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Review Study on Comparison between Static and Dynamic Analysis of RCC Water Tank

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Abstract- The main object of this paper is, to compare the Static and Dynamic analysis of elevated water tank, to study the dynamic response of elevated water tank by both the methods, to study the hydrodynamic effect on elevated water tank, to compare the effects of Impulsive and Convective pressure results. From detail study and analysis it was found that, for same capacity, same geometry, same height, with same staging system, with same Importance factor & Response reduction factor, in the same Zone; response by equivalent static method to dynamic method differ considerably. Even if we consider two cases for same capacity of tank, change in geometric features of a container can shows the considerable change in the response of tank. As the capacity increases difference between the response increases. Increase in the capacity shows that difference between static and dynamic response is in increasing order. It is al-so found that, for small capacity of tank the impulsive pressure is always greater than the convective pressure, but it is vice- versa for tanks with large capacity. Magnitude of both the pressure is different. The effect of water sloshing must be included in the analysis. Free board to be provided in the tank based on maximum value of sloshing wave height. If sufficient free board is not provided, roof structure should be designed to resist the uplift pressure due to sloshing of water.

Index Terms— Convective hydrodynamic pressure, Elevated Water Tank, Equivalent Static analysis, Dynamic analysis.

1. INTRODUCTION

Water supply is a life line facility that must remain functional following disaster. Most municipalities in India have water supply system which depends on elevated water tanks for storage. Elevated water tank is a large elevated water storage container constructed for the purpose of holding a water supply at a height sufficient to pressurize a water distribution system. These structures have a configuration that is especially vulnerable to horizontal forces like earthquake due to the large total mass concentrated at the top of slender supporting structure. So it is important to check the severity of these forces for particular region.

These structures has large mass concentrated at the top of slender supporting structure hence these structure are especially vulnerable to horizontal forces due to earthquakes. All over the world, the elevated water tanks were collapsed or heavily damaged during the earthquakes because of calamities are causing many casualties and innumerable property loss every year. Earthquakes occupy first place in vulnerability. Hence, it is necessary to learn to live with these events. According to seismic code IS: 1893(Part I): 2000, more than 60% of India is prone to earthquakes. After an earthquake, property loss can be recovered to some extent however, the life loss cannot. The main resign for life loss is collapse of structures. It is said that earthquake itself never kills people, it is badly constructed structures that kill. Hence it is important to analyze the structure properly for earth-quake effects.

2. LITERATURE REVIEW

George W. Housner [1] discussed the relation between the motion of water with respect to tank and motion of whole structure with respect to ground. He had considered three basic condition i.e. tank empty, tank partially filled and tank fully filled for the analysis, and finely concluded that the maximum force to which the partially fill tank subjected is less than the half the force to which the full tank is subjected. The actual forces may be little as 1/3 of the forces anticipated on the basis of a completely full tank. Sudhir Jain and U. S. Sameer [2] had given the value of performance factor K =3, which is not included in IS 1893:1984 for the calculation of seismic design force and also given some expressions for calculation of lateral stiffness of supporting system including the beam flexibility. Sudhir Jain & M. S. Medhekar [3] had given some suggestions and modification in IS 1893: 1984. He had replace the single degree of freedom system by two degree of freedom system for idealization of elevated water tank, the bracing beam flexibility is to be included in the calculation of lateral stiffness of supporting system of tank, the effect of convective hydrodynamic pressure is to be included in the analysis. Sudhir Jain & Sajjad Sameer U. [4] added more suggestions other than above i.e. accidental torsion, expression for calculating the sloshing wave height of water, effect of hydrodynamic pressure for tanks with rigid wall and the tanks with flexible wall should be considered separately. M. K. Shrimali & R. S. Jangid [5] discussed the earthquake response of elevated steel

structural failures result in release of hazardous material. Quantitative Risk Analysis (QRA) [1] provides a guide for analysis of industrial risk; such an assessment may include the seismic threat if ground motion related malfunctioning (i.e. failure) rates are available for components [2]. From the structural perspective, steel tanks for oil storage are standardized structures both in terms of design and construction [3], [4], [5]. Review of international standards for the construction points out that design evolved slowly; therefore, a large number of postearthquake damage observations [6] are available and empirical vulnerability functions have been developed [7]. Liquid containing structures (LCS) as part of environmental engineering facilities are primarily used for water and sewage treatment plants and other industrial wastes. Normally, they are constructed of reinforced concrete in the form of rectangular or circular configurations. Currently there are few codes and standards available for seismic design of LCS in North America. In almost all of codes and standards, the Housner's model (Housner, 1963) has been adopted for dynamic analysis of LCS. The hydrodynamic pressures induced by earthquakes are separated into two parts of impulsive and convective components which are approximated by the lumped added masses. 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. Although the Housner's model has been applied in the seismic design of LCS in the past, recent studies show that due to the assumption of the lumped added mass and the rigid tank wall, this method leads to overly conservative results. Chen and Kianoush (2005)

3. SCOPE OF THE STUDY

This paper is to be presented to serve the following objectives-

[1] To compared the Static and Dynamic analysis of Elevated water tank. This objective clearly states that the behavior of water tank is always different with respect to circumstance. Hence it is an attempt to distinguish both static and dynamic behavior of the tank.

[2] To study the hydrodynamic effect on elevated water tank- When a tank containing liquid with a free surface is subjected to horizontal earthquake ground motion, water stored in the tank gets motion. This motion exerts load on the walls. This effect is called as sloshing effect.

[3] To compare the effects of Impulsive pressure and Convective pressure results. Water in impulsive region and in convective region are may exerts pressure of different magnitude. This objective will help to understand this phenomenon quit easily.

4. SEISMIC ANALYSIS OF WATER TANK

Seismic analysis of elevated water tank involved two types of analysis,

4.1 Equivalent Static analysis of elevated water tank.

4.2 Dynamic analysis of elevated water tank.

4.1 Equivalent Static analysis of elevated water tanks.

Equivalent static analysis of elevated water tanks is the conventional analysis based on the conversion of seismic load in equivalent static load. IS: 1893-2002 has provided the method of analysis of elevated water tank for seismic loading. Historically, seismic loads were taken as equivalent static accelerations which were modified by various factors, depending on the location's seismicity, its soil properties, the natural frequency of the structure, and its intended use. Elevated water tank can be analyzed for both the condition i.e. tank full condition and tank empty condition. For both the condition, the tank can be idealized by one- mass structure. For equivalent static analysis, water- structure interaction shows, both water and structure achieve a pick at the same time due to the assumption that water is stuck to the container and acts as a structure itself and both water and structure has same stiffness. The response of elevated water tanks obtained from static analysis shows the high scale value. That's why for large capacities of tanks, static response are not precise. If we analyzed the elevated water tank by static method and design by the same, we get over stabilized or say over reinforced section but it will be uneconomical. That's why static systems of de-signing of elevated water tanks is not useful in seismic zones.

4.2 Dynamic response of elevated water tank

Dynamic response of elevated water tanks is hard to define, as a behavior of tank is unpredictable. Dynamic analysis of liquid storage tank is a complex problem involving water- structure interaction. Based on numerous analytical, numerical and experimental studies, simple springmass models of tank- liquid system have been developed to calculate the hydrodynamic forces. During the earthquake, water contained in the tank exerts forces on tank wall as well as bottom of the tank. These hydrodynamic forces should consider in the analysis in addition to hydrostatic forces.

4.3 Two- Mass model theory for Elevated water tank

Elevated water tank containing the liquid with free surface is subjected to horizontal earthquake ground motion. Due to the ground motion, the tank wall and liquid get accelerate. The liquid in the lower resign of the tank behaves like a mass that is rigidly attached to the tank wall. This mass is termed as impulsive liquid mass (mi) which accelerates along with the wall and exerts impulsive hydrodynamic pressure on tank wall as well as on base of the tank. Liquid mass in the upper region of tank undergoes sloshing motion. This mass is termed as convective liquid mass (mc) and it exerts convective hydrodynamic pressure on tank wall and base. Thus total liquid mass gets divide into two parts, i.e. impulsive mass and convective mass.

In spring- mass model for tank - liquid system, these two liquid masses are to be suitably represented. A qualitative description of hydrodynamic pressure distribution on tank wall and base

4.4 Spring- Mass model for Seismic Analysis of Elevated water Tank

Most elevated water tanks are never completely filled with liquid. Hence a two – mass idealization of the tank is more appropriate as compared to a one-mass idealization, which was used in IS 1893 : 1984. Two mass model for elevated water tank was proposed by Housner (1963b) and is being commonly used in most of the international code.

The response of two-degree of freedom system can be obtained by elementary structural dynamics. However, for most elevated water tank it is observed that two period are well separated. Hence, the system may be considered as two uncoupled single degree of freedom system. This method will be satisfactory for design purpose, if the ratio of the period of the two uncoupled system exceed 2.5. If impulsive and convective time periods are not well separated, then coupled two degree of freedom system will have to be solved using elementary structural dynamics.

5. CONCLUSION

From above mentioned detailed study and analysis some of the conclusions can be made as follows

For same capacity, same geometry, same height, with same staging system, in the same Zone, with same Importance Factor & response reduction factor; response by Equivalent Static Method to Dynamic method differ considerably. It also state that even if we consider two cases for same capacity of tank, change in geometric features of a container can show the considerable change in the response of elevated water tank. At the same time Static response shows high scale values that of the Dynamic response. It happens due to the different picks of time periods. For Static analysis water-structure interaction shows that both water and structure achieve a pick at the same time due to the assumption that water is stuck to the container and acts as a structure itself and both structure and water has same stiffness, while in Dynamic analysis we considered two

mass model which shows two different stiffness for both water and structure hence pick of time for both the components are different hence fundamental time periods are different for both static and dynamic analysis. But secondary time period in dynamic analysis is greater than both fundamental time period because water in the upper region (Convective region) remains in undamped condition (sloshing condition) for some more time.

During the earthquake Impulsive pressure is always greater than Convective pressure for small capacity tanks, but it is vice-versa for tanks with large capacities. Hence Static analysis for large capacities tanks can be uneconomical as all the water mass acts itself as a convective. This statement de-notes that if large capacities tanks are designed by static meth-od distortion in the container can be seen at the same time of collapse ofstaging. Large capacities are liable of producing high stresses on the wall and the slabs of the container, if the hydrodynamic factors are ignored during the analysis they will affect vigorously and collapse of the structure can take place.

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