DESIGN OF R.C.C. OVER HEAD TANK

MAIN PROJECT REPORT

Submitted in partial fulfilment of the Requirements for the award of the degree of

Bachelor of Technology
In
Civil Engineering

By

G.HEMALATHA (09245A0105) J.TEJASWI (09245A0106)

Under the esteemed guidance of
MR.MALLIKARJUN REDDY
Assistant professor of Civil Engineering Department

Department of Civil Engineering
Gokaraju Rangaraju Institute of Engineering and Technology
(Affiliated to JNTU)
Hyderabad
2012
DESIGN OF R.C.C OVER HEAD TANK
ABSTRACT

Storage reservoirs and overhead tank are used to store water, liquid petroleum, petroleum products and similar liquids. The force analysis of the reservoirs or tanks is about the same irrespective of the chemical nature of the product. All tanks are designed as crack free structures to eliminate any leakage.

This project gives in brief, the theory behind the design of liquid retaining structure (Elevated circular water tank with domed roof and conical base) using working stress method. Elements are design in limit state method.
ACKNOWLEDGEMENTS

I would like to express my gratitude to all the people behind the screen who helped me to transform an idea into a real application.

I would like to express my heart-felt gratitude to my parents without whom I would not have been privileged to achieve and fulfill my dreams. I am grateful to our principal, 
Mr. Jandyala N. Murthi who most ably run the institution and has had the major hand in enabling me to do my project.

I profoundly thank Mr. G. Venkataramana, Head of the Department of CIVIL Engineering who has been an excellent guide and also a great source of inspiration to my work.

I would like to thank my internal guide Mr. V. Mallikarjun reddy Asst. Professor for his technical guidance, constant encouragement and support in carrying out my project at college.

The satisfaction and euphoria that accompany the successful completion of the task would be great but incomplete without the mention of the people who made it possible with their constant guidance and encouragement crowns all the efforts with success. In this context, I would like thank all the other staff members, both teaching and non-teaching, who have extended their timely help and eased my task.

G. Hemalatha 09245A0105 J. Tejaswi 09245A0106
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SYMBOLS

A  = Total area of section
A_b = Equivalent area of helical reinforcement.
A_c = Equivalent area of section
A_h = Area of concrete core.
A_m = Area of steel or iron core.
A_{sc} = Area of longitudinal reinforcement (comp.)
A_{st} = Area of steel (tensile.)
A_l = Area of longitudinal torsional reinforcement.
A_{sv} = Total cross-sectional are of stirrup legs or bent up bars within distance S_v.
A_w = Area of web reinforcement.
A_0 = Area of cross-section of one bars.
    a = lever arm.
a_c = Area of concrete.
B = Flange width of T-beam.
b = width.
b_r = Width of rib.
C = Compressive force.
c = Compressive stress in concrete.
c' = Stress in concrete surrounding compressive steel.
D = Depth
d = Effective depth
d_c = Cover to compressive steel

d_s = Depth of slab
\( d_t = \) cover to tensile steel

\( e = \) eccentricity.

\( = \) compressive steel depth factor \((=d_e/d)\).

\( F = \) shear force characteristic load.

\( F_d = \) design load

\( F_r = \) radial shear force.

\( f = \) stress (in general)

\( \sigma_{ck} = \) characteristic compressive stress.

\( F_y = \) characteristic strength of steel.

\( H = \) height.

\( I = \) moment of inertia.

\( I_e = \) equivalent moment of inertia of stress.

\( j = \) lever arm factor.

\( K_a = \) coefficient of active earth pressure.

\( K_p = \) coefficient of passive earth pressure.

\( k = \) neutral axis depth factor \((n/d)\).

\( L = \) length.

\( L_d = \) development length.

\( l = \) effective length of column; length; bond length.

\( M = \) bending moment; moment.

\( M_r = \) moment of resistance; radial bending moment.

\( M_t = \) torsional moment.

\( M_u = \) bending moment (limit state design)

\( M_\theta = \) circumferential bending moment

\( m = \) modular ratio.

\( n = \) depth of neutral axis.

\( n_c = \) depth of critical neutral axis.
$P_a$ = active earth pressure.

$P_p$ = passive earth pressure.

$P_a$ = axial load on the member (limit state design).

$P$ = percentage steel.

$P'$ = reinforcement ratio.

$P_a$ = active earth pressure indemnity.

$P_e$ = net upward soil pressure.

$Q$ = shear resistance.

$q$ = shear stress due to bending.

$q'$ = shear stress due to torsion.

$R$ = radius.

$s$ = spacing of bars.

$s_a$ = average bond stress.

$s_b$ = local bond stress.

$T$ = tensile force.

$T_u$ = torsional moment.

$t$ = tensile stress in steel.

$t_c$ = compressive stress in compressive steel.

$V_u$ = shear force due to design load.

$V_{us}$ = strength of shear reinforcement.

$W$ = point load.

$X$ = coordinate.

$x_u$ = depth of neutral axis.

$Z$ = distance.

$\alpha$ = inclination.
\( \beta \) = surcharge angle.

\( \gamma \) = unit weight of soil

\( \gamma_f \) = partial safety factor appropriate to the loading.

\( \gamma_m \) = partial safety factor appropriate to the material.

\( \sigma_{cc} \) = permissible stress in concrete.

\( \sigma_{cbc} \) = permissible compressive stress in concrete due to bending.

\( \sigma_{sc} \) = permissible compressive stress in bars.

\( \sigma_{st} \) = permissible stress in steel in tension.

\( \sigma_{sr} \) = permissible tensile stress in shear reinforcement.

\( \sigma_{sy} \) = yield point compressive stress in steel.

\( \mu \) = coefficient of friction.

INTRODUCTION
A water tank is used to store water to tide over the daily requirement. In the construction of concrete structure for the storage of water and other liquids the imperviousness of concrete is most essential. The permeability of any uniform and thoroughly compacted concrete of given mix proportions is mainly dependent on water cement ratio. The increase in water cement ratio results in increase in the permeability. The decrease in water cement ratio will therefore be desirable to decrease the permeability, but very much reduced water cement ratio may cause compaction difficulties and prove to be harmful also. Design of liquid retaining structure has to be based on the avoidance of cracking in the concrete having regard to its tensile strength. Cracks can be prevented by avoiding the use of thick timber shuttering which prevent the easy escape of heat of hydration from the concrete mass. The risk of cracking can also be minimized by reducing the restraints on free expansion or contraction of the structure.

1.1 OBJECTIVE

1. To make a study about the analysis and design of water tanks.

2. To make a study about the guidelines for the design of liquid retaining structure according to IS Code.

3. To know about the design philosophy for the safe and economical design of water tank.

4. To develop programs for the design of water tank of flexible base and rigid base and the underground tank to avoid the tedious calculations.

5. In the end, the programs are validated with the results of manual calculation given in Concrete Structure.

2.1 SOURCES OF WATER SUPPLY:
The various sources of water can be classified into two categories:

Surface sources, such as

1. Ponds and lakes;
2. Streams and rivers;
3. Storage reservoirs; and
4. Oceans, generally not used for water supplies, at present.

Sub-surface sources or underground sources, such as

1. Springs;
2. Infiltration wells; and
3. Wells and Tube-wells.

3.1 Water Quantity Estimation

The quantity of water required for municipal uses for which the water supply scheme has to be designed requires following data:

Water consumption rate (Per Capita Demand in litres per day per head)

Population to be served.

\[
\text{Quantity} = \text{Per demand} \times \text{Population}
\]

3.2 Water Consumption Rate

It is very difficult to precisely assess the quantity of water demanded by the public, since there are many variable factors affecting water consumption. The various types of water demands, which a city may have, may be broken into following class

<table>
<thead>
<tr>
<th>Types of Consumption</th>
<th>Normal Range (lit/capita/day)</th>
<th>Average</th>
<th>%</th>
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<tr>
<td>1 Domestic Consumption</td>
<td>65-300</td>
<td>160</td>
<td>35</td>
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<tr>
<td>2 Industrial and Commercial Demand</td>
<td>45-450</td>
<td>135</td>
<td>30</td>
</tr>
<tr>
<td>3 Public including Fire Demand Uses</td>
<td>20-90</td>
<td>45</td>
<td>10</td>
</tr>
<tr>
<td>4 Losses and Waste</td>
<td>45-150</td>
<td>62</td>
<td>25</td>
</tr>
</tbody>
</table>
3.3 Fire Fighting Demand:

The per capita fire demand is very less on an average basis but the rate at which the water is required is very large. The rate of fire demand is sometimes treated as a function of population and is worked out from following empirical formulae:

<table>
<thead>
<tr>
<th>Authority</th>
<th>Formulae (P in thousand)</th>
<th>Q for 1 lakh Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Insurance Association</td>
<td>Q (L/min)=4637 ÖP (1-0.01 ÖP)</td>
<td>41760</td>
</tr>
<tr>
<td>Kuchling's Formula</td>
<td>Q (L/min)=3182 ÖP</td>
<td>31800</td>
</tr>
<tr>
<td>Freeman's Formula</td>
<td>Q (L/min)= 1136.5(P/5+10)</td>
<td>35050</td>
</tr>
<tr>
<td>Ministry of Urban Development Manual Formula</td>
<td>Q (kilo liters/d)=100 ÖP for P&gt;50000</td>
<td>31623</td>
</tr>
</tbody>
</table>

3.4 Factors affecting per capita demand:

- **Size of the city**: Per capita demand for big cities is generally large as compared to that for smaller towns as big cities have sewered houses.
- **Presence of industries**.
- **Climatic conditions**.
- **Habits of economic status**.
- **Quality of water**: If water is aesthetically $ people and their medically safe, the consumption will increase as people will not resort to private wells, etc.
- **Pressure in the distribution system**.
- **Efficiency of water works administration**: Leaks in water mains and services; and unauthorised use of water can be kept to a minimum by surveys.
- **Cost of water**.
- **Policy of metering and charging method**: Water tax is charged in two different ways: on the basis of meter reading and on the basis of certain fixed monthly rate.
3.5 Fluctuations in Rate of Demand:

Average Daily Per Capita Demand

\[
\text{Average Daily Per Capita Demand} = \frac{\text{Quantity Required in 12 Months}}{(365 \times \text{Population})}
\]

If this average demand is supplied at all the times, it will not be sufficient to meet the fluctuations.

- **Seasonal variation**: The demand peaks during summer. Firebreak outs are generally more in summer, increasing demand. So, there is seasonal variation.
- **Daily variation** depends on the activity. People draw out more water on Sundays and Festival days, thus increasing demand on these days.
- **Hourly variations** are very important as they have a wide range. During active household working hours i.e. from six to ten in the morning and four to eight in the evening, the bulk of the daily requirement is taken. During other hours the requirement is negligible. Moreover, if a fire breaks out, a huge quantity of water is required to be supplied during short duration, necessitating the need for a maximum rate of hourly supply.

So, an adequate quantity of water must be available to meet the peak demand. To meet all the fluctuations, the supply pipes, service reservoirs and distribution pipes must be properly proportioned. The water is supplied by pumping directly and the pumps and distribution system must be designed to meet the peak demand. The effect of monthly variation influences the design of storage reservoirs and the hourly variations influences the design of pumps and service reservoirs. As the population decreases, the fluctuation rate increases.

**Maximum daily demand** = 1.8 x average daily demand

**Maximum hourly demand of maximum day i.e. Peak demand**

\[
= 1.5 \times \text{average hourly demand}
\]

\[
= 1.5 \times \text{Maximum daily demand}/24
\]

\[
= 1.5 \times (1.8 \times \text{average daily demand})/24
\]

\[
= 2.7 \times \text{average daily demand}/24
\]

\[
= 2.7 \times \text{annual average hourly demand}
\]
4.1 Design Periods & Population Forecast

This quantity should be worked out with due provision for the estimated requirements of the future. The future period for which a provision is made in the water supply scheme is known as the design period.

Design period is estimated based on the following:

- Useful life of the component, considering obsolescence, wear, tear, etc.
- Expandability aspect.
- Anticipated rate of growth of population, including industrial, commercial developments & migration-immigration.
- Available resources.
- Performance of the system during initial period.

4.2 Population Forecasting Methods

The various methods adopted for estimating future populations are given below. The particular method to be adopted for a particular case or for a particular city depends largely on the factors discussed in the methods, and the selection is left to the discretion and intelligence of the designer.

1. Incremental Increase Method
2. Decreasing Rate of Growth Method
3. Simple Graphical Method
4. Comparative Graphical Method
5. Ratio Method
6. Logistic Curve Method
7. Arithmetic Increase Method
8. Geometric Increase Method.
WATER TANKS
5.1 CLASSIFICATIONS

Classification based on under three heads:

1. Tanks resting on ground
2. Elevated tanks supported on stagging

Classification based on shapes

1. Circular tanks
2. Rectangular tanks
3. Spherical tanks
4. Intze tanks
5. Circular tanks with conical bottom

6.1 DESIGN REQUIREMENT OF CONCRETE (I. S. I)

In water retaining structure a dense impermeable concrete is required therefore, proportion of fine and course aggregates to cement should be such as to give high quality concrete. Concrete mix weaker than M20 is not used. The minimum quantity of cement in the concrete mix shall be not less than 30 kN/m³. The design of the concrete mix shall be such that the resultant concrete is efficiently impervious. Efficient compaction preferably by vibration is essential. The permeability of the thoroughly compacted concrete is dependent on water cement ratio. Increase in water cement ratio increases permeability, while concrete with low water cement ratio is difficult to compact. Other causes of leakage in concrete are defects such as segregation and honeycombing. All joints should be made water-tight as these are potential sources of leakage. Design of liquid retaining structure is different from ordinary R.C.C, structures as it requires that concrete should not crack and hence tensile stresses in concrete should be within permissible limits. A reinforced concrete member of liquid retaining structure is designed on the usual principles ignoring tensile resistance of concrete in bending. Additionally it should be ensured that tensile stress on the liquid retaining area of the equivalent concrete section does not exceed the permissible tensile strength of concrete as given in table 1. For calculation purposes the cover is also taken into concrete area. Cracking may be caused due to restraint to shrinkage, expansion and contraction of concrete due to temperature or shrinkage and swelling due to moisture effects. Such restraint may be caused by.
(i) The interaction between reinforcement and concrete during shrinkage due to drying.

(ii) The boundary conditions.

(iii) The differential conditions prevailing through the large thickness of massive concrete

Use of small size bars placed properly, leads to closer cracks but of smaller width. The risk of cracking due to temperature and shrinkage effects may be minimized by limiting the changes in moisture content and temperature to which the structure as a whole is subjected. The risk of cracking can also be minimized by reducing the restraint on the free expansion of the structure with long walls or slab founded at or below ground level, restraint can be minimized by the provision of a sliding layer. This can be provided by founding the structure on a flat layer of concrete with interposition of some material to break the bond and facilitate movement. In case length of structure is large it should be subdivided into suitable lengths separated by movement joints, especially where sections are changed the movement joints should be provided. Where structures have to store hot liquids, stresses caused by difference in temperature between inside and outside of the reservoir should be taken into account.

The coefficient of expansion due to temperature change is taken as 11 x 10^-6 /° C and coefficient of shrinkage may be taken as 450 x 10^-6 for initial shrinkage and 200 x 10^-6 for drying shrinkage.

6. JOINTS IN LIQUID RETAINING STRUCTURES

6.1 MOVEMENT JOINTS. There are three types of movement joints.

(i) **Contraction Joint.** It is a movement joint with deliberate discontinuity without initial gap between the concrete on either side of the joint. The purpose of this joint is to accommodate contraction of the concrete.

The joint is shown in Fig. (a)

![Fig (a)](image-url)

A contraction joint may be either complete contraction joint or partial contraction
A complete contraction joint is one in which both steel and concrete are interrupted and a partial contraction joint is one in which only the concrete is interrupted, the reinforcing steel running through as shown in Fig.(b). Figure

(ii) Expansion Joint. It is a joint with complete discontinuity in both reinforcing steel and concrete and it is to accommodate either expansion or contraction of the structure. A typical expansion joint is shown in Fig.(c)

This type of joint is provided between wall and floor in some cylindrical tank designs.

6.2 CONTRACTION JOINTS
This type of joint is provided for convenience in construction. This type of joint requires the provision of an initial gap between the adjoining parts of a structure which by closing or opening accommodates the expansion or contraction of the structure.

![Diagram of Sliding Joint]

(iii) **Sliding Joint.** It is a joint with complete discontinuity in both reinforcement and concrete and with special provision to facilitate movement in plane of the joint. A typical joint is shown in Fig. This type of joint is provided between wall and floor in some cylindrical tank designs.

![Diagram of Sliding Joint Details]

### 6.3 Contraction Joints

This type of joint is provided for convenience in construction. Arrangement is made to achieve subsequent continuity without relative movement. One application of these joints is between successive lifts in a reservoir wall. A typical joint is shown in Fig(f)
6.4 TEMPORARY JOINTS

A gap is sometimes left temporarily between the concrete of adjoining parts of a structure which after a suitable interval and before the structure is put to use, is filled with mortar or concrete completely as in Fig.3.5(a) or as shown in Fig.3.5 (b) and (c) with suitable jointing materials. In the first case width of the gap should be sufficient to allow the sides to be prepared before filling. Figure (g)

7 GENERAL DESIGN REQUIREMENTS (I.S.I)

7.1 Plain Concrete Structures. Plain concrete member of reinforced concrete liquid retaining structure may be designed against structural failure by allowing tension in plain concrete as per the permissible limits for tension in bending. This will automatically take care of failure due to cracking. However, nominal reinforcement shall be provided, for plain concrete structural members.
7.2. Permissible Stresses in Concrete.

(a) For resistance to cracking. For calculations relating to the resistance of members to cracking, the permissible stresses in tension (direct and due to bending) and shear shall confirm to the values specified in Table 1. The permissible tensile stresses due to bending apply to the face of the member in contact with the liquid. In members less than 225mm thick and in contact with liquid on one side these permissible stresses in bending apply also to the face remote from the liquid.

(b) For strength calculations. In strength calculations the permissible concrete stresses shall be in accordance with Table 1. Where the calculated shear stress in concrete alone exceeds the permissible value, reinforcement acting in conjunction with diagonal compression in the concrete shall be provided to take the whole of the shear.

7.3 Permissible Stresses in Steel

(a) For resistance to cracking. When steel and concrete are assumed to act together for checking the tensile stress in concrete for avoidance of crack, the tensile stress in steel will be limited by the requirement that the permissible tensile stress in the concrete is not exceeded so the tensile stress in steel shall be equal to the product of modular ratio of steel and concrete, and the corresponding allowable tensile stress in concrete.

(b) For strength calculations.

In strength calculations the permissible stress shall be as follows:

(i) Tensile stress in member in direct tension 1000 kg/cm²
(ii) Tensile stress in member in bending on liquid retaining face of members or face away from liquid for members less than 225mm thick 1000 kg/cm²
(iii) On face away from liquid for members 225mm or more in thickness 1250 kg/cm²
(iv) Tensile stress in shear reinforcement,

For members less than 225mm thickness 1000 kg/cm²
For members 225mm or more in thickness 1250 kg/cm²
(v) Compressive stress in columns subjected to direct load 1250 kg/cm²
7.4 Stresses due to drying Shrinkage or Temperature Change.

(i) Stresses due to drying shrinkage or temperature change may be ignored provided that .

(a) The permissible stresses specified above in (ii) and (iii) are not otherwise exceeded.

(b) Adequate precautions are taken to avoid cracking of concrete during the construction period and until the reservoir is put into use.

(c) Recommendation regarding joints given in article 8.3 and for suitable sliding layer beneath the reservoir are complied with, or the reservoir is to be used only for the storage of water or aqueous liquids at or near ambient temperature and the circumstances are such that the concrete will never dry out.

(ii) Shrinkage stresses may however be required to be calculated in special cases, when a shrinkage co-efficient of 300 x 10^-6 may be assumed.

(iii) When the shrinkage stresses are allowed, the permissible stresses, tensile stresses to concrete (direct and bending) as given in Table 1 may be increased by 33.33 per cent.

7.5 Floors

(i) Provision of movement joints.

Movement joints should be provided as discussed in article 3.

(ii) Floors of tanks resting on ground.

If the tank is resting directly over ground, floor may be constructed of concrete with nominal percentage of reinforcement provided that it is certain that the ground will carry the load without appreciable subsidence in any part and that the concrete floor is cast in panels with sides not more than 4.5m. with contraction or expansion joints between. In such cases a screed or concrete layer less than 75mm thick shall first be placed on the ground and covered with a sliding layer of bitumen paper or other suitable material to destroy the bond between the screed and floor concrete. In normal circumstances the screed layer shall be of grade not weaker than M 10, where injurious soils or aggressive water are expected, the screed layer shall be of grade not weaker than M 15 and if necessary a sulphate resisting or other special cement should be used.

(iii) Floor of tanks resting on supports

(a) If the tank is supported on walls or other similar supports the floor slab shall be designed as floor in buildings for bending moments due to water load and self weight.
(b) When the floor is rigidly connected to the walls (as is generally the case) the bending moments at the junction between the walls and floors shall be taken into account in the design of floor together with any direct forces transferred to the floor from the walls or from the floor to the wall due to suspension of the floor from the wall. If the walls are non-monolithic with the floor slab, such as in cases, where movement joints have been provided between the floor slabs and walls, the floor shall be designed only for the vertical loads on the floor.

(c) In continuous T-beams and L-beams with ribs on the side remote from the liquid, the tension in concrete on the liquid side at the face of the supports shall not exceed the permissible stresses for controlling cracks in concrete. The width of the slab shall be determined in usual manner for calculation of the resistance to cracking of T-beam, L-beam sections at supports.

(d) The floor slab may be suitably tied to the walls by rods properly embedded in both the slab and the walls. In such cases no separate beam (curved or straight) is necessary under the wall, provided the wall of the tank itself is designed to act as a beam over the supports under it.

(e) Sometimes it may be economical to provide the floors of circular tanks, in the shape of dome. In such cases the dome shall be designed for the vertical loads of the liquid over it and the ratio of its rise to its diameter shall be so adjusted that the stresses in the dome are, as far as possible, wholly compressive. The dome shall be supported at its bottom on the ring beam which shall be designed for resultant circumferential tension in addition to vertical loads.

7.6 Walls

(i) Provision of joints

(a) Where it is desired to allow the walls to expand or contract separately from the floor, or to prevent moments at the base of the wall owing to fixity to the floor, sliding joints may be employed.

(b) The spacing of vertical movement joints should be as discussed in article 3.3 while the majority of these joints may be of the partial or complete contraction type, sufficient joints of the expansion type should be provided to satisfy the requirements given in article

(ii) Pressure on Walls.

(a) In liquid retaining structures with fixed or floating covers the gas pressure developed above liquid surface shall be added to the liquid pressure.
(b) When the wall of liquid retaining structure is built in ground, or has earth embanked against it, the effect of earth pressure shall be taken into account.

(iii) Walls or Tanks Rectangular or Polygonal in Plan.

While designing the walls of rectangular or polygonal concrete tanks, the following points should be borne in mind.

(a) In plane walls, the liquid pressure is resisted by both vertical and horizontal bending moments. An estimate should be made of the proportion of the pressure resisted by bending moments in the vertical and horizontal planes. The direct horizontal tension caused by the direct pull due to water pressure on the end walls, should be added to that resulting from horizontal bending moments. On liquid retaining faces, the tensile stresses due to the combination of direct horizontal tension and bending action shall satisfy the following condition:

\[
\frac{t}{\tau} + \frac{\sigma_{ct}}{\tau_{ct}} \leq 1
\]

\(t\) = calculated direct tensile stress in concrete  
\(t\) = permissible direct tensile stress in concrete (Table 1)  
\(\sigma_{ct}\) = calculated tensile stress due to bending in concrete.  
\(\sigma_{ct}\) = permissible tensile stress due to bending in concrete.

(d) At the vertical edges where the walls of a reservoir are rigidly joined, horizontal reinforcement and haunch bars should be provided to resist the horizontal bending moments even if the walls are designed to withstand the whole load as vertical beams or cantilever without lateral supports.

(c) In the case of rectangular or polygonal tanks, the side walls act as twoway slabs, whereby the wall is continued or restrained in the horizontal direction, fixed or hinged at the bottom and hinged or free at the top. The walls thus act as thin plates subjected triangular loading and with boundary conditions varying between full restraint and free edge. The analysis of moment and forces may be made on the basis of any recognized method.

(iv) Walls of Cylindrical Tanks.

While designing walls of cylindrical tanks the following points should be borne in mind:

(a) Walls of cylindrical tanks are either cast monolithically with the base or are set in grooves and key ways (movement joints). In either case deformation of wall under influence of liquid pressure is restricted at and above the base. Consequently, only part of the triangular hydrostatic load will be carried by ring tension and part of the load at bottom will be supported by cantilever action.
(b) It is difficult to restrict rotation or settlement of the base slab and it is advisable to provide vertical reinforcement as if the walls were fully fixed at the base, in addition to the reinforcement required to resist horizontal ring tension for hinged at base, conditions of walls, unless the appropriate amount of fixity at the base is established by analysis with due consideration to the dimensions of the base slab the type of joint between the wall and slab, and , where applicable, the type of soil supporting the base slab.

7.7 Roofs

(i) Provision of Movement joints.

To avoid the possibility of sympathetic cracking it is important to ensure that movement joints in the roof correspond with those in the walls, if roof and walls are monolithic. It, however, provision is made by means of a sliding joint for movement between the roof and the wall correspondence of joints is not so important.

(ii) Loading

Field covers of liquid retaining structures should be designed for gravity loads, such as the weight of roof slab, earth cover if any, live loads and mechanical equipment. They should also be designed for upward load if the liquid retaining structure is subjected to internal gas pressure. A superficial load sufficient to ensure safety with the unequal intensity of loading which occurs during the placing of the earth cover should be allowed for in designing roofs. The engineer should specify a loading under these temporary conditions which should not be exceeded. In designing the roof, allowance should be made for the temporary condition of some spans loaded and other spans unloaded, even though in the final state the load may be small and evenly distributed.

(iii) Water tightness. In case of tanks intended for the storage of water for domestic purpose, the roof must be made water-tight. This may be achieved by limiting the stresses as for the rest of the tank, or by the use of the covering of the waterproof membrane or by providing slopes to ensure adequate drainage.

(iv) Protection against corrosion. Protection measure shall be provided to the underside of the roof to prevent it from corrosion due to condensation.

7.8 Minimum Reinforcement

(a) The minimum reinforcement in walls, floors and roofs in each of two directions at right angles shall have an area of 0.3 per cent of the concrete section in that direction for sections up to 100mm, thickness. For sections of thickness greater than 100mm, and less than 450mm the minimum reinforcement in each of the two directions shall be linearly reduced from 0.3 percent for 100mm thick section to 0.2 percent for 450mm, thick
sections. For sections of thickness greater than 450mm, minimum reinforcement in each of the two directions shall be kept at 0.2 per cent. In concrete sections of thickness 225mm or greater, two layers of reinforcement steel shall be placed one near each face of the section to make up the minimum reinforcement.

(b) In special circumstances floor slabs may be constructed with percentage of reinforcement less than specified above. In no case the percentage of reinforcement in any member be less than 0.15% of gross sectional area of the member.

7.9 Minimum Cover to Reinforcement.

(a) For liquid faces of parts of members either in contact with the liquid (such as inner faces or roof slab) the minimum cover to all reinforcement should be 25mm or the diameter of the main bar whichever is greater. In the presence of the sea water and soils and water of corrosive characters the cover should be increased by 12mm but this additional cover shall not be taken into account for design calculations.

(b) For faces away from liquid and for parts of the structure neither in contact with the liquid on any face, nor enclosing the space above the liquid, the cover shall be as for ordinary concrete member.

8. DOMES:

A dome may be defined as a thin shell generated by the revolution of a regular curve about one of its axes. The shape of the dome depends on the type of the curve and the direction of the axis of revolution. In spherical and conoidal domes, surface is described by revolving an arc of a circle. The centre of the circle may be on the axis of rotation (spherical dome) or outside the axis (conoidal dome). Both types may or may not have a symmetrical lantern opening through the top. The edge of the shell around its base is usually provided with edge member cast integrally with the shell.

Domes are used in variety of structures, as in the roof of circular areas, in circular tanks, in hangers, exhibition halls, auditoriums, planetorium and bottom of tanks, bins and bunkers. Domes may be constructed of masonry, steel, timber and reinforced concrete. However, reinforced domes are more common nowadays since they can be constructed over large spans.

Membrane theory for analysis of shells of revolution can be developed neglecting effect of bending moment, twisting moment and shear and assuming that the loads are carried wholly by axial stresses. This however applies at points of shell which are removed some distance away from the discontinuous edge. At the edges, the results thus obtained may be indicated but are not accurate.
The edge member and the adjacent hoop of the shells must have very nearly the same strain when they are cast integrally. The significance of this fact is usually ignored and the forces thus computed are, therefore, subject to certain modifications.

Stresses in shells are usually kept fairly low, as effect of the edge disturbance, as mentioned above is usually neglected. The shell must be thick enough to allow space and protection for two layers of reinforcement. From this point of view 80 mm is considered as the minimum thickness of shell.

9. Membrane Theory of Shells of Revolution

Fig shows a typical shell of revolution, on which equilibrium of an element, obtained by intersection of meridian and latitude, is indicated. Forces along the circumference are denoted by $N_\phi$ and are called meridian stresses and forces at right angles to the meridian plane and along the latitude are horizontal and called the hoop stresses, denoted by $N_\theta$. Neglecting variations in the magnitudes of $N_\phi$ and $N_\theta$, since they are very small the state of stress in the element is shown in fig (b).

![Diagram](image1.png)

Fig (a)

![Diagram](image2.png)

Fig (c)
two forces $N\phi(\text{rd } \theta)$ have the resultant $N\phi(\text{rd } \theta)d\phi$ as shown in Fig. (c) and the resultant acts normal to the surface pointed towards the insideside. Forces $N\theta(\text{rd } \phi)$ again have horizontal resultant of magnitude $N\phi(\text{rd } \phi)d\theta$ as shown in Fig (d). It has a component $N\phi(\text{rd } \phi)d\theta \sin \phi$ directed normally to the shell and pointing towards the inner side. These two forces and the external force normal to the surface and a magnitude $Pr(\text{rd } \theta)$ must be in equilibrium.

Thus, $N\phi(\text{rd } \theta)d\phi + N\theta(\text{rd } \phi)d\theta \sin \phi + Pr(\text{rd } \theta)(\text{rd } \theta) = 0$.

Combining and as $r = r_2 \sin \phi$ from Fig. (a)

$N\phi/r_1 + N\theta/r_2 = -Pr = $ pressure normal to the surface

In this equation $pr$ is considered positive when acting towards the inner side and negative when acting towards the outer side of the shell. Values and $N\phi$ and $N\theta$ will be positive when tensile and negative compressive.

The equation is valid not only for shells in the form of a surface of revolution, but may be applied to all shells, when the coordinate lines for $\phi = $ constant and $\theta = $ constant, are the lines of curvature of the surface.
Forces in shell

Force $N\phi$ act tangentially to the surface all around the circumference. Considering the equilibrium of a segment of shell cut along the parallel to latitude defined by the angle $\phi$ as shown in Fig.

$$2\pi r N\phi \sin \phi + W = 0,$$

Where $W =$ total load in the vertical direction on the surface of the shell above the cut.

This gives, $N\phi = -W/2\pi r \sin \phi$

Eq. is readily solved for $N\phi$ and $N \theta$ may then be determined by Eq. This theory is applicable to a shell of any material as only the conditions of equilibrium have been applied and no compatibility relationships in terms of deformation have been introduced. It is, therefore, immaterial whether Hooke's law is applicable or not.

**10. Water tank with spherical bottom**

Referring to the tank in Fig.(a), supported along the circumference as shown, the magnitude of $N_a$ may be obtained from consideration of equilibrium. If it is required to obtain $N_a$ at section 1 - 1 from calculation of the total downward load, there are two possibilities. The downward load may be taken to be the weight of water and tank of the annular part i.e. $W_1$ shown in Fig.(b)
Alternatively, the downward load may be calculated from the weight of water and tank bottom of the part i.e. W2 less upward reaction of the support as shown in Fig.

For section which cuts the tank bottom inside the support, the reaction has to be considered with the weight of water and tank of the annular part.

Similar is the case with Intze reservoir as in Fig. (a), which combines a truncated dome with a spherical segment. Pattern of the two forces Nφ1 and Nφ2 at point A are shown in Fig(b). To eliminate horizontal forces on the supporting ring girder, it is necessary that Nφ1cos α1 = Nφ2cos α2.

11. Design of Reinforced Concrete Domes:

The requirements of thickness of dome and reinforcement from the point of view of induced stresses are usually very small. However, a minimum of 80 mm is provided so as to accommodate two layers of steel with adequate cover. Similarly a minimum of steel provided is 0.15% of the sectional area in each direction along the meridians as well as
along the latitudes. This reinforcement will be in addition to the requirements for hoop tensile stresses.

The reinforcement is provided in the middle of the thickness of the dome shell. Near the edges usually some ring beam is provided for taking the horizontal component of the meridian stress. Some bending moment develops in the shell near the edges. As shown in Fig. it is normal to thicken the shell near the edges and provide increased curvature. Reinforcements near the top as well as near the bottom face of the shell are also provided. The size of the ring beam is obtained on basis of the hoop tension developed in the ring due to the horizontal component of the meridian stress. The concrete area is obtained so that the resulting tensile stress when concrete alone is considered does not exceed 1.1 N/mm² to 1.70 N/mm² for direct tension and 1.5 N/mm² to 2.40 N/mm² for tension due to bending in liquid resisting structure depending on the grade of concrete.

Reinforcement for the hoop stress is also provided with the allowable stress in steel as 115 N/mm² (or 150 N/mm²) in case of liquid retarding structures and 140 N/mm² (or 190 N/mm²) in other cases. The ring should be provided so that the central line of the shell passes through the centroid of the ring beam. Reinforcement has to be provided in both the directions. If the reinforcement along the meridians is continued up to the crown, there will be congestion of steel there. Hence, from practical considerations, the reinforcement along the meridian is stopped below the crown and a separate mesh, as shown in Fig(a), is provided. Alternatively, the arrangement of the bars may be made as shown in plan in Fig.(b)

In case of domes with lantern opening with concentrated load acting there, ring beam has to be provided at the periphery of the opening. The edge beam there will, however, be subjected to hoop compression in place of hoop tension.

Openings may be provided in the dome as required from other functional or architectural requirements. However, reinforcement has to be provided all around the opening as shown in Fig. (c). The meridian and hoop reinforcement reaching the opening should be well anchored to such reinforcement.
The allowable stresses specified in IS 3370 for such tanks are as follows:

Type of stresses: Permissible stress in N/mm².

- High yield strength
  - Plain bars confirming to deformed bars as per Grade-I of IS 432-1966. IS 1786-1966 or is 1139-1966.

(‡) Tensile stress in members under

No table of contents entries found
direct load.

Direct tensile stress in concrete a may be taken as 1.1 N/mm², 1.2, N/mm², 1.3 N/mm², 1.5 N/mm², 1.6 N/mm² and 1.7 N/mm² for M15, M20, M25, M30, M35 and M40 respectively, the value in tension due to bending i.e., σ being 1.5 N/mm², 1.7 N/mm², 1.8 N/mm², 2.0 N/mm², 2.2 N/mm² and 2.4 N/mm².

When steel and concrete are assumed to act together for checking the tensile stress in concrete for avoidance of cracks, the tensile stress in the steel will be limited by the requirements that the stress as mentioned above should not be exceeded. The tensile stress in steel will be modular ratio multiplied by the corresponding allowable tensile stress in concrete.

Stresses due to shrinkage or temperature change may be ignored if these permissible stresses in concrete and steel are not exceeded and adequate precautions are taken to avoid cracking of concrete during construction period, until the reservoir is put into use.
and if it is assured that the concrete will never dry out. If it is required to calculate shrinkage stresses, a shrinkage strain of \(300 \times 10^{-6}\) may be assumed.

When shrinkage stresses are considered, the permissible stresses may be increased by 33.3\%.

When shrinkage stresses are considered it is necessary to check the thickness for no crack.

Minimum reinforcement of each of two directions at right angles shall have an area of 0.3\% for 100 mm thick concrete to 0.2\% for 450 mm thick concrete wall. In floor slabs, minimum reinforcement to be provided is 0.15\%. The minimum reinforcement as specified above may be decreased by 20\%, if high strength deformed bars are used.

Minimum cover to reinforcement on the liquid face is 25 mm or diameter of the bar, whichever is larger and should be increased by 12 mm for tanks for sea water or liquid of corrosive character.

12. Overhead Water Tanks And Towers

Overhead water tanks of various shapes can be used as service reservoirs, as a balancing tank in water supply schemes and for replenishing the tanks for various purposes. Reinforced concrete water towers have distinct advantages as they are not affected by climatic changes, are leak proof, provide greater rigidity and are adoptable for all shapes.

Components of a water tower consists of –

(a) Tank portion with -

(1) Roof and roof beams (if any)

(3) Floor or bottom slab

(b) Staging portion, consisting of-

(5) Columns

(7) Foundations

Types of water Tanks may be –
(a) Square-open or with cover at top       (b) Rectangular-open or with cover at top

(c) Circular-open or with cover at which may be flat or domed.

Among these the circular types are proposed for large capacities. Such circular tanks may have flat floors or domical floors and these are supported on circular girder.

The most common type of circular tank is the one which is called an Intze Tank. In such cases, a domed cover is provided at top with a cylindrical and conical wall at bottom. A ring beam will be required to support the domed roof. A ring beam is also provided at the junction of the cylindrical and conical walls. The conical wall and the tank floor are supported on a ring girder which is supported on a number of columns.

Usually a domed floor is shown in fig a result of which the ring girder supported on the columns will be relieved from the horizontal thrusts as the horizontal thrusts of the conical wall and the domed floor act in opposite direction.

Sometimes, a vertical hollow shaft may be provided which may be supported on the domed floor.

The design of the tank will involve the following

. (1) The dome at top usually 100 mm to 150 mm thick with reinforcement along the meridians and latitudes. The rise is usually 1/5th of the span.

(2) **Ring beam supporting the dome.** The ring beam is necessary to resist the horizontal component of the thrust of the dome. The ring beam will be designed for the hoop tension induced.

(3) **Cylindrical walls :** This has to be designed for hoop tension caused due to horizontal water pressure.

(4) **Ring beam at the junction of the cylindrical walls and the conical wall.** This ring beam is provided to resist the horizontal component of the reaction of the conical wall on the cylindrical wall. The ring beam will be designed for the induced hoop tension.

(5) **Conical slab,** This will be designed for hoop tension due to water pressure. The slab will also be designed as a slab spanning between the ring beam at top and the ring girder at bottom.

(6) **Floor of the tank.** The floor may be circular or domed. This slab is supported on the ring girder.
(7) **The ring girder:** This will be designed to support the tank and its contents. The girder will be supported on columns and should be designed for resulting bending moment and Torsion.

(8) **Columns:** These are to be designed for the total load transferred to them. The columns will be braced at intervals and have to be designed for wind pressure or seismic loads whichever govern.

(9) **Foundations:** A combined footing is usually provided for all supporting columns. When this is done it is usual to make the foundation consisting of a ring girder and a circular slab.

Suitable proportions for the Intze.

for case(1) suggested by Reynolds. Total volume \( \sim 0.585D^3 \)

for case (2), the proportion was suggested by Grey and Total Volume is given by

\[
V1 = \pi(D)^2/4 \times (H) = 0.3927 D^3 \text{ for } H = D/2
\]

\[
V2 = \pi.h/12(D^2+d^2+d) = 0.10263 D^3
\]

With \( h = D/5 \) and \( d = 3/5D \)

\[
V3 = (\pi h1)/6 ((3r)^2+(h1)^2) = 0.0179 D^3
\]

With \( h1 = 3/25D \) and \( r = 3/10D \)

Volume \( V = 0.4693 D^3 \)

With \( h1 = D/6 \) and \( r = 3/10D \)

Volume \( V = 0.493 D^3 \)
14. DETAILS OF DESIGN:

Population calculation:

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<th>Year</th>
<th>Population</th>
<th>Increase per decade.</th>
<th>Incremental increase.</th>
<th>Percentage increase.</th>
<th>Decrease in percentage increase.</th>
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<td>50</td>
<td>49.84</td>
<td>11.9</td>
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</tbody>
</table>

**Population in 2010.**

i. Arithmetical progression method
   
   \[= 1000 + 233 = 1233.\]

ii. Geometrical progression method
   
   \[= 1000 + \left(\frac{49.84}{100}\right) (1000)\]
   \[= 1498.4\]

iii. Incremental increase method
   
   \[= 1000 + 233 + 50\]
   \[= 1283\]

iv. Changing increase rate method
   
   \[= 1000 + \left(\frac{42.87 - 11.9}{100}\right) (1000) / 100\]
   \[= 1529.7\]

Considering geometrical progression method = 1498.4 ≈ 1500 population.

**PER CAPITA DEMAND:**

\[= 1500 \times 165 = 2,50,000 \text{ liters.}\]

**Design of tank:**

Design of an intez tank for a capacity of 250,000lts

Assuming height of tank floor above G.L 12m
Safe bearing capacity of soil 100kn/m^2

Wind pressure as per IS875 1200N/m^2

Assuming M20 concrete

For which $\sigma_{cbe} = 7\text{N/mm}^2$, $\sigma_{cc} = 5\text{N/mm}^2$

Direct tension $\sigma_t = 5\text{N/mm}^2$

Tension in bending $= 1.70 \text{N/mm}^2$

Modular ratio $m = 13$

For Steel stress,

Tensile stress in direct tension $= 115 \text{N/mm}^2$

Tensile stress in bending on liquid face $= 115 \text{N/mm}^2$ for $t < 225$ mm

and $125 \text{N/mm}^2$ for $t > 225$ mm.

**Solution**: Taking the volume as 0.585 $D^3$ for proportion given in Fig.

\[ D = 7.50 \text{ m}. \] The dimension of the Tank is shown in fig.

**Design of Roof Dome:**

Considering a rise of 1.50 m, radius of the roof dome is given from

\[ 1.50(2R-1.50) = (3.75)^2 \]

\[ R = 5.4375 \text{m}. \]

\[ \cos \phi = (5.4375 - 1.50)/5.4375 \]
\[ = 0.7241 \]

and

\[ \varphi = 43.602 < 51.8^\circ \]

Hence no tension

Assuming $t = 100\text{mm}$.

Self wt. = 2400N/m^2
Equivalent of wind load, accidental loading and live load = 2600 N/m²/5000N/m²

Meridian stress at of edge of dome

\[ N\varphi = -\frac{wR}{(1+\cos\varphi)} \]
\[ = -\frac{5000(5.4375)}{(1+0.7241)} \]
\[ = 15769.10 \text{ N} \]

And meridian stress = 15769.10/1000(100) = -0.1577N/mm²(comp)

Maximum hoop stress at crown = \(-\frac{wR}{2t} = -\frac{5000(5.4375)}{2(100)(1000)} \)
\[ = -0.136 \text{ N/mm}^2(\text{comp}) \]

Use nominal reinforcement 0.3% = 300mm²
Use 8 mm bars @ 160 mm c/c. both ways.

**Design of ring beam at top:**
Horizontal component of \(N\varphi = N\varphi\cos\varphi\)
\[ = 15769.10(0.7241) \]
\[ = 11418.41 \text{ N} \]

Hoop tension in ring = 11418.41(7.5/2) = 42819.10N
Steel required for hoop tension = \( \frac{42819.10}{115} \) 
= 372.33\( \text{mm}^2 \)

Use 4 Nos. 12 mm bars at corners.

Area of cross section of ring beam considering concrete only
= \( \frac{42819.10}{1.20} \)
= 35682.58\( \text{mm}^2 \)

Use a ring beam 225mm X 160mm

Area provided = 36000\( \text{mm}^2 \) > 35682.58\( \text{mm}^2 \)

Use 6mm dia nominal stirrups @ 100mm c/c.

Shear stress along the edge = \( N\phi \sin\phi = 15769.10 \times 0.690 = 10880.68\text{N} \)

Shear stress = \( \frac{10880.68}{100(1000)} = 0.1088\text{N/mm}^2 \) – very low.

**Design of cylindrical wall:**

Height of the wall = 5.0 m

\( P_t = 10000(5) = 50000\text{N/m}^2 \)

\( N\phi = 50000(7.50/2) = 187500\text{N} \)

Area of steel required = \( \frac{187500}{115} = 1630.43\text{mm}^2 \)

Use 12 mm bars @ 135mm c/c on both faces.

With \( A_s = 1675.52\text{m}^2 \)

Thickness of concrete required \( 187500+60(1675.52) = 240026.12 \)

Considering \( A = A_c + (m-1) A_s = A_c + (12) (1675.52) = A_c + 20106.24 = 240026 \)

\( A_c = 219919.76\text{mm}^2 \)

Use \( t = 230\text{mm} \) at bottom, tapered to 200mm at top

Minimum \( A_{st} = 0.30-0.10 (130) = 0.2629\% \)

\( 350 \)

Maximum \( A_{st} = 604.57\text{mm}^2 \)

Hence 12mm \( \phi \) @ 135 c/c. at both faces adequate.

**Cantilever beam:**

From table 1, for \( H^2/Dt = 14.493 \)

Cantilever B.M. \( 0.0090 \times (wH^3) = 0.0090 \times (10000)(5)^3 = 11250\text{Nm/m} \)

For no crack \( t = 230\text{mm} \) adequate.

Use vertical steel And \( A_{st} = 11250(1000) = 573.42\text{mm}^2 \)
Use 12 mm $\phi$ vertically @ 150 mm c/c. as both faces.

Roof load = $(2\pi R) h_1 (w_{d+e}) = 2\pi R^2 (1+\cos\phi) w_{d+e}$

$$= 2\pi (5.4375)^2 (1-0.7241) (5000) = 256271.38N$$

Wt. of ring beams = $(0.225) (0.160) (\pi) (7.725) (24000)$

$$= 20968.25N$$

Wt. of side wall = $(7.715) (0.215) (5) (25000) = 625324.59N$ 

$$= 902564.22N$$

Direct compressive stress = $\frac{902564.22}{\pi(7.715) (1000) (230)} = 0.162 N/mm^2$

Hence ok

**Design of ring beam at bottom of cylindrical wall and top of conical slab:**

From top $\Sigma W = 902564.22N$

Self Wt. of ring beam = 80000.00N

$$= 982564.22N$$

Inclined thrust at top of conical portion = $\frac{982564.22}{\pi(7.725)\sin\theta} = 57256.10N/m$

where $\theta = 45^\circ$

Horizontal component = $57256.10(\cos 45^\circ) = 40486.18N/m$

Hoop tension in ring beam = $40486.18 (7.50/2) = 151823.16N$

Pressure of water at ring level = $10000 (5) = 50000N/m$

Hoop tension due to this on the ring beam

$$= 50000(7.5/2) \text{(width of the ring beam)} = 56250N$$

Taking width as 300mm

Total hoop tension = $151823.16 + 56250 = 208073.16$

Steel required = $\frac{208073.16}{115} = 1809.33mm^2$

Use 6 nos. 20 mm $\varnothing$ bars

$$A_e + (m-1)A_{st} = A_e + 12(1884.96)$$

Hence $A_e = \frac{208073.16 - 12(1884.33)}{115} = 154551mm^2$
1.20

Use ring size 520mm x 300mm
Use 12 mm 2 legged stirrups in ring beam @ 150c/c.

**Design of conical slab:**

Wt of side wall and dome = 902564.22N
Wt of conical bottom assuming
250 mm thick = \( \pi (97.50 + 4.70) \cdot (1.40 \sqrt{2}) \cdot \frac{2}{2} \)

\[ \frac{250}{1000} (24000) = 227653.345N \]

Wt of water on dashed part in fig

\[ \frac{\pi}{4} ((7.50)^2 - (4.70)^2) \cdot (5.00) (10000) + \pi (1.40)/12 \]

\[ = ((7.50)^2 + (4.70)^2 + (7.50)(4.70)) (10000) - \pi/4(4.70)^2 (1.40) (10000) \]

\[ = 1514896.92N \]

\[ 2645114.48N \]

Meridian force \( N_\phi = \frac{2645114.48 \sqrt{2}}{2} = 253344.65N/m \)

Compressive stress = \( \frac{253344.65}{1000 (250)} = 1.013 \text{ N/mm}^2 \)

Hoop tension \( N_\theta \)

Diameter of conical dome at ht ‘h’
Above base = \( 4.70 + \frac{7.50 - 4.70 (h)}{1.40} = 4.70 + 2h \)

Intensity of water pressure there = \( (5 + 1.40 - h) (10000) = 64000 - 10000h \)

Self Wt. = \( \frac{250}{1000} \cdot 24000 = 6000 \text{ N/m}^2 \)

\[ N_\theta = \frac{(6.40 - h)10000 + 6000\sqrt{2} \cdot (4.70 + 2h)\sqrt{2}}{2} \]

\[ = \frac{(10000\sqrt{2}(6.40 - h) + 6000)}{2} (4.70 + 2h) \]

\[ N_\theta \text{ from } N_\phi/r_1 + N_\theta/r_2 = -P_r \]

\[ r_1 = \infty \quad r_2 = (4.70 + 2h) \]

\[ 2 \]

At \( h = 0 \), \( N_\theta = 2226797.72N \)

\( h = 0.70 \), \( N_\theta = 264161.028N \)
\[ h = 1.40 \text{ N} \theta = 287665.05 \text{N} \]

maximum \( A_{st} = \frac{287665.05}{115} = 2501.44 \text{mm}^2 \)

Use 16 mm Øbars on each face @ 160 mm c/c.

Checking thickness,

\[
A_{eq} = A_c + (m-1)A_{st} = A_c + 12(2513.27)
\]

Thickness reqd. = \[
\frac{1}{1000}[287665.05 - 12(2513.27)] \approx 210 \text{mm}
\]

Hence \( t=250 \text{mm} \) in adequate

**Design as inclined slab of conical Dome:**

Total \( W \) on top of Inclined slab = 2645114.48 N - Wt. of side wall and done.

\[
= 2645114.48 - 902564.22 = 1742550.26 \text{N}
\]

Vertical load on slab /m = \[
174255026/ (\pi(7.50+4.70)/2) = 90929.67 \text{ N/m}
\]

B.M. = 90929.67(1.40)/8 = 15912.70 Nm

with partial fixity B.M. = 12730.16 Nm

Axial compression = 902564.22 N = 37238.50 N/m.

Resulting B.M. = 15912.70 + 37238.50\sqrt{2} [(0.210 - 0.125)] = 20389.07 Nm

\[ A_{st} = 20389.07(1000)/ 115 (0.853) (210) = 989.76 \text{ mm}^2 \]

Min\(^n\) Steel = 0.30 - (0.10/350)(150) = 0.257% \( i.e., = 642.86 \text{ mm}^2 \)

Use 12 mm Ø @ 110 mm c/c on both faces.

**Design of Bottom dome:**

Span of the dome = 4.70 m.

Rise of the dome = 0.950 m.
Radius of the dome from 0.950 \((2R - 0.950) = (4.70/2)^2\)

Hence \(R = 3.3816\) m

Angle subtended by the dome = \(2\theta\)

\[
\sin \theta = \frac{(4.70/2)}{3.3816} = 0.695
\]

and \(\theta = 44.02^\circ; \cos \theta = 0.71\)

Take thickness of dome as 200 mm

Loading

D.L. of dome = 0.200 \((24000) = 4800\) N/m\(^2\)

Wt. of water on dome = 10,000 \[\pi/4(4.70)^2 (6.40) - \pi/6(0.950) (3 \times 2.35^2 + 0.950^2)]

= 1023465.44 N

Area of dome surface = \(2 \pi (3.3816) (0.950) = 20.185\) m\(^2\)

Load intensity = \((1023465.44/20185) + 4800\) = 55504.26 N/m\(^2\)

Meridian thrust at springing level = \(wR/(1+\cos \theta)\)

\[
= \frac{55504.26 \times 3.3816}{1.719} = 109187.43 \text{ N/m}\]

Meridian compressive stress = \(109187.43 / 1000\) = 0.546 N/m\(^2\)

Hoop stress = \(wR/t[\cos \theta - (1/1+\cos \theta)]\)

Maximum at \(\theta = 0\), where

Max hoop stress = 0.469 N/mm\(^2\)

Stresses are low and provide 0.30 % steel.

Use 8 mm Ø bars @ 80 mm c/c.

**Design of Circular Girder:**

Assume size of girder as 400 x 600 (deep) Center to center of Girder = 4.70 + 0.400 = 5.10 m.

Check for Hoop Stress on Ring Beam

From inclined conical slab with \(\phi_0 = 45^\circ\)
Nφ₀ = 253344.65N

Horizontal component = 253344.65 \cos \phi = 179141.72N

From bottom of Dome Nφ₁ = 109187.43 N/m

with \quad \phi = 44.02°

Horizontal component = 78505.76 N

Hoop stress as Ring Beam = (179141.72 - 78505.76)(5.10/2) = 256621.70N

Hoop stress (compression) = 256621.70/(1000(400))

= 0.642N/mm²

Total loads on the circular girder are

Weight of water = 1514896.92 + 1023465.06 N = 2538362.06 N

Wt. of Top dome and side slab = 902564.22 N

Wt. of Conical wall = 227653.34 N

Wt. of Lower dome = (4800) (20.185) = 96888.0 N

Wt. of Circular girder

with a size of 400 x 600 = 78200.0 N

Total Wt. 3843667.62 N

With D = 4.70 + 0.400 = 5.10,

W = 239897.53 N/m

Provide Six Columns.

At location of Maxm+ VcBM. at Center of the Girder i.e., at \phi = 0, Torsional moment = 0

From \quad M_\phi = (\frac{\theta \cos \phi - 1}{\sin \theta})WR

T_\phi = [(\theta / \sin \theta) \sin \phi - \theta]WR

V_\phi = WR\phi
For the case $\theta = 60^\circ$; With 6 Columns
Considering column of diameter 600 mm (531.74 mm eq. square)

$\varphi = 24^\circ$ on face of column from center of span
$\varphi = 0^\circ$ at center.
$\varphi = 17.27^\circ$ from center for $T_{\text{max}}$

Design negative BM on face of column = $ \left[ \frac{\pi}{6}/0.50 \cos 24^\circ \right] (239897.53)(2.55)^2$

$= 67603.52 \text{Nm}$

Maximum +Ve BM at $\varphi = 0$,
B.M. = $ \left[ \frac{\pi}{6}/0.50 \cos 0^\circ \right] (239897.53)(2.55)^2$

$= 73625.05 \text{Nm}$

Maxm. Torsion Moment at $\varphi = 17.27^\circ$ from center

$T_{\text{max}} = \left[ \frac{\pi}{6} \sin 17.27^\circ - (17.27)(\pi) \right] \frac{239897.53(2.55)^2}{0.05 \ 180}$

$= 14769.97 \text{Nm}$

At location of- Ve B.M. on face of columns.

$T_{\varphi} = \left[ \frac{\pi}{6} \sin 24^\circ - (24)(\pi) \right] \frac{239897.53(2.55)^2}{0.05 \ 180}$

$= 11004.70 \text{Nm}$

S.F. at distance $d = 560$ mm from face of support
Where $\varphi = 11.44^\circ$

$V = wR\varphi = (239897.53)(2.55) \frac{\pi(11.44)}{180} = 122143.22 \text{N}$

S.F on face of column $V_c = V + 1.6(TR/b) = 122143.22 + 1.6 (11004.70/0.400)$

$= 166162 \text{N}$

$\tau_{ve} = \frac{166162}{(400)(560)} = 0.742 < \tau_{\text{max}}, \text{i.e., 1.80 N/mm}^2$
Shear reinforcement necessary
Design moment at face of column = \( M + M_t \)
\[
= 67670.52 + (11004.70/1.70)(1+600/400)
= 83853.90M
\]

Hence section is under reinforced
\[
A_{st} = 83583.90(1000) = 1526.47 \text{ mm}^2
\]
\[
115(0.853)(550)
\]

Use 5 Nos. 20 mm \( \phi \) at top in one layer

As \( M_t < M \), longitudinal reinforcement on flexural compression face not necessary.

For positive B.M.
\[
A_{st} = 73625.05(1000) = 1526.47 \text{ mm}^2
\]
\[
115(0.853)(560)
\]

Use 5 Nos. 20 mm \( \phi \) at bottom.

SF at a distance \( d = 56 \text{mm} \) from face of column where \( \phi = 11.44^\circ \)

and SF there = 166162.42 = \( V_e \)

\( \tau_{ve} \) there = 0.742 N/mm\(^2\) < 1.80 N/mm\(^2\)

Shear reinforcement is necessary.

At location of \( T_{max} \).
\[
V_e = 184389.28 + 1.6 + (14769.97/0.40)
\]
\[
\tau_{ve} = 1.087 \text{ N/mm}^2 < \tau_{max}
\]

\( 100(A_{st}/bd) = 0.70 \) and \( \tau_c = 0.340 \text{N/mm}^2 \)

Transverse reinforcement to be not less than
\[
A_{sv} = \left( \tau_{ve} - \tau_c \right)b.S_v/\Sigma = \left[ (1.087-0.340)(400S_v) \right]/125
\]

For two legged 12 mm \( \phi \) stirrups. \( S_v \) @ 95 mm c/c.

Also
\[
A_{sv} = (T S_v/b_1d_1\sigma_{sv}) + V S_v/2.5 d_1 \sigma_{sv}
\]
\[ b_1 = 400 - 2(25 + 12 + 10) = 306 \text{mm} \]
\[ d_1 = 600 - 2(25 + 12 + 10) = 506 \text{mm} \]
\[ A_{sv} = \frac{[(14769.97 \times 1000) S_v]}{(306 \times 506 \times 125)} + \frac{[(184389.28 S_v/2.5 \times 506 \times 125)]}{(306 \times 506 \times 125)} \]
\[ = 0.76313 S_v + 1.16610 S_v = 1.92923 S_v \]

With 2 legged 12 mm \( \phi \) stirrups

\[ S_v = 117 \text{mm c/c. Use } S_v = 95 \text{ c/c.} \]

**Design of Columns** – Six columns of 600 mm diameter to be symmetrically placed at 60° c/c. Length of column = 12 + 1 = 13 m. Consider column to have a batter of 1 in 20,
\[ \alpha = 2.862^\circ \text{ and } \cos \alpha = 0.999; \sin \alpha = 0.050 \]

Total load:

- Load from Top = 3843667.62 N
- Self wt. of 6 columns = 529300.00 N
- Wt. of Bracing = 60000.00N

Total = 4432967.62 N

Load on each column due to \( W = 738828 \) N

Thrust on each column = 739567.50 N

Diameter at base = 5.10+(12/10) = 6.30 m

Wind Loading Considering \( V_b \) - 50 m/sec.

\[ V_z = V_b k_1 k_2 k_3 = 0.90 V_b k_2 k_3 \text{ taking } k_1 \text{ as } 0.90 \text{ for 25 yrs. life.} \]

Taking \( k_2 \) and \( k_3 \) both as unity.

\[ p_z = 0.60 v^2 = 0.60 \times (45)^2 = 1215 \text{ N/m}^2 \]

\[ P_1 = [7.5 + 0.450)(5.0(7.69)(2/3)(1.60) + (7.69 + 5.10)(1.60)/2] \]
\[ (1215)(0.70) = 49915 \text{N} \]
taking shape factor as 0.70

This acts at a height \( = 12 + \frac{1}{2}(1.60 + 5 + 1.6) \)

\[ P_2 = \text{Due to column, Bracing and circular Girder} \]

\[ = [(5.50) (0.600) + V_t (0.60) (4.0) (6.0)] (1215) (0.70) \]

\[ + (5.50) (0.300) (1215) (0.70) \]

\[ = 10333.58 \text{N at L2m above G.L.} \]

\[ P_3 = \text{On column and Bracing} \]

\[ = [6 (0.600) (4) + (5.80) (0.300)] (1215) (0.70) \]

\[ = 13727 \text{N at 4 m above G.L.} \]

\[ P_4 = [6(0.600) (4) + (6.20) (0.300)](1215) (0.70) \]

\[ = 13829 \text{N at 4 m above G.L.} \]

35
Consider column fixed at base
Considering P.I. at mid height of column

<table>
<thead>
<tr>
<th>Levels</th>
<th>Shear (N)</th>
<th>M(Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>49915+10334=60249</td>
<td>49915 (4.10+2)+10334(2) =325149.50</td>
</tr>
<tr>
<td>2-2</td>
<td>60249+13727 =73976</td>
<td>49915 (6.10+4)10334(6)+13727(2) =667575.50</td>
</tr>
<tr>
<td>3-3</td>
<td>73976+13829=87805</td>
<td>49915(14.10)+13727(6)+10334(10) +13829(2) = 917161.50</td>
</tr>
</tbody>
</table>
Referring to Fig. For XX axis

\[ \sum y^2 = 4(D^2/3)^2/8 = 3/4d^2 \]

For YY axis

\[ \sum x^2 = 2(D/2)^2 + 4(D/4)^2 = 3/4D^2 \]

For bending about XXaxis, due to wind loading Referring to line 3-3.

\[ V1 = V4 = 0 \]

And \[ V2 = V3 = V5 = V6 = \pm 917161.50/3(3/4(6.10))^2 (\sqrt{3}/4(6.10)) \]

\[ = \pm 86807.12 \]

For bending about YYaxis,

\[ V1 = V4 = 917161.50*6.10 \]

\[ \frac{3}{4}(6.10)^2 \]

\[ V2 = V4 = V5 = V6 = \pm 50118.1 \ N \]

Maxm. Thrust in column = 739567.50 + 100236.23 /0.999 = 83994 N

At point 3-3,

On each column H= 878.5/6 = 14634.17 N

Vertical load at (3) due to W.L. = 100236.23 N.

B.M on column = 14634.17(2)-100236.23N

\[ = 19244.72 \ N.m. \]
(Refer Fig.) design of column can be done by limit state method

M - 20 Concrete F_e 415 steel. Self wt. of a column = 81530 N

Axial force = 839904 N + 81530N

\[ M_{fy} = 19244.72 \text{ Nm. This case 1} \]

Axial force = 839904 N + 81530N

\[ M_{ux} = 2058.64 \text{ Nm. this is case 2} \]

Safety factor to be used is 1.20

Case-I: Pu = 1105720.80 N

\[ M_{b} = 23093.664 \text{ Nm.} \]

CaseII : Pu = 1089589.38N

\[ M_{uxx} = 24705.17 \text{ N} \]

With 600φ column

\[ \frac{Pu(fck d^2)}{2} = 0.154 \text{ for Case -1 and 0.151 for Case – II} \]

\[ \frac{Mu(fck D^3)}{2} = 0.0053 \text{ for Case -1 and 0.0057 for Case – II} \]

\[ d/D = (40+8)/0.08 \]

use \( d/D = 0.10 \)

\[ \text{Min Steel} = 0.80 \% \ i.e., \ p/fck = 0.04 \]
Muxx ~ Muyy = 0.06(20) (600)^3

Hence column is adequate.

Use 8 Nos. 20 mm § bars as longitudinal bars; Ties 10 mm @ 300 c/c.

**Design of Bracing:**

\[ \sum M \text{ at Joint above (3)} = 20587.64 + 9167(2) = 389.21.64 \text{Nm} \]

\[ \text{Moment in bracing} = 38931.64 \sqrt{2} \]

Providing 300 mm x 300 mm section and design as a doubly reinforced beam with equal steel at top and bottom.

\[ A_{st} = A_{sc} = \frac{(38921.64(1.2 (1000)))(0.87(415)(260))}{2} \]

\[ = 497.54 \text{mm}^2 \]

Use 4 Nos. 16 mm both at top and bottom

Use 2 legged 12 mm stirrups @ 200 c/c

**Check for Seismic effect:**

Refer IS 1893 - Consider zone III

Wt. of empty Tank = 1305305.56 N

Wt. of full Tank = 3843667.62 N

For Empty condition Total Wt. = 1305305.56 + \frac{1}{3}(600.00) = 1505305.56 N

For Tank full condition

\[ \text{Total Wt.} = 4043667.62 \]

Stiffness of a column in a bay

\[ K_c = 12EI/L^3 \]

\[ E = 5000\sqrt{fck} = 22360.68 \text{N/mm}^2 \]

\[ I = \frac{\pi}{4}(D)^4 = 6.362 \times 10^9 \text{mm}^4 \]

\[ L = 4\text{m} = 4000 \text{mm.} \]

\[ k_c = 12(22360.68)(6.362)10^9/4000^3 \]

\[ = 26673.56 \text{N/mm} \]

Stiffness of six column,

\[ \sum k_c = 6(26673.50) = 160040.98 \text{N/mm} \]
Neglecting effect of bracing or stiffness.

\[
\frac{1}{K} = \sum \frac{1}{k},
\]

When \( \frac{K}{3} = 160040.98 = 53347 \text{N/mm} \)

Fundamental period
\[
T = 2\pi \sqrt{\frac{W}{gK}} = 2\pi \sqrt{\frac{4043667.62}{9810(53397)}} = 0.552 \text{sec.}
\]

From IS:1893,
\[
A_h = Z I S_a/2Rg
\]
For zone III \( Z = 0.16; I = 1; R = 2.50 \)

Considering hard soil site
\[
S_a/g = 1.00(1)/T(0.552) = 1.8116
\]

Taking it as \( 1.887 > 1.8116 \)

and
\[
A_h = \frac{0.16(1.887)}{2(2.50)} = 0.0604
\]

Hence
\[
V = 0.0604(4043667.62) = 244237.52 \text{ N}
\]
acting horizontal at the C.G. of the tank. Seismic effect \( V > \sum H \) forces due to wind. Hence seismic effect controls.

Design of column has to be done considering seismic effects
\[
V = 244237.52 \text{ N acts at 14.10m above hinge along 3-3}
\]
\[
M = 244237.52 (14.10) \text{ Nm}
\]
Maxm. Vertical force on column = \(\frac{[244237.52(14.10)(6.10)]}{\pi(6.10)^2(2)}\)
\[= 376366.02 \text{ N}\]
Maxm. Thrust on the column = \(739567.50 + 37666.02/0.999\)
\[= 1116310.26 \text{ N}\]
Horizontal force on column = \(232157.52/6 = 38692.92 \text{ N}\)
As in case of wind forces.
BM on column = \(38692.92 (2) - 376366 (0.10)\)
\[= 39749.24 \text{ Nm}\]

Using Limit state Method
\[
P_u = 1.20 (1116310.26 + 81530) = 1437408.33 \text{ N}
\]
\[
P_u/f_{ck}D^2 = 0.200
\]
\[
M_u = 1.20 (41610.74) = 49932.89
\]
Refer to fig. A.9

\[ \frac{d'}{D} = 0.08 \sim 0.10 \]

with minimum steel 0.08%, \( p/f_{ck} = 0.04 \)

\[ M_u = 0.056 \times (20) \times (600)^3 = 241920 \text{Nm} \]

Hence adequate

Use bracing

Empty condition

\[ A_h \text{ taken 0.08 the maximum value} \]

\[ V = 0.08 \times (1505305.56) = 120424.45 \text{N} < 232157.52 \text{N} \]

Hence empty condition does not control.

The column size can be reduced to 450 mm Ø

Design of the ring beam at top will practically remain the same as before except that the Maximum BM and Torsion at the face of the column (eq square = 400 mm) to be calculated and checked.

For the case \( \phi = 25.50^\circ \)

Negative BM on face of column = -85507.61 Nm

\[ T_\phi \text{ there } = 9002.70 \text{Nm} \]

\[ M_e = 85007.61 + 9002.70 \frac{(1+600/400)}{1.70} = 98746.88 \text{Nm} \]

\[ A_{st} = 98746.88 \times 1000 / 115 \times (0.853) \times (560) \]

\[ = 1797.58 \text{mm} \]

Use 6 Nos. 20 mm at top

Other details will be the same as before

**Check for Seismic effect**

for empty Tank = 1505305.56 N

for Tank full = 4043667.60 N

for the column \( I = \pi/64(450)^4 = 2.012889590 \times 10^9 \text{mm}^4 \)

\[ L = 4000 \text{mm} \]

\[ k_c = 8439.30 \text{N/m} \]

As before \( K = 6(8439.30) / 3 = 16878.60 \text{N/m} \)

\[ T = 2\pi \sqrt{4043667.62 / 9810(16878.60)} = 0.982 \text{sec} \]
Considering for safety soft soil (in place of hard soil considered earlier)

\[ \frac{S_v}{g} = \frac{1.67}{0.982} = 1.70 \]

\[ A_h = \frac{0.16}{2(250)} = 0.0544 \]

\[ V = 0.0544 \times 4043667.62 = 219975.52 \text{ N} \]

acting at 14.10 m. above 3-3

\[ M = 219975.52(14.10) \text{ Nm} \]

Maxm. vertical force on column = 219975(14.10)(6.10)/\(\frac{3}{4}(6.10)^2\) = 338978.67N

Maxm. Thrust on column = 739567.50 + (338978.67/0.999) = 1078885.42 N

Horizontal force on column = 219975.52/6 = 36662.59 N

As before

BM on column = 36662.59 (2) - 338978.6 (0.10) = 39427.32 Nm

Using Limit State Method

\[ P_u = 1.20 (1078885.42 + 45804.42) = 1349627.81 \text{ N} \]

\[ \frac{P_u}{f_{ck}D^2} = 0.332 \]

\[ M_u = 1.20(39427.32) = 47312.78 \text{ Nm} \]

With 0.80% steel \( P/f_{ck} = 0.04 \)

\[ d'/D = \frac{50}{450} = 0.11 - 0.10 \]

from fig A-9,

\[ M_{ud} = 0.035(20)(450)^3 = 63787.50 \text{Nm} > 47312.78 \text{Nm} \]

Hence 450 \( \phi \) column adequate.

Use 0.80% steel i.e., Use 8 Nos 16 mm \( \phi \) longitudinal

Ties For bracing Use 10 mm \( \phi \) @ 250 c/c.

Total M. from (2) (2) and (3) (3) = 2 (39427.32) Nm

\[ \sum M \text{ on column} = 2 (39427.32) \text{ Nm} \]
Part of this moment taken by two bracings equally.
partly by Moment and partly by Torsion.

\[
\text{Angle} = 60^\circ
\]

\[
M = 2(23427.32 \sin 30^\circ)/2 = 19713.67 \text{Nu.M}
\]

\[
T = 39427.32 \cos 30^\circ = 34145.06 \text{ Nm}
\]

\[
V = 6160 \text{N}
\]

\[
M_e = 1.20(19713.67+34145.06(1+350/300)) = 75878.28 \text{ Nm}
\]

\[
d = 300 \text{mm}, D = 350 \text{ OK}; d = 350-(25+10) = 315 \text{ mm}
\]

Use \( A_{st} = 811.92 \text{ mm}^2 \) i.e. Use 5 Nos. 16 mm \( \phi \) at top and bottom.

\[
V_e = 6160 + 1.6(34145.06)(1.20) = 225920.384 \text{ N}
\]

\[
\tau_{ve} = 2.39 < 2.80 \text{ N/m}
\]

\[
100(A_{st}/bd) = 5(\pi/4)(16)^2(100)/300*315 = 1.069
\]

\[
\tau_c = 0.633
\]

\[
A_{sv} = \tau_{ve} - \tau_c (bS_v)/0.87f_y = (2.39-0.633)(300)S_v/0.87(415)
\]

\[
= 1.46 \text{ S}_v
\]

Also \( A_{sv} = \frac{\tau_u S_v}{b_1 d_1 (0.87)(415)} + \frac{V_u S_v}{2.5d_1 (0.87)(415)} = 2.03 \text{ S}_v \)

as \( b_1 = 300-(25+12+8) = 210; d_1 = 270; \text{ S}_v = 111 \)

Use 12mm@ 100 c/c.

**Design of Foundation:**

Consider bottom of foundation at 2 m below G.L.

Vertical load:

Tank full = 3843667.62 + 274826.52 + 75000 = 4193494.15 N

Tank Empty = 1305305.56 + 274826.52 + 75000 = 1655132.08 N

**Moment at bottom of Foundation:**

For Tank full = 219975.52(18.10) = 3981556.91Nm

For Tank Empty 113753.152(18.10) = 2058932.05Nm,

with \( A_h = 0.08 \) (for safety maximum value of \( A_h \) taken);
Diameter at base c/c. of columns = 6.40 m.

Consider an outside diameter of Foundation as 9.60 m and 3.20 m inside diameter.

\[
\text{Area} = \pi (4.80^2 - 1.60^2) = 64.33982 \text{ m}^2
\]

\[
I = \frac{\pi}{4} (4.80^4 - 1.60^4) = 411.77483 \text{ m}^4
\]

Considering 10% as the approximate Wt. of Foundation

\[
P = \frac{1.10 (4193494.15)}{64.33982} = 71.695 \text{ kN/m}^2 < 100 \text{ kN/m}^2
\]

For Tank full:

\[
p_{\text{max}} = 118.1074392 \text{ kN/m}^2
\]

\[
p_{\text{min}} = 25.2825661 \text{ kN/m}^2 < 1.25 (100) \text{ i.e., 125 kN/m}^2
\]

For Tank Empty:

\[
p_{\text{max}} = 56.24325 \text{ kN/m}^2
\]

\[
p_{\text{min}} = 8.241 \text{ kN/m}^2
\]

No Tension and Base is adequate.

Assume a Ring girder of Size 450 x 700.

Design on basis of \( p_{\text{rel}} = 65.177 \text{ kN/m}^2 \)

Supported on six column of 450 mm diameter

\( \text{eq. square} = 400 \text{ mm and } \theta = 30^\circ \)

On face of column \( \varphi = 25.50^\circ \)

Location of Maxm. \( T, \varphi = 17.27^\circ \)

For S.F at distance \( d = 620 \text{ mm from} \)

Location of maximum. \( T, \varphi = 15.32^\circ \)

Load on ring beam = 65.177(3.20) = 208.567 kN/m

As self wt. acts toward.

Maximum - \( V_c \) BM on face of column = 117.0696 kN/m

\( T_{\varphi} \) at the location = 12.3257 kN/m

Maximum + \( V_c \) BM at center = 100.801 kN/m

\( T_{\text{max}} \) at \( \varphi = 17.27^\circ \) = 20.22176 kNm

SF at \( \varphi = 17.27^\circ \) = 201.171 kN

Design by limit state method.
As only vertical (D.L+L.L) considered
load factor =1.50
with M-20 concrete and Fe 415 steel
Mu, limit = 0.138(20)(450)(620)2 = 477.425kNm
Section is under reinforced
At face of column Mu = 1.50 \[117.0696+12.3257\left(1+(700/450)\right)\] =203.3976kNm

Lever arm j = 0.927 and A_{st} =980.18mm^{2}
Use 5nos. 16mm at bottom; minimum A_{st} =572 mm^{2}
For +V_{c} BM =100.801 kNm
No torsion occurs there,
\[Mu = 1.50(100.801) =151.2015kNm\]
\[J = 0.947\text{ and } A_{st} =713.25 \text{ mm}^{2}\]
Use 4Nos.16mm φ at top.
At of T_{max}
SF \quad V_{c} =201.171+1.6(20.22176/0.450) =273.071kN
\[V_{uc}= 1.50(273.071) = 409.606kN\]
\[\tau_{ve} = 409.606(10)^{3}/450(620) = 1.468 < \tau_{\text{max}}.\]
100(A_{st}/bd) =\left[100(4\pi/4(16)^{2}\right]/(450)(620) =0.288\%
\( \tau_c = 0.378 \text{ N/mm}^2 \)

minimum transverse reinforcement

\[ A_{sv} = (\tau_{ve} - \tau_c) b s_v / 0.87 f_y = 1.35854 s_v \]

With 2 legged 10 mm O @ 115 c/c. or 12 mm 0@ 160 c/c.

Also

\[ A_{sv} = \frac{T_y S_y}{b d_l (0.87 f_y)} + \frac{V_y S_y}{2.5 (d_l)(0.87) f_y} \]
\[ b_1 = 450 - 2(40+20+8) = 330 \text{ mm} \]
\[ d_1 = 700 - 2(40+12+8) = 580 \text{ mm} \]

and \[ A_{sv} = 1.0153 \text{ Sv} \] – this gives smaller spacing

Use 12 mm φ @ 150 c/c.

For side face reinforcement use 0.10% of web area

\[ = 0.10/100(500) (450) = 225 \text{ mm}^2 \]

Half on each face i.e. Use 12 mm 0 bar longitudinally.

**Design of bottom slab** — Use 400 mm thick slab

Projection = 1.60(0.450/2) = 1.375 m

Designed for variation of bearing pressure considering effect of Moment Downward load from top due to slab and soil = 40 kN/m² Referring to Fig.

Maximum BM = \[ \frac{(104.81-40)(1.375)^2}{2}+13.297[(1.375)^2 /3] \] = 69.4556 kNm

Maxm. SF at distance \( d = 3.50 \) from face of beam

\[ = \frac{1}{2}(108.20 + 118.107) -40 \] (1.375 -0.350)

\[ = 74.982 \text{ KN} \]

\[ \tau_v = 1.5(74.962)(10)^3/1000(350) = 0.321 \text{ N/mm}^2 \]

100A_{wv}/be required = 0.202%

For BM.

\[ M_w = 1.50(69.4556) = 104.1834 \text{ kNm} \]

\[ J = 0.948 \text{ and } A_{st} = 869.67 \text{ mm}^2 \]

Use 12mmφ @125 c/c

\[ 100(A_{wv}/bd) = 0.258\% \] hence it is adequate

**Check for stability:**

Sliding - Due to seismic loading

\[ V = 244237.52 \text{ N} \]

\[ W = 4193494.15 + \text{Wt. of base} + \text{Circular Bear} \]

\[ = 4193494.15 + 617662.25 + 65144.06 \]

\[ = 4876300.56 \text{ N} \]

FS against sliding \( \mu W/244237.52 = 9.98 > 2 \) OK
FS against overturning = 4876300.56(4.80)/244237.52(18.10) = 5.295 > 2  OK

For empty condition = W = 1655132.08 + 617662.25 + 65144.06 = 2337938.39

FS against sliding = μW/V

V = 120424.45N = 9.707 > 2.0

F.S against over turning = 2337938.39(4.80)/120424.45(18.10) = 5.15 > 2.0

Fig 4 shows the details of the tank.

(a) Details of tank
(b) Bracing of Columns

10 mm @ 150 c/c

12 mm @ 150 c/c

12 mm @ 125 c/c  5 Nos 16 mm at bottom

(c) Details of foundation
ESTIMATION
Detailed estimation:

Detailed estimate is an accurate estimate and consists of working out the quantities of each item of works, and working the cost. The dimensions, length, breadth and height of each item are taken out correctly from drawing and quantities of each item are calculated, and abstracting and billing are done.

The detailed estimate is prepared in two stages:

Details of measurement and calculation of quantities.

The details of measurements of each item of work are taken out correctly from plan and drawing and quantities under each item are calculated in a tabular form named as details of measurement form.

Abstract of estimated cost:

The cost of each item of work is calculated in a tabular form the quantities already computed and total cost is worked out in abstract estimate form. The rates of different items of work are taken as per schedule of rates or current workable rates for finished item of work.

### Detailed estimation

<table>
<thead>
<tr>
<th>S.N o.</th>
<th>DESCRIPTION OF WORK</th>
<th>NOS</th>
<th>L m</th>
<th>B m</th>
<th>A m²</th>
<th>D m</th>
<th>QTY m³</th>
<th>REMARKS</th>
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<tbody>
<tr>
<td>1</td>
<td>EARTH WORK IN EXCUVATION</td>
<td>1</td>
<td>64.32</td>
<td>2</td>
<td>128.64</td>
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<td>L =2πR = 2π*2.55 = 16.022m, R =5.1/2 = 2.55m</td>
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<td>EARTH WORK IN FILLING</td>
<td>1</td>
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<td></td>
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<td>100.198</td>
<td>L =2πR = 2π*3.75 = 23.56m, R =7.5/2 = 3.75m</td>
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<td>3</td>
<td>RCC WORK IN FOUNDATION (1:1.5:3)</td>
<td>1</td>
<td>64.32</td>
<td>0.4</td>
<td>25.728</td>
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<td>4</td>
<td>RCC WORK IN COLOUMNS BELOW G.L (1:1.5:3)</td>
<td>6</td>
<td>0.282</td>
<td>1.6</td>
<td>2.714</td>
<td></td>
<td>Sa = 2πhRc =π (h² + r²) =π (1.5²+5.4375²) =99.95m²,h =1.5m,r = 5.4375</td>
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<td>5</td>
<td>RCC WORK IN COLOUMNS ABOVE G.L UPTO 4M HT (1:1.5:3)</td>
<td>6</td>
<td>0.282</td>
<td>4</td>
<td>6.785</td>
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<td>Davg =(7.5+5.1)/2 = 6.3m, R=6.3/2= 3.15m, Sa =πr(r+h) = π*(3.15+1.6) = 47.006m²</td>
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<td>RCC WORK IN COLOUMNS FROM 4M TO 8M HT(1:1.5:3)</td>
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<td>0.282</td>
<td>4</td>
<td>6.785</td>
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<td>R = 3.3816m,Sa = 2πhRc =π (h² + r²) =π (0.950²+3.3816²) =</td>
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<td>RCC WORK IN</td>
<td>DESCRIPTION</td>
<td>QTY</td>
<td>D</td>
<td>R</td>
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<td>RCC WORK IN</td>
<td>COLOUMNS FROM</td>
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<td>0.282</td>
<td>4</td>
<td>6.785</td>
<td>D = (0.23+0.2) = 0.25m, S&lt;sub&gt;a&lt;/sub&gt; = 2πR h = 2π<em>3.75</em>5 = 117.80m</td>
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<td>TOTAL RCC WORK</td>
<td>IN COLOUMNS (1:1:5:3)</td>
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<td>23.069</td>
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<td>RCC WORK IN</td>
<td>BRACING AT 4m HT (1:1.5:3)</td>
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<td>18.535</td>
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<td>RCC WORK IN</td>
<td>BRACING AT 8m HT (1:1.5:3)</td>
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<td>17.278</td>
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<td>RCC WORK IN</td>
<td>CIRCULAR GIRDER</td>
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<td>0.4</td>
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<td>12</td>
<td>RCC WORK IN</td>
<td>RING BEAM AT BOTTOM OF THE CL WALL (1:1.5:3)</td>
<td>1</td>
<td>23.56</td>
<td>0.3</td>
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<td>RCC WORK IN</td>
<td>RING BEAM AT TOP OF THE CL WALL (1:1.5:3)</td>
<td>1</td>
<td>23.56</td>
<td>0.16</td>
<td>0.225</td>
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<td>DOMED ROOF (1:1.5:3)</td>
<td>RCC WORK IN CONICAL SLAB (1:1.5:3)</td>
<td>1</td>
<td>47.06</td>
<td>0.25</td>
<td>11.751</td>
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<td>16</td>
<td>RCC WORK IN</td>
<td>CONICAL DOME (1:1.5:3)</td>
<td>1</td>
<td>38.76</td>
<td>0.2</td>
<td>7.752</td>
<td>R = 3.3816m, S&lt;sub&gt;a&lt;/sub&gt; = 2πrRc = π (h^2 + r^2) = π (1.5^2 + 5.4375^2) = 99.95m^2, h = 1.5m, r = 5.4375</td>
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<td>17</td>
<td>RCC WORK IN</td>
<td>CYLINDRICAL WALL (1:1.5:3)</td>
<td>1</td>
<td>0.215</td>
<td>117.8</td>
<td>5</td>
<td>126.35</td>
<td>D = (0.23+0.2) = 0.25m, S&lt;sub&gt;a&lt;/sub&gt; = 2πR h = 2π<em>3.75</em>5 = 117.80m</td>
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<td>DEDUCTIONS IN RCC WORK IN BRACINGS IN COLOUMNS</td>
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<td>2*6</td>
<td>0.3</td>
<td>0.3</td>
<td>0.6</td>
<td>0.648</td>
<td>QTY = 2<em>6</em>0.3<em>0.3</em>0.6 =0.648m^3</td>
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<td>19</td>
<td>TOTAL RCC WORK IN COLOUMNS AFTER DEDUCTIONS</td>
<td>22.901</td>
<td>QTY = 23.609 - 0.648 = 22.961m^3</td>
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<td>21</td>
<td>PLASTERING IN C M (1:2) FOR INNER SURFACE OF CONIVAL SLAB (12MM)</td>
<td>1</td>
<td>47.06</td>
<td>47.006</td>
<td>,R=6.3/2= 3.15m, Sa =\pi(r+h) = \pi*3.15(3.15+1.6) = 47.006m^2</td>
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<td>22</td>
<td>PLASTERING IN C M (1:6) FOR OUTER SURFACE OF CONICAL SLAB (12MM)</td>
<td>60.2</td>
<td>60.2</td>
<td>R=6.3/2+0.5= 3.65m, Sa =\pi(r+h) = \pi*3.65(3.65+1.6) = 60.2m^2</td>
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<td>23</td>
<td>PLASTERING IN C M (1:2) FOR INNER SURFACE OF CONICAL DOME (12MM)</td>
<td>1</td>
<td>38.76</td>
<td>38.76</td>
<td>R = 3.3816m, Sa = 2\pi Rc =\pi (h2 + r2) =\pi (0.950^2+3.3816^2) = 38.760m^2</td>
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<tr>
<td>24</td>
<td>PLASTERING IN C M (1:6) FOR OUTER SURFACE OF CONICAL DOME (12MM)</td>
<td>43.13</td>
<td>43.135</td>
<td>R = 3.3816+0.2m = 3.5816,Sa = 2\pi Rc =\pi (h2 + r2) =\pi (0.950^2+3.3.5816^2) = 43.135m^2</td>
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<td>25</td>
<td>PLASTERING IN C M (1:2) FOR INNER SURFACE OF CYLINDRICAL WALL (12MM)</td>
<td>117.8</td>
<td>117.8</td>
<td>D = (0.23+0.2) =.215m,Sa =2\pi h = 2\pi<em>3.75</em>5 = 117.80m</td>
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<td>26</td>
<td>PLASTERING IN C M (1:6) FOR OUTER SURFACE OF CYLINDRICAL WALL (12MM)</td>
<td>125.0</td>
<td>125.03</td>
<td>D = (0.23+0.2) =.215m,R=3.75+.23 =3.98m,Sa =2\pi h = 2\pi<em>3.98</em>5 = 125.03m</td>
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<td>27</td>
<td>PLASTERING IN C M (1:2) FOR INNER SURFACE OF DOMED ROOF (12MM)</td>
<td>96.5</td>
<td>96.556</td>
<td>Sa = 2\pi Rc =\pi (h2 + r2) =\pi (1.5^2+5.3375^2) =96.56m^2,h =1.5m,r = 5.3375</td>
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<td>28</td>
<td>PLASTERING IN C M (1:6) FOR OUTER SURFACE OF DOMED ROOF (12MM)</td>
<td>99.95</td>
<td>99.95</td>
<td>Sa = 2\pi Rc =\pi (h2 + r2) =\pi (1.5^2+5.4375^2) =99.95m^2,h =1.5m,r = 5.4375</td>
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<td>Description</td>
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<td>Area</td>
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<tr>
<td>29</td>
<td>PLASTERING IN C M (1:6) FOR COLUMNS (12MM)</td>
<td>6</td>
<td>-45.23</td>
<td>271.433</td>
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<td></td>
<td>$P = 2 \pi R = 2 \pi \times 6 \times 12 = 45.23 \text{m}^2$</td>
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<td>30</td>
<td>PLASTERING IN C M (1:6) FOR CIRCULAR GIRDER (12MM)</td>
<td>1</td>
<td>16.022</td>
<td>91.732</td>
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<td></td>
<td>$L = 2 \pi R = 2 \pi \times 2.55 = 16.022 \text{m, } R = 5.1/2 = 2.55 \text{m}$</td>
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<td>31</td>
<td>PLASTERING IN C M (1:2) FOR RING BEAM AT TOP (12MM)</td>
<td>23.56</td>
<td>0.16</td>
<td>18.213</td>
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<td>$S_{\text{a}} = 2 \times 23.56 \times 0.225 + 2 \times 0.225 \times 0.16 + 2 \times 0.16 \times 23.56 = 18.213 \text{m}^2$</td>
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<td>32</td>
<td>PLASTERING IN C M (1:2) FOR RING BEAM AT BOTTOM (12MM)</td>
<td>23.56</td>
<td>0.3</td>
<td>0.225</td>
<td>38.950</td>
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<td>$S_{\text{a}} = 2 \times 23.56 \times 0.52 + 2 \times 0.52 \times 0.3 + 2 \times 0.3 \times 23.56 = 38.950 \text{m}^2$</td>
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<td>33</td>
<td>PLASTERING IN C M (1:6) FOR BRACING AT 4M HT (12MM)</td>
<td>18.535</td>
<td>0.3</td>
<td>0.52</td>
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<td>$S_{\text{a}} = 2 \times 18.535 \times 0.3 + 2 \times 0.3 \times 0.3 + 2 \times 0.3 \times 18.535 = 22.422 \text{m}^2$</td>
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<td>34</td>
<td>PLASTERING IN C M (1:6) FOR BRACING AT 8M HT (12MM)</td>
<td>17.278</td>
<td>0.3</td>
<td>0.3</td>
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<td>$S_{\text{a}} = 2 \times 17.278 \times 0.3 + 2 \times 0.3 \times 0.3 + 2 \times 0.3 \times 17.278 = 20.936 \text{m}^2$</td>
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<td>TOTAL PLASTERING IN CM (1:2) 12MM THICK</td>
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<td>$QTY = 47.006 + 38.76 + 117.8 + 96.56 + 18.213 + 38.95 = 357.289 \text{m}^2$</td>
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<td>36</td>
<td>TOTAL PLASTERING IN CM (1:6) 12MM</td>
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<td>652.838</td>
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<td>$QTY = 60.2 + 43.135 + 125.03 + 99.95 + 271.433 + 9.732 + 22.422 + 20.936 = 652.838 \text{m}^2$</td>
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<td>37</td>
<td>THICK WATER PROOF CEMENT PAINTING FOR TANK PORTION</td>
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<td>$QTY = 47.006 + 60.2 + 38.76 + 43.135 + 117.8 + 125.03 + 96.56 + 99.95 + 18.213 + 0.52 = 647.174 \text{m}^2$</td>
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<td>38</td>
<td>WHITE WASHING FOR COLUMNS</td>
<td>6</td>
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<td>$P = 2 \pi R = 2 \pi \times 6 \times 12 = 45.23 \text{m}^2$</td>
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<td>39</td>
<td>TOTAL WHITE WASHING</td>
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<td>$QTY = 647.174 + 271.433 = 918.607 \text{m}^2$</td>
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<td>QTY OR NOS</td>
<td>RATE</td>
<td>COST</td>
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DATA SHEET

RCC M-20 Nominal mix (Cement:fine aggregate: coarse aggregate) corresponding to Table 9 of IS 456 using 20mm size graded machine crushed hard granite metal (coarse aggregate) from approved quarry including cost and conveyance of all materials like cement

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</tr>
<tr>
<td>Sand</td>
<td>Cum</td>
<td>0.45</td>
</tr>
<tr>
<td>Cement</td>
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</tr>
<tr>
<td>1st Class Mason</td>
<td>Day</td>
<td>0.133</td>
</tr>
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<td>2nd Class Mason</td>
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<td>1</td>
</tr>
<tr>
<td>Cost of Diesel for Miller</td>
<td>Liters</td>
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</tr>
<tr>
<td>Cost of Petrol for Vibrator</td>
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<tr>
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<tr>
<td>Add MA 20%</td>
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<tr>
<td>Add TOT 4%</td>
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BASIC COST per 1 cum

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Rate Rs.</th>
<th>Amount Rs.</th>
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<tr>
<td>20mm HBG graded metal</td>
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<td>1405.04</td>
<td>1264.54</td>
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<tr>
<td>Sand</td>
<td>Cum</td>
<td>0.45</td>
<td>509.92</td>
<td>229.46</td>
</tr>
<tr>
<td>Cement</td>
<td>Kgs</td>
<td>400</td>
<td>5.42</td>
<td>2169.60</td>
</tr>
<tr>
<td>1st Class Mason</td>
<td>Day</td>
<td>0.167</td>
<td>285.00</td>
<td>47.60</td>
</tr>
<tr>
<td>2nd Class Mason</td>
<td>Day</td>
<td>0.167</td>
<td>260</td>
<td>43.42</td>
</tr>
<tr>
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</tr>
<tr>
<td>Material hire charges for centering</td>
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BASIC COST per 1 cum

<table>
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<th>Rate Rs.</th>
<th>Amount Rs.</th>
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<tr>
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<td>285.00</td>
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<td>Day</td>
<td>0.167</td>
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</tr>
<tr>
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<td>Day</td>
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<td>Add 20% in Labour</td>
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<td>Add TOT 4%</td>
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BASIC COST per 1 cum

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<th>Amount Rs.</th>
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<tr>
<td>Add TOT 4%</td>
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BASIC COST per 1 cum

5538.00

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<td>0.167</td>
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BASIC COST per 1 cum

7383.144
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<td>Kgs</td>
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<td>2169.60</td>
</tr>
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<tr>
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<td>509.92</td>
<td>229.46</td>
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<td>Kgs</td>
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<td>2169.60</td>
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<td>19.10</td>
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<th>Amount Rs.</th>
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<td>1405.04</td>
<td>1264.54</td>
</tr>
<tr>
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<td>0.45</td>
<td>509.92</td>
<td>229.46</td>
</tr>
<tr>
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<td>Kgs</td>
<td>400</td>
<td>5.42</td>
<td>2169.60</td>
</tr>
<tr>
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<td>day</td>
<td>0.067</td>
<td>285.00</td>
<td>19.10</td>
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<td>day</td>
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<td>260</td>
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</tr>
<tr>
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<td>day</td>
<td>2.5</td>
<td>215</td>
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<td>Material hire charges for centering</td>
<td>Sqm</td>
<td>5</td>
<td>1915</td>
<td>9575</td>
</tr>
<tr>
<td>Concrete Mixer 10 / 7 cft (0.2 / 0.8 cum) capacity</td>
<td>hour</td>
<td>0.267</td>
<td>248.40</td>
<td>66.32</td>
</tr>
<tr>
<td>Water (including for curing)</td>
<td>kl</td>
<td>1.2</td>
<td>77.00</td>
<td>92.40</td>
</tr>
<tr>
<td>Add 20% in Labour</td>
<td></td>
<td></td>
<td></td>
<td>1616.23</td>
</tr>
<tr>
<td>Add MA 20%</td>
<td></td>
<td></td>
<td></td>
<td>1939.48</td>
</tr>
<tr>
<td>Add TOT 4%</td>
<td></td>
<td></td>
<td></td>
<td>25035</td>
</tr>
<tr>
<td><strong>BASIC COST per 1 cum</strong></td>
<td></td>
<td></td>
<td></td>
<td>25035</td>
</tr>
</tbody>
</table>
Mazdoor (Both Men and Women) | Day | 4.7 | 215 | 1010.50
Labour for centering | Cum | 1 | 896 | 896.00
Material hire charges for centering | Cum | 1 | 89 | 89.00
Concrete Mixer 10 / 7 cft (0.2 / 0.8 cum) capacity | Hour | 1 | 248.40 | 248.40
Water (including for curing) | Kl | 1.2 | 77.00 | 92.40
Add 20% in Labour (1st Floor) | | | | 399.50
Add MA 20% | | | | 479.40
Add TOT 4% | | | | 278.79
BASIC COST per 1 cum | | | | 7249.00

RCC RING BEAM AT BOTTOM OF CYLINDRICAL WALL

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Quantity</th>
<th>Rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>20mm HBG graded metal</td>
<td>cum</td>
<td>0.9</td>
<td>1405.04</td>
<td>1264.54</td>
</tr>
<tr>
<td>Sand</td>
<td>cum</td>
<td>0.45</td>
<td>509.92</td>
<td>229.46</td>
</tr>
<tr>
<td>Cement</td>
<td>Kgs</td>
<td>400</td>
<td>5.42</td>
<td>2169.60</td>
</tr>
<tr>
<td>1st Class Mason</td>
<td>day</td>
<td>0.067</td>
<td>285.00</td>
<td>19.10</td>
</tr>
<tr>
<td>2nd Class Mason</td>
<td>day</td>
<td>0.133</td>
<td>260</td>
<td>34.58</td>
</tr>
<tr>
<td>Mazdoor (Both Men and Women)</td>
<td>day</td>
<td>2.5</td>
<td>215</td>
<td>537.50</td>
</tr>
<tr>
<td>Labour for centering</td>
<td>Cum</td>
<td>1</td>
<td>1113</td>
<td>1113.00</td>
</tr>
<tr>
<td>Material hire charges for centering</td>
<td>Cum</td>
<td>1</td>
<td>1276</td>
<td>1276.00</td>
</tr>
<tr>
<td>Concrete Mixer 10 / 7 cft (0.2 / 0.8 cum) capacity</td>
<td>hour</td>
<td>0.267</td>
<td>248.40</td>
<td>66.32</td>
</tr>
<tr>
<td>Water (including for curing)</td>
<td>kl</td>
<td>1.2</td>
<td>77.00</td>
<td>92.40</td>
</tr>
<tr>
<td>Add 20% in Labour</td>
<td></td>
<td></td>
<td></td>
<td>341</td>
</tr>
<tr>
<td>Add MA 20%</td>
<td></td>
<td></td>
<td></td>
<td>409.036</td>
</tr>
<tr>
<td>Add TOT 4%</td>
<td></td>
<td></td>
<td></td>
<td>302.10</td>
</tr>
<tr>
<td>BASIC COST per 1 cum</td>
<td></td>
<td></td>
<td></td>
<td>7854.636</td>
</tr>
</tbody>
</table>

RCC CIRCULAR GIRDER

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Quantity</th>
<th>Rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>20mm HBG graded metal</td>
<td>cum</td>
<td>0.9</td>
<td>1405.04</td>
<td>1264.54</td>
</tr>
<tr>
<td>Sand</td>
<td>cum</td>
<td>0.45</td>
<td>509.92</td>
<td>229.46</td>
</tr>
<tr>
<td>Cement</td>
<td>Kgs</td>
<td>400</td>
<td>5.42</td>
<td>2169.60</td>
</tr>
<tr>
<td>1st Class Mason</td>
<td>day</td>
<td>0.067</td>
<td>285.00</td>
<td>19.10</td>
</tr>
<tr>
<td>2nd Class Mason</td>
<td>day</td>
<td>0.133</td>
<td>260</td>
<td>34.58</td>
</tr>
<tr>
<td>Mazdoor (Both Men and Women)</td>
<td>day</td>
<td>2.5</td>
<td>215</td>
<td>537.50</td>
</tr>
<tr>
<td>Labour for centering</td>
<td>Cum</td>
<td>1</td>
<td>751</td>
<td>751.00</td>
</tr>
<tr>
<td>Material hire charges for centering</td>
<td>Cum</td>
<td>1</td>
<td>875</td>
<td>893.00</td>
</tr>
<tr>
<td>Concrete Mixer 10 / 7 cft (0.2 / 0.8 cum) capacity</td>
<td>hour</td>
<td>0.267</td>
<td>248.40</td>
<td>66.32</td>
</tr>
<tr>
<td>Water (including for curing)</td>
<td>kl</td>
<td>1.2</td>
<td>77.00</td>
<td>92.40</td>
</tr>
<tr>
<td>Add 20% in Labour (1st Floor)</td>
<td></td>
<td></td>
<td></td>
<td>268.44</td>
</tr>
<tr>
<td>Add MA 20%</td>
<td></td>
<td></td>
<td></td>
<td>322.12</td>
</tr>
<tr>
<td>Add TOT 4%</td>
<td></td>
<td></td>
<td></td>
<td>265.92</td>
</tr>
<tr>
<td>BASIC COST per 1 cum</td>
<td></td>
<td></td>
<td></td>
<td>6914.00</td>
</tr>
</tbody>
</table>

RCC BRACING AT 4M HEIGHT

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Quantity</th>
<th>Rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>20mm HBG graded metal</td>
<td>cum</td>
<td>0.9</td>
<td>1405.04</td>
<td>1264.54</td>
</tr>
<tr>
<td>Sand</td>
<td>cum</td>
<td>0.45</td>
<td>509.92</td>
<td>229.46</td>
</tr>
<tr>
<td>Cement</td>
<td>Kgs</td>
<td>400</td>
<td>5.42</td>
<td>2169.60</td>
</tr>
<tr>
<td>1st Class Mason</td>
<td>day</td>
<td>0.067</td>
<td>285.00</td>
<td>19.10</td>
</tr>
<tr>
<td>2nd Class Mason</td>
<td>day</td>
<td>0.133</td>
<td>260</td>
<td>34.58</td>
</tr>
<tr>
<td>Mazdoor (Both Men and Women)</td>
<td>day</td>
<td>2.5</td>
<td>215</td>
<td>537.50</td>
</tr>
<tr>
<td>Labour for centering</td>
<td>Cum</td>
<td>1</td>
<td>875</td>
<td>875.00</td>
</tr>
<tr>
<td>Material hire charges for centering</td>
<td>Cum</td>
<td>1</td>
<td>1276</td>
<td>1276.00</td>
</tr>
<tr>
<td>Concrete Mixer 10 / 7 cft (0.2 / 0.8 cum) capacity</td>
<td>hour</td>
<td>0.267</td>
<td>248.40</td>
<td>66.32</td>
</tr>
<tr>
<td>Water (including for curing)</td>
<td>kl</td>
<td>1.2</td>
<td>77.00</td>
<td>92.40</td>
</tr>
</tbody>
</table>
### RCC BRACING AT 8M HEIGHT

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Rate 1</th>
<th>Rate 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>20mm HBG graded metal</td>
<td>cum 0.9</td>
<td>1405.04</td>
<td>1264.54</td>
</tr>
<tr>
<td>Sand</td>
<td>cum 0.45</td>
<td>509.92</td>
<td>229.46</td>
</tr>
<tr>
<td>Cement</td>
<td>Kgs 400</td>
<td>5.42</td>
<td>2169.60</td>
</tr>
<tr>
<td>1st Class Mason</td>
<td>day 0.067</td>
<td>285.00</td>
<td>19.10</td>
</tr>
<tr>
<td>2nd Class Mason</td>
<td>day 0.133</td>
<td>260.00</td>
<td>34.58</td>
</tr>
<tr>
<td>Mazdoor (Both Men and Women)</td>
<td>day 2.5</td>
<td>215.00</td>
<td>537.50</td>
</tr>
<tr>
<td>Labour for centering</td>
<td>Cum 1</td>
<td>954.00</td>
<td>954.00</td>
</tr>
<tr>
<td>Material hire charges for centering</td>
<td>Cum 1</td>
<td>1276.00</td>
<td>1276.00</td>
</tr>
<tr>
<td>Concrete Mixer 10 / 7 cft (0.2 / 0.8 cum) capacity</td>
<td>hour 0.267</td>
<td>248.40</td>
<td>66.32</td>
</tr>
<tr>
<td>Water (including for curing)</td>
<td>kl 1.2</td>
<td>77.00</td>
<td>92.40</td>
</tr>
<tr>
<td>Add 20% in Labour (1st Floor)</td>
<td></td>
<td></td>
<td>309.036</td>
</tr>
<tr>
<td>Add MA 20%</td>
<td></td>
<td></td>
<td>370.84</td>
</tr>
<tr>
<td>Add TOT 4%</td>
<td></td>
<td></td>
<td>292.93</td>
</tr>
<tr>
<td><strong>BASIC COST per 1 cum</strong></td>
<td></td>
<td></td>
<td>7616.30</td>
</tr>
</tbody>
</table>

### Plastering with CM (1:3), 12 mm thick - 10 Sqm

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Rate 1</th>
<th>Rate 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Mortor (1:3)</td>
<td>cum 0.15</td>
<td>3191.00</td>
<td>478.65</td>
</tr>
<tr>
<td>Mason 1st class</td>
<td>day 0.6</td>
<td>285.00</td>
<td>171.00</td>
</tr>
<tr>
<td>Mazdoor (unskilled)</td>
<td>day 0.96</td>
<td>215.00</td>
<td>206.40</td>
</tr>
<tr>
<td>Add MA 20%</td>
<td></td>
<td></td>
<td>75.48</td>
</tr>
<tr>
<td>Add TOT 4%</td>
<td></td>
<td></td>
<td>37.26</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td></td>
<td></td>
<td>969.00</td>
</tr>
</tbody>
</table>

### Plastering with CM (1:6), 12 mm thick - 10 Sqm

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Rate 1</th>
<th>Rate 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Mortor (1:6)</td>
<td>cum 0.15</td>
<td>1889.00</td>
<td>283.35</td>
</tr>
<tr>
<td>Mason 1st class</td>
<td>day 0.6</td>
<td>285.00</td>
<td>171.00</td>
</tr>
<tr>
<td>Mazdoor (unskilled)</td>
<td>day 0.96</td>
<td>215.00</td>
<td>206.40</td>
</tr>
<tr>
<td>Add MA 20%</td>
<td></td>
<td></td>
<td>75.48</td>
</tr>
<tr>
<td>Add TOT 4%</td>
<td></td>
<td></td>
<td>29.45</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td></td>
<td></td>
<td>766.00</td>
</tr>
</tbody>
</table>

Painting to new walls of tank portion with 2 coats of water proof cement paint of approved brand and shade over a base coat of approved cement primer grade I making making 3 coats in all to give an even shade after thoroughly brushing the surface to remove all dirt and remains of loose powdered materials, including cost and conveyance of all materials to work site and all operational, incidental, labour charges etc. complete for finished item of work as per SS 912 for walls.

<table>
<thead>
<tr>
<th>Material</th>
<th>Pack</th>
<th>Rate 1</th>
<th>Rate 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epoxy primer for Hibond floor &amp; protective coatings : Procoat SNP2 or Zoriprime EFC 2</td>
<td>1</td>
<td>725.00</td>
<td>725</td>
</tr>
<tr>
<td>1st class painter</td>
<td>day 0.21</td>
<td>285.00</td>
<td>59.85</td>
</tr>
<tr>
<td>2nd class painter</td>
<td>day 0.49</td>
<td>260.00</td>
<td>127.40</td>
</tr>
<tr>
<td>cost of water proof cement paint</td>
<td>1.00 cum (35.28 cft)</td>
<td>3.50</td>
<td>35</td>
</tr>
<tr>
<td>1st class painter</td>
<td>day 0.15</td>
<td>285.00</td>
<td>42.75</td>
</tr>
</tbody>
</table>
Painting to new columns with 2 coats of water proof cement paint of approved brand and shade over a base coat of approved cement primer grade I making making 3 coats in all to give an even shade after thoroughly brushing the surface to remove all dirt and remains of loose powdered materials, including cost and conveyance of all materials to work site and all operational, incidental, labour charges etc. complete for finished item of work as per SS 912 for walls

### Cost of Cement Primer

<table>
<thead>
<tr>
<th>Description</th>
<th>per</th>
<th>rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st class painter</td>
<td>day</td>
<td>0.21</td>
<td>285.00</td>
</tr>
<tr>
<td>2nd class painter</td>
<td>day</td>
<td>0.49</td>
<td>260</td>
</tr>
</tbody>
</table>

### Cost of water proof cement paint

<table>
<thead>
<tr>
<th>Description</th>
<th>per</th>
<th>rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st class painter</td>
<td>day</td>
<td>0.15</td>
<td>285.00</td>
</tr>
<tr>
<td>2nd class painter</td>
<td>day</td>
<td>0.35</td>
<td>260</td>
</tr>
<tr>
<td>Mazdoor (unskilled)</td>
<td>day</td>
<td>1.50</td>
<td>215</td>
</tr>
</tbody>
</table>

### Total cost/ 10 sqm

| Total cost/ 10 sqm | 1660 |

### V.R.C.C (1:1 1/2 :3) 20mm size HBG, machine crushed chips including cost, seignorage and conveyance of all materials and labour charges such as Machine mixing, vibrating, curing etc., -Foundation - SF

<table>
<thead>
<tr>
<th>S.no</th>
<th>Quantity</th>
<th>Description</th>
<th>per</th>
<th>rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25.728</td>
<td>V.R.C.C (1:1 1/2 :3) 20mm size HBG, machine crushed chips including cost, seignorage and conveyance of all materials and labour charges such as Machine mixing, vibrating, curing etc., -Foundation - SF</td>
<td>1 cum</td>
<td>5538.00</td>
<td>142,482</td>
</tr>
<tr>
<td>2</td>
<td>23.069</td>
<td>V.R.C.C (1:1 1/2 :3) 20mm size HBG, machine crushed chips including cost, seignorage and conveyance of all materials and labour charges such as Machine mixing, vibrating, curing etc., -columns - SF</td>
<td>1 cum</td>
<td>7383.144</td>
<td>170,322</td>
</tr>
<tr>
<td>3</td>
<td>0.848</td>
<td>V.R.C.C (1:1 1/2 :3) 20mm size HBG, machine crushed chips including cost, seignorage and conveyance of all materials and labour charges such as Machine mixing, vibrating, curing etc., -Ring beam at top - SF</td>
<td>1 cum</td>
<td>7450.37</td>
<td>6,318</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>V.R.C.C (1:1 1/2 :3) 20mm size HBG, machine crushed chips including cost, seignorage and conveyance of all materials and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.995 Cum</td>
<td>labour charges such as Machine mixing, vibrating, curing etc., - domical roof - SF</td>
<td>1 cum</td>
<td>61,141</td>
<td>6,11,105</td>
<td></td>
</tr>
<tr>
<td>7.752 Cum</td>
<td>V.R.C.C (1:1 1/2 :3) 20mm size HBG, machine crushed chips including cost, seignorage and conveyance of all materials and labour charges such as Machine mixing, vibrating, curing etc., - conical dome base slab - SF</td>
<td>1 cum</td>
<td>25,035</td>
<td>1,94,072</td>
<td></td>
</tr>
<tr>
<td>126.635 cum</td>
<td>V.R.C.C (1:1 1/2 :3) 20mm size HBG, machine crushed chips including cost, seignorage and conveyance of all materials and labour charges such as Machine mixing, vibrating, curing etc., - cylindrical wall - SF</td>
<td>1 cum</td>
<td>7249</td>
<td>9,17,978</td>
<td></td>
</tr>
<tr>
<td>3.675 Cum</td>
<td>V.R.C.C (1:1 1/2 :3) 20mm size HBG, machine crushed chips including cost, seignorage and conveyance of all materials and labour charges such as Machine mixing, vibrating, curing etc., - ring beam at bottom of cylindrical wall - SF</td>
<td>1 cum</td>
<td>7,854.636</td>
<td>28,866</td>
<td></td>
</tr>
<tr>
<td>3.845 cum</td>
<td>V.R.C.C (1:1 1/2 :3) 20mm size HBG, machine crushed chips including cost, seignorage and conveyance of all materials and labour charges such as Machine mixing, vibrating, curing etc., - circular girder - SF</td>
<td>1 cum</td>
<td>6,914</td>
<td>26,585</td>
<td></td>
</tr>
<tr>
<td>11.751 cum</td>
<td>V.R.C.C (1:1 1/2 :3) 20mm size HBG, machine crushed chips including cost seignorage and conveyance of all materials and labour charges such as Machine mixing, vibrating, curing etc., - inclind cone shaped slab - SF</td>
<td>1 cum</td>
<td>25,035</td>
<td>29,4,187</td>
<td></td>
</tr>
<tr>
<td>1.668 cum</td>
<td>V.R.C.C (1:1 1/2 :3) 20mm size HBG, machine crushed chips including cost seignorage and conveyance of all materials and labour charges such as Machine mixing, vibrating, curing etc., - Bracing at 4m heigh - SFt</td>
<td>1 cum</td>
<td>7,498</td>
<td>12,507</td>
<td></td>
</tr>
<tr>
<td>S.no</td>
<td>Quantity</td>
<td>Description</td>
<td>per</td>
<td>rate</td>
<td>Amount</td>
</tr>
<tr>
<td>------</td>
<td>----------</td>
<td>-------------</td>
<td>-----</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td>11</td>
<td>1.555 cum</td>
<td>V.R.C.C (1:1 1/2 :3) 20mm size HBG, machine crushed chips including cost seignorage and conveyance of all materials and labour charges such as Machine mixing, vibrating, curing etc., - Bracing at 8m heigh - SFt</td>
<td>1 cum</td>
<td>7617</td>
<td>11,845</td>
</tr>
<tr>
<td>12</td>
<td>41.45 mt</td>
<td>Supplying,placing and fitting of HYSD bars reinforcement, complete as per drawings and technical specifications for bars below 36 mm dia including over laps and wastage, where they are not welded-SF</td>
<td>1 mt</td>
<td>55419.00</td>
<td>22,97240</td>
</tr>
<tr>
<td>13</td>
<td>357.29 sqm</td>
<td>Plastering inside 12mm thick in single coat in cm (1:3) with finishing including of cost of conveyance of all materials and water to work site and all operational incidental labour charges such as scaffolding. Mixing mortar ,curing etc., complete for finished item of work.-SF</td>
<td>10 sqm</td>
<td>969</td>
<td>34,622</td>
</tr>
<tr>
<td>14</td>
<td>652.84 sqm</td>
<td>Plastering outside 12mm thick in single coat in cm (1:6) with finishing including of cost of conveyance of all materials and water to work site and all operational incidental labour charges such as scaffolding. Mixing mortar ,curing etc., complete for finished item of work.-SF</td>
<td>10 sqm</td>
<td>766</td>
<td>50,000</td>
</tr>
<tr>
<td>15</td>
<td>647.174 sqm</td>
<td>Painting to new outer walls with 2 coats of Epoxy primer for Hibond floor &amp; protective coatings : Procoat SNP2 or Zorprime EFC 2 approved brand and shade over primary coat, after thoroughly brushing the surface yo removing of loose powdered materials and all operational incidental labour charges etc.,completed for finished item of work-SF</td>
<td>10 sqm</td>
<td>1660</td>
<td>10,431</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Columns with 2 coats of water proof cement paint of approved brand and shade over a base coat of approved cement primer grade I making making 3 coats in all to give an even shade after thoroughly brushing the surface to remove all dirt and remains of loose powdered materials, including cost and conveyance of all materials to work site and all</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>271.433 sqm</td>
<td>operational, incidental, labour charges etc. complete for finished item of work as per SS 912 for walls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 sqm</td>
<td>1035</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>28,152</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>47,33,576</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Earth work</td>
<td>12,336</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Over all cost</td>
<td>47,45,912</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Add 10% contractors profit</td>
<td>4,74,591</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total cost</td>
<td>52,20,503</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total cost estimated by the reference of standard scheduled rates (SSR 2011-2012).
### Table 16.2. Coefficients for moment in cylindrical wall fixed at base (Per IS3370)

Moment = Coefficient \((wH^3)\) Nm/m

<table>
<thead>
<tr>
<th>(H^2)</th>
<th>Coefficient at points</th>
</tr>
</thead>
<tbody>
<tr>
<td>(DT)</td>
<td>0.1 (H)</td>
</tr>
<tr>
<td>0.4</td>
<td>+0.0005</td>
</tr>
<tr>
<td>0.8</td>
<td>+0.0011</td>
</tr>
<tr>
<td>1.2</td>
<td>+0.0012</td>
</tr>
<tr>
<td>1.6</td>
<td>+0.0011</td>
</tr>
<tr>
<td>2.0</td>
<td>+0.0010</td>
</tr>
<tr>
<td>3.0</td>
<td>+0.0006</td>
</tr>
<tr>
<td>4.0</td>
<td>+0.0003</td>
</tr>
<tr>
<td>5.0</td>
<td>+0.0002</td>
</tr>
<tr>
<td>6.0</td>
<td>+0.0001</td>
</tr>
<tr>
<td>8.0</td>
<td>0.0000</td>
</tr>
<tr>
<td>10.0</td>
<td>0.0000</td>
</tr>
<tr>
<td>12.0</td>
<td>0.0000</td>
</tr>
<tr>
<td>14.0</td>
<td>0.0000</td>
</tr>
<tr>
<td>16.0</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

### Reference Books:

- I.S 496:2000 for RCC.
- I.S 800:1984 for STEEL.
- I.S 872 Part I and Part II.
- I.S 3373 (Part IV-1967).
- Rein force concrete structures (Dr B.C PUNMIA).
- Element of environmental engineering (BIRID).
CONCLUSION

Storage of water in the form of tanks for drinking and washing purposes, swimming pools for exercise and enjoyment, and sewage sedimentation tanks are gaining increasing importance in the present day life. For small capacities we go for rectangular water tanks while for bigger capacities we provide circular water tanks.

Design of water tank is a very tedious method. With out power also we can consume water by gravitational force.