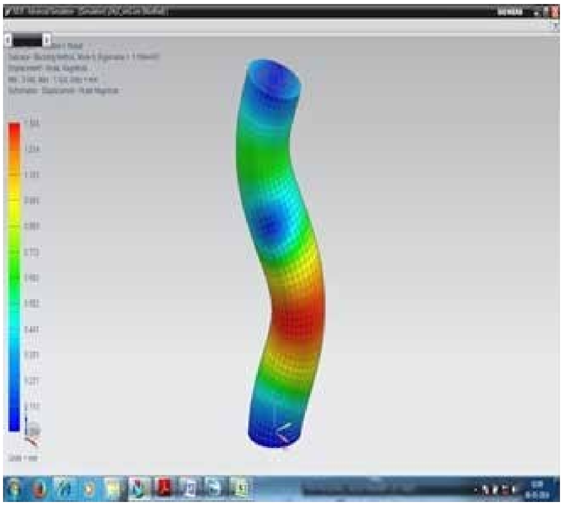
APPLYING LOAD ON TOP FACE OF CONCRETE FILLED STEEL TUBE

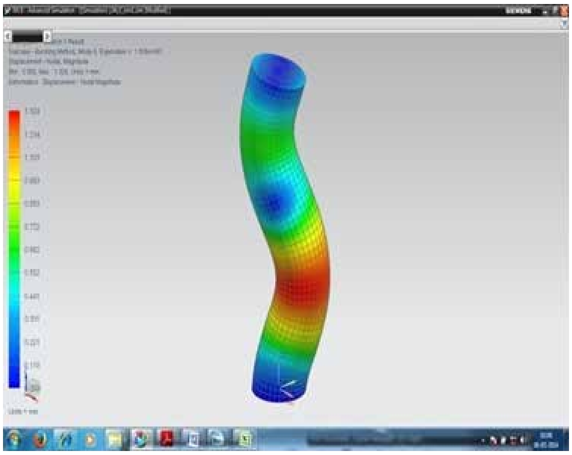


DIFFERENT MODES SHAPES OF CONCRETE FILLED STEEL TUBES



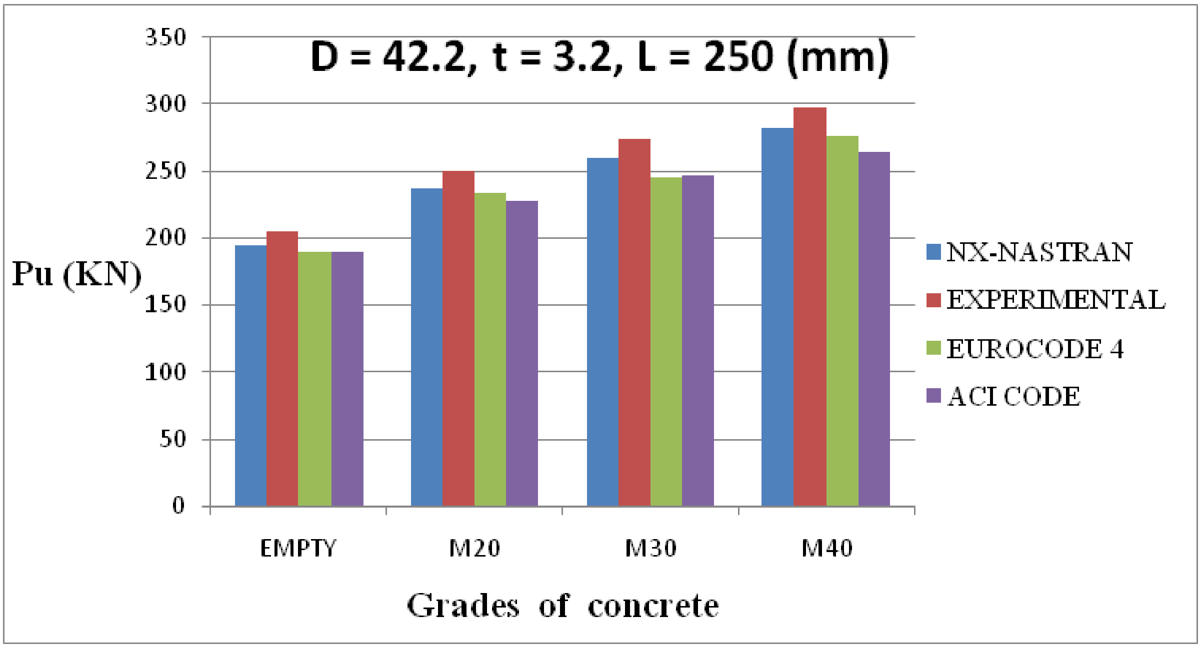






ANALTICAL RESULTS OF HOLLOW AND CFST TUBES USING NX-NASTRAN AND COMPARING WITH EXPERIMENTAL RESULTS AND THEORETICAL FORMULAE

SL NO.	Diameter (mm)	Thickness(mm)	Length (mm)	D/t Ratio	L/D Ratio	Grade of Concrete	% of Epoxy	(Pu) NX-NASTRAN	(Pu) EXPERIMENTAL	EUROCODE 4 NEC4=AS*fy+AC*fc	ACI method, NACI,=AS*fy+0.85*AC*f c
1	42.4	3.2	250	13.25	5.89	HOLLOW	-	114.0	119.7	106.5	106.5
2	42.4	3.2	250	13.25	5.89	M20	0%	132.0	138.6	126.8	123.7
3	42.4	3.2	250	13.25	5.89	M20	1%	133.1	139.7	127.1	124.6
4	42.4	3.2	250	13.25	5.89	M20	2%	133.9	140.5	127.8	125.3
5	42.4	3.2	250	13.25	5.89	M20	3%	134.8	141.5	129	125.9
6	42.4	3.2	250	13.25	5.89	M30	0%	146.0	153.3	137.0	132.4
7	42.4	3.2	250	13.25	5.89	M30	1%	147.1	154.4	138.1	133.3
8	42.4	3.2	250	13.25	5.89	M30	2%	147.9	155.2	138.9	133.8
9	42.4	3.2	250	13.25	5.89	M30	3%	148.6	156.0	140.5	134.5
10	42.4	3.2	250	13.25	5.89	M40	0%	156.5	164.3	147.9	141.0
11	42.4	3.2	250	13.25	5.89	M40	1%	157.2	165.0	148.3	142.3
12	42.4	3.2	250	13.25	5.89	M40	2%	157.6	165.4	148.9	142.6
13	42.4	3.2	250	13.25	5.89	M40	3%	158.2	166.1	149.3	143.1



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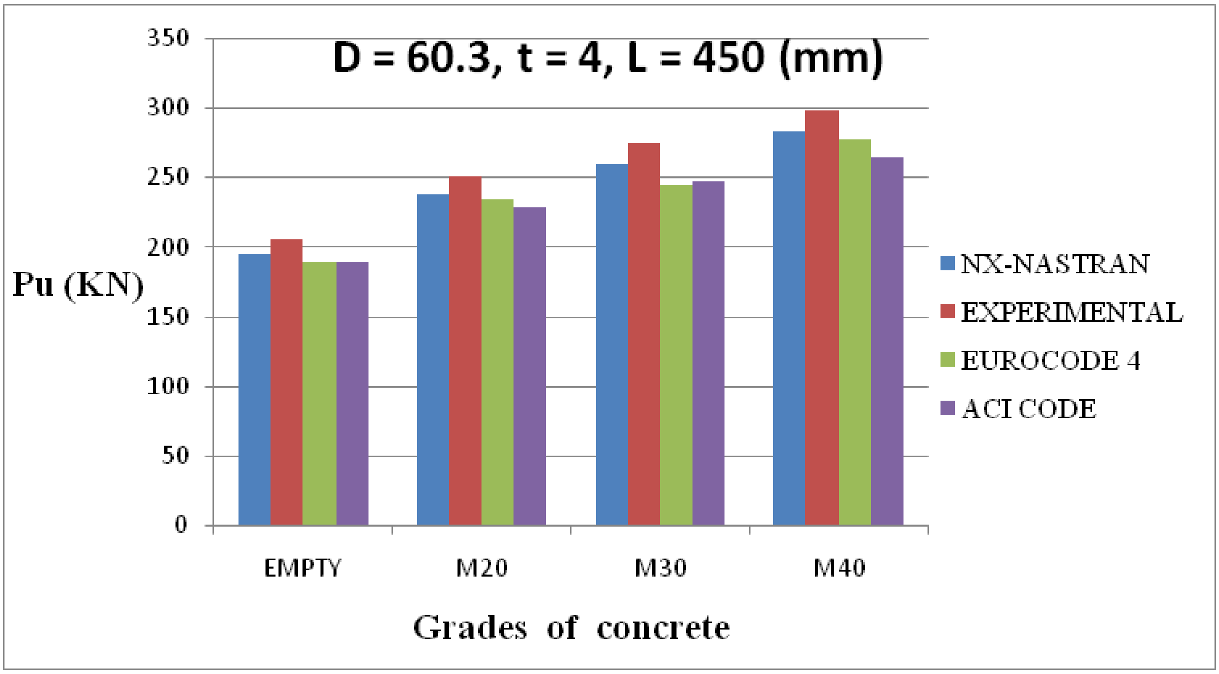
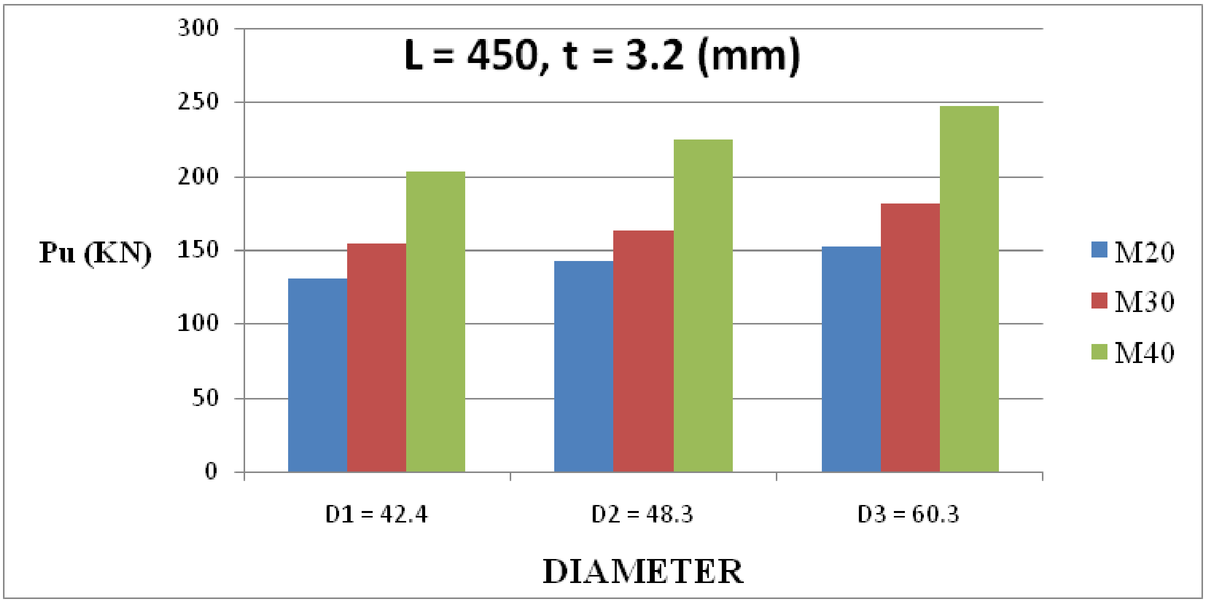
SL NO.	Diameter(mm)	Thickness(mm)	Length (mm)	D/t Ratio	L/D Ratio	Grade of Concrete	% of Epoxy	(Pu) NX-NASTRAN	(Pu) EXPERIMETAL	EUROCODE 4 NEC4=AS*fy+AC*fc	ACI method, NACI,=AS*fy+0.85*AC*fc
1	60.3	4	450	18.84	7.46	HOLLOW	-	195.0	205.7	189.3	189.3
2	60.3	4	450	15.07	7.46	M20	0%	236.0	248.9	232.2	225.7
3	60.3	4	450	15.07	7.46	M20	1%	236.8	249.8	232.9	226.3
4	60.3	4	450	15.07	7.46	M20	2%	237.1	250.1	233.6	227.1
5	60.3	4	450	15.07	7.46	M20	3%	237.8	250.8	234.2	227.8
6	60.3	4	450	15.07	7.46	M30	0%	258.0	272.1	253.7	244.0
7	60.3	4	450	15.07	7.46	M30	1%	258.2	272.4	254.2	244.9
8	60.3	4	450	15.07	7.46	M30	2%	259.4	273.6	254.9	245.6
9	60.3	4	450	15.07	7.46	M30	3%	259.9	274.1	245.1	246.3
10	60.3	4	450	15.07	7.46	M40	0%	280.0	295.4	275.1	262.2
11	60.3	4	450	15.07	7.46	M40	1%	281.1	296.5	275.6	262.8
12	60.3	4	450	15.07	7.46	M40	2%	281.8	297.2	276.1	263.7
13	60.3	4	450	15.07	7.46	M40	3%	282.6	298.1	276.9	264.5

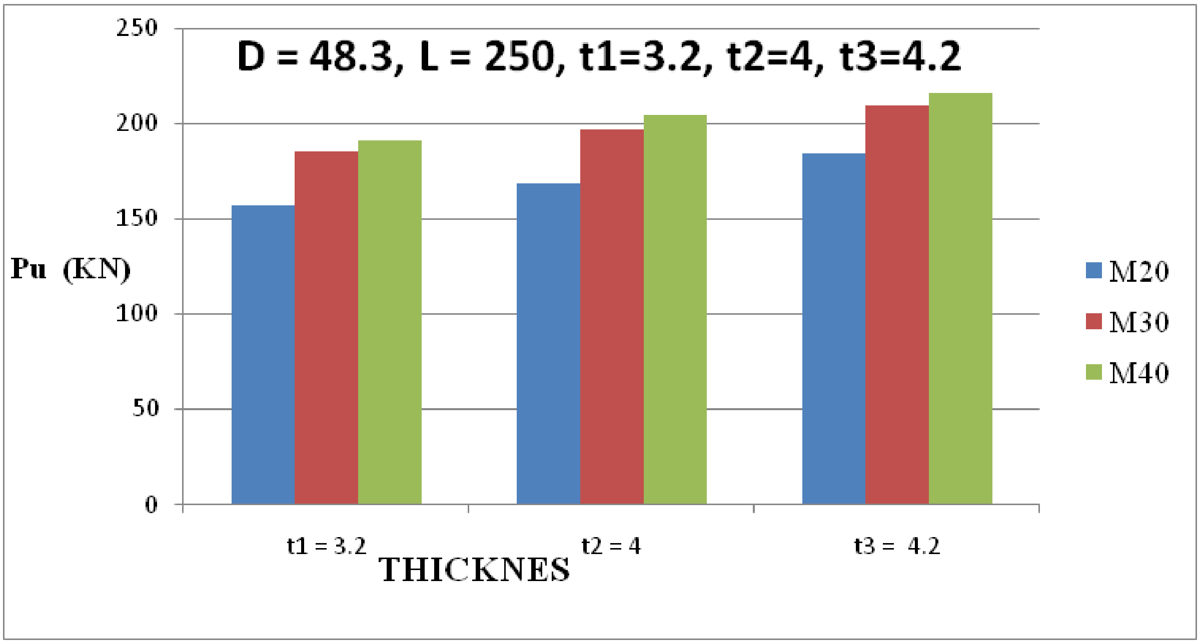


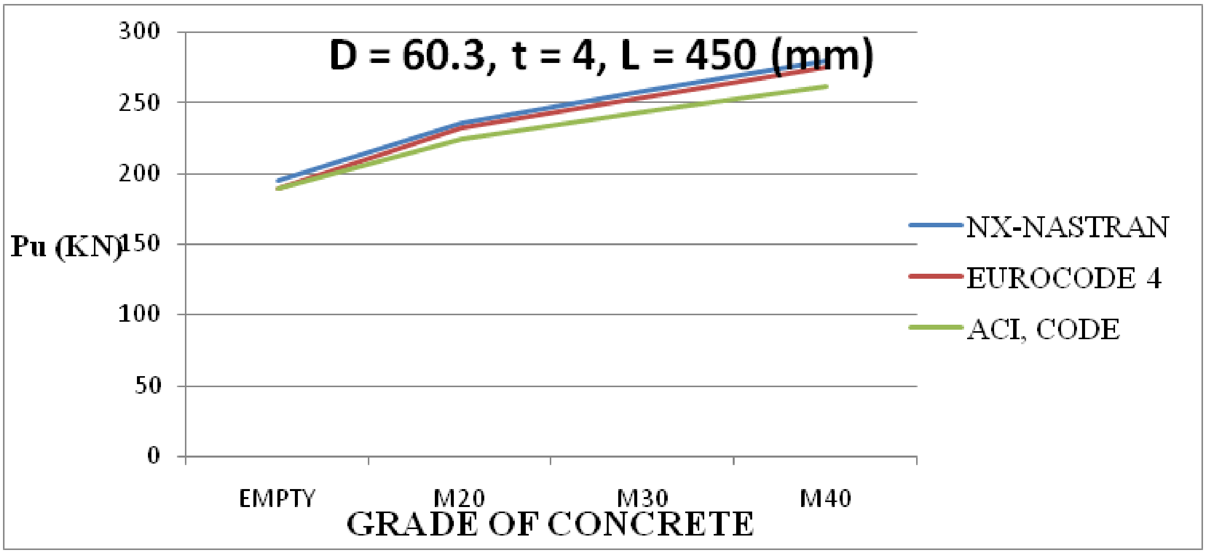
ANALTICAL RESULTS OF HOLLOW AND CFST TUBES USING NX-NASTRAN AND COMPARING WITH EXPERIMENTAL RESULTS AND THEORETICAL FORMULAE

SL NO.	Diameter(mm)	Thickness(mm)	Length (mm)	D/t Ratio	L/D Ratio	Grade of Concrete	% of Epoxy	(Pu) NX-NASTRAN	(Pu) EXPERIMETAL	EUROCODE 4 NEC4=AS*fy+AC*fc	ACI method, NACI,=AS*fy+0.85*AC*fc
1	48.3	3.2	350	15.09	7.24	HOLLOW	-	126.5	132.8	121.3	121.3
2	48.3	3.2	350	15.09	7.24	M20	0%	153.0	160.65	148.8	144.7
3	48.3	3.2	350	15.09	7.24	M20	1%	154.1	161.8	149.1	145.2
4	48.3	3.2	350	15.09	7.24	M20	2%	154.3	162.3	149.7	145.8
5	48.3	3.2	350	15.09	7.24	M20	3%	155.1	163.2	150.1	146.7
6	48.3	3.2	350	15.09	7.24	M30	0%	167.0	175.3	162.6	156.0
7	48.3	3.2	350	15.09	7.24	M30	1%	167.8	176.4	163.1	156.8
8	48.3	3.2	350	15.09	7.24	M30	2%	168.2	177.1	163.7	157.2
9	48.3	3.2	350	15.09	7.24	M30	3%	169.9	177.9	164.2	158.4
10	48.3	3.2	350	15.09	7.24	M40	0%	180.0	189.0	176.4	168.1
11	48.3	3.2	350	15.09	7.24	M40	1%	181.1	191.2	176.8	168.8
12	48.3	3.2	350	15.09	7.24	M40	2%	181.8	191.9	177.2	169.2
13	48.3	3.2	350	15.09	7.24	M40	3%	182.4	192.2	177.9	169.7
14	48.3	3.2	350	15.09	7.24	HOLLOW	-	155.4	162.7	151.6	151.6
15	48.3	4	350	12.07	7.24	M20	0%	181.5	190.5	177.1	173.1
16	48.3	4	350	12.07	7.24	M20	1%	182.4	191.1	177.8	173.8

17	48.3	4	350	12.07	7.24	M20	2%	182.8	191.9	178.2	174.2
18	48.3	4	350	12.07	7.24	M20	3%	183.4	192.6	178.8	174.6
19	48.3	4	350	12.07	7.24	M30	0%	195.6	204.5	189.9	184.4
20	48.3	4	350	12.07	7.24	M30	1%	196.2	206.2	190.5	185.2
21	48.3	4	350	12.07	7.24	M30	2%	196.7	207.2	191.1	185.8
22	48.3	4	350	12.07	7.24	M30	3%	197.1	207.9	191.6	186.2
23	48.3	4	350	12.07	7.24	M40	0%	206.4	216.8	202.6	194.8
24	48.3	4	350	12.07	7.24	M40	1%	206.8	217.1	202.9	195.2
25	48.3	4	350	12.07	7.24	M40	2%	207.1	217.2	203.6	195.8
26	48.3	4	350	12.07	7.24	M40	3%	207.8	218.3	206.8	196.3







5.0 VERIFICATION OF FINITE ELEMENT RESULTS

1) Eurocode 4

The Euro code 4 for calculating the axial capacity of concrete filled steel tube columns, the general method and the simplified method. In the general method, the second order effects and imperfections of the compression members are taken into consideration explicitly.

This method may be used for members with symmetrical sections, but they are also applicable to nonprismatic axial members. Consequently, appropriate software for numerical computation is essential for the application of the general method. In the simplified method, the European buckling curves for steel columns are utilized. The element's imperfections are implicitly taken into account. Unlike the general method, the simplified one is limited to prismatic composite axial members with symmetrical sections.

NEURO =fcAc + fyAs

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.

2) American concrete code , ACI CODE

NACI =0.85fCAC + fyAs

According to ACI code, the steel tube in a CFSHS column is converted into equivalent reinforcing bars that are distributed around the concrete infill. Then, strength of a composite column shall be computed for the same limiting conditions applicable to ordinary reinforced concrete column. The steel is assumed to follow an elastic-perfectly plastic stress-strain relationship; however, 15% of the concrete segment is reduced to account for its uncertainties. In other words, the compression composite members are considered as regular reinforced concrete in this code. To account for local buckling of the structural steel tube, a limiting thickness is specified and, not to be exceeded.

The magnitude of this thickness is based on the achievement of yield stress in the empty steel tube when subjected to axial monotonic loading. Moreover, this formula does not differentiate between different cross-sectional

6.0 CONCLUSION

A Finite element analysis is carried out to find buckling strength of Hollow Steel Tube and CFST structures. Hollow Steel Tube and CFST members are mainly used in columns of multistory structures, bridge piers, earthquake resisting structure and other industrial applications. The results summary is as follows.

1) As length of tube increases, load carrying capacity decreases.
2) The ultimate load (Pu) for Hollow tube is found to be 114.0 KN (NX-NASTRAN) and 119.0 KN (experimental) and % error is 4.76%
3) The ultimate load (Pu) for M20 concrete is found to be 132.0KN (NX-NASTRAN) and 138.1 KN (experimental) and % error is 4.41%
4) The results show the Hollow Tube buckling load carrying capacity less compared to the CFST buckling loads.
5) Comparision of results of NX-NASTRAN with Eurocode 4 and ACI code

Grade of concrete	Pu (KN) NX-NASTRAN	Pu (KN) Eurocode 4	Pu (KN) ACI code	% Error
M20	132.0	126.8	123.7	3.93%
M30	146.0	137.0	132.4	6.16%
M40	156.5	147.9	141.0	5.49%

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