GUIDELINES FOR R.C. WATER TOWERS UPTO 1000 KL CAPACITY

PREFACE

As seen from past records, many reinforced concrete elevated water tanks were collapsed or highly damaged during sever earthquakes, occurring all over the world. General observations point out the reasons related to the failures mainly of the supporting system, whether RC frame or the shell type towers. Thus, the supporting tower system of the elevated tanks has more critical importance in the Earthquake stability than the structural shape of the tanks. Most of the damages observed during the seismic events arise due improper / unsuitable design of supporting system, improper arrangement of structural elements, improper detailing of reinforcing steel and mistakes during construction of the supporting system.

A review of literature shows the considerable changes in the seismic design practices of elevated tanks. IS: 1893 (Part 2) 2007 has incorporated various modifications to ensure safe earthquake resistant design of water towers in various seismic zones of India.

The Public Health Engineering Department, Government of Bihar has a huge program of construction of Water Towers. It was considered necessary to prepare a guideline which may provide safety considerations and higher quality for Seismic Design and Construction of Water Towers in Bihar.

This Guideline is divided into two parts. Part 1 considers Earthquake Design aspects including elements of seismic analysis, other design considerations, aesthetics, quality control in design and reinforcement detailing in various members of Intze Type RCC water tower. Part 1 covers elevated water tanks of RCC supported on staging with capacity less than or equal to 1000 kL and also for steel water towers with capacity of 200 kL or less.

Part 2 specifies various Indian Standards to ensure appropriate exploration of sub-soil; defects in concrete and RCC construction; tests of construction materials; supervision, inspection and their documentations.

Appendix contains a complete set of structural drawings for 225 kL Intze type water tower, having staging height of 18 meter, to be constructed in sesmic zone IV.

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Part- 1 EARTHQUAKE RESISTANT DESIGN*

1 INTRODUCTION

According to IS:1893 – 2002, eight districts (Sitamarhi, Madhubani, Darbhanga, Supaul, Saharsa, Madhepura, Araria and Kishanganj) fall in severely damaging Seismic Zone V, while, 24 districts of middle Bihar fall in very damaging Seismic Zone IV and rest six district on southern border of Bihar fall in damaging Seismic Zone III. A large number of Water Towers have fallen partially or fully, during Bhuj Earthquake 2001 of magnitude 7.7 on Richter scale. The 1934 Bihar – Nepal Earthquake also caused damages and even collapse of a number of water towers in Bihar.

The Public Health Engineering Department, Government of Bihar has a huge program of construction of Water Towers to provide piped water supply to the villages of Bihar. In view of Giant Earthquake of 1934, which may repeat itself anytime in future, it was considered necessary to provide safety considerations and higher quality for Seismic Design and Construction of Water Towers in Bihar.

This Guideline is divided into two parts. Part 1 considers Earthquake Design aspects including Detailing of Reinforcement in various members. The Design aspect covers Earthquake Resistant Design of Water Tower of RCC type for a capacity of 1000 kL and Steel Tank of 2000 kL. The Detailing of Reinforcement is described for the Intze Type Tank which is being constructed in the most cases by the PHED. Part 2 specifies various Indian Standards to ensure appropriate Exploration of Sub-soil, RCC Construction, Tests of Materials, Supervision, Inspection and their Documentations. Appendix contains sample structural drawings for an Intze Type Water Tower.

2 OBJECTIVE AND SCOPE

The extract covers elevated water tanks of RCC supported on staging with capacity less than or equal to 1000 kl, also for steel water towers with capacity of 200 kL or less. References are made to the relevant clauses of **IS: 1893 - Part-2** and are shown under bracket within the clauses of this Guideline.

2.1 One Mass Approximation

In the light of the ongoing practice for construction of large number of water tanks, it is considered expedient to permit the option of one mass idealization, in certain cases, as stated here below, in which the *whole water mass is taken as if in impulsive mode*. Sloshing of water is neglected. (**IS: 1893 - Part-2, Clause 5.2)**

2.1.1 Ground supported or elevated liquid retaining RC structure of up to and including 1000 kL capacity, wall of the container if in concrete, can be regarded as rigid. (**IS: 1893 - Part-2, Clause 5.2.1)**

2.1.2 Wall in steel may not be regarded as rigid, hence for design of steel tanks by one mass model, the capacity should not exceed 200 kl and h/D or h/L should be 0.4 or higher. (**IS: 1893 - Part-2, Clause 5.2.2)**

2.1.3 For one mass model, water mass in convective mode will not be considered. Total water mass will be assumed in impulsive mode and the impulsive force will be assumed to act at centre of gravity of the whole water mass. (**IS: 1893 - Part-2, Clause 5.2.3)**

2.1.4 The design shall be worked out both when the tank is full and when empty, when empty, the weight W used in the design shall consist of the dead load of the tank and one-third the weight of the staging lumped at the centre of gravity of the tank. When full, the weight of the fluid contents is to be added to the weight under empty conditions. (**IS: 1893 - Part-2, Clause 5.2.4)**

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* An Extract of IS: 1893 - Criteria for Earthquake Resistant Design of Structures: (Part-2) Liquid retaining tanks.

3 NOTATION

T_e	Time period of the empty tank in seconds
T_f	Time period of the full tank in seconds
m_e	Mass of empty container and one-third mass of staging
m_w	Mass of water in tank
k_s	Lateral stiffness of staging
A_h	Design horizontal seismic coefficient
Z	Seismic Zone factor
I	Importance factor
R	Response reduction factor
Sa/g	Average response acceleration coefficient
V_e	Base shear in impulsive mode, for tank empty condition
V_f	Base shear in impulsive mode, for tank full condition
m_e	Mass of empty container and one-third mass of staging
m_w	Mass of water in the container
g	Acceleration due to gravity, 9.81 **m/sec^2**
M_e	Overturning moment, at the base of the staging, for tank empty condition
M_f	Overturning moment, at the base of the staging, for tank full condition
H	Height of cg of **m_w** above the bottom of tank wall
h	Maximum depth of Liquid
L	Inside Length of Rectangular Tank parallel to the direction of seismic force
h_i	Height of impulsive mass above
h_s	Height of staging, from top of footing of staging to the bottom of tank wall
h_{cg}	Height of cg of the empty container of elevated tank, **m_e**, from the top of footing

4 REFERENCES

(a) The following standards contain provisions which, through reference in this text, constitute provisions of this standard.

1. IS - 456:2000, Code of Practice for plain and Reinforced Concrete
2. IS - 1893 (Part-1), Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings
3. IS - 3370:1967, Code of practice for Concrete Structures for the Storage of Liquids
4. IS - 4326:1993, Code of practice for Earthquake Resistant Design and Construction of Buildings
5. IS -11682:1985, Criteria for Design of RCC staging for Overhead Water Tanks
6. IS -13920:1993, Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces – Code of Practice

(b) Papers and Text books:

1. Gokaraju Rangaraju Institute of Engineering and Technology, Report on DESIGN AND ESTIMATION OF INTZE TANK
2. M.K. Sharma, Z. Ahmed, P. Bhardwaj and S. Choudhury on A PARAMETRIC STUDY OF AN INTZE TYPE TANK
3. Dr. B. C. Punamia, Ashok Kumar Jain and Arun Kumar Jain on RCC DESIGNS
4. Department of Civil Engineering, N I T Rourkela on SEISMIC DESIGN OF ELEVATED TANKS

5 ELEMENTS OF SEISMIC ANALYSIS

5.1 General

Hydrodynamic forces exerted by liquid on tank wall may not be considered in the analysis in addition to hydrostatic forces.

For tank full as well as empty conditions, tank shall be analyzed for all the load combinations as per IS 1893 (Part 1). For load combination with seismic load, the amount of liquid considered in the tank will be normal liquid level under service condition only. (**IS: 1893 - Part-2, Clause 4.1)**

5.2 Time Period of Elevated tank (IS: 1893 - Part-2, Clause 4.3.1.3)

Time period of the empty and full tank condition tower; Te and Tf in seconds, are given by

$$T_e = 2\pi \sqrt{m_e / k_s} \quad \text{---} \quad (5.1)$$

$$T_f = 2\pi \sqrt{(m_e + m_w) / k_s} \quad \text{---} \quad (5.2)$$

Where,

m_e = mass of empty container and one-third mass of staging and

k_s = lateral stiffness of staging

m_w = mass of water in tank

Lateral stiffness of the staging is the horizontal force required to be applied at the center of gravity of the tank to cause a corresponding unit horizontal displacement.

NOTE – The flexibility of bracing beam shall be considered in calculating the lateral stiffness, k_s of elevated moment resisting frame type tank staging.

5.3 Damping

Damping in the impulsive mode shall be taken as 2 percent of the critical for steel tanks and 5 percent of the critical for concrete or masonry tanks.

5.4 Design Horizontal Seismic Coefficient (IS: 1893 - Part-2, Clause 4.5)

Design horizontal seismic coefficient, Ah shall be obtained by the following expression,

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g} \quad \text{---} \quad (5.3)$$

Where,

Z = Zone factor given in Table 1.

I = Importance factor given in Table 2.

R = Response reduction factor given in Table 3.

Sa/g = Average response acceleration coefficient as given by Fig. 1, here and multiplying factors for obtaining values for other damping as given in Table 4, here.

Table 1 - Zone Factor, *Z*
(as per **Table 2 and Clause 6.4.2 of IS: 1893, Part-1**)

Seismic Zone	II	III	IV	V
Seismic Intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

Table 2 - Importance Factor, *I, as per* Table 1 of IS: 1893, Part-2

Sl.No.	Type of liquid storage tank	*I*
i)	Tanks used for storing drinking water, non-volatile material low inflammable petrochemicals etc, and intended for emergency services such as fire fighting services. Tanks of post earthquake importance	1.5
ii)	All other tanks with no risk to life and with negligible consequences to environment, society and economy	1.0

Table 3 - Suggested Values of 'R' for Elevated Tanks (as per Table 2A of IS: 1893, Part-2)		
Sl. No.	**Type of Elevated Tank**	**'R'**
i)	**Tank Supported on Masonry Shaft:** **(Not permitted in Zone IV and V)** a) Masonry Shaft reinforced with horizontal bands b) Masonry Shaft reinforced with horizontal bands and vertical bars	 2 3
ii)	**Tank Supported on RC Shaft** a) RC Shaft with reinforcement in one curtain (in both directions) at center of shaft thickness b) RC Shaft with reinforcement in two curtains (in both directions) c) RC Shaft with reinforcement in two curtains (in both directions) and with stiffened openings and bracings	 2.5 3.5 4
iii)	**Tank Supported on RC Frame** a) Ordinary Moment resisting Frame type staging'* b) Special Moment Resisting Frame conforming ductility requirements of IS 13920 – 1993*	 2.5 4
iv)	**Tank supported on Steel Frame** a) Special moment resistant Frame without diagonal' bracing* b) Special moment resistant Frame with diagonal bracing*	 3.5 4

*P-Delta effect to be included in design of staging.

Table 4 - Multiplying Factors for Obtaining Values for Other Damping
(as per **Table 3 and Clause 6.4.2 of IS: 1893, Part-1**)

Damping Percent	0	2	5	7	10	15	20	25	30
Factors	3.20	1.40	1.00	0.90	0.80	0.70	0.60	0.55	0.50

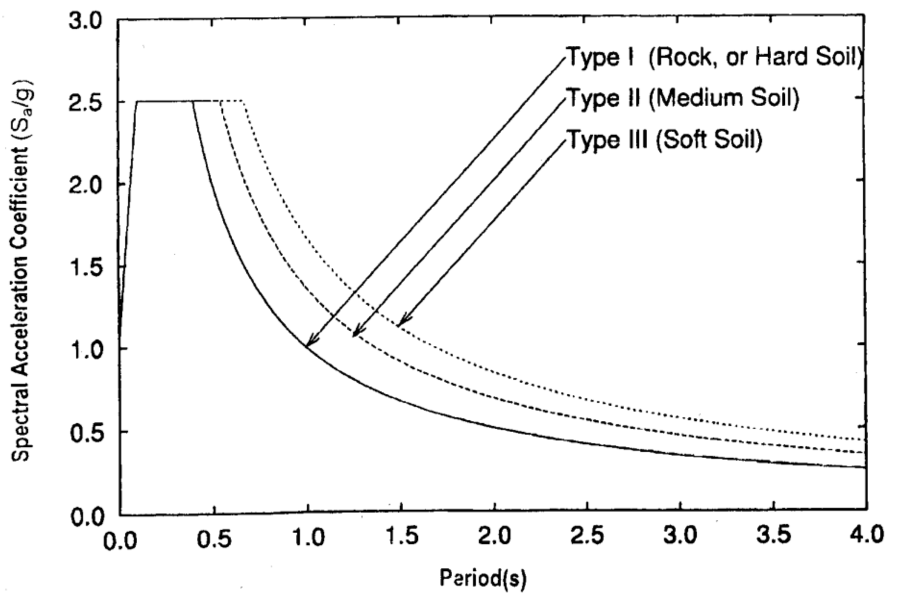


Fig. 1: **Response Spectra for Rock and Soil Sites for 5 Percent Damping**
(as per **Figure 2 of IS: 1893, Part-1**)

5.5 Base Shear and moment of Elevated Tank

5.5.1 For elevated tanks, the design shall be worked out for tank empty and tank full conditions.

5.5.2 Base shear in impulsive mode, just above the base of staging (i.e. at the top of footing of staging) is given by, **(IS: 1893 - Part-2, Clause 4.6.2)**

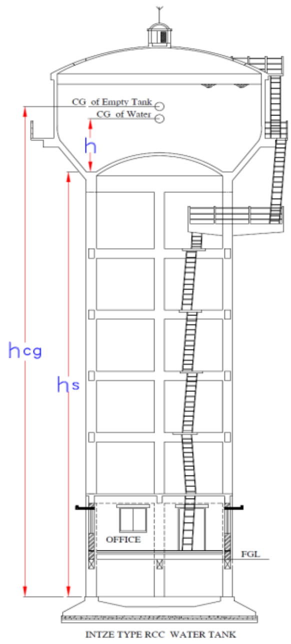
$\mathbf{V_e = A_h\, m_e}$ for tank empty condition --- (5.4)

$\mathbf{V_f = A_h\, (m_e + m_w)\, g}$ for tank full condition --- (5.5)

Where,

$\mathbf{m_e}$ = Mass of empty container and one-third mass of staging

$\mathbf{m_w}$ = Mass of water in the container



5.5.3 The Overturning moment, at the base of the staging is given by: **(IS: 1893 - Part-2, Clause 4.7.2)**

$\mathbf{M_e = A_h\, m_e\, h_{cg}\, g}$, for tank empty condition --- (5.6)

$\mathbf{M_f = A_h\, [m_w\, (h + h_s) + m_e\, h_{cg}]\, g}$, for tank full condition --- (5.7)

Where,

$\mathbf{h}$ = height of cg. of $\mathbf{m_w}$ above the top of the Bottom Ring Beam

$\mathbf{h_s}$ = Structural height of staging, measured from top of footing of staging the top of the Bottom Ring Beam, and

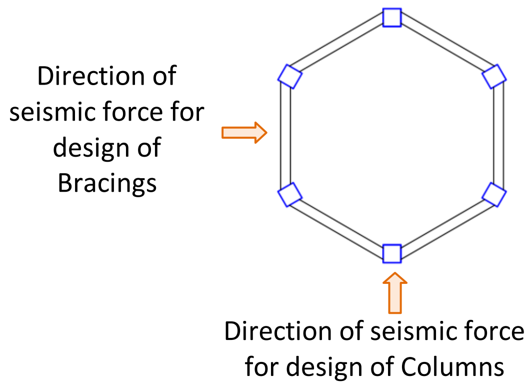
$\mathbf{h_{cg}}$ = Height of centre of gravity of the empty container of elevated tank, $\mathbf{m_e}$, measured from the top of footing

5.6 Effect of Vertical Ground Acceleration (IS: 1893 - Part-2, Clause 4.10)

Due to upward vertical ground acceleration, effective weight of liquid increases, this induces additional pressure on tank wall, whose distribution is similar to that of hydrostatic pressure, and should be considered in the design of tank walls.

6 OTHER DESIGN CONSIDERATIONS

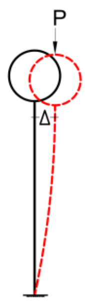
6.1 For elevated tanks, staging components should be designed for the critical direction of seismic force. Different components of staging may have different critical directions.



6.2 P-Delta Effect

Staging columns and braces (or beams) for the elevated tank shall be designed for P-Delta effect.

(IS: 1893 - Part-2, Clause 6.5)



6.3 Strong Column – Weak Beam (IS: 1893 - Part-2, Clause 8.4)

For column and beam type of staging of elevated tank, sum of moment of resistance of column at a junction should not be less than 1.1 times the sum of moment of resistance of beams in any one plane taken at a time. This check is to be applied by *limit state method*.

7 AESTHETICS (IS: 1893 - Part-2, Clause 7)

Elevated water tanks are prominently in public view and visible from near as well as long distance. They often become landmarks on the landscape. It is therefore important that the shape and form of the container and the supporting structure must receive due attention from the point of aesthetics. Innovations in the shape and form should be encouraged when they improve the ambience and enhance the quality of the environment.

Where unusual shapes and forms for supporting structures are used, the designer may use some discretion in choosing the value of response reduction factor R consistent with expected seismic performances and ductility. It will be incumbent on the designer, however, to justify the choice of R value vis-à-vis the seismic safety.

8 QUALITY CONTROL IN DESIGN (IS: 1893 - Part-2, Clause 8)

Quality control in design and constructions are particularly important for elevated tanks in view of several collapses of water tanks **during testing**. It is necessary that quality of materials and construction tolerances are strictly adhered to during construction phase. Some construction tolerances and detailing are listed below. The information given is not exhaustive and designers and construction engineers are expected to have competence to take adequate measures to ensure required structural performance.

NOTE – The design/construction details for reinforced concrete should strictly follow IS 456, IS 3370, and IS 11682. The recommendations are made here to ensure safety under normal as well as service loads.

8.1 RC Frame Staging

8.1.1 Columns (IS: 1893 - Part-2, Clause 8.1.1)

a) Minimum size of column should be 400 mm (diameter and/or side of rectangular column). For tanks having 200 m^3 or less capacity, columns of 300 mm size may be used.

b) Clear height of column between braces should not be more than ten times the size of column.

c) Reinforcement detailing including overlaps in longitudinal bars should follow that shown in IS 13920.

d) During construction and casting of columns, some eccentricity in the verticality of column may develop. Eccentricity up to 20 mm may be allowed in column between two brace levels. Additional moment due to this eccentricity should be considered in the analysis.

8.1.2 Braces (IS: 1893 - Part-2, Clause 8.1.2)

a) Minimum width of un-flanged brace shall not be less than 1/30th of its **clear length** between junctions.

b) In seismic zones IV and V, use of diagonal bracings in vertical plane shall be encouraged. Information on detailing of RC and steel diagonal bracings is given in IS 11682.

8.1.3 Foundation (IS: 1893 - Part-2, Clause 8.1.3)

For isolated footings, tie beam near top of footing shall be provided as per IS 4326.

8.2. RC Shaft Staging

8.2.1 *Thickness of Shaft* (IS: 1893 - Part-2, Clause 8.2.1)

i) Minimum thickness of shaft shall be suitable for constructability which depends on height of formwork for one lift of concrete. Minimum thickness of shaft shall be 150 mm for shaft diameter upto 4 m. For larger diameter shafts, following equations shall be used to arrive at minimum thickness.

a) For shafts with diameter less than 8000 mm.

$$t_{min} = 150 + (D – 4000)/80 \text{ mm}$$

b) For shafts with diameter equal to or greater than 8000 mm.

$$t_{min} = 200 + (D – 8000)/120 \text{ mm}$$

ii) Additional thickening of shaft and extra vertical and circumferential reinforcement shall be provided at top and bottom level of shaft (i.e. at junctions with foundation and with container). This is required to account for secondary moments and eccentricities. *Additional* vertical and circumferential reinforcement shall be same as that required as per design calculations.

8.2.2 *Reinforcement in Shaft* **(IS: 1893 - Part-2, Clause 8.2.2)**

a) Minimum vertical reinforcement shall be 0.25 percent of concrete area. The reinforcement shall be provided in two layers. The minimum diameter of vertical bars shall be 10 mm. Maximum centre-to-centre distance between vertical reinforcement in each layer shall not exceed 300 mm.

b) Circumferential reinforcement shall not be less than 0.2 percent of concrete area in vertical section. Since reinforcement is provided in two layers, circumferential reinforcement shall be divided equally in two layers. The spacing of circumferential bars in each layer shall not be more than 300 mm or shell thickness whichever in less. Circumferential reinforcement shall be placed nearer the faces of shell.

c) At horizontal construction joints in shaft, one additional layer of vertical bars projecting on either side of the joint with Id anchorage length shall be provided. Continuity of concreting at construction joint shall be done with application of neat cement slurry.

d) Openings in shaft: Detailing of shaft at the opening shall take into consideration effective continuity of reinforcement at all sides. More information on detailing near openings is given in IS 11682. At vertical edges of door opening stiffeners may be required.

8.2.3 *Isolated Footing* **(4326-1993 (Part-1), Clause 5.3.4)**

All the individual footings or pile caps where used in Type III soft soils (**Table 3 of IS 1893 :1984**), shall be connected by reinforced concrete ties at least in two directions approximately at right angles to each other. The ties may be place at or below the plinth level and they may be designed to carry the load of the panel walls also.

8.2.4 *Mat Foundation* **(IS: 1893 - Part-2, Clause 8.2.4)**

In case of mat foundations, lifting of mat on tension side can be allowed at soil contact. The maximum eccentricity at base may be permitted up to 0.25 times the base diameter provided the maximum compression remains within permissible limits.

8.3 RC Tank and Shaft **(IS: 1893 - Part-2, Clause 8.3)**

a) In the tank ring beams, reinforcement bars in direct tension shall have lap length twice the development length in tension. The spliced length of the ring beams in tension shall be enclosed in spirals made of bars not less than 6 mm diameter with pitch not more than 100 mm, or enclosed in stirrups of 8 mm diameter with pitch not more than 150 mm, the stirrups shall have 135^0 hooks bent into the core concrete with minimum 50 mm extension.

b) In tank wall or shaft, not more than one-third of vertical bars shall be spliced at any section. For circumferential bars, lap length shall be 1.4 times development length in tension; the laps shall be staggered so that not more than one-third the bars shall be spliced at any one section.

9 MISCELLANEOUS

9.1 Piping **(IS: 1893 - Part-2, Clause 6.1)**

Piping system connected to tanks should be given consideration of potential vibration and movement at the pipe joints during earthquakes and sufficient flexibility should be introduced by proper detailing of pipe joints to avoid de-function. Piping system and its connection to the tank should be designed to comply with the assumptions made and the likely performance; merely neglecting the weight of piping system may not be adequate in all cases.

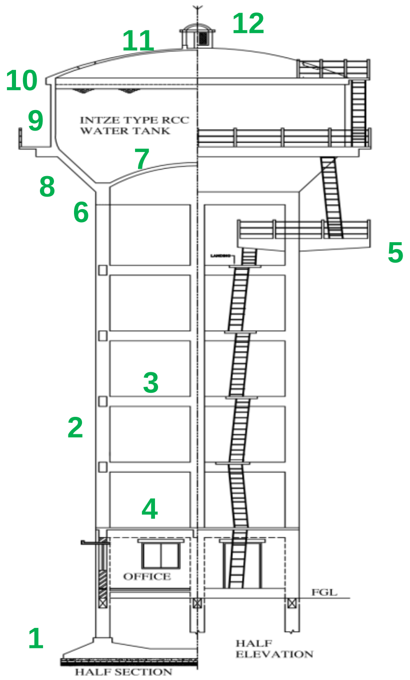
The piping system shall be designed so as not to impart significant mechanical loading on tank. Local loads at pipe connections can be considered in the design of the tank. Mechanical devices, which add flexibility to piping such as bellows, expansion joints and other special couplings, may be used in the connections.

9.2 Staircase design – Provisions of IS 11682 shall be followed for the staircase design. (**IS: 1893 - Part-2, Clause 8.5)**

10 REINFORCEMENT DETAILING IN RCC WATER TOWER

10.1 DETAILINGS

1. FOUNDATION : SOLID / ANNULAR RAFT
2. COLUMN
3. BRACING BEAM
4. OFFICE ROOM : ROOF SLAB
5. LANDING SLAB & BEAM
6. JUNCTION 1
7. BOTTOM DOME
8. JUNCTION 2
9. CYLINDRICAL WALL
10. JUNCTION 3
11. TOP DOME
12. VENTILATION SHAFT

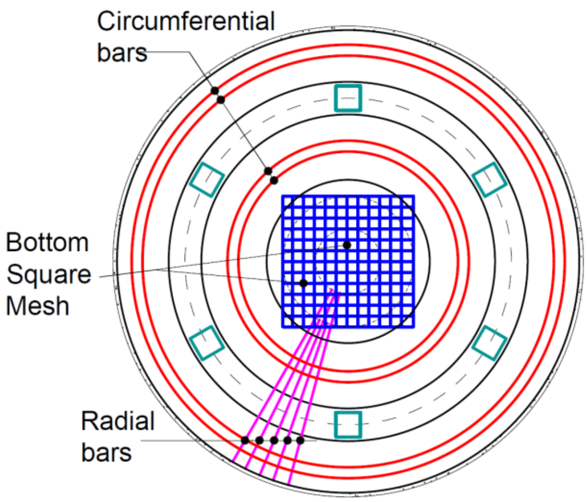


10.2 FOUNDATION: SOLID RAFT

10.2.1 BOTTOM LAYER BARS

Circumferential bars, Radial bars and bottom square mesh are shown in Plan.

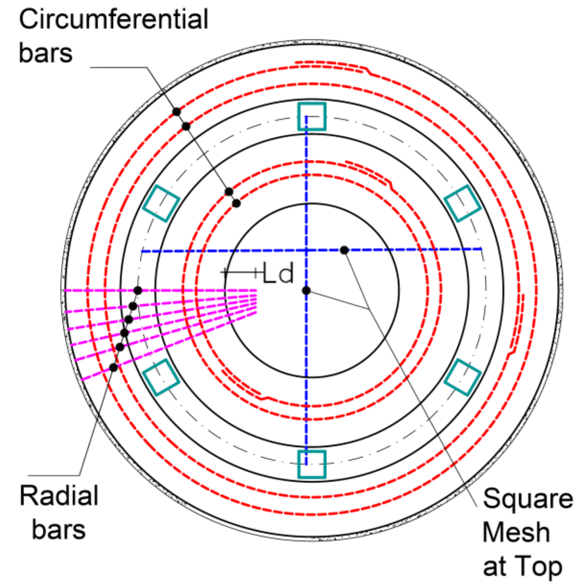
Lap Length of bars = 47 x dia of bars



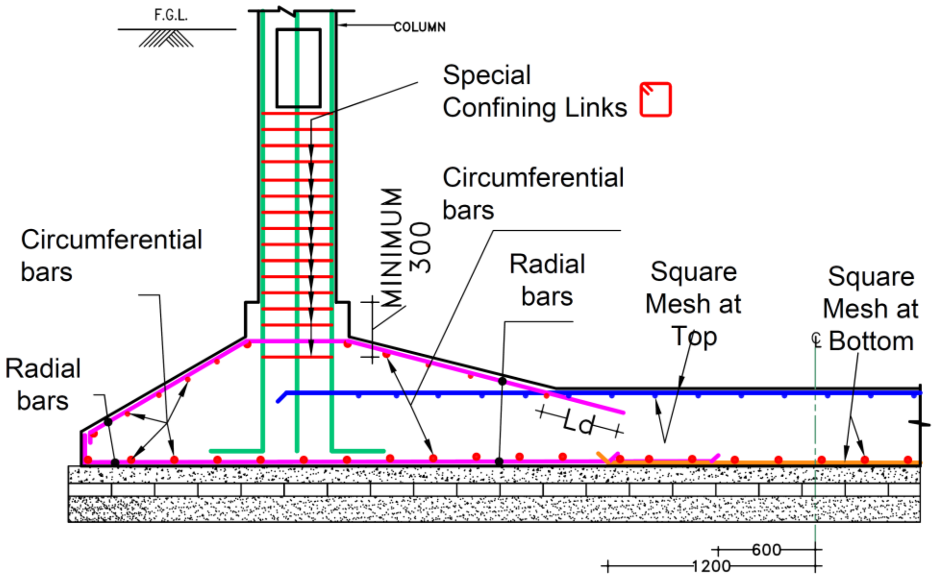
10.2.2 TOP LAYER BARS

Circumferential bars, Radial bars and top square mesh are shown in Plan.

Lap Length of bars = 47 x dia of bars



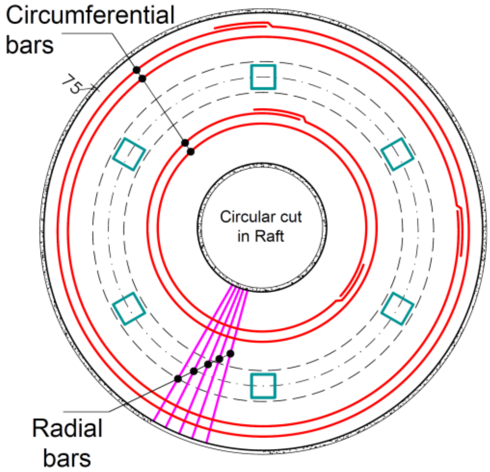
10.2.3 SOLID RAFT : SECTION



Circumferential bars, Radial bars, Top square mesh, Bottom square mesh, Column Dowels are shown in Section along with anchorage of radial bars equal to a length of Ld. Where Ld = 47 x dia of bars. Special confining links in columns are also shown.

10.3 FOUNDATION: ANNULAR RAFT

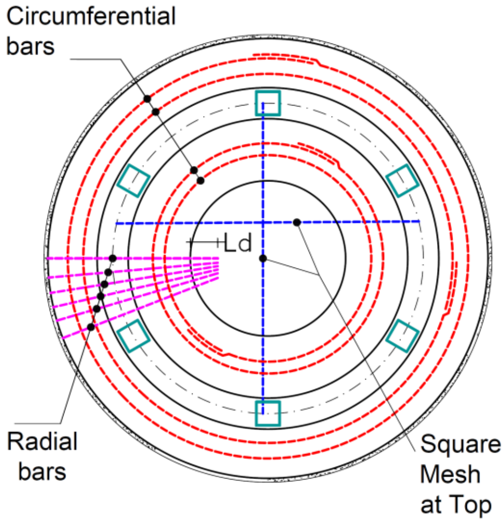
10.3.1 BOTTOM LAYER BARS



Circumferential bars and Radial bars are shown in Plan.

Lap Length of bars = 47 x dia of bars

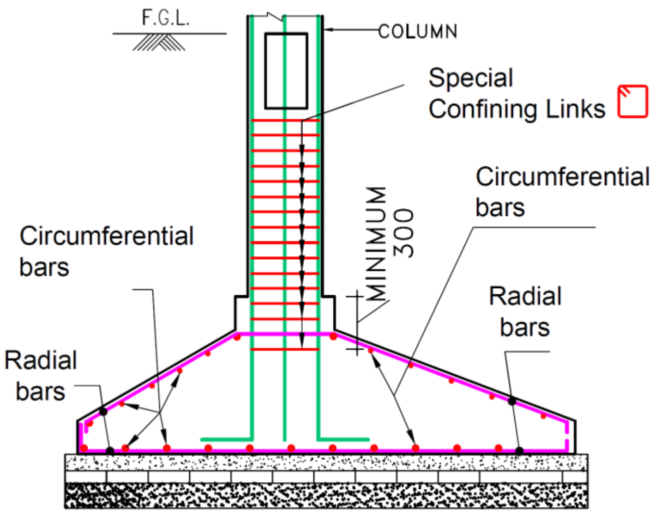
10.3.2 FOUNDATION: ANNULAR RAFT, TOP LAYER BARS



Circumferential bars and Radial bars are shown in Plan.

Lap Length of bars = 47 x dia of bars

10.3.3 ANNULAR RAFT : SECTION



Circumferential bars, Radial bars, and Column Dowels are shown in Section. Special confining links in columns are also shown.

Lap length of bars = 47 x diameter of bar.

10.4 SPECIAL CONFINING LINKS IN STAGING COLUMNS

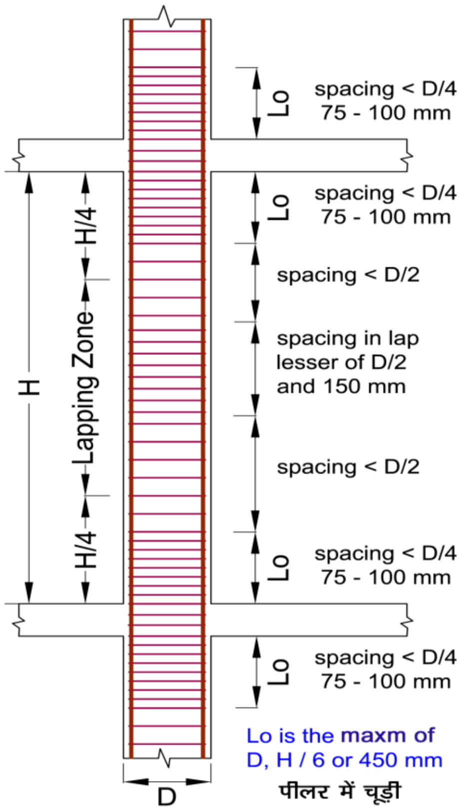
Column
b = lesser dimension
D = Larger dimension

Links
Minimum spacing @ b/2 c/c
Reduced spacing of special confining links at the joints shown in the figure.

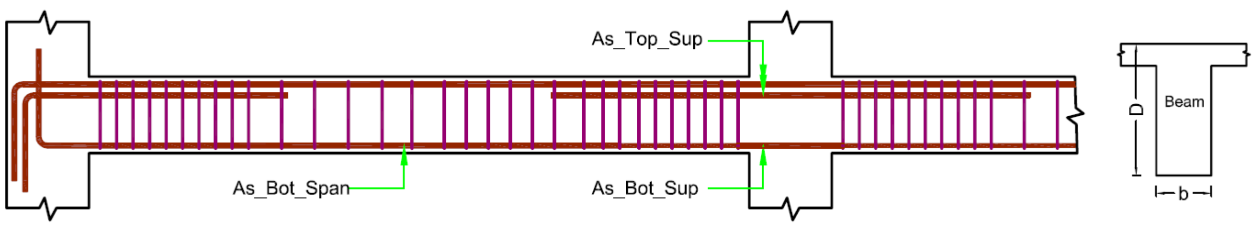
Lapping of longitudinal bars
Maximum 50% of longitudinal bars to be lapped at any section

Lapping Zone and Reduced spacing of links in the lapping zone shown in the figure.

Lap length = 40 x bar diameter



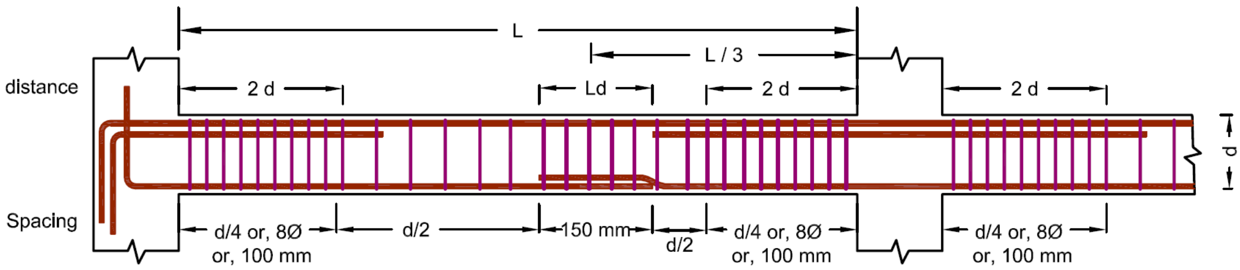
10.5 STAGING - BRACING BEAM



As_Bot_sup > 0.5 x As_Top_Sup
As_Bot_Span > 0.25 x As_Top_Sup

Minimum Steel = 0.24 (√ fck / fy) bD
Maximum Steel = 0.025 bD

LONGITUDINAL REINFORCEMENT IN BEAMS

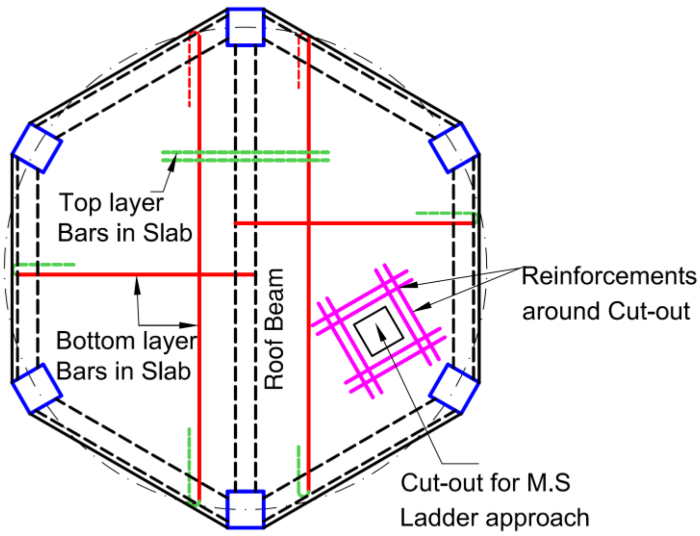


Note :- Ø = dia. smallest longitudinal bar
Ld = Lap length of longitudinal bar in tension
d = Effective depth of beam

MAXIMUM SPACING OF VERTICAL STIRRUPS IN BEAMS

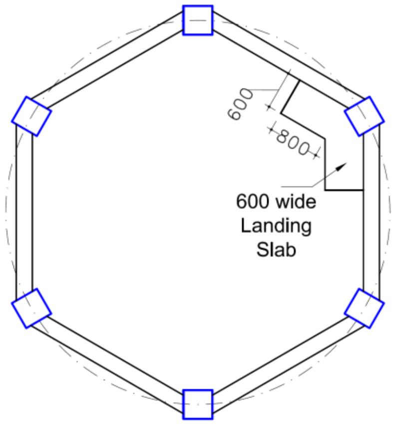
10.6 OFFICE ROOM: ROOF SLAB

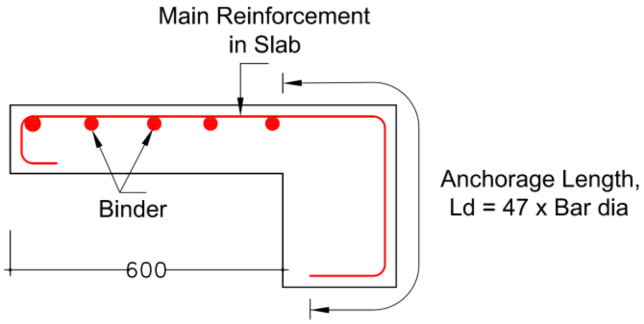
Location of Roof beam, Slab reinforcement and Reinforcement around the edge of cutout are shown in plan.



10.7 CANTILEVER LANDING SLAB

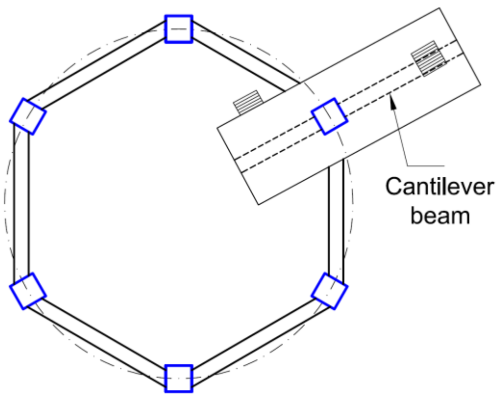
600 mm wide landing slab is shown in Plan. Slab is projected from the bracing beam.



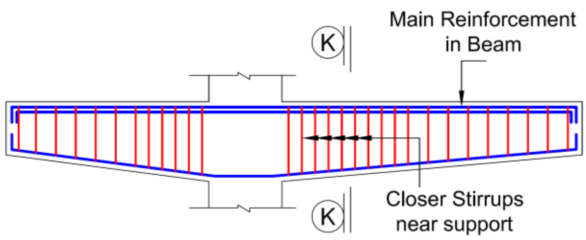


Details of reinforcement for cantilever slab are shown in Section.

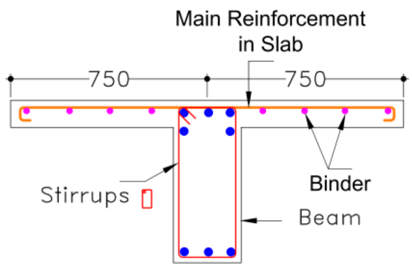
10.8 LARGER LANDING BELOW TANK



PLAN



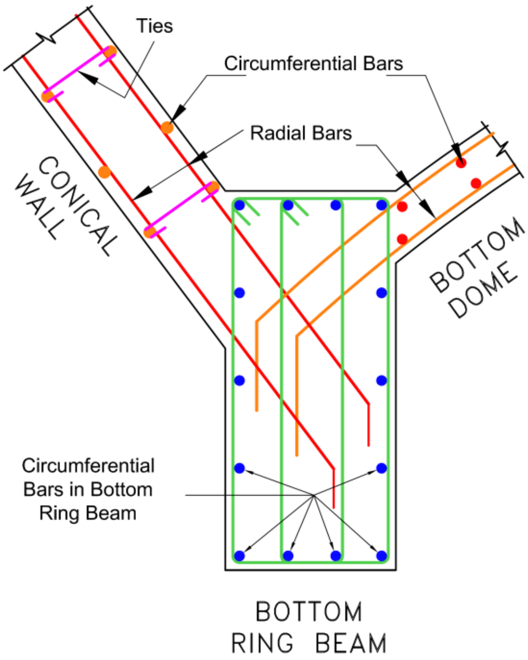
SECTION THROUGH CANTILEVER BEAM



SEC - K - K

10.9 JUNCTION WITH BOTTOM RING BEAM

Radial bars from the Bottom dome and the Conical wall enter straight into the Bottom ring beam and these bars are anchored into the Bottom ring beam by an anchorage length = Ld, where, Ld is equal to 47 x diameter of bar.
Ties are shown in the Conical wall. Circumferential bars and stirrups of bottom ring beam are also shown.

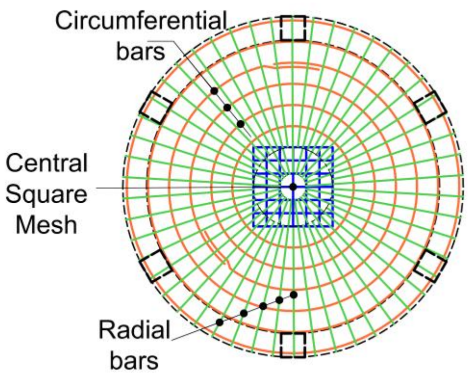


10.10 BOTTOM DOME

10.10.1 BOTTOM DOME : BOTTOM LAYER BARS

The reinforcements consisting of Circumferential bars, Radial bars and central Square mesh are shown in plan.

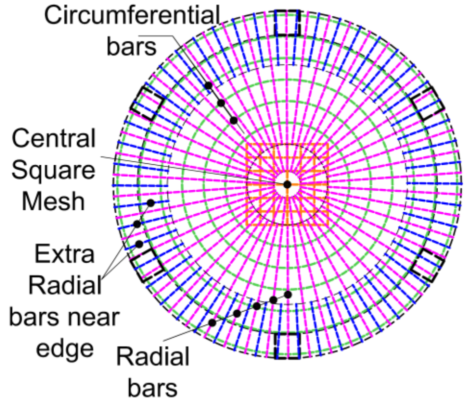
Lapping of Circumferential bars are also shown. Lap length = 47 x diameter of bar.



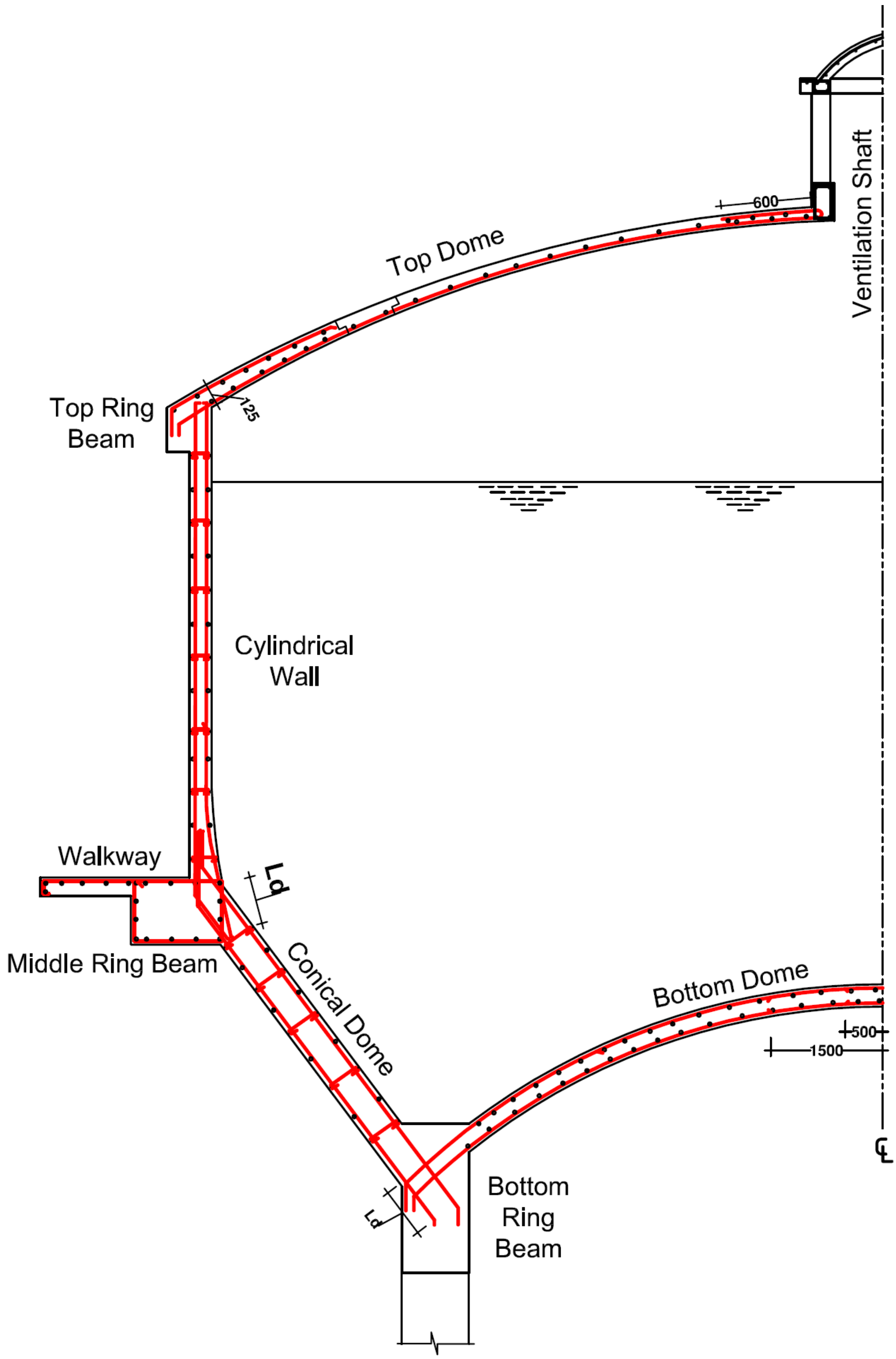
10.10.2 BOTTOM DOME : TOP LAYER BARS

The reinforcements consisting of Circumferential bars, Radial bars, Extra Radial bars and central Square mesh are shown in plan.

Lap length = 47 x diameter of bar.

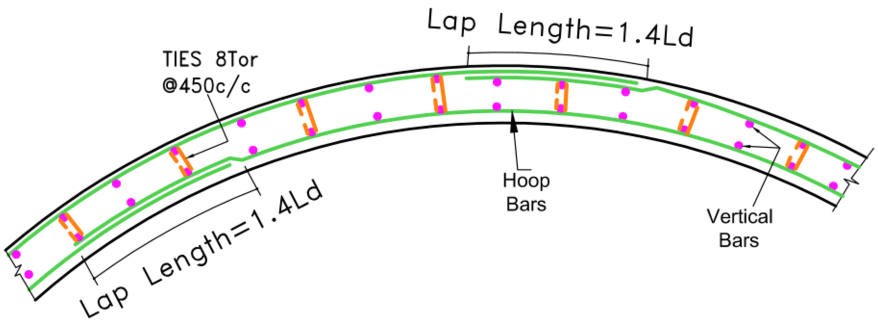


10.11 HALF - CROSS SECTIONAL VIEW OF TANK



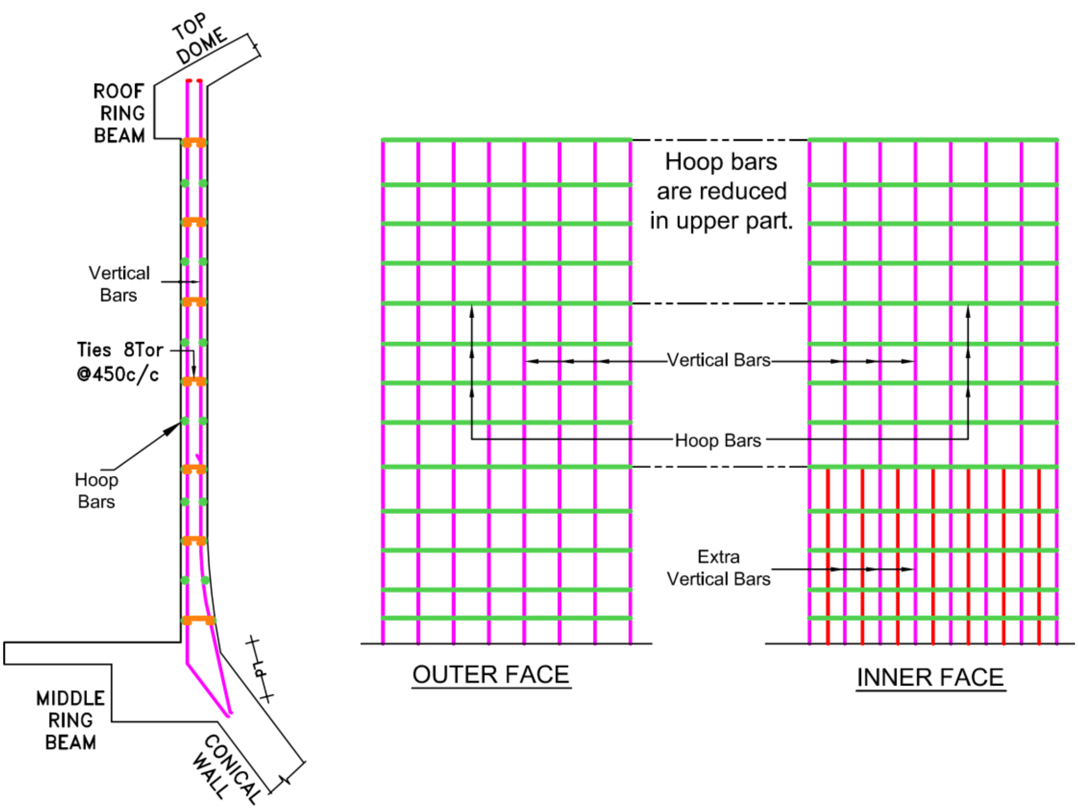
10.12 CYLINDRICAL WALL

10.12.1 CYLINDRICAL WALL IN PLAN



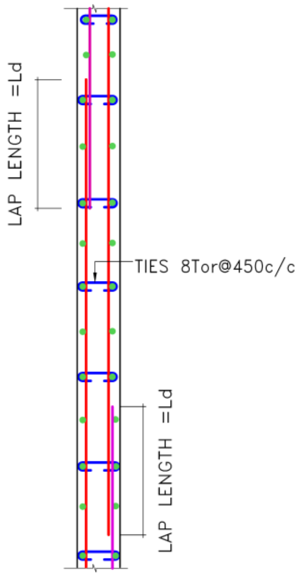
The reinforcements in cylindrical wall consisting of Hoop bars, Vertical bars and ties are shown in the Sectional Plan.
Lap length of hoop bars shall be 1,4 x Ld,

10.12.2 CYLINDRICAL WALL IN ELEVATION



The reinforcements in cylindrical wall consisting of Hoop bars, Vertical bars, Extra Vertical bars and ties are shown in the Sectional Elevation. Reinforcements on inner and outer faces are also shown on Elevations.

10.12.3 LAPPING OF VERTICAL BARS

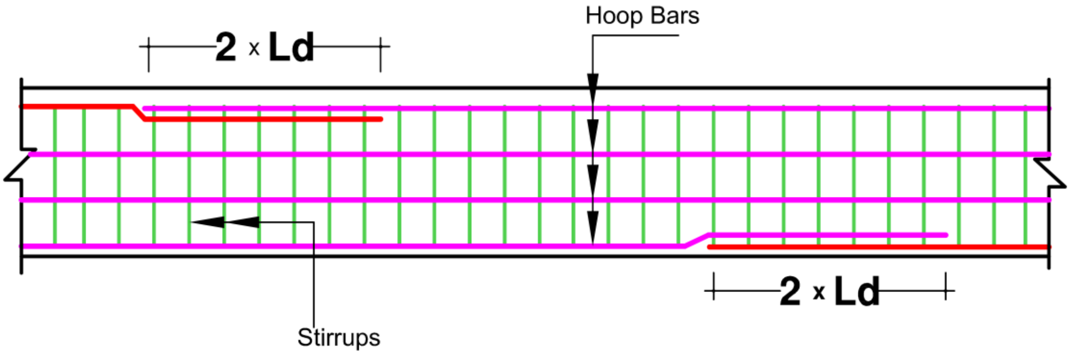


Lap length of vertical bars shall be equal to Ld, where Ld = 47 x diameter of bar.

Maximum 1/3rd bars shall be spliced at any section. (Staggered splicing)

10.13 MIDDLE RING BEAM

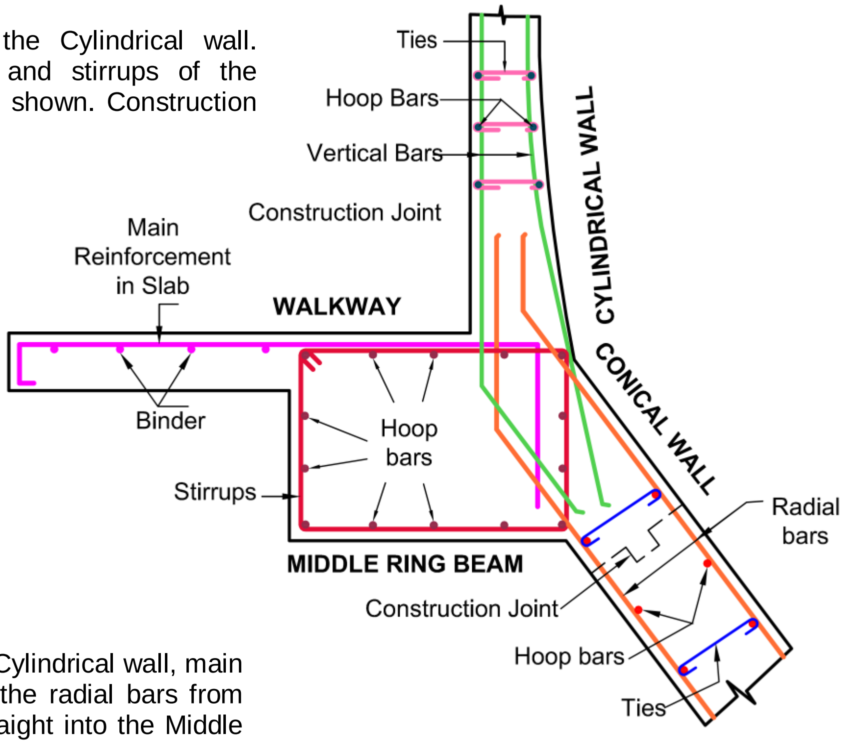
10.13.1 LAPPING OF CIRCUMFERENTIAL BARS



Lap = 2 x Ld, where, Ld = 47 x diameter of bar.

10.13.2 JUNCTION WITH MEMBERS

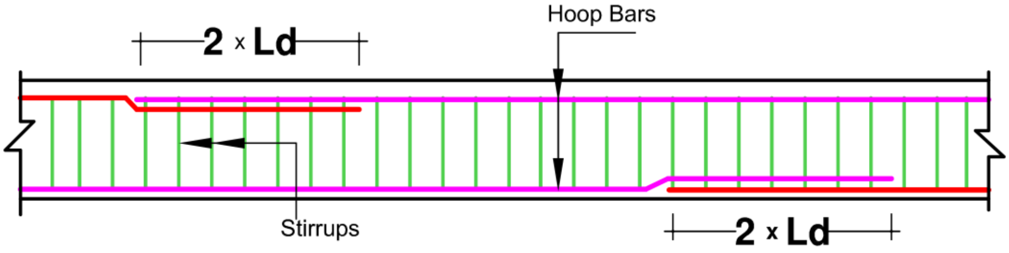
Ties are shown in the Cylindrical wall. Circumferential bars and stirrups of the Middle ring beam are shown. Construction joints are also seen.



Vertical bars from the Cylindrical wall, main bars of Walkway and the radial bars from Conical wall enters straight into the Middle ring beam and these bars are anchored by anchorage length = Ld. Where, Ld is equal to 47 x diameter of bar.

10.14 ROOF RING BEAM

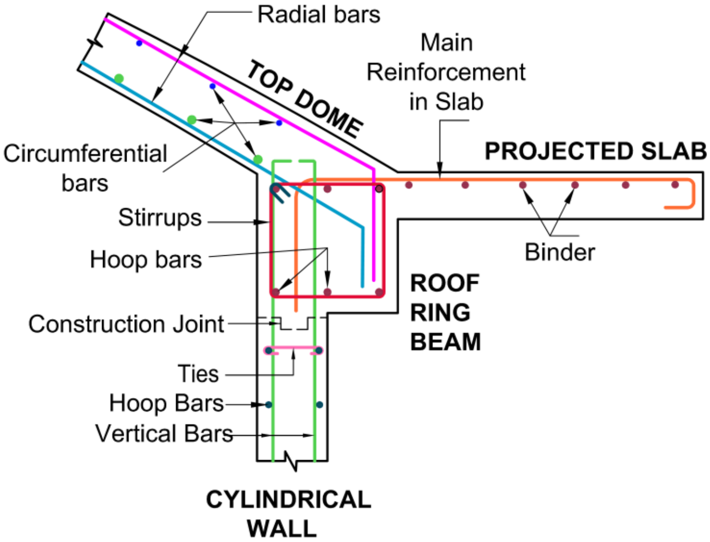
10.14.1 LAPPING OF CIRCUMFERENTIAL BARS



Lap = 2 x Ld, where, Ld = 47 x diameter of bar.

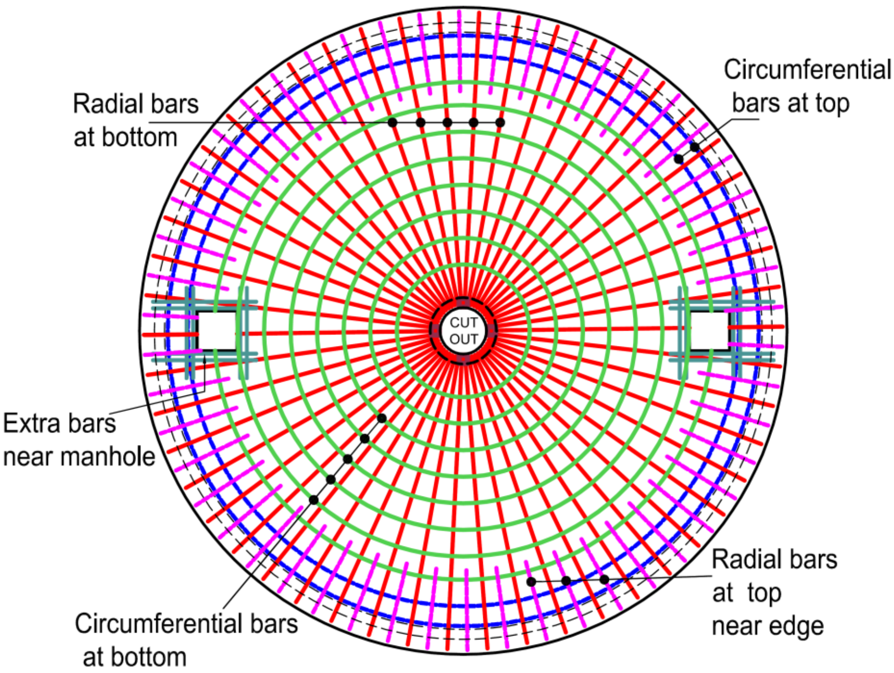
10.14.2 JUNCTION WITH ROOF RING BEAM

Radial bars from the Top dome, main bars of the projected slab and the Vertical bars from Conical wall enters into the Roof ring beam and these bars are anchored by anchorage length = Ld. Where, Ld is equal to 47 x diameter of bar. Ties are shown in the Cylindrical wall. Circumferential bars and stirrups of the Roof ring beam are shown.

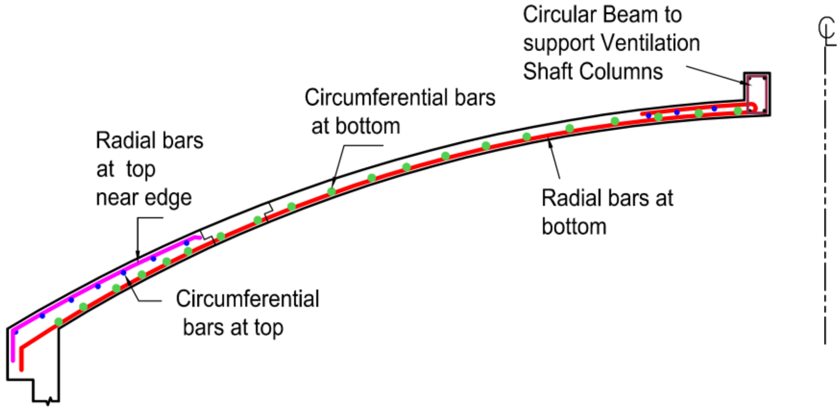


10.15 TOP DOME

10.15.1 REINFORCEMENT PLAN

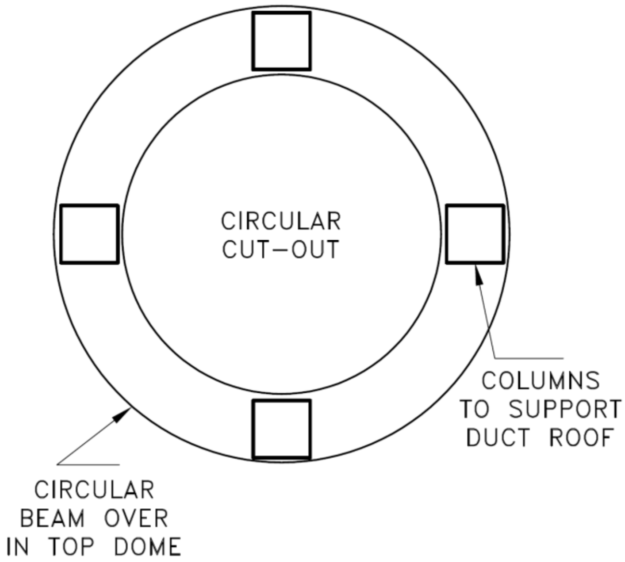


10.15.2 SECTION

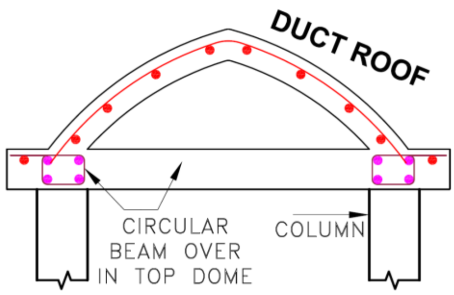


10.16 VENTILATION SHAFT

10.16.1 PLAN SHOWING SUPPORTING COLUMN



10.16.2 SECTION



GUIDELINES FOR R.C. WATER TOWERS UPTO 1000 kL CAPACITY

Part- 2 CONSTRUCTION CONTROL PROVISIONS
As stipulated in IS: 456, IS: 3370 & IS: 11682*

1.0 GENERAL

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- It is most important to ensure water supply even under post – earthquake situation.
- Water Towers are important structure.
- IS:1893-Part 2 stipulates that 1.5 times the normal seismic forces should be considered in designs.

Hence, Construction Control procedure should be laid down for quality assurance.

1.1 REASONS OF WEAKNESS OF STRUCTURE

- Foundation on weak soil
- Improper structural arrangement
- Deficient structural design
- Lack of checking of designs
- Lack of detailed structural drawing
- Poor connection of non- structural elements with main structure
- Poor construction material
- Untrained construction labour
- Lack of Supervision / Inspection

2.0 FOUNDATION

2.1 SELECTION OF SITE — IS: 3370 Part I clause 4, IS: 1904-1986 clause 5.3

Extra precaution is needed at the following sites:

- Saturated fine sand below the foundation
- Expansive clay or loose silt below the foundation
- Filled up sites
- Sloping ground
- Water-logging at the site
- Chemically injurious soil or ground water

2.2 OBJECT OF SUBSURFACE INVESTIGATION

- To determine shear strength and compressibility of soil layers **(IS: 1892– 1979)**
- To determine soil type: Hard, Medium or Soft soil **(IS: 1893 Part 1)**

2.3 SUBSURFACE INVESTIGATION — IS:1892– 1979

- ✓ Minimum Depth of Borehole = Depth of foundation + 1.5 x diameter of foundation
- ✓ In weak soil, exploration up to a depth at which the loads can be carried
- ✓ Highest Annual flood level, Depth of Underground water table before and after monsoon
- ✓ Chemical analysis of the soil and ground water

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*Prepared by: ***B K MISHRA, Senior Advisor, Bihar State Disaster Management Authority*** for ***Training on quality assurance in construction of RCC water tanks and towers***

2.4 NECESSARY SOIL TESTS OF DIFFERENT LAYERS

- Standard Penetration Test ✽ **(IS 2131-1981)**
- Visual classification of soil **(IS 1498 - 1970)**
- Grain size analysis **(IS 2720 Part IV)**
- Unit weight and Specific gravity **(IS 2720 Part III)**
- Natural moisture content **(IS 2720 Part II)**
- Plastic and Liquid limits **(IS 2720 Part V)**
- Unconfined compression **(IS 2720 Part X)**
- Tri-axial compression, C, Ø **(IS 2720 Part XI)**
- Direct Shear test (sandy soil) **(IS 2720 Part XIII)**
- Coefficient of consolidation for Cohesive soil **(IS 2720 Part XV)**
- Chemical analysis including pH determination **(IS 2720 Part XXVI)**
- Chlorides and sulphates **(IS 2720 Part XXVII)**

✽ Supervision is necessary during various operation, e.g. Boring, Logging and sampling.

2.5 RECCOMMENDATIONS IN SOIL TEST REPORT

- Depth of Foundation to achieve bearing pressure
- Type of foundation to be adopted
- Discussions for
    - Possible Liquefaction
    - Expansion and contraction of soil due to seasonal changes?
    - Foundation soil is not eroded by flowing water?
- Calculation for Safe bearing capacity of Open foundation
    - On shear failure criteria **IS: 6403 – 1981**
    - On settlement criteria **IS: 8009 (Part I) – 1976**

☞ If necessary, Shear capacity and settlement can be verified separately, by the Plate Load Test, as per **IS: 1888 – 1982**

2.6 SAFETY AND STABILITY OF FOUNDATION

IS: 3370 Part I clause 4.2

- Proportioning the foundation for safe bearing pressure
- Permissible settlement **IS: 1904-1986 Table 1**
- No tension at base (under seismic condition)
- Safety against sliding and overturning **IS: 1904-1986 clause 17**
- RCC tie beams for isolated foundations
- Protecting coat against injurious soils: asphalt, chlorinated rubber, epoxy or polyurethane

3.0 DEFECTS IN CONCRETE

3.1 SEGREGATION

- Coarse aggregate separate out from the paste
- Bottom: surplus of aggregate, large voids, reduced strength, less durability
- Top, lack of aggregate, cracking

3.2 BLEEDING OF WATER

- Aggregates cannot hold water and Cement-water rises to the surface.
- Bleeding continues until the cement paste has stiffened enough to end the sedimentation process
- Causes
  - Lack of fines, Excess of water, Non-cohesive mix
  - Inappropriate placing and Insufficient compaction

3.3 PLASTIC SHRINKAGE CRACKING

- Rate of water evaporation > rate of bleeding water to the top
- Drying while concrete is plastic
  - surface cracking
  - Loss of bond between concrete and rebar

3.4 CONTROL OF PLASTIC SHRINKAGE

- Reduce evaporation of water
  - Cool concrete, use ice
  - Use curing compound
  - Erect wind barriers
  - Cover with polyethylene
- Increase the humidity
  - Moisten forms
  - Spray water

3.5 HONEYCOMBING

- **Too much coarse aggregate and Lack of paste**
- **Causes: Poor compaction, Rebar congestion, Joint leakages**

3.6 CORROSION **IS: 3370 Part I clause 5.1, 9.8**

- **Low cement content**
- **Less Compaction**
- **Less cover to steel**

3.7 INCOMPLETE COMPACTION (DEFECTS)

- 5% of air voids loss of strength by 30%
- 10% of air voids loss of strength by 60%

4.0 EXECUTION OF WORK

Work to be carried out under an experienced supervisor (IS: 11682)

4.1 MATERIALS

4.1.1 CEMENT

- Use 43 grade OPC (**IS: 8112**), Slag cement (**IS: 455**) or PPC (**IS: 1489**)
- Cement must be fresh, Protect from moisture
- Cement mixture should be used within an hour after adding the water
- Manufactures: Ultra tech, JP cement, Lafarge, Birla Gold, (ISI marked)

4.1.2 WATER

- Clean (like drinking water)

4.1.3 STONE CHIPS

- Provides volume stability
- Use 20 mm to 4.75 mm, Well graded (**IS 383**)
- Clean and Fresh, Protect from dust

4.1.4 RIVER SAND

- 4.75 mm to 75 micron, FM > 2
- Well graded zone II (IS 383) zone II
- Clean and Fresh, Protect from dust

4.1.5 ADMIXTURE: SUPER PLASTICISER **IS 9103-1999**

✓Improves workability of concrete
✓Reduces required water up to 12% or more

- Approve with past experience and mix design
- Maximum weight, 2 % by weight of cement
- Establish slump with and without the use of admixtures

4.1.6 STEEL REINFORCING BARS

- High Yield strength deformed steel bars conforming to **IS 1786**.
- Standard manufacturer such as Tata, SAIL
- Do not use bars manufactured from (re-rolled steel)

4.1.7 FORMWORK

- Gives concrete its shape
- Formwork must be: accurate, strong and no leak from the joints
- Formwork placed, can be removed
- Simple to build, easy to handle and re-useable
- Materials: steel, ply board, timber
- Bolts to secure and align the form-work: Don't pass completely through walls / slabs, unless, or, take precautions for water-tightness, **(IS: 3370 P1 Cl. 9.7)**
- Face of formwork in contact with concrete **(IS: 456 2000 Cl. 11.2)**
  - Clean and treat with form release agent
  - Release agents should not coat the reinforcement

4.2 CONSTRUCTION CONTROL **(IS: 1893 - Part-2, Clause 8.2.3)**

a) Vertical Alignment – The centre point of shaft shall not vary from its vertical axis by more than 0.2 percent of shaft height.

b) Over any height of 1.6 m, wall of shaft shall not be out of plumb by more than 10 mm.

c) Shaft diameter – the measured centerline diameter of shaft at any section shall not vary from the specified diameter by more than 20 mm plus 0.1 percent of the specified theoretical diameter.

d) Shaft thickness – the measured wall thickness shall not vary from the specified wall thickness by more than – 5 mm or + 10 mm.

4.3 ASSEMBLY OF REINFORCEMENT

- Bar bending schedule to be prepared
- Bars to be placed as shown in the drawings
- Steel bars not to be re-bent
- Proper position by using cover blocks, spacers, chairs etc.
- Keep beam and column bars straight at joints
- Beam bars should pass within column bars
- Welded Joints or Mechanical Connections: Test the joints for full strength of bars

4.4 CONCRETE COVER TO REINFORCEMENT

Cover provided to protect corrosion of reinforcing bar

- Proper cover blocks casted a month earlier
- Chair is used for top layer bars in slab

NOMINAL COVER **(IS 456 2000 Clause 26.4)**

✓ Depth of concrete cover to steel bars, including links

- Nominal Cover >= diameter of main bar
- Nominal cover for Moderate Exposure 30 mm

Nominal cover < Actual concrete cover < Nominal cover + 10 mm

- Minimum cover for footings = 50 mm
- Minimum cover to long bar in column = 40 mm

IS: 3370 (Part II) clause 7.2

- Liquid face and inner face of roof, 25 mm
- In corrosive soil, minimum cover = 50+12 mm

4.5 CONCRETE GRADE, W/C RATIO & CEMENT QUANTITY

(IS 456 2000 Table 3, Table 5)

- Exposure condition: Mild, Moderate, Severe, Very severe, Extreme
- Adopt exposure: Moderate (Exposed to rain or under water)
- Minimum concrete grade M25
- 20 mm nominal maximum size aggregate
- Minimum quantity of cement in RCC ≥ 300 kg / cum
- Maximum water / cement ratio ≤ 0.5

IS: 3370 Part I clause 3.1

- Minimum quantity of cement in RCC ≥ 330 kg / cum
- Maximum quantity of cement in RCC ≤ 530 kg / cum

4.6 CONCRETE PROPORTIONING

(IS 456 2000 Clause 10)

- Material should be stocked at least a day before use
- The grading of aggregates to be checked frequently
- Proportion, type and grading of aggregates to obtain densest concrete
- Mix design as per **IS 10262-1982**
- Allowance moisture and bulking to be made
- Weigh-batching of all ingredients of the concrete
- In case of volume batching, mass volume relationship to be checked frequently

4.7 CONCRETE MIXING

- Always machine mixing
- Mixers to be fitted with water measuring devices
- Maintain water-cement ratio
- Pour 25% of the total quantity of water into the drum
- Discharge dry coarse and fine aggregates into the drum
- Deposit full quantity of cement into the drum
- Pour balance quantity of water
- 25 to 30 revolutions are needed for mixing with drum rotating @ 15-20 revolutions per minute, Mixing time, at least 2 min
- Continue mixing till uniform colour and consistency
- Slump to be checked at frequent intervals

4.8 WORKABILITY

- Easy to mix, place, compact and finish
- Easy to flow (slump)

MEASUREMENT OF SLUMP **IS: 1199-1959**

- Cone not bent or dented, clean surface inside
- Keep cone on clean, stable and levelled flat base of adequate size
- representative sample, middle fraction from the mixer
- Fill the cone, in three layers,
- Tamping with 16 mm diameter bar, each layer 25 times
- scrape off the surface, Lift cone vertically
- Measure the subsidence, Record the result
- Details: date, concrete batch, members

(IS 456 2000 clause 7.1)

- 50-100 mm slump heavily reinforced sections in slabs, beams, walls, columns

4.9 CONCRETE CASTING, COMPACTION

- Maximum free fall 1.5 m.
- Keep proper space at the joints for concreting
- Vibrate and compact before initial setting
- Compaction may be by immersion vibrator
- Compact thoroughly around the reinforcement and embedded fixtures
- Compact by 16 mm bar at congested locations, comers and edges
- Design the formwork for location, if external vibrator is used
- Uniform and full compaction

4.10 CONSTRUCTION JOINT **IS: 3370 Part I clause 8, 9 and IS 456 2000 Clause 13.4**

- Position of joints between successive lifts should be indicated on the drawings
- The height of any lift ≤ 2 m unless precautions are taken to ensure compaction
- Prepare Joint Surface of the first-placed concrete
  - Surface film be removed immediately after initial setting
  - Expose the aggregate and leave a sound irregular surface.
  - This may be achieved by air or water jet and wire brush.
  - Prepare clean SSD condition surface.
  - If the concrete has hardened, the desired surface may be achieved by hacking the whole of the surface, without damaging the aggregate.

- Curing of the joint surface may be suspended a few hours before second concreting
- The roughened joint surface should be thoroughly cleaned and freed from loose matter and then treated with a thin layer of cement grout, worked well into the surface
- Special care should be taken to avoid segregation of the concrete along the joint plane and to obtain thorough compaction.
- Alternatively, for horizontal joints the layer of grout or mortar may be omitted, provided that the workability of first batches of concrete placed in contact with the joint is slightly increased

4.11 CURING OF CONCRETE (IS 456 2000 Clause 13.5)

CURING

- Prevents the loss of moisture
- Maintains temperature gradients within
- Ample water, do not let it dry
- Dry concrete = dead, all reactions stop, Cannot revitalize if dries

- Curing is important in low w/c ratio, high rate of strength development
- Begin the curing of exposed surface as soon as the surface has hardened i.e. 1 to 2 hours after placement and finishing
- Exposed horizontal surfaces of concrete shall be kept wet by ponding
- Exposed vertical surfaces of concrete shall be kept wet by covering with sacking, canvas, hessian etc.
- Period of curing at least 10 days for OPC and 14 days for PPC
- Temperature > 45°, fast setting, durability suffers
- Best temperature is room temperature

4.12 REMOVAL OF FORMWORK (IS 456 2000 Clause 11.3.1)

- If temperature does not fall below 15°C and adequate curing is done

Period for Striking Formwork		
Type of Formwork	**For OPC**	**For PPC**
Vertical formwork to columns, walls, beams	16 – 24 hrs	24 hrs
Props to beams and arches: 1) Spanning up to 6 m 2) Spanning over 6 m	 14 days 21days	 21 days 24 days

- In spherical dome formwork to be removed from centre towards sides

5.0 TESTS OF CONSTRUCTION MATERIALS

5.1 SIEVE ANALYSIS OF SAND AND STONE CHIPS

- Sieve analysis of Sand, stone chips and their mix **(IS: 2386 P1 Cl. 2)**
- Limits **of** deleterious materials as per **IS: 383 1970 Table 1**
- Sieve analysis of, stone chips, **IS: 383 1970 Table 2**
- Sieve analysis of Sand, **IS: 383 1970 Table 4**
- Mix of sand and stone chips (All in aggregate) **IS: 383 1970 Table 4**

PROCEDURE

- ✓ Dry
- ✓ Weigh 1000 gm of fine aggregate & 2000 gm of coarse aggregate
- ✓ 2 minutes in sieve shaker then weigh & take % passing.

Sieve	Sand zone-II	Stone chips 20mm	Stone chips 10mm	All in aggregate
40	-	100	-	100
20	-	85-100	-	95-100
12.5	-	-	100	-
10	-	0-20	85-100	25-35
4.75	90-100	0-5	0-20	0-10
2.36	75-100	-	0-5	-
1.18	55-90	-	-	-
600 micron	35-59	-	-	-
300 micron	8-30	-	-	-
150 micron	0-10	-	-	-
75 micron	-	-	-	-

5.2 TESTS FOR REINFORCING BARS

Mass per meter **IS: 1786-1985 Table 1**

STRENGTH & ELOGATION IS: 1786-1985 Table 3			
Test	Fe 415	Fe 500	Fe 550
Minimum 0.2 percent proof stress / yield stress	415.0 mpa	500.0 mpa	550.0 mpa
Minimum elongation in %	14.5 %	12.0 %	8.0 %

Minimum yield stress is stress at 0.2 % elongation
Minimum elongation is measured at fracture

5.3 TESTS FOR CEMENT

IS: 4031 Part V 1988 Clause 2

Initial setting time > 30 min, Final setting time < 600 min

Compressive strength of 70.6 mm size cube, IS: 4031 Part 6				
Cement	**IS code**	**3 days**	**7 days**	**28 days**
33 Grade OPC	**IS 269**	16 mpa	22 mpa	33 mpa
Portland Slag Cement	**IS 455**	16 mpa	22 mpa	33 mpa
PPC	**IS 1489 P1**	10 mpa	18 mpa	33 mpa
43 Grade OPC	**IS 8112**	23 mpa	33 mpa	43 mpa
53 Grade OPC	**IS 12269**	27 mpa	37 mpa	53 mpa
Approximate Strength		50 %,	70 %	100 %

5.4 CONRETE CUBE TESTS

Sampling as per **IS: 1199-1959 clause 3**
Cubes made, cured and tested as per **IS: 516-1959**

→ 15 cm Moulds: clean and properly bolted, A steel tamping bar
→ Oil the moulds with proper shutter oil
→ Representative sample of fresh concrete, Compact the concrete in layers
→ Cover the cubes with wet hessian covered with polythene
→ Label the cubes and keep records

5.4.1 SAMPLE OF CONCRETE CUBE

IS: 456-2000 Clause 15

- One sample from each Shift
- One sample = 3 test specimens
- Test Result = average of the strength of 3 specimens
- Specimen test result variation< ±15 % of the average

Concrete in m3	Number of Samples
1 - 5	1
6 - 15	2
16 - 30	3
31 - 50	4
51 – 100	5
100 - 150	6 .....

5.4.2 TEST RESULT OF SAMPLE CONCRETE CUBE

IS: 456-2000 Clause 15.4

- Test Result = 28 days strength
- For quicker idea of quality, 7 days tests

5.4.3 ACCEPTANCE CRITERIA

IS 456 2000 Clause 16.1

- Mean of 4 consecutive test results > fck + 0.825 x standard deviation, and > fck + 4 mpa
- Any individual test result > fck - 4 mpa

5.5 TESTS FOR WATER TIGHTNESS AT FULL SUPPLY LEVEL IS: 3370 P1 Cl. 10

External faces should not show signs of leakage and remain apparently dry over the period of 7 days after filling.

6.0 IMPORTANT BIS CODES

Safety of Structure

IS: 456 – 2000 Plain and Reinforced Concrete – Code of Practice
IS: 3370 – 1965 Code of practice for concrete structures for the storage of liquids:
(Part I) general requirements
(Part II) Reinforced Concrete Structures
IS: 11682 -1985 Criteria for design of RCC staging for overhead water tanks
IS: 1893 (P2) - 2002 Criteria for Earthquake Resistant Design of Liquid retaining tanks
IS: 13920 - 1993 Ductile detailing of RCC structures against EQ forces: Code

Protection of Foundation

IS: 1498-1970 Classification and identification of soils for engineering purposes
IS: 1892- 1979 Subsurface investigation for foundations: Code of Practice
IS: 1904- 1986 Foundations in Soils: Code for General Requirements
IS: 2131- 1981 Method of Standard Penetration Test for soils (First Revision)
IS: 2950 Part 1-1981 Design and Construction of Raft foundations: Code of Practice
IS: 6403- 1981 Determination of bearing capacity of Shallow foundations: Code
IS: 8009 Part 1 Calculation of settlement of shallow foundation: Code

Tests for Construction Materials

IS: 383- 1970 Specification for coarse and fine aggregates for concrete
IS: 516- 1959 Methods of tests for strength of concrete
IS: 1199- 1959 Methods of sampling and analysis of concrete

7.0 SUPERVISION, INSPECTION AND DOCUMENTATION OF CONSTRUCTION

7.1 SUPERVISION (IS 456 2000 Clause 13.6)

- Constant and strict supervision of all construction items
  - ✓ Formwork for sizes of structural elements, Level of formwork
  - ✓ Reinforcement and its placing
  - ✓ Proportioning, mixing of and Compaction the concrete
  - ✓ Curing and Stripping of the formwork

7.2 TEST REPORTS AND CERTIFICATES

- Test reports and certificates for materials
- Concrete mix design details
- Concrete Pour Details
- Concrete mix test reports
- Site order book,
  - ✓ Record of geometry and reinforcement checking
  - ✓ Clearance for concrete placement
  - ✓ non-conformance reports

7.3 INSPECTION (IS 456 2000 Clause 17.1, 17.2)

- Set up inspection procedure, quality assurance scheme
- Ensure compliance of design in construction
- Verify quality of individual parts
- Tests and Records of construction materials
- Clear instructions on inspection and permissible deviations
- Identify workmanship, durability & appearance

7.4 SUPERVISION CHECK LIST

7.4.1 Before **actual start of construction: use CHECK LIST : 1**

CHECK LIST : 1	PRE- CONSTRUCTION	
Name of Project with Location ?		
Name of equipment required ?		
Cement, Aggregate, Sand, Admixtures, water & Steel Reinforcement	Available ☐	Not Available ☐
Space for storage of materials	Available ☐	Not Available ☐
Temporary sheds, drinking water and toilets	Available ☐	Not Available ☐
Trained Mason and Labor	Available ☐	Not Available ☐
Site Order Book	Available ☐	Not Available ☐
Note : Fill in the blanks or tick the check box.		

Engineer	Name	Signature	Date
JE			
AE			

7.4.2 With the supply of every new lot of construction materials : use **CHECK LIST : 2**

CHECK LIST : 2	CONSTRUCTION MATERIALS			
Name of Project with Location ?				
Type of cement	PPC☐	Slag cement☐	OPC 33 Gr.☐	OPC 43 Gr.☐
Manufacturing week of cement ?				
Cement cube test	DONE ☐	NOT DONE☐		
Concrete cube test after Mix Design	DONE ☐	NOT DONE☐		
Proportion of materials by Weight, as per Mix design ?	Cement: sand: chips: water: super-plasticizer			
Proportion of materials by Volume, as per Mix design ?	Cement: sand: chips: water: super-plasticizer			
Sieve analysis of stone chips conforms to IS:383.	YES ☐	NO ☐		
Sieve analysis of sand conforms to IS:383.	YES☐	NO ☐		
Sieve analysis of All in Aggregates conforms to IS:383.	YES☐	NO ☐		
Aggregates are free from dust and foreign matter	YES☐	NO ☐		
Aggregates are protected from environmental dust	YES☐	NO ☐		
Test for steel reinforcement as per IS:1786: Value of Yield stress ?				
Test for steel reinforcement as per IS:1786: Value for Elongation ?				
Water is clean and portable	YES☐	NO ☐		
Value of Slump with Super-plasticizer ?				
Value of Slump without Super-plasticizer ?				
Photograph: Cement Store	ATTACHED ☐	NOT ATTACHED ☐		
Photograph: Aggregates	ATTACHED ☐	NOT ATTACHED ☐		
Note : Fill in the blanks or tick the check box.				

Engineer	Name	Signature	Date
JE			
AE			

7.4.3 For construction of Foundation, Staging, Bottom dome & Conical Ring Beam, Middle Ring Beam, Cylindrical Wall and Top Dome : use **CHECK LIST : 3**, **CHECK LIST : 4** and **CHECK LIST : 5.**

CHECK LIST : 3	**CENTERING-SHUTTERING AND REBARS PLACING**		
Name of Project with Location ?			
Materials used for formwork	WOODEN PLANK☐	PLY BOARD☐	STEEL PLATE ☐
Materials used for props	STEEL PIPE ☐	SAL BALLAH☐	BAMBOO ☐
Shuttering is sufficiently strong to bear the loads.		YES ☐	NO ☐
Props are strong, properly placed, fixed and tied.			☐
Inner face of formwork is smooth.		YES ☐	NO ☐
Inner face of formwork is cleaned.		YES ☐	NO ☐
Inner face of formwork is treated with form release agent		YES ☐	NO ☐
Vertical & horizontal alignment is as per drawing.		YES ☐	NO ☐
The width and depth/height of formwork is as per drawing.		YES ☐	NO ☐
Vertical sides should be absolutely in line and plumb.		YES ☐	NO ☐
The formwork is water-tight.		YES ☐	NO ☐
Thin sheets are provided along joints of wooden formwork.		YES ☐	NO ☐
Foam is provided along the joint of steel formwork.		YES ☐	NO ☐
Width of section is adequate for inserting vibrator.		YES ☐	NO☐
Proper location, size & orientation of cut-outs.		YES ☐	NO☐
Proper location and size of inserts & bolts.		YES ☐	NO☐
Bars are rust free.		YES ☐	NO☐
Bars are straight.		YES ☐	NO☐
Bar diameter, length and spacing is as per drawing.		YES ☐	NO☐
Bars are bent as and placed as per drawing.		YES ☐	NO☐
The lap length is accurate as per drawing.		YES ☐	NO☐
Laps are staggered.		YES ☐	NO☐
Adequate and accurate cover blocks & chairs.		YES ☐	NO☐
Minimum 25 mm clear distance between two bars.		YES ☐	NO☐
The rods are tied properly with binding wire.		YES ☐	NO☐
Walk-way planks to be used while casting the slab.		YES ☐	NO☐
Over all cleaning done before concreting.		YES ☐	NO☐
Photograph: multiple view of works		ATTACHED ☐	NO☐
Photograph: Subject of technical interest.		ATTACHED ☐	NO☐
Photograph: Any unusual difficulty		ATTACHED ☐	NO☐
Photograph: Safety violations, Accident scenes, Defects		ATTACHED ☐	NO☐
ALLOWED FOR CONCRETING		YES ☐	NO☐
Note : Fill in the blanks or tick the check box.			

Engineer	Name	Signature	Date
JE			
AE			

CHECK LIST : 4	CORCRETE MAKING, CASTING, CUBE MAKING	
Name of Project with Location ?		
Spare Vibrator and needles was kept ready before concreting.	YES ☐	NO☐
Additional precaution was taken for shuttering during concreting.	YES ☐	NO☐
Slump was tested at regular intervals to ensure proper workability.	YES ☐	NO☐
Concrete was not poured from more than 1.5 m height	YES ☐	NO☐
Concrete was compacted properly.	YES ☐	NO☐
Concrete top is at proper level.	YES ☐	NO☐
Construction joints are properly made at correct location.	YES ☐	NO☐
Concrete surface was finished properly.	YES ☐	NO☐
Concrete was used within initial setting (after adding the water).	YES ☐	NO☐
Concrete cubes was made for testing.	YES ☐	NO☐
Concrete sample was collected from random mixes.	YES ☐	NO☐
Adequate number of cube samples taken for test at 7 & 28 days.	YES ☐	NO☐
Photograph: Multiple view of works	YES ☐	NO☐
Photograph: Defective work	YES ☐	NO☐
Note : Fill in the blanks or tick the check box.		

Engineer	Name	Signature	Date
JE			
AE			

CHECK LIST : 5	CURING AND STRIPPING OF FORMWORK	
Name of Project with Location ?		
For how many days curing was continuously done ?		
Curing compound was used for member not easily accessible.	YES ☐	NO☐
After how many days Formwork was removed ?		
7 days Cube Test Results ?		
28 days Cube Test Results ?		
Photograph: multiple view of works	YES ☐	NO☐
Photograph: Defective work	YES ☐	NO☐
Note : Fill in the blanks or tick the check box.		

Engineer	Name	Signature	Date
JE			
AE			

7.4.4 **CHECK LIST : 6** shall be used to inform weekly progress of works.

CHECK LIST : 6	WEEKLY CONSTRUCTION REPORT	
Name of Project with Location ?		
Weather (temperature, cloud, rain etc.) ?		
Indicate any major decision taken ?		
Members constructed during the week ?		
Equipment working in the activity ?		
Name of Contractor's technical person ?		
Corrective actions, if any to be taken ?		
Problems or delays and resolution ?		
Communications with contractor staff ?		
Progress photos, (where applicable).	ATTACHED ☐	NO ☐
Note : Fill in the blanks or tick the check box.		

Engineer	Name	Signature	Date
JE			
AE			

7.4.5 **CHECK LIST : 7** shall be used for any non compliance of works or specification.

CHECK LIST : 7	**NONCONFORMITY REPORT**				
Project ?					
Contractor ?					
Structural Element ?					
Item of Work ?					
Summary of Nonconformity ?					
Suggestions ?					
Use as it is	☐	Repair	☐	Reject	☐
Engineer	Name	Signature	Date		
JE					
AE					

7.5 INSPECTION CHECK LIST

CHECK LIST : 8 shall be used by senior engineers like EE, SE or CE during their inspection of works.

CHECK LIST : 8	**INSPECTION CHECK LIST**		
Name of Project with Location ?			
Date of inspection ?			
Structural member inspected in the inspection ?			
Concrete Cube Test results	PASSED ☐	FAIL☐	
Tests of construction materials conform to IS Codes.	YES☐	NO ☐	
Tests of construction materials conform to IS Codes.	YES☐	NO ☐	
Construction has been done as per drawing.	YES☐	NO ☐	
Workmanship & appearance are satisfactory.	YES☐	NO ☐	
Segregation or honeycombing on the concrete surface.	SEEN ☐	NO☐	
Photograph: taken properly and kept properly	YES☐	NO ☐	
Note : Fill in the blanks or tick the check box.			
Engineer	Name	Signature	Date
EE ☐ SE ☐			

7.6 DOCKETING

Table below shows the name of the offices where documents and reports will be kept safe for future references.

Documents and Reports	**Office of**
Soil Investigation Report	**ENC, CE, SE, EE**
Design Calculations and Drawing Details	**ENC, CE, SE, EE**
Detailed Drawings	**EE, AE, JE**
All Check lists, photographs and Test Reports	**CE, SE, EE**
Geometric and Rebar measurements	**EE, AE, JE**

APPENDIX

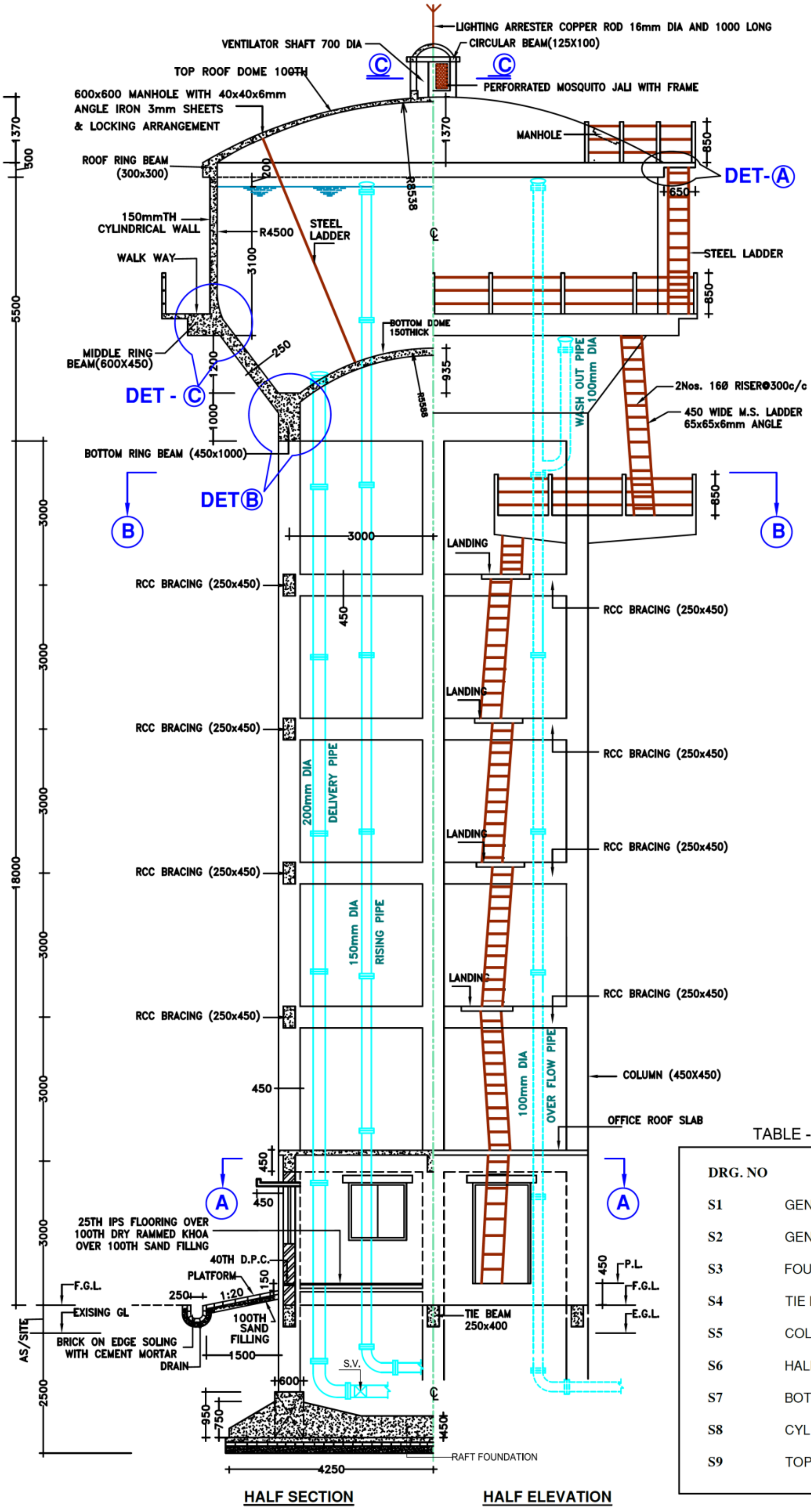


TABLE - B (REFER DETAILS)

DRG. NO	DETAILS
S4	DETAIL - Ⓐ
S4	SECTION Ⓐ-Ⓐ
S4	SECTION Ⓑ-Ⓑ
S7	DETAIL - Ⓑ
S9	SECTION Ⓒ-Ⓒ

TABLE - A (REFER DRAWINGS)

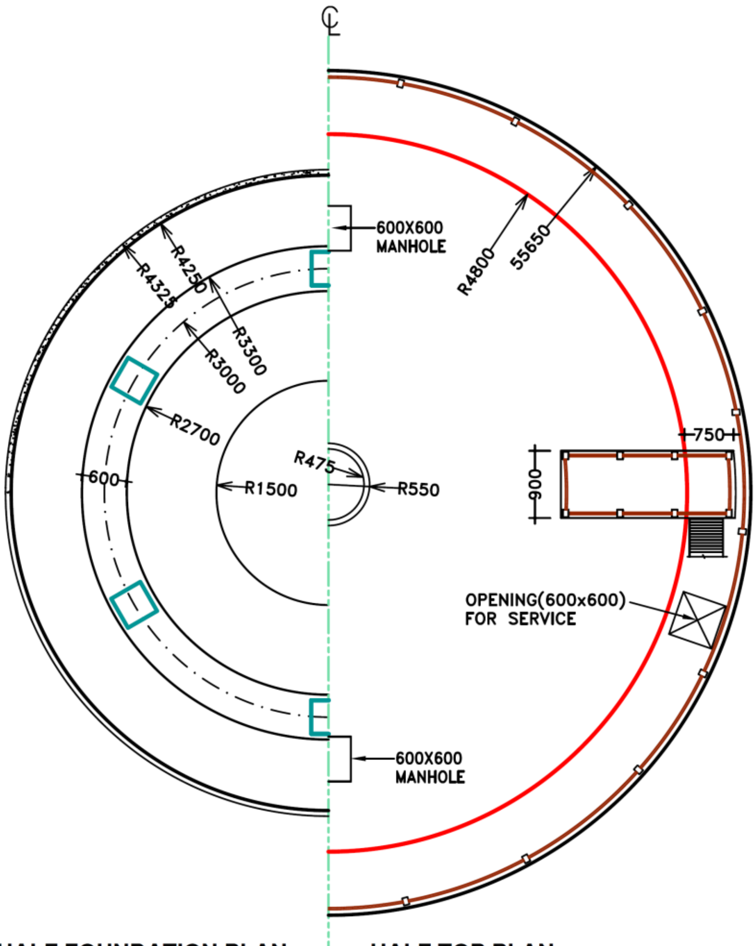
DRG. NO	TITLE
S1	GENERAL OUTLINE DRAWING
S2	GENERAL PLAN AND NOTES
S3	FOUNDATION DETAILS
S4	TIE BEAM, LANDINGS, LADDER
S5	COLUMN, BRACING AND OFFICE ROOF
S6	HALF SECTION OF WATER TANK
S7	BOTTOM DOME DETAILS
S8	CYLINDRICAL WALL DETAILS
S9	TOP ROOF DOME & VENTILATION

225 KL CAPACITY INTZE TYPE RCC WATER TOWER, STAZING 18M IN SEISMIC ZONE IV.	DRAWING No. S-1	TITLE **GENERAL OUTLINE DRAWING**

APPENDIX

GENERAL NOTES:-

1. ALL DIMENSIONS ARE IN mm .
2. FOR CONCRETE MIX REFER TABLE-I
3. "Tor" INDICATES TOR STEEL YIELD STRENGTH 415 N/mm². Ø INDICATES PLAIN ROUND MILD STEEL BARS.
4. ALL CONCRETE SHALL BE MACHINE MIXED AND MACHINE VIBRATED.
5. STRUCTURAL DESIGN OF R.C.C. ELEMENT CONFIRM TO IS:456-2000, IS:3370(Pt.II)1965,IS:1893-2002,IS:4326-1976.
6. THE WATER TOWER HAS BEEN DESIGNED FOR SEISMIC FORCE ADOPTING EARTHQUAKE ZONE IV AS PER IS:1893-2002 (PART II)
7. COLD TWISTED HIGH YIELD STRENGTH DEFORMED BARS CONFIRMING TO IS:1786-1985 SHALL BE USED.
8. C.I. D/F PIPE FITTING AND SLUICE VALVE SHALL CONFIRM TO IS:7181-1975, IS:1538-1975, & IS:780-1984 RESPECTIVELY.
9. ALL DIMENSIONS ARE TO BE READ NOT TO BE MEASURED.
10. THE BEARING CAPACITY OF SOIL ADOPTED AS 12.0MT/M².
11. REFER TABLE - II FOR LAP LENGTH & TABLE - III FOR COVERS.
12. LAP LENGTH FOR COLUMNS SHALL BE 40 TIMES DIA OF THE BAR.
13. LAP LENGTH FOR OTHER ELEMENTS (NOT SHOWN IN TABLE-II) OF WATER TOWER SHALL BE 47 TIMES DIA OF THE BAR.
14. REFER TABLE - IV FOR SCHEDULE OF DOORS & WINDOWS.
15. NOT MORE THAN 1/3 OF THE BAR SPLICED AT ANY SECTION IN CYLINDRICAL WALL , TOP DOME, BOTTOM DOME , CONICAL WALL, TOP RING BEAM & BOTTOM RING BEAM OF THE TANK.
16. NOT MORE THAN 50% OF THE BAR IN COLUMNS & BEAMS SHALL BE SPLICED AT ONE SECTION.



HALF FOUNDATION PLAN **HALF TOP PLAN**

TABLE - I (CONCRETE MIX)

ELEMENTS	CONRETE GRADE
ROOF DOME ROOF RING BEAM CYLINDRICAL WALL MIDDLE RING BEAM CONICAL WALL BOTTOM DOME BOTTOM RING BEAM	**M25**
COLUMNS BRACINGS OFFICE ROOM ROOF TIE BEAM FOUNDATION	**M20**

TABLE - II (COVER)

ELEMENTS	COVER	
	INNER FACE	INNER FACE
TOP DOME	30mm	20mm
ROOF RING BEAM CYLINDRICAL WALL MIDDLE RING BEAM CONICAL WALL BOTTOM DOME	40mm	25mm
BOTTOM RING BEAM BRACINGS TIE BEAM	25mm	
COLUMNS	40mm	
OFFICE ROOM ROOF SLAB	20mm	
FOUNDATION	50mm	

TABLE - III (LAP LENGTH)

ELEMENTS	LAP LENGTH
CIRCUMFERENTIAL BAR OF CYLINDRICAL WALL & CONICAL WALL	**1.4 x Ld**
CIRCUMFERENTIAL (HOOP) BAR OF ROOF RING BEAM & MIDDLE RING BEAM	**2 x Ld**
Ld = 47 x DIAMETER OF BAR	

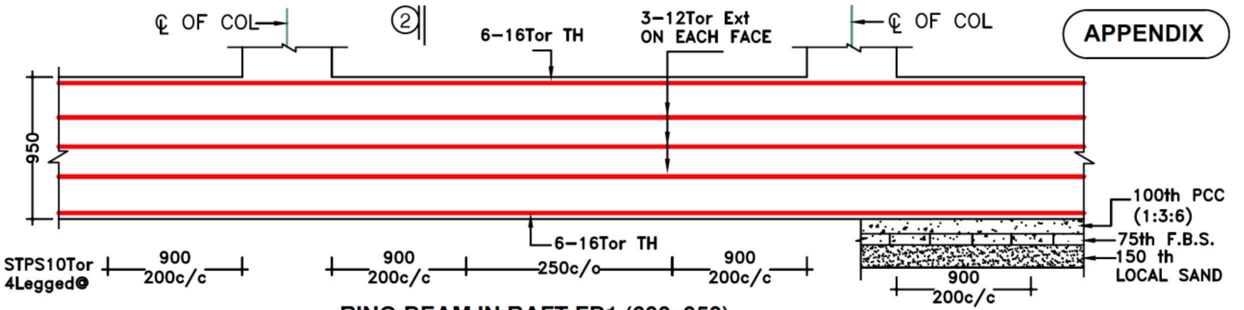
TABLE - IV (OFFICE ROOM OPENINGS)

SCHEDULE OF DOORS & WINDOWS

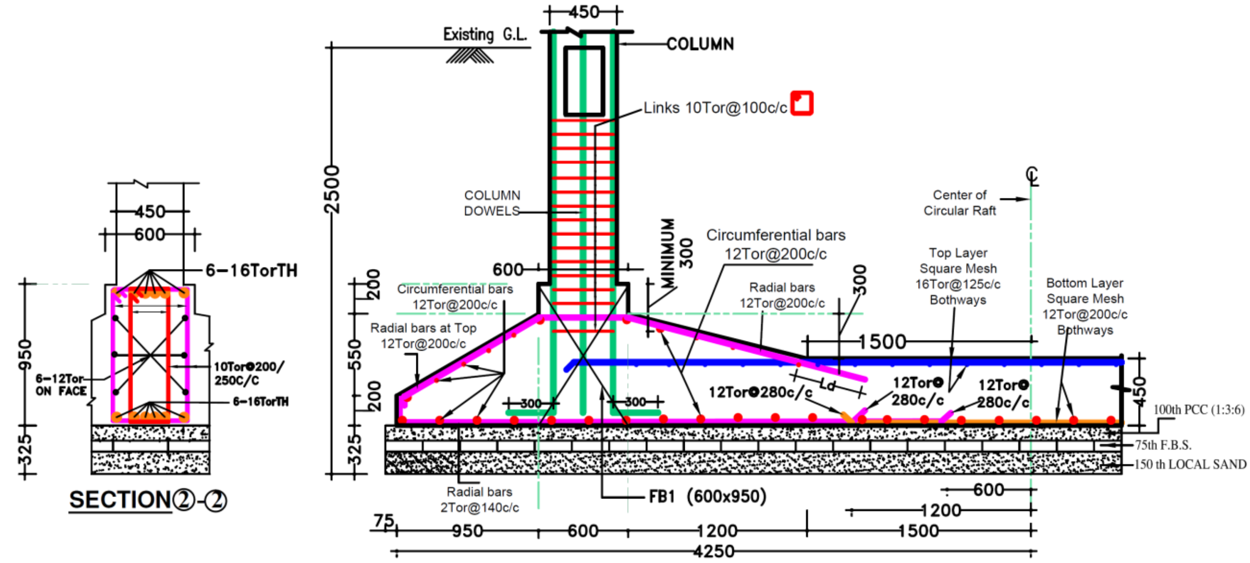
TYPE	WIDTH	HEIGHT
D	1200	2100
D1	750	2100
W	1500	1200
V	450	450

225 KL CAPACITY INTZE TYPE RCC WATER TOWER, STAZING 18M IN SEISMIC ZONE IV.	DRAWING No. S-2	TITLE **GENERAL PLAN AND NOTES**

APPENDIX

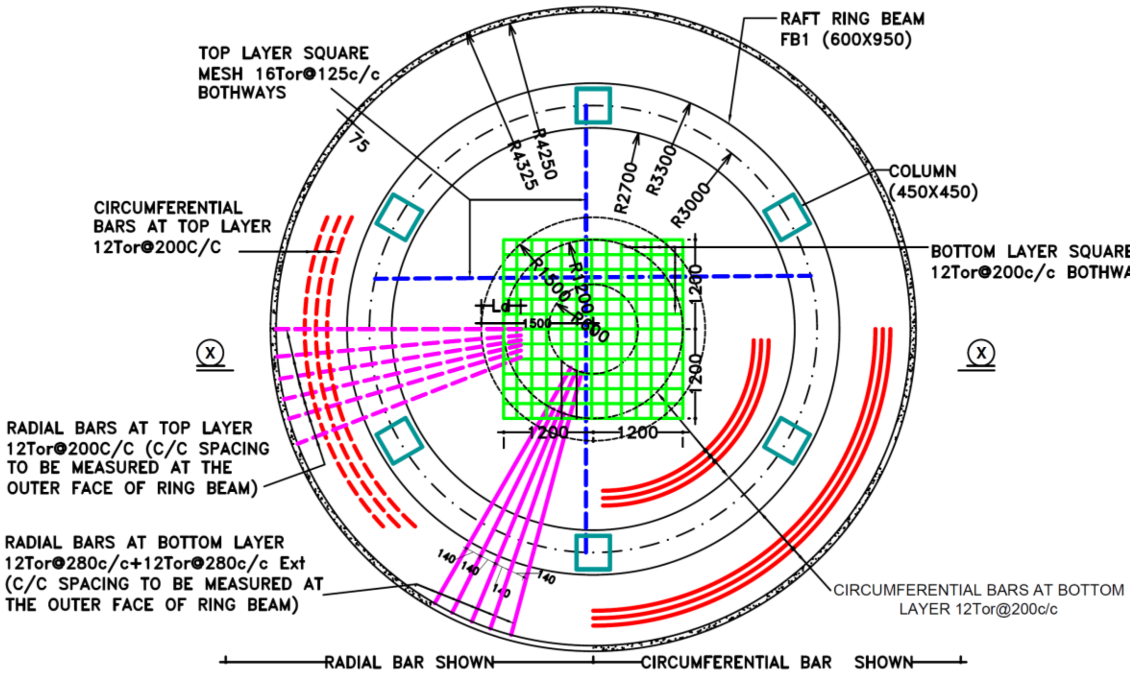


RING BEAM IN RAFT FB1 (600x950)



SECTION②-②

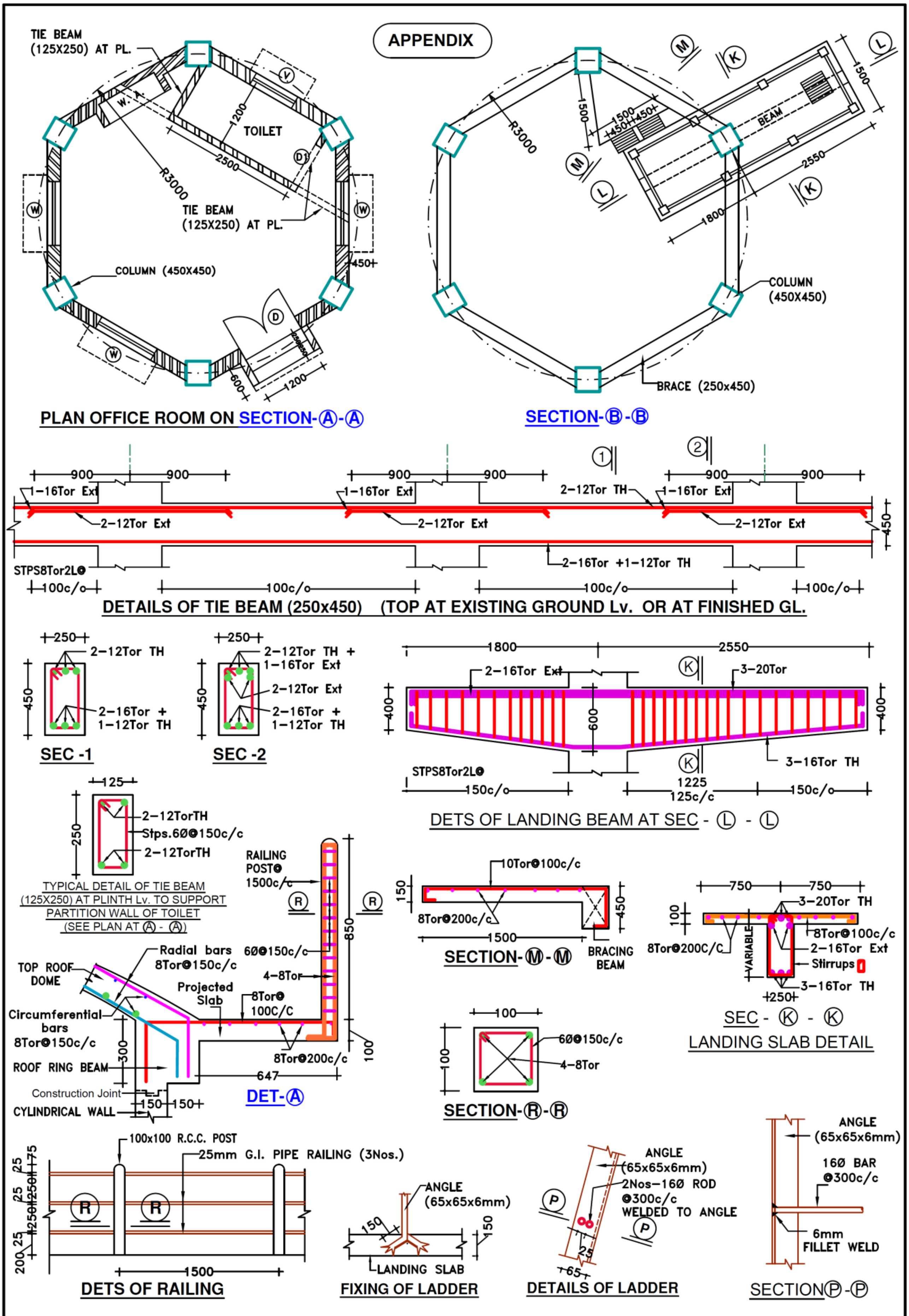
SECTION Ⓧ - Ⓧ



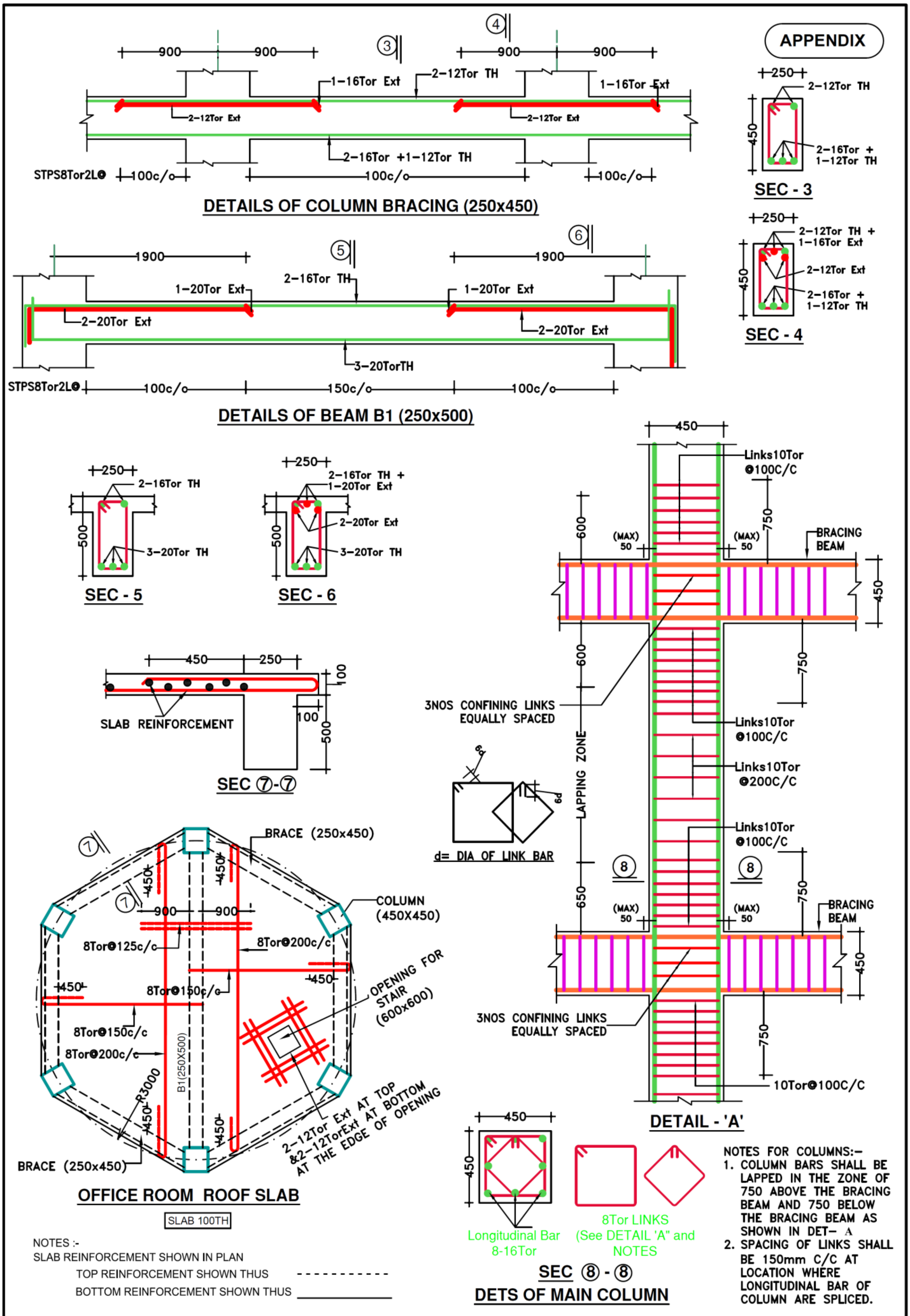
DETAILS OF REINFORCEMENT IN RAFT FOUNDATION PLAN

NOTES :-
RAFT REINFORCEMENT SHOWN IN PLAN
TOP REINFORCEMENT SHOWN THUS - - - - - - - -
BOTTOM REINFORCEMENT SHOWN THUS ________

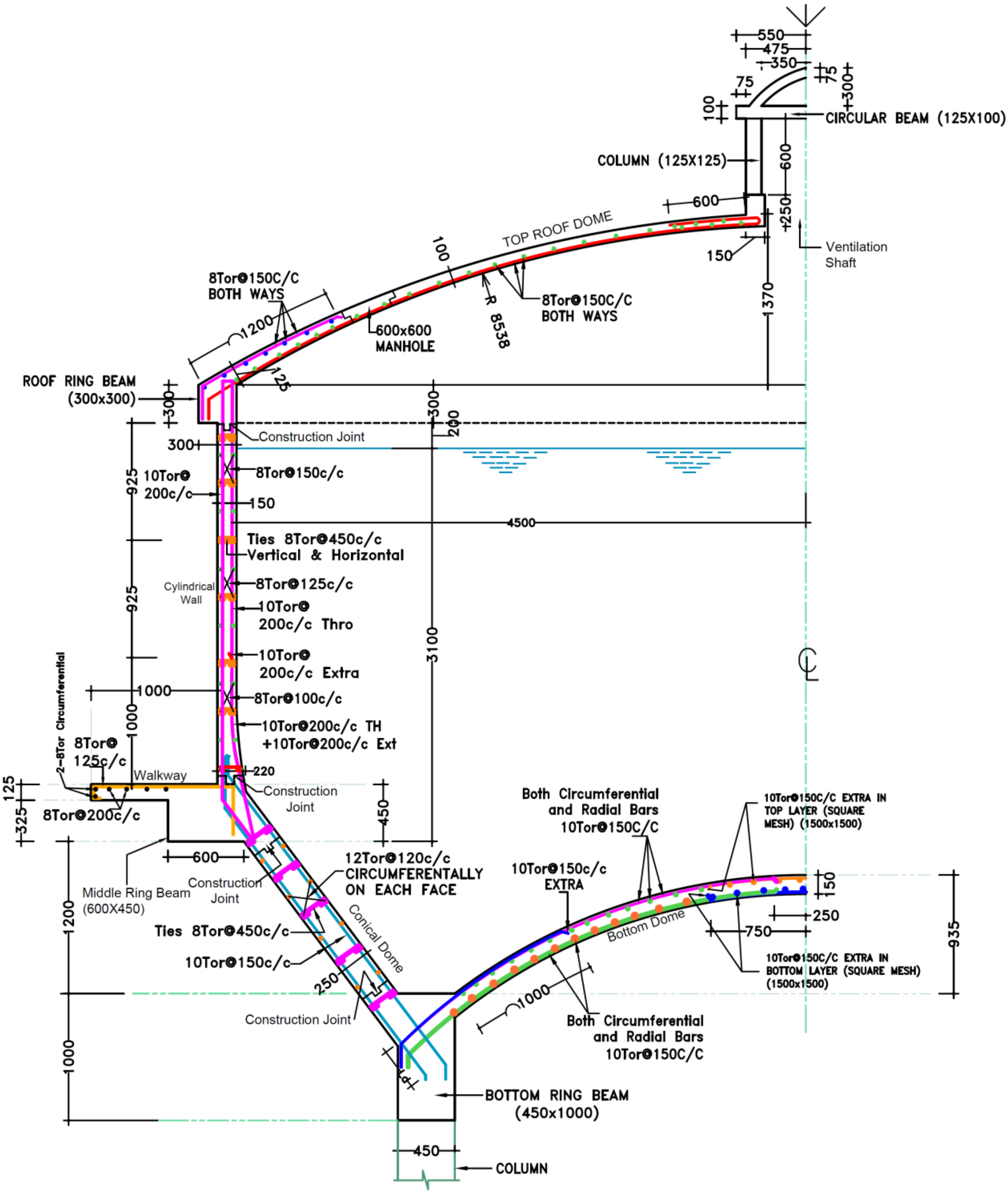
225 KL CAPACITY INTZE TYPE RCC WATER TOWER, STAZING 18M IN SEISMIC ZONE IV.	DRAWING No. S-3	TITLE	FOUNDATION DETAILS



225 KL CAPACITY INTZE TYPE RCC WATER TOWER, STAZING 18M IN SEISMIC ZONE IV.	DRAWING No. S-4	TITLE **TIE BEAM, LANDINGS, LADDER**



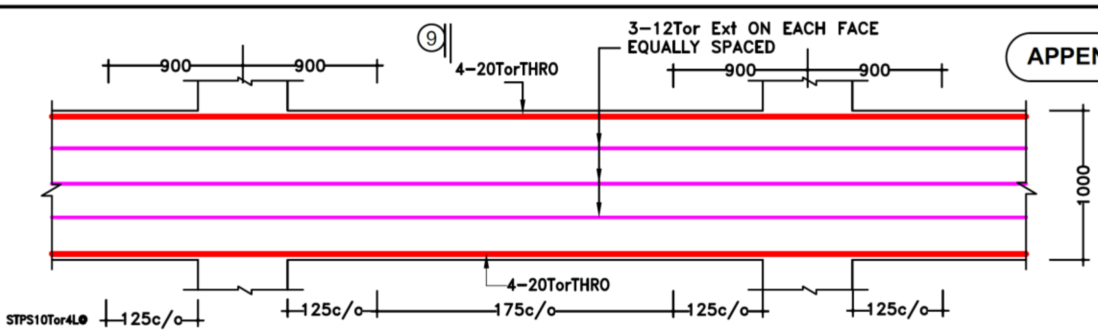
225 KL CAPACITY INTZE TYPE RCC WATER TOWER, STAZING 18M IN SEISMIC ZONE IV.	DRAWING No. S-5	TITLE COLUMN, BRACING AND OFFICE ROOF



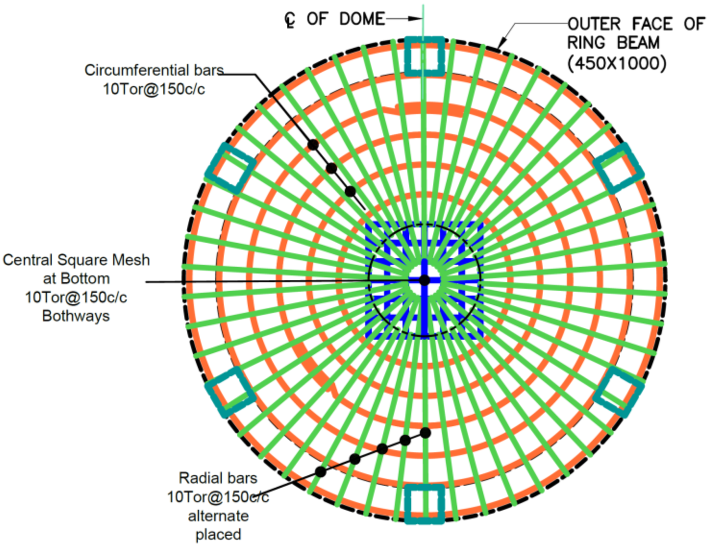
HALF SECTION OF WATER TANK

225 KL CAPACITY INTZE TYPE RCC WATER TOWER, STAZING 18M IN SEISMIC ZONE IV.	DRAWING No. S-6	TITLE HALF SECTION OF WATER TANK

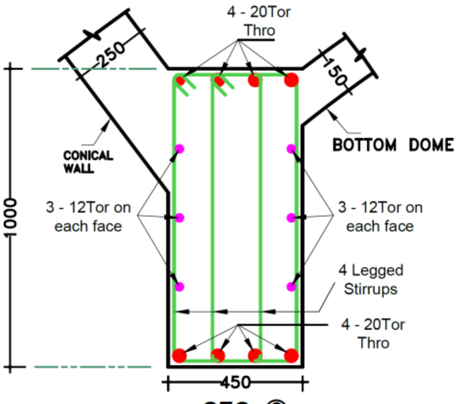
APPENDIX



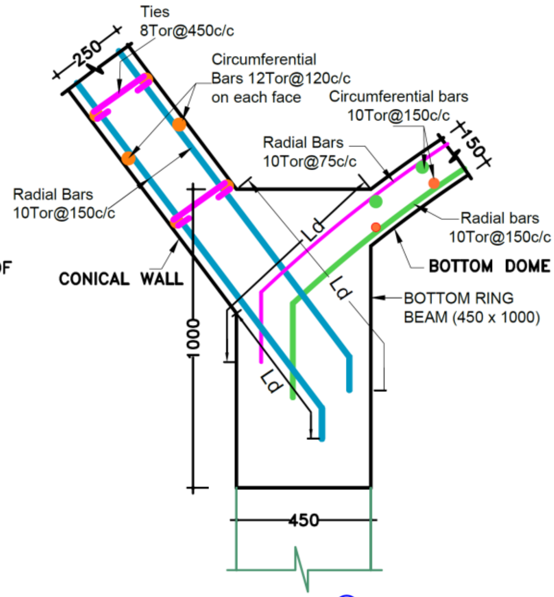
DETAILS OF BOTTOM RING BEAM IN TANK (450x1000)



PLAN
SHOWING ARRANGEMENT OF BOTTOM STEEL IN BOTTOM DOME

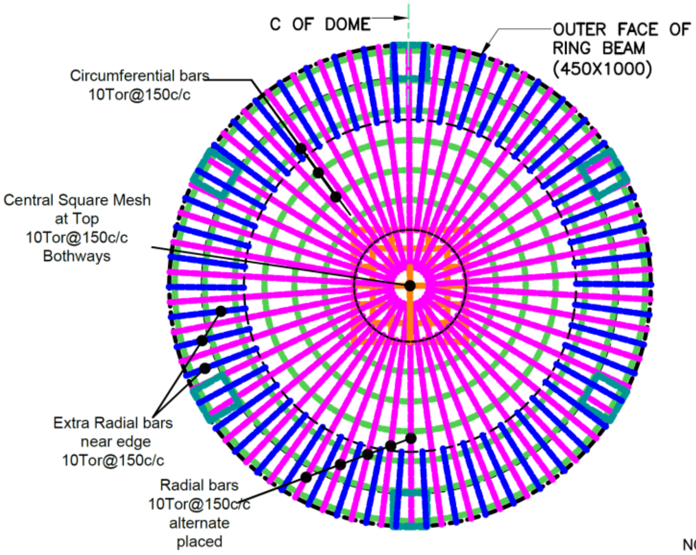


SEC - 9



DETAIL B

JUNCTION OF CONICAL WALL - BOTTOM RING BEAM - BOTTOM DOME

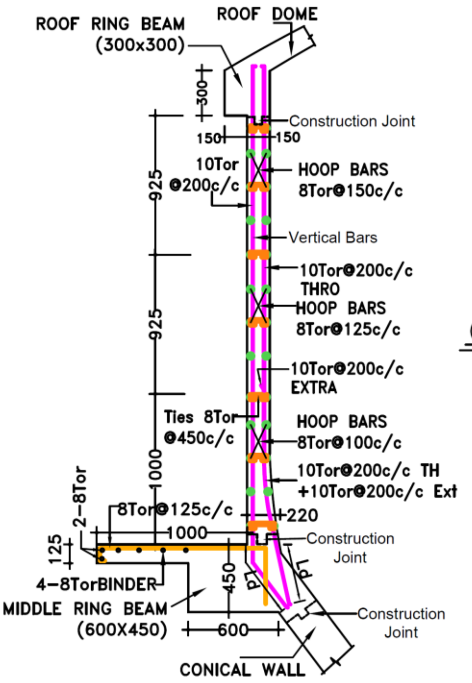


PLAN
SHOWING ARRANGEMENT OF TOP STEEL IN BOTTOM DOME

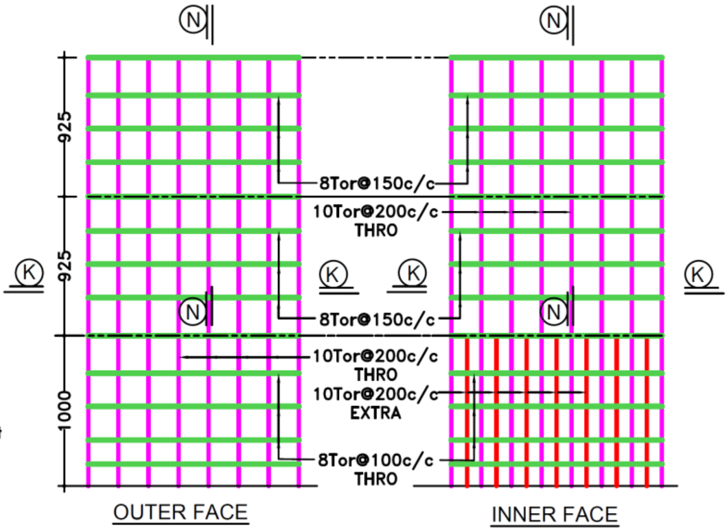
NOTES :-
BOTTOM DOME REINFORCEMENT SHOWN IN PLAN
TOP REINFORCEMENT SHOWN THUS ---------------
BOTTOM REINFORCEMENT SHOWN THUS _______________

225 KL CAPACITY INTZE TYPE RCC WATER TOWER, STAZING 18M IN SEISMIC ZONE IV.	DRAWING No. S-7	TITLE BOTTOM DOME DETAILS

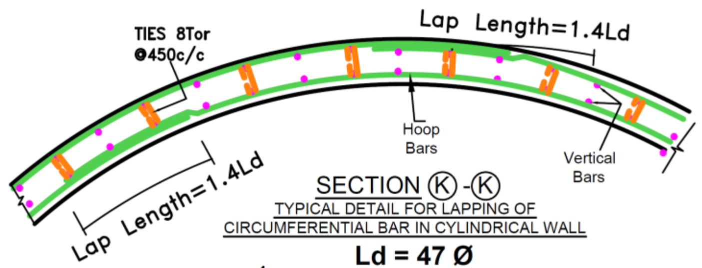
APPENDIX



DETAILS OF CYLINDRICAL WALL



SECTIONAL ELEVATION OF CYLINDRICAL WALL
(SHOWING ARRANGEMENT OF STEEL)

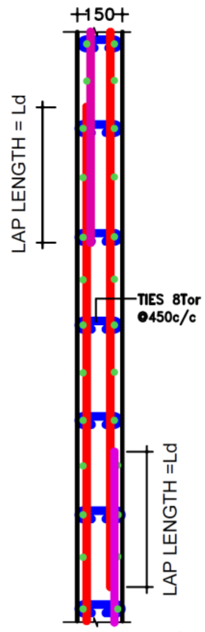


SECTION (K)-(K)

TYPICAL DETAIL FOR LAPPING OF
CIRCUMFERENTIAL BAR IN CYLINDRICAL WALL

Ld = 47 Ø

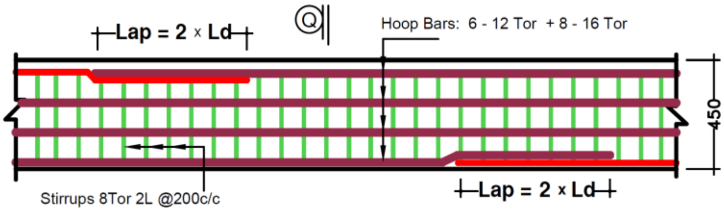
Maximum ⅓rd shall be spliced at any section



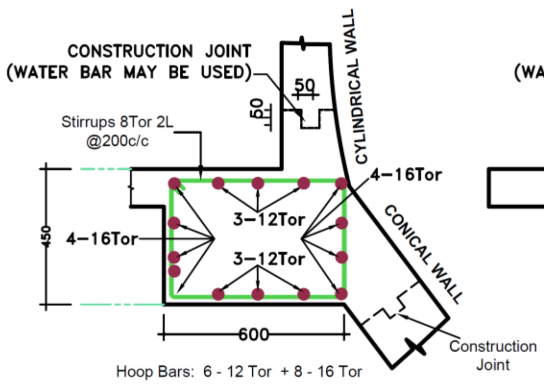
SECTION (N) - (N)

SHOWING LAPPING OF
VERTICAL BAR IN CYLINDRICAL WALL
Ld = 47 TIMES DIA OF BAR

(NOTE: NOT MORE THAN ⅓rd OF THE BAR
SHALL BE SPLICED AT ANY SECTION)

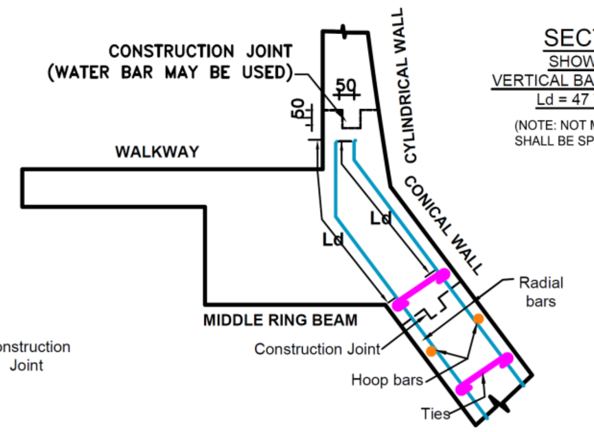


DETAILS OF MIDDLE RING BEAM (600 x 450)



SECTION (Q)

DETAILS OF MIDDLE RING BEAM
(600 x 450)

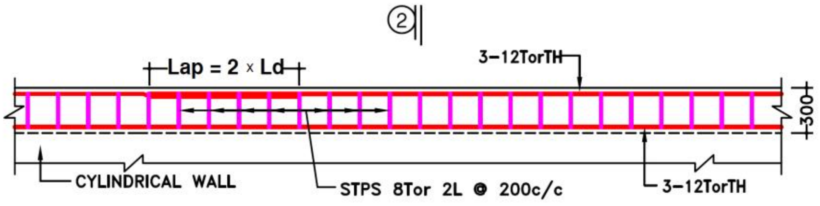


DETAIL -(C)

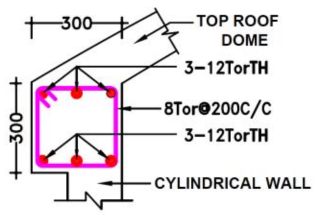
JNCTION OF MIDDLE RING BEAM - CONICAL WALL

225 KL CAPACITY INTZE TYPE RCC WATER TOWER, STAZING 18M IN SEISMIC ZONE IV.	DRAWING No. S-8	TITLE **CYLINDRICAL WALL DETAILS**

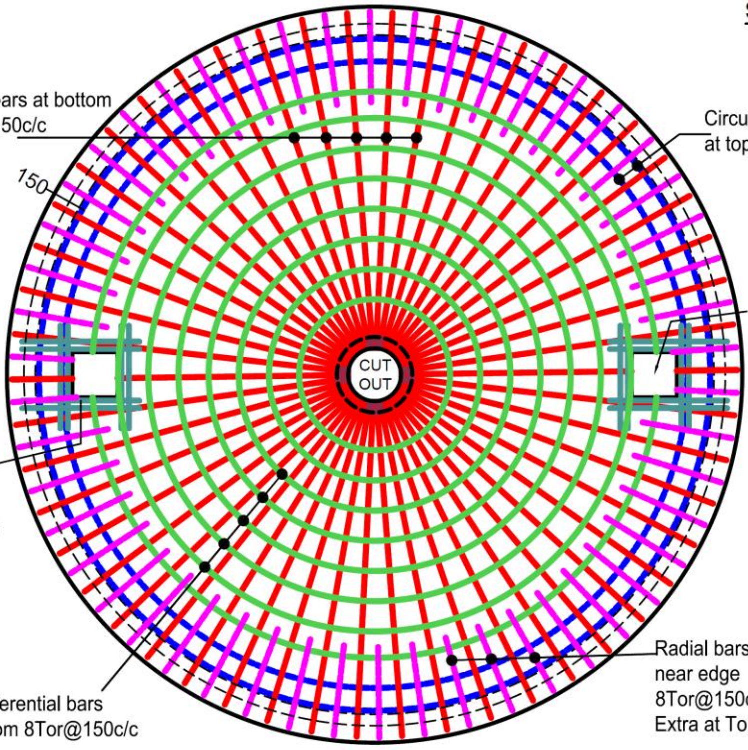
APPENDIX



DETAILS OF ROOF RING BEAM(300x300)



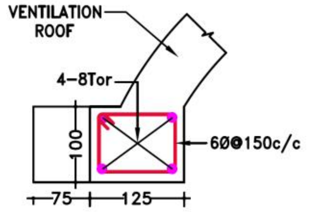
SEC -2



PLAN

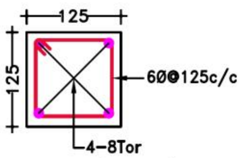
SHOWING ARRANGEMENT OF REINFORCEMENT TOP ROOF DOME

NOTES :-
TOP ROOF DOME REINFORCEMENT SHOWN IN PLAN
TOP REINFORCEMENT SHOWN THUS ---------------
BOTTOM REINFORCEMENT SHOWN THUS ―――――――



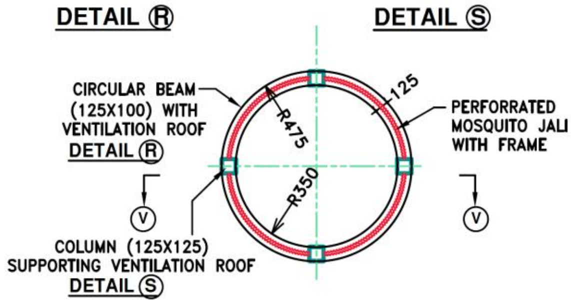
CIRCULAR BEAM (125X100)
WITH VENTILATION ROOF

DETAIL Ⓡ



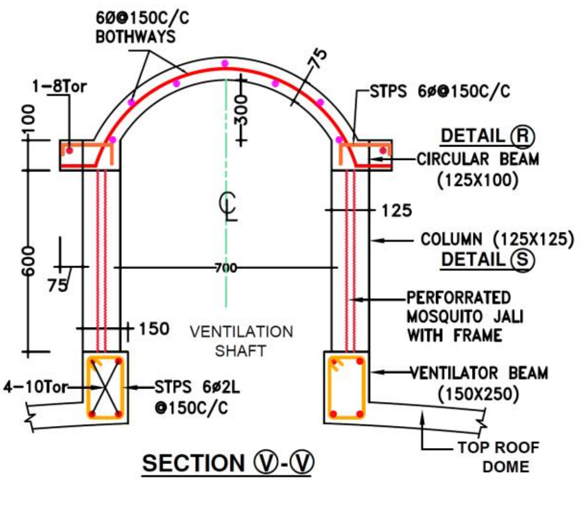
COLUMN (125X125)
SUPPORTING VENTILATION ROOF

DETAIL Ⓢ



PLAN SHOWING VENTILATION DUCT ON

SECTION-Ⓒ-Ⓒ



SECTION Ⓥ-Ⓥ

225 KL CAPACITY INTZE TYPE RCC WATER TOWER, STAZING 18M IN SEISMIC ZONE IV.	DRAWING No. S-9	TITLE TOP ROOF DOME & VENTILATION