ANALYSIS AND DESIGN OF WATER TANK

D.Raghupathi (Asst. Prof) [1]. Adapa Shravani. M Tech[2]
Siddhartha Institute of Technology & Sciences (SITS) Narapally village, Peerzadiguda, Hyderabad, Telangana 500088

ABSTRACT

Storage reservoirs and overhead tank are used to store water, liquid petroleum, petroleum products and similar liquids. The force analysis of the reservoirs or tanks is about the same irrespective of the chemical nature of the product. All tanks are designed as crack free structures to eliminate any leakage.

This project gives in brief, the theory behind the design of liquid retaining structure (circular water tank with flexible and rigid base and rectangular underground water tank) using working stress method. This report also includes computer subroutines to analyse and design circular water tank with flexible and rigid base and rectangular undergroundwater tank. The program has been written as Macros in Microsoft Excel using Visual Basic programming language. In the end, the programs are validated with the results of manual calculation given in "Concrete Structure" book.

INTRODUCTION

1.1 General

Storage reservoirs and overhead tank are used to store water, liquid petroleum, petroleum products and similar liquids. The force analysis of the reservoirs or tanks is about the same irrespective of the chemical nature of the product. All tanks are designed as crack free structures to eliminate any leakage. Water or raw petroleum retaining slab and walls can be of reinforced concrete with adequate cover to the reinforcement.

Water and petroleum and react with concrete and, therefore, no special treatment to the surface is required. Industrial wastes can also be collected and processed in concrete tanks with few exceptions. The petroleum product such as petrol, diesel oil, etc. are likely to leak through the concrete walls, therefore such tanks need special membranes to prevent leakage. Reservoir is a common term applied to liquid storage structure and it can be below or above the ground level. Reservoirs below the ground level are normally built to store large quantities of water whereas those of overhead type are built for direct distribution by gravity flow and are usually of smaller capacity.

A water tank is a container for storing liquid. Theneed for a water tank is as old as civilization, to providestorage of water for use in many applications, drinking water, irrigation, agriculture, fire suppression, agricultural farming, both for plants and livestock, chemical manufacturing, food preparation as well as many other uses. Water tank parameters include the general design of the tank, and choice of construction materials, linings. Reinforced Concrete Water tank design is based on IS 3370: 2009 (Parts I – IV). The design depends on the location of tanks, i.e. overhead, on ground or underground water tanks. The tanks can be made of RCC or even ofsteel. The overhead tanks are usually elevated from the ground level using number of columns and beams. In the other hand the underground tanks rest below the ground level.

1.2 Types of Water Tanks

In this section, the types of water tanks are discussed in detail. There are different type of water tank depending upon the shape, position with respect to ground level etc. From the position point of view, water tanks are classified into three categories. Those are,

a) Underground tanks

b) Tanks resting on ground

c) Overhead water tanks

In most cases the underground and on ground tank are circular or rectangular in shape but the shape of the overhead tanks are influenced by the aesthetical view of the surroundings and as well as the design.

LITERATURE REVIEW

Much of a literature has presented in the form of technical papers till date on thedynamic analysis of Elevated Water Tanks. Different issues and the points are covered in thatanalysis i.e. dynamic response to ground motion, sloshing effect on tank, dynamic responseof framed staging etc. Some of those are analyzed below.

George W. Housner [1963]

The basic plot behind this paper was the Chilean Earthquake, took place in 1960. In this earthquake most of the elevated water tanks are totally collapse or badly distorted. This paper was clearly speaks about the relation between the motion of water in the tank with respect to tank and motion of whole structure with respect to ground. He has considered three basic conditions for this analysis. He said that if water tank is fully filled i.e. without free board then the sloshing effect of water is neglected, if the tank is empty then no sloshing as water is absent. In above two cases water tower will behave as one-mass structure. But in third case i.e. water tank is partially filled, the effect of sloshing must be considered. In that case the water tower will behave as two-mass structure. Finally he concluded that the tank fully filled is compared with the partially filled tank then it is seen that the maximum force to which the half-full tank is subjected may be significantly less than half the force to which the full tank is subjected. The actual forces may be as little as 1/3 of the forces anticipated on the basic of a completely full tank.

METHODOLOGY

3.1 DESIGN REQUIREMENT OF CONCRETE (I. S. I)

In water retaining structure a dense impermeable concrete is required therefore, proportion of fine and course aggregates to cement should be such as to give high quality concrete. Concrete mix weaker than M20 is not used. The minimum quantity of cement in the concrete mix shall be not less than 30 kN/m3.

The design of the concrete mix shall be such that the resultant concrete is sufficiently impervious. Efficient compaction preferably by vibration is essential. The permeability of the thoroughly compacted concrete is dependent on water cement ratio. Increase in water cement ratio increases permeability, while concrete with low water cement ratio is difficult to compact. Other causes of leakage in concrete are defects such as segregation and honey combing. All joints should be made water-tight as these are potential sources of leakage. Design of liquid retaining structure is different from ordinary R.C.C, structures as it requires that concrete should not crack and hence tensile stresses in concrete should be within permissible limits.

A reinforced concrete member of liquid retaining structure is designed on the usual principles ignoring tensile resistance of concrete in bending. Additionally it should be ensured that tensile stress on the liquid retaining face of the equivalent concrete section does not exceed the permissible tensile strength of concrete as given in table 1. For calculation purposes the cover is also taken into concrete area.

Cracking may be caused due to restraint to shrinkage, expansion andcontraction of concrete due to temperature or shrinkage and swelling dueto moisture effects. Such restraint may be caused by –

(i) The interaction between reinforcement and concrete during shrinkage due to drying.

(ii) The boundary conditions.

(iii) The differential conditions prevailing through the large thickness of massive concrete.

Use of small size bars placed properly, leads to closer cracks but of smaller width. The risk of cracking due to temperature and shrinkage effects may be minimized by limiting the changes in moisture content and temperature to which the structure as a whole is subjected. The risk of cracking can also be minimized by reducing the restraint on the free expansion of the structure with long walls or slab founded at or below ground level, restraint can be minimized by the provision of a sliding layer. This can be provided by founding the structure on a flat layer of concrete with interposition of some material to break the bond and facilitate movement.

In case length of structure is large it should be subdivided into suitable lengths separated by movement joints, especially where sections are changed the movement joints should be provided. Where structures have to store hot liquids, stresses caused by difference in temperature between inside and outside of the reservoir should be taken into account. The coefficient of expansion due to temperature change is taken as 11 x 10-6 /° C and coefficient of shrinkage may be taken as 450 x 10-6 for initial shrinkage and 200 x 10-6 for drying shrinkage.

3.2.3 TEMPORARY JOINTS

A gap is sometimes left temporarily between the concrete of adjoining parts of a structure which after a suitable interval and before the structure is put to use, is filled with mortar or concrete completely as in Fig.3.5(a) or as shown in Fig.3.5 (b) and (c) with suitable jointing materials. In the first case width of the gap should be sufficient to allow the sides to be prepared before filling.

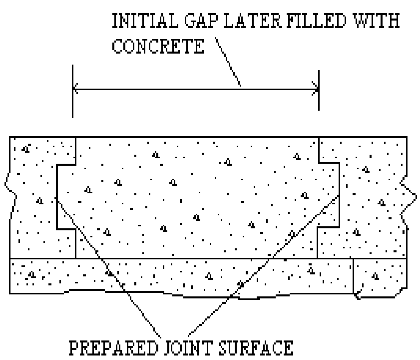

Figure 3.5(a)

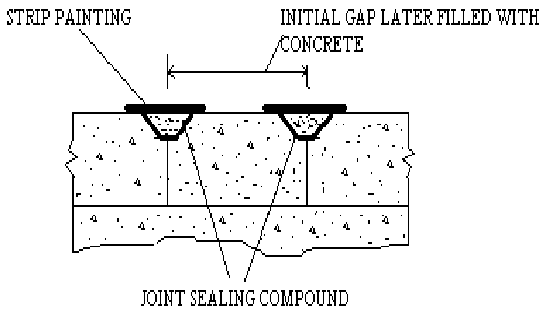

Figure 3.5 (b)

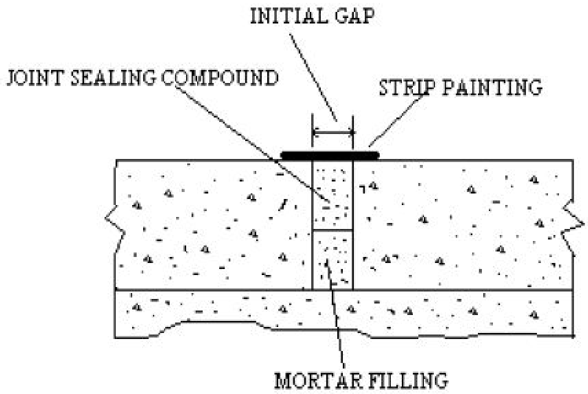

Figure 3.5(c)

CONCLUSION

Storage of water in the form of tanks for drinking and washing purposes, swimming pools for exercise and enjoyment, and sewage sedimentation tanks are gaining increasing importance in the present day life. For small capacities we go for rectangular water tanks while for bigger capacities we provide circular water tanks.

Design of water tank is a very tedious method. Particularly design of underground water tank involves lots of mathematical formulae and calculation. It is also time consuming. Hence program gives a solution to the above problems.

There is a little difference between the design values of program to that of manual calculation. The program gives the least value for the design. Hence designer should not provide less than the values we get from the program. In case of theoretical calculation designer initially add some extra values to the obtained values to be in safer side.

Analysis & design of elevated water tanks against earthquake effect is of considerable importance. These structures must remain functional even after an earthquake. Elevated water tanks, which typically consist of a large mass supported on the top of a slender staging, are particularly susceptible to earthquake damage. Thus, analysis & design of such structures against the earthquake effect is of considerable importance. After details study of all the papers, following points are to be consider at the time of seismic analysis of elevated water tank

1. In India, there is only one IS code i.e. IS 1893: 1984, in which provisions for aseismic design of elevated water tanks are given. IS 1893(Part-1): 2002 is the fifth revision of IS 1893, still it is under revision. So detail criteria for aseismic analysis of elevated water tank are not mentioned in above IS code. Thus, the recommendations &suggestions given by all the above author has to be considered at the time of analysis. IITK-GSDMA has given some

guidelines for seismic design of elevated water tank that should consider at the time of analysis.

2. Most elevated water tank are never completely filled with water. Hence, a two – mass idealization of the tank is more appropriate as compared to one-mass idealization.

3. Basically, there are three cases that are generally considered while analyze the elevated water tank – (1) Empty condition. (2) Partially filled condition. (3) Fully filled condition. For (1) & (3) case, the tank will behave as a one-mass structure and for (3) case the tank will behave as a two-mass structure.

4. If we compared the case (1) & (3) with case (2) for maximum earthquake force, the maximum force to which the partially filled tank is subjected may be less than half the force to which the fully filled tank is subjected. Actual forces may be as little as 1/3 of the forces anticipated on the basis of a fully filled tank.

5. During the earthquake, water in the tank get vibrates. Due to this vibration water exerts impulsive & convective hydrodynamic pressure on the tank wall and the tank base in addition to the hydrostatic pressure. The effect of impulsive & convective hydrodynamic pressure should consider in the analysis of tanks. For small capacity tanks, the impulsive pressure is always greater than the convective pressure, but it is vice-versa for tanks with large capacity. Magnitudes of both the pressure are different.

6. The effect of water sloshing must be considered in the analysis. Free board to beprovided in the tank may be 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.

7. Earthquake forces increases with increase in Zone factor & decreases with increase in staging height. Earthquake force are also depends on the soil condition.

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