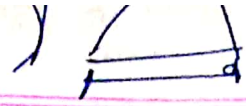
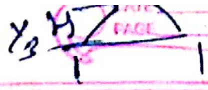


CHIMNEY



Q. Design for Delhi a Self Supporting Steel Stack of Ht 72m above the foundation. the diameter of the cylindrical part of the chimney is 3m. the foundation has to rest on medium Soil having bearing capacity of 200 KN/m². the thickness of fire brick work lining is 100 mm, and the lining is Supported by the Stack throughout the height. the chimney has one breech opening. the topography at the site is almost flat, and the location is of terrain category 2.

Solution

Step 1 Basic Dimension of chimney

(a) Total Ht of chimney = 72m

(b) Height of Flare $= \frac{1}{3}H = \frac{1}{3} \times 72 = 24m$

(c) Diameter of the flare = 1.6×3 = 4.8m

Step-2 Computation of wind Pressure:-

For Computation of wind pressure, let us divide the entire Chimney into Section of 8m height

80 – 700 (1)

The design wind speed at any height z is given by

$$V_z = V_b \cdot k_1 \cdot k_2 \cdot k_3$$

The value of k_2 depends upon terrain category if the maximum dimension is greater than 50 m it is class C structure

k_1 = Risk coefficient
k_2 = terrain, ht. and structure size factor (c)
k_3 = Topography factor

$V_z = 47 \times 1 \times 1 \times k_2$

$V_z = 47 k_2$

$P_z = 0.6 V_z^2$

$= 0.6 (47 k_2)^2 \times 10^{-3}$ kN/m²

$= 1.3254\, k_2^2$ kN/m²

for chimney adapting shape factor of 0.7

$P_z = (P_z \cdot D \Delta z)\, 0.7$

(1) Section 1 Ht to the top of Section 1,

H = 50 ⇒ k_2 = 1.10

H = 100 ⇒ k_2 = 1.17

$H_1 = 72$ m

Diameter of part 1, $D_1 = 3$ m

~~$k_2 = 1.10 + \frac{(1.17 - 1.10)}{(100-50)} \times (100-72)$~~

~~$k_2 = 1.10 + \frac{(1.17-1.10)}{(}$~~

$$K_2 = 1.17 - \frac{(1.17-1.10)}{(100-50)} \times (100-72)$$

$$\boxed{K_2 = 1.1308}$$

$$P_2 = 1.3254\, K_2^2$$
$$= 1.3254 \times (1.1308)^2$$
$$P_2 = \sout{1.6498\ kN/mm^2}\ 1.6948\ N/mm^2$$

$$P_1 = \sout{1.6498}\ 1.6948 \times 3 \times 8 \times 0.7$$
$$= 28.473$$

This act at a height of: $h_1 = 72 - 4 = 68m$ above the base

(ii) Section 2

$H_2 = \sout{100-64 = 3}\ 72 - 8 = 64$

$$K_2 = 1.17 - \frac{(1.17-1.10)}{(100-50)} \times (100-64)$$

$$K_2 = 1.1196$$

$$P_2 = 1.3254 \times (1.1196)^2$$
$$= 1.6614\ kN/m^2$$

$$P_2 = 1.6614 \times 3 \times 8 \times 0.7$$
$$= 27.911\ kN$$

$h_2 = 64 - 4 = 60$ m above the base

(iii) Section 3:

$H_3 = 64 - 8 = 56$

$K_2 = \cancel{1.17} - \frac{(\cancel{1}\ 0.07)}{50} \times (100 - 56)$

$K_2 = 1.1084$

$P_z = 1.3254 (1.1084)^2$
$= 1.6283$

$P_3 = 1.6283 \times 3 \times 8 \times 0.7$
$= 27.356\ kN$

This acts at a height of 56 − 4 = 52m above the base

(iv) Section-4

$H_4 = 58 - 8 = 48\ m$

$K_2 = 1.10 - \frac{(1.10 - 1.04)}{(\cancel{100 -}\ (50 - 30)} \times \cancel{(48)}\ (\overset{50}{\cancel{100}} - 48)$

$= 1.094$

$P_z = 1.3254 \times (1.094)^2$
$= 1.5863\ N/mm^2$

$P_4 = 1.5863 \times 3 \times 8 \times 0.7$
$= 26.65\ kN$

This acts at a ht of 48−4 = ~~36~~ 44m above the base

(v) Section−5:

$$H_5 = 48 - 8 = 40m$$

$$K_2 = 1.10 - \frac{(1.10 - 1.04)}{(50 - 30)} \times (50 - 40)$$

$$= 1.07$$

$$P_z = ~~1.35~~ 1.3254 \times (1.07)^2$$
$$= 1.5174 \; KN/m^2$$

$$P_5 = 1.5175 \times 3 \times 8 \times 0.7 = 25.473 \; KN$$

This acts at a ht of 40 − 4 = 36m above the base

(vi) Section−6

$$H_6 = 40 - 8 = 32$$

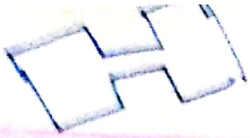
$$K_2 = 1.10 - \frac{(1.10 - 1.04)}{(50 - 30)} \times (50 - 32)$$

$$= 1.046$$

$$P_z = 1.3254 \times (1.046)^2$$
$$= ~~1.5~~ 1.450 \; KN/m^2$$

$$P_6 = 1.450 \times 3 \times 8 \times 0.7 = 24.362$$

This acts at a ht of 32 − 4 = 28m above the base



$\frac{3.6+3}{2}$

0.6

3.6

Section 7

$H_7 = 32 - 8 = 24$

$K_2 = 1.04 - \frac{(1.04 - 1.00)}{(30-20)} \times (30-24)$

$K_2 = 1.016$

$D = \frac{4.8-3}{3} = 0.6$

$= \frac{3+3.6}{2} = 3.3$

$P_z = 1.3254 \times (1.016)^2$
$= 1.3682\ kN/m^2$

$P_7 = 1.3682 \times 3.3 \times 8 \times 0.7$
$= 25.283\ kN$

This acts at a height of 24-4 = 20 m above the base

(iii) Section 8:

$H_8 = 24 - 8 = 16\ m$

$D_8 = \frac{1}{2}(3.6 + 4.2) = 3.9\ m$ $\quad (3.6+0.6)$

$K_2 = 1.00 - \frac{(1.00 - 0.97)}{(20-15)} \times (20-16)$
$= 0.976$

$P_z = 1.3254 \times (0.976)^2$
$= 1.2625\ kN/m^2$

$P_8 = 1.2625 \times 3.9 \times 8 \times 0.7$
$= 27.574$

This acts at a ht. of 16−4 = 12 m above the base

(ix) Section 9:

$H_9 = 8\,m$

$D_9 = \frac{1}{2}(4.2+4.8) = 4.5\,m$

$k_2 = 0.93$

$P_2 = 1.1463\ kN/m^2$

$P_9 = 1.1463 \times 4.5 \times 8 \times 0.7 = 28.888\ kN$

This acts at a ht of 8−4 = 4 m above the base

Step-3 Determination of overturning moments due to wind force

(i) Moments at the base

$M_{W1} = P_1 \cdot h_1 = 28.473 \times 68 = 1936.16\ kN\text{-}m$

~~M_{W2}~~ $M_{W2} = P_2 \cdot h_2 = 27.911 \times 60 = 1674.67\ kN\text{-}m$

$M_{W3} = P_3 \cdot h_3 = 27.356 \times 52 = 1422.51\ kN\text{-}m$

$M_{W4} = P_4 \cdot h_3 = 26.65 \times 44 = 1172.60\ kN\text{-}m$

$M_{w5} = P_5 . h_5 = 25.493 \times 36 = 917.754 \, kN\text{-}m$

$M_{w6} = P_6 . h_6 = 24.362 \times 28 = 682.14 \, kN\text{-}m$

$M_{w7} = P_7 . h_7 = 25.283 \times 20 = 505.66 \, kN\text{-}m$

$M_{w8} = P_8 . h_8 = 27.574 \times 12 = 330.89 \, kN\text{-}m$

$M_{w9} = P_9 . h_9 = 28.888 \times 4 = 115.55 \, kN\text{-}m$

Total $(M_w) = 8757.93 \, kN\text{-}m$

(b) Moment at Section $X_1 X_1$

$M_{w x_1 x_1} = 28.473 \times 4 = 113.892 \, kN\text{-}m$

(c) moment at Section $X_2\text{-}X_2$

$M_{w x_2 x_2} = (28.473 \times 12) + (27.911 \times 4) = 453.32 \, kNm$

(d) Moment at Section $X_3 X_3$

$M_{w x_3 x_3} = (28.473 \times 20) + (27.911 \times 12) + (27.356 \times 4)$

$= 1013.82$

(e) moment at section $x_4 x_4$

$M_{w x x_4} = (28.473 \times 28) + (27.911 \times 20) + (27.356 \times 12) + (26.65 \times 4)$
$= 1790.34$ kN-m

(f) Moment at section $x_5 x_5$

$M_{w x x_5} = (28.473 \times 36) + (27.911 \times 28) + (27.356 \times 20) + (26.65 \times 12)$
$+ (25.493 \times 4)$
$= 2775.43$ kN-m

(g) Moment at section $x_6 x_6$

$M_{w x x_6} = (28.473 \times 44) + (27.911 \times 36) + (27.356 \times 28) + (26.65 \times 20)$
$+ (25.493 \times 12) + (24.362 \times 4)$
$= 3958.94$ kN-m

(h) moment at section $x_7 x_7$

$M_{w x x_7} = (28.473 \times 52) + (27.911 \times 44) + (27.356 \times 36) + (26.65 \times 28)$
$+ (25.493 \times 20) + (24.362 \times 12) +$ (~~25.493×28~~) (25.283×4)
$= 5343.03$

(i) Moment at Section $x_8 x_8$

$M_{w x x_8} = (28.473 \times 60) + (27.911 \times 52) + (27.356 \times 44) + (26.65 \times 36)$
$+ (25.493 \times 28) + (24.362 \times 20) + (25.283 \times 12) + (27.574 \times 4)$
$= 6937.55$ kN-m

Step-4 Design of chimney Shell

Stress due to chimney wt., $f_s = 0.0785h$ N/mm²

Stress due to wt of lining, $f_l = 0.002\frac{h}{t}$ N/mm²

Stress due to wind, $f_w = \pm\frac{0.004 M_w}{\pi d^2 t}$ N/mm²

- Minimum thickness of shell from stability pt of view

$$= \frac{D}{500} = \frac{3\times1000\text{ mm}}{500} = 6\text{ mm}$$

- It is assumed that the design life of steel chimney shell will be 20 years and coal is used as fuel for boiler. Hence addition 4mm thickness to account for corrosion.

Hence

total minimum thickness of plate = 6+4 = 10 mm

(1) Design of Section 1:

$h = 8$ m at Section $x_1 - x_1$; $D = 3.0$ m

$M_{w\max_1} = 113.892$ kN-m

Effective $t = 10-4 = 6$ mm

$$\frac{D}{t} = \frac{3000}{6} = 500$$

$$\frac{he}{D} = \frac{8}{3} = 2.67$$

$\sigma_c = 58\ N/mm^2$

Taking efficiency of riveted joint in compression $\eta_1 = 1$, $\sigma_c \eta_1 = 58\ N/mm^2$

permissible tensile stress $= 0.6 f_y$

$= 0.6 \times 250 = 150\ N/mm^2$

Taking efficiency of riveted joint in tension, $\eta_2 = 0.7$, $\sigma_t \eta_2 = 150 \times 0.7$

$= 105\ N/mm^2$

$f_S = 0.0785 \times 8 = 0.63\ N/mm^2\ m^2$

$f_R = \frac{0.002 \times 8}{0.006} = 2.67\ N/mm^2\ m^2$

$f_{w} = \pm \frac{0.004 \times 113.892}{\pi \times (3.0)^2 \times 0.006} = \pm 2.69\ N/mm^2\ m^2$

$f_{c\,max} = 0.63 + 2.67 + 2.69 = 5.99\ N/mm^2 < 58$ hence safe

$f_{t\,max} = 2.69 - 0.63 = 2.06\ N/mm^2 < 105$ Hence safe

(ii) Design of Section 2

$\sigma_{cn_1} = 58\ N/mm^2$, $\sigma_{tn_2} = 150 \times 0.7 = 105\ N/mm^2$

$h = 16m$

$f_s = 0.0785 \times 16 = 1.26\ N/mm^2$

$f_l = 0.002 \times \frac{16}{0.006} = 5.33\ N/m^2$

$f_w = \frac{\pm 0.004 \times 453.32}{\pi \times (3.0)^2 \times 0.006} = \pm 10.69\ N/mm^2$

$f_{c\,max} = 1.26 + 5.33 + 10.69 = 17.28 < 58$ Safe

$f_{t\,max} = 10.69 - 1.26 = 4.43 < 105$ Safe

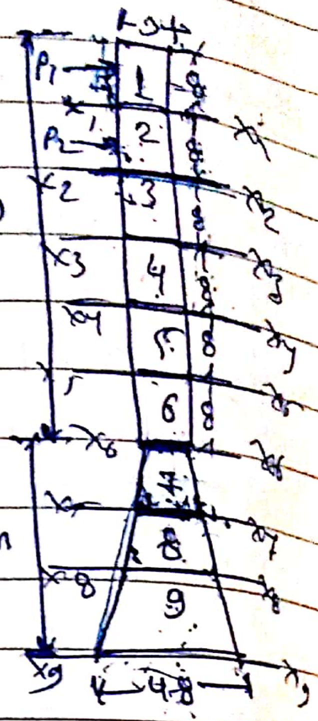
So All Section are Computed Same Procedure

Design-5 Design of base plate

the maximum Compressive force per unit circumferential length is calculated by the formula.

$$f_1 = \left(\frac{4M_W}{\pi \times d_1^2 \times t} + \frac{(W_s + W_L)}{\pi \times d_1 \times t} \right) \times (t \times 1) \text{ kN/mm}$$

$$= \left[\frac{4M_W}{\pi \times d_1^2} + \frac{(W_s + W_L)}{\pi d_1} \right]$$



$$W_s = f \times \pi \times d \times t \times h$$
$$= 79 \times \pi \times 4.8 \times 6 \times 0.072$$
$$= 514.63$$

$$W_L = 2 \times \pi \times d \times h$$
$$= 2 \times \pi \times 4.8 \times 0.072$$
$$= 2.171$$

$$f_1 = \left(\frac{4 \times \sout{514.63}\ 8757.93}{\pi \times 4.8^2} + \frac{(514.63 + 2.171)}{\pi \times 4.8} \right)$$

$$= \sout{483.98 +}$$
$$= 518.25 \text{ N/mm}$$

$A = l \times b$

$= l \times 129.56$

width of base plate $= \frac{518.25}{4} = 129.56$ mm

Length of base plate $= \frac{129.56}{1.25}$

3

4.8

$\frac{4.8-3}{3}$

$= 0.6$

$3+0.6 = 3.6$

$\frac{3+3.6}{2} =$

Step-6 Design of Anchor Bolts

The maximum tensile force per unit length of circumference

$$F_2 = \left(\frac{4M_{w}}{\pi d_1^2} - \frac{W_s}{\pi \times d_1}\right)$$

$$= \left(\frac{4 \times 8757.93}{\pi \times 4.8^2} - \frac{514.63}{\pi \times 4.8}\right)$$

$= 483.98 -$

$= 449.85$ N/mm^2

Provide 20 mm dia anchor bolt

Area at the root of thread $= \frac{\pi}{4} \times d^2$

$= \frac{\pi}{4} \times (20)^2$

$= 314.15$ mm^2