ANALYSIS OF SELF SUPPORTED STEEL CHIMNEY

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ABSTRACT

From the last few decades the construction of tall stacks increases due to increase in air pollution. Here in this paper, the "Self supporting steel chimney" of height 60m was considered and analysed for the prevailing wind forces and seismic forces considering chimney in four different earthquake zones and bending moments, shear forces were calculated using IS 6533 (part1&2):1989 and were also plotted. Also the chimney was modelled using STAAD PRO Vi8 software. And in the next part, is to justify the code criteria with regard to basic dimensions of industrial steel chimney. A total of 66 numbers self supporting steel flared unlined chimneys with different top-to-base diameter ratio and height-to-base diameter ratio were considered for this study. The thickness of the chimney was kept constant for all the cases. Maximum bending moments and stresses for all the chimneys were calculated for wind load using MS- Excel sheets and were plotted as a function of top-to-base diameter ratio and height-to-base diameter ratio.

Keyword :, *Self-supporting steel chimney, Seismic loads, Geometrical limitations, Bending moments, Stresses.*

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1. INTRODUCTION

A. About Steel Chimneys

Chimneys are used to escape and disperse flue burned gases coming from furnaces of boilers to such a height that gas does not contaminate atmosphere. Different materials such as Steel, Concrete and bricks are used for the construction of chimneys [1].
steel chimneys are ideally suited for process work where a short heat-up period and low thermal capacity are required. When the gases in a steel chimney are heated, then the gases expand. The hot gases occupy larger volume than before. The weight of gases per cubic meter becomes less. As a result of this, the unit pressure at the bottom of chimney due to weight of hot gases also becomes less than the unit pressure due to weight of cold air outside of chimney. The difference between two pressures results in the flow of the burnt gases up the chimney [2].

B. Literature Review

Rekadi Rama Suvarna Varma1, VLD Prasad Reddy (2016) Here in this paper, an attempt has been made to analyses the industrial steel chimney for the established wind forces and seismic force considering self-supported and guyed steel chimney at various heights 54m,72m&90m at various wind speeds of 33m/s,44m/s&50m/s respectively. Thus maximum lateral displacements and maximum stresses are compared by using software package STAAD.Pro.V8i for the above considered heights and wind speeds.
Harshal Deshpande, Roshni John (2015) this study deals with the interrelation of geometrical configuration and obtained dynamic response of short self-supported steel stacks under dynamic wind loading and seismic loadings. 42 steel stack configurations for 7 different heights of stacks are selected and analysed as per IS 6533(part 2) and IS 1893(part 4). A relation between dynamic response and governing geometry of the stack is found out. Use of excel sheets and STAAD PRO software is done for analysis.

C. Objectives

1) To analyse the chimney in four earthquake zones as per IS: 1893 (part 5) 2004 and wind zones as per IS 875 (part 3): 1987 manually and using STAAD PRO software also.

2) To study and compare the maximum shear forces and maximum bending moments of the chimney at different zones. 3) Assess the geometry limitations imposed by IS 6533:1989 (part 1&2) for designing self supporting steel chimney.

D. Scope

Self-supporting flared steel chimney is considered for the present study.

Chimneys are considered to be fixed at their support. Soil flexibility is not considered in the present study

Chimney considered here is of single-flue type

Only wind and seismic loads are taken into consideration for design of the chimney.

E. Analysis of Steel Chimney

1) Loads Acting on Steel Chimney:

Self-weight of chimney
Weight of lining
Wind loads
Seismic loads

2) Material Properties:
Density of steel – 78.5 KN/m3
Yield stress of steel – 250 N/mm2
Poisson's ratio – 0.

Strain in elastic range – 0.2/0
Modulus of Elasticity (E) of steel – 2x108 KN/m2

3) Load Combinations:

Dead load+ Wind load

Dead load + Earthquake load

Dead load+ Load due to lining+ Imposed load on service platforms + Wind load

Dead load++ Load due to lining+ Imposed load on service platforms+ Earthquake load

F. Design Data

Table 1 Design Parameters

Zone	Place	Basic Wind Speed-m/s	Zone Factor
II	Visakhapatnam	50	0.10
III	Varanasi	47	0.16
IV	Roorkee	39	0.24
V	Kohima	44	0.36

Table 2 Basic Dimensions

Height considered	60m
Height of flare= (⅓) 60	20m
Terrain type considered	Flat
Terrain category	2
Thickness of brick lining	100mm

Top diameter of chimney	3m
Bottom diameter of chimney	4.8
Corrosion allowances	3mm

For analysis purpose, chimney is behaved like a cantilever beam with flexural deformations. Analysis is carried out by following one of the methods according to the IS codal provision [6],

Response-spectrum method (first mode)

Modal-analysis technique (using response spectrum)

Time-history response analysis.

For chimneys which are less than 90m high called as short chimney, response spectrum method is used.

By Using IS 6533 (part1&2):1989, self supported steel chimney of 60m was analysed under different wind loads and in different seismic zones. For this analysis, 60m self-supported steel chimney is divided into sections each of 10m and the wind analysis is carried out as per IS 875(part-3):1987 and seismic analysis is carried out as per IS 1893(part-4):2005. The results obtained from this analysis were plotted as shown in below graphs.

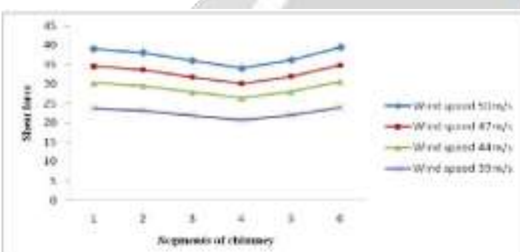


Fig. 1 Shear force variation along the height of

Chimney due to wind

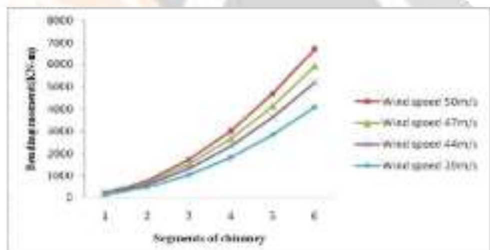


Fig. 2 Bending moment variation along the height of

Chimney due to wind

Fig. 1 & 2 shows the variation of shear force and bending moment due to different wind speeds along the height of 60m chimney. The value of shear force on the segments of the chimney from top to bottom decreases till the 4th segment and then increases due to flared portion and the value of bending moment increases with increase in height of segments and the maximum bending moment occurs at the base of the chimney.

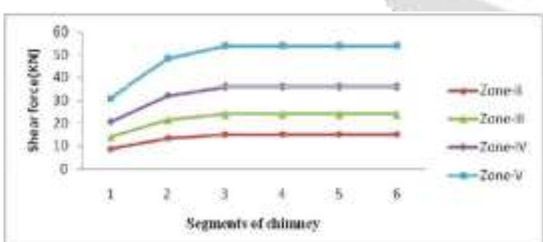


Fig.3 Shear force variation along the height of

Chimney due to seismic

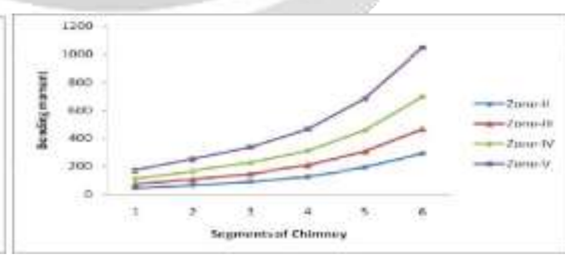
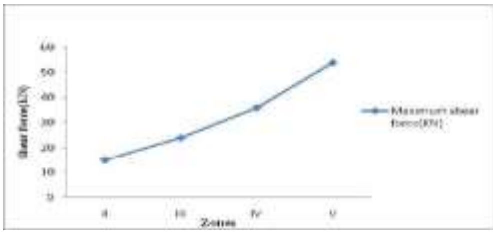


Fig.4 Bending moment variation along the height of

Chimney due to seismic

Fig.3 & 4 shows the variation of shear force and bending moment due to different seismic zones along the height of 60m chimney. The value of shear force on the segments of the chimney from top to bottom increases till the 3rd segment and then becomes constant till the full height of chimney and the value of bending moment increases with increase in height of segments and also with increase in seismic zones.



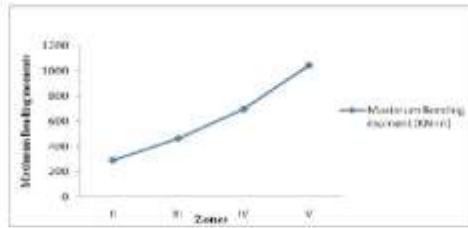


Fig.5 Maximum Shear forces for a chimney of height 60m in all zones

Fig.6 Maximum Bending moments for a chimney of height 60m in all zones

Fig.5 & 6 shows the maximum shear force and maximum bending moment for a chimney in all zones. The increment in values of shear force and bending moment for all the zones are almost similar.

3. EFFECT OF GEOMETRY ON STEEL CHIMNEY

A. Introduction

Geometry of a self-supporting steel chimney plays an important role in its structural behaviour under different loading. However, basic dimensions of industrial self supporting steel chimney, such as height, diameter at exit, etc., are generally derived from the associated environmental conditions [5]. To ensure a desired failure mode design code (IS-6533: 1989 Part 2) imposes several

This part of analysis is to justify the code criteria with regard to basic dimensions of industrial steel chimney. A total of 66 numbers self supporting steel flared unlined chimneys with different top-to-base diameter ratio and height-to-base diameter ratio were considered for this study. The thickness of the chimney was kept constant for all the cases. Maximum bending moment and stress for all the chimneys were calculated for wind load as per the procedure given in IS 6533: 1989 (Part 2) using MS- Excel sheets and were plotted as a function of top-to-base diameter ratio and height-to-base diameter ratio.

B. Design Parameters

Type of stack = circular self-supporting industrial steel stacks

Variation in top diameter for each stack for fixed value of base diameter will be in the following ratios (ratio Dt/Db): 0.5, 0.6, 0.7, 0.8, 0.9, and 1
Height to base diameter ratios (h/Db): 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20.
Heights of stacks : 40m, 44m, 48m, 52m, 56m, 60m, 64m, 68m, 72m, 76m, 80m.

Number of chimneys: 66

Type: unlined single flume.

Flare height: one third of total height.

Thickness of chimney shell = 16mm (constant for all stacks)

Base: rigid

Location: Visakhapatnam

Wind speed: 50 m/s

Material: Mild steel

C. Sample Calculation using Ms-Excel Sheet

The following table's presents the calculation of bending moments and stresses for 40m chimney model due to wind and here the maximum stress do not exceed permissible stress which is represented by σc. Similarly 66 chimney models are analysed by varying top-to-base diameter ratio and height-to-base diameter ratio using excel sheets.

Table 3

Stress calculation for 40m chimney model

Db=4m, h=40m, Dt=2m, h/Db = 10, Dt/Db = 0.5, h flare= 13.33m

Dt/Db= 0.5	D/t= 250						
H	M	fs	fl	Fw	fc,max	h/D	σ_c
40	2077.185	3.140	5.0	10.331	18.471	10	99
44	2554.937	3.454	5.5	12.707	21.661	11	99
48	3083.420	3.768	6.0	15.336	25.104	12	99
52	3314.074	4.082	6.5	16.483	27.065	13	99
56	3903.102	4.396	7.0	19.412	30.808	14	99
60	4538.817	4.710	7.5	22.574	34.784	15	99
64	5199.471	5.024	8.0	25.860	38.884	16	99
68	5933.950	5.338	8.5	29.513	43.351	17	99
72	6708.820	5.652	9.0	33.367	48.019	18	99
76	7533.944	5.966	9.5	37.471	52.937	19	99
80	8435.790	6.280	10.0	41.956	58.236	20	99

Table 4

Calculation of design shear and moments for 40m chimney

height of section	segment	dia at bottom	dia at top	avg. dia of seg.	k2	Pz (kN/m^2)	Pz (KN)	height from base	Moment (KN-m)
10	10	4	2.46	3.23	0.980	1.441	32.572	5	162.860
13	3	2.46	2	2.23	1.004	1.512	7.081	11.5	81.429
20	7	2	2	2.00	1.050	1.654	16.207	16.5	267.411
30	10	2	2	2.00	1.100	1.815	25.410	25	635.250
					1.12				

40	10	2	2	2.00	5	1.898	26.578	35	930.234

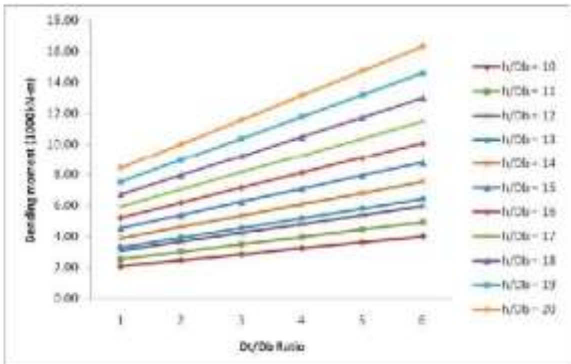


Fig:7

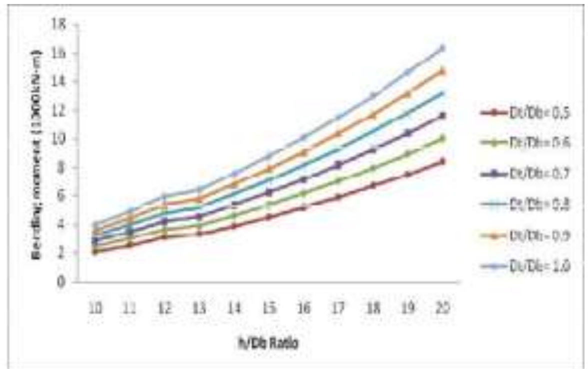


fig: 8

Fig.7 presents the bending moment at the base of the chimney for static wind load as a function of top-to-base diameter ratio for different height-to-base diameter ratio. This figure shows that the base moment increases with the increase of top-to-base diameter ratio almost proportionally.

Fig.8 presents the base moment as a function of height-to-base diameter ratio for different top-to-base diameter ratio. This figure also shows similar results, i.e., that base moment increases with the increase of height-to-base diameter ratio. However, the rate of increase in base moment is slightly less for lower value of height-to-base diameter ratio. There is a sudden increase of the gradient of the base moment curve for height-to-base diameter ratio = 13.

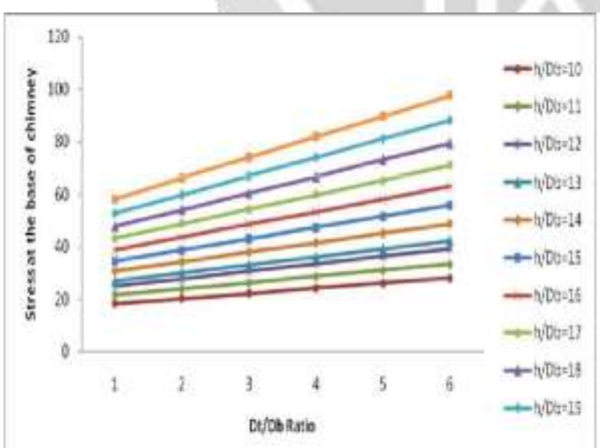


Fig.9 Variation of bending stress as a function of top-to-base diameter ratio

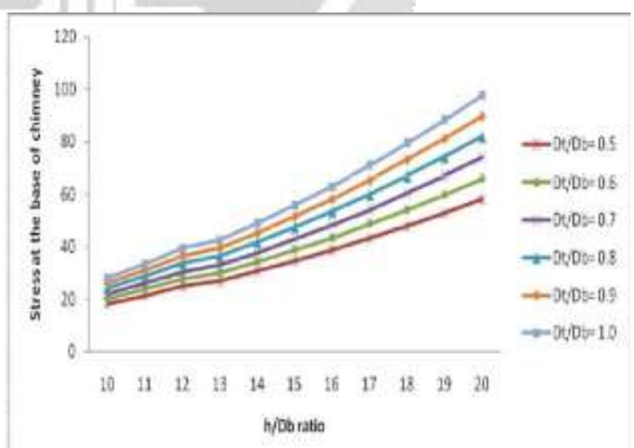


Fig.10 Variation of bending stress as a function of height-to-base diameter

CONCLUSIONS

Maximum bending stresses in the chimney also calculated and presented in above figures for different height-to-base diameter ratio and top-to-base diameter ratio. The variation in bending stress is similar to the variation in maximum bending moments.

From the first part of analysis it is found that,

A. There is more impact of wind load on the chimney when compared to seismic load.

B. The value of bending moment increases with increase in height of segments from bottom to top and also with increase in seismic zones.

C. The value of base shear increases with the zone factor increases from zone 2 to zone 5 and percentage increase of base shear from zone 2 to zone 5 is the 72%.

D. The stress distribution is uni-axial stress and there are no stress concentration locations. From the second part of analysis it is found that,

E. he maximum moment and the maximum bending stress due to static wind load in a self supporting steel chimney are continuous function of the geometry (top-to-base diameter ratio and height-to-base diameter ratio).

F. This study does not support the IS 6533 (Part-2): 1989 criteria for minimum top diameter to the height ratio of the chimney and minimum base diameter to the top diameter of the chimney.

6. REFERENCES

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