Buckling Analysis of Silica Fume Concrete Filled Steel Tube Column using ANSYS

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Abstract*: In composite construction, the concrete and steel are combined in such a fashion that the advantages of both the materials are utilized effectively. The lighter weight and higher strength of steel permit the use of smaller and lighter foundations. Concrete filled steel tubes having high load carrying capacity where as when silica fumes is mixed with concrete increases its performance. The subsequent concrete addition enables the building frame to easily limit the sway and lateral deflections. Hollow column has less self weight and a high flexural stiffness and hence its usage in seismic zone proves promising. In this study silica fume concrete (SFC) is used as an infill material instead of normal concrete in steel tube columns. It reduces requirements on labour, construction time and formwork also maintains the construction quality.*

Keywords: silica fume concrete (SFC), buckling analysis, parametric optimization, Finite Element analysis

1. Introduction

A steel-concrete composite column is a compression member widely used in construction field as a load-bearing member in composite framed structure and composite members are constructed such that the structural steel shape and the concrete act together to resist axial compression or bending. Concrete filled steel tube column comprises of a hollow steel section of different shapes filled with concrete. This member comprises and utilizes the advantages of both steel and concrete.

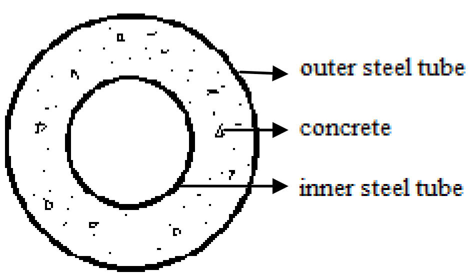

Figure 1: Hollow steel tube column with concrete infill

These columns are used widespread in high-raised structures as they speed up construction by eliminating formwork and the need for tying of longitudinal reinforcement and also provide excellent seismic event resistant structural properties such as high strength, high ductility and large energy absorption capacity. The steel tube acts as formwork which helps in speed up the construction and reinforcement for the concrete core helping it to resist tension, bending moment and shear providing confinement for concrete. Whereas concrete core adds stiffness and compressive strength to the tubular column and reduces the potential for inward local buckling. Circular hollow sections posses many advantages over other open sections, including aesthetic appearance, behavior and economy in terms of material cost.

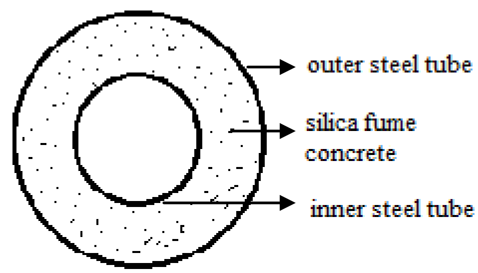

Figure 2: Hollow steel tube column with silica fume concrete infill

Concrete filled steel tubes having high load carrying capacity where as when silica fumes is mixed with concrete increases its performance. So a model of steel tubular column with silica fume concrete in filled is chosen. Silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement with varying percentages like 5%, 10%, 15% etc. Addition of silica fume to concrete has many advantages like high strength, durability as well as reduction in cement production. In this study silica fume concrete (SFC) is used as an infill material instead of normal concrete in double skin steel tube column. About 15 % replacement of cement by silica fume is considered here.

2. Modeling of Columns

2.1 Geometric Model

The software used for the analysis of columns is ANSYS WORKBENH 15, which can carry out advanced engineering analysis quickly and safely for different applications. For modeling the initial step is to assign the engineering data.
The preparation of engineering data includes selection of geometry. Steel tube column with inner diameter of 100mm, outer diameter of 150mm and height of 1500mm is selected.
The material is modeled as a linear isotropic elasticity material, which we need to input Young's modulus and Poisson's ratio of selected materials. The selected materials are structural steel, normal concrete and silica fume concrete. The geometric model of column is shown in Figure.3.

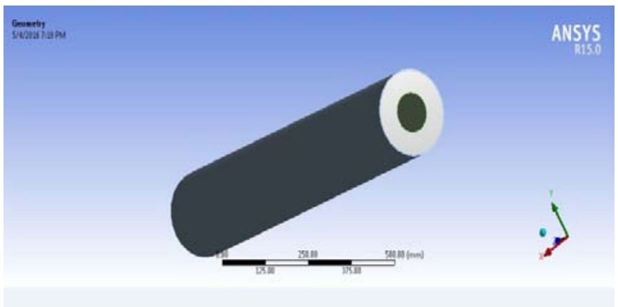

Figure 3: Geometric model of column before meshing

2.2 Mesh Model

The division of a geometric model into different elements is called meshing and the collection of the elements is called a finite element mesh or finite element model. Mesh modeling is done after creating geometric model by assigning engineering data.

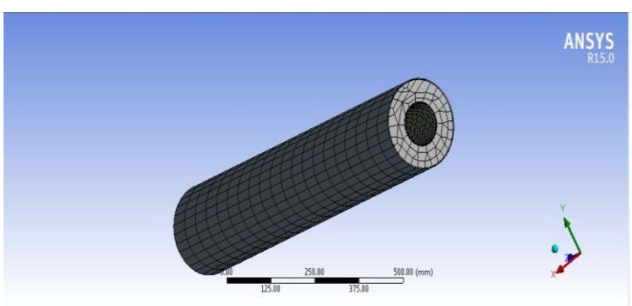

Figure 4: Mesh model of column

2.3 Boundary and Load Setup

A fixed support is provided at the bottom of the column and an axial compressive load of about 1kN is given at the top end of the column**.** The choice of the boundary is arbitrary as long as we can specify the boundary conditions on the entire boundary surfaces. Force is given as remote force, so that it can uniformly distribute along the column, it is applied gradually and corresponding stress values and deflections can be obtained.

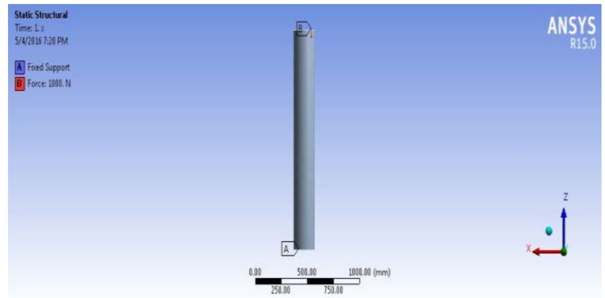

Figure 5: Model after assigning support and load

3. Column Analysis Using Ansys

3.1 Buckling Analysis

Linear buckling analysis gives the user, an estimate of the critical load to induce buckling. Buckling analysis is helpful to determine if there are more than one possible modes of buckling.
During buckling analysis of columns, corresponding load multiplier will get according to the type of materials used. Hence the buckling analysis of steel tube column with concrete and silica fume infill is selected.
The Figure 6 shows the buckling deformation of the steel tube column which is filled with concrete when a 1kN load is applied. The corresponding deformations are shown in figure. A load multiplier of 471.31 is attained and then multiplies this with 1000; the resulting answer is the maximum load that the column withstands. The load multiplier is interpreted as the buckling factor of safety for the applied load.

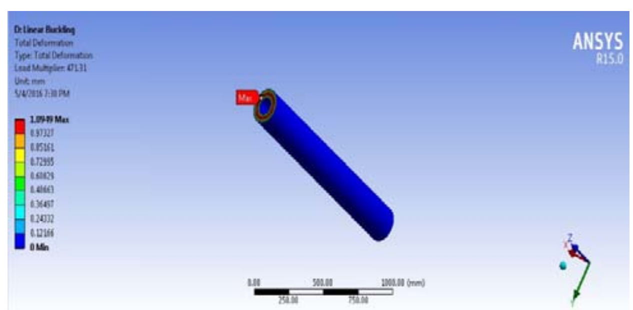

Figure 6: Buckling analysis of column filled with concrete

Figure 7 shows the buckling deformation of the steel tube column which is filled with silica fume concrete. The corresponding deformations are shown in figure. A load multiplier of 1618.2 is attained.

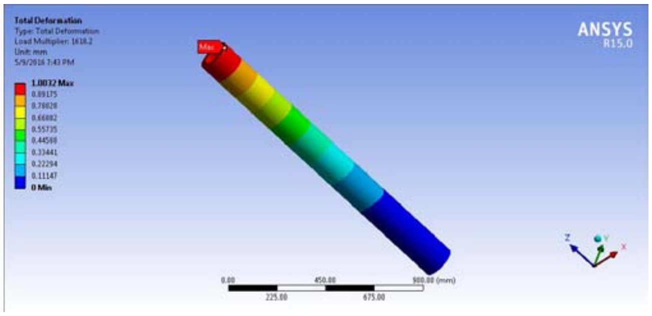

Figure 6: Buckling analysis of column filled with silica fume concrete

3.2 Equivalent stresses and Total deformation

The equivalent stress is also known as Von-Mises stress which is a scalar stress value that can be calculated from the Cauchy's stress tensor and it gives the average values of all stresses.

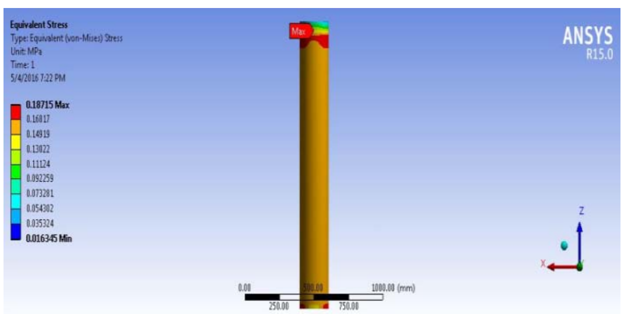

Figure 7: Equivalent stresses of column with concrete infill.

Figure 7 and 8 which shows the equivalent (Von-Mises) stress and the total deformation of the column with normal concrete infill respectively

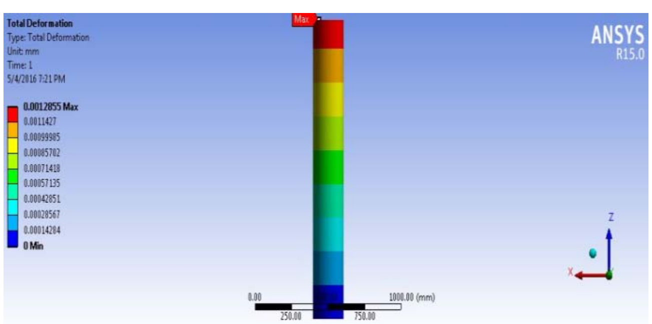

Figure 8: Total deformation of column with concrete infill.

Figure 9 and figure 10 which shows the equivalent (Von Mises) stress and the total deformation of the column with normal silica fume infill respectively. Here the equivalent stresses are smaller than the ultimate stress of the materials used, hence the columns are safe in the case of stress condition.

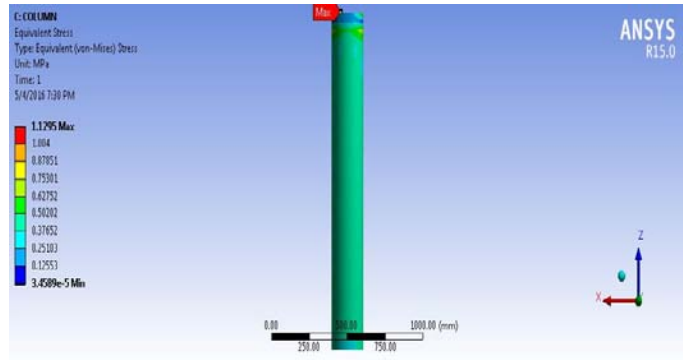

Figure 9: Equivalent stresses of column with silica fume concrete infill

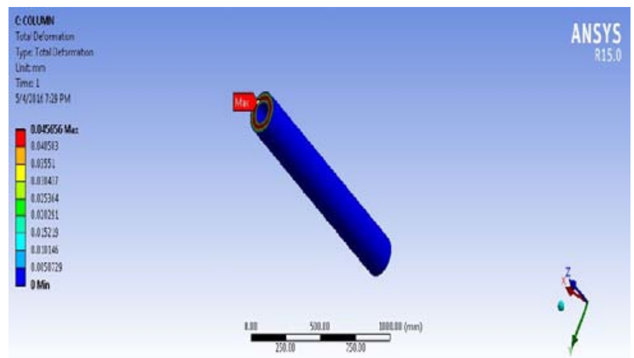

Figure 10: Total deformation of column with silica fume concrete infill.

3.3 Parametric Study

By parametric optimization means that to find out the best parameters which are suitable for the column with SFC and normal concrete infill in the steel tube column. In this study with a constant values of load, length and outer thickness of tube and by changing the inner thickness of the tube, find out the deformation and equivalent stresses. By finding these values the model with lesser value of deformation and thickness gives the suitable model with all its properties. The selected inner thicknesses of tubes are 2mm, 3mm, 3.5mm, 4mm, 5mm and 6mm.

4. Results and Discussions

4.1 Buckling Analysis

From the output of ANSYS, various results are obtained. In buckling analysis the load multiplier from the tube with silica fume is 1618.2 and that of normal concrete is 471.31.

Table 1: Details of total deformation with load multiplier

Model	*Axial Load (N)*	*Load Multiplier*	*Deformation (mm)*
Concrete	1000	471.31	0.0456
Silica Fume Concrete	1000	1618.2	0.00128

Models with higher values of load multiplier give the better model. Hence silica fume filled steel column is mostly preferred than concrete filled columns.

4.2 Parametric Optimization

By parametric optimization means that to determine the best suited parameters. The below table shows the equivalent stresses and deformation corresponding to increase in thickness from 2mm to 6mm. By using these values graph should be plotted for both the models with thickness vs. equivalent and thickness vs. deformation corresponding to increase in thickness.

Table 2: Deformation and stress corresponding to various thickness of column with concrete infill

Thickness (mm)	*Stress (Mpa)*	*Deformation (mm)*
2	2.2212	0.054753
2.5	1.7118	0.053796
3	1.4231	0.053135
3.5	1.1682	0.052684
4	0.9758	0.052341
5	0.7502	0.051848
6	0.5991	0.051522

It is seen that from the Table 2, there is a sharp decrease in stress values as the thickness increases from 2mm to 6 mm. Equivalent stresses corresponding to the thickness of 6mm is 0.5991 Mpa and it is the minimum value obtained. The graph obtained from the table is given below.

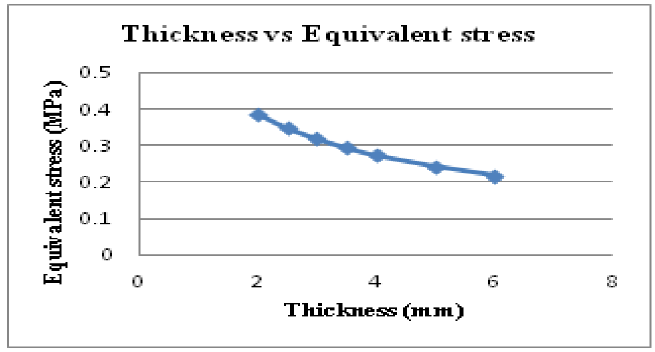

Figure 11: Equivalent stress & thickness for concrete column

Figure 12 shows that there is a sharp decrease in deformation as the thickness increases from 2mm to 6mm. Deformation corresponding to the thickness of 6mm is 0.05152 mm and it is the minimum value obtained.

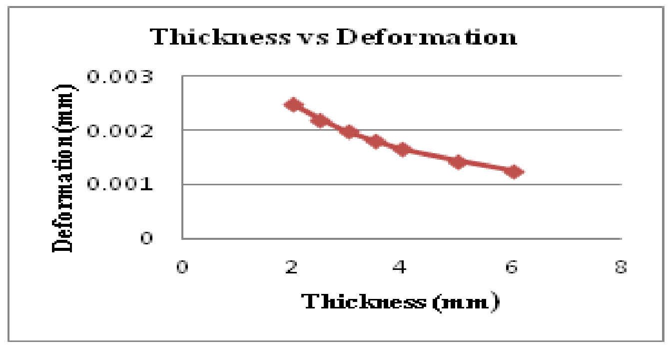

Figure 12: Deformation and thickness for concrete column

Table 3: Deformation and stress corresponding to various thickness of column with silica fume concrete infill

Thickness (mm)	*Stress (Mpa)*	*Deformation (mm)*
2	0.38653	0.00248
2.5	0.34701	0.00220
3	0.31789	0.00198
3.5	0.29297	0.00180
4	0.27358	0.00165
5	0.24179	0.00142
6	0.21645	0.00125

Table 3 shows the stress and deformations corresponding to various thicknesses for SFC columns.

The following Figure 13 explains that there is a sharp decrease in stress values as the thickness increases from 2mm to 6 mm. Equivalent stresses corresponding to the thickness of 6mm is 0.001253 Mpa and it is the minimum value obtained.

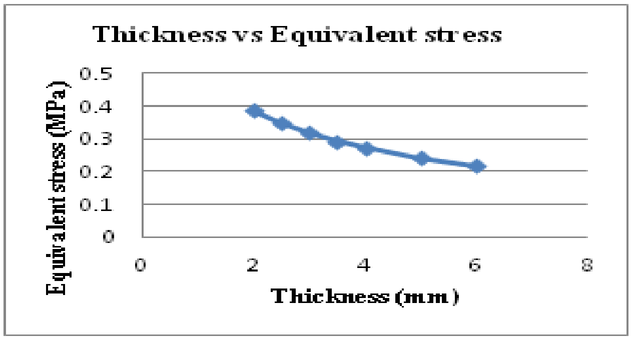

Figure 13: Equivalent stress and thickness for silica fume concrete column

There is a sharp decrease in deformation as the thickness increases from 2mm to 6mm. Deformation corresponding to the thickness of 6mm is 0.21645 mm and it is the minimum value obtained.

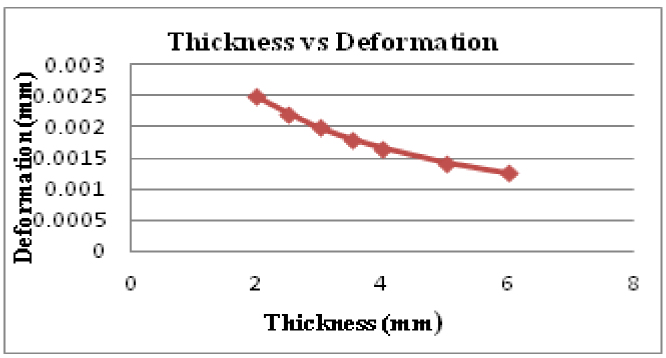

Figure 14: Deformation and thickness for SFC column

5. Conclusions and Future scope

5.1 Conclusions

The main conclusions obtained from the analysis are the following.

- Since the load multiplier is high in column with silica fume infill, steel tube column with silica fume concrete infill shows better results than column with concrete infill.
- The deformation of column with concrete infill is about 1.0949mm and for silica fume concrete infill is 1.0058mm.
- Suitable parameters are obtained from parametric optimization and find that the thickness of 6mm shows lower deformation. So 6mm thickness tube is better.

5.2 Future scope

- These study can be extended by changing different types of infill's and use other materials instead of steel.

6. References

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