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PERFORMANCE OF ELEVATED WATERTANK UNDER NEAR FAULT AND FAR FIELD EARTHQUKE MOTION

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Abstract: Elevated water tank are one of the most important lifeline structures in the earthquake region. As water tanks required to provide water for drinking and fire fighting purpose. This type of structure has large mass concentrated at the top of slender supporting structure. So extremely vulnerable under lateral forces due to an earthquake. At near fault region water tank damages more during earthquake. Elevated water tanks collapsed or damaged during earthquakes because of unsuitable design and wrong selection of supporting system. The aim of the study is analyses seismic effect on different shape and types elevated water tank due to near fault and far field earthquakes. So it is very important to select proper supporting system and shape of tank according to codal provisions. For this purpose study Circular , Intez types of elevated water tanks with different staging Height 12m , 16m, 20m and 10 lac littre capacity. Here model two different staging profiles such as shaft and frame and simulated to near fault and far field ground motion with STAAD.PRO. Software. Here analysis time history records from past earthquake ground motion records. Seismic responses including base shear, base moment and displacement have been observed under different earthquake time history records.
KEYWORDS: Elevated water tank, Staging, Seismic response, Time history, near fault far field earthquakes, Staad Pro.

I. INTRODUCTION

An elevated water tank is a large water storage container constructed for the purpose of holding water supply at certain Height to pressurization the water distribution system.During the earthquakes, a number of large elevated water tanks were severely damaged whereas others survived without damage. Elevated water tanks consist of huge water mass at the top of a slender staging which are most critical consideration for the failure of the tank during earthquakes. These tank structures more vulnerable to the action of horizontal forces like earthquakes owing to large total mass concentrated at the top of a slender supporting structure. So there is need to focus on seismic safety of lifeline structure is required.

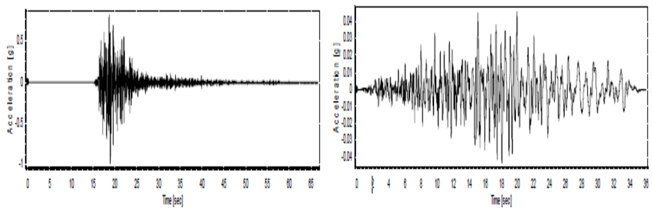
Durgesh C Rai [9]In this paper study supporting structures of elevated water tanks damage due to Bhuj earthquake (Mw 7.7)of January 26th, 2001 Tank stag-ing in Manfera village (figure 1) in the epicentral collapsed whereas severe damage to a tank in Bhachau Clearly, brace and column members of tanks in Manfera and Bhachau do not meet the ductility and toughness requirements for earthquake resistance.

Figure1: Failure of elevated water tank in bhuj earthquake in Bhachau.

As per the information according to GSI, about 67 active faults of regional extent exist in the country; India is divided into different seismic zones. As per IS 1893:1984 Code India is divided from Zone 1 to Zone 5.

A. Near Fault and Far Field earthquakes

After Loma Prieta 1989 earthquake, Mohraz [1] has divided earthquakes in 3 groups: Near-field earthquakes: the distance between site and fault is less than 20 km. Mid-field earthquakes: the distance between site and fault is between 20 km to 50 km. Far-field earthquakes: the distance between site and fault is larger than 50 km. Near-fault earthquake ground motions are different in many ways in comparison to the far-fault earthquake ground motions. The main characteristic of near-fault earthquakes is the high energy content in the lower frequency range would not allow enough time for the high frequency content to be damped out of the record. The people of the nearby areas were affected most in all cases. Unfortunately, the typical natural frequency of base-isolated structures lies in the zone where near-fault ground motion possesses maximum energy. Hence the base-isolated structures are very much vulnerable to near-fault earth quakes. The other important characteristic of near-fault earthquakes is the presence of pulses in their time histories. For this reason, equivalent pulse type motions are proposed by several researchers to study the effect of near-fault earthquakes on the structures.In Fig 2 we can see the differences between bam (near-field) and Morgan (far-field) records. [2]&[3].



a: Bam earthquake's record b: Morgan earthquake's record

Figure 2 Comparing the differences between bam (near-field) and Morgan (far-field) earthquakes

The above discussion show that there is lot of difference between near field and far field earthquakes that cause to different response of structures under these earthquakes.

B. Objectives

1. To study earthquake response on elevated water tank at near fault and far field region.
2. To identify performance of elevated water tank for different shapes like circular and Intez.
3. Comparing relations between Type of Staging, Structural response, Capacity and near fault and far field effect on elevated water tank.

II. MODELLING OF STRUCTURE AND EARTHQUAKE RECORDS

In this study, models of Intz shape tank with 10 lac litres storage capacity have been investigated. Variations are made in tanks, staging, both in height and pattern. Adapted staging heights are 12 m, 16 m, 20 m and 24 m and for each height two staging pattern, frame and shaft are taken under consideration. All the structures are made of RCC and grade of concrete is M25. Tanks are designed with perfect accordance to the Indian Standard criteria for liquid retaining structure located in seismic zone IV. Other structural configurations are as per Table 1. Figure 3 shows the finite element models of the tanks prepared in STTAD-pro.

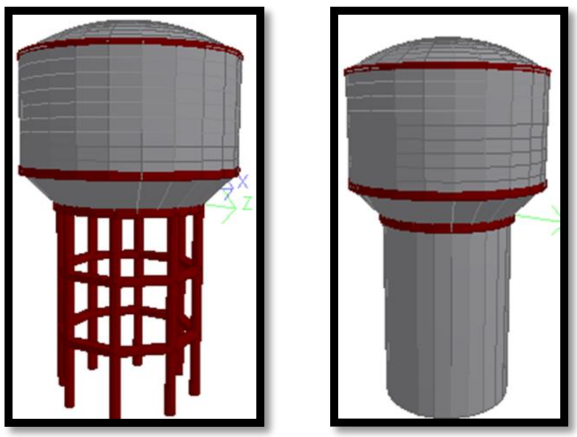
TABLE I Dimension of circular elevated water tank

	Frame staging	Shaft staging
Diameter of tank (m)	15.5	15.5
Thickness of top dome (m)	0.1	0.1
Dimension of top ring beam(m)	0.3×0.3	0.3×0.3
Dimension of bottom ring beam(m)	0.55×0.4	0.65×0.45
Thickness of wall (m)	0.32	0.22
Height of cylindrical wall (m)	5.3	5.3
Thickness of bottom slab (m)	0.3	0.3
Column diameter (m)	0.7	-----
Bracing beam dimensions (m)	0.4×0.55	-----
Shaft thickness (m)	------	0.17

TABLE II Dimension of intez elevated water tank

	Frame staging	Shaft staging
Diameter of top dome (m)	12.7	16.8
Thickness of top dome (m)	0.1	0.1
Dimension of top ring beam (m)	0.3×0.3	0.4×0.3
Height of cylindrical wall(m)	7.62 m	3.76
Thickness of wall (m)	0.3 m	0.2
Dimension of middle ring beam (m)	0.5×0.6	0.68×0.6
Thickness of conical dome (m)	2.6	0.4
Diameter of bottom dome (m)	0.5	12.73
Height of conical dome (m)	8.89	3.15
Thickness of bottom dome (m)	0.32	0.22
Dimension of bottom ring beam (m)	0.70×0.85	0.17×0.67
Column diameter (m)	0.65	------
Bracing beam dimensions (m)	0.35×0.45	-----
Shaft thickness (m)	-----	0.2

Elevated tanks are could be supported on RCC shaft and frame type staging. In The frame type is the most commonly used staging in practice. The main components of frame type of staging are columns and braces. In shaft type tank Staging consisting of shell like a circular or polygonal cylinder or hollow prism. This type of construction needs special attention to maintain the accuracy in construction.In frame type of arrangement columns are mainly under the effect of direct and bending stresses, while braces develop reversible bending stresses due to lateral loads. As being a flexible structure this type of system attract less seismic load. Figure 3 shows staad pro model of frame and shaft type staging of elevated water tank



(a) frame type staging (b) shaft type staging

Figure 3 Staad pro model of elevated intez type tank

A. Fluid structure interaction

The paper presented by AlgreaneGareane A. I.et al (2009) suggests the dynamic behaviour of elevated concrete water tank with alternative impulsive masses configurations. The suggested model is to distribute the impulsive mass, by different alternative configurations which are easier than Westergaard technique. The impulsive mass is considered to be acting at the level of gravity centre of empty container tank walls, and distributed into 4, 8, 16, 24 and 48 masses, as shown in the figure 4.

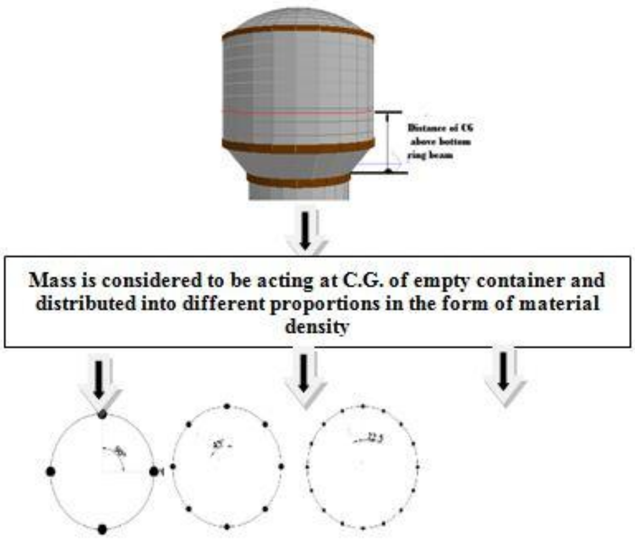


Figure 4 Location of C.G in STAAD model

B. Earthquake records

To study the effect of near-fault earthquake on elevated water tank, here Northridge (1994) and Loma Preita (1989) earthquake are taken into consideration.

Table III Ground motion data of earthquake

Earthquake	Northridge		Loma Preita	
Seismic Characteristic	Near fault	Far field	Near fault	Far field
Magnitude	6.69		6.93	
Station	CDMG 24087	USC 90059	CDMG 47125	CDMG 47006
Epicentre Distance (km)	11.10	23.18	9.78	28.98
PGA (g)	0.3298	0.1403	0.480	0.3341
PGV (cm/sec)	30.90	9.09	34.51	26.94
PGD (cm)	12.80	2.05	7.13	5.33

Acceleration time histories for these earthquakes are collected from PEER NGA database for two stations, i.e. one located in near-fault region and the other in far-field region. Table 3shows the seismic characteristics of Loma Prieta (1989) and Northridge (1994) time history data, regarding location of the record station.

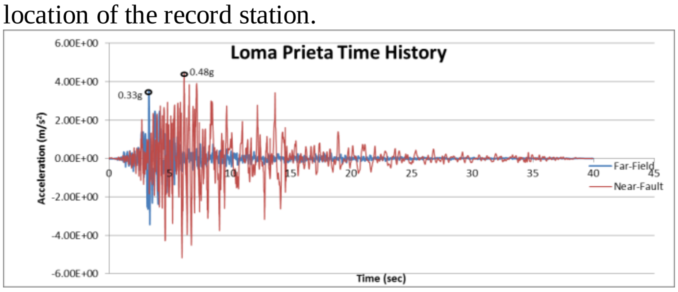


Figure 4 Time History Record Loma Preita (1989)

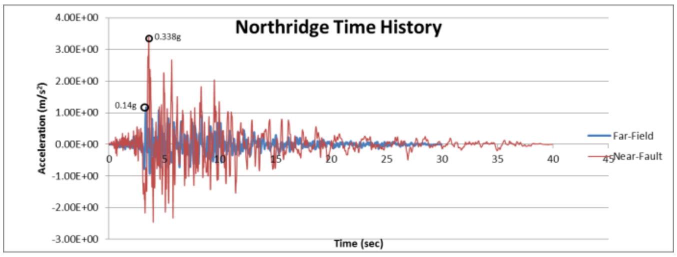


Figure 5 Time History Record Northridge (1994)

III. RESULT AND DISCUSSION

The seismic behaviour of elevated water tank is studied here in the terms of base shear, basemoment and displacement at different height levels. By studying the variations in these parameters for near-fault and far field earthquake suitability of tanks in different regions can be decided. Results for different staging height and staging patterns can suggest the favourable staging configuration.

A. Displacement results

By comparing the result of 10 lac litters of water tank of intez and circular type for both frame and shaft supported water tank, at different staging levels and height compare for near fault and far earthquake for Northridge and Loma Preita earthquakes. From the graphs show that Increase in displacements is also observed with increment in height of staging.

B. Inteztank frame staging

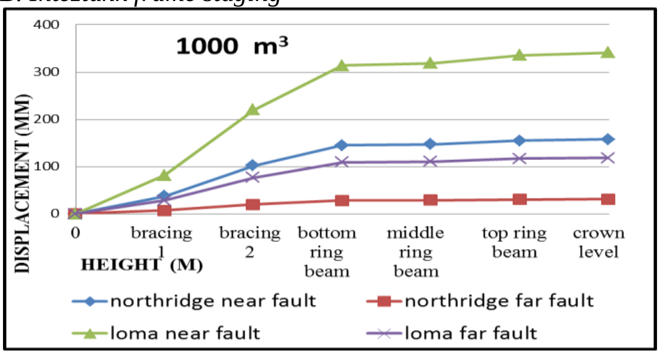


Figure 6 Displacement of frame type 10 lac litre intez tank for 12 m height staging

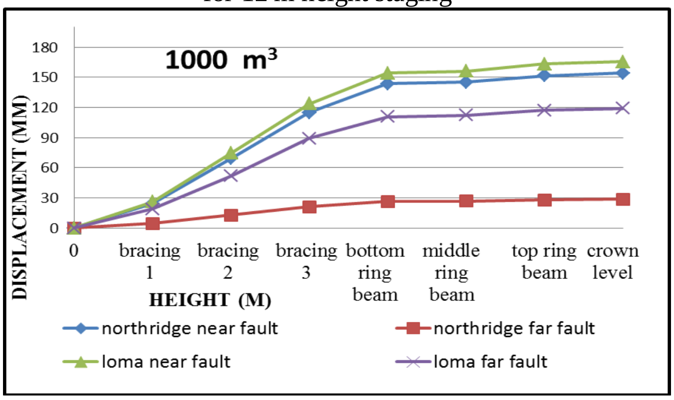


Figure 7 Displacement of frame type 10 lac litre intez tank for 16 m height staging

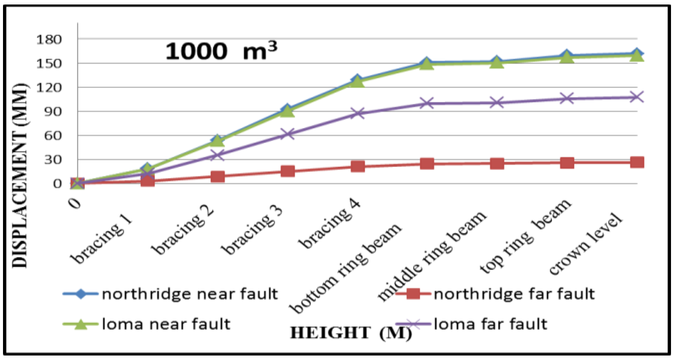


Figure 8 Displacement of frame type 10 lac litre intez tank for 20 m height staging

C. Intez tank shaft staging

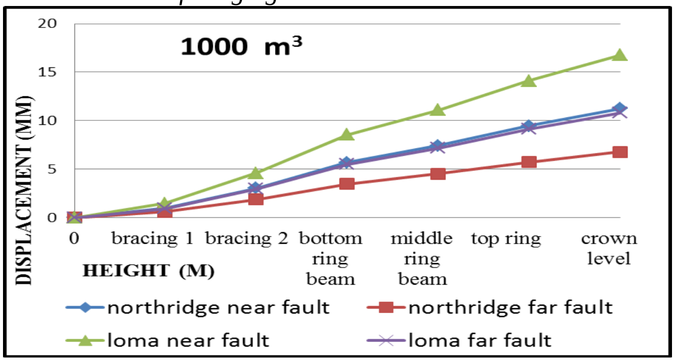


Figure 9 Displacement of shaft type 10 lac litre intez tank for 12 m height staging

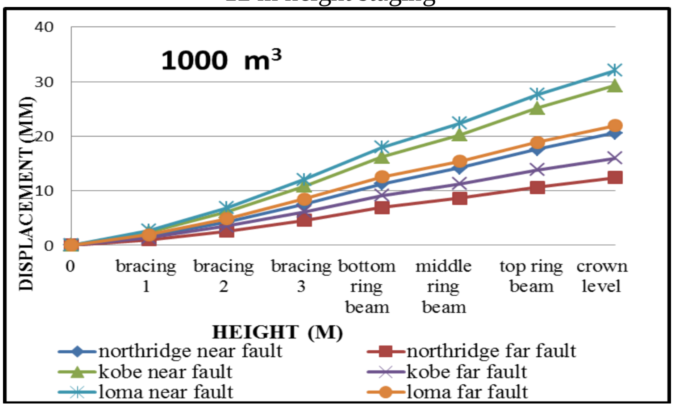


Figure 10 Displacement of shaft type 10 lac litre intez tank for 16 m height staging

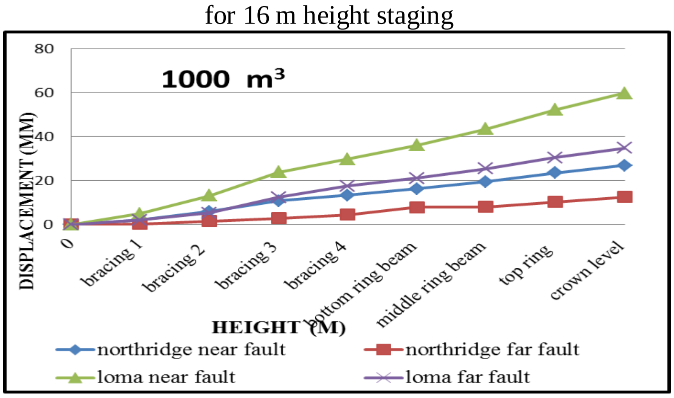


Figure 11 Displacement of shaft type 10 lac litre intez tank for 20 m height staging

D. Circular tank frame staging

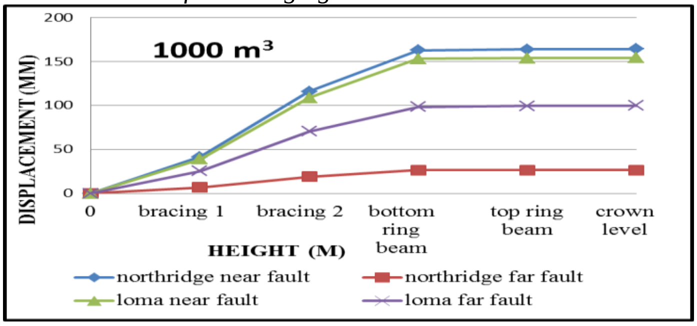


Figure 12 Displacement of frame type 10 lac litre circular tank for 12 m height staging

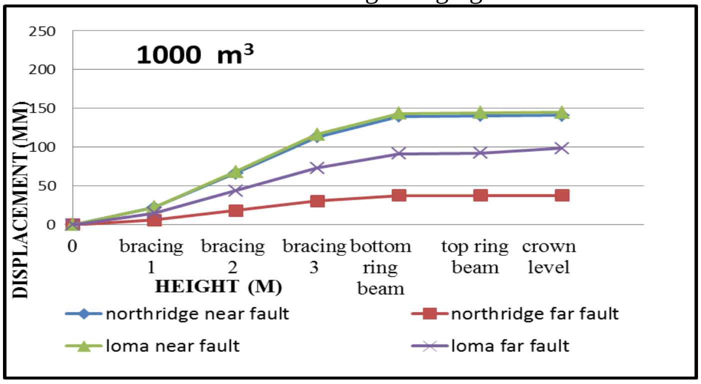


Figure 13 Displacement of frame type 10 lac litre circular tank for 16 m height staging

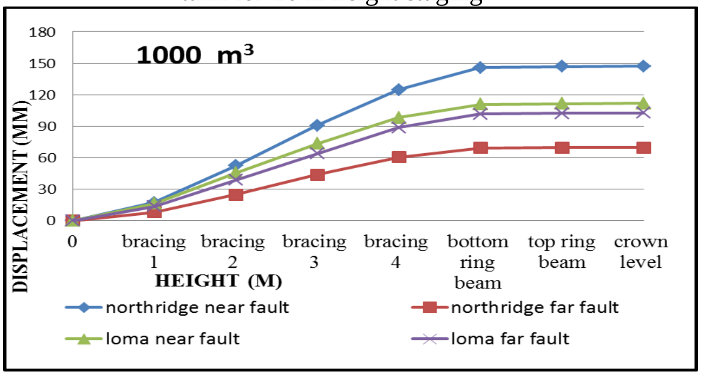


Figure 14 Displacement of frame type 10 lac litre circular tank for 20 m height staging

E. Circular tank shaft staging

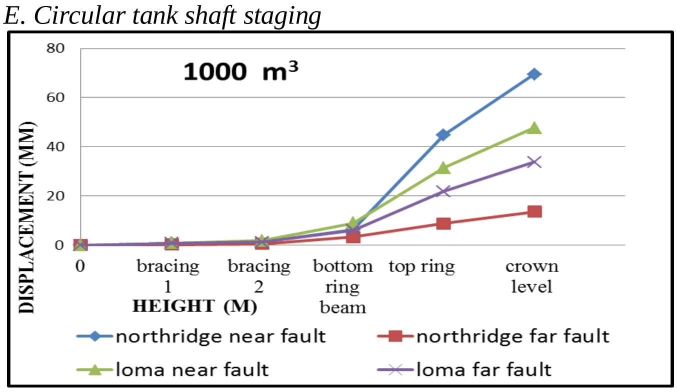


Figure 15 Displacement of shaft type 10 lac litre circular tank for 12 m height staging

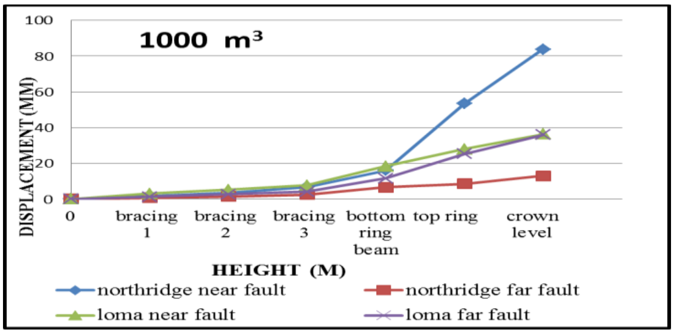


Figure 16 Displacement of shaft type 10 lac litre circular tank for 16 m height staging

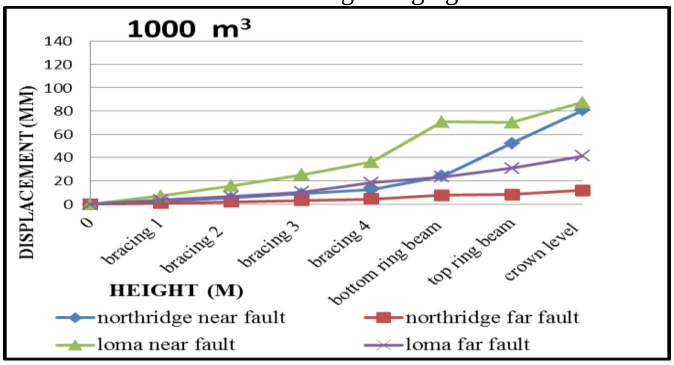


Figure 17 Displacement of shaft type 10 lac litre circular tank for 20 m height staging

F. Base shear results

For all the water tanks considered here base shear value for time history analysis is high in case of near-fault earthquake than far-field earthquake. Figures shows the base shear values for circular and intez type frame and shaft supported water tank of different staging height. From graph shows that base shear value is more at near fault earthquake than far field once. Base shear value decrease as height decrease in frame staging water tank in both type of shape. But in shaft type staging base shear value increase as height of tank increase.

1. Intez tank frame staging

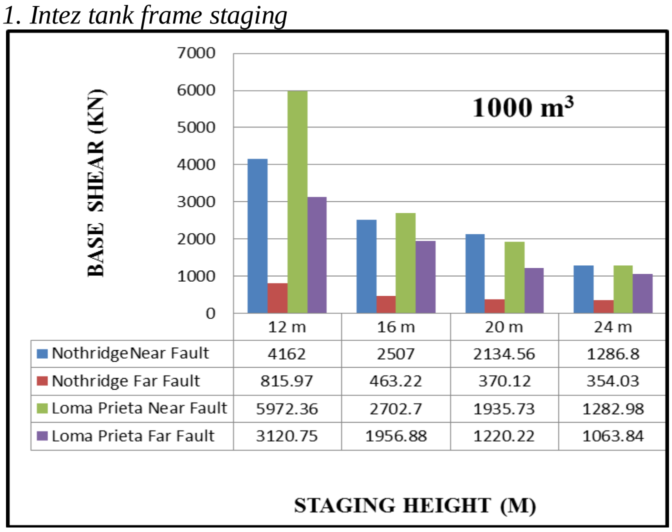


Figure 18 Base shear for 10 lac lire capacity frame type intez tank

2. Intez tank shaft staging

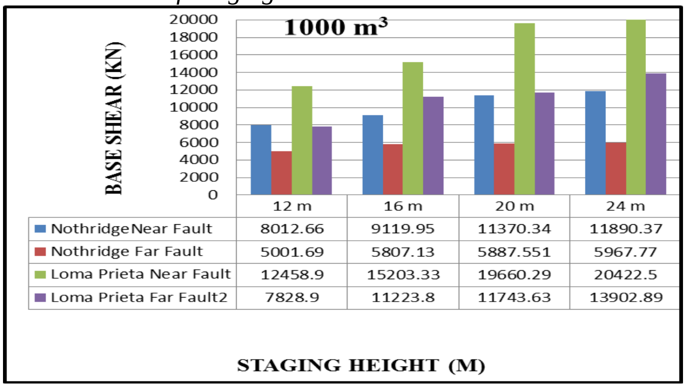


Figure 19 Base shear for 10 lac lire capacity shaft type intez tank

3. Circular tank frame staging

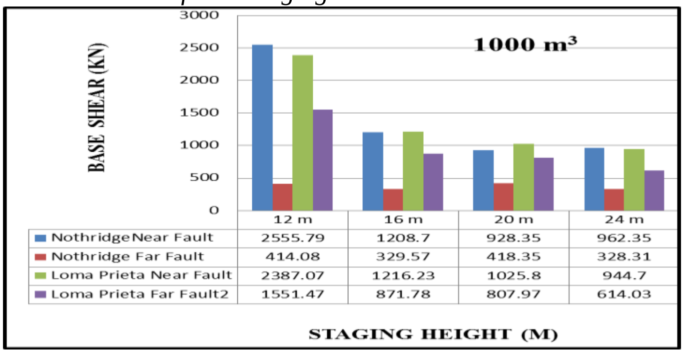


Figure 20 Base shear for 10 lac lire capacity frame type circular tank

4.Circulartank shaft staging

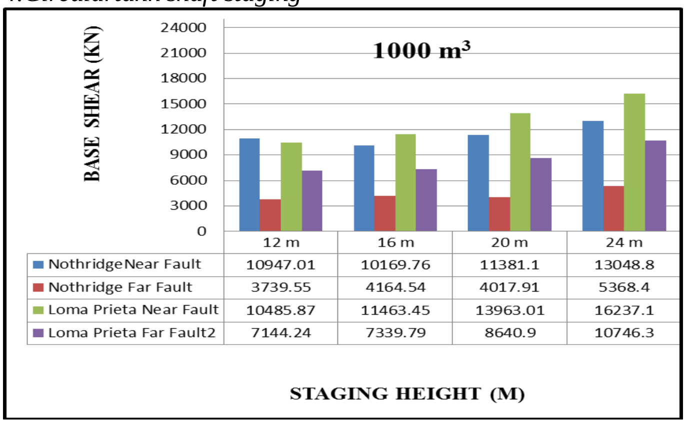


Figure 21 Base shear for 10 lac lire capacity shaft type circular tank

IV. CONCLUSION

STAAD.Pro analysis results are compared to do a parametric study for the structural responses of water tanks with change in staging type, shapes and staging Height. The conclusions are made based on the comparison of the results generated by time history analysis for three different types of earthquake motions.

- With increase in Height for shaft type staging and both shape of water tanks base shear also increase.

But in frame type staging base shear decrease with increase in Height generally. Only few cases it was increase.

- Response of the elevated water tank subjected to Near-Fault ground motion isvery high as compared to Far-field ground motion for each model.
- In Northridge earthquake base shear variation is more in near fault and far field earthquake.
- Due to system frame type staging base shear value is more than shaft type staging.
- Maximum variation in displacement is shown in between bottom ring beam and staging. This variation is more in circular type staging than intez tank because of absent of conical dome in circular type tank. For exampleIntez tank of 10 lac 12 m Heightnorthridge near fault earthquake this variation is 25% and this variation is increase in circular tank is about 52%.
- From study it is observed that horizontal displacement value is more in frame type staging water tank than shaft type water tank .
- In shaft type staging for same capacity displacement value increase with increase in Height level of staging.

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