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Analysis of Self Supporting Steel Chimney with Different Shape Factors for Wind Forces

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ABSTRACT

Present work investigates the performance of self-supported steel chimney considering different shape factors for wind forces at different heights. The work consists two parts, one is the calculation of static wind forces using IS- 875- Part-III-2015 and implementation of chimney using FEA based software ANSYS, considering calculated wind forces. Flared Chimney of 60m height and unflared chimney of 30m height considering different shape factors (Circular, Square, Equilateral Triangle and Regular hexagon) have analyzed using ANSYS. It has been observed that, for 60m flared chimney, induced equivalent stresses in hexagonal shape in less than the stresses induced in other shapes but total deformation was found lesser for circular as compared to other shapes. Analysis of 30m unflared chimney shows better performance towards hexagonal shape that means lesser values of induced stresses and total deformation as well.

Keywords: ANSYS, Steel Chimney, IS 875 Part-III 2015, Equivalent Stress, Deformation

I. INTRODUCTION

Chimneys or stacks are very important industrial structures for emission of poisonous gases to a higher elevation such that the gases do not contaminate surrounding atmosphere. Every structure is designed for strength, serviceability, permissible deflection & durability. While achieving these characteristics the designer should consider the functions and aesthetics too. It may be possible only when a designer had sufficient knowledge about architectural requirements also. In case of tall structure few failures may occur due to the lateral loads. The lateral loads mainly wind and earthquake loads. This type of structure is designed in such a way that its each member must resist two types of loads one is the vertical loads due to gravity force and other is lateral loads due to wind or earthquake force.

The wind load exerted at any point on a chimney can be considered as the sum of quasistatic and a dynamic load component. The wind load is always dominating the earthquake load or forces. As most of the industrial chimneys are tall structures with circular cross section their structures are slender, light damped structures which are prone to wind excited vibration. Geometrical parameters play an important role in the analysis & design of chimneys and structural behavior under lateral dynamic loading. The primarily responsible factor for stiffness parameters is geometry

II. OBJECTIVE OF STUDY

The objective of this research is behavioral study of different structural shapes of chimney. To design and the effect of wind on different shape factors of self –supported steel chimney referring IS codes (IS 6533- 1989, IS 875-2015, IS 800-2007). To analyze the effect of wind on different shape factors of self-supporting steel chimney by FEM modelling software ANSYS.

III. ANALYSIS OF CHIMNEY

1. Analysis of 60m Chimney with flared base:

Figure 3.1 represents total deformation on 60m circular chimney. Modelling done on the ANSYS software. This figure shows the total deformation for 60 m circular chimney from minimum to maximum.

Figure 3.2 represents equivalent stress on 60m circular chimney. Modelling done on the ANSYS software. This figure shows the total stress for 60 m circular chimney from minimum stress to maximum stress.

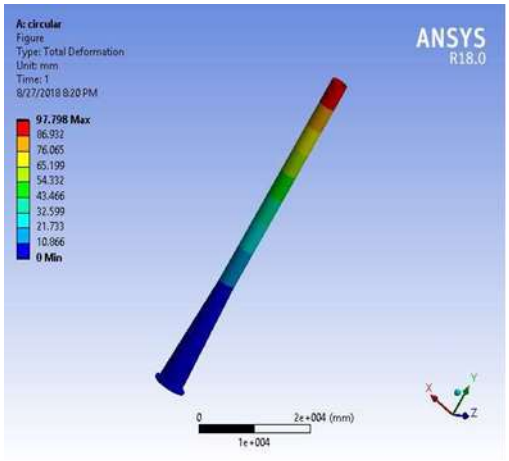

Figure 3.1 Total Deformation on Circular Chimney

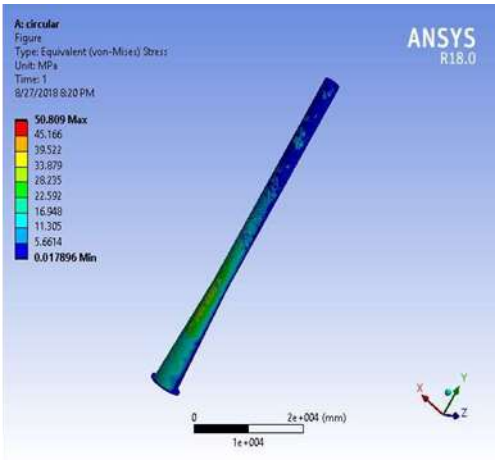

Figure 3.2 Equivalent Stress on Circular Chimney

Figure 3.3 represents total deformation on 60m hexagonal chimney. Modelling done on the ANSYS software. This figure shows the total deformation for 60 m circular chimney from minimum to maximum. Figure 3.4 represents equivalent stress on 60m hexagonal chimney. Modelling done on the ANSYS software. This figure shows the total stress for 60 m circular chimney from minimum stress to maximum stress.

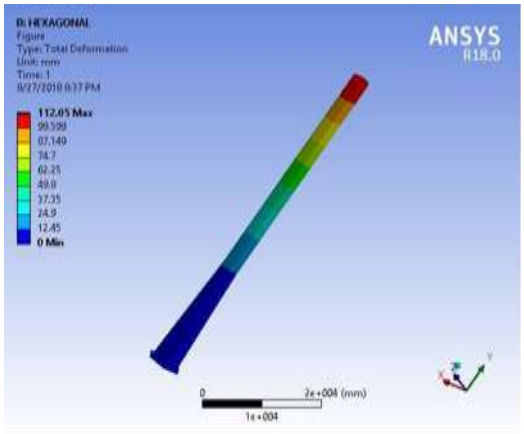

Figure 3.3 Total deformation on Hexagonal Chimney

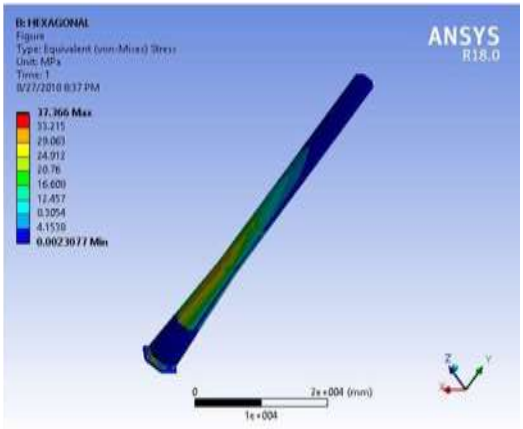

Figure 3.4 Equivalent Stress on Hexagonal Chimney

Figure 3.5 represents total deformation on 60m triangular chimney. Modelling done on the ANSYS software. This figure shows the total deformation for 60 m circular chimney from minimum to maximum. Figure 3.6 represents equivalent stress on 60m triangular chimney. Modelling done on the ANSYS software. This figure shows the total stress for 60 m circular chimney from minimum stress to maximum stress.

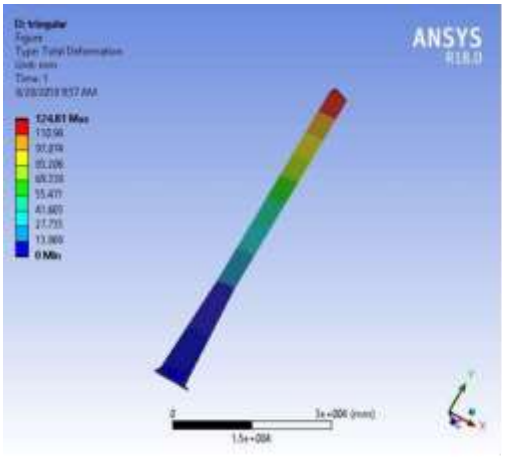

Figure 3.5 Total deformation on Triangular Chimney

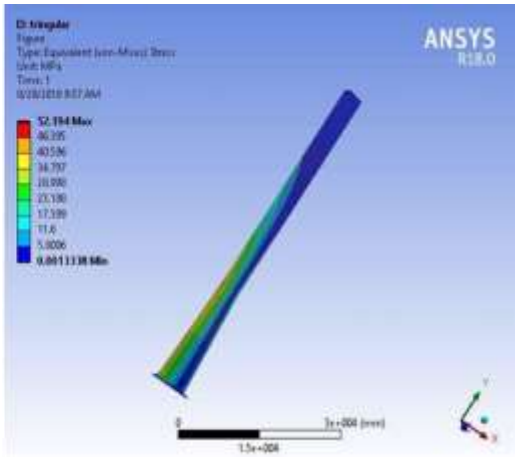

Figure 3.6 Equivalent Stress on Triangular Chimney

Figure 3.7 represents total deformation on 60m square chimney. Modelling done on the ANSYS software. This figure shows the total deformation for 60 m circular chimney from minimum to maximum.

Figure 3.8 represents equivalent stress on 60m square chimney. Modelling done on the ANSYS software. This figure shows the total stress for 60 m circular chimney from minimum stress to maximum stress.

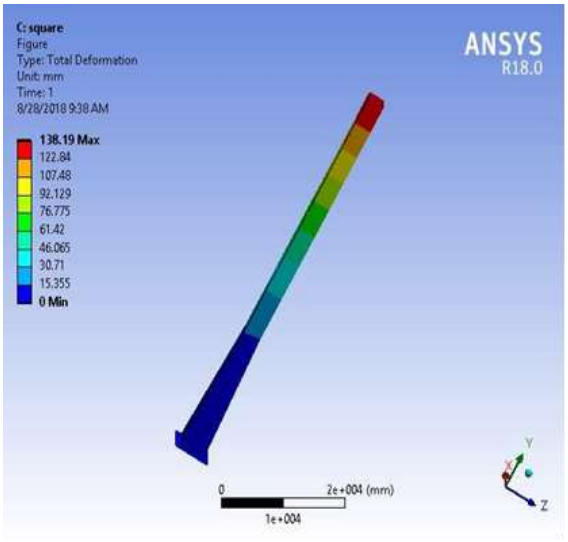

Figure 3.7 Total Deformation on Square Chimney

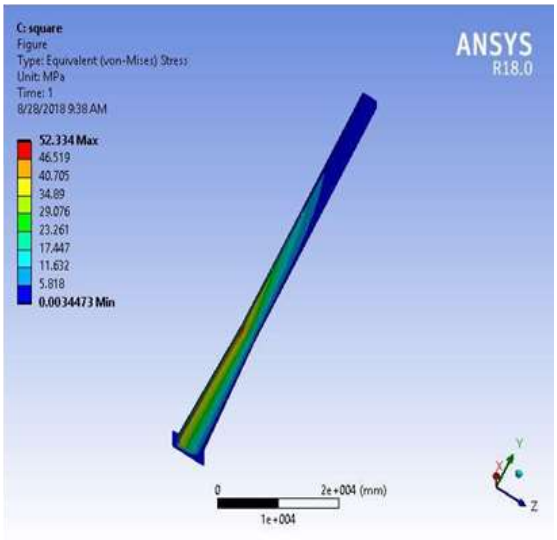

Figure 3.8 Equivalent Stress on Square Chimney

Table 3.1 shows results static loading of minimum & maximum of total deformation & equivalent stress of different shapes of 60 m chimney with flared base.

Table 3.1: Results of 60 m Chimney with Flared Base

Table 3.1: Results of 60 m Chimney with Flared Base			
Shape of Chimney		Minimum	Maximum
Circular	Total Deformation (mm)	0	97.798
	Equivalent Stress (mPa)	0.017896	50.809
Hexagonal	Total Deformation (mm)	0	112.05
	Equivalent Stress (mPa)	0.0023077	37.366
Triangular	Total Deformation (mm)	0	124.81
	Equivalent Stress (mPa)	0.0013338	52.194
Square	Total Deformation (mm)	0	138.19
	Equivalent Stress (mPa)	0.0034473	52.334

2. Analysis of 30 m Chimney without Flared Base

Figure 3.9 represents total deformation on 30m circular chimney. Modelling done on the ANSYS software. This figure shows the total deformation for 30 m circular chimney from minimum to maximum.

Figure 3.10 represents equivalent stress on 30m circular chimney. Modelling done on the ANSYS software. This figure shows the total stress for 30 m circular chimney from minimum stress to maximum stress.

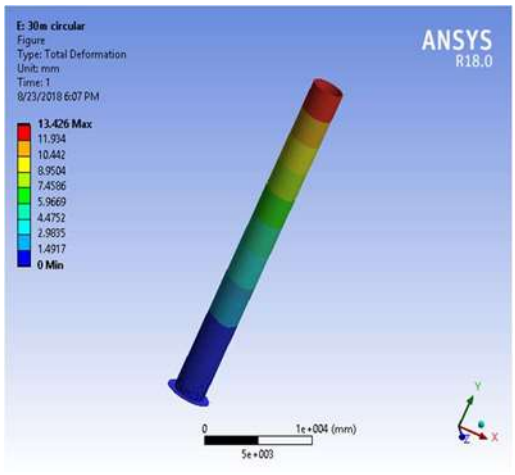

Figure 3.9 Total Deformation on 30m Circular Chimney

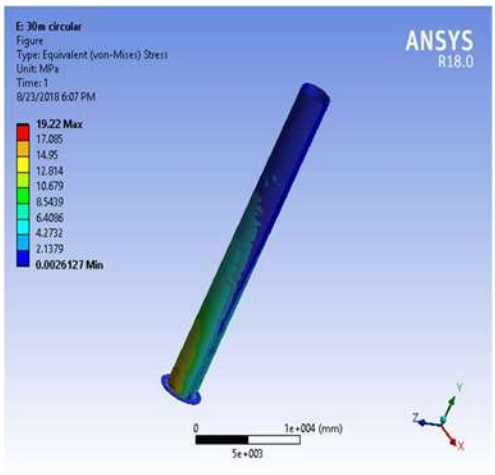

Figure 3.10 Equivalent Stress on 30m Circular Chimney

Figure 3.11 represents total deformation on 30m hexagonal chimney. Modelling done on the ANSYS software. This figure shows the total deformation for 30 m circular chimney from minimum to maximum. Figure 3.12 represents equivalent stress on 30m hexagonal chimney. Modelling done on the ANSYS software. This figure shows the total stress for 30 m circular chimney from minimum stress to maximum stress

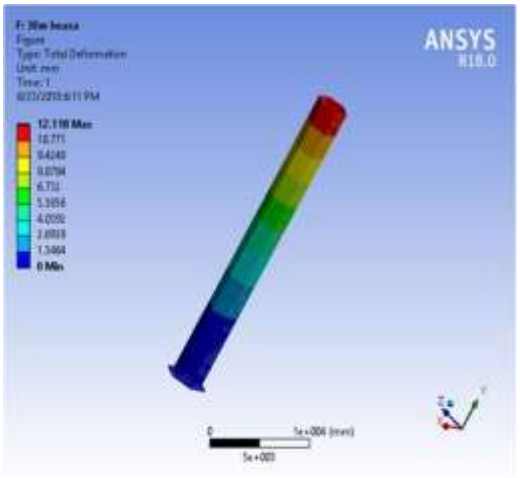

Figure 3.11 Total Deformation on 30m Hexagonal

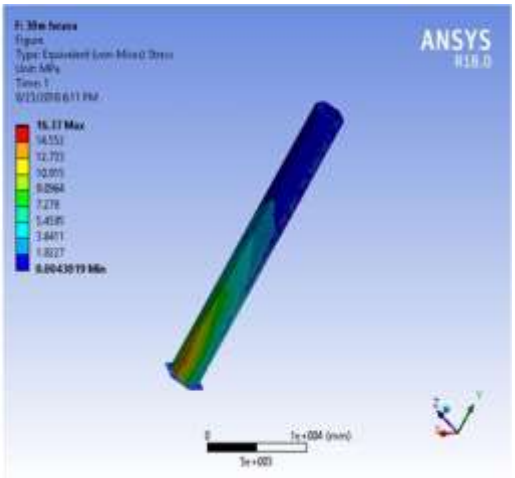

Figure 3.12 Equivalent Stress on 30m Hexagonal Chimney Chimney

Figure 3.13 represents total deformation on 30m triangular chimney. Modelling done on the ANSYS software. This figure shows the total deformation for 30 m circular chimney from minimum to maximum. Figure 3.14 represents equivalent stress on 30m triangular chimney. Modelling done on the ANSYS software. This figure shows the total stress for 30 m circular chimney from minimum stress to maximum stress

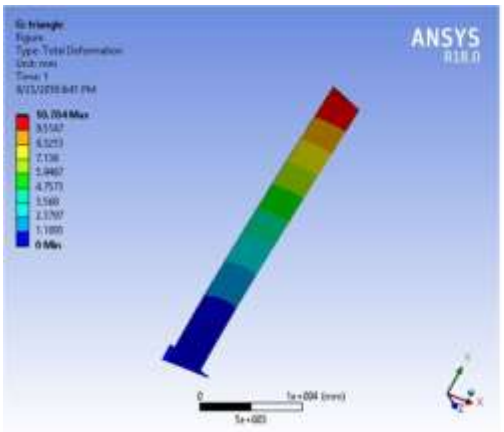

Figure 3.13 Total Deformation on 30m Triangular Chimney

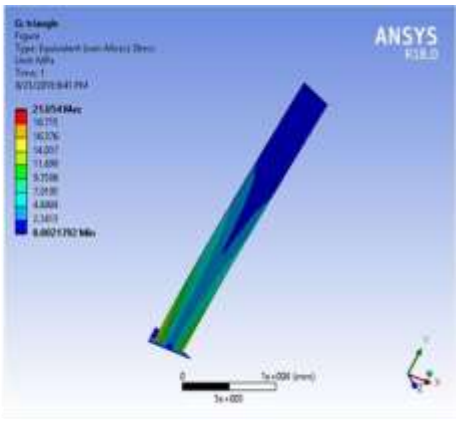

Figure 3.14 Equivalent Stress on 30m Triangular Chimney

Figure 3.15 represents total deformation on 30m square chimney. Modelling done on the ANSYS software. This figure shows the total deformation for 30 m circular chimney from minimum to maximum.

Figure 3.16 represents equivalent stress on 30m square chimney. Modelling done on the ANSYS software. This figure shows the total stress for 30 m circular chimney from minimum stress to maximum stress.

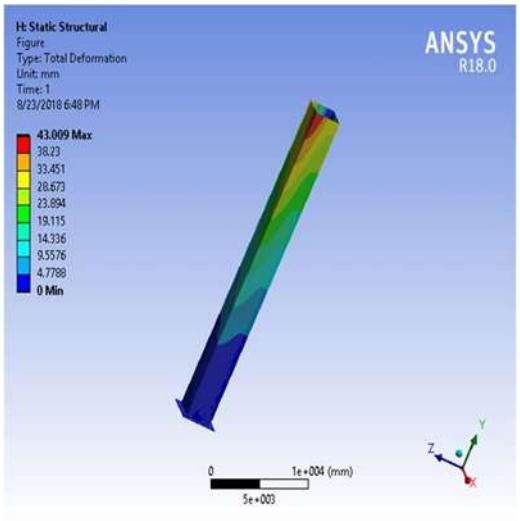

Figure 3.15 Total Deformation on 30m Square Chimney

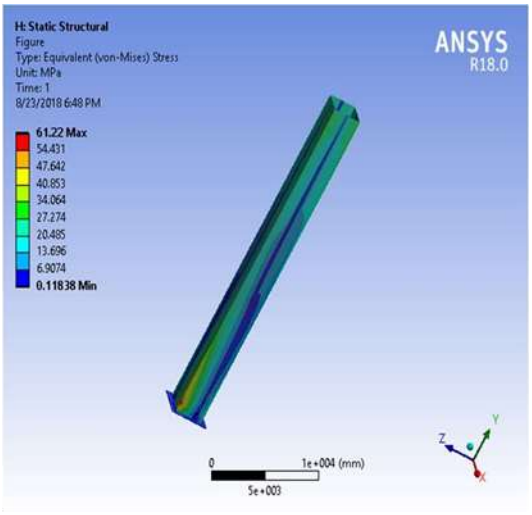

Figure 3.16 Equivalent Stress on 30m Square Chimney

Table 3.2 shows results of minimum & maximum of total deformation & equivalent stress of different shapes of 30 m chimney without flared base.

Table 3.2: Results of 30 m Chimney without Flared Base

Table 3.2: Results of 30 m Chimney without Flared Base			
Shape of Chimney		Minimum	Maximum
Circular	Total Deformation (mm)	0	124.81
	Equivalent Stress (mPa)	0.0013338	52.194
Hexagonal	Total Deformation (mm)	0	12.118
	Equivalent Stress (mPa)	0.0043019	16.37
Triangular	Total Deformation (mm)	0	10.704
	Equivalent Stress (mPa)	0.0021792	21.054
Square	Total Deformation (mm)	0	43.009
	Equivalent Stress (mPa)	0.11838	61.22

IV. RESULTS

The wind forces for chimneys are calculated according to ARE Code (IS 875 (part 3): 2015). Analysis of chimney with different shape factors is carried out according to the IS Code (IS 6533:1989). The shapes which are taken for analysis are as follows-

i. Circular

ii. Hexagonal

iii. Triangular

iv. Square

- **60 m Chimney with Flared Base**

Table 4.1 Results of 60 m with Flared Base chimney				
Shapes	**Total Deformation (mm)**		**Equivalent Stress (MPa)**	
	Minimum	**Maximum**	**Minimum**	**Maximum**
Circular Chimney	0	97.798	0.017896	50.809
Hexagonal Chimney	0	112.05	0.0023077	37.366
Triangular Chimney	0	124.81	0.0013338	52.194
Square Chimney	0	138.19	0.0034473	52.334

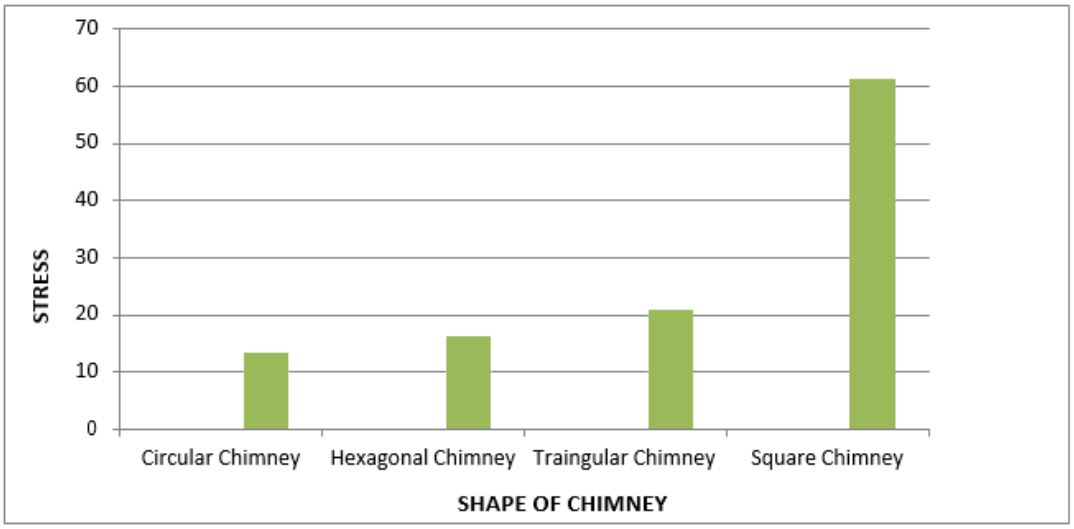

Figure 4.1 Shape of Chimney vs Stress Graph of 60 m Chimney with Flared Base

Figure 4.1 shows the graph plot between different shape of chimney and stress. This graph shows the maximum stress occurs when shape of chimney is square and minimum stress occurs when shape of chimney is hexagonal for 60 m with flared base. The stress was found permissible as per IS 800-1984.

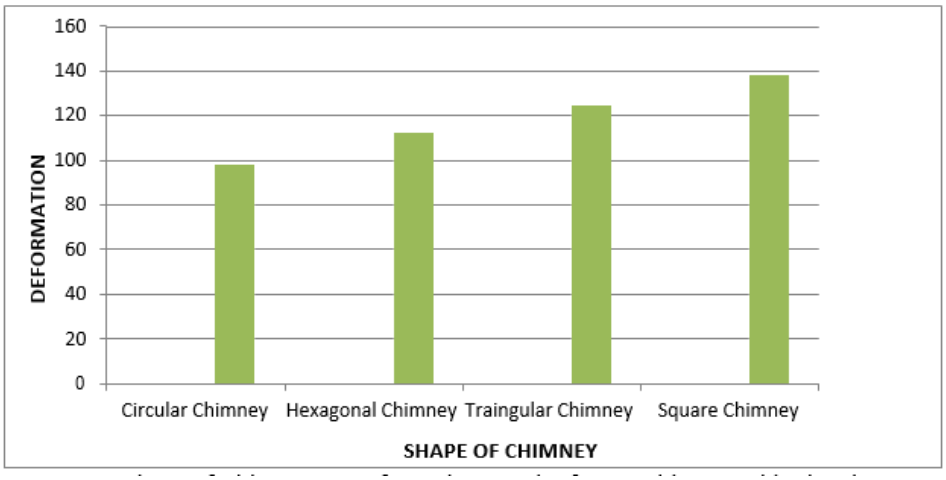

Figure 4.2 Shape of Chimney vs Deformation Graph of 60 m Chimney with Flared Base

Figure 4.2 shows the graph plot between different shape of chimney and deformation. This graph shows the maximum deformation occurs when shape of chimney is square and minimum deformation occurs when shape of chimney is hexagonal for 60 m with flared base. The deformation was found permissible as per IS 800-1984.

➢ **30 m Chimney without Flared Base**

Table 4.2 Results of 30 m without Flared Base chimney

Shapes	Total Deformation (mm)		Equivalent Stress (MPa)	
	Minimum	Maximum	Minimum	Maximum
Circular Chimney	0	13.426	0.0026127	19.22
Hexagonal Chimney	0	12.118	0.0043019	16.37
Triangular Chimney	0	10.704	0.0021792	21.054
Square Chimney	0	43.009	0.11838	61.22

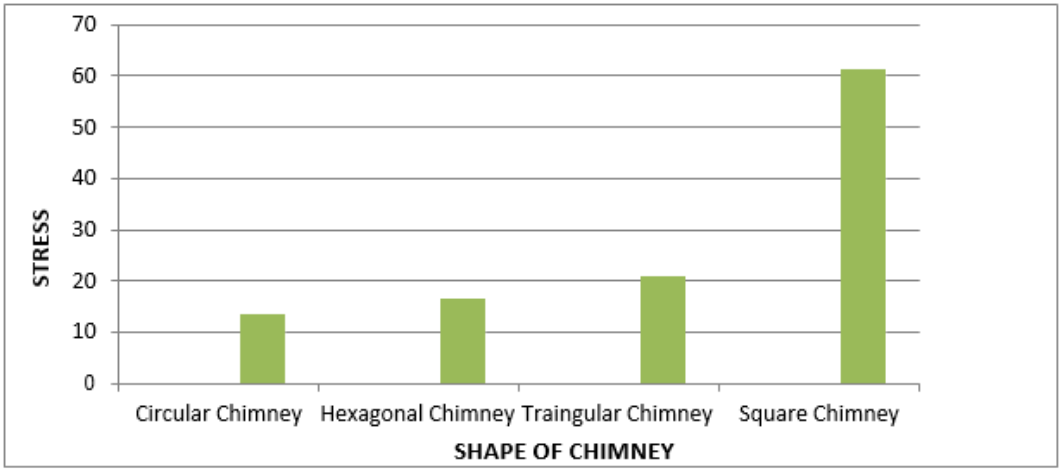

Figure 4.3 Shape of Chimney vs Stress of 30 m without Flared Base chimney

Figure 4.3 shows the graph plot between different shape of chimney and stress. This graph shows the maximum stress occurs when shape of chimney is square and minimum deformation occurs when shape of chimney is hexagonal for 30 m without flared base. The stress was found permissible as per IS 800-1984.

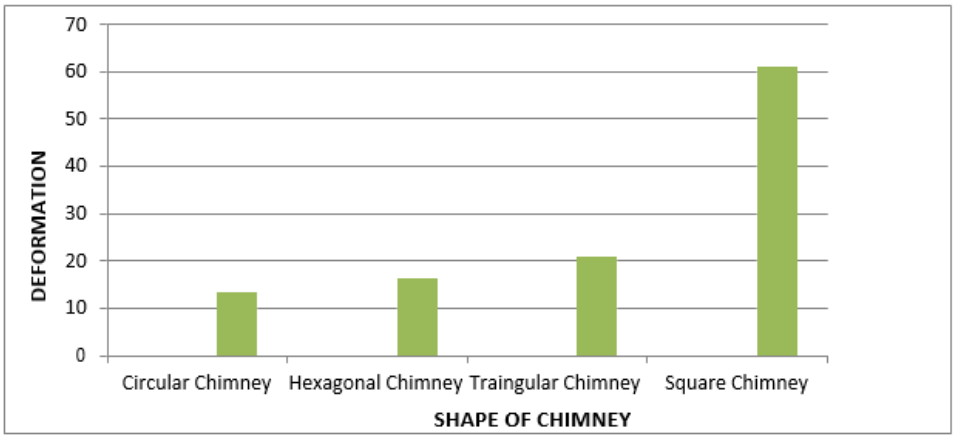

Figure 4.4 Shape of Chimney vs Deformation Graph of 30 m without Flared Base chimney

Figure 4.4 shows the graph plot between different shape of chimney and deformation. This graph shows the maximum deformation occurs when shape of chimney is square and minimum deformation occurs when shape of chimney is hexagonal for 30 m without flared base. The deformation was found permissible as per IS 800-1984.

V. CONCLUSION

Analysis of self-supported steel chimney is carried out for both flared base and without flared base chimney. Modelling of steel chimneys with flared base and without flared base are done and same is taken for analysis through software. When we compare circular chimney with hexagonal chimney on the basis of stress induced in model, we may prefer hexagonal chimney because the maximum stress induced in hexagonal chimney is less than circular chimney. (i.e., for circular = 50.809 mPa and for hexagonal = 37.366mpa) but the induced stress was found permissible as per IS 800:1984. When we compare circular chimney with hexagonal chimney on the basis of total deformation induced the hexagonal chimney has slightly more deformation than the circular chimney. (i.e., for circular = 97.798 mm and for hexagonal = 112.05 mm) which was lesser than the other shapes but the induced deformation was found permissible as per IS 6533 (Part 2) :1987. When we compare circular chimney with hexagonal on the basis of stress induced in model, we may prefer hexagonal chimney because the stress induced in hexagonal chimney is less than circular chimney. (i.e., for circular = 19.22mpa and for hexagonal = 16.37 mPa) but the induced stress was found permissible as per IS 800:1984. When we compare circular chimney with triangular chimney on the basis of total deformation the triangular chimney has lesser deformation than the circular chimney, we may prefer triangular chimney. (i.e., for circular = 13.426 mm and for triangular = 10.704 mm) but the induced deformation was found permissible as per IS 6533 (Part 2) :1987.

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