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Structural Assessment of Flask Overhead Water Tank with Different Slant Inclinations

D.S.Ingle[1], Dr. R.S.Londhe[2]
[1]*P.G.Student Government College Of Engineering, Aurangabad, Maharashtra, India*
[2]*Professor And Head, Applied Mechanics Department Government College Of Engineering, Aurangabad, Maharashtra, India*

Abstract:- Water is human basic needs for daily life. Elevated water tanks should be competent of keeping the expected performance during and after earthquake. It has large mass concentrated at the top of slender supporting structure hence extremely vulnerable against horizontal forces due to earthquake. Staging is formed by a group of columns and horizontal braces provided at intermediate levels to reduce the effective length of the column. A dynamic analysis of such tanks must take into account the motion of the water relative to the tank as well as the motion of the tank relative to the ground. For certain proportions of the tank and the structure the displacement of the tank may be the dominant factor, whereas for other proportions the displacement of tank may have small effect.

The main objective of this study is to examine the behaviour of overhead flask water tank supported on frame staging considering different modeling systems. The present work aims at checking the adequacy of flask type water tank with different slant inclinations for the seismic excitations. And suggest the optimum slant inclination for the flask water tank. The result shows that structure response is exceedingly influenced by shape of water tank and their modeling systems i.e. Two Mass models and earthquake characteristics. The responses includes Displacement and Base shear, acceleration of 3-D model and Two mass models under the three different time history records have been compared.

Keywords:- two mass model, flask type water tank, slant inclinations

I. INTRODUCTION

Seismic safety of liquid tanks is of considerable importance. Water storage tanks should remain functional in the post earthquake period to ensure potable water supply to earthquake-affected regions and to cater the need for fighting. Industrial liquid containing tanks may contain highly toxic and inflammable liquids and these tanks should not loose their contents during the earthquake. 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.

Frame type staging:

The frame type is the most commonly used staging in practice. The main components of frame type of staging are columns and braces. In frame staging, columns are arranged on the periphery and it is connected internally by bracing at various levels. The staging is acting like a bridge between container and foundation for the transfer of loads acting on the tank. In elevated water tanks, head requirement for distribution of water is satisfied by adjusting the height of the staging portion. Frame type staging are generally regarded superior to shaft type staging for lateral resistance because of their large redundancy and greater capacity to absorb seismic energy through inelastic actions. Framed staging have many flexural members in the form of braces and columns to resist lateral loads. RC frameworks can be designed to perform in a ductile fashion under lateral loads with greater reliability and confidence as opposed to thin shell sections of the shaft type staging. The sections near the beam-ends can be designed and detailed to sustain inelastic deformation and dissipate seismic energy. Frame members and the brace column joints are to be designed and detailed for inelastic deformations, or else a collapse of the staging may occur under seismic overloads. The collapse of the members could have been prevented if the members of staging were detailed according to BIS.

The collapse of the structure could have been prevented if the frame members of staging were detailed according to provisions of IS: 13920- 1993(BIS 1993a) and IS: 11682-1985 (BIS 1985) which refers to the ductility requirements of IS: 4326-1976(BIS 1976).

II. MODAL PROVISION

2.1 Two mass model

The two mass model of elevated tank was firstly proposed by Housner (1963) after the chileane earthquake of 1960, which is more appropriate and is being commonly used in most of the international codes including GSDMA guideline. The pressure generated within the fluid due to the dynamic motion of the tank can be separated into impulsive and convective parts. When a tank containing liquid with a free surface is subjected to horizontal earthquake ground motion, tank wall and liquid are subjected to horizontal acceleration. The liquid in the lower region of tank behaves like a mass that is rigidly connected to tank wall, termed as impulsive liquid mass. Liquid mass in the upper region of tank undergoes sloshing motion, termed as convective liquid mass. For representing these two masses and in order to include the effect of their hydrodynamic pressure in analysis, two-mass model is adopted for elevated tanks. The response of the two-degree of freedom system can be obtained by elementary structural dynamics. In spring mass model convective mass (m_c) is attached to the tank wall by the spring having stiffness (K_c), whereas impulsive mass (m_i) is rigidly attached to tank wall. Spring mass model can also be applied on elevated tanks, but two-mass model idealization is closer to reality

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 (b). The stiffness (K_s) is lateral stiffness of staging. The mass (m_s) 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 roof slab, container wall, gallery if any, floor slab, floor beams, ring beam, circular girder, and domes if provided. The two- mass model is shown in Fig. 2.

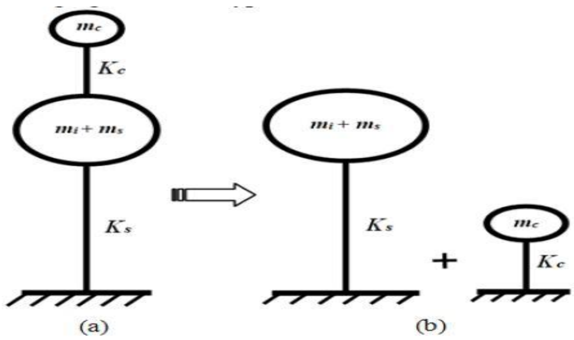

Fig.2: Two mass model for elevated tank

where, m_i, m_c, K_c etc. are the parameters of spring mass model and charts as well as empirical formulae are given for finding their values. The parameters of this model depend on geometry of the tank and its flexibility.

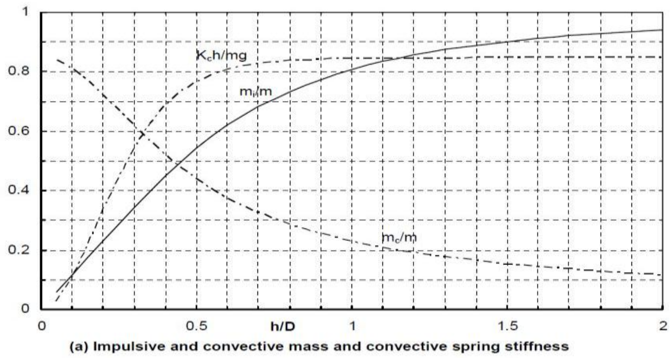

Fig.3: impulsive and convective mass and convective spring stiffness

Time period of impulsive mode, *Ti* in seconds, is given by;

$$T_i = 2\pi\sqrt{\frac{m_i + m_s}{K_s}}$$

Where

m_i = impulsive mass

m_s = mass of container and one-third mass of staging, and

K_s = lateral stiffness of staging.

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.
Time period of convective mode, T_c in seconds, is given by

$$T_c = C_c \sqrt{D / g}$$

Where
C_c = Coefficient of time period for convective mode.
D = Inner diameter of tank.
g – Acceleration due to gravity.

For modeling of the two mass model the lateral stiffness K_s is calculated by applying the lateral force to the staging of the existing tank. And deflection (Δ) is noted then by using following formula the stiffness is calculated.

$$K = P / \Delta \ldots\ldots\ldots..(1)$$

This calculated stiffness is given by ,

$$K = 3EI / L^3 \ldots\ldots\ldots(2)$$

Where,
EI – flexural rigidity of structure.
Equating eq^n (1) and (2);
The equivalent diameter (D_e) for one mass model is calculated.
The lumped masses m_i and m_s for two mass model is calculated from the provisions of the IS 1893-2002 and it consists of mass of water, mass of container and one third mass of staging. The convective spring stiffness K_c and the convective mass m_c is calculated from the IS1893-2002 provisions which are based on the h / D ratio of the tank container shown in fig.3.

III.PROBLEM DESCRIPTION

The main objective of this study is to examine the behaviour of overhead flask water tank supported on frame staging with different slant inclinations.
Two mass model (As per Draft IS:1893-2002)
3-D modeling of actual tank (neglecting hydro dynamic effect)

All the above cases are analyzed for three different earthquake records i.e. time history analysis. The analysis is carried out using SAP 2000 software. And response spectrum analysis is also carried out for Zone – V. The comparison is made between the structural responses of 3-D model and two mass models of overhead flask water tank with different slant inclinations. For the study, water tanks with 500m3 capacity is considered, 3-D model and two mass model is made for overhead flask tank with different slant inclinations. The different slant inclinations are considered are as 25, 38, 43, 52, 65 degrees respectively.

The water tanks which are considered are actually designed tank. The above models are analyzed for different time history data such as Kern city, North ridge, Imperial Valley along with this response spectrum analysis is also carried out for Zone – V with zone factor 0.36 for hard soil condition. The comparison is made between the structural responses of 3-D model, two mass models of flask type water tank.

Table-III

Record	Imperial valley (1979)	North ridge (1994)	Kern city (1952)
Station	EC meloland overpass	Sylmar country hospital	Taft lincoln tunnel
PGA(g)	0.348	0.604	0.275
Magnitude	6.5	6.7	7.5

IV. RESULTS AND CONCLUSIONS

Free vibration analysis is carried out to determine the Time period and mode shape of all models. It is clearly observed that period for two mass model and 3-D model changes significantly.

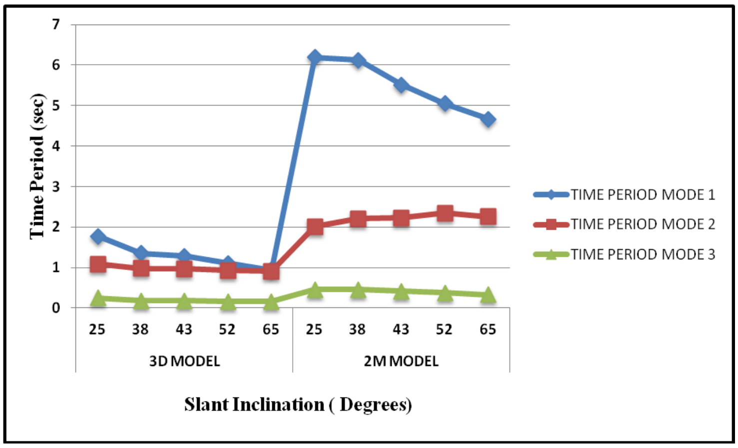

Figure 4: Time period variation of 3-D model and two mass model with different slant inclinations

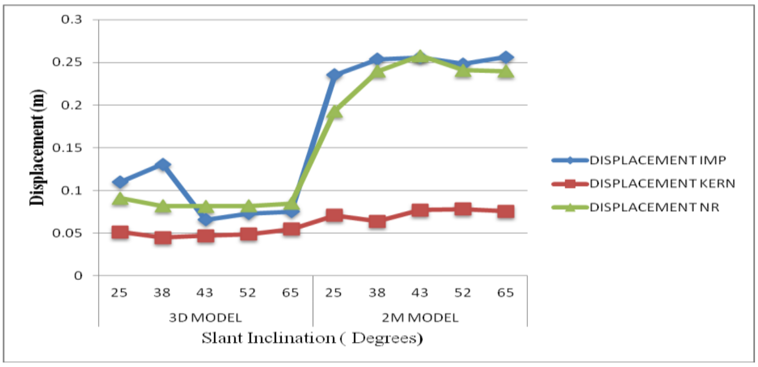

Figure 5: Displacement variation of 3-D model and two mass model with different slant inclinations

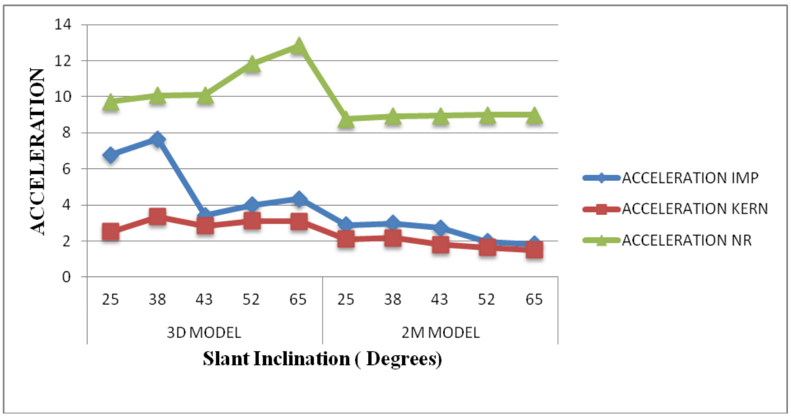

Figure 6: Acceleration variation of 3-D model and two mass model with different slant inclinations

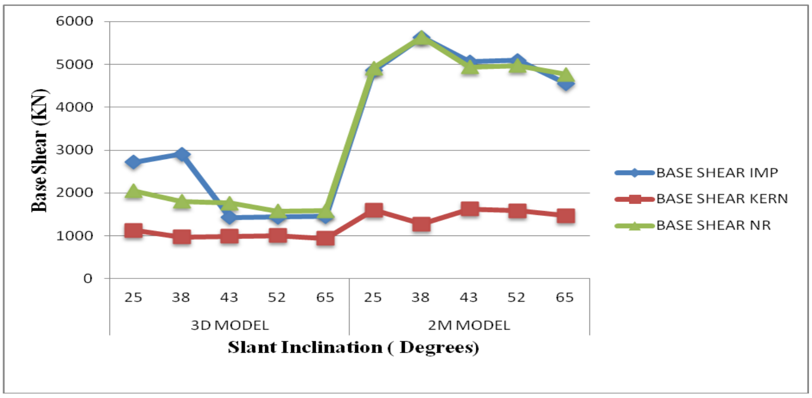

Figure 7: Base Shear variation of 3-D model and two mass model with different slant inclinations

V. RESULT AND DISCUSSIONS

1. It is observed that the time period for two mass model increases for convective mode as compared to 3-D model.
2. For two mass models, first mode shows time period for convective mode. After first mode, time period for two mass models suddenly decreases. And after first mode the time period is nearly same as that of impulsive mode of one mass model.
3. As the slant height increases the time period of water tank decreases for both 3-D model and two mass models.
4. Two mass models show higher value of base shear and displacement than 3-D model.
5. Two mass model shows lower values of acceleration than 3-D model.
6. Lower the slant inclination higher are the values of all the responses i.e. displacement, base shear and acceleration.
7. Displacement base shear and acceleration shows less value for higher values of slant inclination.
8. 43 degrees is the optimum angle for the flask type water tank.
9. Before 40 degree slant inclination; all the responses shows the significant variation for both the cases i.e. 3-D model and two mass models.
10. And after 40 degree slant inclination; all the responses are nearly same for both the cases i.e. 3-D model and two mass models.
11. From all the slant inclination the reposes are higher for 38 degree slant inclination.
12. The ascending order of responses for different slant inclination is as 25 degrees < 38 degrees < 43 degrees and after 43 degree responses are nearly same.

REFERENCES

[1]. G. W. Housner, The Dynamic Behavior of Water Tanks, Bulletin of the Seismological Society of America, Vol.53, No.2, pp.381-387, Feb1963.

[2]. Durgesh C Rai, (2003) "Performance of Elevated Tanks in Mw 7.7 Bhuj Earthquake of January 26th, 2001" International journal of advanced engineering research Proc. Indian Acad. Sci. (Earth Planet. Sci.), 112, No. 3, September 2003, pp. 421-429

[3]. Pravin B.Waghmare, Atul M. Raghatate & Niraj D.Baraiya "Comparative Performance of Elevated Isolated Liquid Storage Tanks (With Shaft Staging)", International Journal of Advance technology in civil engineering, ISSN:2231-5721, Volume 1, Issue 2-2012.

[4]. Chirag N. Patel, Burhan k. kanjetawala, H. S. Patel "Influence of Frame Type Tapered Staging on Displacement of Elevated Water Tank " GIT-Journal of Engineering and Technology, ISSN 2249 – 6157, Sixth volume, 2013,

[5]. S. C. Duta, S. K. Jain and C. V. R. Murty, "Assessing the seismic torsional vulnerability of elevated tanks with RC frame-type staging", Soil Dynamics and Earthquake Engineering (ELSEVIER), 2000, Vol. 19, pp. 183-197

[6]. S. C. Duta, S. K. Jain and C. V. R. Murty, "Alternate tank staging configurations with reduced torsional vulnerability", Soil Dynamics and Earthquake Engineering (ELSEVIER), 2000, Vol. 19, pp. 199-215

[7]. M. Kalani and S. A. Salpekar, "A comparative study of different methods of analysis for staging of elevated water tanks", Indian Concrete Journal, July-August – 1978, Pg No.210-216.

[8]. S.K. Jain, U.S. Sameer, "Seismic Design of Frame Staging for Elevated Water Tanks", Ninth Symposium on Earthquake Engineering, Roorkee, December 14-16, 1990, Vol.1.

[9]. M. V. Waghmare, S.N.Madhekar "Behaviour of elevated water tank under Sloshing effect" International Journal of Advanced Technology in Civil Engineering, Volume-2, Issue-1, 2013

[10]. S.K.Jain & et al., " proposed provision of aseismic design of a liquid storage tank" , journal of structural engineering,vol 20 no.4 january 1994 pp. 167-175.

[11]. Ayazhussain.M.Jabar, H.S.Patel, "Seismic Behaviour Of RC Elevated Water Tank Under Different Staging Pattern And Earthquake Characteristics", International Journal Of Advanced Engineering Research And Studies, April-June2012.

[12]. Pavan .S. Ekbote, Jagdish Kori, "Seismic Behaviour of RC Elevated Water Tank under Different Types Of staging Pattern", Journal Of Engineering,Computers and Applied Sciences, Volume 2, No.8, August 2013.

[13]. Soheil Soroushnia, Sh. Tavousi Tafreshi, F. Omidinasab, N. Beheshtian, Sajad Soroushnia, "Seismic Performance of RC Elevated Water Tanks with Frame Staging and Exhibition Damage Pattern" The Twelfth East Asia-Pacific Conference on Structural Engineering and Construction, (ELSEVIER) Procedia Engineering 14 (2011) 3076–3087R. K. Ingle, "Proportioning of columns for water tank supporting structures", The Indian Concrete Journal, April – 1999, pp. 255-257.

[14]. .R. Livaoglu, A. Dogangün, “An Investigation about Effects of Supporting Systems on Fluid-Elevated TanksInteraction”, First International Conference on Seismology and Earthquake Engineering (SEE), Turkey, May – 2007
[15]. Durgesh C Rai, (2003) “Performance of Elevated Tanks in Mw 7.7 Bhuj Earthquake of January 26th, 2001” International journal of advanced engineering research Proc. Indian Acad. Sci. (Earth Planet. Sci.), 112, No. 3, September 2003, pp. 421-429
[16]. Gaikwad Madhukar V.1 Prof. Mangulkar Madhuri N.2 “Seismic performance of circular elevated water tank with framed staging system” International Journal of Advanced Research in Engineering and Technology ,Volume 4, Issue 4, May – June (2013)
[17]. Suchita Hirde, Asmita Bajare2,Manoj Hedaoo “Seismic performance of elevated water tanks” International Journal of Advanced Engineering Research and Studies,Vol. I, Issue I, October-December, 2011, Pg No 78-87.
[18]. Chirag N. Patel, H. S. Patel” Supporting systems for reinforced concrete elevated water tanks”, International Journal of Advanced Engineering Research and Studies, Vol. II, Issue I, Oct.-Dec.,2012, pg no-68-71
[19]. Mostafa Masoudi, Sassan Eshghi, Mohsen Ghafory-Ashtiany “Evaluation of response modification factor (R) of elevated concrete tanks”(ELSEVIER) Engineering Structures 39 (2012) Pg. No.199–209.
[20]. Syed Saif Uddin ,” Seismic Analysis Of Liquid Storage Tanks **“**International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.1, Pages : 357 – 362 (2013) Special Issue of ICACSE 2013 - Held on 7-8 January, 2013 in Lords Institute of Engineering and Technology, Hyderabad.
[21]. M. Moslemia, M.R. Kianoush, W. Pogorzelski “Seismic response of liquid-filled elevated tanks” (Elsevier) Engineering Structures 33 (2011) 2074–2084
[22]. IS: 11682-1985, Criteria for Design of RCC Staging For Overhead Tanks (1985), Bureau of Indian Standards, New Delhi.
[23]. IITK-GSDMA Guidelines for Seismic Design of Liquid Storage Tank, 2005, Indian Institute of Technology, Kanpur, India.