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Water Tank Seismic Analysis Noting Effect on Time Period

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Abstract: In the case of an earthquake, an elevated water tank is a crucial building component. In order to store water at a constant level, an elevated water tank is built and height for water distribution system pressurization. Uplifted water tanks, as was learned the hard way, suffered significant damage or collapsed during earthquakes. As a result of the raised water tanks' extreme sensitivity to earthquake parameters including peak ground acceleration, frequency contents, and duration records. The purpose of this study is to gain insight into the dynamic behavior of an elevated water tank fitted with a UG sump subjected to various recorded ground vibrations from earthquakes. An RCC square water tank with 14-, 17-, and 20-meter staging heights was subjected to a Time History Analysis using StaadPro software to simulate the effects of five distinct seismic ground movements. Roof displacement, velocity, acceleration, base shear, drift, and natural frequency were measured and compared for three different tank fill levels: empty, halfway, and full. Bhuj earthquake ground motion was the strongest, whereas Kobe earthquake ground motion was the weakest.

Keywords: Elevated water tank, Time history Analysis, Water filling conditions, Seismic Response

Introduction

Much like food and oxygen, water is essential to a living organism's survival. The raised water storage tank was built for the purpose of storing water at a certain altitude in order to pressurize the water supply. Water, flammable liquids, and other chemicals are often stored in liquid storage tanks by municipalities and businesses. Cylindrical, square, rectangular, and toroidal shapes are all common for raised tanks. Several kinds of support systems, such as RC shafts, RC braced frames, steel frames, and masonry pedestals, are used to hold up these raised tanks. The frame style is the most common when it comes to actual production staging.[1] The major features of the frame style of staging are the columns and braces. After an earthquake, the water delivery system as a whole should still work, including the water storage tanks. When it comes to casualties and material damage, earthquakes are far and away the worst natural disaster there is. Because of the great bulk of the tank and the concentration of water at a height from the base, water tanks are very vulnerable to earthquake loading and suffer severe damage from the trembling of the ground. Seismic waves, which carry the vast majority of the energy generated by this phenomena, travel all the way from the point of origin to the water tank, where they may have a variety of effects according to their Peak ground acceleration, frequency contents, and effective duration of the ground motion[2].

Damage to high water tanks during earthquakes may threaten the safety of drinking water supplies, lead to the inability to prevent catastrophic fires, and result in significant economic

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loss.As elevated tanks are often utilized in seismic zones as well, it is crucial to examine earthquake loading as a non-stationary process and conduct thorough research into their seismic behavior. Several of the high tanks suffered significant damage or collapsed because of inadequate support[3]**.**

In order to meet the demand for water in the aftermath of an earthquake, it is crucial that water tanks stay operational throughout the tremor. The water storage capacity of the ground-supported tank has been extensively used. The foundation slab and tank walls are the primary components of a ground-supported tank. The foundation slab is not a significant part since the tank is sitting on stable ground; thus, just nominal reinforcing and nominal steel are required; nonetheless, the tank walls need careful analysis. Tank walls and liquid are susceptible to horizontal acceleration when horizontal earthquake ground motion is applied to a tank holding free-surface liquid. The liquid at the bottom of the tank acts as a solid mass that is fixed to the tank's interior. As this mass of liquid accelerates with the tank's walls, it exerts a force on the tank's walls and floor known as impulsive hydrodynamic pressure. There is a sloshing action in the top part of the tank where the liquid is. This mass, known as the convective liquid mass, presses on the tank's walls and floor via hydrodynamic forces. As a result, the entire mass of the liquid is partitioned into two categories: the impulsive mass and the convective mass[4-7].

Tank Systems

The value of water as a heavenly blessing is increasingly recognized. In semiarid regions, tanks are an essential tool for preserving scarce water supplies. Natural or artificial, a tank is a reservoir that collects surface runoff by the use of a basic earthen building. Traditional, decentralized irrigation methods that make use of tanks are highly valued. In addition to its use in irrigation, tanks benefit the environment by allowing water to percolate and replenishing aquifers. Moreover, it is a tool for managing drought and preventing flooding. Tanks not only replenish groundwater supplies, but also supply water for a wide variety of other uses, such as fish farming, silt for fertilization, animal and duck raising, washing, bathing, drinking, foraging, fuel wood gathering, vegetable and tree planting, and even clay for pottery. The tank's day-long usage for a wide range of functions meant that it was never really separate from the way of life of the people who inhabited it[8].

The size of the control room and the kind of augmentation water used are the two main criteria by which tanks are categorized. System tanks and non-system tanks are the two main categories[9]. Water is pumped into system tanks from local sources significant external sources, such as other water systems' catchments or reservoirs.

They help farmers succeed in growing more than one crop often. Single crops are often grown in nonsystem tanks since they are not linked to the river system and must rely on the rainfall in their own catchment region. Upper and lower tanks in the shape of a cascade are commonly created by connecting non-system tanks with the other tanks. The top tanks' excess water will trickle down to the lower tanks during times of severe rainfall. Because to its extra water sources, system tanks have a lower command to catchment area ratio than non-

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system tanks, which may range from 1:2 to 1:5. Nevertheless, this ratio can be as high as 1:15 in areas with poor rainfall[10].

Tanks are also categorised depending on the size of command area and the nature of control. Typically, the tanks after standardizing are classed as major and minor tanks. Large tanks irrigate more than 80 acres of land and small tanks irrigate less than 80 hectares. Yet, the maintenance responsibility sis based on a separate size categorization. Tanks irrigating more than 40 ha are the duty of the PWD while the tanks irrigating less than 40 ha are the \responsibility of the Panchayat (local office) Unions

Literature Review

Hitesh Kumar *et.al* (2021) The effect of soil-structure interaction (SSI) on the seismic performance of elevated water storage tanks is studied. Peak seismic responses and the seismic fragility of elevated tanks are discussed after taking SSI into account. In this analysis, we take into account a spectrum of soil stiffness, from very soft soil to extremely hard rock. Also, the seismic enhancement capabilities of raised liquid storage tanks that use a base isolation strategy are assessed. Also, the impacts of several characteristics on the seismic behaviour of raised tanks are investigated. These elements include the tank's slenderness ratio, the staging's stiffness, and the isolator's natural period. Both the peak reactions and seismic fragility of the raised tanks are analyzed for two distinct versions of the base isolation system: (1) an isolator between the staging and the foundation, and (2) an isolator between the tank and the staging. The current research demonstrates that soil stiffness and staging stiffness are critical factors in determining the seismic vulnerability of tank structures. Moreover, the isolation system is proven to be helpful in improving overall seismic behavior of the elevated liquid storage tanks regardless of the arrangement.

Sourabh Vern et.al (2021) For bidirectional earthquake excitations, the effectiveness of vertical baffles as that of the passive management in liquid storage tanks (LSTs) to dampen seismic responses was studied. The optimal linked configuration of baffles in the LSTs was determined after considering a number of different baffle layouts. The effect of several characteristics, such as earthquake type, maximum horizontal acceleration (PGA), and angle of impact, on the optimal baffle layout was investigated. Two LSTs made of flexible concrete (6x6x4.8 and 12x6x4.8 m) and filled with water (3.6 m) were used in a numerical analysis. Base shear, overturning force, top-board movement, hemodynamic pressure, and sloshing height were some of the measured responses. The study found that (1) the sloshing height can be reduced by as much as 70% with the right baffle arrangement; (2) the type of quake does have some significant effect on response reductions; and (3) both PGA and the incidence angle of earthquakes have moderate effects on response reductions**.**

Carl Bernier et.al (2020) Despite the overwhelming evidence of debris-induced damage during prior severe storms, probabilistic models are still insufficient to estimate the susceptibility of terrestrial storage tanks (ASTs) exposed to aqueous debris impacts during storm surge occurrences. This study fills a knowledge gap by generating simulink fragility models and an accompanying risk assessment methodology for probabilistic performance

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evaluation of ASTs exposed to waterborne debris such as shipping containers. To begin, we create bounded models of ASTs and a shipping container so that we can analyze the effect of debris and determine the extent of any damage that may occur. Statistical sampling, debris impact analysis findings, and logistic regression are used to generate parametrized fragility models. Two damage processes, inelastic tank shell damage and sliding, are modeled for fragility. Finally, the paper proposes a risk assessment methodology to calculate the odds of an AST being hit by debris and shows how the obtained fragility models may be used to gauge and lessen the exposure of ASTs in manufacturing hubs. A case study of a storage tank terminal is used to demonstrate the framework. The results of the fragility and risk analyses show that big ASTs are more resilient to debris effects than small ones, and that ignoring debris impacts for ASTs situated near possible debris sources might dramatically understate the vulnerability of ASTs during storm surge occurrences.

Ram K. Mazumder et.al.,(2020) Corrosion and the gradual erosion of buried water pipes make them susceptible to damage from natural disasters (e.g., earthquakes). Water distribution systems have been disrupted in the past due to seismic damage sustained by corroded metallic subterranean pipes (WDS). Fires caused by earthquakes need a steady supply of water, which is why a reliable water supply is essential. Thus, it is crucial that both the water service provider and the communities they serve evaluate the WDS's functioning and the restoration of its service following an earthquake. This research proposes a paradigm for assessing the seismic risk and resilience of WDS at both the component and system levels while accounting for the time-varying corrosion of pipes. Using a modified version of the American Lifelines Alliance (ALA) pipeline vulnerability functions that takes corrosion strength loss into account explicitly, we estimate the vulnerability of individual pipelines. A functionality curve is used to represent resilience, which shows the relationship between the likelihood of a system failing and the amount of time spent fixing it. By combining the fragility curves with the restoration functions, a probabilistic functionally fragility surface (FFS) is created for the system and its constituent parts. Two fictitious water networks, one on the small scale and one on the medium size, are used to illustrate the utility of the suggested framework. The form of the FFS is significantly affected by the restoration procedure, as shown by the findings of the two case histories. Key elements that affect the form of the FFS include the time to repair the break, the amount of breaks, the topology of the network, the extent of oxidation, and the resources available of utility companies. It has also been shown that the amount of disruptions in older and more extensive WDS networks greatly reduces their robustness. Asset management for WDS vulnerable to seismic risks may benefit greatly from the suggested approach**.**

Seismic Performances of Overhead Water Tanks

Maximum seismic response quantities, including structural displacement, velocity, and acceleration, plotted against NTP form what is known as the response spectrum. There are often three distinct areas. There are three types of sensitive areas: those attuned to acceleration, those attuned to velocity, and those attuned to displacement. The acceleration response is expected to be much larger than the other two in the acceleration-sensitive zone. The acceleration-sensitive area of the response spectrum occurs at shorter NTP durations,

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whereas the displacement-sensitive region occurs at longer NTP durations. The velocity-sensitive zone lies between these two zones. The seismic properties of a structure exposed to ground acceleration caused by an earthquake cannot be calculated using the standard analytical technique since ground acceleration fluctuates arbitrarily with regard to time. So, one might use any of the many available alternatives, including some of the most popular time-stepping approaches, i.e. numerical methods. Time-stepping processes may be divided into three categories: those that rely on finite difference expressions of velocity and acceleration, those that assume a constant acceleration, and those that interpolate the excitation function. Newmark's approach, which is based on the assumed fluctuation in acceleration, is found to be the most accurate of the numerical methods considered, hence it is used for the project. Both linear and nonlinear systems benefit from Newmark's technique.

Calculation of Linear Seismic Performances of OverheadWater Tanks

Here are detailed procedures for determining the overhead water tank 8's dynamic parameters, including its mass, stiffness, natural frequencies, and natural time periods. All other tanks' dynamic features have also been determined. The density of water and the density of reinforced concrete are measured in as 25 kN/m3 and 9.81 kN/m3 respectively

Table 1. Structural properties of overhead water tanks

Sl. No	Structural Properties	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
1.	Capacity (m^3)	105.8	223.2	429.4	522.4	693.6	764.4	846.7	989.6
2.	No of columns	7	13	17	31	21	21	21	31
3.	W_w(kN)	1038.5	2190.36	4212.8	5125.3	6804.8	7500.0	8306.4	9708.3
4.	W_c (kN)	677.38	1536.56	2845.9	7847.8	4494.9	5230.9	6093.6	7223.6
5.	W_s(kN)	748.04	1333.02	2022.0	4321.1	3098.8	3390.2	3648.0	4122.9
6.	$W_c + W_s/3$ (kN)	926.73	1930.90	3519.8	9288.1	5527.8	6360.9	7309.5	8597.8
7.	h_{cg}^{*} (m)	0.778	0.865	0.802	0.891	0.461	0.634	0.56	0.923
8.	m_i (tonne)	45.52	94.89	133.1	121.8	166.4	178.3	194.7	227.6
9.	m_c(tonne)	55.05	120.5	279.1	378.7	492.5	554.2	619.8	712.5
10.	h_i(m)	1.125	1.331	1.331	1.528	1.340	1.340	1.340	1.528
11	h_i^* (m)	2.7	3.771	5.325	8.404	6.703	7.373	7.373	7.742
12.	h_c(m)	1.8	1.996	1.952	2.241	2.002	1.966	1.894	2.200
13.	h_c^*(m)	2.625	3.372	5.325	9.168	7.596	8.043	8.222	8.659
14.	h_s(m)	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7
15.	h_{cg}(m)	16.47	16.56	16.50	16.59	16.16	16.33	16.26	16.62

The different structural parameters, such as tank capacity, lateral stiffness, and masses, are shown in Table 1

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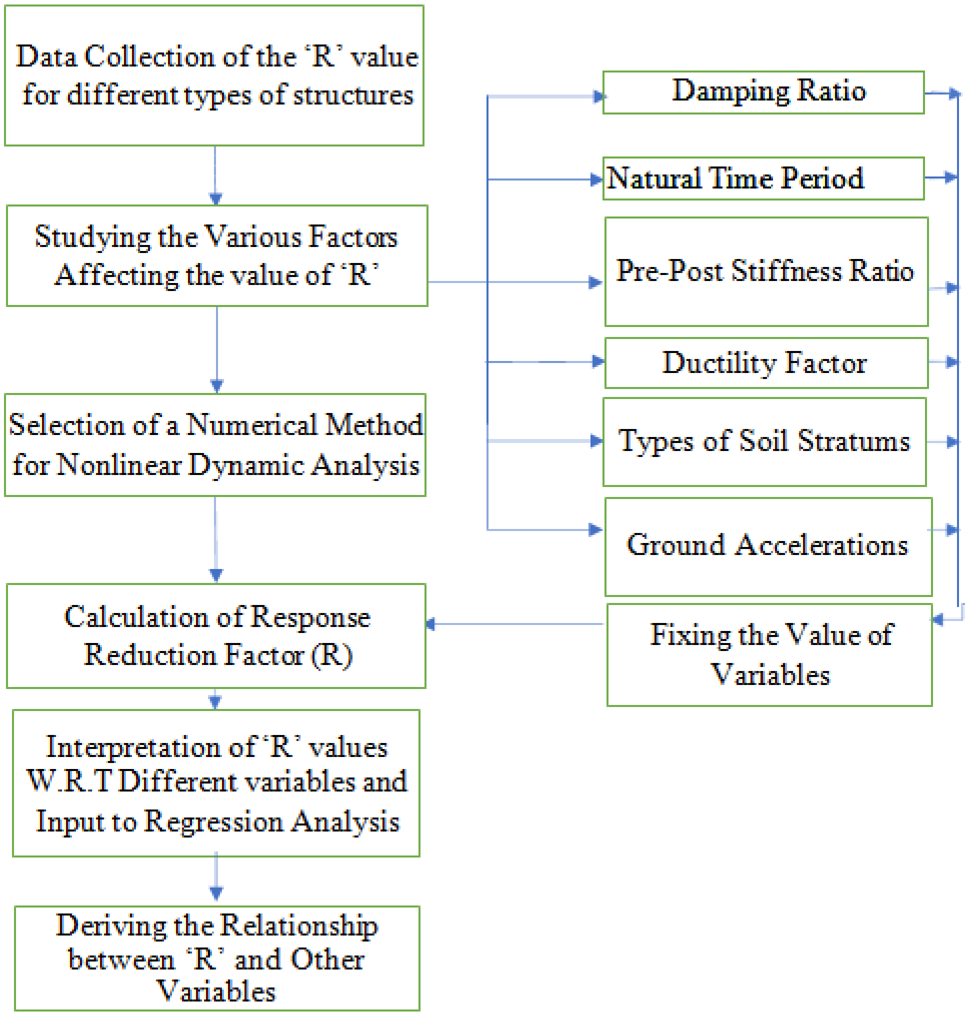

Figure 2. Procedure in arriving response reduction factor for overhead water tanks

It's common knowledge that buildings' seismic performances are negatively impacted by ground movement and settlement. As a result, while doing seismic analysis, it is crucial to include a representation of the foundation alongside the structural model. It's important to keep in mind that the foundation's behavior varies depending on the geotechnical and structural features of the underlying materials. In the case of distributed footing, the soil is represented by geotechnical elements with appropriate force-displacement qualities, while the footing itself is a rigid plate of concrete. Modeling geotechnical components is similar to modeling structural components in that the primary goal is to establish a correlation between the applied load and the resulting displacement. In terms of the load-displacement connection of the geotechnical components, it is well-known that the strength and stiffness of the soil materials play a role. Assumptions often used in the study of traditional structural modeling are also used in the analysis of the modeling of SSI's impacts.The method proposed is mostly based on finite element analysis, and key locations are highlighted to show where the continuous qualities are concentrated. The inelastic behavior of each finite element is taken

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into account directly to calculate hysteretic performance.Viscous damping is disregarded because of the low energy dissipation of soil materials.

The kinematic effects of SSI are ignored in the technique. .

Notwithstanding the above caveats, if shortened inelastic processes of the technique are used, they are conservative for practically all types of buildings and foundations**.**

Basic Structural System

The impacts of earthquake ground accelerations on building foundations are often more noticeable in taller structures. On the other hand, buildings of the short variety and multi-bay moment resistant frames may safely disregard it. It should also be noted that structures with a basic NTP in the range of 0.3 sec to 1.0 sec are more susceptible to foundation effects than those with a higher NTP. The impact of the foundation on various building types is shown in Table 2.

Table 2 Sensitivity of structural systems to the effects of foundation

Type of structures	Aspect ratio	Relative sensitivity to foundation movement
Slender frame		High
Slender bearing frame	$h/l > 2 \pm$	
Narrow frame		
Short frame		Moderate
Short bearing frame	$h/l > 2 \pm$	
Long frame		Low

Properties of Geotechnical Components

The models of the foundational elements rely heavily on the strength and stiffness behavior of the soil components, which are defined by the properties of geotechnical components. Because of these characteristics, the inelastic load-displacement envelopes seen in Figure 3 may be constructed**.**

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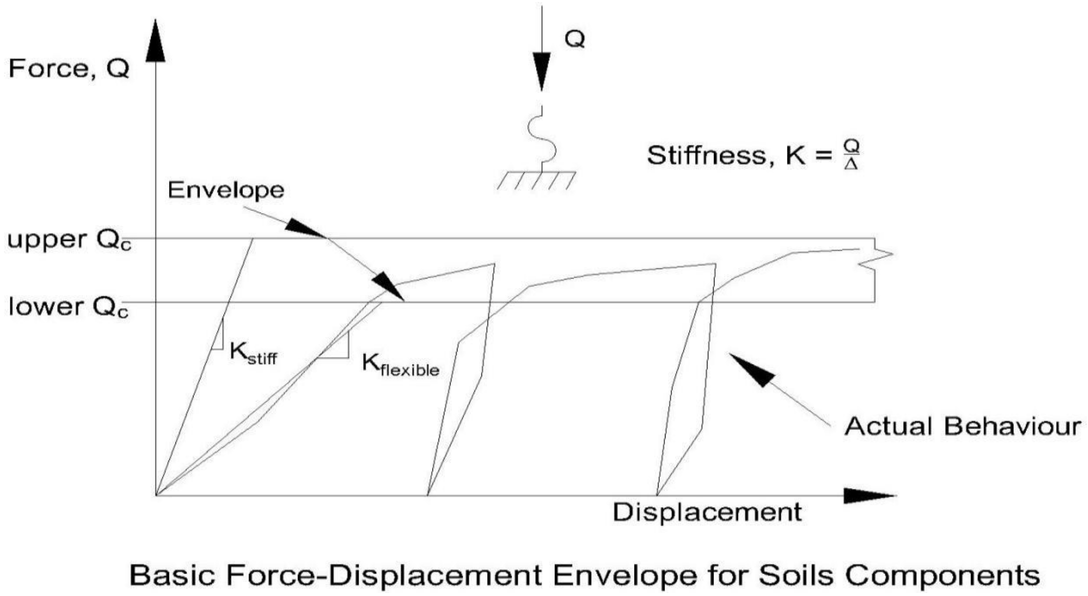

Figure 3. Basic Force-Displacement envelope for soil components

Models of Overhead Water Tanks

Figure 4 depicts a model for studying the above water tanks with a fixed basis and soft soil, whereas Figure 5 depicts a model with a fixed base and hard soil.

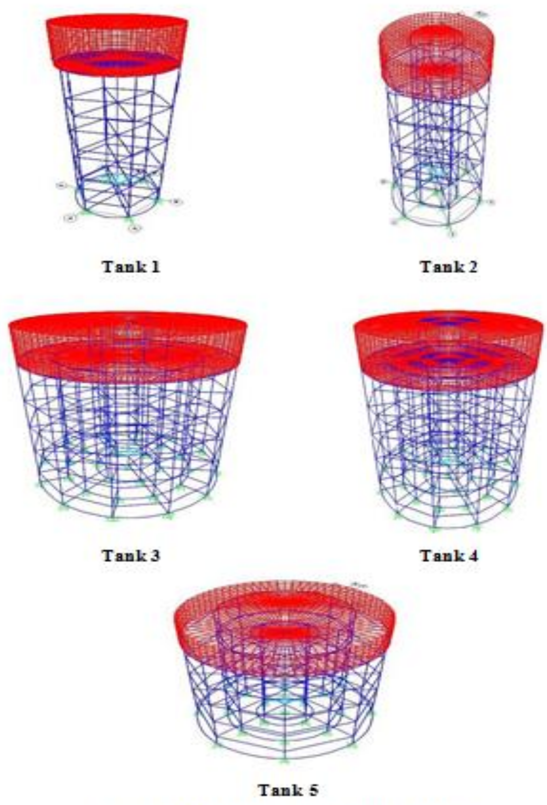

Figure 4. Models of overhead water tanks

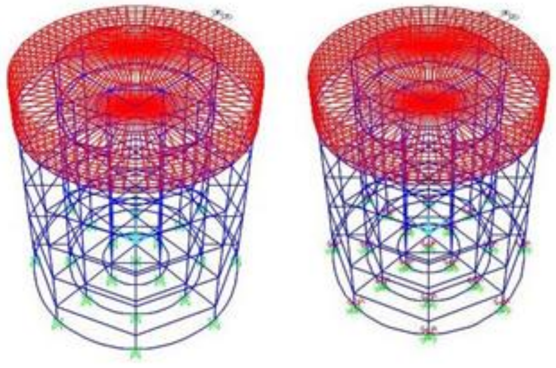

Figure 5 Model of tank 5 with a fixed base and hard soil stiffnesses

Conclusion

The roof displacement grows in proportion to the staging height. When the magnitude of an earthquake is amplified, the roof displacement diminishes dramatically.Base shear's reaction weakens as the earthquake's moment magnitude (PGA) rises.The tank responses such as roof displacement, velocity, acceleration, base shear, elemental moments are highly scattered, indicating that the structure is highly influenced by the characteristics of earthquake records. The critical response of the elevated water tanks does, not always happen in full tank condition and increases with the staging height of the tank**.**

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