SUITABILITY OF FEMA METHOD FOR DYNAMIC ANALYSIS OF WATER TANK

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Abstract: It is well recognized that liquid tanks possess low ductility and energy absorbing capacity as compared to the conventional buildings. Seismic safety of liquid storage tanks is of considerable importance. As known from very upsetting experiences, elevated water tanks were heavily damages or collapsed during earthquake Due to the fluid-structure interactions, the seismic behaviour of elevated tanks has the characteristics of complex phenomena. Water storage tanks should remain functional in the post earthquake period to ensure potable water supply to earthquake affected regions. The main aim of this study is to analysis the Elevated Circular Liquid Storage Tank by using Response spectrum method (IS 1893 method) and Displacement Coefficient method (FEMA method).The results obtained by these methods will be compared and suitability of these methods will be checked according to various factors.

Keywords: Elevated Water Tank, Fluid-Structure Interactions.

1. INTRODUCTION

Water is human basic needs for daily life. Sufficient water distribution depends on design of a water tank in certain area. An elevated water tank is a large water storage container constructed for the purpose of holding water supply at certain height to pressurize the water distribution system. Many new ideas and innovation has been made for the storage of water and other liquid materials in different forms and fashions. There are many different ways for the storage of liquid such as underground, ground supported, elevated etc. 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. 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. So there is need to focus on seismic safety of lifeline structure using with respect to alternate supporting system which are safe during earthquake and also take more design forces.

In this work, Response Spectrum Method (IS1893 method) and Displacement Coefficient method (FEMA method) are used for analysis the seismic responses of the elevated RCC liquid storage tanks and the results obtained are compared with the results obtained by computational analysis.

2. LITERATURE REVIEW

[1]Butterworth and Heinemann, Earthquakes represent an external hazard for industrial plants and may trigger accidents, i.e. fire and explosions resulting in injury to people and to near field equipments or constructions, if structural failures result in release of hazardous material. Quantitative Risk Analysis (QRA).

[2] A. I. Algreane, Siti Aminah Osman Othman A. Karim, This paper is concerned with the soil and water behavior of elevated concrete water tank under seismic load. An artificial seismic excitation has been generated according to Gasparini and Vanmarcke approach, at the bedrock, and then consideration of the seismic excitation based on one dimension nonlinear local site has been carried out. Seven cases are chosen to make comparisons with direct nonlinear dynamic analysis, mechanical models with and without soil structure interaction (SSI) for single degree of freedom (SDOF), two degree of freedom (2DOF), and finite elements method (FEM) models. The analysis is based on superposition modal dynamic analysis. SSI and fluid structure interaction (FSI) have been accounted using direct approach and added mass approach respectively.

[3] Kianoush, M. R., Mirzabozorg, H. and Ghaemian, M. (2006), The added mass in terms of impulsive pressure is assumed rigidly connected to the tank wall and the added mass in terms of convective pressure is assumed connected to the tank wall using flexible springs to simulate the effect of sloshing motion. In this model, the boundary condition in the calculation of hydrodynamic pressures is treated as rigid.

3. SCOPE OF THE STUDY

In this work various methods of Dynamic analysis of water tank are studied.

The aim is to analysis this tank by using following methods.

1. Response spectrum method (IS 1893 method)
2. Displacement Coefficient method (FEMA method)
3. Computational analysis

Following are the main focus of this study.

Obtaining the results by various methods above stated and comparing the results obtained by various methods. To determine the stresses, displacement of water tank due to dynamic effects.

4. METHODOLOGY

4.1Dynamic analysis by response spectrum method (IS-1893 method)

Indian standard IS 1893-1984 provides guidelines for earthquake resistant design of several types of structures including liquid storage tanks. This standard is revised. In the fifth revision IS 1893 has been split into following five parts: Part 1: General provisions and buildings ,Part 2: Liquid retaining tanks, Part 3: Bridges and retaining walls, Part 4: Industrial structures including stack like structures, Part 5: Dams and embankments

IS 1893 suggests two different methods of analysis of liquid storage tanks. In the present study Response spectrum method is proposed to used for the dynamic analysis of elevated RCC liquid storage tank.

4.2 Displacement Coefficient Method (FEMA method)

Nonlinear static procedures are one type of inelastic analysis that can be used to estimate the response of structures to seismic ground shaking. The differences among the various approaches to inelastic analysis in general relate to the level of detail of the structural model and the characterization of the seismic ground shaking. Detailed structural models can often be simplified into equivalent multi-degree-of-freedom models; or, in some cases, single-degree-of-freedom oscillator models, as with nonlinear static procedures. The most detailed characterizations of seismic ground motion are actual ground motion records that comprise accelerations, velocities, and displacements expected at the ground surface at a specific site. A simplification can be made by representing the effects ground motion has in the frequency domain with response spectra that plot maximum response of an elastic SDOF oscillator as a function of period. This is the type of characterization normally used for nonlinear static procedures. The discussion in this part includes basic descriptions of the two nonlinear static procedures that are currently used in practice. FEMA 356 uses a displacement modification procedures (Coefficient Method) in which several empirically derived factors are used to modify the response of a single-degree-of-freedom model of the structure, assuming that it remains elastic. The alternative Capacity-Spectrum Method of ATC-40 is actually a form of equivalent linearization. This technique uses empirically derived relationships for the effective period and damping as a function of ductility to estimate the response of an equivalent linear SDOF oscillator.

5. DYNAMIC ANALYSIS OF LIQUID STORAGE TANKS

Problem description

A RCC circular water tank of 50 m^3 capacities having following properties is selected for this study.

Internal diameter = 4.65 m, Height of circular water tank = 3.3 m (including freeboard of 0.3 m),Lowest water level = 12 m above ground level, Density of concrete = 25 kN/m^3;Grade of concrete = M25 ,Grade of steel = Fe 415.It is supported on RC staging consisting of 4 columns of 450 mm diameter with horizontal bracings of 300 x 450 mm at four levels. Staging conforms to ductile detailing as per IS13920. Staging columns have isolated rectangular footings at a depth of 2m from ground level. Tank is located on soft soil in seismic zone II.

5.1 Dynamic Analysis By Response Spectrum Method (IS1893 METHOD)

Tank must be analyzed for tank full and empty conditions.

Member Ductility Capacity

Plastic Displacement,

$$\Delta_p = \left(\frac{M_u}{M_n} - 1\right)\Delta_y + L_p(\phi_u - \phi_y)\left(L - 0.5L_p\right)$$

= (1130/883 -1) 0.002727+ (1.16 x 0.000471446) (11.663 – 0.5x 1.16) **= 0.00682 m**

Therefore, Ultimate Displacement Δu = Δy + Δp **= 9.547 mm**

5.2 Dynamic Analysis by Displacement Coefficient Method (FEMA Method)

The analysis procedure is based upon nonlinear static procedures. Both the coefficient method of FEMA 356 and the capacity spectrum method of ATC 40 are used to estimate the displacement.

Data:

Elevated RCC water tank	– FEMA model building type C2
Total height of structure	– 17m
Plan Dimensions	– 3430 mm x3430 mm c/c
Dead load intensity	– 25 KN/m^3
Vertical support	– Concrete columns 4 nos.
Lateral supports	– Bracings at four levels as shown.
Foundations	– Spread foundation
Soil condition	– soft soil having SBC as 150 KN/m^2
Ground Motion	– Shaking with 10% chances being exceed in 50 years
Analysis objective	– Maximum global displacement for specified ground motion.

Select ground motion spectrum Site class C and shear wave velocity V_s=1200 fps

Acceleration parameters for MCE shaking. Short period S_s= 1.5g,Long period S_l = 0.6g;Damping coefficient B_s = 1.0 ,B_l = 1.0, Adjustment for site class C .Short period=Fa S_S= 1x1.5g=1.5g

Long period= F_vS_l =1.3x 0.6g=0.78g ,To reduce the level motions, multiply accelerations by 2/3

Short period	S_{DS}= 2/3 S_S	= 1.00g
Long period	S_{DL} = 2/3 S_L	= 0.52g

Modified Kinematic soil structure interaction

Effective foundation size ,a= 3430 mm, b =3430 mm ,Embedment e = 0 (As no basement) ,RRS_e =1.0, $b_a = \sqrt{ab}$ =3430 mm, Ratio of Response spectra for base slab averaging

$RRS_{bsa} = 1 - \frac{1}{14100}\left(\frac{b_e}{T}\right)^{1.2} \geq$ the value for T =0.2 sec Foundation input motion (FIM)

$(S_a)_{FIM} = RRS_{bsa} RRS_e (S_a)_{FIM}$

Check for effective post elastic stiffness

$$\alpha_e = \alpha_{p-\Delta} + \lambda(\alpha_2 - \alpha_{p-\Delta})$$

Where

λ = 0.8 near field

0.2 non near field Assuming $\alpha_{p-\Delta}$ = 0 and α_2 = -25% α_e = -20% near field -5% non near field

Check minimum strength

$R_{\max} = \frac{\Delta_d}{\Delta_y} + \frac{|\alpha_e|^{-t}}{4}$,Where t= 1+0.15InT = 0.76, R_{max} = 1.85 near field 3.42 non near field

Non strength degrading valuation assumption

$R = \frac{S_a}{V_y/W} C_m = 1.56$,C_o=1.22, $C_1 = 1 + \frac{R-1}{aT_e^2}$ =1.16 , Where a = 90 for site class C , $C_2 = 1 + \frac{1}{800}\left(\frac{R-1}{T_e}\right)^2 = 1.01$ **Calculate target displacement** $\delta_t = C_0 C_1 C_2 S_a \frac{T_e^2}{4\pi^2} g$ = 0.008879m = **8.879mm**

6. CONCLUSIONS

The water tank is analyzed by following methods

1. Dynamic analysis by IS 1893 (2002) method 2. Dynamic analysis by FEMA Method (Displacement coefficient method)

Here in this work the main focus was giving the dynamic analysis by IS1893-2002, FEMA Method (Displacement coefficient method) .In dynamic analysis by IS 1893 method, since total base shear (60 kN) and base moment (931 kN-m) in tank full condition are more than that total base shear (50 kN) and base moment (760 kN-m) in tank empty condition, design will be governed by tank full condition. The maximum displacement by capacity based approach in IS 1893 method is **9.547 mm.**

In dynamic analysis by FEMA Method (Displacement coefficient method), the target displacement for the positive post-elastic stiffness model is calculated using the displacement modification. The procedure is the Coefficient Method of FEMA 356 modified with the suggested changes for the coefficients *C*1 and *C*2. The coefficient *C*2 is included in the calculation since a concrete structure is likely to have stiffness degradation. Note that the solution for maximum displacement for the strength-degrading model (near and non-near field) would be the same, since the displacement-modification procedure does not directly consider negative post-elastic stiffness in the calculation of the coefficients. The maximum displacement by Displacement Coefficient method is **8.879mm.** The solutions for the positive post elastic-stiffness model are essentially equivalent for displacement modification and equivalent linearization.

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IS codes

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[6] 1893 (Part 1): 2002 Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings

[7] 3370: 1967 Code of Practice for Concrete Structures for the Storage of Liquids