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Response Spectrum Analysis of Elevated Circular and Intze Water Tank

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Abstract - *Elevated water tanks are used for storing water in public water distribution system. These water tanks are most important structures in regions of high seismic intensity, the failure of these water tanks may cause serious hazards for people due to shortage of water or difficulty in putting out fire during earthquake. Earthquake causes various types of failures such as failure of supporting soil and damage to supporting staging. In this present study twelve number of elevated circular and Intze water tanks of 2L litres capacity supported on RCC frame staging under earthquake loads as per draft code Part II of IS 1893: 2002 are considered out of which six models are Intze type and six models of circular type. Response spectrum analysis for elevated circular and Intze water tanks with empty, half-filled and full condition in seismic zones II and V is Carried out using STAAD Pro V8i SS6.*

Key Words: **Elevated circular water tank, Elevated Intze water tank, Response spectrum analysis.**

1.INTRODUCTION

Indian sub-continent is vulnerable to natural disasters like earthquakes, cyclones etc. These natural calamities especially earthquake is causing many casualties and innumerable property loss every year. Hence, it is necessary to learn to live with these events. According to seismic code IS: 1893(Part I):2002, more than 60% of India is prone to earthquakes. Elevated tank structures are normally used to store water for domestic activities and also firefighting purposes. Their safety performance is a critical concern during strong earthquakes. The failure of these structures may cause serious hazards for citizens due to the shortage of water or difficulty in putting out fires during earthquakes.
Liquid storage tanks are mainly of two types: ground supported tanks and elevated tanks. Elevated tanks are mainly used for water supply schemes and they could be supported on RCC shaft, RCC or steel frame, or masonry pedestral. The height of the column usually varies from about 7m to 25m. Such structures not only should have sufficient strength but should also be free from any cracks. The present study is to identify the behavior of elevated water tanks under different seismic zones with consideration and modelling of tanks using structural software Staad Pro V8i SS6 and using relevant IS codes.

2. DESCRIPTION OF MODELS.

The models considered here are circular and Intze type of elevated water tanks of 2L litres capacity supported on RCC frame staging of height 12m and six number of columns with horizontal bracing at four levels. The elevated water tanks are situated in zone II and Zone V on medium soil. The grade of concrete M30 and grade of steel Fe-415 are considered for study. These models were analyzed using Response Spectrum analysis method in Staad Pro V8i SS6.

2.1 Elevated Circular tank.

Table -1: Parameters of Elevated Circular Tank

Particulars	Values or Dimensions
The Thickness of Top Dome	100mm
Rise of Top Dome	1.4m
Radius of Top Dome at base	8m
Size of Top Ring Beam	250mm x 250mm
Diameter of Cylindrical Wall	8m
Height of the Cylindrical wall	4m
Thickness of Cylindrical Wall	150mm
Thickness of Bottom Slab	175mm
Size of Bottom Ring Girder	350mm x 350mm
No. of Columns	6nos.
No. of Bracing Levels.	3m,6m,9m,12m
Distance between intermediate Braces	3m
Size of Bracing	0.350m x 0.450m
The Size of Columns	0.375m x 0.375m

Fig 1 .3D model of Elevated Circular Tank

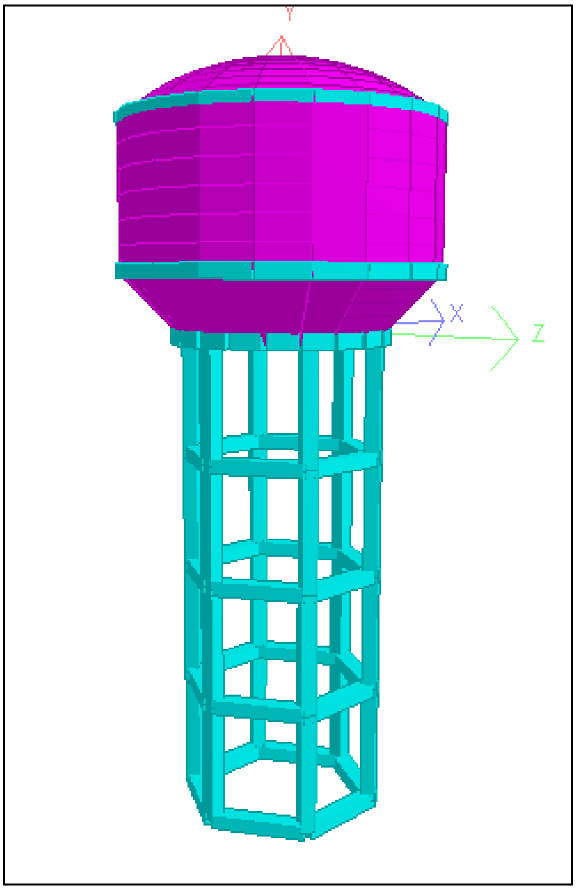

Fig 2.3D model of Elevated Intze Tank

2.2 Elevated Intze tank

Table 2 Parameters of Elevated Intze Tank

Particulars	Values or Dimensions
The Thickness of Top Dome	100mm
Rise of Top Dome (h1)	1.4m
Size of Top Ring Beam	250mm x 250mm
Diameter of Cylindrical Wall	8m
Height of the Cylindrical wall	3.6m
Thickness of Cylindrical Wall	150mm
Size of Middle Ring Beam	350mm x 350mm
Height of Conical Dome	1.6m
Average diameter of Conical dome	6.45m
Thickness of Conical Dome	200mm
Rise of Bottom Dome	0.9m
Radius of Bottom Dome	3.75m
Thickness of Bottom Dome	175mm
Size of Bottom Ring Girder	375mm x 750mm
No. of Columns	6nos.
No. of Bracing Levels.	3m,6m,9m,12m
Distance between intermediate Braces	3m
Size of Bracing	0.350m x 0.450m
The Size of Columns	0.375m x 0.375m

3.METHODOLOGY

The methodology includes the selection of type of water tank, fixing the dimensions of components for the selected water tank and performing linear dynamic analysis (Response Spectrum Method of Analysis) by IS 1893-2002 (Part 1) and IS: 1893-2002 (Part 2) draft code.

The response spectrum analysis is performed with following data with medium soil in seismic zones II and V.

3.1 Live load :1.5KN/m^2 of load acting on the Top Dome, usually considered for maintenance work.

3.2 Hydrostatic Pressure.Water Load for Full Tank: The cylindrical wall portion is modelled as plate elements and the height is divided in 6 plates the pressure acting on these plates is trapezoidal such that at surface the pressure is less and more at bottom and pressure calculated are as follows.

1) 0 KN/m^2.-5.886KN/m^2.
2)5.886KN/m^2.- 11.772KN/m^2.
3) 11.772KN/m^2.-17.65 KN/m^2.
4) 17.65 KN/m^2.-23.54 KN/m^2.
5) 23.54 KN/m^2.-29.43 KN/m^2.

6) 29.43 KN/m².-35.31 KN/m².
7) 51.012 KN/m² acting on bottom dome.
8) 42.183 KN/m² acting on conical wall.

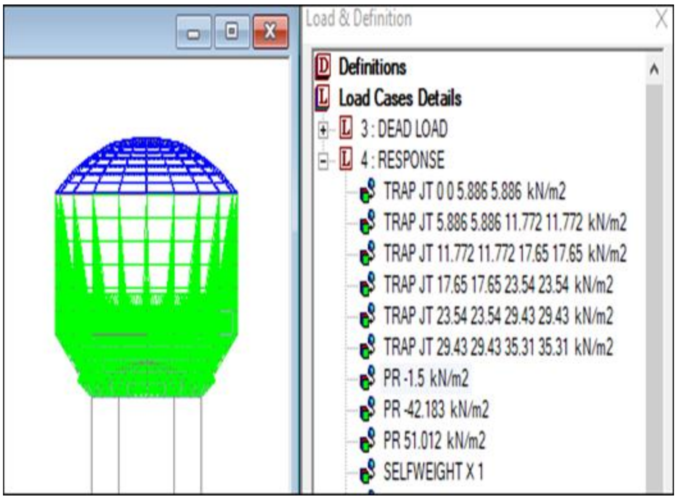

Fig. 3 Water Load for Full Tank for Intze Tank

Water Load for Half Tank

Acting on Cylindrical Wall for Half Tank
1)0.00KN/m²-0.00KN/m².
2) 0.00KN/m²-0.00KN/m².
3) 0.00KN/m²-0.00KN/m².
4) 0.00 KN/m².-6.539KN/m².
5)6.539 KN/m².-13.079 KN/m².
6)13.079 KN/m².-19.619 KN/m².
7) 19.619 KN/m² acting on bottom Slab.

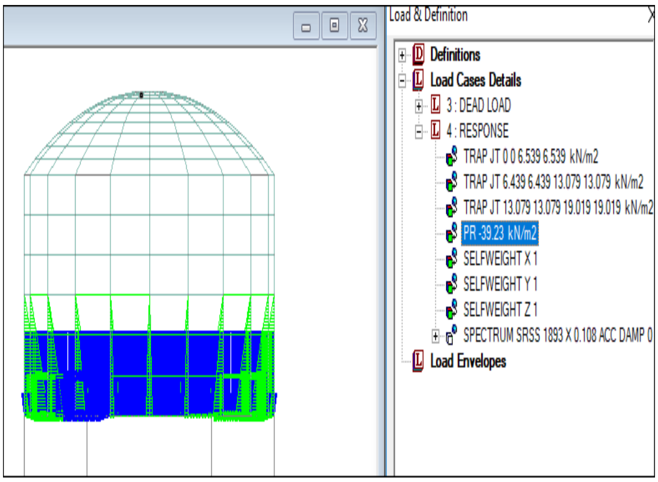

Fig. 4 Water Load for Half Tank for Circular Tank

Water Load for Empty Tank

Zero force acting on all walls

3.3 Seismic loads

In seismic loads factors such as zone factor, importance factor and response reduction factors are used for response spectrum analysis

Zone factors used are 0.10 and 036 for seismic zones II and V respectively as per IS Code 1893:2002

Importance factor considered here is 1.5 for tanks used for storing drinking water, non-volatile material, low inflammable petrochemicals etc. and intended for emergency services such as firefighting services.

Response reduction factor is dependent on type of frame used, For Frame not conforming to ductile detailing, i.e., ordinary moment resisting response reduction factor of 1.8 is considered this type of frame is used in zone II.

For Frame conforming to ductile detailing, i.e., special moment resisting response reduction factor of 2.5 is considered this type of frame is used in zone V

4.Results and Discussions

The maximum responses are determined for different parameters of elevated water tanks. These responses include base shear force, nodal displacement and time period. The seismic demands of the elevated water tanks are determined using the response spectrum analysis for the full tank condition, half-filled and empty tank. The seismic zones II and V are considered for the analysis.

4.1 Base Shear (in KN)

Base shear values for circular and Intze models are obtained using Response spectrum analysis from the staad.pro software

Table 3 Base Shear Values for Zone V

Base Shear Values for Zone – V,		
Water levels in tank	Circular Tank	Intze Tank
	Fx(in KN)	Fx(in KN)
Empty Tank Level	193.66	208.65
Half Tank Level	207.32	288.38
Full Tank Level	307.21	323.68

Table 4 Base Shear Values for Zone II

Base Shear Values for Zone – II,		
Water levels in tank	Circular Tank	Intze Tank
	Fx (in KN)	Fx (in KN)
Empty Tank Level	75.31	81.14
Half Tank Level	81.13	112.15
Full Tank Level	98.14	125.88

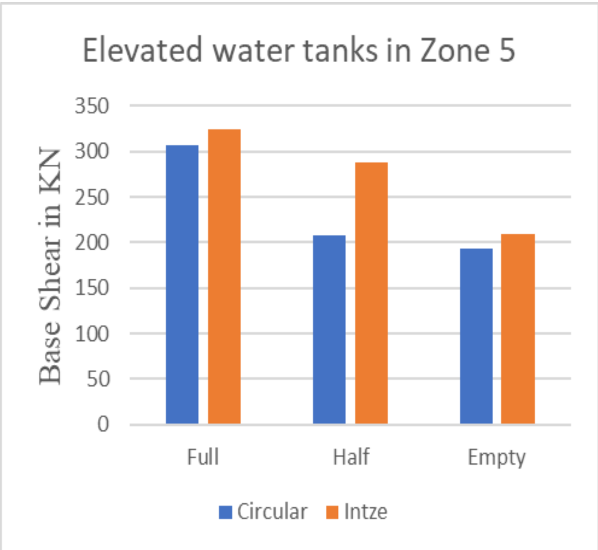

Chart 1: Base shear values for circular tank and Intze tank in zone V

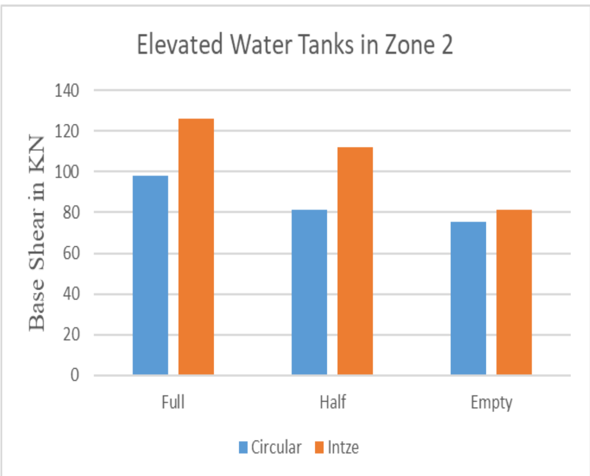

Chart 2: Base shear values for circular tank and Intze tank in zone II

Discussion on the Base Shear values on the models

1. The base shear for Intze type of tank is 5.36% more than that of circular tank for full tank condition in seismic zone V.
2. The base shear increases 2.13 times for circular type of tank when Zone II is changed to Zone V for full tank condition.
3. The base shear increases 1.57 times for Intze type of tank when Zone II is changed to Zone V for full tank condition

4.2 Nodal Displacement.

Displacement values for circular and Intze models are obtained from Response spectrum analysis from the staad.pro software under seismic zones II and V for different levels of water.

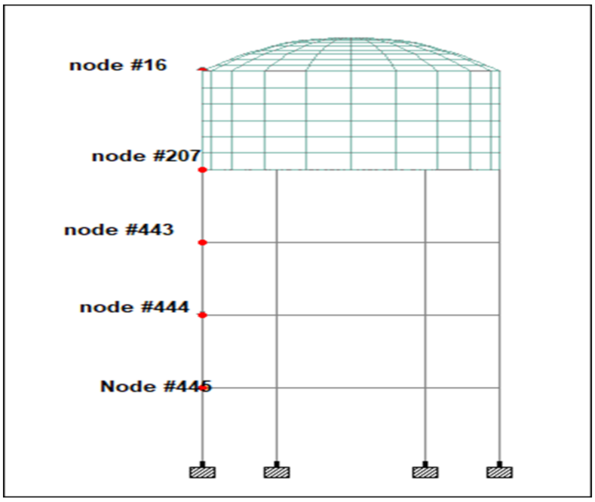

Fig. 5 Nodes numbers in circular tank

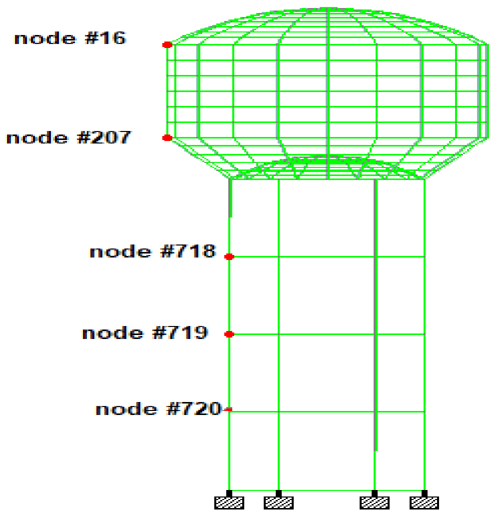

Fig. 6 Nodes numbers in Intze tank

Table 5: Displacements in circular tank in zone V

Seismic Zone-V			
Response Spectrum Analysis of Elevated Circular Tank			
Node Numbers	Displacements in mm		
	full	half	empty
445	7.412	7.379	7.365
444	19.551	19.345	19.255
443	34.362	33.586	33.23
207	58.258	55.993	54.903
16	59.262	56.949	55.876

Table 6: Displacements in circular tank in zone II

Seismic Zone-II			
Response Spectrum Analysis of Elevated Circular Tank			
Node Numbers	Displacements in mm		
	full	half	empty
445	2.859	2.847	2.841
444	7.542	7.467	7.429
443	13.254	12.971	12.82
207	22.467	21.64	21.182
16	22.855	22.013	21.557

Table 7: Displacements in Intze tank in zone II

Seismic Zone-V			
Response Spectrum Analysis of Elevated Intze Tank			
Node Numbers	Displacements in mm		
	full	half	empty
720	6.77	6.446	6.43
719	17.22	16.365	16.247
718	29.467	27.92	27.448
207	52.533	49.495	47.965
16	55.336	52.027	50.669

Table 8: Displacements in Intze tanks in zone II

Seismic Zone-II			
Response Spectrum Analysis of Elevated Intze Tank			
Node Numbers	Displacements in mm		
	full	half	empty
720	2.633	2.487	2.186
719	6.697	6.314	5.513
718	11.459	10.772	9.624
207	20.429	19.095	18.324
16	21.519	20.072	19.075

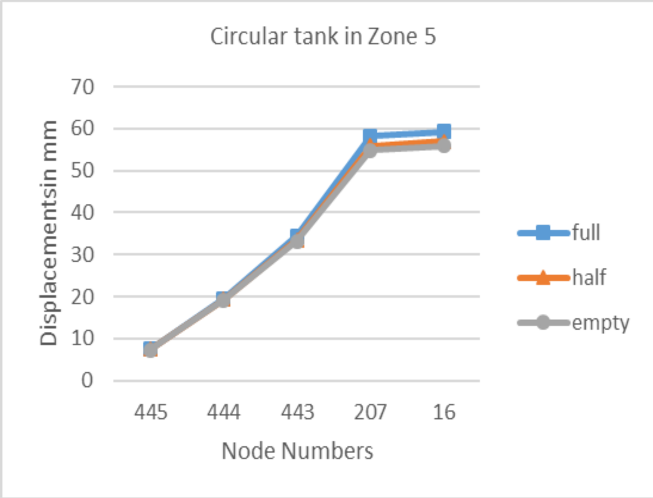

Chart 3 Displacements in Circular tanks in zone V

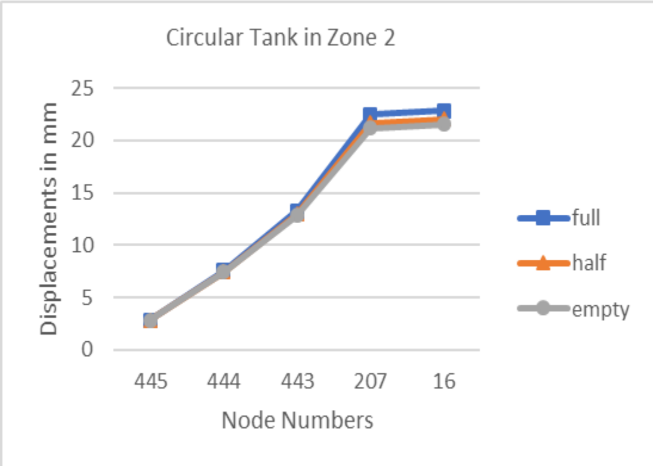

Chart 4 Displacements in Circular tanks in zone II

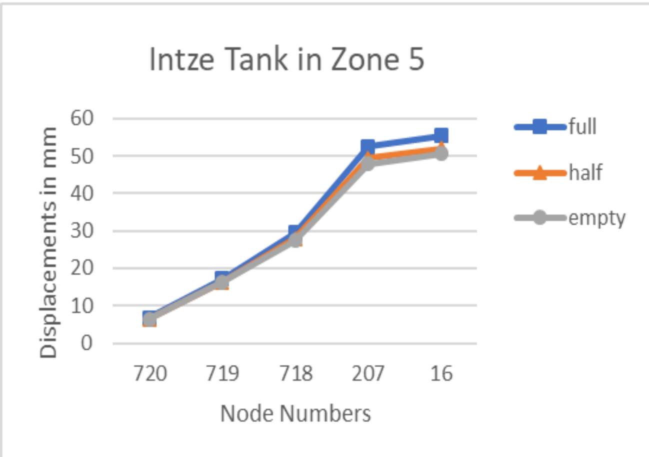

Chart 5 Displacements in Intze tanks in zone V

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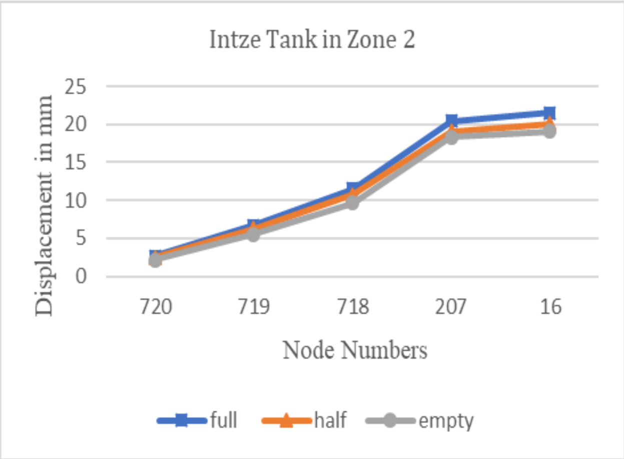

Chart 6 Displacements in Intze tanks in zone II

Discussion on the Nodal displacements on the models

1.The maximum displacement usually occurs at top most node and minimum at the bottom supports node for all models irrespective of shape.
2.The displacement increases 1.59 times for the circular tank in full tank condition when Zone II is changed to Zone V.
3.The displacement increases 1.57 times for the Intze tank in full tank condition when Zone II is changed to Zone V.

4.3 Time period:

The time period is calculated for convective mode wherein the liquid mass in the upper region undergoes sloshing motion this mass is called as convective liquid mass and it exerts convective hydrodynamic pressure on the tank and the base.

Table 9: Time periods in Intze & Circular tanks

Time Period in Seconds		
	Circular tank	Intze tank
Empty	2.05231	2.3755
Half	2.37	3.066
Full	2.8634	3.587

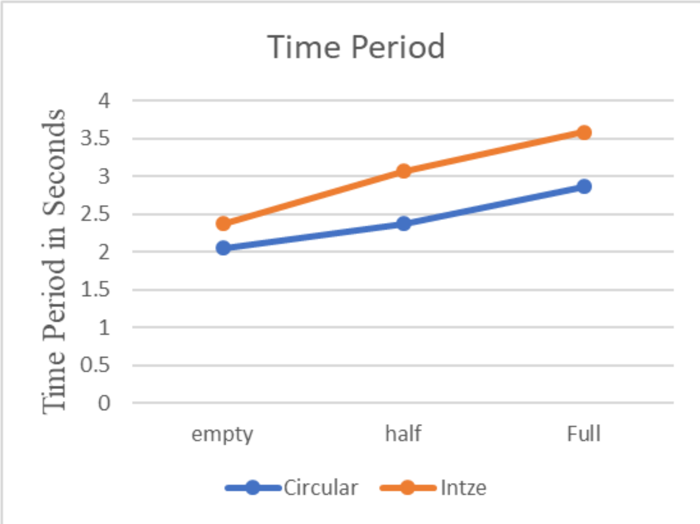

Chart 7: Time periods in Intze & Circular tanks

Discussion on the time period of the models.

1. The time period of elevated water tanks is independent of seismic zones and is obtained same for Zone II and Zone V.
2. The time period is maximum for Intze for full condition and minimum for Circular tank for empty condition.
3. The time period for Intze water tank is 25% more than that of circular tank for full filled condition.

CONCLUSION

1.The total base shear in full tank condition are more than those in empty tank condition and half-filled condition in both seismic zones II and seismic zone V for both Intze and circular type of tank. Hence design is governed by full tank condition.
2.The increment in the base shear is very large with change in zone II to Zone V in both circular and Intze type of water tanks.
3.From the analysed results it is seen that maximum displacement occurs at topmost node and is maximum in Intze type o water tank.
4.The maximum displacement occurs in Intze tank in comparsion with circular tank in both seismic zones II and seismic zone V.
5.The maximum displacement in circular and Intze tank occurs in full tank condition and displacement value increases in zone V in comparsion to zone II.
6.The increment in displacement from empty condition to full tank condition for Intze tank is more in comparsion to the circular water tank in both seismic zones II and seismic zone V.
7.The time period is more for Intze tank in full-filled condition in comparsion to circular tank and is independent of zones.

8.Design of elevated water tank is very complex which involves lot of mathematical calculations and time consuming. Hence Staad pro gives all parameters which are useful in design of elevated water tank.

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