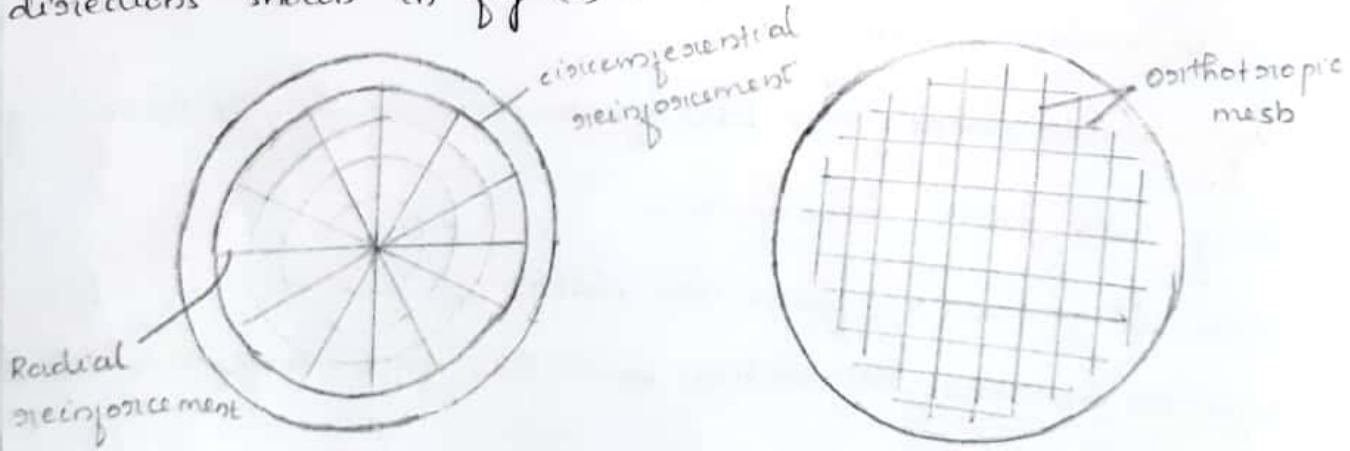


Module - IV

must be provided in the radial and circumferential directions near the tension face. Various moments are, radial, circumferential and twisting moments along with radial and circumferential shear forces, for the given loading condition, are required for designing the slab.

Reinforcement in a circular slab

As easily explained, radial and circumferential stresses are developed in a circular slab and hence reinforcement must be provided in a radial and circumferential directions near the tension face as shown in fig (a). This way of providing reinforcement results in congestion near the centre and makes the placing of circumferential bars near the centre very difficult. Hence reinforcement can also be provided in the form of orthotropic mesh in any two perpendicular directions shown in fig (b).



Normally the reinforcement is provided in the form of orthogonal mesh reinforcement along with radial and circumferential reinforcement. Near the centre of the slab it is provided in the form of orthogonal mesh.

and near the edge of the slab, the reinforcement is provided along the radial and circumferential lines.

For a circular slab subjected to uniformly distributed loads and having symmetrical boundary conditions the following types of moments and shear forces are to be considered for design:

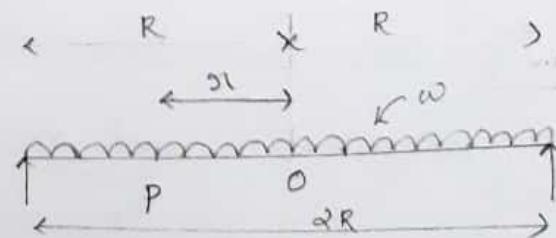
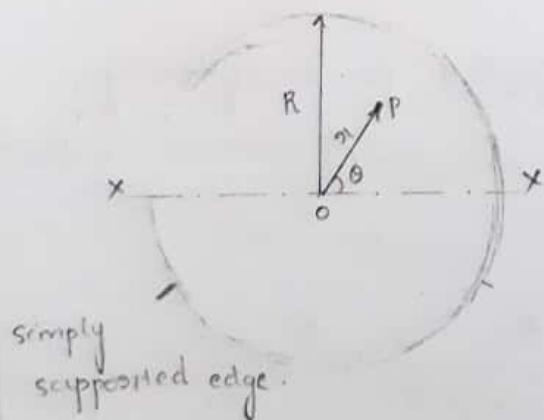
c) M_{r1} = Maximum positive and negative moments in the radial direction.

M_{θ} = Maximum +ve and -ve moments in the circumferential direction.

Q_{r1} = Maximum shear force in the radial direction.

Note: For all the cases assumed that poisson's ratio is zero for reinforced concrete.

case-1. simply supported slab subjected to uniformly distributed load all over the surface.



i. Radial moment at point P, a radial distance r_1 from centre O

$$M_{r1} = \frac{3w}{16} (R^2 - r_1^2)$$

which gives maximum value of moment at centre as:

$$M_{SI} = \frac{3WR^2}{16} \quad \text{at } r=0$$

2. circumferential moment at point P:

$$M_{CQ} = \frac{W}{16} (3R^2 - 2r^2)$$

which gives maximum value of moment at centre as:

$$M_{CQ} = \frac{3WR^2}{16}$$

and at supports, $M_{CQ} = + \frac{2WR^2}{16}, \quad (r=R)$

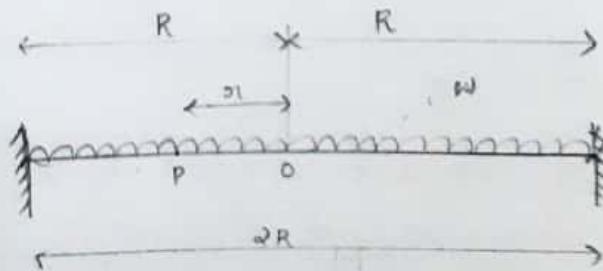
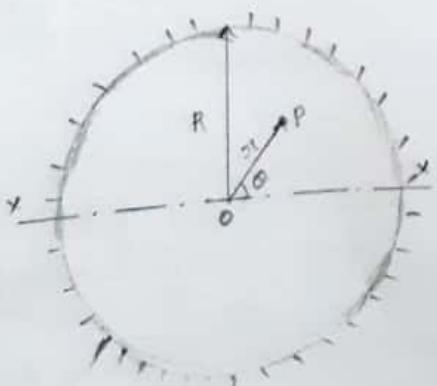
3 Radial shear force at point P

$$V = 0.5\omega r^2$$

which gives the maximum value at the support as

$$V = \frac{WR}{2} \quad (r=R)$$

case-2 - Fixed circular slabs subjected to uniformly distributed load all over its surface.



Fixed point

Radial moment at point p:

$$M_{\text{R}} = \frac{W}{16} (R^2 - 3r^2)$$

which gives maximum value of positive moment at centre
at $r=0$ and maximum value of -ve moment at supporting
edge ($r=R$)

$$M_{\text{R}} = + \frac{WR^2}{16} \quad \text{at centre } (r=0)$$

$$M_{\text{R}} = - \frac{2WR^2}{16} \quad \text{at support } (r=R)$$

Circumferential moment at point P

$$M_{\theta} = \frac{W}{16} (R^2 - r^2)$$

which gives maximum value at centre ($r=0$)

$$M_{\theta} = + \frac{WR^2}{16}$$

$$M_{\theta} = 0 \quad \text{at support } (r=R)$$

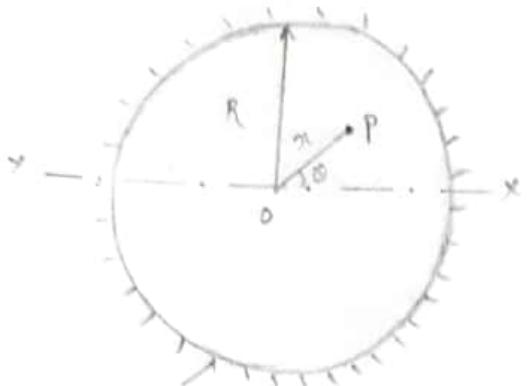
Radial shear force P.

$$V = 0.5WR$$

Maximum shear force at support ($r=R$)

$$V_{\text{max}} = 0.5WR$$

case - 3 Practically fixed circular slab subjected to uniformly distributed load all over the surface



Practically fixed support

1. Radial moment at p:

$$M_{\text{ri}} = \frac{\omega}{16} (2R^2 - 3r^2)$$

Radial moment at centre

$$M_{\text{ri}} = \frac{2\omega R^2}{16}$$

Radial moment at supporting edge

$$M_{\text{ri}} = \frac{-\omega R^2}{16} \quad (\text{at } r=R)$$

2. circumferential moment at p

$$M_{\theta} = \frac{\omega}{16} (2R^2 - r^2)$$

Circumferential moment at centre

$$M_{\theta} = \frac{+2\omega R^2}{16} \quad (\text{at } r=0)$$

Circumferential moment at support

$$M_{\theta} = +\frac{1}{16} \omega R^2 \quad (\text{at } r=R)$$

Shear force at point P,

$$V = 0.5 WR.$$

Maximum shear force at support

$$V_{\max} = 0.5 WR \quad (r=R)$$

The maximum radial and circumferential moments and shear force for various types of supporting conditions of circular slab

Type of slab	Radial moment		Circumferential moment		Shear force at support
	Centre	Support	Centre	Support	
Circular slab simply supported at the edges.	$+ \frac{3WR^2}{16}$	0	$+ \frac{3WR^2}{16}$	$+ \frac{2WR^2}{16}$	$\frac{WR}{2}$.
Circular slab fixed at the edges.	$+ \frac{WR^2}{16}$	$- \frac{2WR^2}{16}$	$+ \frac{WR^2}{16}$	0	$\frac{WR}{2}$.
Circular slab partially fixed at the edges.	$+ \frac{2WR^2}{16}$	$- \frac{WR^2}{16}$	$+ \frac{2WR^2}{16}$	$+ \frac{WR^2}{16}$	$\frac{WR}{2}$

Design a simply supported circular slab carrying a specific imposed load of 4 kN/m². The diameter of the slab is 6 m. Use M20 concrete and Fe 415 steel. Assume the poisson's ratio for RCC as zero.

Step-I - Given data

$$R = D/2 = 5/2 = 2.5 \text{ m}$$

Superimposed load (live load) = 4 kN/m^2 .

$$f_{ck} = 20 \text{ N/mm}^2 \quad f_y = 415 \text{ N/mm}^2$$

Step-II - Thickness of slab.

Assuming the thickness of slab as $\frac{1}{20}$ of span = 120 mm

Step-III - Load calculations.

Dead load of slab = $0.12 \times 1 \times 2.5 = 3 \text{ kN/m}^2$.

Superimposed load = 4 kN/m^2 .

Total load = 7 kN/m^2 .

Factored load $w_u = 1.5 \times 7 = 10.5 \text{ kN/m}^2$.

Step-IV Bending moment values.

Maximum radial bending moment per m width of slab at the centre = M_{rl} .

$$M_{rl} = \frac{3 w_u R^2}{16} = \frac{3 \times 10.5 \times 2.5^2}{16}$$
$$= 12.3 \text{ kNm/m}$$

Maximum circumferential moment per m width of slab at centre is

$$M_{cl} = \frac{3 w_u R^2}{16} = \frac{3 \times 10.5 \times 2.5^2}{16}$$
$$= 12.3 \text{ kNm/m}$$

Radial bending moment at supporting edge = 0.

Circumferential moment at supporting edge = $\frac{\text{d} \cdot w \cdot R^2}{16}$

$$= \frac{2 \times 10.5 \times 2.5^2}{16}$$

$$\approx 8.203$$

Step-V : Depth check.

$$M_u = 12.3 \times 10^6$$

$$d_{\text{req}} = \sqrt{\frac{M_u}{R_u \cdot b}}$$

for M_u and Fe 415 steel $R_u = 2.76$.

$$\therefore d = \sqrt{\frac{12.3 \times 10^6}{2.76 \times 1000}}$$
$$= 66.75 \text{ mm.}$$

Assuming an effective cover of 30mm.

$$D_{\text{req}} = 66 + 30 = 96 \text{ mm.} < 120 \text{ mm.}$$

$$d_{\text{provided}} = 120 - 30 = 90 \text{ mm. hence ok.}$$

Step-VI : Area of steel

$$M_u = 0.87 f_y A_{\text{st}} d \left[1 - \frac{f_y A_{\text{st}}}{f_{ck} b \cdot d} \right]$$

$$12.3 \times 10^6 = 0.87 \times 415 \times A_{st} \times 90 \left[1 - \frac{415 A_{st}}{20 \times 1000 \times 90} \right]$$

$$1.49 A_{st}^2 - 324.94 A_{st} + 12.3 \times 10^6 = 0$$

$$A_{st \text{ req}} = 418.9 \approx 420 \text{ mm}^2$$

Minimum area of steel, $A_{st \text{ min}} = 0.12\%$ of total cross-sectional area

$$\text{area} = \frac{0.12}{1000} \times 1000 \times 120$$

$$= 14.4 \text{ mm}^2 < 420 \text{ mm}^2, \text{ hence ok}$$

Hence providing 10 mm basis @ 180mm c/c in the form of mesh in the middle position of the slab.

Area of steel for circumferential moment M_c at supports

$$\text{edge } M_c = 8.203$$

which is $\frac{1}{3}$ of the central circumferential moment

\therefore total circumferential reinforcement required at edges

$$= \frac{1}{3} \times 420 = 140 \text{ mm}^2 > 144 \text{ mm}^2$$

using 10 mm diameter circular rings at edges.

Development length of 10mm diameter rings = L_d .

$$L_d = 56 \phi$$

$$= 56 \times 10 = 560 \text{ mm.}$$

No. of rings required $N = \frac{\text{Area of circumferential reinforcement}}{\text{area of one base}}$

$$= \frac{250}{\gamma_{sA} 10^2} = \frac{250}{98.5}$$

$$= 2.56 = 4$$

Provide 4 bars in a width of $\frac{1}{3} \times 560 \text{ mm}$.

Note

Hence providing 4-16 mm diameter circular bars @ 18 mm/c at the edge.

In addition to above reinforcement -ve moment reinforcement is provided near the supporting edges to resist moment due to partial fixity as a simple support case not perfect.

This is generally taken as $\gamma_{sA} NR^2$, which is $\frac{1}{3}$ times the moment at centre.

\therefore spacing required is 3 times that of the centre, that is

$$3 \times 180 \text{ mm} = 540 \text{ mm} > 300 \text{ mm}.$$

Hence providing 6 mm diameter bars @ 300 mm c/c gradually for a distance of 600 mm ($56\phi = 560 \text{ mm}$) from the support at top for -ve moment.

Step VII - check for shear.

The conical section for shear is at a distance of 90 cm from support.

$$g_1 = 2500 - 90 = 2410 \text{ mm}.$$

$$V_a = \frac{W_a g_1}{2} = 10.5 \times 2.41$$

$$\approx 12.65$$

$$V_{ca} = 12.65$$

$$\tau_v = \frac{V_{ca}}{bd} = \frac{12.65 \times 10^3}{1000 \times 90}$$

$$= 0.14 \text{ N/mm}^2.$$

$$\text{Ast provided.} = \frac{A\phi \times 1000}{180} = \frac{18.5 \times 1000}{180}$$

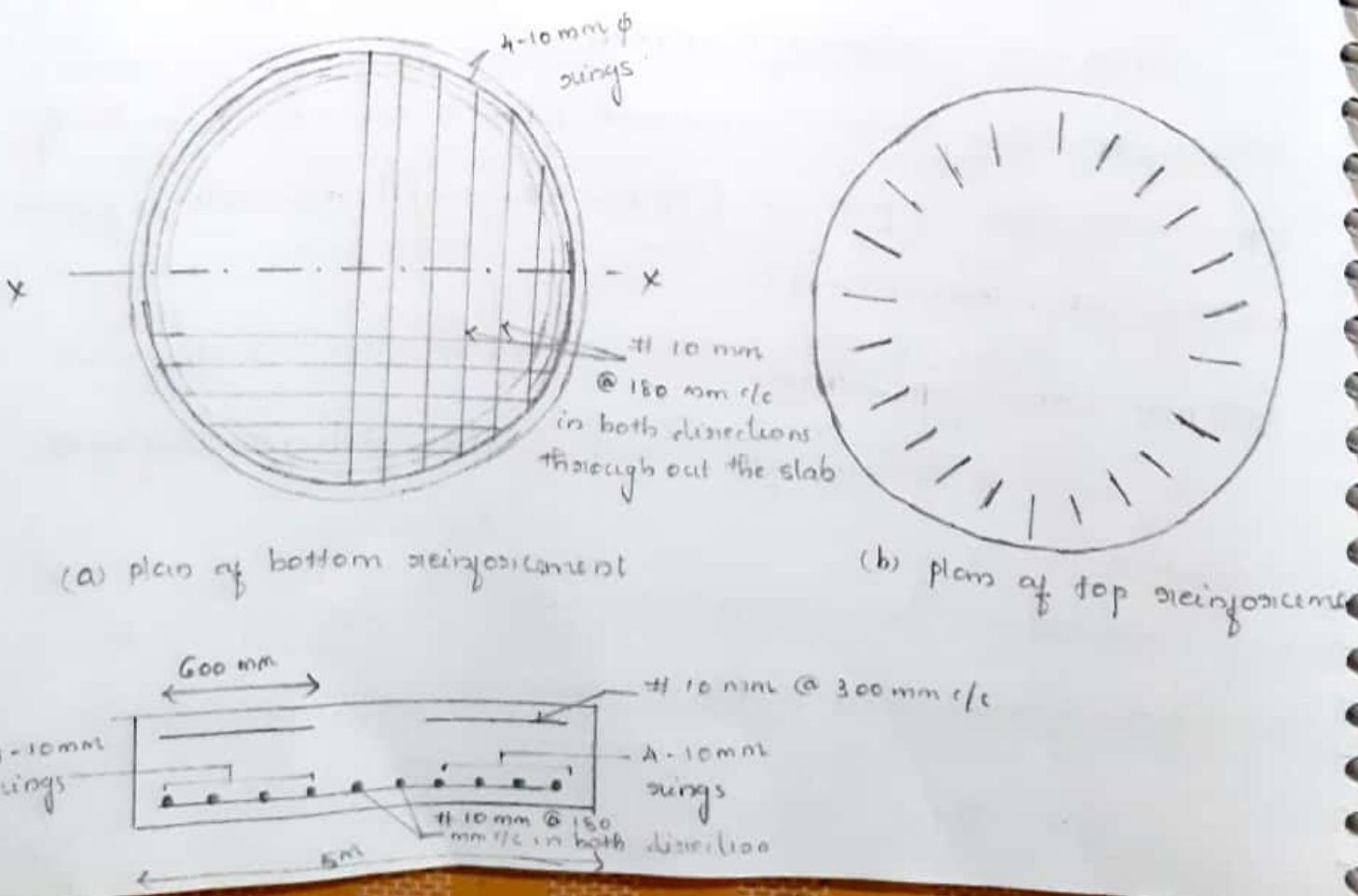
$$= 436$$

$$\% \text{ of steel pt} = \frac{100 \text{ Ast}}{bd} = \frac{436 \times 100}{1000 \times 90} = 0.48 \%$$

$$\tau_c = 0.47 \text{ N/mm}^2 \text{ (from Table 5.1)}$$

$\tau_c > \tau_v$ so, slab is safe in shear.

Hence there is no need of shear reinforcement.



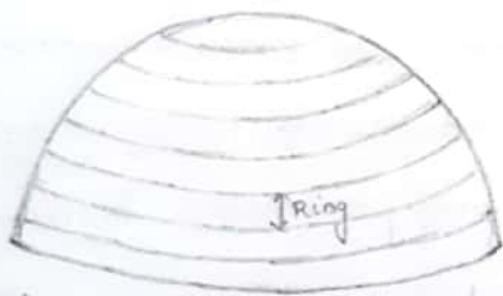
DOMES

A dome may be defined as a thin shell generated by the revolution of a regular cone about one of its axes. The shape of the dome depends upon the type of the cone and the direction of the axis of revolution. When the segment of a circular cone revolves about its vertical diameter, a spherical dome is obtained. Similarly conical dome is obtained by the revolution of a right angled triangle about its vertical axis, while an elliptical dome is obtained by the revolution of an elliptical cone about one of its axes. However, all of these spherical domes are more commonly used. In the case of a spherical dome the vertical section through the axis of revolution is any direction is an arc of a circle.

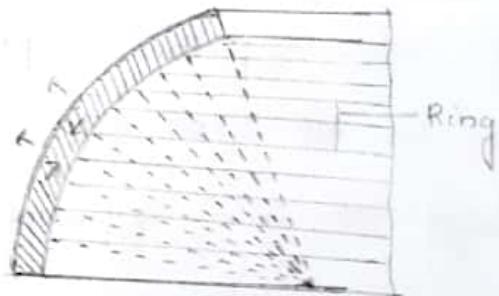
Domes are used in variety of structures, such as i) roof of circular areas ii) circular tanks
iii) hangars iv) exhibition halls, and auditoriums and planetariums v) bottoms of tanks, bins and bunkers. Domes may be constructed of masonry, steel timber and reinforced cement concrete. Stone and brick domes are one of the oldest architectural forms. However, reinforced concrete domes are more common now-a-days, since they can be constructed over large spans.

NATURE OF STRESSES IN SPHERICAL DOMES

A spherical dome may be imagined to consist of a no. of horizontal rings placed one over the other. The diameter of the successive rings increase in the downward direction and the equilibrium is maintained independently of the rings above it. The circle of each ring is called latitude while the circle drawn through two diametrically opposite points on a horizontal diameter and the crown is known as a meridian circle. All meridian circles converge at the crown of the spherical dome.



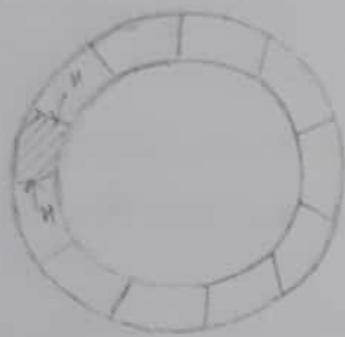
(a) foliations of a spherical dome



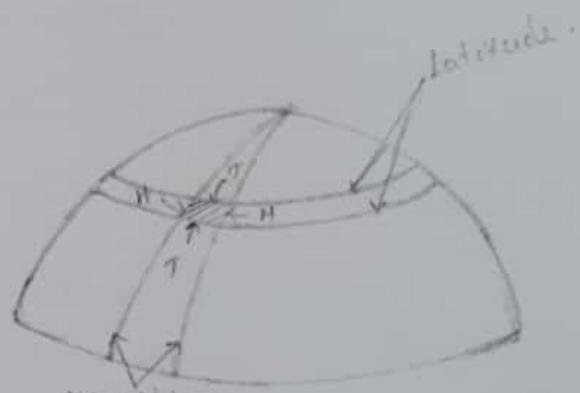
(b) vertical section

Fig b shows the vertical section of a spherical dome. The successive horizontal rings subtend equal angle at the centre of the sphere. The joints between successive horizontal rings are radial. Every horizontal ring supports the load of the ring above it and transmit it to the one below it. The reaction between the ring is tangential to the curved surface, giving rise to compression along the meridians. The compressive stress is called meridional thrust or meridional compression.

Fig c shows the plan of a horizontal ring, which may be imagined to consist of a no. of voussoirs. The joints between adjacent voussoirs of the ring are radial. The tendency of separation of any voussoir will be prevented because of its wedge shape and therefore, hoop compression will be caused in each ring.



fig(c) - plan of a ring



meridians.

Two types of stresses are induced in a dome.

- Meridional thrust (T) along the direction of meridians.
- Hoop stress (H) along the latitudes.

ANALYSIS OF SPHERICAL DOMES.

Let us now analyse stresses developed in a spherical dome of uniform thickness. Two cases loading will be considered.

- uniformly distributed load.
 - concentrated load at centers.
1. Uniformly distributed load.

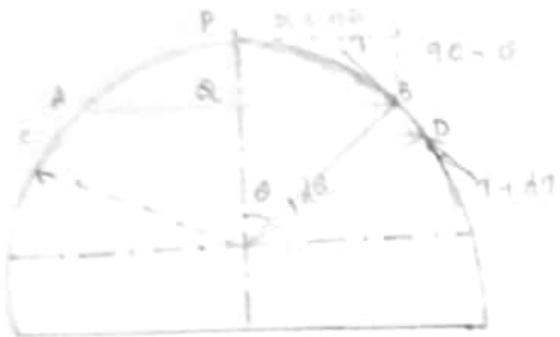
$w = \text{UDL}$, inclusive of its own weight per unit area.

$r = \text{radius of the dome.}$

t = thickness of dense shell.

T = Intensity of meridional thrust

H = Intensity of hoop stress.



a) Meridional thrust (T)

$$T = \frac{w \sigma (1 - \cos \theta)}{\sin \theta}$$

$$= \frac{w \sigma}{1 + \cos \theta}$$

b) Hoop stresses (H)

$$H = \frac{w \sigma (\cos^2 \theta + \cos \theta - 1)}{1 + \cos \theta}$$

The above expression gives the hoop stress in any horizontal ring the extremity of which subtends an angle θ with the vertical at the centre. the value of H is positive, hoop force will be compressive. otherwise, i.e., if θ is negative hoop force is tensile.

At the bottom, $\theta = 0$

$$H = \frac{w \sigma}{\theta}$$

$$\text{Intensity of hoop stress at crown} = \frac{H}{t} = \frac{w\sin\theta}{2t} \text{ (compressive)}$$

This is the maximum value of hoop stress. The hoop stress will go on decreasing as θ increase till it become zero.

After that it becomes tensile. To find the position of the plane where hoop stress becomes zero, we have:

$$H = \frac{w\sin(\cos\theta + \cos\theta - 1)}{1 + \cos\theta} = 0$$

$$\cos\theta = 0.618$$

$$\theta = 51^\circ 49' 38''$$

Hence around the circle of latitude at which the angle $\theta = 51^\circ 49' 38''$, hoop stress is zero. For all position of dome about this angle, hoop compression will be developed, while for the position below this plane, hoop tension will be developed which will go on increasing further towards the base of the dome.

a. Concentrated load at the crown.

$$T = \frac{W}{d\pi t \sin^2\theta}$$

$$\text{hoop stress} = \frac{H}{t} = -\frac{W}{d\pi t} \cosec\theta$$

t = thickness of the dome.

The minus sign shows that hoop stress will be tensile throughout due to concentrated load.

At the crown, $\theta = 0$, hence H becomes infinite.

∴ any concentrated load in the form of lantern or ornament etc. should always be distributed over sufficient area, to reduce the hoop stress at the crown. It is also desirable to thicken the dome at the top to spread the load over greatest area.

Stresses due to combined uniformly distributed load and point load.

The stresses due to point load applied at the crown should be added algebraically to the stresses developed due to uniformly distributed live load and self-weight of the dome, to get the final stresses.

a. Problems

Design a spherical dome over a circular room, for the following data:

i) Inside diameter of room = 12 m.

ii) Rise of dome = 4 m.

iii) Live load due to wind, ice, snow etc = 1.5 kN/m².

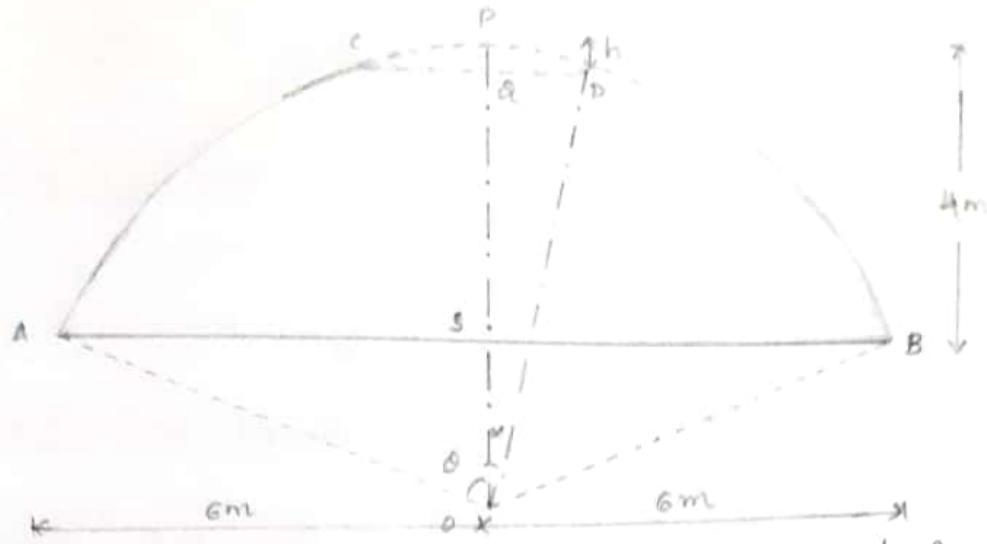
The dome has an opening of 1.6 m diameter at its crown.

A lantern is provided at its top, which causes a dead load of 20 kN acting along the circumference of the opening solution.

Step-I. gives data.

room dia = 12 m.

rise = 4 m.



Live load (inclusive of all loads) = 1.5 kN/m^2 .

Diameter of opening = 12.

dead load of lanterns = 22 kN

Step - II Geometry of dome.

diameter of room = 12.

radius of dome be r_1 .

$$(2r_1 - r_s) r_s = 6 \times 6.$$

$$(2r_1 - 4) 4 = 36.$$

$$r_1 = AO = 6.5 \text{ m}.$$

Diameter of opening = $CD = 12 \text{ m}$.

PA = rise at opening $PA = h$.

$$h (2 \times 6.5 - h) = c\alpha^2 = 0.8 \alpha^2.$$

$$h \approx 0.05 \text{ m}.$$

From which

$$\sin \alpha = \frac{0.8}{6.5} = 0.1231; \quad \cos \alpha = 0.9924$$

$$\alpha = 7^\circ 4'$$

$$\sin \alpha = \frac{6}{6.5}, \quad \cos \alpha = 0.8840$$

$$\beta = 67^\circ 23'$$

Step - III Loading.

The various formulae derived earlier are valid when there is no opening at the crown. In our case, there is an opening of 1.6 m. dia. However, for calculation purpose we can assume that there is no opening, and the weight of extra portion of the lantern shell CPD can be accounted for by reducing the load of the lantern and taking into consideration of the effective weight of lanterns. i.e.,

Effective wt of lanterns = Actual wt of lanterns -
wt of dome shell CPD.

Let the thickness of the dome be 100 mm.

The wt per sq-m of surface area are:

i) self wt of dome shell = $0.1 \times 25 = 2.5 \text{ kN/m}^2$.

ii) Live Load = 1.5.

∴ Total Load = 4 kN/m^2 .

$$\begin{aligned}\text{wt of the dome shell CPD} &= w \times d \pi h \\ &= w \times d \pi \times 6.5 \times 0.05 \\ &= 8.17 \text{ kN}\end{aligned}$$

∴ Effective wt of lanterns = dead load of lanterns -

$$W = 22 - 8 \cdot 17$$

$$= 13.83 \text{ kN}$$

Step IV - calculation of stresses due to combined load.

The stress at any horizontal plane will be equal to the algebraic sum of stresses due to the σ loading and the dome will be designed for the maximum of these stresses.

$$\text{Total meridional stress} = \frac{W \alpha (1 - \cos \theta)}{t \sin^2 \theta} + \frac{W}{2\pi r t \sin^2 \theta}$$

$$= \frac{4 \times 6.5 (1 - \cos \theta)}{0.1 \sin^2 \theta} + \frac{13.83}{2\pi \times 6.5 \times 0.1 \sin^2 \theta}$$

$$= \left[260 \frac{1 - \cos \theta}{\sin^2 \theta} + \frac{3.39}{\sin^2 \theta} \right] \times 10^{-3} \text{ N/mm}^2$$

$$= 0.26 \frac{1 - \cos \theta}{\sin^2 \theta} + \frac{0.00339}{\sin^2 \theta} \text{ N/mm}^2.$$

$$\text{Hoop stress} = \frac{W \alpha}{t} \left(\frac{\cos^2 \theta + \cos \theta - 1}{1 + \cos \theta} \right) - \frac{W}{2\pi r t} \frac{1}{\sin^2 \theta}$$

$$= \frac{4 \times 6.5}{0.1} \left(\frac{\cos^2 \theta + \cos \theta - 1}{1 + \cos \theta} \right) - \frac{13.83}{2\pi \times 6.5 \times 0.1} \times \frac{1}{\sin^2 \theta}$$

$$= \left[260 \left(\frac{\cos^2 \theta + \cos \theta - 1}{1 + \cos \theta} \right) - \frac{3.39}{\sin^2 \theta} \right] \times 10^{-3} \text{ N/mm}^2$$

$$= 0.26 \frac{\cos^2 \theta + \cos \theta - 1}{1 + \cos \theta} - \frac{0.00339}{\sin^2 \theta} \text{ N/mm}^2.$$

The values of meridional stress and hoop stress for various values of θ are tabulated in the table.

θ	Meridional Stress (N/mm ²)			Hoop Stress N/mm ²		
	Due to w	Due to N	Total	Due to w	Due to N	Total
1° 4'	0.1305	0.223	0.354	0.127	-0.225	-0.098
10°	0.131	0.112	0.243	0.125	-0.113	+0.012
20°	0.134	0.029	0.163	0.102	-0.029	+0.073
30°	0.140	0.018	0.153	0.086	-0.014	+0.072
40°	0.148	0.008	0.156	0.052	-0.008	+0.044
50°	0.158	0.006	0.164	0.009	-0.006	+0.003
60°	0.174	0.004	0.178	-0.044	-0.004	-0.048
67° 23'	0.186	0.004	0.190	-0.088	-0.004	-0.092

Step V - Hoop stress in absence of line load.

Hoop stresses should also be found in absence of line load. This will increase the tensile stresses in the upper part of the dome, specially near the periphery of the opening. However, meridional thrust will not increase by omitting the line load.

$$w = 0.1 \times 29 = 2.9 \text{ kN}$$

$$\therefore \text{Effective wt of lantern} = 20 - 2.5 \times 2.9 \text{ kN}$$

$$= 22 - 2.5 \times 2.9 \times 0.5 \times 0.05 \\ = 16.89 \text{ kN}$$

Now the hoop stresses due to w calculated above will decrease in the ratio of $\frac{150}{400}$ (0.625) while hoop stress due to N will

will be increased by the ratio of $\frac{16.89}{13.84} \approx 1.22$) the results are tabulated on the table.

θ	Hoop Stress		
	Due to CW	Due to W	Total
$4^\circ A$	0.080	-0.275	-0.195
10°	0.078	-0.188	-0.060
20°	0.064	-0.085	+0.029
30°	0.054	-0.017	+0.037
40°	0.039	-0.010	+0.029
50°	0.006	-0.007	-0.001
60°	-0.027	-0.005	-0.032
$64^\circ 23'$	-0.055	-0.005	+0.060

Thus we see that the maximum hoop tension at the opening has been increased from -0.098 to ~~-0.195~~ 0.195 N/mm^2 .

Step - vi Provision for reinforcement

$$\text{Max. compressive stress} = 0.354 \text{ N/mm}^2.$$

$$\text{Max. hoop stress} = 0.195 \text{ N/mm}^2.$$

\therefore max hoop tension per m length of members

$$= 0.195 \times 100 \times 1000 = 19500 \text{ N.}$$

$$\therefore \text{Area of Steel} = \frac{19500}{140} = 139 \text{ mm}^2. \quad [140 = \text{Permissible stress of steel}]$$

$$\text{Reinforcement for temp.} = \frac{0.15}{100} \times 100 \times 1000 = 150 \text{ mm}^2/\text{m}^2$$

$$\therefore \text{total reinforcement} = 139 + 150 = 289 \text{ mm}^2.$$

$$\text{Using } 8\text{mm } \phi \text{ bars, spacing} = \frac{1000 \times 50}{200} = 175 \text{ mm.}$$

However, provide 8 mm ϕ bars @ 160 mm c/c where hoop tension developed. In the position where no hoop tension developed, minimum area of steel @ 0.15% will be 150 mm². Hence provide 8 mm ϕ bars @ 300 mm c/c.

Design of Locally slung beam.

Meridional thrust per m length of the dome at its base

$$= 0.19 \times 100 \times 1000 = 19000 \text{ N/m.}$$

Horizontal component T per m length.

$$= 19000 \cos 67^\circ 23' = 7307 \text{ N/m.}$$

\therefore Hoop tension, trying to disrupt the beam.

$$= 7307 \times \frac{12}{2} = 43840 \text{ N}$$

$$\therefore \text{Area of steel required} = \frac{43840}{140} = 313 \text{ mm}^2.$$

$$\text{Using } 10 \text{ mm } \phi \text{ bars, No. of slings} = \frac{313}{78.5} = 4.$$

\therefore Hence provide 4 slings of 10 mm ϕ bars.

Equivalent area of composite section of beams of area of cross section A.

$$\begin{aligned} & A + (m-1) A_{st} = A + 18 \times 78.5 \times 4 \\ & = A + 5652. \end{aligned}$$

Allowing tensile stress of 1.2 N/mm² in the composite section we have:

$$\frac{43840}{A + 5652} = 1.2$$

$$A = 30880 \text{ mm}^2.$$

However, provide a swing beam of 200 mm x 100 mm. provide 6 mm ϕ stirrups @ 100 mm c/c to tie the swings in the swing beams.

Step VIII - Design of swing beams at the opening.

Hoop compression in the swing beam:

$$= (0.345 \times 100 \times 1000) \cos \alpha \times \frac{1.6}{\alpha}$$

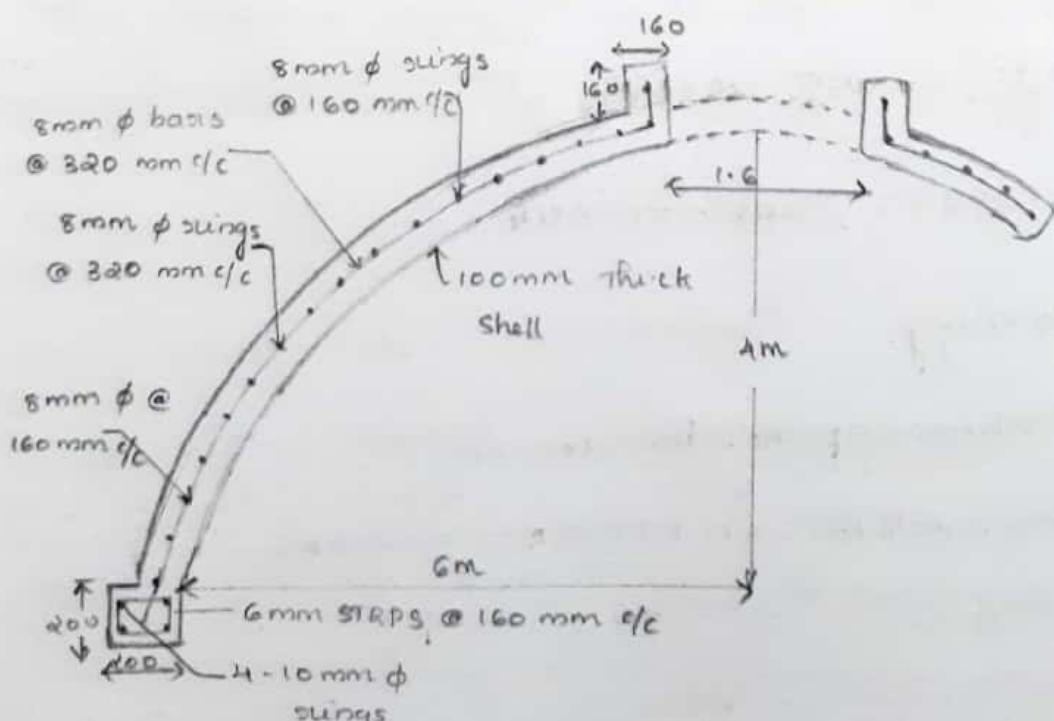
$$\approx 35400 \times 0.9924 \times 0.8 = 28105 \text{ N}$$

The horizontal component will be provided for by a beam which will form the link between the lantern and the dome

provide a swing beam of size 160 mm x 160 mm either above the dome or below the dome, as required from architectural requirements

$$\text{compressive stress in swing beam} = \frac{28105}{160 \times 160} = 1.1 \text{ N/mm}^2.$$

Extend the 8 mm ϕ swings in the swing beams also.



CONICAL DOMES

$$T = \frac{W}{2} \frac{y}{\cos \theta}$$

∴ Intensity of meridional stress = $\frac{w}{2t} \frac{y}{\cos \theta}$

Hoop stress $H = w y \tan \theta$

Intensity of hoop stress = $\frac{w y}{t} \tan \theta$.

The hoop stress will be compressive throughout out.

a. Problem.

Design a conical roof for a hall having a diameter of 20m. The rise of the dome has to be 4m. Assume the live and other loads as 1500 N/m².

Step-I Geometry of the dome.

Diameter AB = 20 m

Height PA = 4 m.

$$\tan \theta = \frac{10}{4} = 2.5; \theta = 68^\circ 12'$$

$$\sin \theta = 0.9285; \cos \theta = 0.3714$$

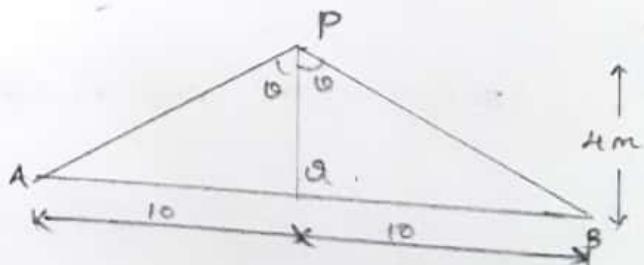
Step-II - Loading.

Let the thickness of shell be 200 mm.

$$wt \text{ of dome shell/m}^2 = 0.1 \times 1 \times 25 = 2.5 \text{ kN}$$

$$\text{Live load} = 1.5 \text{ kN}$$

$$\text{Total load} = 4 \text{ kN.}$$



Step-III calculation of stress

$$\text{Meridional thrust } T = \frac{wy}{2 \cos^2 \theta}$$

Maximum T will occur at the base AB cohesive $y=1m$

$$\therefore T_{\max} = \frac{4000 \times 4}{2(0.3+1)^2} = 58200N.$$

$$\therefore \text{Meridional stress} = \frac{58200}{100 \times 1000} = 0.582 \text{ N/mm}^2. \text{ Is hence ok}$$

(Assume M20 concrete from IS 456 page 81. permissible stress in concrete σ_{bc} direct = σ N/mm²)

$$\text{Hoop force } H = wy \tan \theta.$$

$$H_{\max} = 4000 \times 4 (2.5)^2 = 100000N$$

$$\therefore \text{Hoop stress} = \frac{100000}{100 \times 1000} = 1 \text{ Is hence ok.}$$

Step-IV Steel reinforcement.

The stresses work out to be safe. Hence only nominal reinforcement has to be provided @ 0.15% of the area of concre

$$A_{st} = \frac{0.15}{100} \times 100 \times 1000 = 150 \text{ mm}^2.$$

Using 8mm ϕ bars, $A\phi = 50 \text{ mm}^2$.

$$\text{spacing} = \frac{1000 A\phi}{A_{st}} = \frac{1000 \times 50}{150} = 333 \text{ mm.}$$

However provide 8mm ϕ bars @ 300mm c/c both the ways.
The meridional bars may be discontinued near the apex, on a wise mesh may be provided there to avoid congestion

of steel.

Step-V Design of swing beam

Horizontal component of mesudional thrust T will cause an outward force on the support, causing hoop tension. Hence a swing beam is necessary.

$$\text{Hoop tension } p \text{ in swing beam} = T \sin\theta$$

$$= 58200 \times 0.9285 = 54000 \text{ N/m}$$

$$\therefore \text{Total tensile force} = p \times D_{1/2} = 54000 \times 10 = 540000 \text{ N}$$

$$\therefore \text{Area of steel to resist this, } A_{st} = \frac{540000}{140} = 3857 \text{ mm}^2$$

Using 25 mm ϕ bars, $A\phi = 490 \text{ mm}^2$.

$$\therefore \text{No. of bars} = \frac{A_{st}}{A\phi} = \frac{3857}{490} \approx 8$$

Actual area of steel provided = 3920 mm².

Tie these by 8 mm ϕ 2-legd. stirrups @ 300 mm c/c.

Let A be the area of swing beam.

$$\begin{aligned} \text{Equivalent area of composite section} &= A + (m-1) A_{st} \\ &= A + 18 \times 3920 = A + 70560. \end{aligned}$$

Assuming the allowable tensile stress in composite section to be 1.2 N/mm² we have:

$$\frac{540000}{A + 70560} = 1.2$$

$$A = 359440 \text{ mm}^2$$

Provide swing beam of size 100mm \times 100mm.

