International Journal of Engineering &Technology, 7 (3.12) (2018) 715-721

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Buckling Analysis of Belly Shaped Composite Column

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Abstract:

The study of Non prismatic column is designed to minimize the volume of material in the column by changing its shape, the column is subject to both buckling and strength constraints under axial compression load. The belly column is designed as Encased Composite column to improve the strength and ductility of column. The effective use of material through optimal shape of the column. Five models have been created in ANSYS WORKBENCH and all the columns having the same volume of materials, fixed end conditions and length of column. The behaviour of non-prismatic column is always based on tapering ratio and the slenderness ratio of the column. As the taper ratio increases, the elastic buckling load increases and stress decreases in the mean while the maximum stress occurs in the prismatic column compared with the non-prismatic column. As a result of this analysis Equivalent stress, Equivalent elastic strain, Total Deformation and Buckling load Deformation was observed and hence Stress-Strain graphs, Load -Deformation graphs and Mode-Load multiplier graph had been plotted.

Keywords: *Non Prismatic column, Encased composite column, Buckling, Load Multiplier Factor.*

1. Introduction

Non-Prismatic Column

The Non prismatic column is a column having different cross sections[1]. For many structures using tapered members may increase structural efficiency and be economical. The advantage of the structural efficiency of tapered members offers by reducing the amount of material required and increasing the overall performance of the structure[2]. The Non prismatic structures used in buildings frames, bridge members and masts, etc. which are designed as a non-uniform cross-sections in order to minimize the required material.

Belly Column

Belly column is the column used in ancient times, this gives aesthetic appearance[3]. Belly column is nothing but increasing the cross section of column in middle or below middle to prevent buckling failure. The Ancient belly column can be used in present trends of construction to improving the strength and stiffness of columns[4].

2. Analytical Study

The finite element analytical software ANSYS is a computational tool for modelling structure. It mainly helps to find load and behaviour of model failure mode, stress criteria, displacement criteria and other useful values like reaction under load rotation etc. The ANSYS WORKBENCH toolbox presents different types of data that can easily added to the project.

Buckling Analysis

The Buckling analysis is based on Eigen value that predicts the theoretical buckling strength of an ideal elastic structure[5]. The structures have an infinite number of buckling load factor. Each load factor is associated with a different instability pattern, but typically the lowest load factor is of interest. The Buckling mode shapes do not represent actual displacement but it helps to visualize the deformation part while buckling[6]. The buckling analysis is used to determine the specific set of loads which cause buckling and to find the shape of the buckling mode.

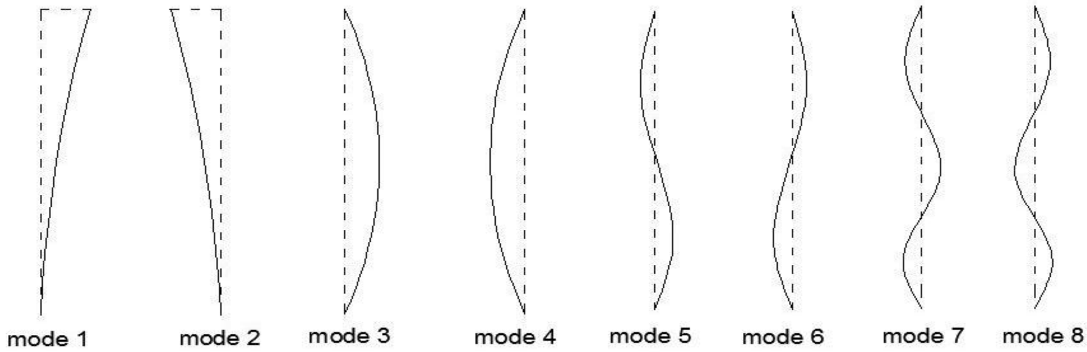

Fig. 1: Deformation respect to modes

Table 1: Mode with Load Multiplier for Columns

Mode	Load Multiplier Factor				
	Circular Encased Column	**Belly at Center**	**Belly at Bottom**	**Belly with Projection at Top (model 4)**	**Belly with Projection at Top (model 5)**
1	1.64	1.47	1.87	1.36	1.65
2	1.64	1.47	1.87	1.36	1.65
3	14.41	12.43	12.80	11.48	13.58
4	14.41	12.43	12.80	11.48	13.58
5	38.04	33.02	28.41	31.46	37.30
6	38.04	33.02	28.41	31.46	37.30
7	43.27	58.75	33.65	58.33	40.05
8	43.27	58.75	33.65	58.33	40.05
9	44.56	89.79	34.01	78.69	42.69
10	44.56	89.79	34.01	78.69	42.69

Stress Strain for Axial loading

All the Five modals are created in ANSYS WORKBENCH 14.5 for same support condition (one end fixed and other end free) and loading (axial load of 700KN)[7]. The bottom of the column is considered as fixed and the force is applied on the free end, actually the axial load of 700KN applied on the plate to distribute the load for inner core steel and encased concrete members. As the result of this loading, Total Deformation, Equivalent stress and Equivalent elastic strain was observed for all the columns and analytical study was also carried out.

Belly at Center and Belly at Bottom Encased Composite Columns

The axial load of 700KN applied on the plate to distribute the load to inner core steel and encased concrete members[8]. As the result of this loading, Total Deformation, Equivalent stress and Equivalent elastic strain and buckling load deformation was observed for Belly at Center Encased Composite column and Belly at Bottom Encased Composite Column as shown in the figure 2 and 3.

Belly at Center Encased Compositecolumn

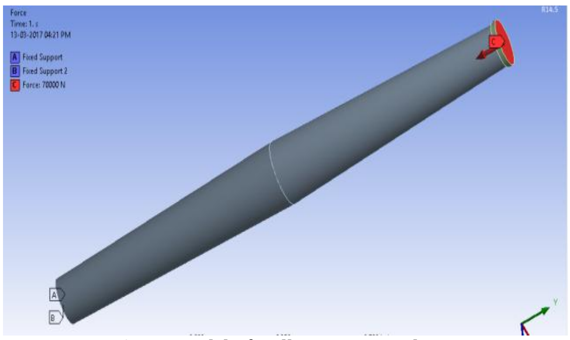

Fig. 2: Model of Belly at Center column

Belly at Bottom Encased Compositecolumn

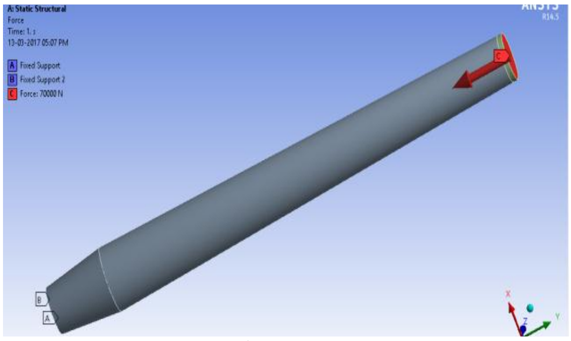

Fig. 3: Model of Belly at Bottom column

Belly with Projection at Top Encased Composite column

The axial load of 700KN applied on the plate to distribute the load to inner core steel and encased concrete members. As the result of this loading, Total Deformation, Equivalent stress and Equivalent elastic strain and buckling load deformation was observed for Belly with Projection at Top Encased Composite column Figure 4

Belly with Projection at Top Column

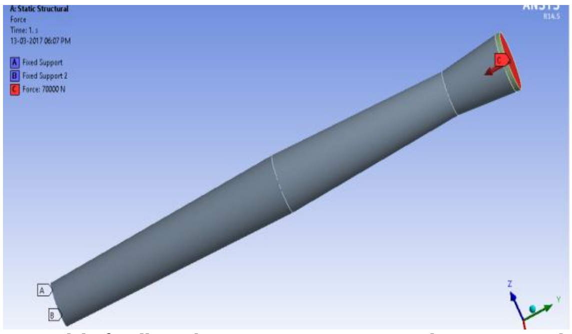

Fig. 4: Model of Belly with Projection at Top Encased Composite column

Belly with Projection at Top Column

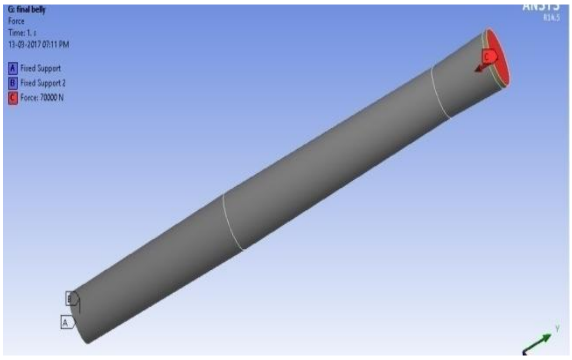

Fig. 5: Model of Belly with Projection at Top Encased Composite column

3. Observation

In this session, the Conventional column (Circular Encased Composite column) is compared with other four Non-Prismatic columns[10]. All the column having same volume of materials, one end is fixed and another end is free and axial load of 700KN. This comparison is done among the four major parameters i.e. Total Deformation, Equivalent stress, Equivalent elastic strain and Buckling load analysis.

Stress Comparison

Table 7: Maximum and Minimum stress values in Encased Concrete and Inner core steel of Different columns

Models	Concrete		Steel	
	Maximum	Minimum	Maximum	Minimum
	N/mm^2	N/mm^2	N/mm^2	N/mm^2
Circular Encased Composite Column	33.5(Top)	12.18(Bottom)	333.5(Top)	138.6(Bottom)
Belly at Centre	52.3(Top)	19.53(Belly)	477.15(Top)	137.4(Belly)
Belly at Bottom	52.6(Top)	12.36(Belly)	470.13(Top)	134.5(Belly)
Belly with Projection at Top	40.67(Neck)	12.9(Top)	310.37(Top)	150.78(Belly)
Belly with Projection at Top	32.2(Bottom)	14.36(Top)	314.2(Top)	164.2(Belly)

The circular encased Composite Column has maximum stress (33.5 N/mm^2 at concrete and 333.5 N/mm^2 in steel) at top because of the applied load in top. Theoretically the column having maximum stress at centre, but according to ANSYS the second maximum stress (27.7 N/mm^2 at concrete and 181.1 N/mm^2 in steel) is occurs in the centre of the column[11]. The belly column is designed to carry more load and reduce the stress in the column, but in case of belly at centre and bottom, the maximum stress occurred at top because of small cross sections in top. The columns are designed based on stress distribution by providing projections at top. Increase the cross section wherever having maximum stress and reduce the cross section wherever having minimum stress.The belly with projection at top is efficient column,when comparing with all other columns. The maximum stress in column is reduced upto 3.88% KN/m^2 in concrete and 5.78% KN/m^2 in steel compared to the normal conventional column.

Buckling Load Comparison

Table 8: Comparison Buckling load capacity of columns

Modals	Maximum Load Multiplier at the Mode	Maximum Load Multiplier
Circular Encased Composite Column	6	38.012
Belly at Centre	22	247.06
Belly at Bottom	10	34.017
Belly with Projection at Top	8	58.337
Belly with Projection at Top	6	37.307

The load multiplier is a factor that depends upon the number of modes. The load multiplier values increase with increasing the number of mode. At the particular number of mode the load multiplier reaches the ultimate point, further increasing the number of mode there is no big change in load multiplier. That load multiplier factor gives the critical buckling load of the column[12].

Critical Buckling load= Ultimate load multiplier x Applied Load (700KN)

From the table, it clearly shows that the belly at centre column is very efficient to carry high Buckling load, but in case of stress it is very weak in top. The Belly with projection at top column has also withstand for high buckling load, but heavy stress is occurs in the neck that leads to cause failure.[13] The conventional circular encased composite column and Belly with Projection at Top are nearly having equal Buckling load capacity but in stress constrains the Belly with Projection at Top is very efficient to distribute stress.

4. Results and Discussion

In this section, The ANSYS analysis results are discussed with Stress – Strain, load – deformation and Mode-Load Multiplier graphs

Stress – Strain graph

For the linear analysis, the stress is directly propositional to strain. Every columns has different stress-strain graph under the axial load of 700KN.

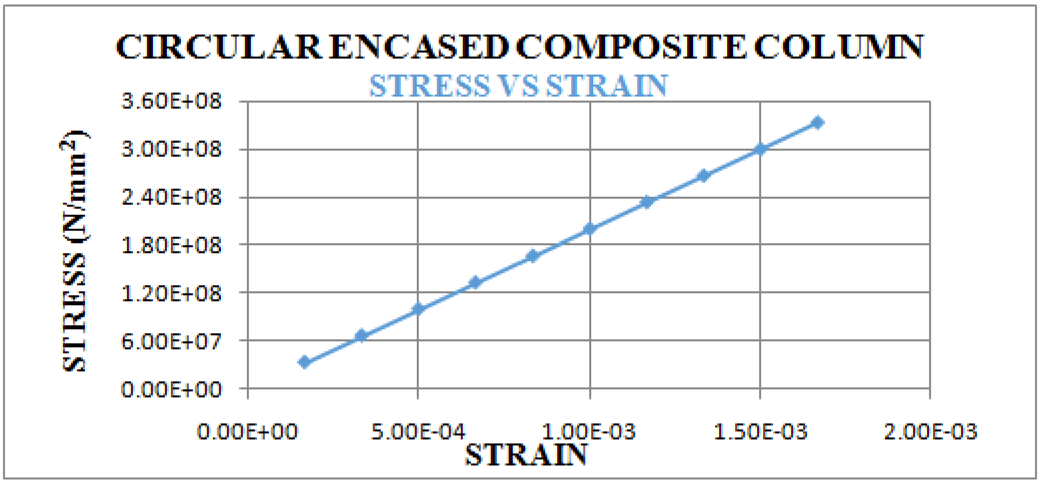

Fig. 6: Stress-Strain Graph for Circular Encased Composite Column (model 1)

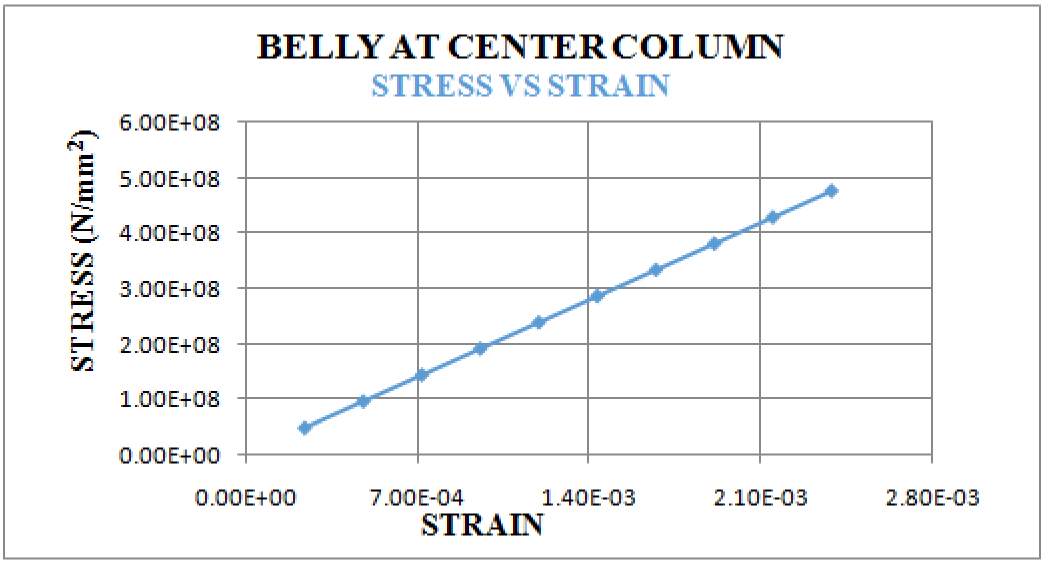

Fig. 7: Stress-Strain Graph for Belly at Center Column (model 2)

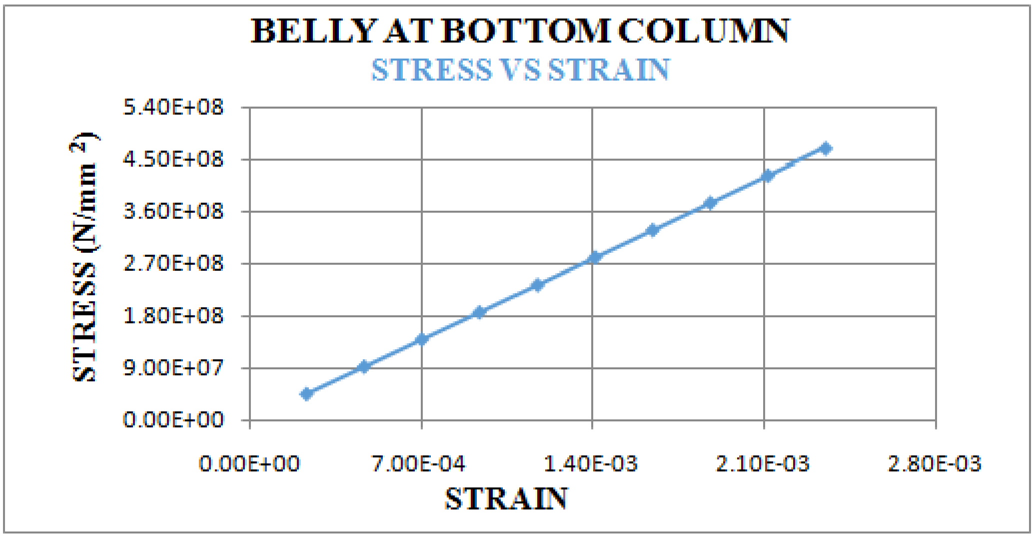

Fig. 8: Stress-Strain Graph for Belly at Bottom Column (model 3)

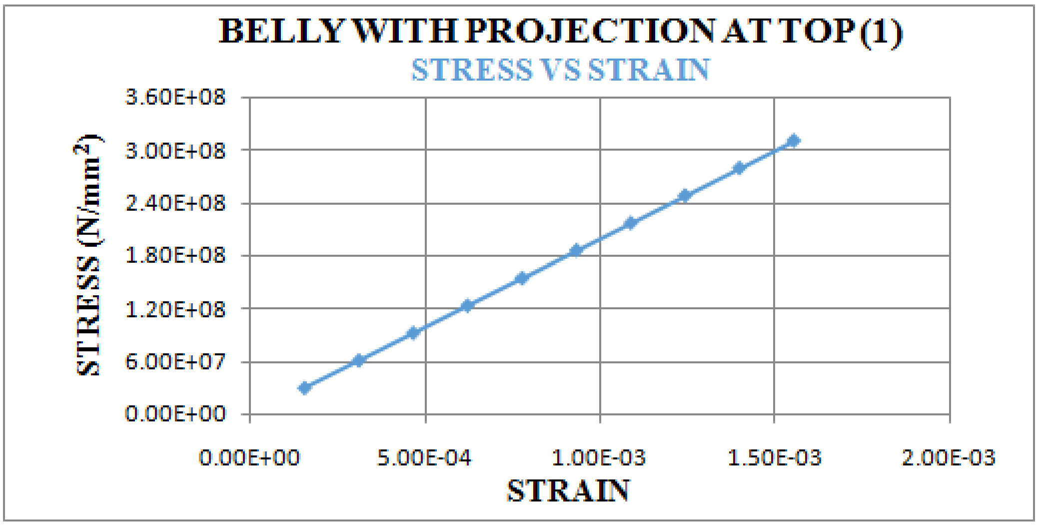

Fig. 9: Stress-Strain Graph for Belly with Projection at Top (model 4)

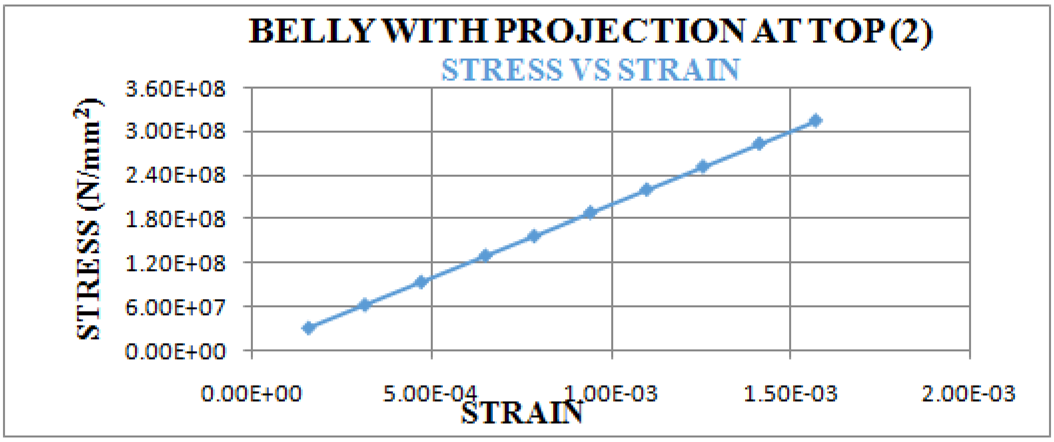

Fig. 10: Stress-Strain Graph for Belly with Projection at Top (model 5)

According to the graphs, the belly at centre shown in Figure 7 and belly at bottom shown in the Figure 8 columns having maximum stress in inner steel core (477.15N/mm^2 and 470.13 N/mm^2) and concrete (52.3 N/mm^2 and 52.6 N/mm^2) at the top of the column, so the column fails at that top because of the small cross section at top compared to belly cross section area. The belly with projection at top column as shown in the Figure 9 has maximum stress in the concrete (40.67 N/mm^2) at the neck portion of the column, it also fails due to maximum stress in concrete[14]. The belly with projection at top column shown in the Figure 10 is the effective column compared to all other columns. The stress is reduced upto 3.88% in concrete and 5.78% in steel, when compared to the normal conventional column.

Load Deformation graph

For linear analysis, the load is directly proportional to the deformation. The deformation is inversely proportional to the strength and stiffness of the column.

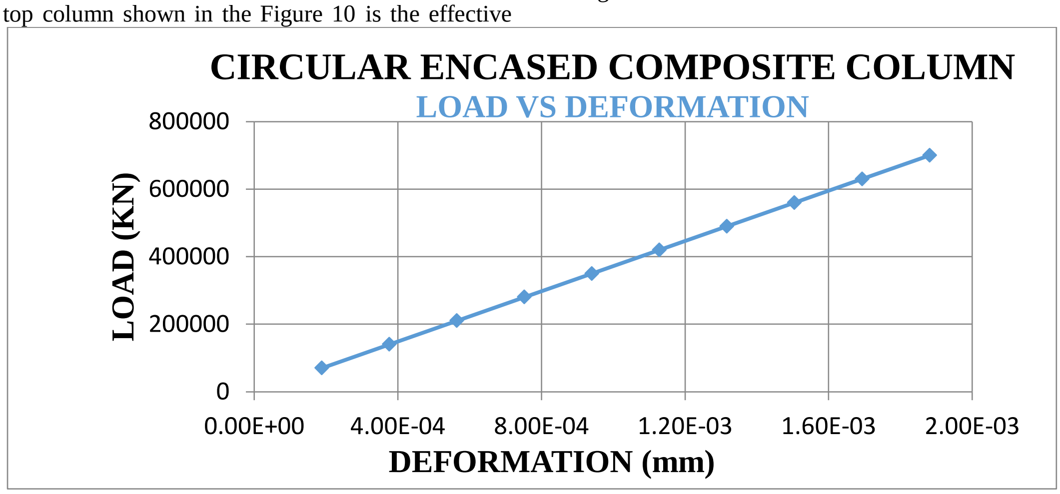

Fig. 11: Load-Deformation Graph for Circular Encased Composite Colum (model 1)

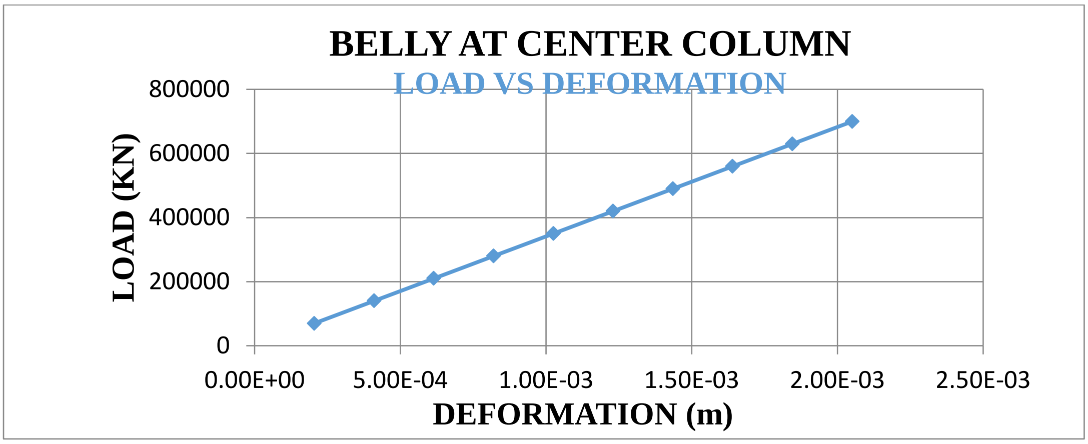

Fig. 12: Load-Deformation Graph for Belly at Center Column (model 2)

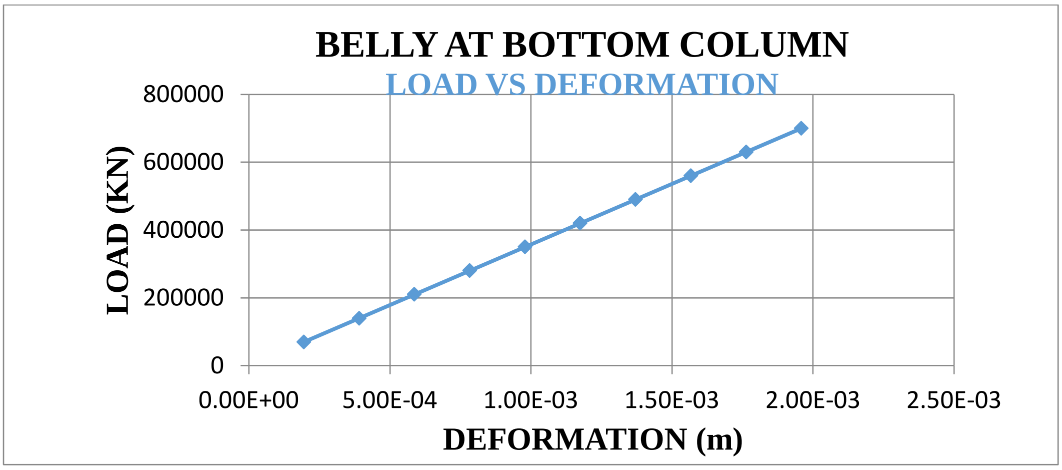

Fig. 13: Load-Deformation Graph for Belly at Bottom Column (model 3)

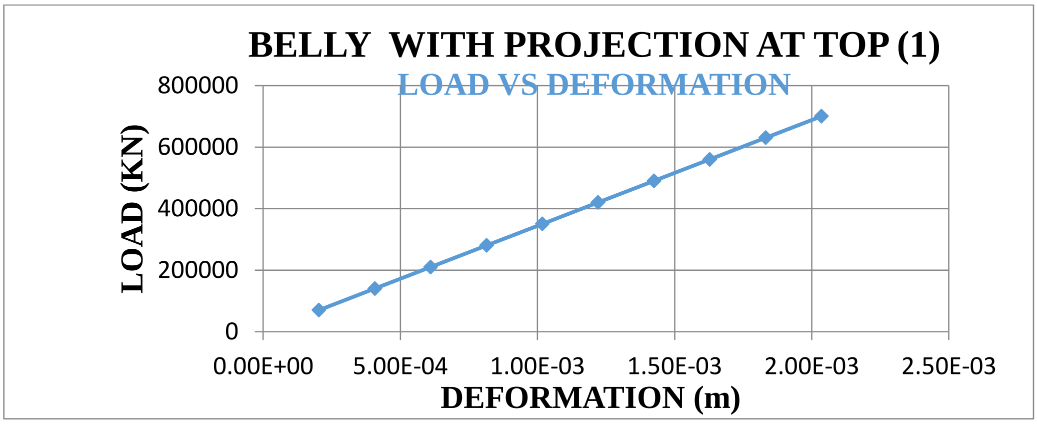

Fig. 14: Load-Deformation Graph for Belly with Projection at Top (model 4)

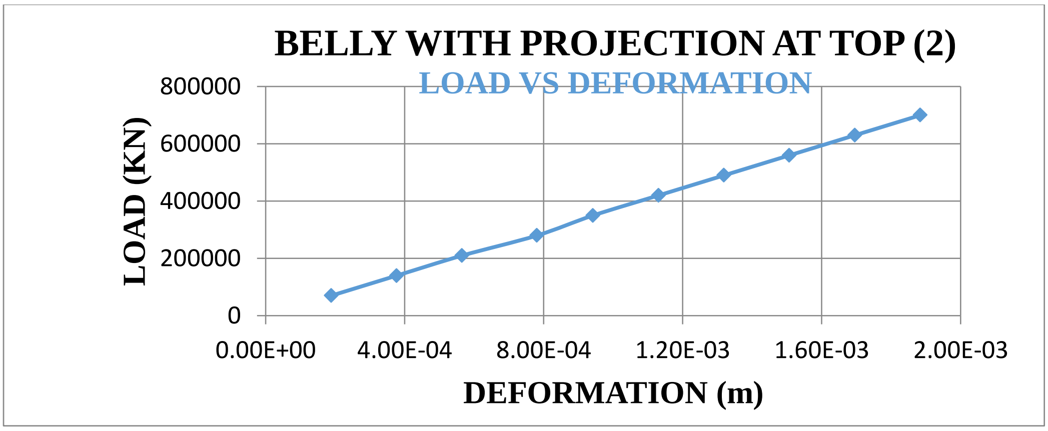

Fig. 15: Load-Deformation Graph for Belly with Projection at Top (model 5)

From the graphs, the belly at centre shown in the Figure 12 and belly at bottom shown in the Figure 13 and belly projection at top shown in the Figure 14 are having maximum deformation, that reduce the strength and stiffness of the column. The belly with projection at top as shown in the Figure 15 and circular encased composite conventional column shown in the Figure 11 are nearly having equal and low deformation, this gives high strength, stability and stiffness[15].

5. Conclusion

The Analytical research on behaviour of Non-Prismatic column subjected to an axial load was done in this paper for five different model having same volume and support condition. The material properties of structural steel, concrete and reinforcement have been incorporated in the models. The composite columns stress, strain, deformation of the columns were predicted using Finite Element model. The Belly with Projection at Top (model 5) has effective stress distribution, when compared to other columns. The stress is in the range of 14.36 to 32.2 in concrete and 164.2 to 314.2 in steel. The range of stress is less, this shows that the concrete and steel caries stress effectively. The Maximum stress in the column is reduced upto 3.88% in concrete and 5.78% in steel compared to the normal conventional column. From all the results, the Belly with projection at top column (model 5) has effective stress distributing capacity than all other columns.

6. Acknowledgments

The authors are thankful to the management of SRM IST and Head of the Department, Department of Civil Engineering for their continuous support and encouragement.

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