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Cementitious Laminates for Calculating Seismic Strengthening of Beam–Column Joint

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ABSTRACT
This research mainly deals with study of seismic performance of circular shaped overhead water tanks (OWTs) made of concrete material. Out of the two types of staging provided for OWTs, framed staging is considered. Moreover, the performances of OWTs resting on different soil strata such as hard soil, medium soil, and soft soil are taken into consideration in addition to the OWTs with fixed base. Initially, to understand the seismic performance, eight tanks of different storage capacities have been studied. Since there is no specification for seismic analysis of overhead water tanks in the Indian code IS1893 (part 1):2016, the guidelines 'Indian Institute of Technology Kanpur- Gujarat State Disaster Management Act' (IITK-GSDMA) has been adopted for seismic analysis of OWT. It provides guidelines for structural idealisation of tanks for both empty and full conditions. It idealise the filled OWT as two degree of freedom system and they are impulsive and convective mode.

INTRODUCTION

This deals with the basics of overhead water tanks, their types, guidelines available for their seismic analysis, and enhancing theirearthquake resistance. It also consists of a brief literature review on thepresent work.

GENERAL

Overhead water tanks (OWTs) are very essential for storing drinking water in the public distribution system and storing chemicals in the case of industries. Giving importance to the dynamic analysis of OWTs started after the occurrence of Chilean earthquakes in the year 1960. Since therequirement of water after the occurrence of an earthquake is an urgent need, the main job of the earthquake engineer is to ensure that water tanks are functional even after the occurrence of the earthquakes, failing which leads to big problems. Water tanks are classified into two types according to the type of staging used. They are shell tubular and framed structures. This research is focused on framed staging tanks.

The configuration of OWT resembles the performance of the cantilever beam. As the mammoth amount of mass is lumped at the top of the slender staging system, mainly filled water tanks, OWTs are highly susceptible to horizontal loads mainly due to earthquakes. There are two types of motions normally taking place in OWTs during an earthquake. The firstone is the motion of water stored with respect to the tank wall and another oneis the motion of the water tank as a whole with respect to the ground level. These motions induce the dynamic forces from the bottom to the top of the OWTs. Poor construction, heavy gravity load compared to conventional buildings, and improper design detailing leave the water tanks with minor cracks to Catastrophe of tanks.

METHODOLOGY

Methods of Dynamic Analysis

Generally, two methods are available to do the dynamic analysis ofa structure and they are Time history analysis is one of the methods available to calculate the seismic performances of a structure at every increment of time interval (Δt) when the base of the structure is subjected to a particular ground acceleration time history.
The response spectrum method is a desirable one compared to others. The adoption of the Response spectrum is the core of the response spectrum method. It is of two types, namely elastic and inelastic response spectrum. The response spectrum is defined as the graphical representation of maximum response quantities, i.e., displacement, velocity, and acceleration, of a single degree of freedom system subjected to ground excitation due to an earthquake against the NTP (T_n) or Natural Frequency (ω_n). Out of the various factors, namely Source Mechanism, Epi-Central Distance, Focal Depth, Geological Conditions, Richter

Magnitude, Soil Conditions, and Damping Ratio (ζ), affecting the response spectrum, (Anil 2012, Ray 1993) nowadays design response spectrum curves are specified only by two parameters, i.e., soil conditions and damping ratio and it is shown in Figure 1.5. An EDRS is mainly intended for designing a new structure or to evaluate the safety level of the existing structures in resisting future earthquakes.

LITERATURE REVIEW

The seismic performances of OWTs are very extensively investigated by many researchers experimentally as well as analytically.

The dynamic responses of the OWTs due to ground accelerations may either be linear or nonlinear based on its Peak Ground Acceleration (PGA). The response reduction factor is the factor by which the actual base shear force, which would be generated if the structure were to remain elastic during its response to the DBE shaking, shall be reduced to obtain the design lateral force. Later on, knowledge of inelastic response spectra, reduction factor, and its determination of the SDOF system was collected.

Housner (1963a, b), Veletsos (1984), Priestley*et al.* (1986) gave a simplified dynamic analysis procedure. Pouyan *et al.* (2017) developed a new analytical method to find out the natural frequencies of OWTs using the configuration of the equivalent mass-spring model. It also showed that the fluid-structure-soil interaction influences the natural periods mainly on soft soil.

Dutta (2000) highlighted the importance of the problem of repetition of torsional failure of overhead water tanks in past earthquakes, mainly 1952 Kern County and recent 1993 Killari earthquakes. It was found out that the susceptibility of the OWT to this torsion-induced rotation might have amplified when the ratio of torsional to lateral natural period was approximately equal to unity. Moreover, if the ratio was within the critical range of 0.7 to 1.25, coupled lateral-torsional vibration would lead to the amplified displacement of structural elements. Closed-form expressions were also derived for calculating the base shear and base moment of beams as well as columns subjected to torsion and lateral force. These expressions were also used to observe that the framed stagings, designed mainly for resisting the lateral seismic force, might yield in such a way that plastic hinges were formed simultaneously in all columns leaving beams, if they are subjected to large rotational response and having the ratio close to unity. Such a yielding pattern would pave the way for the OWTs to be collapsed suddenly by forming a mechanism. Therefore, it was found out that torsional coupling is the main cause of failure for OWTs.

Borzia *et al. (*2001) recognized that displacement-based seismic design is a potentially lucid approach compared to forced-based practices. A well-controlled ground excitation due to an earthquake was considered to construct the inelastic displacement response spectra. The response reduction factors of displacement and the relationship between ductility and damping had been derived from the spectra constructed.

Luis *et al. (*2003) established the displacement demand, in terms ofsoil type, source to site distance, and magnitude, of SDOF systems from the elastic and inelastic displacement response spectra of an ensemble of ground accelerations due to various earthquakes. Finally, the relationship, inelastic displacement ratio made with soil condition, displacement ductility, and period of vibration, had been proposed

RESULTS AND DISCUSSION

GROUND ACCELERATIONS

Ground accelerations are selected based on the peak ground parameters, i.e, Gopeshwar and Bhatwari are having maximum PGA and theirvalues are 0.36 g and 0.253 g respectively. Ummulong and Mawphlang are having maximum peak ground displacement, i.e., 3084.722 mm and 2103.986 mm respectively. Bhuj is having peak value in all three formats and its PGA, PGV and PGD are 0.106 g, 450.9 mm/sec, and 2982.303 mm respectively. Ghansiali is identified as medium ground acceleration and its value is 0.118 g. The response spectrum of displacement, velocity, and acceleration are readily constructed for the six ground accelerations selected using prism software andit is accompanied by EDRS of the IS 1893:(part 1) 2016). Prism software is based on the Newmark β average acceleration method, i.e., (The manual calculation of seismic responses show the peak values of structural displacement, velocity, and acceleration of the tank 1 of NTP of 2. 9 sec for the damping ratio of 5% due to the Gopeshwar ground acceleration as -167.30077 mm at 7.06 sec, 467.77103 mm/sec at 4.84 sec, and 0.08078 g at 7.02 sec respectively. The acceleration response spectrum is normalized by dividing it by peak ground acceleration and it is along with the Displacement response spectrum is shown in Figure 4.1(a)-(b). The acceleration response spectrum is used for determining dynamic response(Sa/g) of OWTs and the displacement response spectrum is used for knowing

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