DESIGN OF FINAL MOLASSES STORAGE TANK

by

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FINAL MOLASSES STORAGE TANK

- It is a larger diameter storage vessel and designs to store non-toxic , non-hazardous fluid.
- It is not a pressure vessel, therefore, designing is not similar as to other chemical pressure vessel e.g. evaporator, pan etc.
- Basic design criteria used is '**failure criteria**'.

FINAL MOLASSES STORAGE TANK

- Causes of failure

  1. Improper selection of 'Optimum Tank Proportion' (D/H ratio)

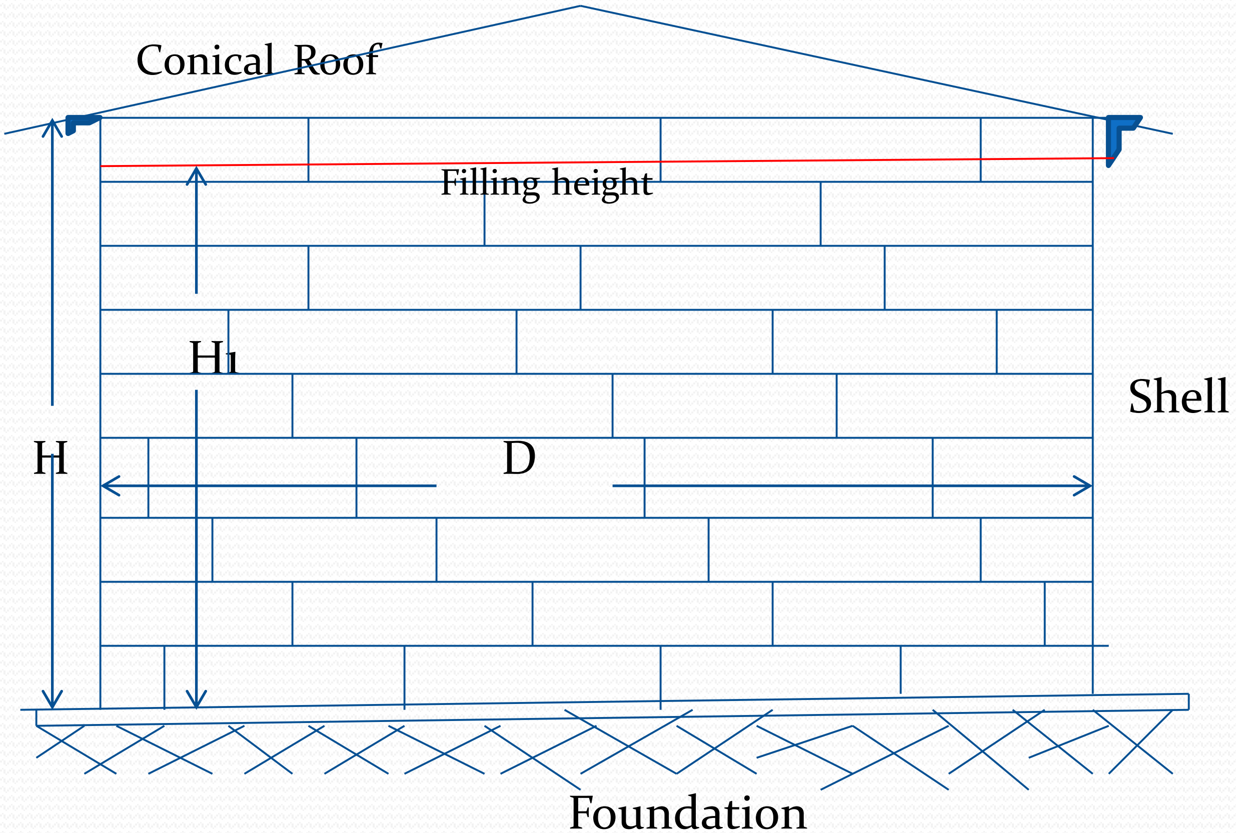
  2. Loosing of its roundness due to improper/lack of reinforcement to shell

  3. No proper compliance on welding procedures & welding standards

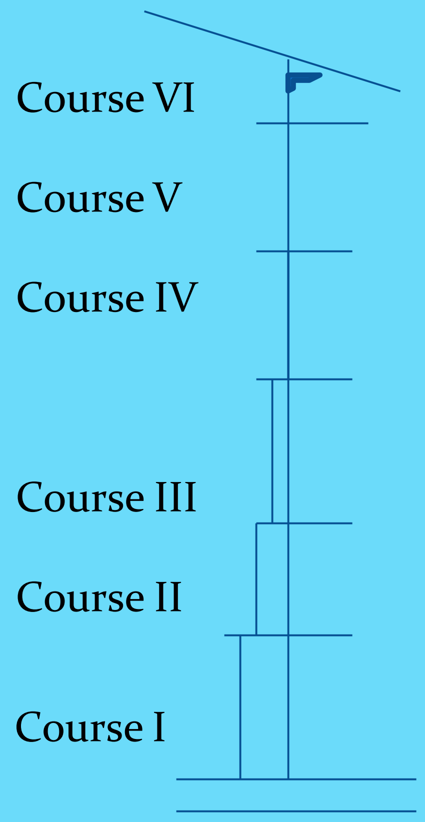
  4. Not maintaining of thickness of various courses

  5. No proper cooling resulting into 'Auto combustion' in stored molasses.

Molasses tank



Sectional view



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- Design parts

1. **Tank shell** - It is fabricated from MS plates welded each other longitudinal and transverse by butt joint.
2. **Tank bottom** – It is also fabricated from MS plates welded each other by lap joint

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3. **Tank conical roof-** It is also fabricated from MS plates welded each other by lap joint and supported on roof structure

4. **Auxiliaries** e.g. ladder, pipes & fittings, pump, surface cooling arrangement etc.

FINAL MOLASSES STORAGE TANK

- Code of practice

Following Indian/International Standards are practiced to design steel tank

1. IS: 5521-1980 – Specification for steel tanks for storage of molasses.

2. IS: 803-1962 – Code of practice for design, fabrication and erection of vertical mild steel cylindrical welded oil storage tanks.

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3. BS: 2654 : Part I -1956 Vertical mild steel welded storage tanks with butt-welded shells for the petroleum industry: Part I Design and fabrication.

4. API STD 650, sixth Edition- 1978 Welded steel tanks for oil storage.

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- Calculation for Number of tanks and their volume

a. Molasses production per season(M^3)

$$= \text{TCD x Fm x season days/ 100 x G}$$

Fm = Molasses % cane

G = Sp. Gravity of molasses(1.41)

b. Total volume required to store above molasses = 10 % higher of molasses produced.

c. Assume standard tank capacity e.g.

1250 m^3, 1500m^3, 2500m^3, 3500m^3, 4000m^3, 4500m^3, 5000m^3, 5500 m^3, 7500 m^3

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d. Number of tanks = Value of **b**/Value of **c**

e. Capacity of each tank will be as selected at c

- **Diameter and height of molasses tank**

a. Optimum tank proportion (D/H ratio)

Standard Value

2.0, 2.1, 2.2, 2.3, 2.4, 2.5

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b. Volume of tank (m^3) $= \dfrac{л \times D^2 \times H}{4}$

c. Select appropriate D/H ratio from above **a**

d. Calculate D and H

e. Calculate filling height H_1

Volume of molasses(m^3) $= \dfrac{л \times D^2 \times H_1}{4}$

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- **Width of the courses**

D/H	width of course(meter)
2.0	1.5
2.1	1.6
2.2	1.8
2.3	2.0
2.4	2.2
2.5	2.5

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- **Stresses on tank shell**

1. Longitudinal stress due to hydraulic pressure of molasses stored
2. Circumferential stress due to hydraulic pressure of molasses stored
3. Residual weld stress resulting from localized welding
4. Stress resulting from superimposed loads such as wind, snow, auxiliary equipments
5. stress due to thermal gradient

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- **Basic equation to calculate thickness of shell**

$$t = \frac{p\,D}{2fE} + c$$

t = thickness of tank shell

p = static pressure in tank

D = Inside dia. of tank

f = Allowable stress(1250 kg/cm^2)

E = Weld joint efficiency (0.85)

c = Corrosion allowance (1.5 mm)

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- **Shell testing is done by filling the tank with water to the level of top course**

therefore, $p = \omega H$

$\omega =$ density of water

$1000 kg/m^3$

$H =$ height of tank in meter

$(H - 0.3)$

$p = 1000 \times (H - 0.3) \ kg/m^2$

$0.1 (H – 0.3) \ kg/cm^2$

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- **Put the values in basic equation**

$$t = \frac{\{0.1\,(H - 0.3)D \times 100\} \times 10}{2 \times 1250 \times 0.85} + C$$

$$\mathbf{t = 0.04(H - 0.3)D + C}$$

t = shell thickness in mm

H = tank height in meter

D = tank diameter in meter

C = Corrosion allowance (1.5mm)

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- **Thickness of bottom plates**

  Keeping in view the static compressive load

  on bottom plates, it is taken as 12 mm thick MS plate irrespective of the size of tank.

- **Wind girder**

  It is provided to maintain tank roundness when tank is subjected to wind load. The size of wind girder is reduced when tank is closed

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by roof since it provides additional structure rigidity to upper course of shell

- **Size of wind girder**

a. 65 x 65 x 6 mm for tank diameter up to 12 m

b. 65 x65 x 8 mm for tank diameter > 12 m and up to 20 m

c. 75 x 75 x 10 mm for tank diameter > 20 m

Roof design

- **Conical Roof Design**
- **Slope of conical roof normally varies from 1 to 5 – 1 to 6**

a. Classification of conical roof:

I) Self supported roof – No structure is required. Roof load is supported on the shell of the tank. It is limited to tank diameter up to 8 meter.

II) Structural supported roof – Structure(only single column) is required up to 12 m diameter tank and for more than 12m diameter tank , multiple columns with rafters, girders are required

b. Stress on conical roof

$$f_s = \frac{pd}{2\,t\,\sin\theta} \qquad \text{-------------} \qquad 1$$

fs = stress on conical roof(kg/cm²)

p = External pressure(kg/cm²)

d = Diameter of roof in cm

t = Roof plate thickness

θ = Cone angle with horizontal

c. Failure of roof shall be due to elastic instability. The compressive stress at which failure of curved plate occurs by wrinkling is given by:

$$f_{critical} = \frac{E}{\sqrt{3(1-\mu^2)}}\,\frac{t}{r}$$

$$f_{allowable} = \frac{1}{12\sqrt{3(1-\mu^2)}} \, E \, \frac{t}{r} \quad \text{-------} \quad 2$$

E = modulus of elasticity

μ = Poissons ratio

t = thickness of roof plate

r = radius of curvature of cone

d. Equate equation 1 with equation 2 and calculate t i.e. thickness of roof plate

Thickness of roof plate under normal climate is recommended as 5 mm with no snow fall and 6 mm for region of snow fall

- **Structure design for structural supported roof**

  Structure of roof consists of :

  I) Rafter

  II) Girder

  III) Column

Rafters and girders are structural steel e.g. equal angle , channel or any formed section and considered as uniformly loaded beams with free ends

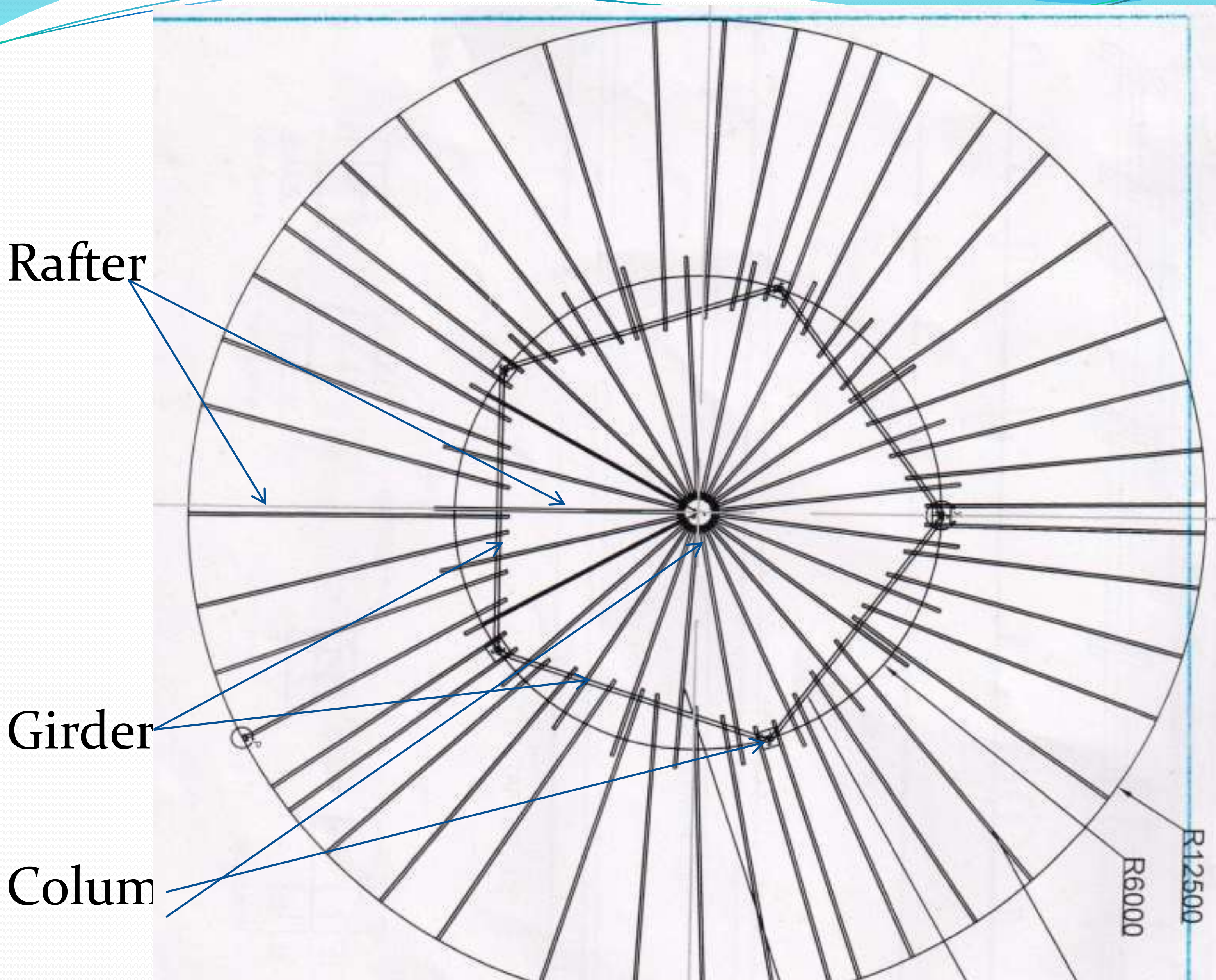

Fig- 1

b. Maximum length of rafter is recommended 6 meter and for girder it is 8 meter

c. Rafters are placed as shown in Fig-1 . These are supported on central column/Polygon of girders/shell of the tank as the case may be.

d. Rafters are placed at calculated rafter spacing and supported on centre column, polygon of girders and on shell of the tank.

e. Rafter spacing (l)

$$l = t\sqrt{2f/p}$$

t = thickness of roof plate

f = allowable stress(1250kg/cm^2)

p = load on roof(live + dead)

e. Live load = 125 kg/m^2 (wind, snow, person etc.)

Dead load = 40 kg/m^2 (wt. of roof plate)

f. first polygon of girder will be pentagon and second will be decagon

g. No. of polygon of girders required will be decided by the diameter of tank

h. The length of one side of polygon of girder having N sides will be :

$$L = 2R \sin (360/2N)$$

i. Calculate No. of rafters such that these should be multiple of 5

j. Find out No of columns which shall to be given at each junction of girders and on at centre of tank.

- **Selection of rafter, girder**

a. Maximum bending moment on rafter and girder (M)

$$M = w\,l^2 / 8$$

w = wt. on rafter/ wt on girder per linear length (kg/ m)

l = length of rafter/ girder

b. Section modulus (Z) = M/f

M = Max. bending moment(kg-m)

f = Allowable stress (1250kg/cm^2)

c. Corresponding to calculated value of Z for rafter/girder, find out appropriate size of structural section.

- **Checking of selection**

a. Add wt. of selected rafters, girders and again calculate revised bending moment for rafter and girder and then calculate Section Modulus.

b. Revised section modulus should be either equal or lower than value taken while selecting structural section .

THANKS