# Non-Linear Behaviour of CFST Columns at Elevated Temperature under Monotonic loading using Finite Element Softwares (Conventional Concrete & SCC infill)

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## ABSTRACT

*This paper is concerned with the Behaviour of Conventional & Self compacting Concrete Filled Steel Tube (CFST) at elevated temperature under monotonic loading is investigated using finite element method (Ansys version 16.0). The parameters chosen for the study are geometry of the specimen – circular section, different grades of conventional and Self Compacting concrete infill, different L/D ratios, and different temperatures. The study includes analytical investigation on a total of eighty-four specimens that includes twelve hollow and seventy-two specimens filled with conventional & Self Compacting concrete of grades M20, M25, & M30. The specimens including three L/D ratio and having a common thickness, which are subjected to different elevated temperature (30°C, 60°C, 90°C & 120°C) were tested. The column strengths are obtained by conducting nonlinear analysis using ANSYS software. The analytical results indicated that the load carrying capacity of CFS Tube decreases with increase in the temperature. The ultimate load carrying capacity is higher for Self Compacting than conventional concrete filled tubes and the ultimate load carrying capacity is higher for SCC filled tubes than the hollow tubes and higher for higher grade of SCC.*

***Keywords:*** *Nonlinear Analysis, Buckling Analysis, Mode Shapes, Conventional Concrete, Self compacting Concrete.*

## INTRODUCTION

Concrete Filled steel tube (CFST) was used in the early 1900s. But till 1960s research on concrete filled steel tube did not begin. Concrete Filled steel tube (CFST) are composite members consists steel tube in filled with concrete materials. Concrete filled column are used in lateral resistance system of both braced and un braced system of the building, commonly concrete filled steel tubes are used in bridges piers. Moreover, Concrete filled steel tube column are used for strengthening the structure in earthquake zones. Concrete Filled Steel Tubular (CFST) composite columns represent a class of structural systems, where the best properties of steel and concrete are used to their maximum advantage. When employed under favorable conditions the steel casing confines the core tri-axially creating a confinement for better seismic resistance and the in-filled concrete inhibits the local buckling of the tubular shell.

Moreover, when compare with hollow steel tube, core concrete the concrete filled steel tube (CFST) will give more compressive stability enormously concrete filled steel tube (CFST) will give more excellent compressive resistance capacity, ductility and energy dissipation ability owning to be confining effect provided by steel tube.

**Benefits of using CFST columns:** Composite segment joins the benefits of both basic steel and cement, to be specific the pace of development, quality, and light weight steel, and the characteristic mass, firmness, damping, and economy of cement. The steel outline serves as the erection casing to finish the development of whatever remains of the structure. In this way enhancing pliability, Furlong reasons that the solid infill delays the neighborhood clasping of the steel tube. Notwithstanding, no expansion in solid quality because of repression by steel tube was watched.

**Brief Description of Software's used:** Finite element method considers being the best tool for analyzing the structures lately, many software's uses this technique for analyzing and creating. For finite factor evaluation and computer aided design field one of the programs is suitable i. e. ALTAIR HYPERMESH was found in 1985 by James R Scapa, George Christ & Mark Kistner, ANSYS was founded in 1970 by John A. Swanson as *Swanson Analysis Systems, Inc*(SASI) for structural design software for bridges and other civil structures. The 3D hollow and concrete filled steel conduit columns are created in the software and then analyzed for buckling and mode shapes under failure are generated.

**Finite Element Modeling:** SOLID45 is used for the 3-D modeling of CFST for both steel and concrete. It is 3-D structural solid element which is defined by 8-noded having 3 degree of freedom at node; translations in -the nodal x, y & z directions. NEWTON-RAPHSON method is chosen for running programe as 3-D non linear transient thermal analysis in Ansys software. Conventional & Self compacting concrete filled in the CFST column are accurately model in finite element software Hyper mesh & exported to Ansys for analysis and compared with experimental results and codes of practice.

## 2. MATERIAL PROPERTIES AND CONTITUTIVE MODELS

**Steel:** Steel tube is modeled as elastic-perfectly plastic with von mises yield criterion. Due to steel tube is subjected to multiple stresses and therefore the stress-strain curve crosses elastic limit and reaches in plastic region. The nonlinear behavior of steel tube is obtained from uniaxial tension test and used in steel modeling. In this analysis Poisson's ratio, density and young's modulus are taken as µ=0.3, ∫=7860kg/m3 and Es=210000MPa, respectively.

**Conventional Concrete:** A rational mix design method of Conventional concrete using a variety of materials is necessary. Coarse aggregate, fine aggregate content in concrete is fixed at 50% & 40% percent of the mortar volume.

**Self Compacting Concrete:** A rational mix design method of Self compacting concrete using a variety of materials is necessary. Coarse aggregate, fine aggregate content in concrete is fixed at 50% & 40% percent of the mortar volume.

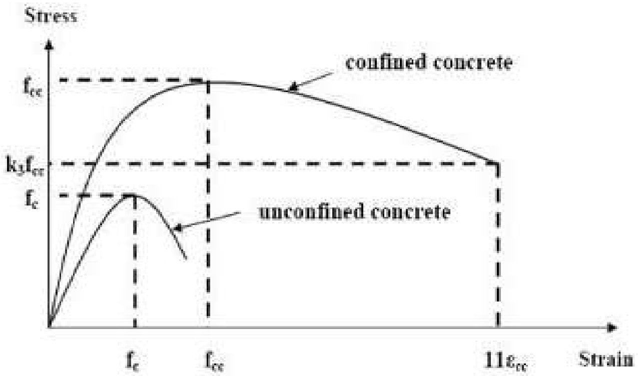

**Figure 1**: Equivalent stress-strain curves for confined and unconfined concrete

**Material Model of Concrete**: In order to understand concrete behavior in the finite element model, a nonlinear stress-strain diagram for confined concrete should be establish. The equivalent stress-strain curve for confined and unconfined concrete under compressive loading. This is used in proposed FE model. The properties of material shown in figure 1 is used to define the nonlinear behavior of concrete under confinement. This is defined as follows. The stress strain curve is divided into 3 parts namely elastic part (Linear), Elasto-Plastic part and Perfectly Plastic (nonlinear).

**Table 1**: Properties of Material

| ***Properties*** | ***Steel*** | ***Conventional concrete*** | ***Self Compacting Concrete*** |
|---|---|---|---|
| Density (ʃ) | 7860 kg/m$^3$ | 2200 to 2600 kg/m$^3$ | 2400kg/m$^3$ |
| Poison ratio ( V) | 0.3 | 0.17 | 0.18 |
| Young's modulus (E) | 210000 MPa | 22360.7 (M20)<br>25386.12 (M25)<br>27386.12 (M30)MPa | 25000 MPa |

**Table 2:** Geometric Properties of CC & SCC

| *Case* | *L(mm)* | *D(mm)* | *t (mm)* | *L/D* | *D/t* |
|---|---|---|---|---|---|
| Hallow tube | 215.8 | 26.9 | 3.2 | 8 | 8.40 |
| | 404.4 | 33.7 | 3.2 | 12 | 10.53 |
| | 678.4 | 42.4 | 3.2 | 16 | 13.25 |
| M20 | 215.8 | 26.9 | 3.2 | 8 | 8.40 |
| | 404.4 | 33.7 | 3.2 | 12 | 10.53 |
| | 678.4 | 42.4 | 3.2 | 16 | 13.25 |
| M25 | 215.8 | 26.9 | 3.2 | 8 | 8.40 |
| | 404.4 | 33.7 | 3.2 | 12 | 10.53 |
| | 678.4 | 42.4 | 3.2 | 16 | 13.25 |
| M30 | 215.8 | 26.9 | 3.2 | 8 | 8.40 |

| | | | | | |
|---|---|---|---|---|---|
| | 404.4 | 33.7 | 3.2 | 12 | 10.53 |
| | 678.4 | 42.4 | 3.2 | 16 | 13.25 |

## 3. MODELING PROCEDURE AND ANALYSIS IN HYPERMESH AND ANSYS

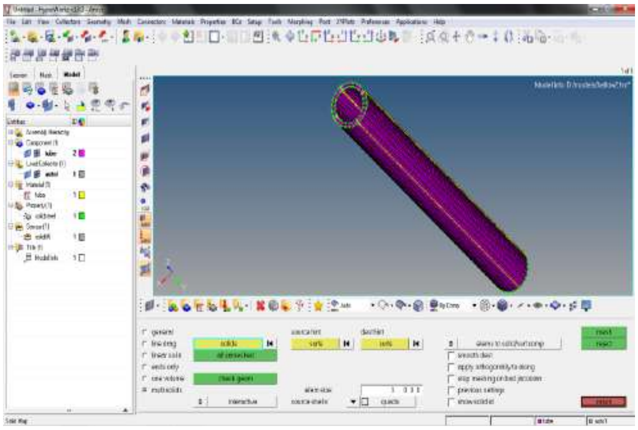

**Figure 1:** Set the Hyper mesh interface for Ansys User profile.

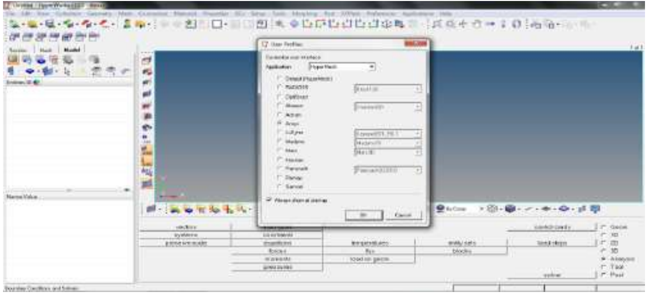

**Figure 2:** Hollow tube meshing by creating component, property & material and by assigning property to component and material to property

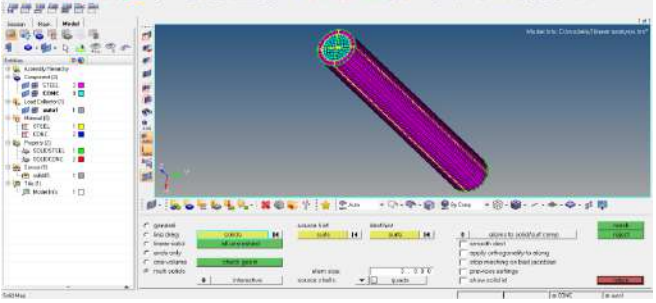

**Figure 3:** CFST meshing by creating component, property & material and by assigning property to component and material to property

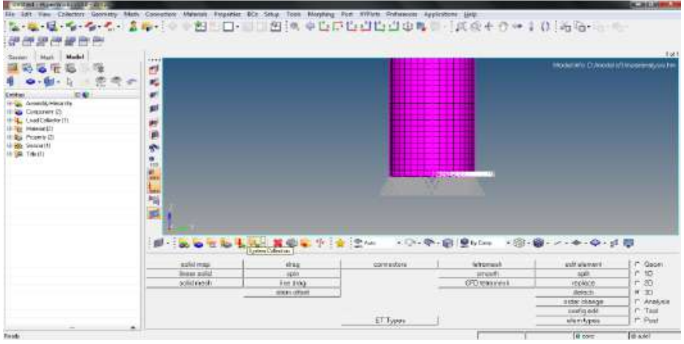

**Figure 4:** Applying Boundary Condition at Bottom Nodes

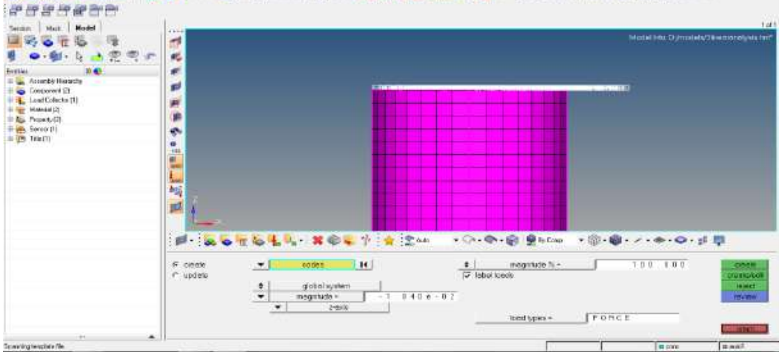

**Figure 5:** Applying load at top nodes

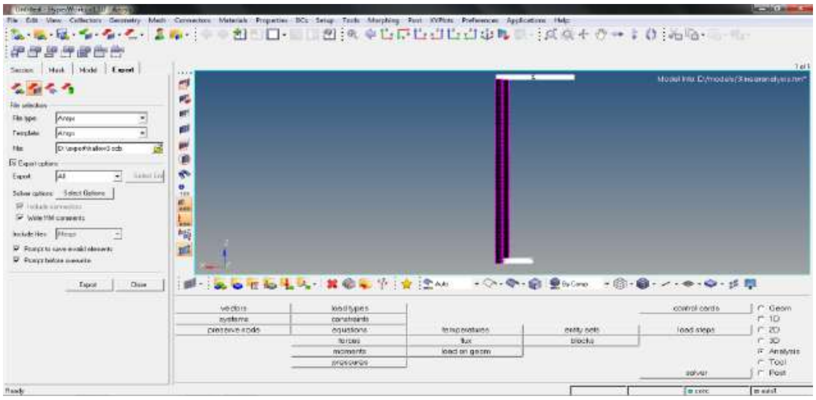

**Figure 6:** Exporting to Ansys from Hyper Mesh as a Solver Deck

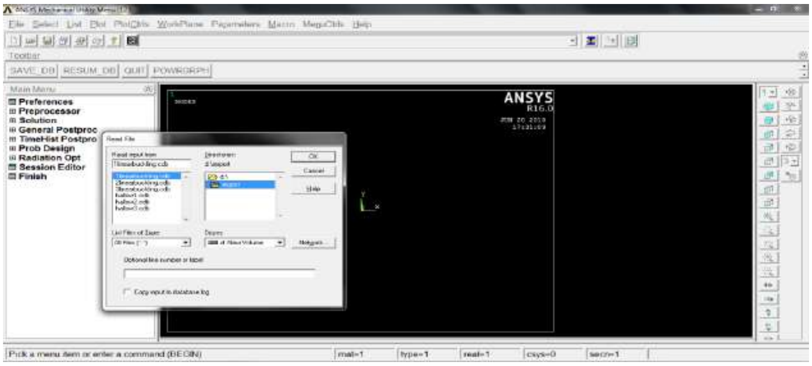

**Figure 7:** Read input from .cdb exported file

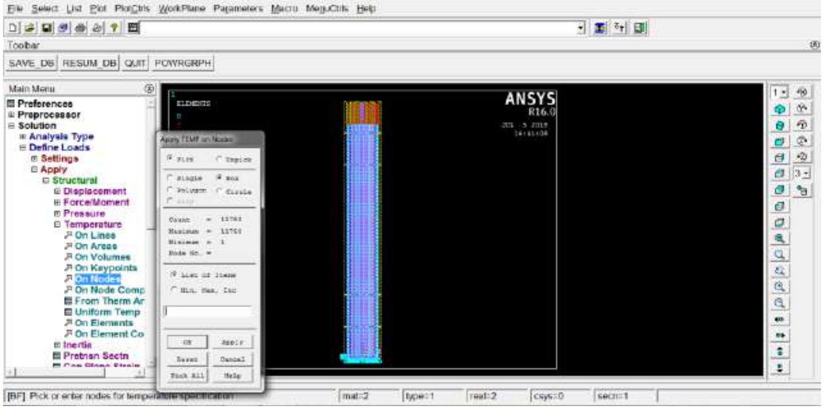

**Figure 8:** Applying temperature

## 4. BTAINING RESULTS MODE SHAPES AND LOAD CALCULATION

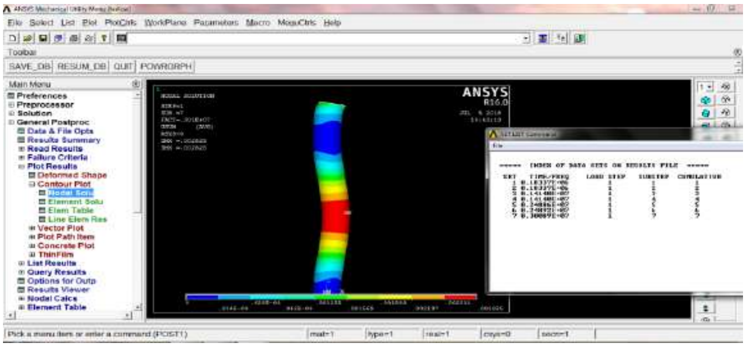

**Figure 9:** Linear Static and buckling analysis were done and the contour plot of Hollow tube is obtained.

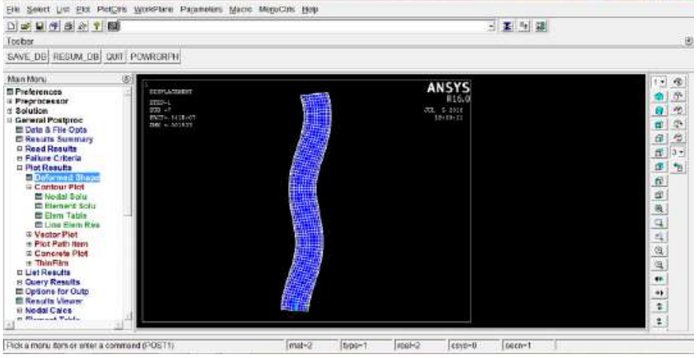

**Figure 10:** Deformed shape of CFST after linear analysis

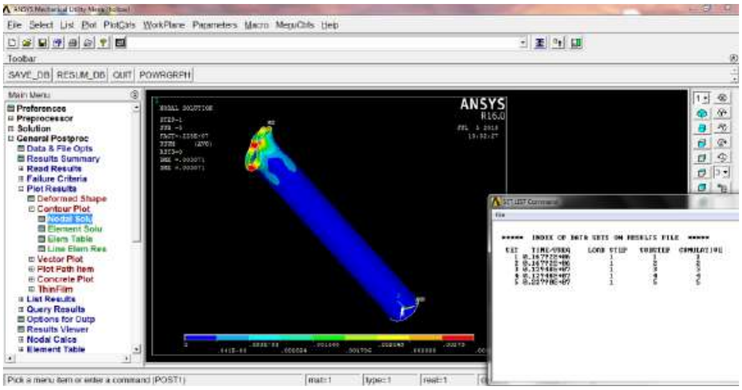

**Figure 11 :** Non-Linear behavior of Hallow Tube

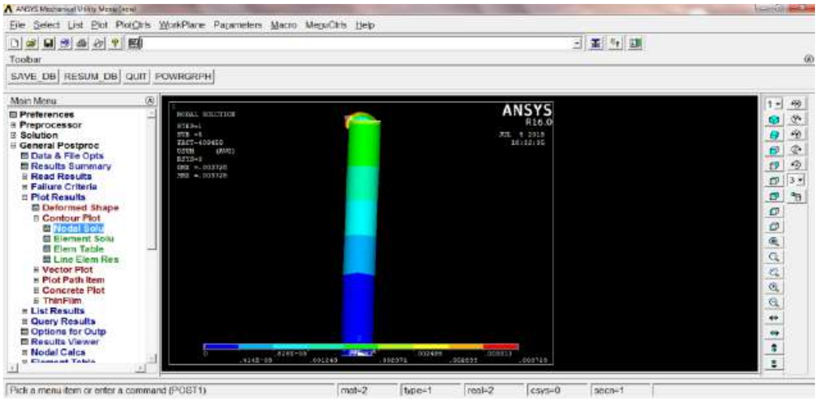

**Figure 12 :** Non-Linear behavior of CFST Column

**Table 3:** Result obtained from analytical investigation for L=215.8mm

| *L(mm)* | *D(mm)* | *t(mm)* | *L/D* | *case* | *Temp(°C )* | *Pu(KN)* |
|---|---|---|---|---|---|---|
| 215.8 | 26.9 | 3.2 | 8 | Hollow | 30 | 112 |
| | | | | | 60 | 90 |
| | | | | | 90 | 83 |
| | | | | | 120 | 76 |

| *L(mm)* | *D(mm)* | *t(mm)* | *case* | *Temp(° C)* | *Pu(KN) cc* | *Pu(KN) scc* |
|---|---|---|---|---|---|---|
| 215.8 | 26.9 | 3.2 | M20 | 30 | 153 | 156 |
| | | | M25 | | 174 | 174 |
| | | | M30 | | 188 | 190 |
| 21.8 | 26.9 | 3.2 | M20 | 60 | 144 | 147 |
| | | | M25 | | 159 | 160 |
| | | | M30 | | 165 | 166 |
| 215.8 | 26.9 | 3.2 | M20 | 90 | 137 | 137 |
| | | | M25 | | 151 | 154 |
| | | | M30 | | 155 | 156 |
| 215.8 | 26.9 | 3.2 | M20 | 120 | 128 | 129 |
| | | | M25 | | 141 | 142 |
| | | | M30 | | 148 | 150 |

**Table 4:** Result obtained from analytical investigation for L=404.4mm

| *L(mm)* | *D(mm)* | *t(mm)* | *L/D* | *case* | *Temp(°C )* | *Pu(KN)* |
|---|---|---|---|---|---|---|
| 404.4 | 33.7 | 3.2 | 12 | Hallow | 30 | 102 |
| | | | | | 60 | 82 |
| | | | | | 90 | 78 |
| | | | | | 120 | 74 |

| *L(mm)* | *D(mm)* | *t(mm)* | *case* | *Temp(°C )* | *Pu(KN ) cc* | *Pu(KN) scc* |
|---|---|---|---|---|---|---|
| 404.4 | 33.7 | 3.2 | M20 | 30 | 147 | 149 |
| | | | M25 | | 167 | 169 |
| | | | M30 | | 181 | 182 |
| 404.4 | 33.7 | 3.2 | M20 | 60 | 136 | 138 |
| | | | M25 | | 145 | 147 |
| | | | M30 | | 154 | 157 |
| 404.4 | 33.7 | 3.2 | M20 | 90 | 131 | 134 |
| | | | M25 | | 140 | 142 |
| | | | M30 | | 147 | 149 |
| 404.4 | 33.7 | 3.2 | M20 | 120 | 124 | 125 |
| | | | M25 | | 133 | 136 |
| | | | M30 | | 141 | 144 |

**Table 5:** Result obtained from analytical investigation for L=678.4mm

| *L(mm)* | *D(mm)* | *t(mm)* | *case* | *Temp(°C)* | *Pu(KN)* |
|---|---|---|---|---|---|
| 678.4 | 42.4 | 3.2 | Hallow | 30 | 92 |
| | | | | 60 | 79 |
| | | | | 90 | 72 |
| | | | | 120 | 65 |

| *L(mm)* | *D(mm)* | *t(mm)* | *case* | *Temp(°C)* | *Pu(KN) CC* | *Pu(KN) SCC* |
|---|---|---|---|---|---|---|
| 678.4 | 42.4 | 3.2 | M20 | 30 | 140 | 143 |
| | | | M25 | | 159 | 162 |
| | | | M30 | | 169 | 172 |
| 678.4 | 42.4 | 3.2 | M20 | 60 | 128 | 130 |
| | | | M25 | | 140 | 141 |
| | | | M30 | | 149 | 151 |
| 678.4 | 42.4 | 3.2 | M20 | 90 | 123 | 125 |
| | | | M25 | | 130 | 131 |
| | | | M30 | | 137 | 138 |
| 678.4 | 42.4 | 3.2 | M20 | 120 | 117 | 120 |
| | | | M25 | | 121 | 123 |
| | | | M30 | | 127 | 127 |

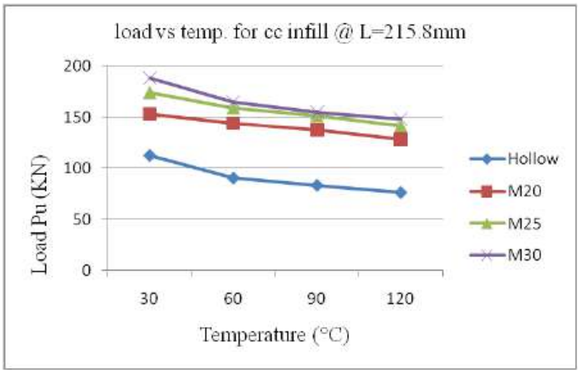

**Figure 13:** Load vs Temperature

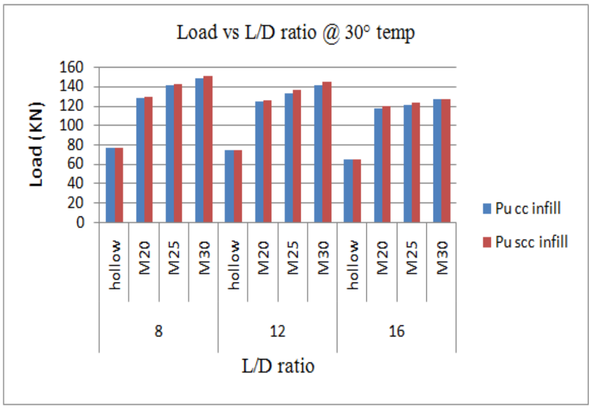

**Figure14:** Load vs L/D Ratio

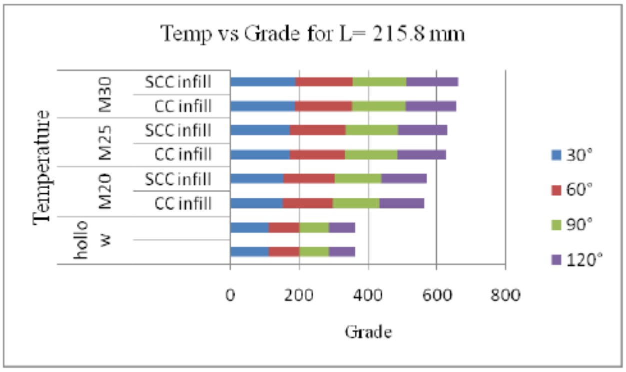

**Figure 15:** Temperature vs Grade

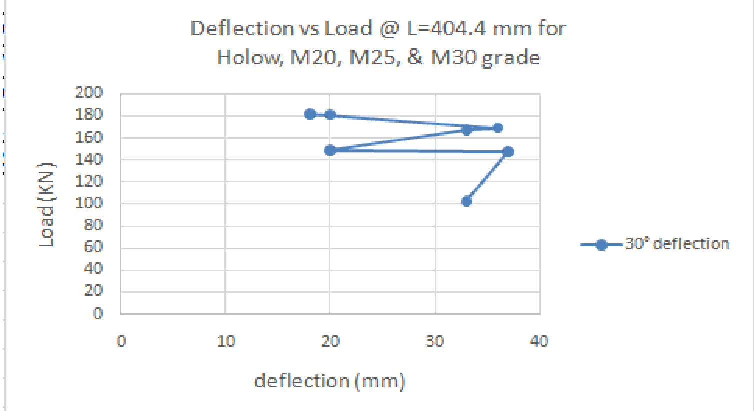

**Figure 16:** Load vs deflection

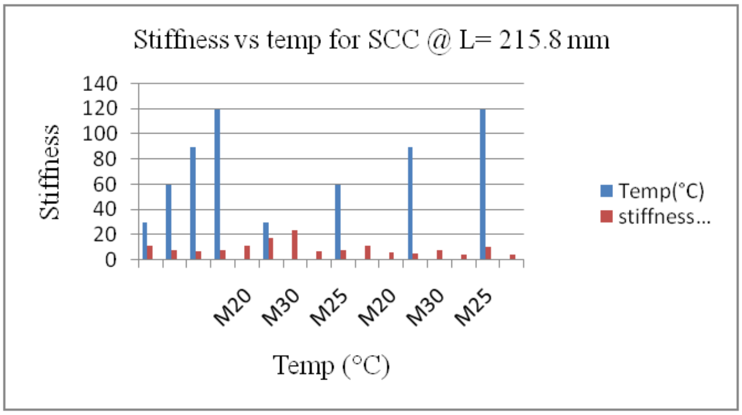

**Figure 17:** stiffness vs temperature

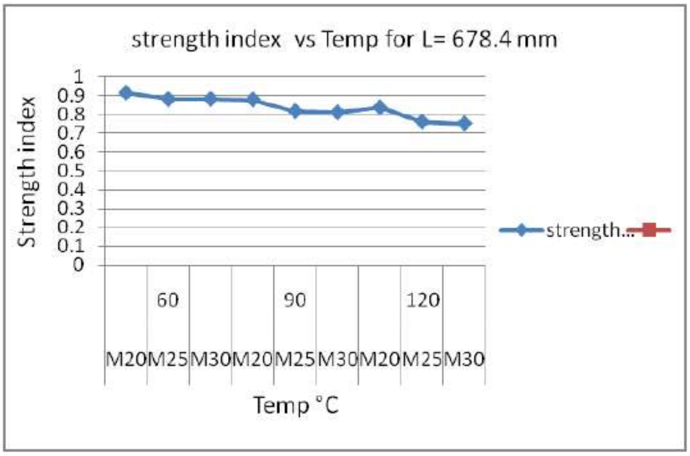

**Figure 18:** strength index vs axial load

## 5. CONCLUSION

1) The ultimate load carrying capacity of CFS tube is higher at room temperature and decreases with increase in temperature (60°C, 90°C, and 120° C).
2) The ultimate load carrying capacity of CFST decreases by 5-10% for each rise in temperature and decreases by 10-15% for hollow tubes.
3) When SCC, CC filled steel columns and hollow tubes subjected to elevated temperature, SCC and CC carry higher ultimate load than the hollow tubes. For CC & SCC filled steel tube the ultimate load is about 13-20% higher than the hollow tubes.
4) The local buckling is delayed in Concrete filled Steel Tube compared to hollow tubes.

5) With increase in grade of concrete, the ultimate load also increases marginally by 4-5%. Thus, the load verses deflection curve is shifted higher for higher grades of CC & SCC.
6) As L/D ratio increases, the load carrying capacity 0f the composite tube decreases by 4%-10%.
7) The ultimate load carrying capacity of SSC filled steel tubes is higher compare to the CC filled steel tube.
8) With increase in temperature, the stiffness of the concrete filled steel tubes will decrease.
9) Stiffness of CFS tubes increases with increase in different grade of concrete.
10) Strength index of concrete filled steel tubes decreases with increase in Temperature.

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