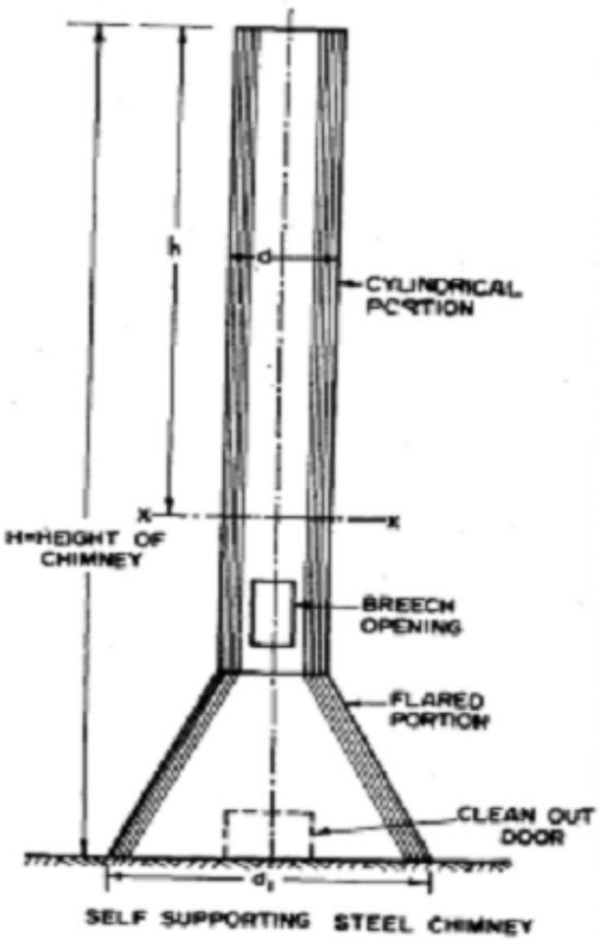
DESIGN OF STEEL STACKS

Chimney or stacks can be classified into two types:

1. Self supporting
2. Guyed steel stack

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 upto 10 m diameter and from 50 m to 100m in height.

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, then these are used at various heights.


h
d
CYLINDRICAL
PORTION
X
X
H=HEIGHT OF
CHIMNEY
BREECH
OPENING
FLARED
PORTION
CLEAN OUT
DOOR
SELF SUPPORTING STEEL CHIMNEY

FORCES ACTING ON STEEL CHIMNEY

The various forces acting on the self-supporting steel chimney are as follows:

1. Self-weight of the steel chimney
2. Weight of lining
3. Wind pressure
4. Seismic forces,

Self-weight of the chimney.

The self-weight of steel chimney, *Ws* acts vertically.

Consider a horizontal section XX as shown in Fig1. The thickness of steel plates of chimney above the section *XX,* may be assumed constant. The self-weight of chimney is given by

$$w_s = \rho \cdot (\pi d) \cdot t \cdot h$$

Unit weight of steel = 79 *kN/m3*

d = Diameter of chimney in meters

t = Thickness of steel plates in meters

h = *Height* of steel chimney above the section XX in meters

$$w_s = 79 \cdot (\pi d) \cdot t \cdot h$$

The compressive stress in the steel plates at the section XX due to the self weight of chimney is, given by

$$f_{s1} = \frac{w_s}{\pi dt} = \frac{\rho \cdot (\pi d) \cdot t \cdot h}{\pi dt} = 0.079h\,(N/mm^2)$$

Weight lining.

The weight of the lining in the steel chimney W_L, also acts vertically. The thickness of brick lining may be assumed as 100 mm.

The weight of brick lining,

$$w_L = \rho_1 \cdot (\pi d) \cdot (0.1) \cdot h$$

Unit weight of brick lining = 20 kN/m^3

The compressive stress in the steel plates at the section *XX* due to the weight of lining

$$f_{s2} = \frac{w_L}{\pi dt} = \frac{20 \cdot (\pi d) \cdot (0.1) \cdot h}{\pi dt} = 0.002\left(\frac{h}{t}\right)$$

Wind pressure:

The wind pressure acts horizontally. The wind pressure acting on a structure depends on the shape of the structure, the width of the structure, the height of the structure, the location of the structure, and the climatic condition. The wind pressure per unit area increases with the height of the structure above the ground level. In order to simplify the· design, the steel chimney is divided into number of segments of equal height. Each segment may be kept equal upto 10 m. The intensity of wind pressure in throughout the area of each segment may be assumed as uniform. The intensity of wind pressure corresponding to the mid-height of each segment may be noted from IS: 875-1984. The wind pressure on the flared portion may be found by using average diameter. The wind pressure is assumed to act at the mid-height of each segment and as also in the flared portion. It has also been practice *to* take uniform wind pressure over the full height of chimney. The wind pressure

P = kxPlx(d'xh1) (projected area of chimney)

k = Shape factor. It accounts for the shape of the structure; the shape factor for cylindrical portion is 0.7.

PI = Intensity of wind pressure

P =0.7(PIx *d'x* h1)kN

where, *d'* = Outer diameter of the chimney.

In addition to the overturning effect due to wind pressure, the wind has also aerodynamic effect. The aerodynamic effect of wind has, not been taken into consideration for the design of steel chimney.

Design a welded self-supported steel stack located in the outskirts

Of Bhopal for the following data.

Terrain category	2
Topography	Almost flat
Height of steel sack	80m
Dia of steel stack	3m
Thickness of Brick lining	100mm

DESIGN OF FLARE:

Height of flare = H/4 = 20m

Diameter of flare d_1 = 4/3 x 3 (not less than 1.25 D)

CALCULATION OF WIND LOAD:

Basic wind speed V_b = 39m/sec (Bhopal)------> pg-53 IS875 PART 3

Assume Ht of each section be 10m

K1 = Risk factor

K2 = Terrain factor

K3 = Topography factor

Divide the height of chimney into various segment such a way that every 10m is a segment with 0-0 ,1-1,2-2,3-3... etc.

SEGMENT 0-1:

For Ht = 80m, dia = 3m

Class of structure=C (Based height of the chimney)

Risk factor, K1 = 1 --------> table 11 pg 11

Topography factor K3 = 1

K2 = 1.1 + 0.07/50 x 30 = 1.142 -> (Pg 12)

Design velocity,

$V2 = K1\ K2\ K3\ V_b = 1 x 1.142 x 1 x 39 = 44.538$ m/s

Design wind pressure

$P2 = 0.6\ (V_2)^2 = 0.6 x (44.538)^2 = 1190 N/mm^2 = 1.19 kN/m$

Wind force in this segment

P1 = Kp2 x (project Area) = 0.7 x 1.19 x (10 x 3) = 24.99 KN

SIMILARLY FOR ALL SEGMENTS calculate wind pressure based on class of the structure

STRESS CALCULATION

Stress due to self weight of stack = $\sigma_s = 0.079h\ N/mm^2$

Stress due to lining (125 mm thick)

$\sigma_L = 0.002\ (h/t)\ N/mm^2$

Minimum Thickness of Shell from stability criteria t= D/500

= 3000/500

= 6mm

SEGMENT 1-1:

Height of steel stack above section 1-1, H_e = 10m

Dia of steel stack = 3m

Assume efficiency of but weld as 85% in tension side and 100% on compressive side, start with thickness of plate 6mm

Allowable tensile stress $\sigma_{st} = \eta x 0.6\ f_y$

based on D/t and H_e/D find σ_c from page 6 of IS6533 part 2

Bending moment due to wind ,$Mw = (p \times h/2)$

where P = Total wind force

$\sigma_m = Mw/(250\pi D^2 t)$

$\sigma_s = 0.079h \ N/mm^2$

$\sigma_L = 0.002 (h/t) \ N/mm^2$

Minimum tensile Stress at the section

$\sigma_{st} = \sigma_m - \sigma_s$

From the above equation find t value

Similarly calculate't' thickness for maximum compressive stress at the section

$\sigma_c = \sigma_m + \sigma_s + \sigma_L$

If't' calculate is less than the required provide required't'

SIMILARLY FOR ALL SEGMENTS calculate thickness based on Height of the structure

HOLDING DOWN BOLTS:

Try 45 mm Φ high tensile bolts with $f_y = 340 \ N/mm^2$

Allowable tensile Stress of bolts $= 0.6 f_y$

Find Strength of bolts and Spacing of bolts.

TENSION MEMBERS

GENERAL

Structural members subjected to tensile forces are known as tension members. IS 800:2007 describes Tension members in Cl. 6.1 as linear members in which axial forces act to cause elongation (stretch). The connections are made in such a way that the eccentricity of loading and bending stresses are avoided. Even though bending stresses may develop due to the self weight of the member, these stresses are very small and often neglected. However if bending stress is developed due to the eccentricity of connections or due to the incapability of the connections to create the above considerations, the additional stresses need to be accounted for as per specifications.

TYPES OF TENSION MEMBERS

Tension members can be classified into the following heads.

1. Wires, strands and cables

A strand consists of individual wires wound helically around a central core. A wire rope consists of a number of strands wound helically around a core. Cables are group of individual strands wound helically around a core.

2. Bars and rods

Bars and rods are straight member which have considerable cross section. These can be either circular square or rectangular in cross section. Unlike cables, wires and strands, they are used individually as structural members. They are often bolted to the other members by means of threaded ends.

3. Plates and flat bars.

They are very commonly used. Plates are members where one dimension (thickness) is very small in comparison with the other dimensions. Flat bars are usually rectangular in cross section and the cross sectional dimensions are comparable where as the length is very large in comparison with the cross sectional dimension.

4. Structural sections

Standard structural steel sections like angles are also used as tension members. These are available in standard dimensions and length.

5. Built up sections

Built-up sections are also used very frequently in construction. These are formed by using a combination of more than one standard sections and/or plates.

FAILURE MODES FOR TENSION MEMBERS

Tension members, as described in IS 800:2007, can sustain loads up to the ultimate load, at which stage they may fail by rupture at a critical section. However, if the gross area of the member yields over a major portion of its length before the rupture load is reached, the member may become non-functional due to excessive elongation. Plates and other rolled sections in tension may also fail by block shear of end bolted regions also.

Lecture 06

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