PERFORMANCE BASED SEISMIC EVALUATION OF INDUSTRIAL CHIMNEYS BY STATIC AND DYNAMIC ANALYSIS

Sagar S[1], Basavarj Gudadappanavar[2]

[1] *PG Student, Department Of Civil Engineering , SDMCET Dharwad , Karnataka, India*
[2] *Asst.Prof, Department Of Civil Engineering , SDMCET Dharwad , Karnataka, India*

---***---

Abstract - *Chimneys are development of industrial growth in any country and while analysis and design of chimneys proper care should be taken by the designer otherwise serious effect on the surrounding peoples. The present paper mainly deals with the linear static and dynamic analysis of RC and Steel chimneys having height of 65m and chimneys were modelled with the help of the SAP2000 Version 12.00 Software, then main purpose of this chimneys studying the effect of base shear, maximum lateral displacement, fundamental time period and frequency of all the zones from zone 2 to zone 5 and their comparison of the results of all the zones. so while dynamic analysis of the both RC and Steel chimneys time history response of the structures with the all respective zones and in the time history mainly concentrating on the base shear of the chimneys and also be check the displacement of the top of the both the chimneys should be within in the permissible limits and for also comparison of modal base shear for RC chimney with the design manually calculated base shear results.*

Key Words: Industrial chimneys, RCC and Steel chimney, Seismic analysis, SAP 2000, Base shear and Time history.

1. INTRODUCTION

Chimneys are answerable for industrial growth in any country and changes in the various parameters or dimensions such as increasing the height of the chimneys is more independent on the structural analysis such as response to earthquake is become more critical criteria. Diameter of the top the chimney and height of the chimney, exit velocity at the top, dispersion of gases are within the allowable limits. Mainly bottom diameter is also controlling by the various structural requirements of the both the concrete shell and foundation base of the chimney. For the development of large scale industries all over the country, enormous numbers of tall structures going to design every year and proper care is to be taken for the design of chimneys. chimneys are self supporting structures to resist earthquake forces and wind forces acting on the tall slender chimneys. wind load is also major factor responsible for the tall structures so evaluate the loads along the wind load and across the wind load is very important thing in the design of self supporting chimneys .the industrial chimneys are librating various poisonous gases and smokes, ashes from the manufacturing process so while designing chimney high importance for the economical plan of the construction of the chimney. while the construction of chimney in seismic zone is the one of the essential thing to concentrating the various parameters of seismic as to be considered and ineffective construction of the chimney is mainly responsible for serious disastrous to the surrounding area of the chimney. If the improper design and construction chimneys are seriously effecting the various types of disease it will lead to death also because poisonous gases are responsible for the diseases to the surrounding chimney hence so economical plan and safety measures also important criteria while the design point of view of the chimney.

Chimneys are tall and slender structures which are mainly used to discharge flue gases at higher elevation with sufficient exit velocity and transfer to the atmosphere with the lower concentration of hot gases and suspended solids(Ash) and also reaching the ground is within the permissible limits accepted by pollution control regular authority. the main purpose of chimney is to take highly poisonous gases which are taken into greater heights with sufficient velocities also which are not acceptable at ground level. chimneys are more harmful to wind and earthquake load may cause serious problem in surrounding areas of major industries and power plants, which are located in higher seismic zone with lower wind speed.

1.1 Wind loads

Evaluation of chimney by using the method of Gust Factor Approach and self supporting chimney is divided into various numbers of segmental element and each segmental element height should not be more than 10m.The along-wind load, W(z) can be calculated for unit height of chimney at any section, z is equal to the summation of the mean along-wind load, W*(z) and the fluctuating component W'(z) of along-wind load.

Along wind load calculation
W(z) = W*(z) + W'(z)
W*(z) along wind load = Cd *D(z)*V*(z)
Where Cd is drag coefficient
D(z) is chimney outer diameter of each section for 10m
The design wind speed V(z) can be calculated by multiplying basic wind speed Vb and with modification factors k1,k2andk3.(coefficients)

v(z) = Vb*K1*K2*K3
Vb is basic wind speed

Fluctuating component of along-wind for the 0 to 10m

$$W'(z)=3*[(G-1) / H^2]*(z/H) \int_0^H W^* * Z * dz$$

1.2 Earthquake loads

The various parameters of wind and seismic

- Chimney is located at level ground.
- Soil condition is medium(type2).
- More than 50m height so class C structures.
- Z = Zone factor as given in 1S 1893:2005 (Part I), Zone2=0.10(Bangalore)
- Basic wind speed 33m/sec.
- Risk coefficient k1=1.
- Risk coefficient k3=1.
- Terrain category 2
- I= Importance factor as given in1893:2005 (part-4), I=1.5
- R =Response reduction factor as given in 1893:2005 (part-4),R=3.0

Details of chimney for model consideration

- Grade of concrete = M25
- Density of concrete = 25 KN/M^3
- Density of brick = 20 KN/M^3
- Grade of steel = 250 N/mm^2
- Height of chimney = 65M
- Outer diameter of chimney at bottom and top = 3.26M and 2.25M
- Thickness of fire brick lining = 0.1M
- Shell thickness for RCC = 0.3M
- Thickness of steel chimney = 0.0135m and 0.015m

By using the fundamental time period T, the horizontal seismic coefficient Ah shall be evaluated

The fundamental time period of the free vibration is

$T = CT*\sqrt{WT*H/Es*A*G}$

Ah= Horizontal seismic coefficient

Ah=Z/2*Sa/G*I/R

2. Modeling and Analysis results

Description of chimney analyzed

Firstly we considering the Reinforced concrete chimney with height of 65m is predetermined and having external diameter at the top of the chimney be the 2.25m and external diameter at the base level of chimney is 3.6m then concrete shell thickness at top level be the 0.15m and bottom level be the 0.30m. Further next consideration of the steel chimney having same height of 65m and the for the height of flare 22m of thickness of the 13.5mm and the cylindrical portion of the chimney for remaining 43m height 15mm thickness of chimney is occupied. For the understanding of results the whole chimney is divided into 10m part and for the chimney of the 0,10,20,30,40,50,60,65m is external diameter of the chimney be the 3.60,3.40, 3.29,3.02, 2.83, 2.63, 2.44, 2.25m respectively and the wind load is on the chimney is applied be the pressure on the area of the chimney the every interval of 10m from height 0 to 65m.

The chimney 65m height with fixed at support and remaining elements of the chimney is to be ensure the cantilever action of the chimney and similarly earthquake parameters as be assigned in the chimney and various imposed load and lining load is applied on the chimney and similarly we are not considering the soil structures interaction is not to be considered. The eight model is to be analyzed for the four of RCC and four of Steel and corresponding of the four zones is to be considered from zone 2 to the zone 5and as same steel chimneys also considered for the all the four zones and expected output be extracted from the analysis results.

By using the fundamental time period T, the horizontal seismic coefficient Ah shall be evaluated

Ah= Horizontal seismic coefficient

Ah=Z/2*Sa/G*I/R

Z = Zone factor as given in 1S 1893:2005 (Part I), Zone 2=0.10

I= Importance factor as given in1893:2005 (part-4), I=1.5

R =Response reduction factor as given in 1893:2005 (part-4) R=3.0

Sa/ g = Spectral acceleration coefficient.

The fundamental time period of the free vibration is

$T = CT*\sqrt{WT*H/Es*A*G}$

CT = Coefficient depending on slenderness ratio of the structure

W t= Total weight of the structure including lining weight =7165.50KN

A = Area of cross-section at the base of the structural shell $= \pi * D^2/4$

$= \pi * 4^2/4 = 12.56\ M^2$

h = Total height of the structure=65M

Es= Modulus of elasticity of material of the structural shell=$5000\sqrt{25}$ =25000

CT = Coefficient depending on slenderness ratio of the structure =K=H/Rc

H=Total height of the chimney =65m

R=Radius of gyration of the structural shell at the base =R= $\sqrt{I/A}$

$I= \pi*1.95^4/64=0.709\ M^4$

$A= \pi*4^2/4=12.56M^2$

R= $\sqrt{0.70975/12.56}$=0.238

K=H/Rc= 65/0.238= 273.109

T= $CT*\sqrt{WT*H/Es*A*G}$

$= 273.109\sqrt{7165.50*10^3*65/25*10^9*12.56*9.81}$

= 2.18 Sec

Sa/g= 1.36/T= 1.36/2.18= 0.62

Ah=Z/2*Sa/G*I/R

$= 0.10/2 *0.62* 1.5/3 = 0.0155$

Design Base shear RC chimney for zone 2=Ah*W (Similarly for zone 3, zone 4, zone5)

=zone 2 =0.0155*7165.50 =107.480KN

=zone 3 = 0.024*7165.50 =171.97KN

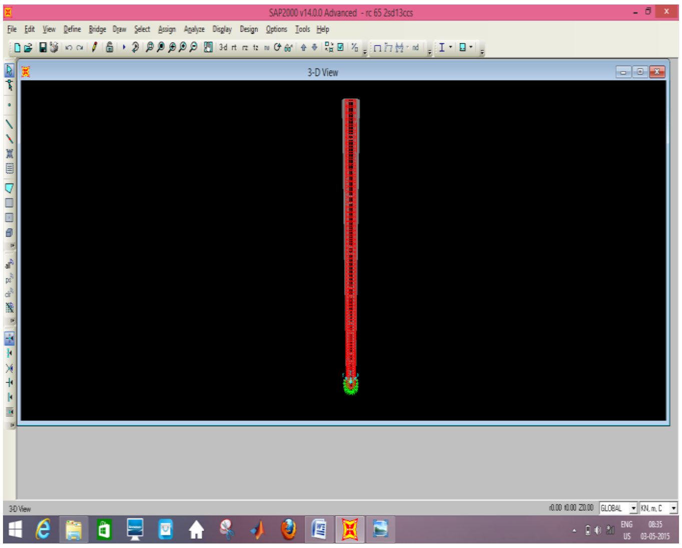
=zone 4 = 0.037*7165.50 = 263.406KN

=zone 5 = 0.055*7165.50 = 394.10KN

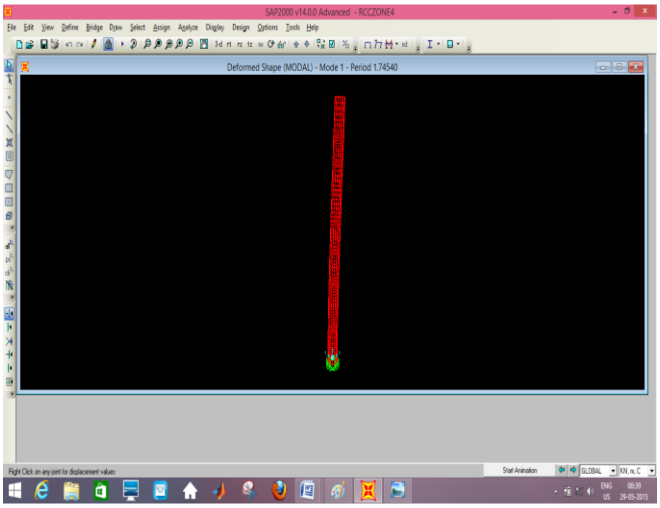
Deflection Criteria for RC Chimney= The max lateral

deflection of the top of stack like structures under all service load conditions= 0.003*h
= 0.003*65=0.195m

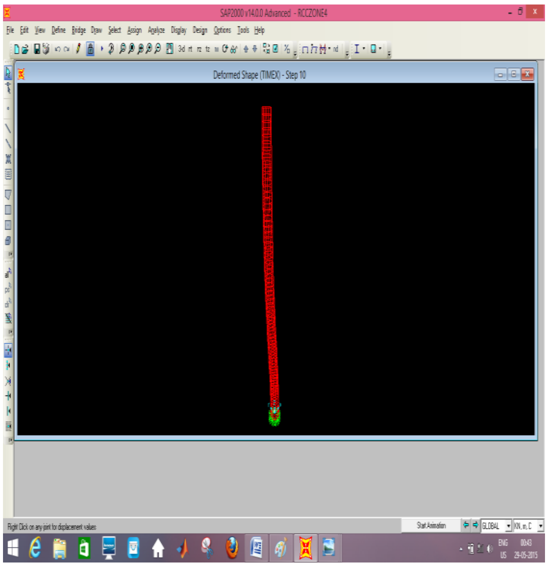
Chimney modeled by using SAP 2000 ver 12



3D VIEW OF 65M RC CHIMNEY



MODAL DEFORMED SHAPE OF 65M RC CHIMNEY



DEFORMED SHAPE OF TIME HISTROY RESPONSE OF 65M RC CHIMNEY

Comparison of Modal Results and Calculated results for RC Chimney

65M RC CHIMNEY BASE SHEAR MODAL VS CALCULATED RESULTS			
Zone	DL+EQ(KN) (Modal results)	Calculated Design Base shear(KN)	% Variation modal vs calculated results
Zone 2	110.101	107.480	2.38
Zone 3	176.162	171.972	2.37
Zone 4	264.244	263.406	0.31
Zone 5	396.366	394.102	0.57

RC CHIMNEY AND STEEL CHIMNEY DISPLACEMENT IN MM			
ZONE	RC CHIMNEY	STEEL CHIMNEY	% of variation
Z 5	163.65	105.41	35.56
Z 4	109.71	88.653	19.19
Z3	72.145	63.602	11.84
Z 2	48.581	30.531	37.15

65m STEEL CHIMNEY TIME PERIOD AND FREQUENCY		
Zones	Time Period(sec)	Frequency(cyc/sec)
Zone 5	1.21875	0.82051
Zone 4	1.24963	0.8002
Zone 3	1.24963	0.8002
Zone 2	1.24963	0.8002

3. CONCLUSIONS

Deflection at the free end of the chimney should be within in the permissible limits of 0.003h for the both the RC and Steel chimney.
Comparison of the modal results and design calculated check base shear for 65m RC chimney percentage variation be the 2.38%.
Steel chimney is more economical in all aspects compared to the RC Chimney.
Base Shear : 65m RC Chimney

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 be the 72%

Base Shear : 65m Steel Chimney

Same phenomenon occurs in the Steel chimney also 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 be the 62.44 %.

Displacement : 65m RC Chimney
Chimney displacement is more in the zone 5 and compare to all the zones, less in the zone 2 then percentage variation from zone 2 to zone 5 is 70.31%.

Displacement : 65m Steel Chimney
Chimney displacement is more in the zone 5 and compare to all the zones, less in the zone 2 then percentage variation from zone 2 to zone 5 is 71.04 %.

Time period and Frequency : 65m Steel Chimney
Time period is nearly same for all the zones from 2 to zone 5 and time period for zone 2 to be the 1.21875 sec and other zone 3, zone 4, zone 5 be the 1.24963 sec.
Frequency is also nearly same for all the zones from 2 to zone 5 and frequency for zone2 to be the 0.82051 cyc/sec and other zone 3, zone 4, zone 5 be the 0.80002 sec.

Maximum base shear in the dynamic analysis is more than static base shear.

Wind loads are always major factor in the design of chimney

REFERENCES

[1] T Subramani , P.Shanmugam " Seismic analysis and design of industrial chimneys by using Staad pro ",Volume 2, Issue 4, July-Aug 2012.

[2] Leonardo E Carrioni , Rodrigo A Dunner And Ivan Fernandez-Davila , "Seismic analysis and design of industrial chimneys".

[3] Francisco J. Pallare`s a , Antino Aug ero b , Manuel Martina , Seismic behaviour of industrial masonry chimneys, International Journal of Solids and Structures 43 (2006) 2076–2090.

[4]. K.Anil Pradeep , C.V.Siva Rama Prasad , volume 3, Issue 8,August 2014 "Governing Loads For design of a 60m Industrial RCC Chimney".

[5] Alok david john , Ajay gairola , Eshan ganju , and Anant gupta Procedia Engineering 14 (2011) 1252–1257 Design Wind Loads on Reinforced Concrete Chimney – An Experimental Case Study.

[6] Rajesh M.N and S.K Prasad, Volume 2, Number 1 (2014), pp.195-201" Seismic Performance Study on RC Chimneys from Pushover Analysis.

[7] G.Murali , B.Mohan , P.Sitara and P.Jayasree 4 Vol. 2, Issue 2, Mar-Apr 2012, pp.490-498 490, Vol. 2, Issue 2, Mar-Apr 2012, pp.490-498 490," Response of Mild Steel chimney Under Wind Loads".

[8] Yoganatham.C and Helen santhi M .
Volume 1, Issue 2, Oct,December,2013,"Modal analysis of RC chimney".

[9] K.R.C. Reddy, O.R.Jaiswal and P.N.Godbole (2011), ISSN 0974-5904, Volume 04, No 06 SPL, October 2011 ,"Wind and Earthquake Analysis of Tall RC Chimneys".

[10] Shivakumar reddy, C Srikanth , V Rohini padmavathi " Wind loads effects on tall RC Chimney of 275m height " (2012)

[11] M.G Shaikh , Hami khan " Dynamic analysis of RC Chimney (2009)

BIOGRAPHIES

PG Student,Department of civil engieering,sdmcet,Dharwad
Sagarsagara226@gmail.com

Asst.Prof, *Department of civil engieering,sdmcet,Dharwad*
gudadappa@gmail.com

