COMPARATIVE STUDY OF ANNULAR RAFT FOUNDATION & SOLID CIRCULAR RAFT FOUNDATION FOR DIFFERENT DIAMETER OF WATER TANK

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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. Water is the prime necessity for survival. Liquid storage tanks are used extensively by municipalities and industries for storing water, inflammable liquids and other chemicals. Thus Water tanks are very important for public utility and for industrial structure.*

This study attempted the achievement of some measure of the best practical solution, that is, the optimum design of elevated reinforced concrete water tanks for a specified performance in which the major objectives are covers the degree of effectiveness of the geometric shapes for the functional requirement, to assess the possible cost implications of each of the choices and to eventually generate Microsoft Excel Spreadsheet Design Programs as a tool for the rather quick assessment of various tank capacities. The main aim of this dissertation is to done the foundation analysis of circular water tank and cost comparison for different type of foundation required like annular raft and solid circular type raft & parametric study about time period, hydrodynamic pressure, and seismic pressure respective to H/D ratio.

Key Words: **circular water tank, raft foundation soft soil & medium soil, Seismic pressure, Hydrodynamic pressure, Time period, Staad pro V8i.**

1. INTRODUCTION

Human civilization has been established long ago. For its development and progress “Civil Engineering” has come into existence, then after there is tremendous continuous progress. In our day-to-day life we see many structures around us, which are the gift of Civil Engineering to human society. There are three basic needs of human namely food, clothes and shelter. The civil engineering satisfy shelter need directly. Further, for the progress of any country good infra-structural facility is required, which is provided by civil engineering. Transportation and Communication facilities plays very important role in improving country’s economic growth rate. There are many special civil engineering structures apart from buildings for example Highways, Bridges, Tunnels, Dams, High-rise Towers, Historical Monuments, Cooling Towers, Nuclear power plants and many more. Elevated Water Tank is also one of them. Reservoir is a common term applied to liquid storage structure and it can be below or above the ground level. Reservoirs below the ground level are normally built to store large quantities of water whereas those of overhead type are built for direct distribution by gravity flow and are usually of smaller capacity. Analysis and design of such tanks are independent of chemical nature of product. In order to avoid leakage and to provide higher strength concrete of grade M25 and above is recommended for liquid retaining structures.

Present study primarily focused on To study the effect of a number of column, batter of column on performance of staging. In addition to the vertical loads is also subjected to horizontal forces. Both these forces produce axial tension or compression in columns as well as moment and shear force on column section. Here attempt is made to find out optimum diameter of staging based on 'No-Tension' in column. Lateral load also affect stability of foundation. Here attempt is made to find out optimum diameter of annular raft footing and solid circular raft footing based on 'No-Tension' in foundation and fulfil all stability requirement of foundation including 'No Uplift. comparative study like hydrodynamic pressure, seismic pressure, time period with respect to H/D ratio of different diameter and cost analysis by using annular raft and circular raft foundation for soft soil and medium soil.

2. METHODOLOGY

In the present paper consider different diameter of container resting on bottom slab & circular staging on periphery maintain H/D ration in 0.02 increment, where H = water height & D = diameter of tank. Seismic analysis of staging is considered as per IS code 1893 (II) & concrete design by using staad pro v8i.design of top slab & bottom slab by using staad pro V8i plate model. Design of annular raft & circular raft as per code (IS 11089 -1984) & also referred book punamia & Jain.

Here hydrodynamic effect is considered by dividing water, in the container, into two different masses namely impulsive and convective. When the tank containing liquid with free surface is subjected to horizontal earthquake ground motion, tank wall and liquid are subjected to horizontal acceleration. The liquid in the lower region behaves like a mass that is rigidly connected to the tank wall. This mass is termed as impulsive liquid mass, which, accelerates along with the wall and induces impulsive hydrodynamic pressure on tank wall and on base. The liquid mass in the upper region of tank undergoes sloshing motion. This mass is termed as convective liquid mass and exerts convective hydrodynamic pressure on wall and base. For representing these two masses and in order to include the effect of their hydrodynamic pressure in analysis, spring mass model is adopted for ground-supported tanks and two-mass model for elevated tanks. In spring mass model convective mass (mc) is attached to the tank wall by the spring having stiffness Kc, whereas impulsive mass (mi) is rigidly attached to tank wall For elevated tanks two-mass model is considered, which consists of two degrees of freedom system. Spring mass model can also be applied on elevated tanks, but two-mass model idealization is closer to reality. The spring mass model for elevated tank is as shown in fig.2.1.

The response of the two-degree of freedom system can be obtained by elementary structural dynamics. However, for most of elevated tanks it is observed that both the time periods are well separated. Hence, the two-mass idealization can be treated as two uncoupled single degree of freedom system as shown in fig.2.1. The mass (ms) shown in fig.2.1 is the structural mass and shall comprise of mass of tank container and one-third mass of staging as staging will acts like a lateral spring. Mass of container comprises of mass of roof slab, container wall, gallery if any, floor slab, floor beams, ring beam, circular girder, and domes if provided.

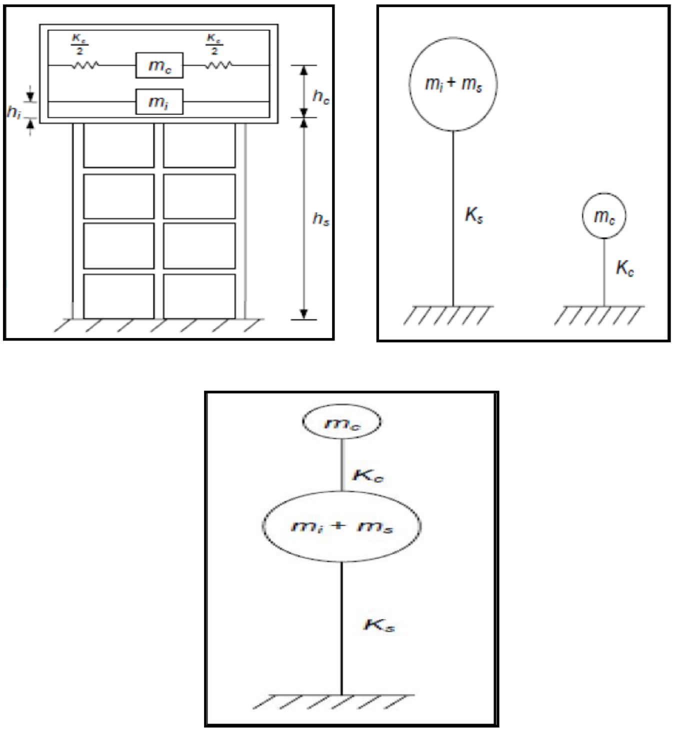


Figure – 2.1 Two Mass Idealization Model

Where,

mi = Impulsive mass

mc = Convective mass

ms = Mass of container of elevated tank and one third of staging

Kc = spring stiffness of convective mode

Ks = Lateral stiffness of tank staging

hc = Height at which resultant of convective pressure on wall is located from the bottom of tank wall

hi = Height at which resultant of impulsive hydrodynamic pressure on wall is located from the bottom of tank wall

hi* = Height at which resultant of impulsive hydrodynamic pressure on wall and base is located from the bottom of tank wall

hc* = Height at which resultant of convective pressure on wall and base is located from the bottom of tank wall

2.1 GENERAL CONSIDERATION

Different capacity of circular water tank selected for study purpose. Twelve models are prepare respective soft soil and medium soil where SBC considered 100 KN/m^2 & 200 KN/m^2.Primary data considered for design mentioned below.

Table -1: Material and permissible stresses considered for design.

Grade of concrete	M30	MPa
Grade of reinforcement	500	MPa
Density of concrete	25	KN/m^3
Density of water	10	KN/m^3
Modulus of elasticity of concrete (Ec)	27386	MPa
Modulus of elasticity of steel (Es)	200000	MPa
Permissible tensile stresses in concrete	434.783	N/mm^2
Permissible stresses in steel	3.834	N/mm^2

Table -2: Location and features.

Seismic Zone	III
z	0.16
Importance Factor	1.5
Wind speed (m/s)	39

Terrain Category	3
Class	A
Type of Soil	Soft & Medium soil
Response Red. Factor	2.5
K1	1.06
K2	1

2.3 ANALYSIS AND CALCULATIONS

The design of overhead circular Water Tank is carried out using the Staad pro V8i. The design is carried out as per relevant analysis procedures combined with Indian Standard Codes of Practices. The water tank top & bottom slab are designed by Limit stress method. The foundation forces at the level of safe bearing capacity are also evaluated and then manually solid circular raft and annular raft foundation design can be done for diff diameter. The software also gives the shape description of the tank and keeping various parameters, one can change the governing parameter to get the optimum result and safe design with economy.

For analysis purpose considered different type of diameter respective to no of column. In these research maintain H/D ratio. Calculate weight of each component like container in empty & full condition, top slab, bottom slab, staging etc.

Evolution of seismic analysis and design of column & bracing used by staad pro V8i. Here 50kl water tank model shown below.

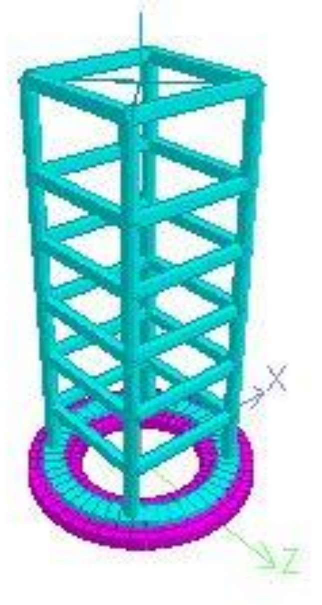


Figure – 2.2 Model geometry of staging part and plate model with annular raft in staad pro V8i.

Size of component considered in design and analysis of different diameter of circular water tank like diameter of container, column size, no of bracing and its size, parameter and size of annular raft and circular raft are mentioned below table – 3.

Table -3: Size and component adopted for different diameter of container, staging, bracing, annular raft and circular raft.

Component	Parameter	Capacity (lit.)
		50 KL
CONTAINER	Dia of tank inner (m)	6
	Thk of wall (m)	0.2
	Height of water (m)	1.90
	Free board (m)	0.4
	total height (m)	2.30
	H/D ratio	0.32
TOP SLAB & BOTTOM SLAB	Top Slab Thk (m)	0.175
	Dia of top slab (m)	6.4
	Bottom Slab Thk (m)	0.275
	Dia of bottom slab (m)	8.8
STAGING	No of staging	4
	Staging height (m)	12
	Staging dia (m)	0.45
	Degree	90
BRACING	No of Bracing	5
	Size of bracing	0.3 x 0.4
	Length of bracing	4.384
	SBC 100 KN/m2	
ANNULAR RAFT	Inner Dia (m)	4.4
	outer dia (m)	8
	Thk of Raft (m)	0.400 to 0.250
CIRCULAR RAFT	Inner Dia (m)	0
	outer dia (m)	9.3
	Thk of Raft (m)	0.250 to 0.150
	SBC 200 KN/m2	
ANNULAR RAFT	Inner Dia (m)	5.2
	outer dia (m)	7.2
	Thk of Raft (m)	0.300 to 0.150
CIRCULAR RAFT	Inner Dia (m)	0
	outer dia (m)	9.3
	Thk of Raft (m)	0.250 to 0.150

Component	Parameter	Capacity (lit.)
		130 KL
CONTAINER	Dia of tank inner (m)	8
	Thk of wall (m)	0.2
	Height of water (m)	2.75
	Free board (m)	0.45
	total height (m)	3.20
	H/D ratio	0.34
TOP SLAB & BOTTOM SLAB	Top Slab Thk (m)	0.2
	Dia of top slab (m)	8.4
	Bottom Slab Thk (m)	0.275
	Dia of bottom slab (m)	10.8
STAGING	No of staging	6
	Staging height (m)	12
	Staging dia (m)	0.5
	Degree	60
BRACING	No of Bracing	5
	Size of bracing	0.3 x 0.4
	Length of bracing	4.1
	SBC 100 KN/m2	
ANNULAR RAFT	Inner Dia (m)	5.2
	outer dia (m)	11.2
	Thk of Raft (m)	0.500 to 0.350
CIRCULAR RAFT	Inner Dia (m)	0
	outer dia (m)	12.3
	Thk of Raft (m)	0.350 to 0.250
	SBC 200 KN/m2	
ANNULAR RAFT	Inner Dia (m)	6.7
	outer dia (m)	9.7
	Thk of Raft (m)	0.450 to 0.200
CIRCULAR RAFT	Inner Dia (m)	0
	outer dia (m)	12.3
	Thk of Raft (m)	0.350 to 0.250

Component	Parameter	Capacity (lit.)
		270 KL
CONTAINER	Dia of tank inner (m)	10
	Thk of wall (m)	0.2
	Height of water (m)	3.60
	Free board (m)	0.5
	total height (m)	4.10
	H/D ratio	0.36
TOP SLAB & BOTTOM SLAB	Top Slab Thk (m)	0.25
	Dia of top slab (m)	10.4
	Bottom Slab Thk (m)	0.3
	Dia of bottom slab (m)	12.8
STAGING	No of staging	8
	Staging height (m)	12
	Staging dia (m)	0.5
	Degree	45
BRACING	No of Bracing	5
	Size of bracing	0.3 x 0.4
	Length of bracing	3.903
	SBC 100 KN/m2	
ANNULAR RAFT	Inner Dia (m)	6.2
	outer dia (m)	14.2
	Thk of Raft (m)	0.500 to 0.350
CIRCULAR RAFT	Inner Dia (m)	0
	outer dia (m)	15.3
	Thk of Raft (m)	0.350 to 0.250
	SBC 200 KN/m2	
ANNULAR RAFT	Inner Dia (m)	8.2
	outer dia (m)	12.2
	Thk of Raft (m)	0.500 to 0.300
CIRCULAR RAFT	Inner Dia (m)	0
	outer dia (m)	15.3
	Thk of Raft (m)	0.350 to 0.250

Component	Parameter	Capacity (lit.)
		485 KL
CONTAINER	Dia of tank inner (m)	12
	Thk of wall (m)	0.2
	Height of water (m)	4.55
	Free board (m)	0.575
	total height (m)	5.13
	H/D ratio	0.38
TOP SLAB & BOTTOM SLAB	Top Slab Thk (m)	0.3
	Dia of top slab (m)	12.4
	Bottom Slab Thk (m)	0.4
	Dia of bottom slab (m)	14.8
STAGING	No of staging	10
	Staging height (m)	12
	Staging dia (m)	0.5
	Degree	36
BRACING	No of Bracing	5
	Size of bracing	0.3 x 0.4
	Length of bracing	3.77
	SBC 100 KN/m2	
ANNULAR RAFT	Inner Dia (m)	6
	outer dia (m)	18.4
	Thk of Raft (m)	0.750 to 0.500
CIRCULAR RAFT	Inner Dia (m)	0
	outer dia (m)	18.4
	Thk of Raft (m)	0.550 to 0.450
	SBC 200 KN/m2	
ANNULAR RAFT	Inner Dia (m)	9.7
	outer dia (m)	14.7
	Thk of Raft (m)	0.6 to 0.4
CIRCULAR RAFT	Inner Dia (m)	0
	outer dia (m)	18.4
	Thk of Raft (m)	0.550 to 0.400

Component	Parameter	Capacity (lit.)
		830 KL
CONTAINER	Dia of tank inner (m)	14
	Thk of wall (m)	0.25
	Height of water (m)	5.60
	Free board (m)	0.5
	total height (m)	6.10
	H/D ratio	0.4
SL AB & BO TT OM	Top Slab Thk (m)	0.35
	Dia of top slab (m)	14.5
	Bottom Slab Thk (m)	0.45
	Dia of bottom slab (m)	16.9
STAGING	No of staging	12
	Staging height (m)	12
	Staging dia (m)	0.5
	Degree	30
BRACING	No of Bracing	5
	Size of bracing	0.3 x 0.4
	Length of bracing	3.688
	SBC 100 KN/m2	
ANNULAR RAFT	Inner Dia (m)	5.95
	outer dia (m)	22.55
	Thk of Raft (m)	0.850 to 0.700
CIRCULAR RAFT	Inner Dia (m)	0
	outer dia (m)	21.4
	Thk of Raft (m)	0.650 to 0.450
	SBC 200 KN/m2	
ANNULAR RAFT	Inner Dia (m)	10.75
	outer dia (m)	17.75
	Thk of Raft (m)	0.700 to 0.500
CIRCULAR RAFT	Inner Dia (m)	0
	outer dia (m)	21.4
	Thk of Raft (m)	0.650 to 0.450

Component	Parameter	Capacity (lit.)
		1275 KL
CONTAINER	Dia of tank inner (m)	16
	Thk of wall (m)	0.3
	Height of water (m)	6.70
	Free board (m)	0.6
	total height (m)	7.30
	H/D ratio	0.42
TOP SLAB & BOTTOM SLAB	Top Slab Thk (m)	0.45
	Dia of top slab (m)	16.6
	Bottom Slab Thk (m)	0.55
	Dia of bottom slab (m)	19
STAGING	No of staging	14
	Staging height (m)	12
	Staging dia (m)	0.55
	Degree	25.71
BRACI NG	No of Bracing	5
	Size of bracing	0.35 x 0.45

	Length of bracing	3.627
	SBC 100 KN/m2	
ANNULAR RAFT	Inner Dia (m)	4.3
	outer dia (m)	28.3
	Thk of Raft (m)	1.200 to 0.750
CIRCULAR RAFT	Inner Dia (m)	0
	outer dia (m)	24.5
	Thk of Raft (m)	0.950 to 0.650
	SBC 200 KN/m2	
ANNULAR RAFT	Inner Dia (m)	11.3
	outer dia (m)	21.3
	Thk of Raft (m)	1.000 to 0.650
CIRCULAR RAFT	Inner Dia (m)	0
	outer dia (m)	24.5
	Thk of Raft (m)	0.900 to 0.650

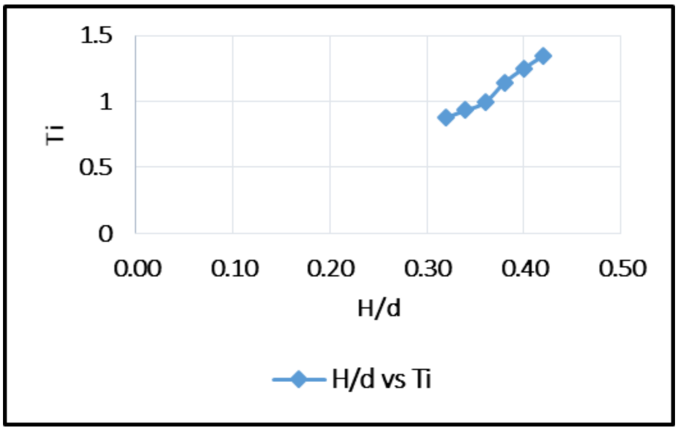
3. RESULTS AND ANALYSIS

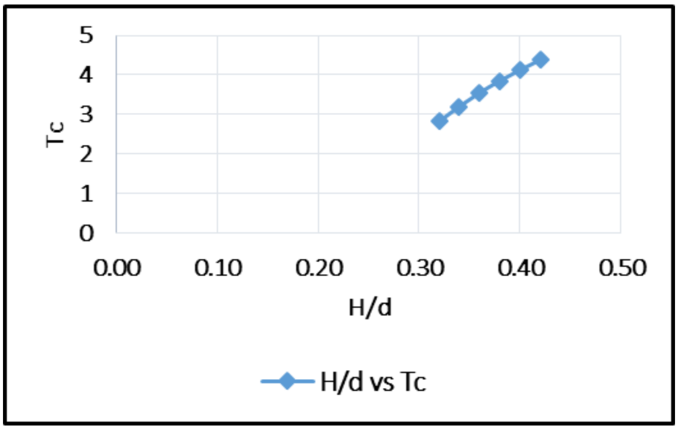
After study and analysis of different diameter of water tank respectively annular raft foundation and circular raft foundation perform following result respectively each parameter like time period, base moment, base shear, hydrodynamic pressure, seismic pressure and analysis of cost estimation.

Parametric study and result for time period of impulsive mode and convective mode.

CASE – I: Tank in full condition:-

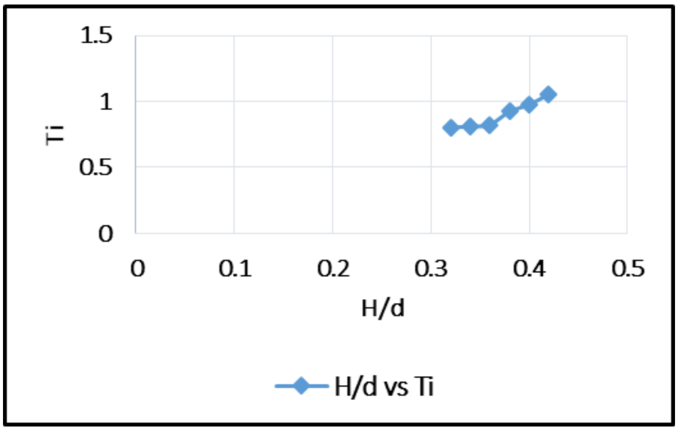
Capacity	H/D	Ti	TC
50 KL	0.32	0.878	2.823
130 KL	0.34	0.933	3.203
270 KL	0.36	0.992	3.55
485 KL	0.38	1.143	3.851
830 KL	0.40	1.252	4.125
1275 KL	0.42	1.346	4.379





CASE – II: Tank in empty condition:-

Capacity	H/D	Ti	TC
50 KL	0.32	0.803	NA
130 KL	0.34	0.81	NA
270 KL	0.36	0.825	NA
485 KL	0.38	0.924	NA
830 KL	0.4	0.977	NA
1275 KL	0.42	1.056	NA



Parametric study and result of base shear and base moment for soft soil (SBC = 100 KN/m^2).

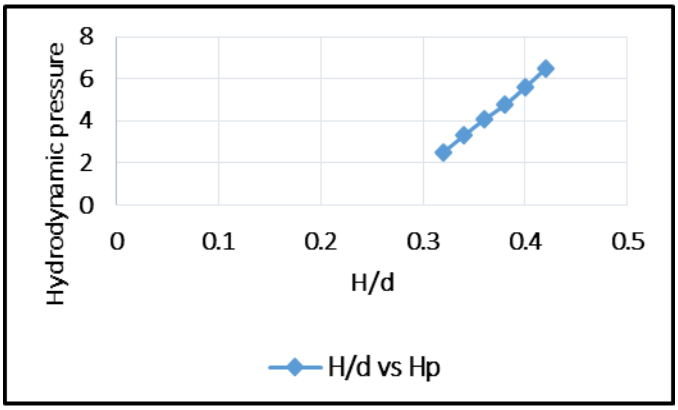
	Tank in full condition		Tank in Empty condition	
H/D	Base shear	Base moment	Base shear	Base moment
0.32	109.236	32.768	98.366	12.714
0.34	189.112	112.452	161.524	13.186
0.36	304.704	281.232	247.322	15.074
0.38	454.604	562.974	354.72	15.143
0.4	643.636	1051.214	486.145	15.417
0.42	981.161	1804.381	751.964	15.604

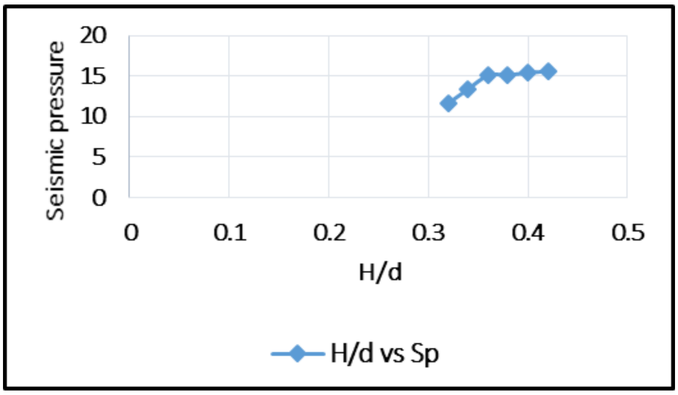
Parametric study and result of base shear and base moment for soft soil (SBC = 200 KN/m²).

	Tank in full condition		Tank in Empty condition	
H/D	Base shear	Base moment	Base shear	Base moment
0.32	89.062	26.714	79.677	12.714
0.34	153.955	91.53	132.156	13.186
0.36	248.404	229.151	201.427	13.667
0.38	371.23	459.894	289.484	14.061
0.4	529.242	857.143	397.216	14.719
0.42	807.895	1473.578	613.444	15.241

Parametric study and behavior of hydrodynamic pressure and seismic pressure respectively H/D ratio in soft soil (SBC = 100 KN/m²).

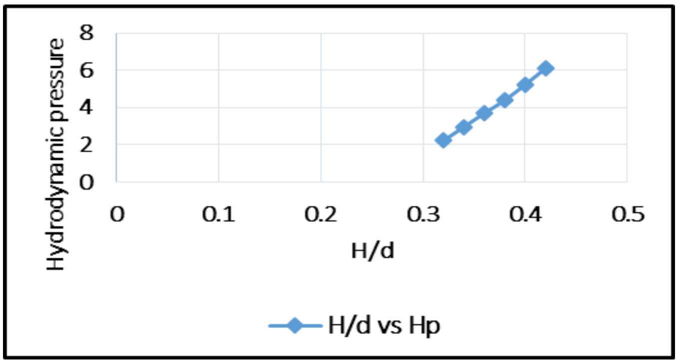
Capacity	H/D	Hydrodynamic pressure	Seismic pressure
50 KL	0.32	2.514	11.641
130 KL	0.34	3.302	13.407
270 KL	0.36	4.068	15.074
485 KL	0.38	4.753	15.143
830 KL	0.4	5.595	15.417
1275 KL	0.42	6.491	15.604

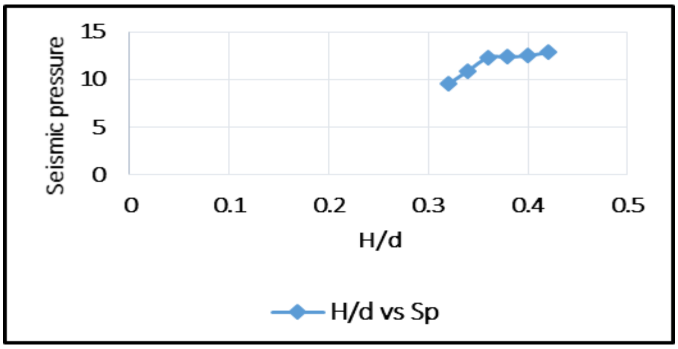




Parametric study and behavior of hydrodynamic pressure and seismic pressure respectively H/D ratio in soft soil (SBC = 200 KN/m²).

Capacity	H/D	Hydrodynamic pressure	Seismic pressure
50 KL	0.32	2.225	9.503
130 KL	0.34	2.966	10.916
270 KL	0.36	3.699	12.298
485 KL	0.38	4.395	12.357
830 KL	0.4	5.235	12.495
1275 KL	0.42	6.12	12.828





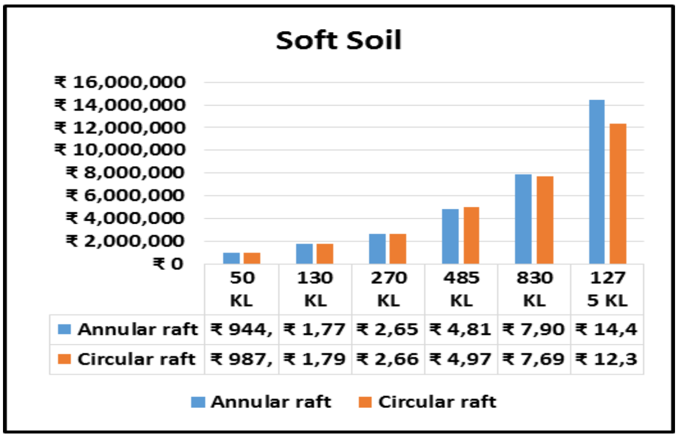
3.1 COST ANALYSIS

After safe design and analysis calculate concrete quantity and steel quantity of each part like container, top slab, bottom slab, staging part, annular raft, and circular raft under guide line schedule of rate (SOR) – 2014-15 (section –

C),Page 43 to 53.*(GUJARAT WATER SUPPLY AND SEWERAGE BOARD).*

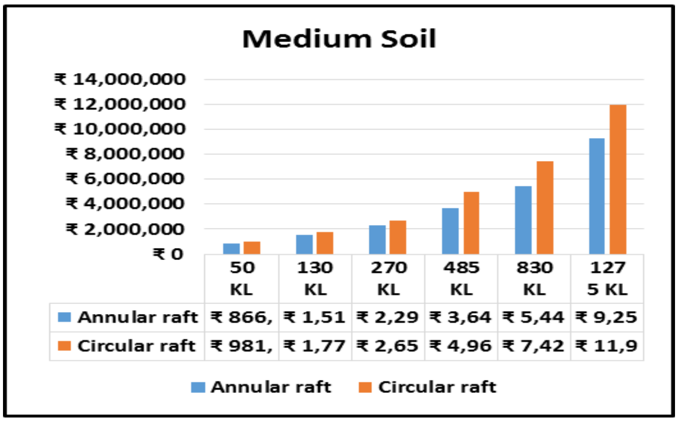
Cost comparison of annular raft and circular raft for 100 KN/m² (Soft soil).

Capacity	Annular raft	Circular raft
50 KL	₹ 944,870	₹ 987,678
130 KL	₹ 1,776,154	₹ 1,798,172
270 KL	₹ 2,659,357	₹ 2,666,777
485 KL	₹ 4,817,682	₹ 4,972,296
830 KL	₹ 7,907,680	₹ 7,698,238
1275 KL	₹ 14,455,964	₹ 12,326,264



Cost comparison of annular raft and circular raft for 200 KN/m² (Medium soil).

Capacity	Annular raft	Circular raft
50 KL	₹ 866,031	₹ 981,186
130 KL	₹ 1,513,452	₹ 1,775,405
270 KL	₹ 2,292,868	₹ 2,650,888
485 KL	₹ 3,645,373	₹ 4,969,293
830 KL	₹ 5,446,555	₹ 7,426,623
1275 KL	₹ 9,250,402	₹ 11,935,489



4. CONCLUSIONS

and study after safe design of circular water tank following conclusion drawn mentioned below respective to annular raft & solid circular raft in soft soil And medium soil and comparative study of different parameter.

1. As per results and analysis H/D ratio vs time period in convective mod and impulsive mode in empty and full condition linearly increase as shown in graph.

2. As per results and analysis H/D ratio vs hydrodynamic pressure and seismic pressure in soft soil (100 KN/m²) and Medium soil (200 KN/m²) and full condition linearly increase as shown in graph.

3. When diameter increase and number of column increase the different movement shown in soft and medium soil like in soft soil (100 KN/m²) up to 12 m diameter of 485 kl capacity of tank resting on 10 circular column annular raft is safe and economical in cost more than solid circular raft and in design more than 12 m diameter solid circular raft is safe and economical in cost shown in graph.

4. In medium soil (200 KN/m²) diameter increase annular raft is safe and economical in cost more than solid circular raft shown in graph.

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