PARAMETRIC STUDY OF INDUSTRIAL STEEL CHIMNEYS

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Abstract— Industrial chimneys serve industries over the years to dissipate the hot flue gases in to atmosphere to reduce air pollution and to maintain air quality standards imposed on industries. Impact of pollutants on surrounding environment can be reduced by dispersing pollutants at higher altitudes. Usually, in case of chimneys draft, air quality standards, stiffness requirements etc governs the height. This paper considers different height to base diameters to study the load effects on industrial chimneys for wind and earthquake forces. Height of industrial chimneys chosen for analysis are 40m, 50m, 60m and height to base diameter ratios of 11, 13, 15, 17, 19 & 21 corresponding to each height considered. Top diameter to Base diameter ratios preferred is 0.6, 0.8 and 1. Based on these parameters, a total of 54 chimneys were analyzed for wind speeds of 39m/s, 47m/s and 55 m/s to evaluate wind response and stiffness criteria based on IS 6533:1989. All the chimneys considered were evaluated for seismic effects of zones III, IV and V based on IS 1893(Part 4):2005. Chimneys are modeled using linear element in STAAD PRO fixed at base for calculation of mode shapes and frequencies. Wind and Earthquake analysis was carried out to evaluate shear force, bending moment and stiffness criteria of industrial chimneys. Results are presented for top diameter to base diameter ratio, height to base diameter ratio, different wind speeds and earthquake zones considered. Conclusions are made based on the discussions of obtained results.

Key Words— Steel chimney, dynamic analysis, seismic, wind and STAAD Pro

I. INTRODUCTION

Industrial chimneys serve industries over the years to dissipate the hot flue gases in to atmosphere to reduce air pollution and to maintain air quality standards imposed on industries. Impact of pollutants on surrounding environment can be reduced by dispersing pollutants at higher altitudes. Usually, in case of chimneys draft, air quality standards, stiffness requirements etc governs the height. This paper considers different height to base diameters to study the load effects on industrial chimneys for wind and earthquake forces. Height of industrial chimneys chosen for analysis are 40m, 50m, 60m and height to base diameter ratios of 11, 13, 15, 17, 19 & 21 corresponding to each height considered. Top diameter to Base diameter ratios preferred is 0.6, 0.8 and 1. Based on these parameters, a total of 54 chimneys were analyzed for wind speeds of 39m/s, 47m/s and 55 m/s to evaluate wind response and stiffness criteria based on IS 6533:1989. All the chimneys considered were evaluated for seismic effects of zones III, IV and V based on IS 1893(Part 4):2005. Chimneys are modeled using linear element in STAAD PRO fixed at base for calculation of mode shapes and frequencies. Wind and Earthquake analysis was carried out to evaluate shear force, bending moment and stiffness criteria of industrial chimneys. Results are presented for top diameter to base diameter ratio, height to base diameter ratio, different wind speeds and earthquake zones considered. Conclusions are made based on the discussions of obtained results

II. STATIC ANALYSIS

One third portion from the base is considered as flared portion of the chimney and reaming portion is of circular cross section up to the top diameter. Chimney was divided in to eleven segments. Ten segments are of equal height and one segment is flared at base. Chimney was analyzed for combined effect of self-weight and static wind effects. Necessary checks have been made in the analysis.

III. DYNAMIC ANALYSIS

The dynamic analysis is done as per the codes IS 6533(part2): 1989 for wind loads and IS 1893(part 4):2005 for earthquake loads. The mode shapes of the chimneys for the wind and earthquake analysis were obtained from STAAD Pro using linear element model. The wind and Earthquake analysis will be discussed as follows:

WIND ANALYSIS

Whenever the time period exceeds 0.25 seconds of self-supported steel chimneys the dynamic effect has to be considered for analysis [2]. The frequency of the chimney will be calculated from

$$\frac{1}{2\pi}\left[\frac{g\sum(mx)}{\sum(mx^2)}\right]^{\frac{1}{2}}$$

Inertial force has to calculated from

$$P_{dyn,ij} = M_j * \xi_i * \eta_{ij} * \nu$$

Resonance check should be made by calculation critical wind speed V_{cr}.

$$V_{cr} = 5\ D_t \times f$$

The combined effects due to static and dynamic wind can be calculated from

$$F = \text{sqrt}(F^2_{res,z} + (F_{st,z} + F_{dyn,z})^2$$
$$M = \text{sqrt}(M^2_{res,z} + (M_{st,z} + M_{dyn,z})^2$$
$$\Upsilon = \text{sqrt}\ (\Upsilon^2_{res,z} + (\Upsilon_{st,z} + \Upsilon_{dyn,z})^2$$

EARTHQUAKE ANALYSIS

By using seismic coefficient method, earthquake analysis is carried out[3].

The fundamental time period for chimneys,

$$T = C_T \sqrt{\frac{W_t\, h}{E_s\, A\, g}}$$

Horizontal seismic coefficient,

$$A_h = \frac{Z}{2} * \frac{S_a}{g} * \frac{I}{R}$$

Design shear force,

$$V = C_v\, A_h W_t D_v$$

Design bending moment,

$$M = A_h W_t \bar{h}\, D_m$$

IV. STAAD MODEL

Model was generated in STAAD Pro, using 4 noded plate element and linear element model. These two models were compared under same load and found that the deflection is same. Hence linear element model was chosen as it is easy to generate model and obtaining mode-shapes will be simple. Mode shapes and frequencies are obtained by considering a factor of 1.2 to take in to account of accessories of chimney to its self-weight.

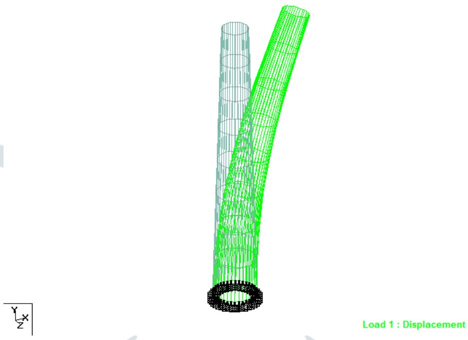
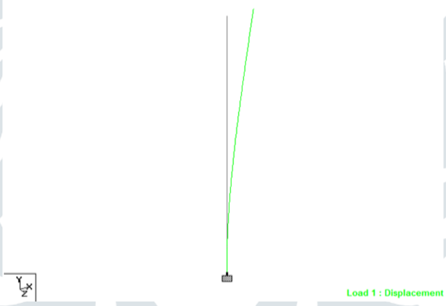


Figure (a) STAAD model of chimney using 4 noded plate elements

The figure (a) shows a STAAD model of chimney generated using 4 node plate elements, having 40m height and fixed supports assigned to base elements and the topmost elements are left free to ensure cantilever action.



Figure(b) STAAD model of chimney using line/beam elements

The figure (b) shows a STAAD model of chimney using Line/Beam elements, having the same dimension as in fig(b). Cross sections were assigned using tapered tube section. Hence, for modal analysis linear element model was adopted for easier evaluation and interpretation of results.

V. RESULTS:

STATIC ANALYSIS RESULTS:

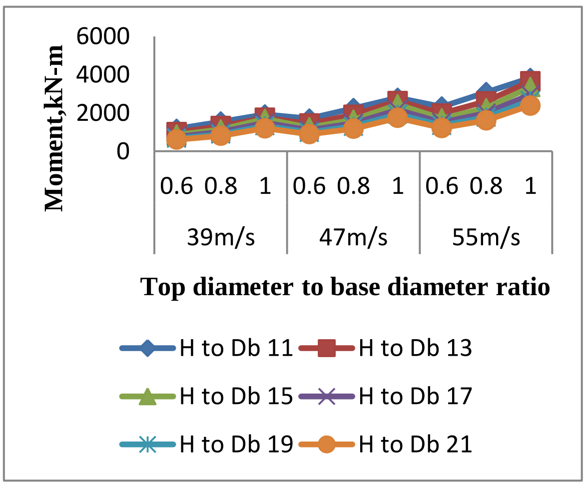


Fig. 1 Moment for 40 m chimney

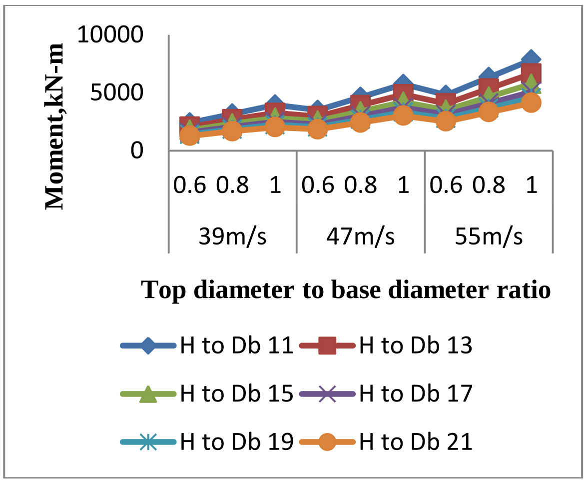


Fig. 2 Moment for 50 m chimney

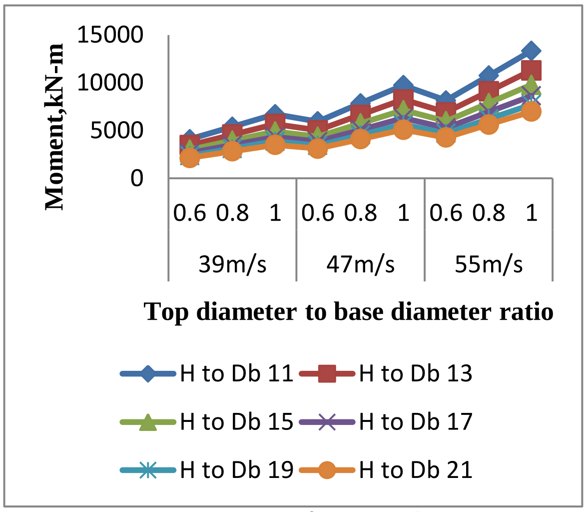


Fig. 3 Moment for 60 m chimney

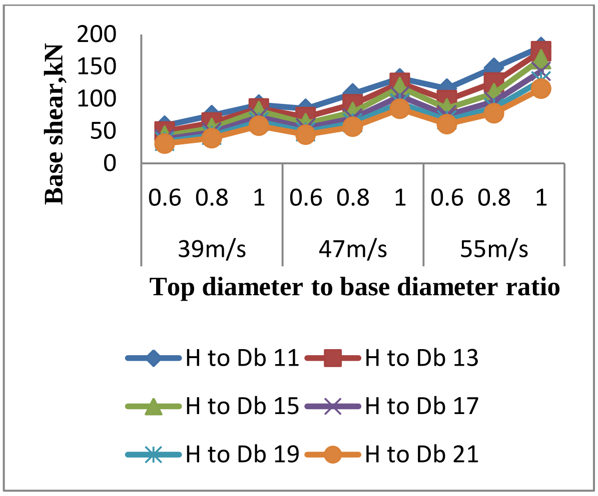


Fig. 4 Base shear for 40 m chimney

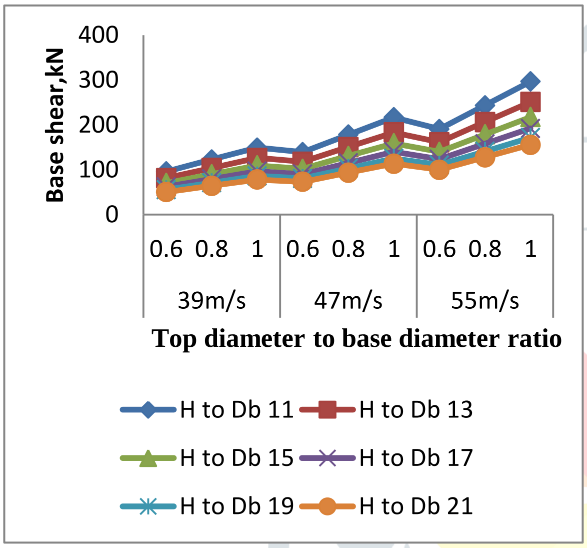


Fig. 5 Base shear for 50 m chimney

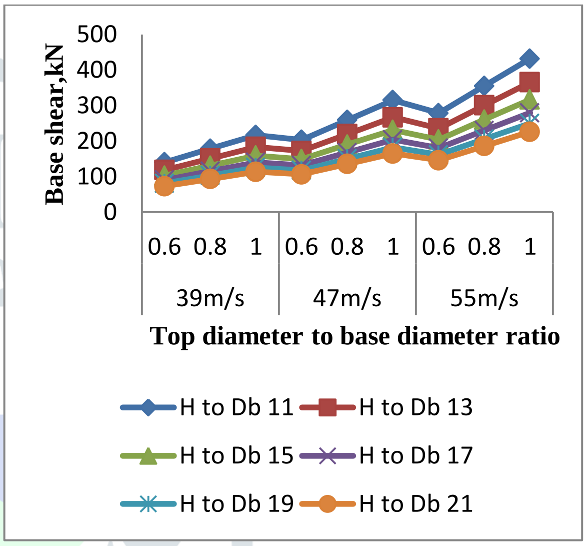


Fig. 6 Base shear for 60 m chimney

EARTHQUAKE ANALYSIS RESULTS:

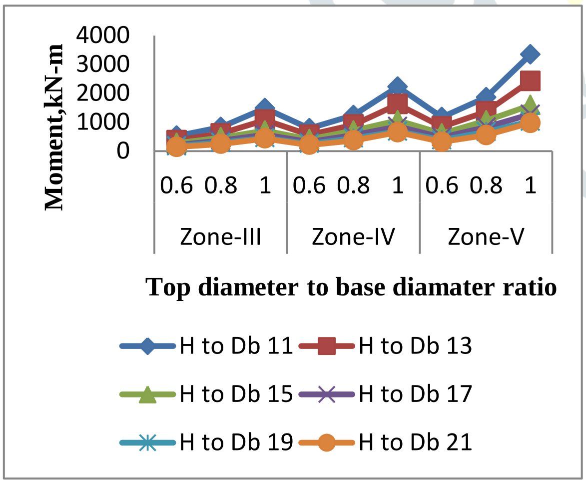


Fig. 7 Moment foe 40 m chimney

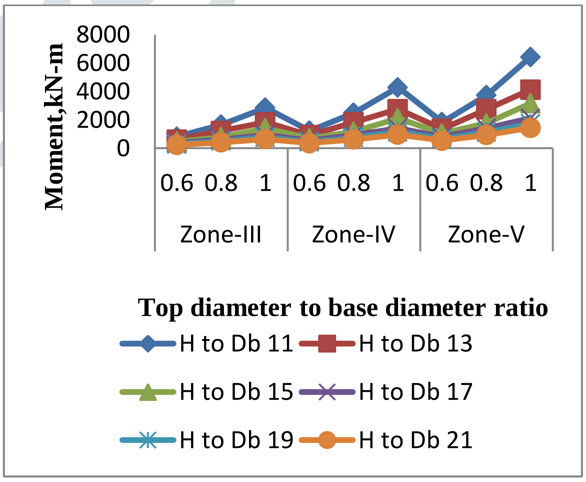


Fig. 8 Moment for 50 m chimney

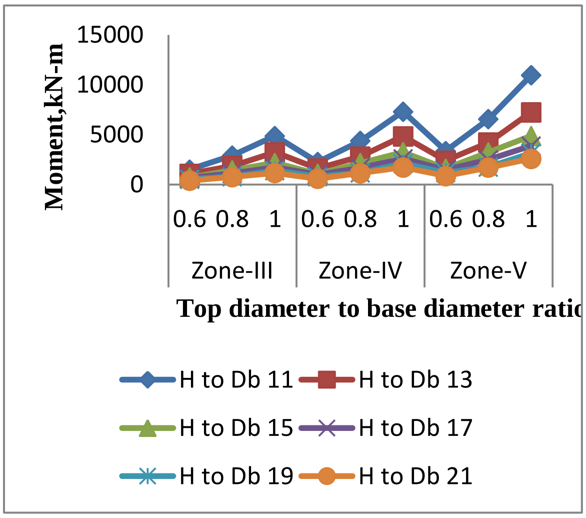


Fig. 9 Moment for 60 m chimney

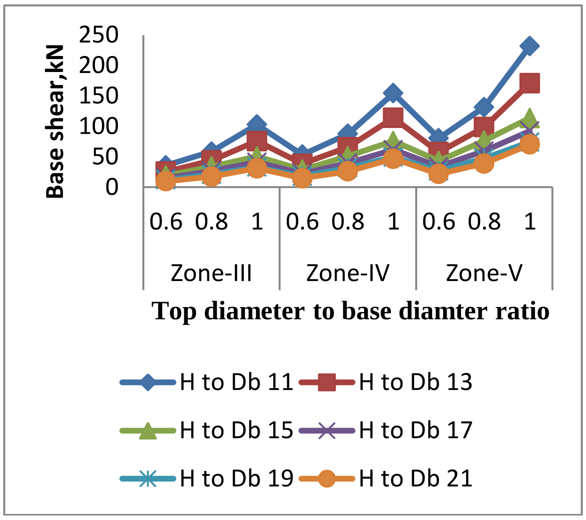


Fig. 10 Base shear for 40 m chimney

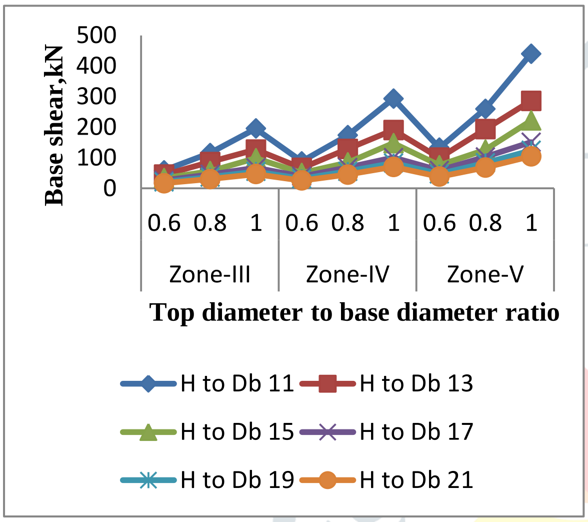


Fig. 11 Base shear for 50 m chimney

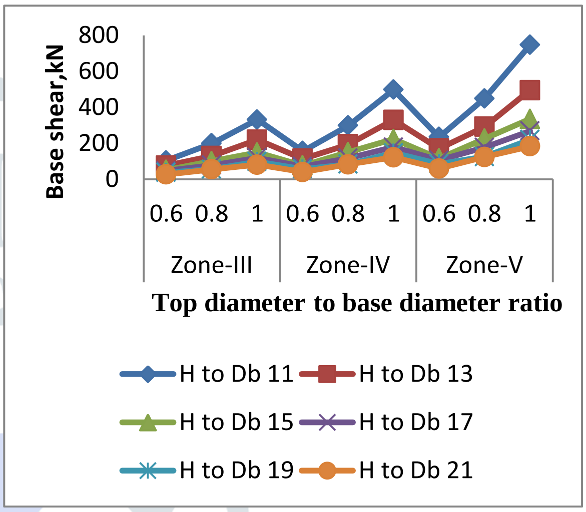


Fig. 12 Base shear for 60 m chimney

WIND ANALYSIS RESULTS:

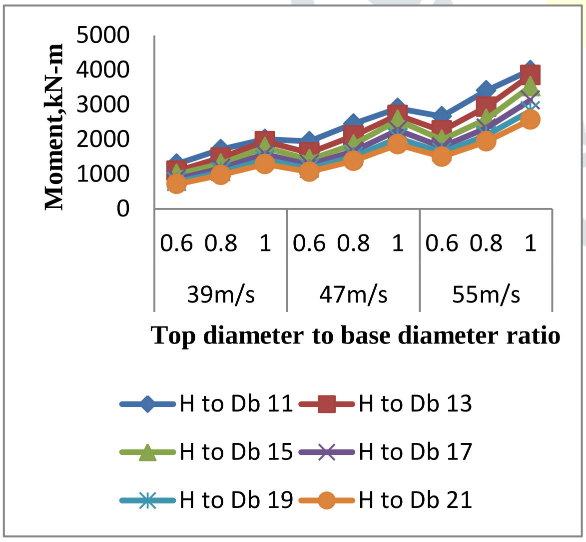


Fig. 13 Moment for 40 m chimney

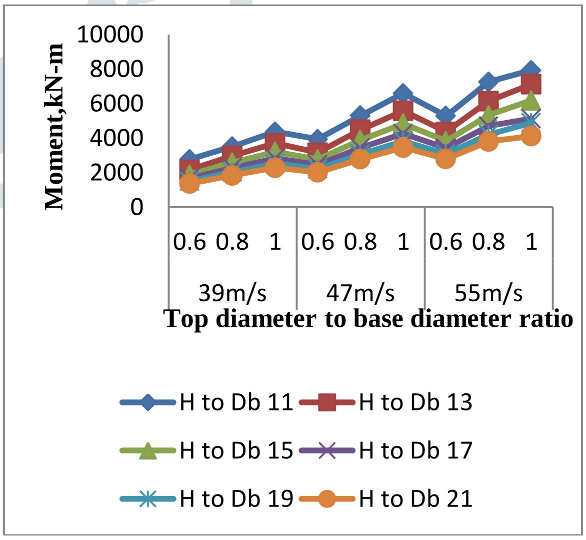


Fig. 14 Moment for 50 m chimney

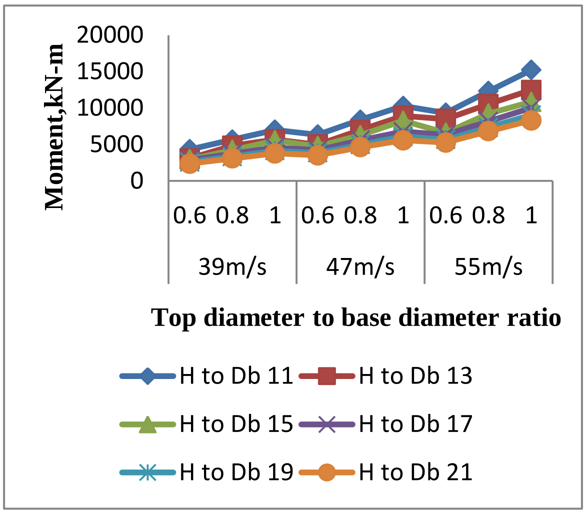


Fig. 15 Moment for 60 m chimney

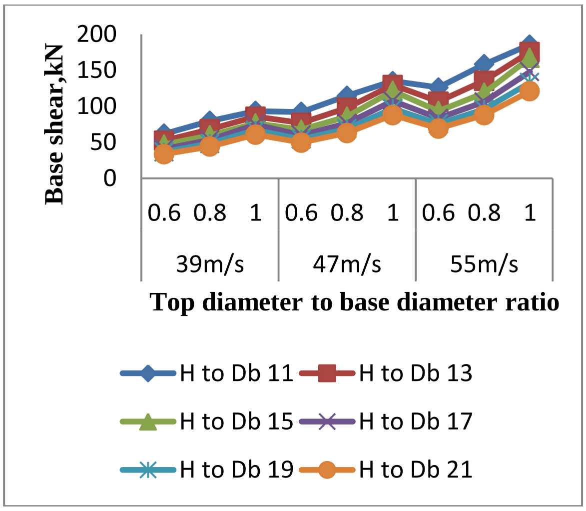


Fig. 16 Base shear for 40 m chimney

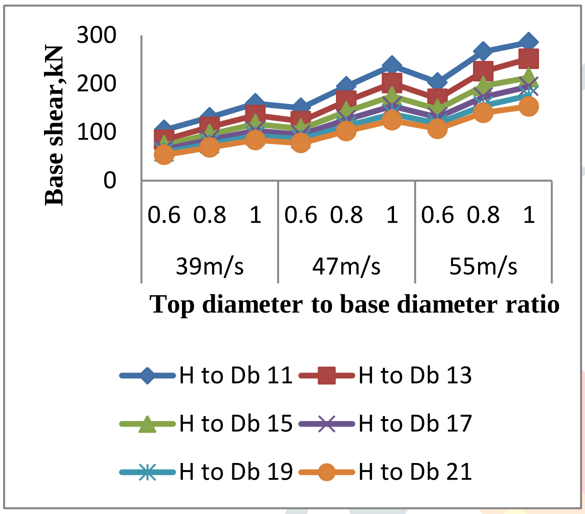


Fig. 17 Base shear for 50 m chimney

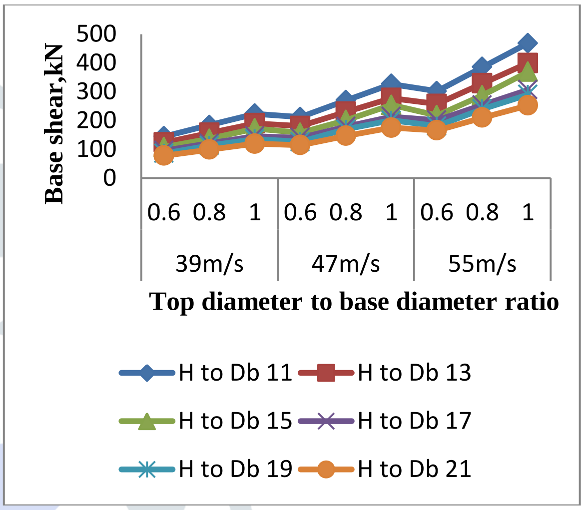


Fig. 18 Base shear for 60 m chimney

VI.CONCLUSIONS

Conclusions from the graph: Static and Dynamic Moments Steel Chimney

1. The static and dynamic moments for the D_t/D_b ratio 0.6 are always less than the moments obtained for D_t/D_b ratio 0.8 for wind speed 39 m/s and for all heights considered.
2. Static and Dynamic moments reduces with the increase in the slenderness ratios for all heights considered.

Conclusions from the graph: Comparison of Wind and Earthquake Moments

3. Increase in weight of the structure increases the Earthquake moments, whereas increase in height of the structure and D_t/D_b ratio increase the wind moments both static and dynamic.
4. Increase in wind speed obviously increases the wind moments. This makes few sections which were safe for 39 m/s is unsafe for 55m/s.
5. Further decrease in D_t/D_b ratio further increases the earthquake moments.

Variable heights such as 40, 50 and 60 m steel self supported chimneys were analyzed for wind and earthquake forces and few inferences are given below

6. Maximum bending moment and shear force are mainly due to wind forces.
7. For Steel Chimneys Wind induced moments governs the design.

VII.REFERENCES

[1] IS 6533(Part 2): 1989, "Design and Construction of Steel Chimney", *Bureau of Indian Standards*, New Delhi,2005.

[2] IS 6533 **(**Part 1): 1989, "Design and Construction of Steel Chimney", *Bureau of Indian Standards*, New Delhi, 2002.

[3] IS 1893 (Part 4):2005, "Criteria for earthquake resistant design of structures", *Bureau of Indian Standards*, New Delhi, 2005