6. Designing and Detailing of example chimney

6.1 Introduction

In the earlier chapters about analysis of the various loads that are incident on a chimney, a number of calculations have been performed on some typical chimneys. Those results will be brought together towards the design of a sample chimney.

Then the detailing of such a chimney is also shown.

In addition the last part of the chapter deals with the design of the footing for the chimney.

6.2 Design of a chimney

The following table gives the list of the various parameters of a chimney and their typical values.

Name of parameter	Practical range	Typical value
Slenderness ratio h/D_o	7-17	11
Taper ratio D_t/D_o	0.3-1.0	0.6
Base diameter to thickness ratio D_b/t_b	20-50	35
Mean, base thickness ratio t_m/t_b	0.3-0.8	0.55
Top mean thickness ratio t_t/t_m	0.7-1.0	0.85

Table 6.1 – Chimney parameters

These values determine the section of the chimney which is given below with the dimensions of the various parameters.

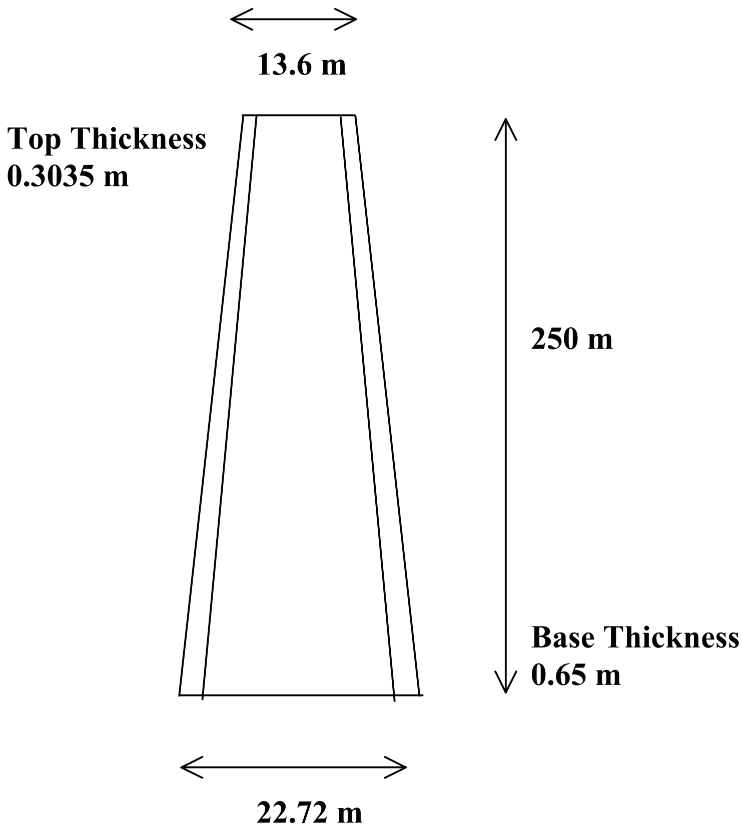

Figure 6.1 – The chimney

Checking the viability of the cross section

Taking the values of the forces as follows, which have been calculated in the earlier chapters. It may be noted that this calculation is for the worst case of the wind load.

Moment = 1552.8 MNm

Axial force = 175 MN

Calculating the values of 'm' and 'n' to be used in the design charts, assuming M30 concrete.

m = 3.089

n = 3.955

The parameter value for use in the design charts without the value of the steel comes to

Parameter = 13.83 (percentage of steel)

With 1% steel, using the curve with a parametric value of 15.56 – **the cross section is safe**.

The design

Fe415 steel

M30 concrete

Steel = 1%

Since the loads and other effects are totally reversible, the steel must be applied equally on both faces of the chimney shell. Hence each face has 0.5 percent of the steel. The detailing is done as follows and the figure is given later.

Using bars of 25mm diameter

Area of a meter length (circumferential) of the chimney = $6500mm^2$

Area of reinforcing bar = $490.9\ mm^2$

Number of bars = 6.6

Spacing between the bars = 150 mm

Provide a cover of 75 mm on either face

This is the scheme to be followed for both the horizontal and the vertical reinforcement at the base of the chimney. The changes to be done are given below

Curtailment

Since the chimney tapers with height, the area of concrete available decreases along with the reinforcement requirement. Hence the vertical steel needs to be curtailed in stages. The following scheme may be followed for the same.

Curtail 1 out of every 6 six bars at about a height of 120m. Curtail a second bar out of the original six (now five) at a height of 200m.

The horizontal steel also needs to be changed with increase in height. Since increasing the spacing alone is not a good option, keeping in mind the requirements of temperature gradient and for preventing the surface cracks. Hence increase in spacing needs to be coupled along with decrease in diameter.

Increase spacing to 180mm after a height of 100m. from a height of 150m use 20mm diameter steel bars at the initial spacing of 150mm. From 200m onwards use 20mm bars at 180mm center to center.

The following is a sketch of the reinforcement details at the base of the chimney.

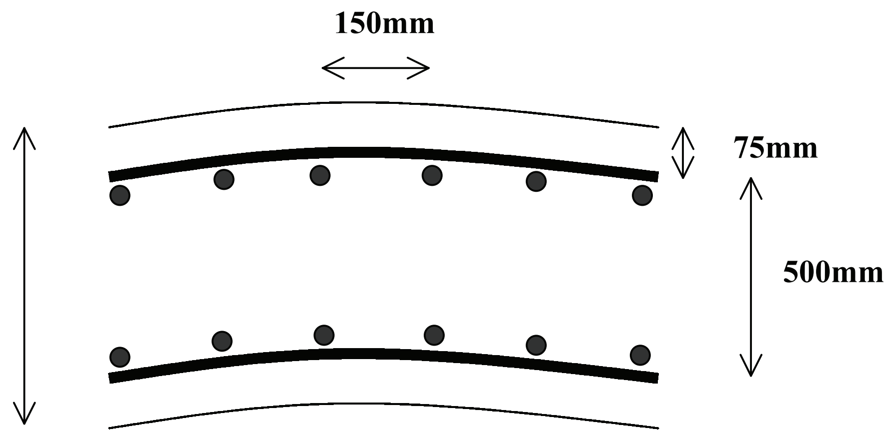

Figure 6.2 – Sectional plan view – Vertical Reinforcement

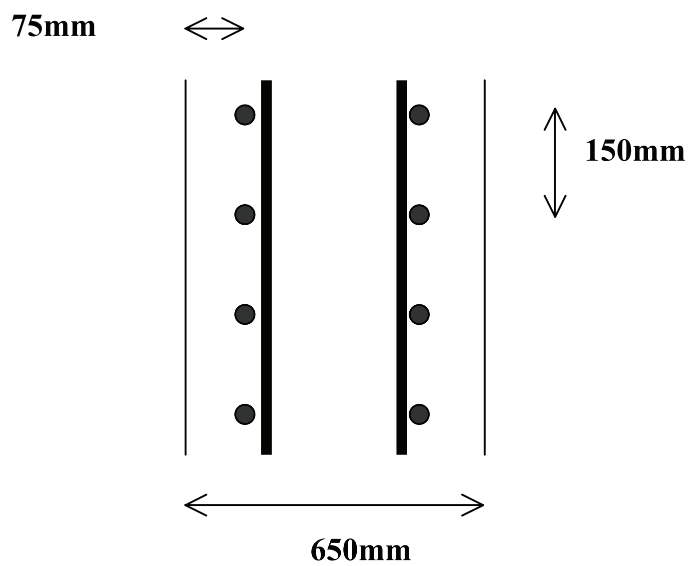

Figure 6.3 – Sectional elevation view – horizontal Reinforcement

6.3 Design of foundation

<u>Load effects</u>

Deal load = 175 MN

Wind load = 1553 MNm

Earthquake load = 800 MNm (Not Critical)

For no tension design we consider

$$\frac{W}{A} = \frac{M}{Z}$$

Where the load is W, and the moment is M

The area A is given by

$$A = \pi \frac{D^2}{4}$$

And the value of Z is

$$Z = \pi \frac{D^3}{32}$$

Substituting and calculating

Diameter = 70.99m

Adopt a smaller diameter and not go for a no-tension approach.

Adopt a diameter of 60m

A rough diagram of the chimney base is shown here

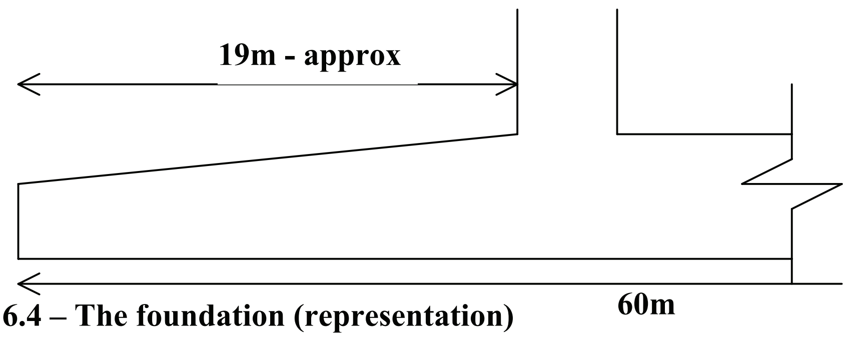

Figure 6.4 – The foundation (representation)

Apportioning the chimney base

The stress distribution on the base of the chimney is calculated by trial and error method. The maximum permissible stress of the soil is assumed to be 300 kN/mm^2 (assuming a rock strata)

The force diagram looks like

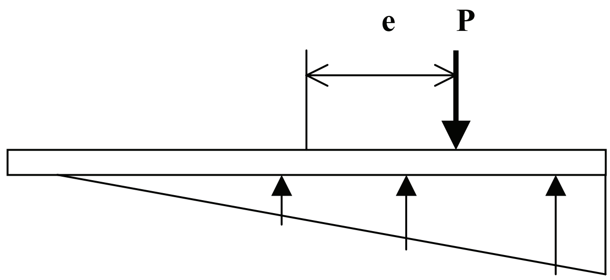

Figure 6.5 – Load and eccentricity

The value of the eccentricity is 9.1m

With a liftoff are segment of 4 meters the resistance capacities are

F = 189476 kN

P = 39.18 from the left of the diagram. Hence the eccentricity of 9.1 meters (total of 30+9.1 = 39.1m) is taken care of.

The loads are calculated keeping in mind the distribution of loads that occur on the foundation as shown

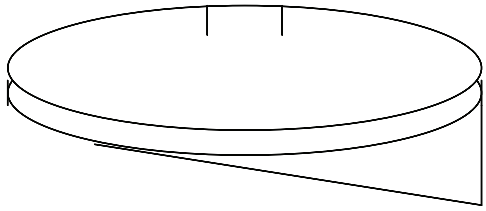

Figure 6.6 – Actual loading pattern

Calculating the maximum moment from the cantilevered part of the chimney

$$M = \frac{W}{8\pi}\left[2\ln(\frac{a}{b}) + 1 - \left(\frac{b}{a}\right)^2\right] - \frac{3}{16}w\left(a^2 - b^2\right)$$

Where

$$w = \frac{4W}{\pi D^2}$$

Moment acting at the base = 11 MNm

Required d_{eff} = 1.795m

Assume 75mm cover

Use a total depth of 2m under the shell of the chimney

Taper the thickness of the foundation to 600mm at the end of the chimney

Reinforcement

Although the footing is circular, the reinforcement is provided orthogonal.

Calculating the steel requirement

Pt/100 = 3.5%

Provide 30mm bars at 100mm center to center

The moment acting on the other direction is due to the landfill and is not very high. Hence providing a nominal reinforcement on the sloping side of the foundation.

Provide 12mm bars at 150 centers.

Also take a local thickening of the shell to take care of transfer of loads. Hence the final detailing of the foundation and the base connection is given below

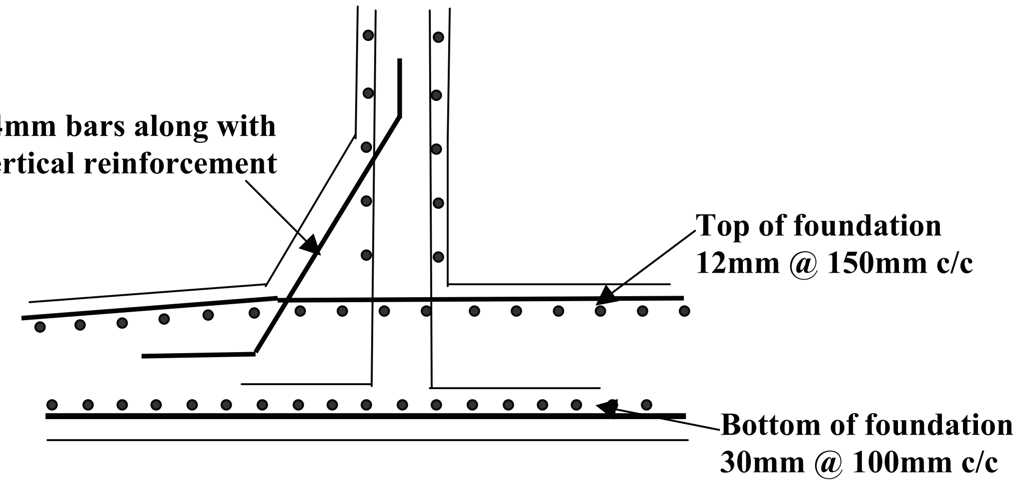

Figure 6.7 – The foundation and the connection

Design of Staircase

A staircase of independent tread slabs can be constructed inside or outside the chimney for the purpose of maintenance and cleaning etc. The cross section of such a stair is given below. The end of the stair is embedded into the shell.

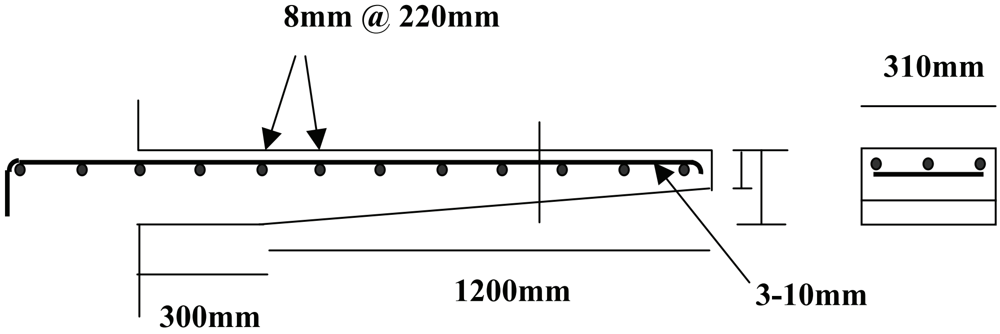

Figure 6.8 – Design of staircase tread

6.4 - Conclusion

The example chimney has been designed and the reinforcement requirements and other details worked out. The foundation for the chimney has been designed too. The interaction curves developed were used in the process of design.