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# DESIGN OF SLAB SHEAR WALL AND DOMES OF ELEVATED STORAGE RESERVOIR

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## ABSTRACT

While designing a reinforced concrete structure, the aim is to provide a safe, serviceable, durable, economical and aesthetically pleasing structure. For the structure to be safe, it must be able to resist the worst loading conditions. Under normal working conditions, the deformation and cracking must not be excessive for the structure to remain serviceable, durable and aesthetically pleasing during the expected design life. Furthermore, the structure should be economical with regard to both construction and maintenance cost. During designing, a sensible designer ought to bear in mind that structure should be a balancing of economy, aesthetic and stability. One can always design a massive structure, which has more than adequate stability strength and serviceability, but the ensuring cost of the structure may be exorbitant and the end product far from aesthetics. In the design of structures, the aim is to design the structure in such a way that it fulfils its intended purpose during its intended life time and be adequately safe in terms of strength, stability and structural rigidity and have adequate serviceability in terms of stiffness, durability etc. Safety requires the possibility of collapse of the structure (partial or total) is acceptably low not under normal expected loads (service loads), but also under less frequent loads (such as due to earthquakes or extreme winds) and accidental loads (blasts, impacts, etc.). Other two important considerations that a sensible designer ought to bear in mind are that the structure should be economical with regard to both construction and maintenance cost and aesthetically pleasing during the expected design life.

A water tank is used to store water for daily requirements like drinking, washing etc. An elevated water tank is a large water storage container constructed for the purpose of holding water supply at certain height to provide sufficient pressure in the water distribution system. Liquid storage tanks are used extensively used by municipalities and industries for storing water, inflammable liquids and other chemicals. These tanks have various types of support structures like RC braced frame, steel frame, RC shaft, and even masonry pedestal. The most commonly used staging in practice is the frame type. The main components of this type of staging are columns and braces. The staging acts like a bridge between the overhead container and foundation to transfer loads acting on the tank. Thus Water tanks are very important for public utility and for industrial structure and also to withstand more design forces. The frame support of the ELSR should have adequate strength to resist axial loads, moment and shear force due to lateral loads. These forces depend upon total weight of the structure, which varies with the amount of water present in the tank container.

## INTRODUCTION

Without water survival is impossible. Water is one of the most important substances on earth. All plants and animals must have water to survive. If there was no water there would be no life on earth. As water is very precious and due to the scarcity of drinking water in day to day life one has to take care of every drop. A water tank is used to store water for daily requirements like drinking, washing etc. An elevated water tank is a large water storage container constructed for the purpose of holding water supply at certain height to provide sufficient pressure in the water distribution system. Liquid storage tanks are used extensively used by municipalities and industries for storing water, inflammable liquids and other chemicals. These tanks have various types of support structures like RC braced frame, steel frame, RC shaft, and even masonry pedestal. The most commonly used staging in practice is the frame type. The main components of this type of staging are columns and braces. The staging acts like a bridge between the overhead container and foundation to transfer loads acting on the tank. Thus Water tanks are very important for public utility and for industrial structure and also to withstand more design forces. The frame support of the ELSR should have adequate strength to resist axial loads, moment and shear force due to lateral loads. These forces depend upon total weight of the structure, which varies with the amount of water present in the tank container.

A dome may be defined as a thin shell generated by revolution of a regular curve about one of its axis. The shape of dome depends on the type of the curve and the direction of axis of revolution. Domes are used in variety of structures, as in the roof of circular areas, in circular tanks, in hangers, exhibition halls, auditoriums and bottom of tanks, bins and bunkers. Domes may be constructed of masonry, steel, timber and reinforced concrete. However, reinforced domes are most commonly used nowadays, since they can be constructed over large spans. Membrane theory for analysis of shells of revolution can be developed neglecting effect of bending moment, twisting moment and shear assuming that loads are carried wholly by axial stresses. The meridional thrust and circumferential forces are calculated to design the domes. However, minimum amount of 0.3% of steel should be provided on both direction of the dome.

## 1.2 POPULATION FORECAST

1.2.1 DESIGN PERIODS & POPULATION FORECAST

This quantity should be worked out with due provision for the estimated requirements of the future. The future period for which a provision is made in the water supply scheme is known as the design period. Design period is estimated based on the following: • Useful life of the component , considering obsolescence, wear, tear, etc. • Expandability aspect. • Anticipated rate of growth of population, including industrial, commercial developments & migration- immigration. • Available resources. • Performance of the system during initial period. 2.4.2 POPULATION FORECASTING METHODS The various methods adopted for estimating future populations are given below. The particular method to be adopted for a particular case or for a particular city Depends largely on the factors discussed in the methods, and the selection is left to the discretion and intelligence of the designer. 12 1. Incremental Increase Method 2. Decreasing Rate of Growth Method 3. Simple Graphical Method 4. Comparative Graphical Method 5. Logistic Curve Method 6. Arithmetic Increase Method 7. Geometric Increase Method

1.1 PROBLEM STATEMENT

STAGING OF TANKS The overhead tanks are generally supported on space frame staging consisting of reinforced concrete columns braced together by ring beams at top and bottom and also at a number of places along the height by braces shown. The arrangement enables effective height of columns to be taken as the distance between centre of adjacent bracings. Alternatively, the tower may be a thin walled reinforced shaft, i.e., cylindrical shell The design should be based on worst possible combination of loads, moments and• shears arising from gravity and lateral loads in any direction when tank is full as well as empty. In case of lateral load due to seismic and wind action, the permissible stresses for• columns of the staging are increased as per IS;456

provision. However, the increase is not allowed in the design of braces because seismic and wind loads are primary forces in them. In addition to the entire load of tank(gravity load), the column carry axial load, shear• forces, and bending moment due to lateral forces exerted by the wind, earthquake and vibration. The axial force in the column due to lateral loads acting on all the part of the tanks as• well as towers, should be calculated by equating the moments due to all lateral forces above the level under consideration to the restraining moment offered by axial forces in column. The vertical spacing rigidly connected horizontally bracings should not exceed 6m.• For staging in seismic zones where horizontal seismic coefficient exceeds 0.05, twin• diagonal vertical bracings of steel of R.C.C. in additional to horizontal bracing may be provided. For the tower situated in seismic zones where horizontal seismic coffecient is above• in 0.05, all the columns are tied together by a ring beam at the base of the tower. The tower foundation is so proportioned that the combined pressure on soil due to• gravity load(with tank full as well as empty) and lateral pressure is within safe bearing capacity, and in the critical direction the footing does not lift uo at any point.

1.2 Research Questions

According to O'Leary (2004; p.47), research questions are essentials to define the investigation, set boundaries, provide direction and act as a frame of reference for assessing the work. The fact that self build houses still exist in other developing and developed nations and has significantly contributed to the housing provision among the public and private sector, indicates that this type of approach has been executed by the low-income group as well as policy makers. It is a wonder how it was able to be implemented, why is it successful there, what are the key ingredients needed and so on. The research questions are as follow to which answers will be sought to further understand about self help/self build housing in Malaysia:

1. Why are self build houses not popular in Malaysia?

2. What are the factors or key features of self help housing that are able to promote such activities among the low-income households in the rural area?



3. What are the main constraints in promoting self build houses among the low income households in rural areas of Malaysia? Another fundamental issue that this research is addressing is to analyse the possibility of introducing a simplified system of house construction which relates to self build principles as a mean to initiate any self build group in rural areas. On that foundation alone, the following are research questions that need to be dealt with:

4. How can the available low technology of self build houses be applied into housing design and planning process?

5. What are the material preferences of Malaysia's rural low-income households should they opt for self build houses? 6. How can prefabrication system be implemented in promoting self build houses?

## LITERATURE SURVEY

2.1 Design of Slab Shear Wall and Domes of Elevated Storage Reservoir

2.1.1 Introduction

Storage reservoirs and overhead tank are used to store water, liquid petroleum, petroleum products and similar liquids. These structures are made of masonry, steel, reinforced concrete and pre stressed concrete. Out of these, masonry and steel tanks are used for smaller capacities. The cost of steel tanks is high and hence they are rarely used for water storages. Reinforced concrete tank is high and hence they are rarely used for water storages. Reinforced concrete tanks are very popular because, besides the construction and designs being simple, they are cheap, monolithic in nature and can be made leak proof. Generally no cracks are allowed to take place in any part of the structure of liquid retaining R.C.C tanks and they made water tight by using richer mix (not less than M20) of concrete. In addition sometimes water proofing materials are also used to make tanks water tight. Permeability of concrete is directly proportional to water cement ratio. Proper compaction using vibrators should be done to achieve imperviousness. Cement content ranging from 330 Kg/$m3$ to 530 Kg/$m3$ is recommended in order to keep shrinkage low. The leakage is more with higher head and it has been observed that head up to 15m does not cause leakage problem. Use of high strength deformed bars of grade 415 are recommended for the construction of liquid retaining structures .However mild steel bars are also used. Correct placing of reinforcement, use of small sized and use of deformed bars lead to differential cracks. A crack width of 0.1mm has been accepted as permissible value in liquid retaining structures. While designing liquid retaining structures recommendation of " Code of Practice for the storage of liquids- IS3370 (Part I to IV)" should be considered..

**2.2 Comparative performance of low cost housing with another housing**

2.2.1 Introduction

In many developing countries, the main housing practice has been through self-help, strongly propelled by massive rural to urban migration. Since the 1980s, international research and policy agendas focused more and more on a broadened habitat approach and attention for self-managed house construction gradually declined. Yet, self-help housing is still a widespread phenomenon, although mostly unattended or even ignored by governments. This thesis stresses the importance of self-help housing and makes a plea for a revaluation of 'assisted self-help' as part of national and local housing policies. In view of the urgency of the urban housing question, new pro-poor housing policies are to be developed that actively support self-build initiatives. Assisted selfhelp housing has to be put central on the urban development agenda.

2.2.3 Literature Review

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

2.2.3.1 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 totally collapsed or badly distorted. This paper 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.

2.2.3.2 Sudhir Jain K. & U. S. Sameer [1991]

IS code provision for seismic design of elevated water tanks have been revised. It was seen that, due to absence of a suitable value of performance factor for tanks, the code provision for rather low seismic design force for these structure. Simple expressions are derived, which allow calculations of staging stiffness, and hence the time period, while incorporating beam flexibility. The code must include an appropriate value of performance factor, say 3.0 for calculation of seismic design force for water tanks. An earthquake design criteria is incomplete, unless clear specifications are include on how to calculate the time period. A method for calculating the staging stiffness including beam flexibility and without having to resort to finite element type analysis has been presented. This method is based on well-known portal method which has been suitably developed to incorporate the beam flexibility and the three dimensional behavior of the staging.

2.2.4. Pilot Study

Today's analysis tools allow engineers to refine designs to an unprecedented degree, and as a result, many utilities feel testing is not warranted. However, while great strides have been made in the analysis and design of water towers, differences between analysis results and full-scale tests still occur. STAAD.Pro features a state-of-the-art user interface, visualization tools, powerful analysis and design engines with advanced finite element and static and dynamic analysis capabilities. From model generation, analysis and design to visualization and result verification, STAAD.Pro is the professional's choice for steel, concrete, timber, aluminum and cold-formed steel design of low and high-rise buildings, culverts, petrochemical plants, tunnels, bridges, piles and much more.The following key STAAD.Pro tools help simplify ordinarily tedious tasks: The STAAD.Pro Graphical User Interface incorporates Research Engineers' innovative tabbed page layout. By selecting tabs, starting from the top of the screen and heading down, you input all the necessary data for creating, analyzing and designing a model. Utilizing tabs minimizes the learning curve and helps insure you never miss a step. The STAAD.Pro Structure Wizard contains a library of trusses and frames. Use the Structure Wizard to quickly generate models by specifying height, width, breadth and number of bays in each direction. Create any customizable parametric structures for repeated use. Ideal for skyscrapers, bridges and roof structures.

2.2.5 Design Loads

2.2.5.1 Loads

should be applied to the structural design of a tank according to its intended use, size, structure type, materials, design lifetime, location and environment, in order to assure life safety and to maintain its essential functions.

2.2.5.2 The applied loads should be as follows, and their combinations should be defined considering the actual probability of occurrence.

(i) Dead loads (ii) Live loads (iii) Snow loads (iv) Wind loads (v) Seismic loads (vi) Impulse and suction due to content sloshing, and pressure due to content (vii) Thermal stresses (viii) Shock, e. g., by crane (ix) Fatigue loads (x) Soil and water pressures (xi) Others. e.g., load from mechanical device. 3.2 Dead Loads Dead loads are the sum of the weights of the tank, its associated piping and equipment and other fixed appurtenances.

2.2.5.3 Live Loads

Live loads should be considered to be the contents of the tank, the temporary weight of personnel, and the weight of other temporary equipment not normally fixed to the tank. If such loads involve a impulsive force, they should be increased by a suitable impulse factor.

Temporary live loads may be discounted if they have been taken into consideration with other load combinations. 3.3.3 For seismic designs, the weight of the tank contents should be considered as being divided into fixed weight (impulsive mass) and free weight (convective mass).

2.2.5.4 Snow Loads

Snow loads should be defined by considering the location, topography, environment, density of the snow, snow accumulating period, and the shape and temperature of the tank, as defined in “Recommendations for Loads on Buildings” (AIJ- 2004).

2.2.5.5Wind loads

Wind loads should be defined by considering the shape of the tank, its structural characteristics, the location, and environment, as defined in “Recommendations for Loads on Buildings” (AIJ - 2004).

2.2.5.6 Seismic Loads

3.6.1 Seismic Loads for Above-ground Storage Tanks 3.6.1.1 Design for Impulsive Mass Design seismic loads for above-ground storage tanks should be calculated by either one of the following methods: (i) Modified Seismic Coefficient Method, or (ii) Modal Analysis The Modified Seismic Coefficient Method should be used for the design seismic loads of tank foundations.

2.3 Factors affecting per capita demand:

• Size of the city:

Per capita demand for big cities is generally large as compared to that for smaller towns as big cities have sewered houses.

• Presence of industries. • Climatic conditions. • Habits or economic status. • Quality of water: If water is aesthetically and medically safe, the consumption will increase as people will not resort to private wells, etc. • Pressure in the distribution system.

• Efficiency of water works administration:

Leaks in water mains and services; and unauthorised use of water can be kept to a minimum by surveys. • Cost of water.

• Policy of metering and charging method:

Water tax is charged in two different ways: on the basis of meter reading and on the basis of certain fixed monthly rate. Fluctuations in Rate of Demand: Average Daily Per Capita Demand = Quantity Required in 12 Months/ (365 x Population) If this average demand is supplied at all the times, it will not be sufficient to meet the fluctuations. • Seasonal variation: The demand peaks during summer. Firebreak outs are generally more in summer, increasing demand. So, there is seasonal variation . • Daily variation depends on the activity. People draw out more water on Sundays • Hourly variations are very important as they have a wide range. During active household working hours i.e. from six to ten in the morning and four to eight in the evening, the bulk of the daily requirement is taken. During other hours the requirement is negligible. Moreover, if a fire breaks out, a huge quantity of water is required to be supplied during short duration, necessitating the need for a maximum rate of hourly supply. So, an adequate quantity of water must be available to meet the peak demand. To meet all the fluctuations, the supply pipes, service reservoirs and distribution pipes must be properly proportioned. The water is supplied by pumping directly and the pumps and distribution system must be designed to meet the peak demand. The effect of monthly variation influences the design of storage reservoirs and the hourly variations influences the design of pumps and service reservoirs. As the population decreases, the fluctuation rate increases.

Maximum daily demand = 1.8 x average daily demand

Maximum hourly demand of maximum day i.e. Peak demand

= 1.5 x average hourly demand

= 1.5 x Maximum daily demand/24

= 1.5 x (1.8 x average daily demand)/24

= 2.7 x average daily demand/24

= 2.7 x annual average hourly demand



2.4 Site Experimentation

This paper is related with the soil & 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. Author has chosen seven cases to make comparisons with direct nonlinear dynamic analysis, mechanical models with and without soil structure interaction for single degree of freedom, two degree of freedom, and finite element method (FEM) models. The analysis is based on superposition model dynamic analysis. Soil structure interaction and fluid structure interaction have been accounted using direct approach and added mass approach respectively.

2.5 Limitations Of Research

Recognizing the limitations and shortcomings in the provision of IS:1893-1984, Jain and Medhekar, Jain and Sameer set of provisions on seismic design of liquid storage tanks, the author has given some recommendations

– 1. Design horizontal seismic coefficient given in revised IS: 1893(Part-1)-2002 is used and values of response reduction factor for different types of tanks are proposed. 2. Different spring-mass model for tanks with rigid & flexible wall are done away with; instead, a single spring-mass model for both types of tank is proposed. 3. Expressions for convective hydrodynamic pressure are corrected. 4. Simple expression for sloshing wave height is used. 5. New provisions are included to consider the effect of vertical excitation and to describe critical direction of earthquake loading for elevated water tanks with frame type staging.

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