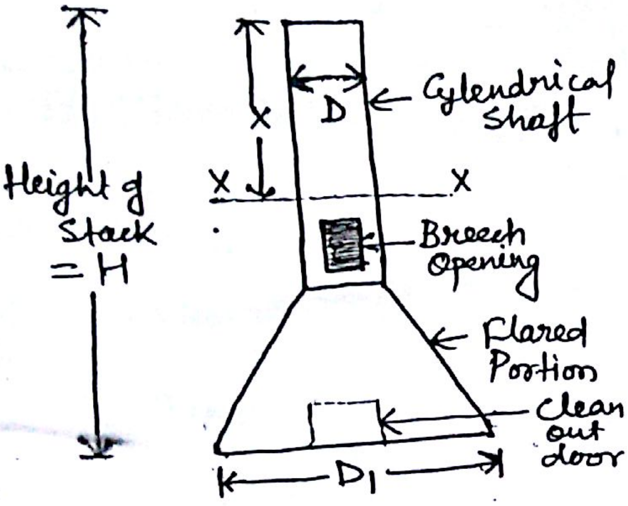
STEEL STACK

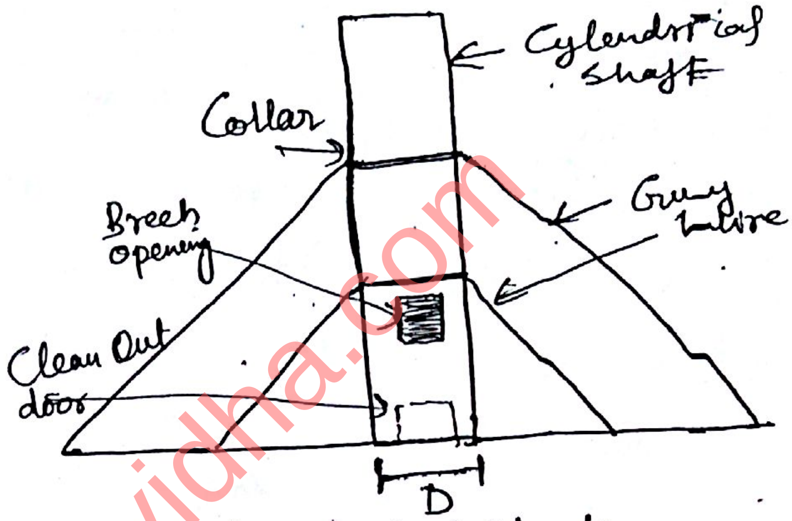
* **DRAFT :-** It is the diffrence in pressure (absolute gas pressure − ambient atmospheric pressure) available for producing a flow of gas. It depend on the height of stack, height of stack above mean sea level, nature of fuel, temprature of gases and furnanced used.

* **Types of Stacks :-** (1) Self Supported (2) Guyed



(1) Self Supported

When the lateral force (wind, seismic etc) are transmitted to foundation by cantilever action.
Used for more heights (≥ 75 m)



(2) Guyed steel stack.

When lateral force (wind, seismic) are partly transmitted through guy wire (one, two, three set attached to stack at diffrent height).
Used for low heights

* **Proportioning of Stack :-**

Inside ~~Shaft~~ dia of shaft $D = \sqrt{\frac{4Q}{\pi V}}$

Q = Quantity of flue gas (m³/s)
V = Velocity of flue gas (m³/s)

Recommendation of Height of Stack,

$H = 74 (Q_p)^{0.27}$ → For emmission of particular matter

$H = 14 (Q_s)^{1/3}$ → For emmission of SO_2

For Self Supporting stack,
ht. of flare from ground = $\frac{1}{3}$ to $\frac{1}{4}$ of total stack ht
Bottom Dia of flare = 1.25 × shaft dia (at least)

Forces w.r.t. a stack:

1) Self wt. of steel stack (2) Wt of lining (3) Wind Pressure
(4) Seismic force.

1> Self wt of steel Stack: (W_s): It act vertically downward and is given by. consider a section X–X.

$$W_s = \rho \pi D t h = 79 \times (\pi D t h) \text{ kN}$$

ρ = Unit wt of steel = 79 kN/m³
D = Dia of stack (m)
t = thickness of steel plate (m)
h = height of steel stack above section XX

Stress due to self wt of stack

Compressive stress, $\sigma_s = \frac{W_s}{\pi D t} = \frac{79 \pi D t h}{\pi D t}$ kN/m² $= 0.079\, h$ N/mm²

2> Wt of Lining: It act vertically downward. The thickness of brick lining may be assumed 100mm. The wt of lining

$$W_L = \rho_1 \pi D (0.1) h = 2\pi D h \text{ (kN)}$$

$\rho_1 = 20$ kN/m³

Stress due to wt of lining

$$\sigma_L = \frac{W_L}{\pi D t} = \frac{2\pi D h}{\pi D t} \text{ kN/m}^2 = 0.002\left(\frac{h}{t}\right) \text{ N/mm}^2$$

3> Wind Pressure (P): It depend on shape, width, height, location of structure and climatic condition. The wind pressure per unit area increases with the height of the structure above ground level. The wind pressure on the flared portion may be found by using avg. dia of flare. The wind force.

$$P = k\, p_d \times \text{projected area of stack} = 0.7\, p_d D h \text{ (kN)}$$

k = shape factor, p_d = design wind pressure, D = Outer dia of stack

h = ht. of the segment of stack over which the wind force is required

Stress due to Wind

M_W = Moment due to wind $= P \times \frac{x}{2}$

x = ht. of stack above section under consideration

$$\sigma_m = \frac{M_W}{I} \times \frac{D}{2} = \frac{M_W}{Z} = \frac{4 M_W}{\pi D^2 t}$$

Z = Section Modulus $= \pi D^2 t / 4$

Seismic force :- ↳ The seismic force also act horizontally. The seismic forces act on a structure, when the structure are located in the seimic areas.

LOAD COMBINATION FOR STEEL STACK :- ↳

i> Dead load + Wind load
ii> Dead load + Seismic load
iii> Dead load + live load + Wind load + Temp Effect
iv> Dead load + Live load + Seismic load + Temp Effect

DESIGN STEPS FOR SELF SUPPORTING STEEL STACK

1) The diameter and height of a steel stack are fixed

$$D = \sqrt{\frac{4Q}{\pi V}} \quad \text{and} \quad H = 74(Q_P)^{0.27}$$
$$H = 14(Q_s)^{1/3}$$

2> STEP2 : Design of flare

Height of flare $= H' = \frac{H}{3}$ to $\frac{H}{4}$

Dia of flare at base $= D_1 = \nless 1.25 D$

H = Ht. of stack , D = Dia of shaft

3 STEP3 DESIGN OF thickness of steel plate forming stack

Since the wind pressure along the ht. of stack varies, increasing with height, the design for thickness of steel plates of stacks is simplified by deviding the cylendrical portion of stack in to seagments of equal height. The number of section on the stack is chosen using a plate width of 0.9 to 2.5 m.

The thickness of steel plate is designed for the various seagments and section of the stack shaft for windward and leeward side using the expression given below.

The windward side of the stack is subjected to tensile stress due to combined effect of wind and self wt of steel plates.

$$\sigma_{t,cal} = \frac{4M_w}{\pi D^2 t} - \frac{W_s}{\pi D t} \; (kN/m^2) < \eta_1 \times 0.6 f_y$$

The leeward side of stack is subjected to compressive stress due to wind and self wt of stack and lining.

$$\sigma_{c,cal} = \frac{4M_w}{\pi D^2 t} + \frac{W_s}{\pi D t} + \frac{W_L}{\pi D t} \; (kN/m^2)$$

η_1, η_2 = Efficiency of the joint on tension and compression side

ETY Design of Base ... (leeward side)

The max compressive stress at base plate is on leeward side

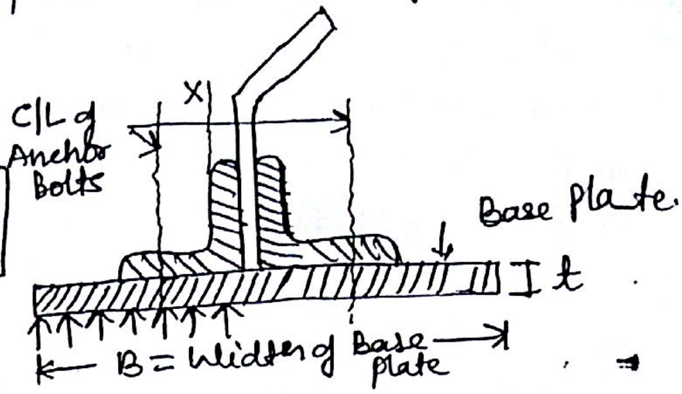
$$\sigma_{c,cal} = \left[\frac{4M_W}{\pi D_1^2 t} + \frac{W_S}{\pi D t} + \frac{W_L}{\pi D_1 t}\right] (kN/m^2)$$

The maximum compressive strength per unit circumferential length, $f_1 = \sigma_{c,cal} \times t$ (kN/m)

The width of base plate,

$$B = \frac{f_1}{\sigma_{p1}}$$

[p_1 = allowable bearing pressure on foundation]



B.M at the critical section x-x,

$$M = \frac{wc^2}{2}$$

Moment of resistence at the critical section x-x,

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

For equillibirium, $M = M_R$

$$\frac{wc^2}{2} = \frac{t_1^2}{6}\sigma_{bs} \quad \text{and} \quad t_1 = c\sqrt{3w/\sigma_{bs}}$$

t_1 = total thickness available at critical section.

t_a = thickness of angle section, σ_{bs} = bending stress in slab = 185 N/mm²

STEP5 Design of Anchor Bolts

~~In self supporting st~~ Anchor bolts are provided to check the uplift. Anchor bolts are normally provided on the base plate from both the inside and outside of stack.

Maxium tensile stress at the base plate on the windward side will be when the lining is absent.

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

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

$$f_1 = \sigma_{t,cal} \times (t \times 1) = \sigma_{t,cal}\, t$$

$$f_1 = \left[\frac{4M_W}{\pi D_1^2 t} - \frac{W_S}{\pi D_1 t}\right] t$$

Maximum uplift force to be resisted by anchor bolts

$$F_2 = f_1$$

Spacing of anchor bolts, $S = \frac{R_t}{F_2}$, $S = \frac{R_t}{\left[\frac{4M_W}{\pi D_1^2} - \frac{W_S}{\pi D_1}\right]}$

EP6: 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 side pyramid. The depth of foundation should not be less than 0.4 times dia of foundation (D_2). Also, for no tension at the base, maximum eccentricity (e) is limited to $D_2/8$. The dia of the foundation is determined as.

$$e = D_2/8 = \frac{M_w}{W_s + W_L + W_F} \Rightarrow \boxed{M_W = \frac{D_2}{8}[W_s + W_L + W_F]}$$

$\boxed{W_F = \text{Wt. of footing}}$ $\boxed{D_2 = \text{Dia of base pedestal}}$

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

$$M_W = \frac{D_2}{8}\left[\frac{\pi}{4}D_2^2 \times 0.4 D_2 \times 24\right] \Rightarrow \boxed{D_2 \simeq M_W^{1/4}}$$

EP7 CHECK FOR THE STABILITY OF STACK

Stability is checked by

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

σ_w = Stress due to wind load

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

σ_d = Stress due to dead load

σ_a = Permissible stress.

GUYED STEEL STACK :-

Classification :- <i> Stack with one set of guy (usually 3 or 4 and sometimes 6 wires) attached to a collar at one third or one quarter of distance from top.

ii> Stack with two sets of guys, usually 3 or 4 wires each, attached to collar at various height.

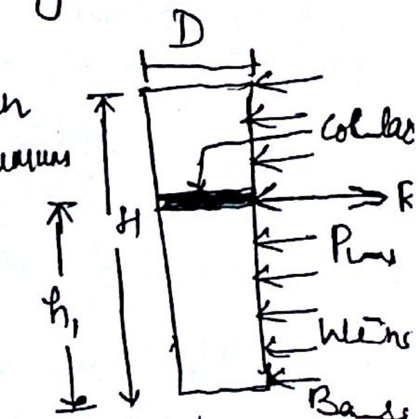
iii> Stack with three set of guys usually 3 or 4 wires each, attached to collar at various height

iv> Stacks in a continuous row with lattice bracing b/w them.

Pull on Guy Wire :-

The max pull in any guy wire will occur when the wind blows along that guy wire. This maximum pull 'P_g' may be

$$P_g = R_c/\sin\theta = R_c \operatorname{cosec}\theta$$



Horizontal forces acting on a guyed steel stack

the vertical component of the pull in the guy wire

$$= P_g\cos\theta = \frac{R_c}{\sin\theta} \times \cos\theta = R_c\cot\theta$$

STEP 1 The number of collars and the number of guy wires to be attached with each collar are selected.

STEP 2 The angle (b/w 30° to 70°) with the vertical that the guy will make is assumed and horizontal wind reaction R_c, at upper collar is determined. Max Pull in the guy

$P_g = R_c \operatorname{cosec}\theta$ is calculated, when the wind blows along it.

Total pull in guy wire = P_g + pull due to initial tension in guy wire

STEP 3 The total max vertical components of the pull of the guy at the upper collar are calculated. The same force may be assumed to act at lower collar. This assumption is safe.

STEP 4 The thickness of plate in the upper portion of stack is designed

Maximum Tensile Stress, $\sigma_{t_1,cal} = \frac{4M_{c_1}}{\pi D^2 t} - \frac{W_{s_1}}{\pi D t} < \eta_1 \times 0.6 f_y$

Max Compressive Stress, $\sigma_{c_1,cal} = \frac{4M_{c_1}}{\pi D^2 t} + \frac{W_{s_1}}{\pi D t} < \eta_2 \eta_c$

M_{c_1} = Moment at collar, W_{s_1} = Wt. of stack above top collar

Thickness of steel plate will be max out of above two, and should be > 6 mm.

STEP 5 The section designed is checked in shear. The horizontal shear just above and below the upper collar are calculated, and the critical one is divided by the net cross sectional area. This should be less than permissible shear stress.

STEP 6 The thickness of the plate of stack b/w the upper and lower collar is designed. The max tensile occur just below upper collar

$$\sigma_{t_2,cal} = \frac{4M_{c_2}}{\pi D^2 t} - \frac{W_{s_2}}{\pi D t} - \frac{P_g}{\pi D t} < \eta_1 \times 0.6 f_y$$

The max compressive stress will occur on a section just above the lower collar.

$$\sigma_{c_2,cal} = \frac{4M_{c_2}}{\pi D^2 t} + \frac{W_{s_2}}{\pi D t} + \frac{P_g}{\pi D t} < \eta_2 \sigma_c$$

The thickness of steel that comes out to be max from above two.

STEP 7 Max shear stress is calculated and checked, and should be less than permissible shear stress.

TEP 8 The thickness of plate to be used in lowest portion of the stack is designed as.

Max tensile stress will occur just below lower collar.

$$\sigma_{t_3,cal} = \frac{4M_{c_3}}{\pi D^2 t} - \frac{W_{s_2}}{\pi D t} - \frac{P_g}{\pi D t} < \eta_1 \times 0.6 f_y$$

Max compressive stress will occur just above the base.

$$\sigma_{c_3,cal} = \frac{4M_{c_3}}{\pi D^2 t} + \frac{W_{s_3}}{\pi D t} + \frac{P_{g_1}}{\pi D t} < \eta_2 \times \sigma_c$$

M_{c_3} = Max moment in this section

W_{s_3} = Wt of stack above base

P_{g_1} = Total sum of vertical component of pull of guys at the upper and lower collar.

TEP 9 The foundation of stack is designed as a concrete pedestal.