Try outer diameter of the raft $=12$ m, inner diameter of the raft$=3$ m, and the outer columns on a diameter of 10 m, and the inner columns on a diameter of 5 m

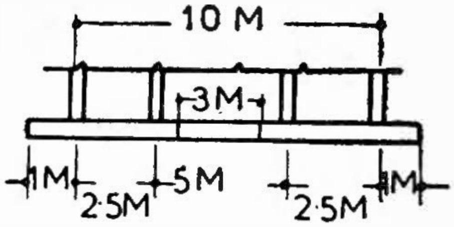
Area of the raft provided$=\frac{\pi}{4}(12^2-3^2)$

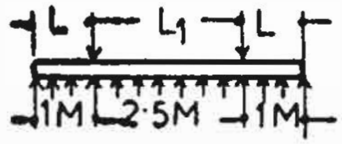
$=\frac{\pi}{4}\ (144-9)=\frac{3{\cdot}14}{4}\times 135=106\ m^2>99\ m^2$

Upward pressure$=\frac{4455}{106}=42\ t/m^2$

2·9·1. Approximate Bending Moment in the Raft

Maximum cantilever moment $=\frac{wl^2}{2}=\frac{42\times 1\times 1}{2}=21$ mt

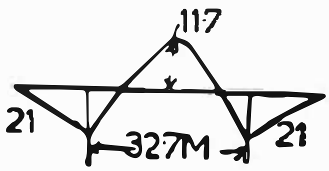




Maximum +ve *BM* at centre

$=\frac{wl_1^2}{8}-\frac{wl^2}{2}=\frac{42\times 2{\cdot}5^2}{8}-21=32{\cdot}7-21=11{\cdot}7$ mt

depth of slab$=\sqrt{\frac{2100{\cdot}000}{100\times 12{\cdot}13}}=41{\cdot}6$cm



Use $d=45$ cm, $d_e=42$ cm

Area of steel required for −ve BM

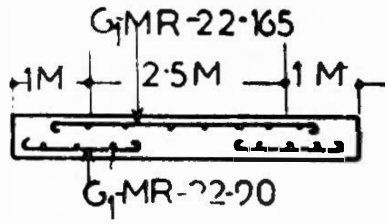
$=\frac{2100{,}000}{1400\times{\cdot}87\times 42}=41\ cm^2$

Use 22 mm ϕ at 9 cm c/c

Area of steel for +ve BM

$=\frac{1170{,}000}{1400\times{\cdot}87\times 42}=22{\cdot}9\ cm^2$

Use 22 mm at 16·5 cm c/c



2·10. Ring Beam

Load on the outer ring beam=2700 t

Load per metre run of circumference of the girder

$=w=\frac{2700}{\pi\times 10}=86$ t

Load on the inner girder per meter run of circumference

$=w=\frac{1350}{\pi\times 5}=86$ t

2·10·1. Design of Inner Ring Beam Bending Moments

Number of supports=4, $\theta=90°$ $w=86$ t

Maximum −ve BM at supports$=0{\cdot}137\times w\times r^2\ \theta$

$=0{\cdot}137\times 86\times 2{\cdot}5^2\ \frac{\pi}{190}\times 90=116$ mt

Maximum +ve BM at centre$={\cdot}07\times w\times r^2\ \theta$

$={\cdot}07\times 86\times(2{\cdot}5)^2\times\frac{\pi}{100}\times 90=59$ mt

Square Wheat Silo 3

3·1. Data

Capacity=600 t, Weight of wheat=850 kg/m³, Angle of repose=25°

For wheat, coefficient of friction of grain on grain $\mu=0{\cdot}466$

Coefficient of friction between the grain and the concrete wall $\mu'=0{\cdot}444$

Elevation of the bottom of the opening above G.L.=3 m

Wind load=150 kg/m²

Use AIRY's theory for pressure computation

Materials available, Concrete$-M$ 150, Steel=grade=1

Bearing capacity of soil=40 t/m²

3·2. Characteristic Strengths

$\sigma_{cb}=50$ kg/cm² $\qquad m=18$

$\sigma_{st}=1400$ kg/cm² $\qquad j_d=0{\cdot}87\,d,\ R=8{\cdot}7$

3·3. Trial Dimensions

Capacity of the silo=600 t$=\dfrac{600{,}000}{850}=705$ cu m

Let the side of the bunker =5 m

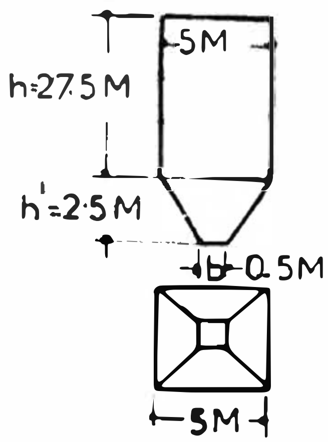
Volume of the hopper

$\frac{1}{3}=h\,(b^2+b_1^2\div\sqrt{b^2b_1^2})$

$=\dfrac{2{\cdot}5}{3}(5^2+{\cdot}5^2+\sqrt{5^2\times{\cdot}5^2})$

$=\dfrac{2{\cdot}5}{3}\,(25+{\cdot}25+\sqrt{25\times{\cdot}25})$

$=\dfrac{2{\cdot}5}{3}\times 27{\cdot}73=22{\cdot}9$ cum



h=depth required for the square portion to accommodate the remaining capacity

$5\times5\times h=705-22{\cdot}9=682{\cdot}1$

$h=\dfrac{682{\cdot}1}{25}=27{\cdot}3$ m, Use 27·5 m

Actual capacity provided, hopper=22·9 cum

Square$=5\times5\times27{\cdot}5=687{\cdot}5$ cum

Total=710·4 cum>705 cum

3·4. Pressure Computations

Plane of rupture

$$\tan\theta=\sqrt{\frac{2h}{b}\times\frac{1+\mu^2}{\mu+\mu'}+\frac{1+\mu^2}{\mu+\mu'}\times\frac{1-\mu\mu'}{\mu+\mu'}}-\frac{1-\mu\mu'}{\mu+\mu'}$$

$$=\sqrt{\frac{2\times27{\cdot}5}{5}\times\frac{1+{\cdot}466^2}{{\cdot}466+{\cdot}444}+\frac{1+{\cdot}466^2}{{\cdot}466+{\cdot}444}\times\frac{1-{\cdot}466\times{\cdot}444}{{\cdot}466+{\cdot}444}}-\frac{1-{\cdot}466\times{\cdot}444}{{\cdot}466+{\cdot}444}$$

$$=\sqrt{11\times 1{\cdot}337+1{\cdot}165}-0{\cdot}871=\sqrt{14{\cdot}7+1{\cdot}165}-0{\cdot}871$$

$$=3{\cdot}981-0{\cdot}871=3{\cdot}11$$

$$\theta=72^\circ-12'$$

$$p=\frac{wb}{2}(2h-b\tan\theta)\times\frac{\text{taa }\theta-\mu}{1-\mu\mu'+(\mu+\mu')\tan\theta}$$

$$=\frac{850\times 5}{2}(2\times 27{\cdot}5-5\times 3{\cdot}11)$$

$$\times\frac{3{\cdot}11-0{\cdot}466}{1-0{\cdot}466\times{\cdot}444+(0{\cdot}466+{\cdot}444)3{\cdot}11}$$

$$=2125(55-15{\cdot}55)\times\frac{2{\cdot}644}{0{\cdot}793+0{\cdot}910\times 3{\cdot}11}$$

$$=2125\times 39{\cdot}45\times\frac{2{\cdot}644}{3{\cdot}643}=60500\text{ kg/sq. m}$$

Total pressure on the sides $=60{,}500\times 5\times 4=1{,}220{,}000$ kg $=1220$t
Weight of grain held by friction $=1{,}20{,}000\times\mu'$
$=1{,}220{,}000\times 0{\cdot}444=542000$ kg $=542$ t.
Weight of grain in the side upto 27·5 m depth

$$=5\times 5\times 27{\cdot}5\times\frac{850}{1000}=584\text{ t}$$

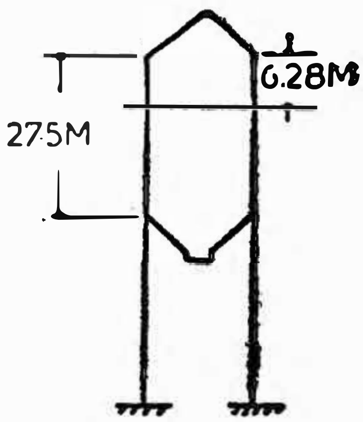
Pressure on the bottom of the silo $=584-542=42$t

3·4·1. Pressure Computations General Expression Smaller Depths

$$\tan\theta=\sqrt{\tfrac{2}{5}h\times 1{\cdot}337+1{\cdot}65}-0{\cdot}871$$

$$p=\frac{850\times 5}{2}(2h-5\tan\theta)\times\frac{\tan\theta-0{\cdot}466}{0{\cdot}793+0{\cdot}91\tan\theta}$$

$$=2125(2h-5\tan\theta)\times\frac{\tan\theta-0{\cdot}466}{0{\cdot}793+{\cdot}91\tan\theta}$$



For smaller depths,

$$\tan\theta=\mu+\sqrt{\mu\frac{1+\mu^2}{\mu+\mu'}}$$

$$=0{\cdot}466+\sqrt{0{\cdot}466\times\frac{1+0{\cdot}466^2}{0{\cdot}91}}=1{\cdot}255$$

$$p=\frac{wh^2}{2\tan\theta}\times\frac{\tan\theta-\mu}{(1-\mu\mu')+(\mu+\mu')\tan\theta}$$

$$=\frac{850h^2}{2\times 1{\cdot}255}\times\frac{1{\cdot}255-0{\cdot}466}{(1-{\cdot}466\times{\cdot}444)+0{\cdot}91\times 1{\cdot}255}$$

$$=\frac{425h^2}{1{\cdot}255}\times\frac{0{\cdot}789}{0{\cdot}793+1{\cdot}142}=140h^2$$

where $h=0$ to $b\tan\theta=5\times 1{\cdot}255=6{\cdot}28$ m

This is the depth for which the plane of separation, which causes maximum pressure on one side of the silo. meets the opposite side at the surface of the grain.

3·4·2. Larger depths >6·28 m

For larger depths, where the plane of separation meets the opposite side within the grain.

$$\tan\theta=\sqrt{\frac{2h}{b}\times\frac{1+\mu^2}{\mu+\mu'}+\frac{1+\mu^2}{\mu+\mu'}\cdot\frac{1-\mu\mu'}{\mu+\mu'}}-\frac{1-\mu\mu'}{\mu+\mu'}$$

For wheat, $\frac{1+\mu^2}{\mu+\mu'}=1{\cdot}337$, $\frac{1-\mu\mu'}{\mu+\mu'}=0{\cdot}871$

$$\frac{1-\mu^2}{\mu+\mu'}\times\frac{1-\mu\mu'}{\mu+\mu'}=1{\cdot}337\times0{\cdot}871=1{\cdot}165$$

$$\tan\theta=\sqrt{\frac{2\times h}{b}\times1{\cdot}337+1{\cdot}165}-{\cdot}871$$

$$p=\frac{wb}{2}(2h-b\tan\theta)\times\frac{\tan\theta-\mu}{1-\mu\mu'+(\mu+\mu')\tan\theta}$$

$$=\frac{850}{2}\times5(2\times h-5\times\tan\theta)\times\frac{\tan\theta-0{\cdot}466}{0{\cdot}793+{\cdot}910\tan\theta}$$

$$=2125\,(2h-5\tan\theta)\times\frac{\tan\theta-0{\cdot}466}{0{\cdot}793+{\cdot}910\tan\theta}$$

Calculations for 10 m depth, $h=10$ m

$$\tan\theta=\sqrt{\frac{2\times10}{5}\times1{\cdot}337+1{\cdot}165}-0{\cdot}871$$

$$=\sqrt{4\times1{\cdot}337+1{\cdot}165}-0{\cdot}871=\sqrt{5{\cdot}35+1{\cdot}165}-0{\cdot}871$$

$$=\sqrt{6{\cdot}515}-0{\cdot}871=2.55-{\cdot}871=1{\cdot}679$$

$$p=2125(2\times10-5\times1{\cdot}679)\times\frac{1{\cdot}679-0{\cdot}466}{0{\cdot}793+{\cdot}91\times1{\cdot}679}$$

$$=2125(20-8{\cdot}4)\times\frac{1{\cdot}213}{2{\cdot}313}=2125\times11{\cdot}6\times\frac{1{\cdot}213}{2{\cdot}313}=12900\text{ kg}$$

Similarly for all other depths at an interval of 1 m computations are carried out,

Depth of grain in silo m	*Tan θ for max. pressure*	*Weight of grain in the silo*	*Pressure P/m run of wall*	*The intensity of side pressure kg/m²*
1	1·255	21.250	140	—
2	1·255	42,500	560	420
3	1·255	63,750	1260	700
4	1·255	85,000	2240	980
5	1·255	106,250	3600	1360
6	1·255	127,500	5050	1450
7	1·345	148,750	6750	1700
8	1·462	170,000	8650	1900
9	1·574	191 250	10,700	2050
10	1·679	212,500	12,900	2200
11	1·784	233,750	15,100	2200
12	1·883	255,000	17.500	2400
13	1·978	276,250	19,900	2400
14	2·070	297,500	22,400	2500
15	2·160	318,750	25,000	2600
16	2·247	340,000	27,800	2800
17	2·331	367,250	30,500	2700
18	2·414	382,500	33,100	2600
19	2·494	403.750	36,100	3000
20	2·573	425,000	39,100	3000
21	2·650	446,250	41,600	2500
22	2·725	467,500	44,600	3000
23	2·798	488,750	47,500	2900
24	2·871	510,000	50,400	2900
25	2·941	531.250	53,500	3100
26	3·011	552,500	56,800	3300
27·5	3.113	584,000	61,000	4200