STUDY ON BEHAVIOUR OF CFST INCLINED COLUMN SUBJECTED TO VERTICAL LOAD USING ANSYS SOFTWARE

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Abstract :Concrete-filled steel tubular CFST structures are one of the modifications to combined load-bearing composite steel-concrete structures. The composite CFST member usually consist of circular, rectangular or multi-side steel tubes, as external steel shells, and internal concrete core .Here an analytical investigation has been carried out using ANSYS software to understand the behaviour of Concrete Filled Steel Tubular inclined column subjected to vertical load.

The study is limited to understand the behaviour of inclined CFST columns fixed at bottom and hinged at top for 0^o, 5^o, 10^o and 15^o inclination only with same geometric and material properties. The 6000mm height CFST columns are circular in shape with the diameter of concrete core and steel tube being 200mm and 192mm respectively for both upright and inclined column making the thickness of steel tube equal to 8mm. The characteristic strength of concrete and steel is taken as $20N/mm^2$ and $235N/mm^2$ respectively.

I. INTRODUCTION:

Concrete filled steel tubular (CFST) members utilize the advantages of both steel and concrete. The parts of these composite members are rigidly connected such that no relative movement can occur. They compromise of a steel hollow section of circular or rectangular shape filled with plain or reinforced concrete. They are widely used in high-rise buildings, multi-storey buildings, bridges, piles and offshore structures as columns and beam-columns, and as beams in low-rise industrial buildings where a robust and efficient structural system is required. Extensive research have been done since 40 years in the field of CFST columns which are used as primary axial load carrying members in many structural applications as mentioned earlier.

The enhancement in structural properties is due to the interaction between steel tube and concrete core. The confinement created by the steel casing enhances the material properties of concrete due to the triaxial state of stress. Conversely, the inward buckling of the steel tube is prevented by the concrete, thus increasing the stability and strength of the column. The inherent buckling problem related to thin-walled steel tubes is either prevented or delayed due to the presence of the concrete core.

Advantages of CFST columns:

A CFST column has many advantages compared with ordinary steel or reinforced concrete systems. The main advantages are listed below:

1.Interaction between steel tube and concrete

- Local buckling of the steel tube is delayed, and the strength deterioration after the local buckling is moderated, due to the restraining effect of the concrete.
- On the other hand, the strength of the concrete is increased due to the confining effect provided by the steel tube, and the strength deterioration is not severe, because the concrete spalling is controlled by the steel tube.
- Drying shrinkage and the creep of the concrete are much smaller than in ordinary reinforced concrete.

2.Cross-sectional properties

- The steel column support several levels of construction prior to concrete being pumped higher strength and stiffness compare with RC columns of same materials properties.
- The steel ratio in the CFST cross-section is much larger than in reinforced concrete and concrete encased-steel cross sections.
- CFST columns are aesthetically pleasing.
- The steel of the CFST section is well plastified under bending because it is usually loaded outside the section.

3.Construction efficiency

- The concrete filling is protected against mechanical damage.
- These composite columns also can be used for outside pressure resisting, such as ocean waves, ice; in seismic regions because of excellent earthquake-resistant properties such as high strength, high

ductility, and large energy absorption capacity.

- Labour for forms and reinforcing bars is omitted, and concreting is carried out by Tremie tube or the Pump up method.
- The efficiency leads to the cleaner construction site and a reduction in manpower, construction cost and project length.

4.Fire resistance

- Concrete improves fire resistance so that fire proof material can be reduced, additional external fire protection is not always necessary.

5.Cost performance

- Because of the merits listed above, better cost performance is obtained by replacing a steel structure with a CFST structure. A number of additional economical benefits from the use of CFTs. The tube serves as formwork in construction, which decreases labour and material costs. In moderate- to high-rise

construction, the building can ascend more quickly than a comparable reinforced concrete.

- structure since the steelwork can precede the concrete by several stories.

6.Ecology

- The environmental burden can be reduced by omitting the formwork and by reusing steel tubes and using high-quality concrete with recycled aggregates.

Disadvantages of CFST columns

Some of the associated disadvantages of CFST columns are as follows:

1. The beam-to-column connections are complicated for CFST frame structures. In Japan, structural frames using CFST columns typically adopt steel beams with specially designed connections, thus increasing the construction cost. Practices in China tend to use more CFST-column and RC beam systems with complicated connections.
2. Due to the fact that a steel tube is used as longitudinal reinforcement to resist axial force and moment, when steel tube yields under excessive longitudinal stresses due to moment or axial load, its transverse confinement particularly in terms of stiffness to the internal concrete is drastically reduced. This may be considered as the fate of steel as an isotropic material.
3. As demonstrated in the cyclic loading tests of conventional CFST columns conducted by and Tomii and Sakino (1981), local plastic buckling may occur at the ends of the steel tube followed by the crushing of internal concrete. This type of failure is very difficult to repair if not impossible. Such failure mode also results in unstable hysteretic loading capacity, particularly for columns with higher axial load.

Behaviour of CFSTs:

The structural behaviour of CFST elements are considerablyaffected by the difference between the Poisson's ratios of the steel tube and concrete core. In the initial stage of loading, the Poisson's ratio for the concrete is lower than that of steel. Thus, the steel tube has no confining effect on the concrete core. As longitudinal strain increases, the lateral expansion of concrete gradually becomes greater than expansion of steel tube . At this stage, the concrete core becomes triaxially and steel tube biaxially stressed .

The steel tube under a biaxial state cannot sustain the normal yield stress, causing a transfer of load from tube to the core. The load transfer mechanism is similar is square and circular CFST elements. In the first stage of loading the steel tube sustains most of the load until it yields(point a)

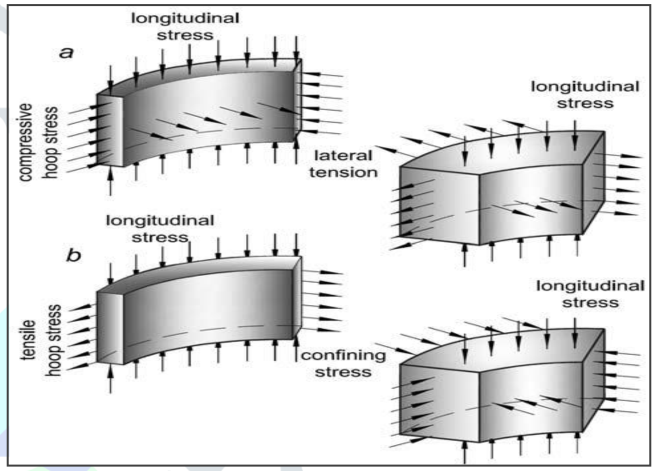


Fig: Stress condition in steel tube and concrete core at different stages of loading.

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 compressive 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 in uniaxial stress-strain hardening relationship.

LITERATURE:

Concrete filled steel tubular columns have many excellent structural properties, such as high compressive strength, large ductility and large energy absorption capacity. Then, composite tubular columns have been widely used in building structures and infrastructure projects throughout the world. Compared with other form of construction CFST columns offer superior structural performance, speed and ease of construction. These columns combine the advantages of ductility, generally associated with steel structures, with the stiffness of a concrete structural system.

The strength of steel and concrete for building structures is getting higher with the development of new materials. The cross section with high strength materials becomes smaller, and consequently a column becomes more slender.

RESULTS AND DISCUSSIONS

Load vsDeformation plots:

Fig 6.1 depicts load-deformation plots from the ANSYS results for upright and inclined columns with an increment of 5 degrees and up to 15 degrees.Fig 6.1(a) depicts for design loads obtained from the ANSYS and from other codal provisions ,the detailed calculations of codal provisions are in the ANNEX , and 6.1(b) shows that ultimate load obtained from the ANSYS. For a given load, the ANSYS predicts the deformation of the structure. Therefore, if the maximum load to be applied is known, the maximum deflection can be worked out.. Here ANSYS results converge to the particular load which the column can withstand.

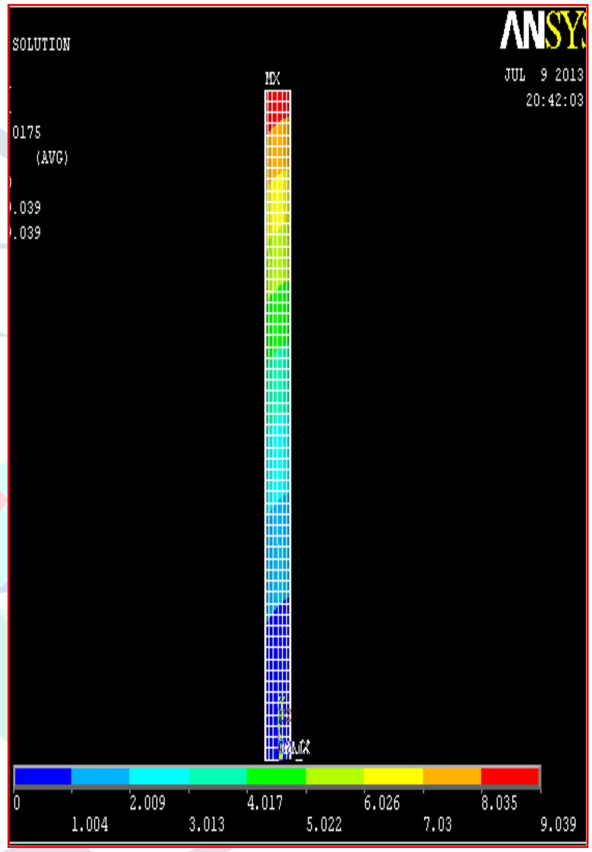
Table: Load and deformation values obtained for yield load

LOAD(KN)	DEFORMATION(mm)			
	0^o	5^o	10^o	15^o
115	9.039	57.758	58.316	83.036
230	17.901	65.763	88.816	157.404
345	19.17	69.486	123.74	236.726
460	20.562	72.521	139.6	360.028
575	21.957	73.279	144.85	
690	23.266	74.210	150.986	
805	24.516	75.95	161.945	
920	30.904	76.823		
1035	38.182			

Table: Design load obtained for upright codal provisions and ANSYS software

Table: Ultimate load obtained from column from ANSYS for 0,5,10,15 degree columns

ANGLE OF INCLINATION	LOAD(KN)
0^o	1035
5^o	920
10^o	805
15^o	460



	DESIGN.LOAD(KN)
ANSYS	1035
EUROCODE-4	889.231
ACI-318	955.24
AISC-LRFD	653.611

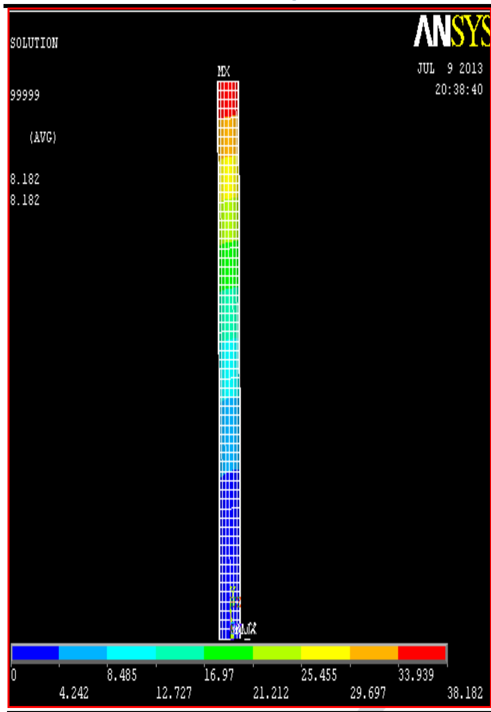


Fig :Deformation contours of 0 degree for 1^{st} and last set load

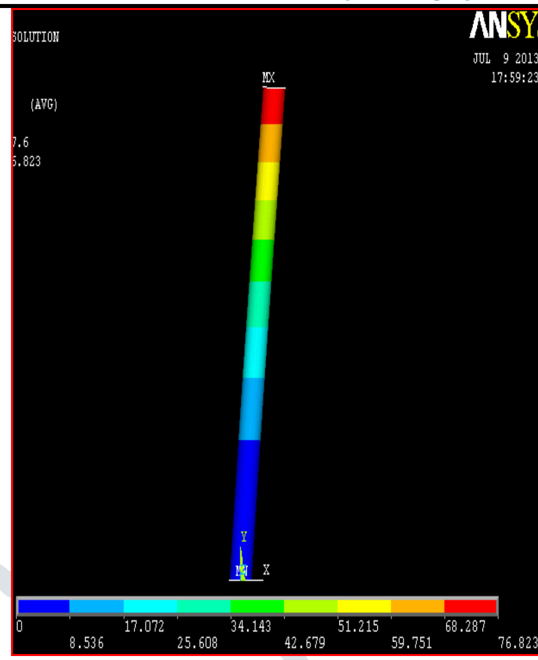
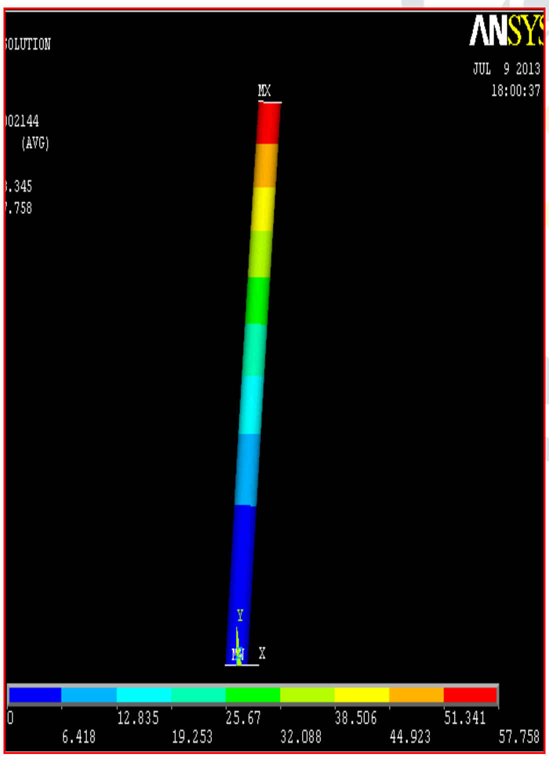
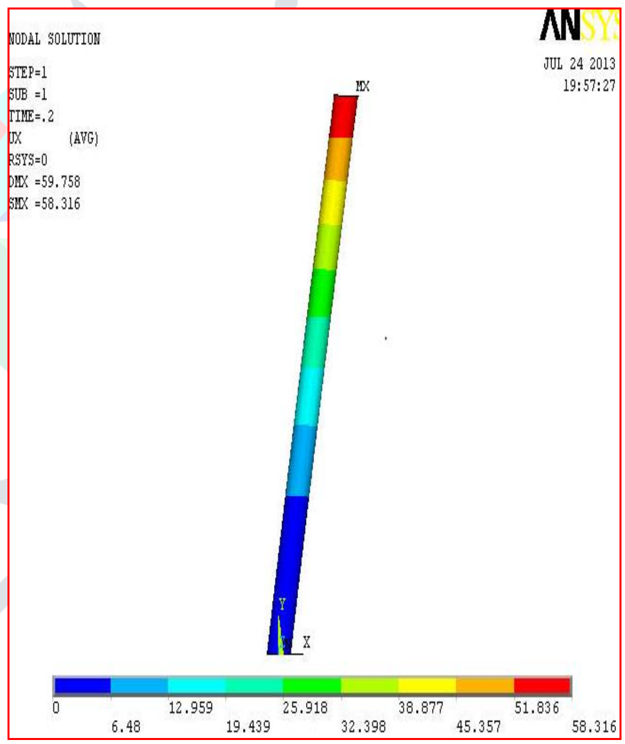


Fig :Deformation contours of 5 degree for 1^{st} and last set load





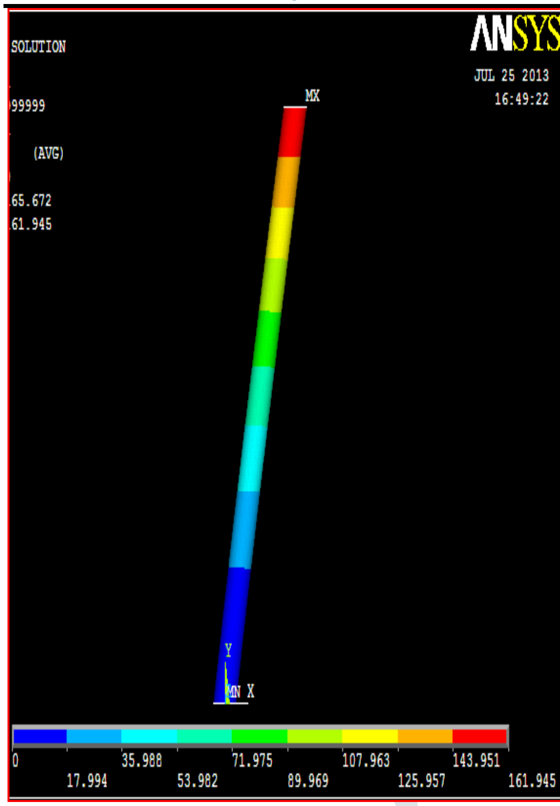
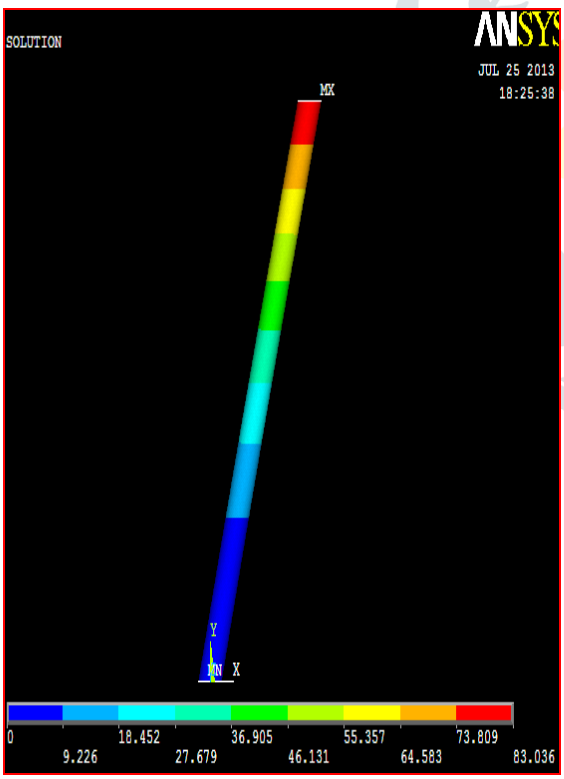


Fig :Deformation contours of 10 degree for 1st and last set load



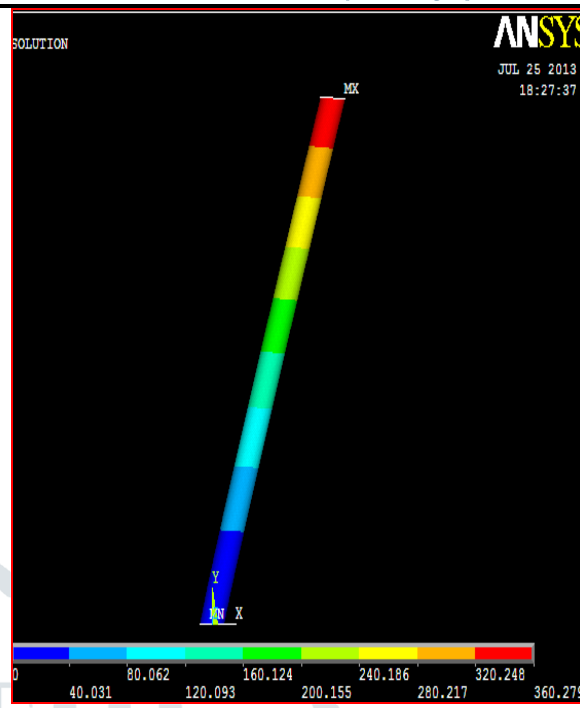


Fig :Deformation contours of 15 degree for 1st and last set load

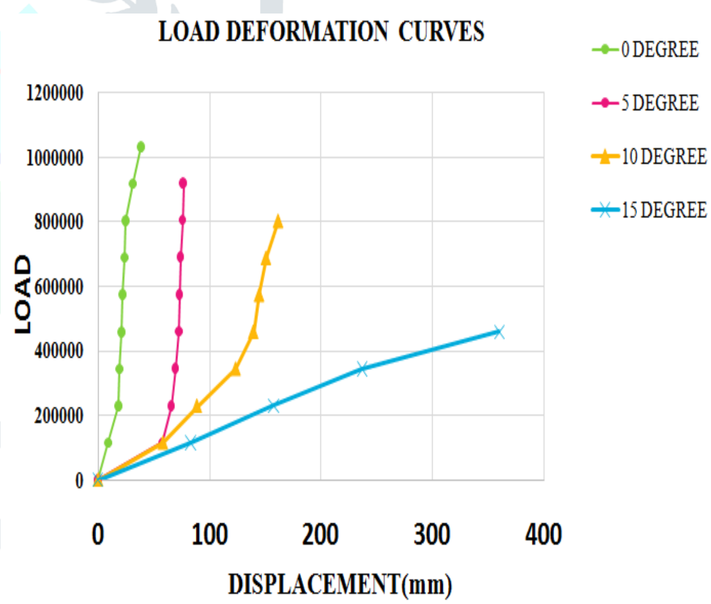


Fig : Load vs Deformation curve obtained for yield load

Stress vs Strain plots:

Variations in stress and strain have been shown in the following figures where the stresses obtained from ANSYS software for each set of ultimate load.

Table :Stress-Strain values obtained for inclination of 0,5,10,15 degree in x,y,z directions

0 DEGREE

X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
STRESS	STRAIN	STRESS	STRAIN	STRESS	STRAIN
0	0	0	0	0	0
0.622	0.000007	0.499	0.000009	0.57	0.000006
0.989	0.000016	0.99	0.000018	0.81	0.000015
1.97	0.000026	1.09	0.00012	0.95	0.000025
2.956	0.000044	2.2	0.00018	2.33	0.000046
4.11	0.000071	3.02	0.00035	3.88	0.000073
7.15	0.00011	5.26	0.00057	6.02	0.000115
9.56	0.00012	7.68	0.00068	8.13	0.00013
11.77	0.00014	8.02	0.00079	10.11	0.00014
13.27	0.00016	9.87	0.00085	12.66	0.00016

5 DEGREE

STRESS	STRAIN	STRESS	STRAIN
X-direction		Y-direction	
3.08	0.0000218	12.993	0.000065
6.174	0.0000436	0.00013	
15.586	0.000085	63.78	0.00038
23.775	0.00012	97.073	0.00061
31.53	0.00016	128.786	0.00081
38.99	0.00019	159.436	0.00099
46.538	0.00023	190.071	0.0011
50.205	0.00024	206.543	0.0013

10DEGREE

STRESS	STRAIN	STRESS	STRAIN	STRESS	STRAIN
X-direction		Y-direction		Z-direction	
6.67	0.000042	30.4	0.00015	6.412	0.000048
21.92	0.000096	93.69	0.000456	20.74	0.00011
33.814	0.00014	143.06	0.00069	32	0.00016
45.47	0.00019	193.58	0.00094	43.024	0.00021
53.55	0.00023	227.74	0.0011	50.655	0.00025
59.83	0.00025	238.03	0.0013	57.128	0.0003
66.55	0.0032	262.02	0.0076	104.63	0.00169

15 DEGREE

X-direction		Y-direction		Z-direction	
STRESS	STRAIN	STRESS	STRAIN	STRESS	STRAIN
0	0	0	0	0	0
37.538	0.00013	170.34	0.00082	36.313	0.00019
56.149	0.0029	254.001	0.0077	109.456	0.0013
74.9	0.0064	260.48	0.0157	120.44	0.0034
104.272	0.0136	276.3	0.0535	124.46	0.0068

Failure modes;

The local buckling of steel tubes in CFST columns, subjected to axial compression, occurs when the applied load reaches the critical buckling load. It is important to understand the behaviour of local buckling in CFST columns as buckling of the steel tube causes reduction in the ultimate strength and stiffness of the member.

It is observed that the areas close to the bottom and to the top of the column suffer the highest stresses. Naturally, local buckling is expected to occur in the compressed parts of these areas. It can be seen from the Figure 6.12,Local failure is occurred in the upright column and 5 degree inclined column and Local buckling is occurred in the 10 and 15 degree inclined columns.

Conclusions and recommendations:

Conclusions:

- The results obtained by ANSYS are comparable with the results obtained by various codes and hence the software can be conveniently used for the analysis of CFST inclined columns.
- It has also been observed that the ANSYS software gives safer results compared to the EC4, ACI and AISC codes by 13.9%, 7.7% and 36.84% respectively.
- Comparison among codes have revealed that European code and ACI yields conservative results and is about 26.49% and 31.57 % more as compared to AISC code respectively. However, several aspects like load factor, material safety factors etc have been considered in these codes. Also, the discrepancies found among various codes for analysis have been highlighted.
- For an inclined column moment plays a primary and major role and the axial load is secondary. According to EC-4 it has been observed that the moment increases by 50% in 10º angle of inclination compare to 5º and 34% in 15º angle of inclination compare to 10º,due to eccentricity.
- For an inclined columns have horizontal forces exist to support the column while there is no horizontal forces exist in the upright column.
- For concrete confined by the steel tube, the cracks occurred after shearing stress reached the tensile strength of concrete. However, these were restrained by the steel tubes resulting in a large torsional resisting capacity.

It has been found that there was 93%, 94% and 95% increase in for 5º, 10º and 15º CFST inclined columns respectively compared to that of an upright column under design load.

<u>Recommendations</u>

Further investigations on:

- Tests, FEM and structural analysis are necessary.
- Different shapes and dimensions.
- Variation in thickness and grade of concrete and steel.
- Connection study on beams and columns.
- Different materials such as steel and wood.

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