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Design of Guy Supported Industrial Steel Chimneys

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***Abstract:** In last three decades, the constructions of tall stacks were prominent to prevent and control air pollution with the growing interest of industrial development. These structures are generally slender, and tall with cylindrical and circular cross-sections. The constructions of chimneys in practice are with different support conditions such as self-supported, guy wire etc. The most frequent construction materials for chimney or stacks are concrete, steel and masonry. This paper presents the analysis and design of Guy Supported industrial steel chimneys comprises a number of sets of collars (guy wire arrangement) and various height to diameter ratios such as 25, 29 and 33 (the most preferable ratios as per IS 6533 (Part 1): 1989), The analysis were carried out by using STAAD software considering various loads such as dead load, temperature effects, wind, seismic loads etc. and combination of it. As lateral loads are dominant the considered basic wind speeds are 39m/s, 47 m/s, and 55m/s (as per IS 875 (Part 3): 1987) and Seismic load are taken as per IS 1893 (Part 4): 2005 for particular work considering seismic zone-II and with medium soil.*

***Keywords:** Stacks, Guy Supported steel chimney, Seismic zone, Basic wind speed.*

I. INTRODUCTION

Chimneys or stacks are very important industrial structures for emission of poisonous and combustible gases to a higher elevation such that the gases do not foul surrounding atmosphere. The construction of tall stacks has been on the increases in the last three decades to prevent and control of air-pollution, because in INDIA deaths causing due to air-pollution are in the fifth place. These structures are slender, tall and generally with cylindrical and circular cross-sections. Chimneys are used to build with different support conditions and different construction materials, such as concrete, steel or masonry. A chimney through which contaminated gases are discharged at a high enough elevation so that after decline due to atmospheric instability, their concentration and that of their entrained solid particulates is within acceptable limits on reaching the ground.

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A chimney achieves simultaneous reduction in concentration of a number of pollutants like SO_2, CO, fly ash, etc.., and being highly reliable it does not require a standby. While these are its distinct merits, it is well to remember that a chimney is not the complete solution to the problem of pollution control.

II. LITERATURE REVIEW

Anurag jain, Behman arya, Charles goddard and Jon galsworthy (2009) : Discussion is about hurricane loading on chimneys pile foundation system by using non-linear dynamic analysis for assessment of the hurricane and wind loads on pile and mat foundations which support 350ft tall chimneys, results from non-linear dynamic analysis were used. In computer simulation model, Concrete wind shield, pile cap and individual pile were modeled. A 157 kmph and 225 kmph wind speeds are considered for the analysis.

Flaga and liepecki (2010) : Analyze the steel chimneys of circular cross-section due to vortex excitation for lateral response. The maximum displacement at top of chimney to vortex shedding is calculated by using a mathematical model on vortex shedding.

G.Murali, B.Mohan, P.Sitara and P.Jayasree : This paper deals with the study of three chimneys of 55m high above ground level. These chimneys were designed as per IS: 6533–1989 and wind load was calculated as per IS: 875–1987. Three different wind speeds were considered for the design viz., 39m/s, 47m/s & 55m/s respectively. The force exerted by wind on the chimney varies with the wind speed and its associated turbulence.

III. OBJECTIVE

The main objective is about Analysis and Design of Guy Supported Industrial Steel Chimneys for considered sets of collars and various height to diameter ratios such as 25, 29 and 33 this are most preferable ratios as per the IS 6533 (Part 1): 1989 and for various loads such as Dead load, Temperature effects, Wind load (basic wind speeds 39m/s, 47 m/s, and 55m/s) as per IS 875 (Part 3): 1987 and seismic load (seismic zone-II) as per IS 1893 (Part 4): 2005 were studied and finding out the governing load for the design And comparison between the static and dynamic design loads as the no of sets of collars increasing with different height to diameter ratios considered.

IV.PROBLEM STATEMENT

For the Analysis and Design of Guy Supported Industrial Steel Chimney with various parameters like Height, Height to Diameter ratios,

No of sets of Guy wires to be considered and different loads.

- Heights of the chimney considered: 220m, 250m, 275m and 300m.
- Different guy angles (θ) with respect to horizontal. θ varying from 30^0 to 72^0.
- Considered sets of Guy wires.
  - For one set -2
  - For two set -5
  - For three set -3
- Height to diameter ratio: 25, 29 and 33. (As per IS 6533 (Part 1):1989)
- Basic wind speeds are 39 m/s, 47 m/s and 55 m/s. (As per IS 875 (Part 3): 1987)
- Seismic zone II. (As per IS 1893 (Part 4): 2005)
- Diameter of the chimney is constant throughout the height of the chimney.
- Thickness of lining provided for Guy supported industrial steel chimneys for all the heights, height to diameter ratios and different wind loads.
- Diameter of the Guy wire considered for all the cases are constant = 25mm

IV. LOADS CONSIDERED

- Dead load
  - Self-weight of the steel shell
  - Self-weight of lining
  - Self-weight of fixtures and ladder etc..
- Wind load as per IS 875 (part 3): 1987
- Seismic load as per IS 1893 (part 4) : 2005
- Temperature effects
- load combnations**:**
- The following load combinations for calculations of stress at any point of steel chimney are considered:
- *(i)* Dead load + Wind load+ Temperature effect
- *(ii)* Dead load + Earthquake (seismic) load + Temperature effect
- The worst combination out of the effect due to seismic (earthquake) loads and wind effect is only taken into consideration. Only one effect is considered for the design of the structure out of these two loads.

VI.ANALYSIS AND DESIGN OF GUY SUPPORTED INDUSTRIAL STEEL CHIMNEY

A. The design of steel chimney can be done as two types:

- Self-supporting steel chimneys
- Guyed steel chimneys.

B. Self-supporting steel chimneys:

When the lateral forces (wind or seismic forces) are transmitted to the foundation by the cantilever action of the chimney, then the chimney is known as self-supporting chimney. The self-supporting chimney together with the foundation remains stable under all working conditions without any additional support. A self-supporting chimney is shown in Fig. The self-supporting chimneys are made up to 12 m diameter and from 50 m to 275m in height.

C.Guyed steel chimneys:

In high steel chimneys, the mild steel wire ropes or guys are attached to transmit the lateral forces. Such steel chimneys are known as guyed steel chimneys. In guyed steel chimneys, all the externally applied loads (wind, seismic force, etc.) are not totally carried by the chimney shell. These attached guys or stays do share these applied loads. These guys or stays ensure the stability of the guyed steel chimney. These steel chimneys may be provided with one, two or three sets of guys. In each set of guys, three or four or sometimes six wires are attached to the collars. When one set of guy is used, then the guys are attached to a collar at one-third or one-fourth of the height from the top. When- more than one set of guys are used, and then these are used at various heights. The temperature of the flue gases before entering the chimney and its likely variation, are studied. The type of lining is decided knowing the composition of the flue gases. The specific weight, the quantity of dust and data about the aggressiveness of the flue gases must be known. The local statutory regulations, relating to height, dispersion of ash, provision for earthing aviation warning lamp, health etc. are the factors which should be considered for selecting a type of steel chimney. The mode of erection is also considered.

D. DESIGN PROCEDURE FOR GUYED STEEL CHIMNEYS:

Guyed steel chimneys must be designed for the unit stresses caused by the self-weight of the chimney, horizontal wind pressure, and pull of the guy wires. Tension and compression will be caused by the moment due to the wind pressure, while the weight of the chimney and vertical component of the pulls of the guys will cause compression only. Hence the unit compressive stress will be larger than the unit tensile stress. The wind pressure and the horizontal components of the pulls of the guy wires will cause horizontal shearing stress.

In the design procedure outline below it is assumed that a guyed steel chimney is provided with the guy wires at two levels along the length. Thus the chimney will be divided in three parts- the upper part of the chimney, i.e., from the top collar to the top of the chimney, the part between the top collar and bottom collar, and the part between the bottom collar and the base. No flare is required at the base of the chimney.A stepwise procedure is given briefly for the design of a guyed chimney with two sets of guys as follows.The number of collars and the number of guy wires to be attached with each collar are selected. The angle ranges between 30^0 to 72^0 with vertical that the guy wires make is assumed and the horizontal wind reaction R_c at the upper collar is determined from the table. The maximum pull in the guy ($P_g = R_c \times \text{cosec}\theta$) is calculated, when the wind blows along it. Total pull in guy wire = P_g + pull due to initial tension in guy wire. The total maximum vertical components of the pulls of the guys at the upper collar are calculated.

The same force may be assumed to act at the lower collar. This assumption is safe. The thickness of plates in the upper portion of the stack is designed using the following equations….

Maximum tensile stress

$$\sigma_{t_{1,}\ cal} = \frac{4M_{c1}}{\pi t D^2} - \frac{W_{s1}}{\pi D t} < \eta_1 \times 0.6 f_y$$

Where M_{c1} = moments at collar

W_{s1} = weight of the chimney above the top collar

Maximum compressive stress

$$\sigma_{c1,cal} = \frac{4M_{c1}}{\pi t D^2} + \frac{W_{s1}}{\pi D t} < \eta_2 \times \eta_c$$

The thickness of steel plates that comes out to be maximum from the above two equation is provided after making necessary correction to account for corrosion and should not be less than 6 mm. The thickness so obtained will be provided for all the sections above it up to top of the chimney.

The section design is checked in shear. The horizontal shears just above and below the upper collar are calculated. This should be less than the permissible shear stress.

The thickness of the plates of the chimney between the upper and lower collars is designed using the following equations.

The maximum tensile stress occurs just below the upper collar.

$$\sigma_{t_{2,}\ cal} = \frac{4M_{c2}}{\pi t D^2} - \frac{W_{s2}}{\pi D t} - \frac{P_g}{\pi D t} < \eta_1 \times 0.6 f_y$$

Where M_{c2} = moments at bottom collar

W_{s2} = weight of the chimney above the bottom collar

The maximum compressive stress will occur on a section just above the lower collar and is

$$\sigma_{c2,cal} = \frac{4M_{c2}}{\pi t D^2} + \frac{W_{s2}}{\pi D t} + \frac{P_g}{\pi D t} < \eta_2 \times \eta_c$$

The thickness of steel plates that comes out to be maximum from the above two equations is provided after making necessary correction to account for provided for all the sections above it up to the top collar.

Maximum shear stress is calculated and checked in a way similarly to as in the step5.

The thickness of the plates to be used in the lowest portion of the stack is designed using following equations.

The maximum tensile stress will occur just below the collar.

$$\sigma_{t_{3,}\ cal} = \frac{4M_{c3}}{\pi t D^2} - \frac{W_{s3}}{\pi D t} - \frac{P_g}{\pi D t} < \eta_1 \times 0.6 f_y$$

The maximum compressive stress will occur just above the base.

$$\sigma_{c3,cal} = \frac{4M_{c3}}{\pi t D^2} + \frac{W_{s3}}{\pi D t} + \frac{P_g}{\pi D t} < \eta_2 \times \eta_c$$

Where M_{c3} = moments at bottom collar and base

W_{s3} = weight of the chimney between the bottom collar and base

P_g = total sum of vertical components of the pulls of the guy wires at the upper and lower collar.

The foundation for the stack is designed as a concrete pedestal.

The design procedure same as of the guy supporting steel chimney:

A. *Determination of Horizontal wind pressure*

(calculated as per IS:875, part-III)

Design Velocity, $V_z = k_1 \times k_2 \times k_3 \times V_b$

Design Wind Pressure,

$$P_z = 0.6 V_z^2 \text{ N/m}^2$$

Wind force in this Segment,

$$P_W = 0.7 \times P_z \times \text{Projected area}$$

Where k_1 is risk factor, k_2 is importance factor, k_3 is topography factor, V_b is basic wind speed

B. *Calculation of Bending moment at level of collar*

$$M_c = 1/2\ (P_W\ H\ (H - h_1)^2)$$

C. *Reaction at the level of collar*

$$(R_C = 3P_W/4)$$

D. *Reaction at the base*

Reaction at the base, $\left(R_b = \frac{PW}{3}\right)$

E. *Position of zero shear force*

Position of zero shear force from the base, $\left(\frac{H}{3}\right)$

Bending moment at zero shear force, M_{cd}

$$\left(M_{cd} = \frac{P_W H}{18}\right)$$

F. *Bending moment at the base*

$$(M_b = (P_W\ H)/2\ (1 - H/2h_1)^2)$$

G.Design of base plate:

The maximum compressive stress at the base plate is on the leeward side and is given by

$$\sigma_{c,cal} = \frac{4M_W}{\pi t D^2} + \frac{W_s}{\pi D t} + \frac{W_L}{\pi D t} \text{kN/m}^2$$

The maximum compressive strength per unit circumferential length,

$$F_1 = \sigma_{c,cal} \times t \text{ kN/m}$$

Base plate width calculations

$$B = \frac{F_1}{\sigma_p}$$

Where, σ_p = allowable bearing pressure on the foundation.

Moments due to wind at the critical section A-A, $M = \frac{wc^2}{2}$

Moment of resistance at the critical section A-A,

$$M_R = \frac{1}{6} \times 1 \times t_1^2 \times \sigma_{bs} = \frac{t_1^2}{6} \times \sigma_{bs}$$

For equilibrium,

$$M = M_R$$

$$\frac{wc^2}{2} = \frac{t_1^2}{6} \times \sigma_{bs}$$

$$t_1 = c\sqrt{\frac{3w}{\sigma_{bs}}}$$

Base plate thickness $t = t_1 - t_a$

Where,

t_1 = total thickness available at critical section

t_a = thickness of angle section

σ_{bs} = 185 N/mm^2

H.Design of the anchor bolts:

The self-supporting steel stack transmits the forces to the foundation by cantilever action.

This causes uplift on the windward side and thrust on the leeward side of stack. Anchor bolts are provided to check the uplift.
Maximum tensile stress at the base plate on the windward side will be when the lining is absent.

$$\sigma_{t,cal} = \frac{4M_W}{\pi D_1{}^2 t} - \frac{W_S}{\pi D_1 t} \text{ kN/m}^2$$

Maximum force per unit circumferential length of the base plate on the windward side of stack

$F_1 = \sigma_{t,cal} \times (t \times 1) = \sigma_{t,cal} \times t$

$F_1 = \left[\frac{4M_W}{\pi D^2 t} - \frac{W_S}{\pi D t}\right] \times t$

Maximum uplift force to be resisted by anchor bolts

$F_2 = F_1$

Spacing S of anchor bolts $= \frac{R_t}{F_2}$

Or $S = \frac{R_t}{\left[\frac{4M_W}{\pi D_1{}^2} - \frac{W_S}{\pi D_1}\right]}$

Where, R_t = Strength of anchor bolt.

I. Design of Plain Concrete Pedestal:

Steel stacks are subjected to large lateral forces. Usually, a massive plain concrete circular foundation in the shape of a frustum of a cone or an eight-sided pyramid is provided. The depth of the foundation should not be less than 0.4 times the diameter of the foundation (D_2). Also, for no tension at the base, the maximum eccentricity (e) is limited to $D_2/8$. The diameter of the foundation is determined as follows.

$$e = \frac{D_2}{8} = \frac{M_W}{W_S + W_L + W_F}$$

or $M_W = \frac{D_2}{8}[W_S + W_L + W_F]$

Where W_F = weight of footing, and D_2 is the diameter of the base of the pedestal.

Since the weight of the lining and self-weight are negligible as compared to the weight of the footing, the former may be neglected.

Assuming unit weight of concrete to be 24kN/m^3,

$$M_W = \frac{D_2}{8}\left[\frac{\pi}{4} D_2{}^2 \times 0.4D_2 \times 24\right]$$

$D_2 \approx M_W{}^{\frac{1}{4}}$

Check for the stability of the stack:

The stability of the stack is checked by the following expression.

$1.6(\sigma_w + \sigma_m) - 0.9\sigma_d < 1.8\sigma_a$

Where, σ_w = stress due to wind load

σ_m = stress by any other load causing an increase in the combined stress

σ_d = stress due to dead load

σ_a= permissible stress

The horizontal reaction R_c at the collar as shown in fig. is found by taking moments about the base.

$\sum M_{base} = R_c \times h_1 - \frac{P_w H}{2} = 0$

$R_c = \frac{P_w H}{2h_1}$

The horizontal reaction at the base R_b

$R_b = P_w - R_c = P_w - \frac{P_w H}{2h_1}$

Where, R_c = horizontal reaction at the collar due to wind

P_w = total wind pressure on stack

R_b = horizontal reaction at base due to wind

H = total height of stack

h_1= height of collar

The shear at the top of the collar $= -\frac{P_w}{H}(H - h_1)$

The shear just below the collar

$= R_c - \frac{P_w}{H}(H - h_1) = \frac{P_w H}{2h_1} - P_w + \frac{P_w h_1}{H}$

The shear at the base $R_c = P_w - \frac{P_w H}{2h_1}$

The bending moment at the collar $= -\frac{P_w}{H}(H - h_1)\frac{(H-h_1)}{2} = -\frac{P_w}{2H}(H - h_1)^2$

The maximum positive bending moments between collar and base $= \frac{P_w H}{2}\left(1 - \frac{H}{2h_1}\right)^2$

And occurs at point of zero shear $=\left(1 - \frac{H}{2h_1}\right)^2$ meters above the base.

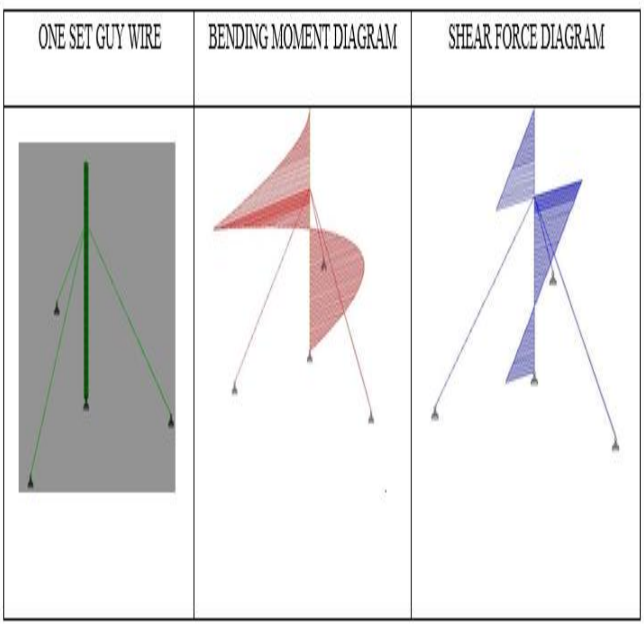

Fig I: One set guy wire-bending moment & shear force diagram

Table II: Static & Dynamic moments results for 1 set guy

Height of collar above base	Reactions		Shear at			Shear Point at	Moments to be used in design	
	R_a	R_b	*Top of collar*	*Below the collar*	*Base*		*At C*	*At zero shear*
$\frac{2H}{3}$	$\frac{3P_w}{4}$	$\frac{P_w}{4}$	$\frac{-P_w}{3}$	$\frac{5P_w}{12}$	$\frac{P_w}{4}$	$\frac{H}{4}$	$\frac{P_wH}{18}$	$\frac{P_wH}{32}$
$\frac{3H}{4}$	$\frac{2P_w}{3}$	$\frac{P_w}{3}$	$\frac{-P_w}{4}$	$\frac{5P_w}{12}$	$\frac{P_w}{3}$	$\frac{H}{3}$	$\frac{P_wH}{32}$	$\frac{P_wH}{18}$

Table I: Approximate B.M. and S.F. for 1 set of guy wire

Wind speeds	39m/s			47m/s			55m/s		
Height to diameter ratio	25	29	33	25	29	33	25	29	33
Wind load P_w, kN	2319	1999	1757.3	3368	2904	2552	4613	3977	3494
Moment at collar, kN-m	15948	13747	12081	23161	19966	17546	31716	27342	24028
Static Moment at centre ,kN-m	28351	24441	21478	41175	35496	31193	56385	48608	42716
Shear force just above collar, kN	579	499	439	842	726.05	638	1153	994	873
Shear force due to wind at base	773	666	585.786	1123	968	850	1537	1325	1165
Seismic base shear V, kN	215	158	122	237	175	138	259	196	164
Dynamic moment M_{dyni}, kN-m	12537	10857	9541	4717	15769	13857	25049	21594	18976
Dynamic moment M_{dynj}, kN-m	30170	26128	22961	43561	37561	33467	60280	51965	45666
Static moments $M_{sti,}$ kN-m	15947	13747	12081	5790	19966	17546	31716	27342	24027
Static moments $M_{stj,}$ kN-m	28351	24440	21478	30881	35495	31193	56385	48608	42716
Base plate thickness, mm	26	28	30	31	34	38	38	42	46
Baseplate width, mm	410	430	450	480	510	540	560	600	650
Dia of foundation required, m	13	12.5	12.1	14.2	13.72	13.2	15.4	14.8	14.3
Depth of foundation required, m	5.4	5.2	5	5.9	5.7	5.5	6.4	6.1	6

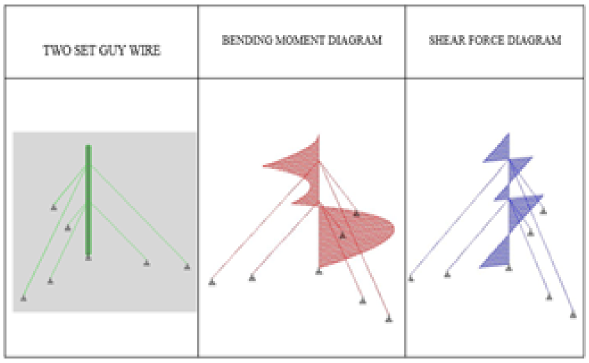

Fig II: Two set guy wire-bending moment & shear force diagram

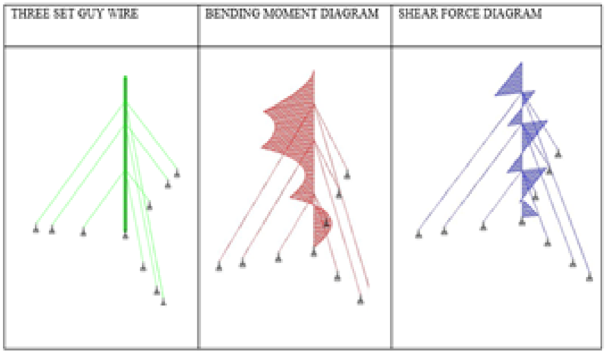

Fig III: Three set guy wire-bending moment & shear force diagram

Table III: Approximate B.M. and S.F. for 2 set of guy wire

Height of collar above base		Reactions at			Moments to be used in design			Sum of moment of reactions about base should = ($0.5P_wH$)
Upper 1	Lower 2	Upper collar 1	Lower collar 2	Base	At 1	Between 1 & 2	Between 1 and base	
$\frac{2H}{3}$	$\frac{H}{3}$	$\frac{2P_w}{3}$	$\frac{P_w}{6}$	$\frac{P_w}{6}$	$\frac{P_wH}{18}$	$\frac{P_wH}{18}$	$\frac{P_wH}{18}$	$\frac{P_wH}{2}$
$\frac{3H}{4}$	$\frac{H}{2}$	$\frac{P_w}{3}$	$\frac{P_w}{4}$	$\frac{P_w}{4}$	$\frac{P_wH}{32}$	$\frac{P_wH}{32}$	$\frac{P_wH}{32}$	$\frac{P_wH}{2}$
$\frac{8H}{10}$	$\frac{H}{2}$	$\frac{9P_w}{20}$	$\frac{3P_w}{10}$	$\frac{P_w}{4}$	$\frac{P_wH}{50}$	$\frac{P_wH}{50}$	$\frac{P_wH}{32}$	$\frac{51P_wH}{100}$
$\frac{85H}{100}$	$\frac{6H}{10}$	$\frac{7P_w}{20}$	$\frac{7P_w}{20}$	$\frac{3P_w}{10}$	$\frac{9P_wH}{800}$	$\frac{9P_wH}{800}$	$\frac{9P_wH}{200}$	$\frac{203P_wH}{400}$
$\frac{85H}{100}$	$\frac{5H}{10}$	$\frac{4P_w}{10}$	$\frac{7P_w}{20}$	$\frac{P_w}{4}$	$\frac{9P_wH}{800}$	$\frac{9P_wH}{800}$	$\frac{P_wH}{32}$	$\frac{103P_wH}{200}$

Table IV: Approximate B.M. and S.F. for 3 set of guy wire

Height of collar above the base			**Reactions at**				**Moments to be used in design**			
Upper 1	*Middle 2*	*Lower 3*	*Upper collar 1*	*Middle collar 2*	*Lower collar 3*	*Base*	*At 1*	*Between 1&2*	*Between 2&3*	*Between 3 and base*
$\frac{3H}{4}$	$\frac{H}{2}$	$\frac{H}{4}$	$\frac{P_w}{2}$	$\frac{P_w}{8}$	$\frac{P_w}{4}$	$\frac{P_w}{8}$	$\frac{P_wH}{32}$	$\frac{P_wH}{32}$	$\frac{P_wH}{32}$	$\frac{P_wH}{32}$
$\frac{8H}{10}$	$\frac{6H}{10}$	$\frac{3H}{10}$	$\frac{4P_w}{10}$	$\frac{3P_w}{20}$	$\frac{3P_w}{10}$	$\frac{3P_w}{20}$	$\frac{P_wH}{50}$	$\frac{P_wH}{50}$	$\frac{P_wH}{50}$	$\frac{P_wH}{50}$
$\frac{85H}{100}$	$\frac{7H}{10}$	$\frac{4H}{10}$	$\frac{3P_w}{10}$	$\frac{3P_w}{20}$	$\frac{7P_w}{20}$	$\frac{P_w}{5}$	$\frac{9P_wH}{800}$	$\frac{9P_wH}{800}$	$\frac{P_wH}{800}$	$\frac{P_wH}{50}$

Table V: For Static and Dynamic analysis and design results of two set guy wires 220m height chimney

Basic wind speed	39m/s			47m/s			55m/s		
Height to diameter	25	29	33	25	29	33	25	29	33
Wind load Pw, kN	2320	2000	1757	3433	2959	2601	3433	2959	4789
Moment at top collar Mt, kN-m	5741	4949	4349	8496	7324	6436	8496	7324	11853
Moment b/w top and bottom collar Mm, kN-m	5741	4949	4349	8496	7324	6436	8496	7324	11853
Static Design Moment at base, kN-m	15948	13748	12081	23600	20345	17879	23600	20345	32925
Shear force just above collar1 SFt, kN	580	500	439	858	740	650	858	740	1197
Shear force just above collar2 SFm, kN	580	500	439	858	740	650	858	740	1197
Max Shear force due to wind, kN	580	500	439	858	740	650	858	740	1197
Seismic base shear V, kN	195	131	98	195	139	104	195	139	206
Dynamic moment M_{dyni}, kN-m	6513	5406	4693	7934	6684	5768	9664	8175	7078
Dynamic design moment M_{dynk},kN-m	21554	18147	15650	27159	22976	19891	33990	28860	25061
Static dynamic moment M_{sti}, kN-m	5741	4949	4349	8496	7324	6436	11852	10218	8979
Static dynamic moment M_{stk}, kN-m	15947	13747	12081	23600	20344	17878	32924	28383	24943
Base plate thickness, mm	20	22	24	24	26	30	28	32	34
Width of the base plate, mm	350	350	360	380	390	410	430	450	460
Diameter of foundation required, m	11.2	10.8	10.4	12.3	11.9	11.5	13.4	12.9	12.5
Depth of foundation required, m	4.7	4.5	4.4	5.2	5	4.8	5.6	5.4	5.2

Table VI: For Static and Dynamic analysis and design results of three set guy wires 220m height chimney.

Basic wind speed	39m/s			47m/s			55m/s		
Height to diameter ratio	25	29	33	25	29	33	25	29	33
Wind load P_w, kN	2319	2319	1757	3432	2959	2600	4789	4128	3628
Static design moment due to wind, kN-m	5741	4949	4349	8496	7324	6436	11853	10218	8979
Shear force just above collar1 SF_1,kN	463	399	351	686	591	520	957	825	725
Shear force just above collar2 and base SF2,kN	289	249	219	429	369	325	598	516	453
Max Shear force due to wind, kN	579	499	439	858	739	650	1197	1032	907
Seismic base shear V, kN	195	131	93	195	131	93	195	131	95
Dynamic design moment M_{dyni}, kN-m	5798	5008	4394	8605	7508	6588	12221	10474	9212
Static dynamic moment M_{sti}, kN-m	5741	4949	4349	8496	7324	6436	11852	10219	8979
Base plate thickness, mm	14	16	18	16	18	20	18	20	22
Width of the base plate, mm	310	300	300	320	320	310	340	330	330
Diameter of foundation required, m	8.7	8.4	8.1	9.6	9.3	9	10.4	10	9.7
Depth of foundation required, m	3.7	3.6	3.4	4	3.9	3.8	4.4	4.2	4.1

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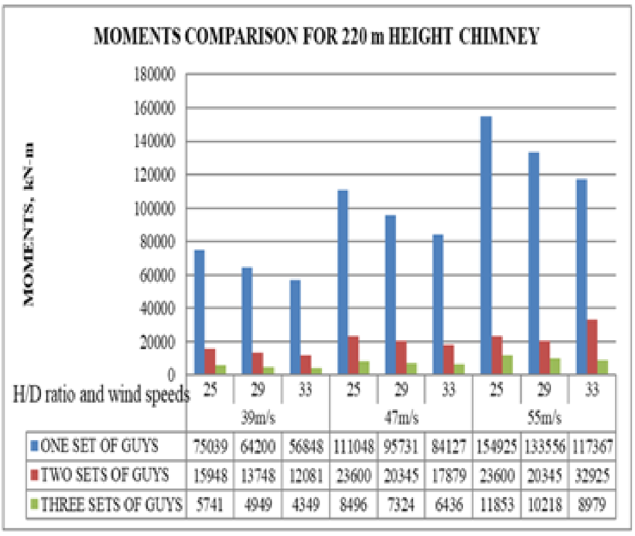
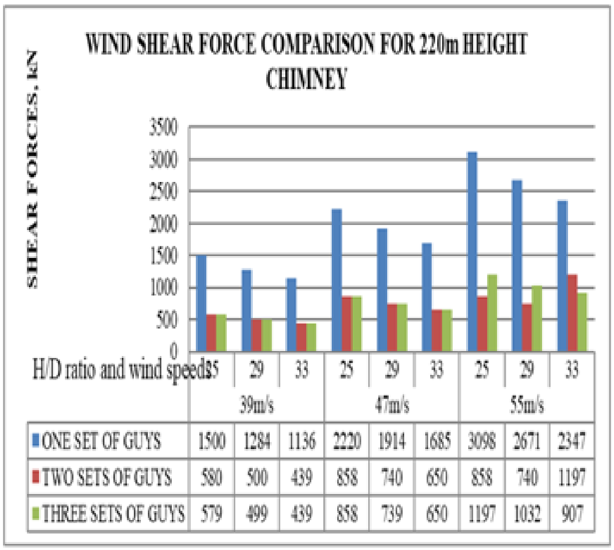
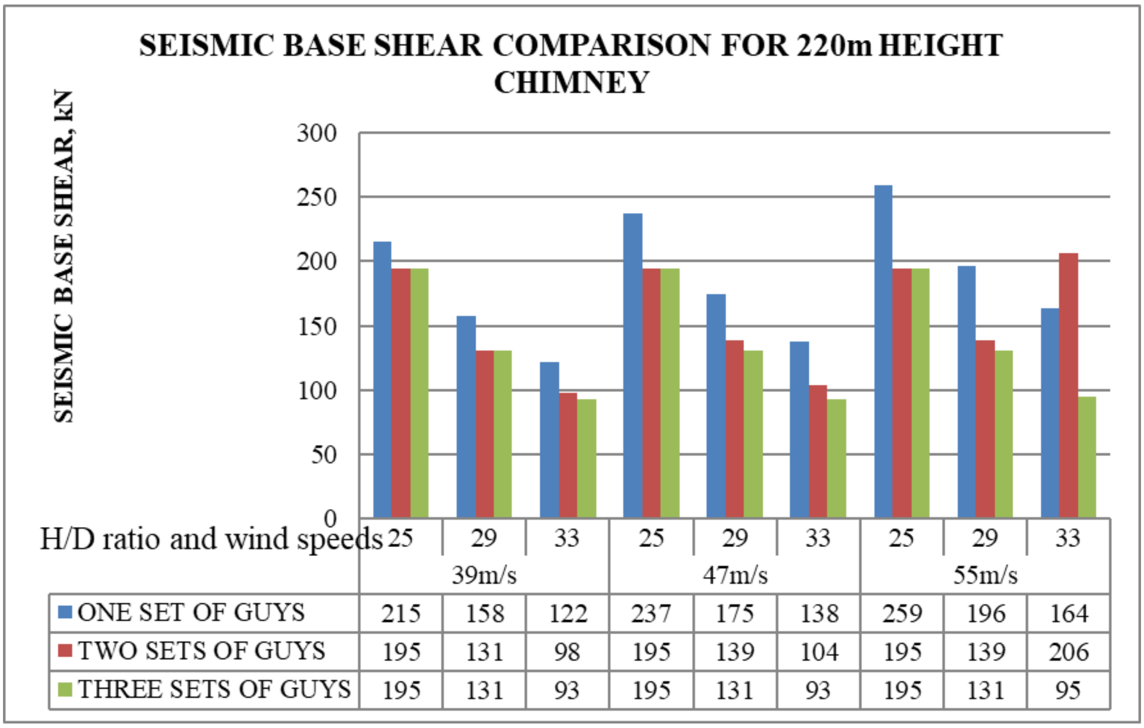
VI. RESULTS AND DISCUSSIONS



Graph I: Comparison of static moments for 220m ht Chimney for different height to diameter ratios



Graph II: Comparison of shear force for 220m height chimney for different height to diameter ratios



Graph III: Comparison of seismic base shear for 220m height chimney with different height to diameter ratios and basic wind speeds as the no of sets guy wires increasing.

VII. CONCLUSIONS

- For a constant height and wind speed, the design moment decreases with increase in H/D ratio.
- For two sets, 78% of static design moments decrease when compared with one set.
- For three sets, 90.8% and 30% of static design moments were decreases when compared to one set and two sets respectively.
- The shear force due to wind is 4 times more than seismic base shear. Shear force due to wind decreases for two and three sets are equal proportions. Seismic base shear for two and three sets are same.
- Base plate thickness decreases in equal proportions i.e 25%.Diameter and depth of foundation decreasing in same proportions.
- As number of guys increases the resisting capacity of chimney increases. Shear force and Bending moment for three set guy chimney is less when compared with one set and two set guy chimneys.
- Wind load acting on the Chimney for same height and same basic wind speed is less for 3 set guy chimney.

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- In the design of Guy supported chimney in order to reduce the wind load acting and also moments we can provide more number of set of guys.

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