A Detailed Review of Elevated Storage Reservoir with Reference to IS: 3370 and IS: 1893

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Abstract— In India more than 68% of its total population lives in rural area. Domestic water is a major problem in these areas, so as to solve this problem innovative design and strategies and solution to existing problem is essential, hence for that study of Elevated Storage Reservoir (ESR) is undertaking. There are so many case studies and report on failure during and post construction of ESR in recent years. The purpose of the study of the ESR is to design and build safe and economical ESR, where in the damage to the structure and its structural components even by natural hazard such as earthquake can be minimized. This paper is aimed at reviewing presently available literature study of ESR behavior according to geometrical shape and comparative study of design of water tank by Limit state Method (LSM) and Working Stress Method (WSM) with reference to IS: 3370. With different storage capacities, different geometrical shapes of water tanks are recommended. The work also aims at checking adequacy of water tank supported on shafts and R.C.C framed structure subjected to seismic excitations.
Key words: Elevated Storage Reservoir, Working Stress Method, Limit State Method

I. INTRODUCTION

Storage tanks are containers that hold liquids, compressed gases or mediums used for the short or long term storage of heat or cold. Storage tanks are often cylindrical in shape, perpendicular to the ground with flat bottoms, and a fixed frangible or floating roof. Storage tanks use in many application such as domestic, agricultural, industrial purposes as well as for storage of oil, petro chemicals and nuclear waste.

A. Storage tanks are usually of three kinds

- Tanks situated on the ground.
- Tanks situated underground.
- Tanks situated above the ground level.

R.C.C storage tanks used for small, medium and large capacity of storage. Large capacity storage tanks are also known as storage reservoir. The ground reservoir include underground storage reservoir (USR) ground storage reservoir (GSR) and high ground level storage reservoir (HGLR), similarly elevated storage reservoir (ESR).Tanks situated on ground and tank situated underground are often called sumps. Liquid from such tanks is delivered for further use in distribution system. In case of elevated storage tank liquid is pumped into them, such tanks built at the head of distribution system. Elevated storage reservoir important structure for public and industrial utility for storage of various purposes.

B. Storage Tanks Type According to Material Used For Construction

- Steel Tanks
- R.C.C Tanks
- Composite Tanks
- Ashlars Masonry Tanks
- Syntax Tanks

C. R.C.C Storage Tank Types According To Shape

- Circular Tank
- Rectangular Tank.
- Spherical Tank.
- Intze Tank.
- Circular Tank with conical bottom.

Fig. 1: R.C.C Storage Tank Types According To Shape

Storage tanks for small capacity say 4000 to 50000 lit tanks square in plan are economical, for above 500000 lit capacity circular tanks prove to be economical and among large capacity say above 750000 lit intze tank are economical.
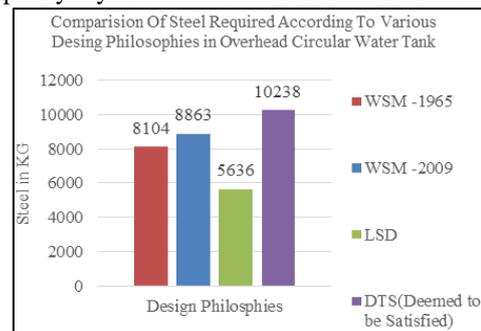

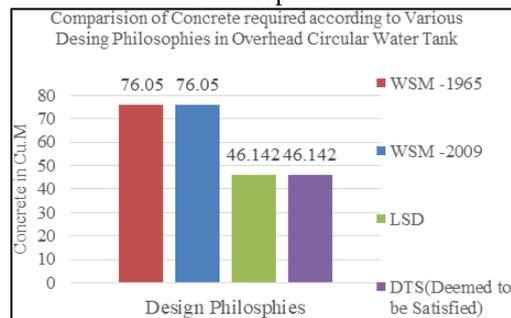Fig. 2: Comparison of Steel According To Design Philosophies

Fig. 3: Comparison of Concrete according to Design Philosophies

The shape and size of concrete tanks may be circular, rectangular, spherical, intze circular tank with conical bottom etc. are governed by functional requirements, economy and site conditions. The layouts of the supporting columns and bracing depend on size of the tank and head of supply. The supporting structure for elevated tanks is usually known as tower and depending on the size of the tank it may vary from single annular shaft to a complex space frame with various arrangements of columns. The columns have generally great heights so as to provide adequate head of water. Hence they need to be suitably braced at appropriate intervals. The design of foundation is governed by the bearing pressure of soil, load on columns and the moment on the entire surface due to wind forces. Depending on this foundation may be isolated or combined footing, annular or full raft or may be pile foundation.

IS: 3370-2009 specifies two theories of design for liquid retaining structures, namely Limit State Method (LSM) and Working Stress Method (WSM).In WSM reinforced concrete members are designed with the usual principle of ignoring the tensile resistance of concrete, however, permissible stresses in steel are reduced to reduce the tendency of cracking. The design is referred to as strength design or design for cracked condition. Permissible stresses in concrete and steel for strength design are given in following table.

D. Permissible stresses in concrete – strength design

Concrete Grade	Bending Compression σ_{cbc} N/mm^2	Direct Compression σ_c, N/mm^2	Average bond stress for plain bars in tension τ_{bd} N/mm^2
M25	8.5	6.0	0.9
M30	10.0	8.0	1.0

Table 1: Permissible stresses in concrete – strength design

E. Permissible stresses in steel reinforcement for strength calculation

Condition	M.S Bars σ_{st} N/mm^2	HYSD Bars σ_{st} N/mm^2
In tension bending and shear	115	130
In column bars in compression	125	140

Table 2: permissible stresses in steel reinforcements for strength calculations

1) Necessity

Major part of population in India is in rural areas. Drinking water is a major problem in these areas so to solve this problem elevated storage reservoirs are necessary. There is lot of failure of elevated storage reservoirs in the recent years. As a Civil Engineer we take serious note of these failures and investigate critically the cause of failure and preventive majors to overcome these failures.

F. Types of Failure

The failure of elevated storage reservoirs may classified into following categories:
– Failures during construction
– Failure just after E.S.R put into service
– Failure after 12-15 years of its useful service
– Natural Disaster such as Earthquake failures etc.

II. LITERATURE REVIEW

W.B.Ajagbe and et.al: Reinforced concrete overhead water tanks are used to store and supply safe drinking water. Design and cost estimation of overhead water tanks is a time consuming task, which requires a great deal of expertise. This study therefore examines the efficiency of Rectangular and Circular tanks. Tanks of 30m^3, 90m^3, 140m^3 and 170m^3 capacities were used in order to draw reasonable inferences on tank's shape design effectiveness, relative cost implications of tank types and structural capacities. The basic tanks construction materials- steel reinforcement, concrete and formwork were taken-off from the prepared structural drawings. Results of the material take-offs showed that, for each of the shapes, the amount of each structural materials increase as the tank capacity increases. Also Circular-shaped tank consumed lesser individual material as compared to Rectangular ones. Hence, this will give Circular-shaped tanks a more favored selection over the rectangular shaped tanks

Bhandari and et.al: The conventional method of designing water tanks which is working stress method outlined in the previous version of IS: 3370 1965 is irrational and leads to relatively thicker sections with a substantial amount of reinforcement. Limit state method which is widely used has been recently adopted in the new version of IS 3370-2009 concrete structures for storage of liquids – code of practice. For quick cost prediction of tanks, the study therefore examines the cost effectiveness in terms of amount of materials and formwork used for Circular, Square and Rectangular overhead water tanks each of three capacities of 100kl, 150kl, 200kl and draw reasonable inferences on tank's shape design effectiveness . Each water tank was designed by Limit State method and then the crack width was checked by limit state of serviceability IS 3370 (2009). The results have been presented in the form of graphs and tables and it has been observed that Circular-shaped tank consumed lesser of each material as compared to Square and Rectangular ones. The amount of formwork required for circular tank is also less than that for square and rectangular tanks thereby giving Circular-shaped tanks a more favorable selection over the rectangular and square shaped tanks.

Thalapathy.M and et.al: Storage reservoirs and water tanks 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. The study gives the detailed analysis of the design of liquid retaining structure using working stress method. The project takes into consideration the design of reservoir for the following cases: 1) Underground Tank, 2) Tank Resting on ground and 3) Overhead water tank. The paper gives idea for safe design with minimum cost of the tank and gives the designer relationship curve between design variable. Thus design of tank can be more economical, reliable and simple. The paper helps in understanding the design philosophy for the safe and economical design of water tank.

Abba Mas'ud Alfanda and et.al: The need for a water tank is as old as civilization, to provide storage of water for use in many applications. Design and cost estimation of

water tanks is a time consuming task, which requires a great deal of expertise. All tanks are designed as crack free structure to eliminate any leakage. This project therefore studies the efficiency of rectangular or circular tanks, 40,000 liters capacities were used in order to draw reasonable inferences on tanks shape design effectiveness, relative cost implications of tank types and structural capacities. The basic tanks construction materials include steel reinforcement, concrete and formwork obtained from the prepared structural drawings. Result of the materials take–off revealed that circular tank consumed lesser individual materials as compared to rectangular one. This will give circular shaped tanks more favored Selection over the rectangular shaped tank, although some other factors must still be assessed.

Basile and et.al: Water distribution system (WDS) design has been the subject of minimal improvements over the last decade, despite the fact that the accessibility of computer models has increased. Water distribution pipes are designed to provide adequate pressure at distribution nodes and reasonable velocities in pipes. This is usually done with a hydraulic solver coupled with the engineering expertise of the designer. Storage tanks are designed according to standard requirements considering minimal values provided by local guidelines. Storage tank allocation is generally done without taking into account the network capacity and robustness. Tanks are located next to the distribution area with highest demand and considering other site-specific constraints (topology, multiple pressure-zone systems, etc.). Optimal network configuration, in terms of hydraulic efficiency and water quality, is rarely considered. Long residence time results in the loss of disinfectant residual and favors water quality degradation. Up to now, the optimization of the WDS design and operations have mostly focused on pipe sizing and pumping schedules without taking into account storage tank locations, storage capacity and water quality. The purpose of this paper is to present a new methodology to optimize water storage tank volume and location. This methodology, will take into account hydraulic requirements as well as water quality requirements (by minimizing the residence time in order to reduce disinfectant decay and disinfection by- product formation). The optimization model, linked with EPANET, is applied to this benchmark and results are analyzed.

M Bhandari and et.al: Limit state method which is widely used has been adopted in the new version of IS 3370-2009 Code of practice for concrete structures for storage of liquids. As per the provisions of the earlier version of the code (IS 3370-1965), the designing of water tanks was permitted by working stress method only. The study was conducted in order to compare the design provisions of IS 3370 (1965) and IS 3370 (2009).In this study, a comparison of design of water tanks using the Working Stress and Limit State methods was carried out. To accomplish the comparative study, design of three types of water tanks that is an elevated circular tank of 500 kl capacity, an elevated square tank of 250 kl capacity and an underground rectangular water tank of 250 kl capacity were taken up. The quantities of materials were calculated for each problem. The results have been presented in the form of graphs and tables, and it has been observed that Design of water tank by Limit State Method is most economical as the quantity of material required is less as compared toworking stress method**.**

Mayank Gopal Manwani and et.al: As known from very upsetting experiences, liquid storage tanks were collapsed or heavily damaged During the earthquakes all over the word. The economic lifetime of concrete or steel tanks is usually in the range of 40 to 75 years (ALA 2001).Damage or collapse of the tanks causes some unwanted events such as shortage of drinking and utilizing water, uncontrolled fires and spillage of dangerous fluids. Due to this reason numerous studies done for dynamic behavior of fluid containers; most of them are concerned with cylindrical tanks. In the study, Seismic forces acting on an Elevated water tank e.g. circular Tank and rectangular tank are studied with constant staging height. Seismic forces acting on the tank are also calculated changing the Seismic Response reduction Factor(R). IS: 1893-1984/2002 for seismic design and then checked the Design of Tanks by using the Software STAAD PRO**.**

SK.NASEEMA and et.al: 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. As from very offensive past records, many reinforced concrete elevated water tanks were collapsed or highly damaged during the earthquakes all over the world. General observations are pointing out the reasons towards the failure of supporting system which reveals that the supporting system of the elevated tanks has more critical importance than the other structural types of tanks. Most of the damages observed during the seismic events arise due to the causes like improper/unsuitable design of supporting system, mistakes during selection of supporting system, improper arrangement of supporting elements and/or underestimated demand or overestimated strength. The present work aims at checking the adequacy of water tank supported on shafts for the seismic excitations. The result shows that structure response is exceedingly influenced by different capacities of water tank and their one mass and two mass models and earthquake characteristics**.**

Chirag N.Patel and et.al: The paper provides a literature review on behavior and suitability of supporting system of reinforced concrete Elevated /overhead tanks during vulnerable force events like earthquake with some unusual alteration. As from very offensive past records, many reinforced concrete elevated water tanks were collapsed or highly damaged during the earthquakes all over the world. General observations are pointing out the reasons towards the failure of supporting system which reveals that the supporting system of the elevated tanks has more critical importance than the other structural types of tanks. Most of the damages observed during the seismic events arise due to the causes like improper/unsuitable design of supporting system, mistakes during selection of supporting system, improper arrangement of supporting elements and/or underestimated demand or overestimated strength etc. Consequently the aim of this study is to know the effectiveness of supporting systems of elevated tanks with different alteration. A reviewed literature demonstrates the considerable change in seismic behavior of elevated tanks with consideration of responses like displacement, base shear, base moment, sloshing, torsion vulnerability etc. Finally study discloses the importance of suitable supporting configuration to remain withstands against heavy damage/failure of elevated water tanks during seismic events.

Ranjit Singh Lodhi and et.al: Intze type tank is commonly used overhead water tank in India. These tanks are designed as per IS: 3370 i.e. Code of practice for concrete structures for storage of liquids. BIS implemented the revised version of IS 3370 (part 1& 2) after a long time from its 1965 version in year 2009. Presently large number of overhead water tanks is used to distribute the water for public utility. In which most of the water tanks were designed as per old IS Code: 3370-1965 without considering earthquake forces. The objective of this dissertation is to shed light on the difference in the design parameters of (a) intze water tanks without considering earthquake forces (b) intze water tanks designed with earthquake forces. First design is based on Indian standard code: 3370- 1965 and second design is based on Indian standard code: 3370-2009 and draft code 1893-Part 2, (2005) considering two mass modal i.e. impulsive and convective mode method. Intze tank supported on frame staging is considered in present study.

G.P.Deshmukh and et.al: From the very upsetting experiences of few earthquakes, like Bhuj earthquake (2001) in India R.C.C elevated water tanks were heavily damaged or collapsed. This was might be due to the lack of knowledge regarding the proper behavior of supporting system of the tank due to the dynamic effect and also due to improper geometrical selection of staging. The main aim of this study is to understand the behavior of different staging, under different loading conditions and strengthening the conventional type of staging, to give better performance during earthquake. Equivalent Static Analysis, for five different types of bracing systems, applied to the staging of elevated circular water tank in zone IV, is carried out using STAAD Pro. Comparison of base storey shear and nodal displacements of the container of circular water tank for empty, half-filled and full condition is done. Eleven models are used for calculating base shear and nodal displacements After calculating base shear and nodal displacements of eleven models for empty, half filled & full condition of container applying with different types of bracing system in staging then economy point of view project study suggest such type of bracing which gives minimum base shear as well as considerable displacement for measure earthquake zones.

Dr. R. B. Khadiranaikar and et.al: Earthquakes are one of the most devastating natural hazards that cause great loss of life and Livelihood. The determination of the natural period of vibration of a reinforced concrete structure is an essential procedure in earthquake design and assessment. The fundamental period of vibration of a reinforced concrete structure appears in the equation specified in building codes to calculate the design base shear and lateral forces. To estimate the period, building codes provide empirical Formulas that depend on the building material, building type and overall dimensions of the structure. The aim of the present investigation is to propose a simplified period – height equation for use in the seismic force estimation of elevated water tank. The period of vibration which has been deriving here in represents the period of first mode of vibration. The study includes the seismic response of elevated water tank with different size, shape, capacities and varying height for high seismic zone in India. Various analytical models were prepared using SAP 2000 V-14.2 software. The new formulation for the estimation of time period of Elevated water tanks are developed using regression analysis from the statistical data generated. The combined general equation thus arrived at, can be used in general for Intze and funnel type of elevated water tanks irrespective of the capacities, height, type of staging, and type of bracing as an alternative to the already available code provisions of IS:1893-2002.

Harry W. Shenton III and et.al: The paper presents the results of an analytical investigation of the seismic response of isolated elevated water tanks. A discrete three-degree-of-freedom model of the isolated structure is presented that includes the isolation system, tower structure, and sloshing fluid. Fluid-structure interaction is modeled using the mechanical analogy proposed by Housner. The model captures the salient features of the system response, yet is still amenable to closed-form solution. The natural frequencies and mode shapes are determined, and a response spectrum analysis is conducted. Results are investigated for the full range of tank capacities and height to diameter ratios found in practice and for the full range of fluid elevations. Results of the isolated elevated tank are compared to the corresponding fixed-base tank design and indicate that seismic isolation is effective in reducing the tower drift, base shear, overturning moment, and tank wall pressure for the full range of tank capacities. Isolation is most effective for the smallest capacity tank; however, in the case, a single mode solution for the isolated structure is not adequate, as the fluid motion contributes significantly to the overall structural response. Isolation does, however, increase the relative convective fluid displacement in the tank.

Bugatha Adilakshmi and et.al: Storage reservoirs and overhead tanks are used to store water. All tanks are designed as crack free structures to eliminate any leakage. In this project, working stress method is used to design an INTZE tank and Elements of the INTZE tank are designed by limit state method. In general, for a given capacity, circular shape is preferred because stresses are uniform and lower compared to other shapes. Lesser stresses imply, lower quantities of material required for construction which brings down the construction cost of water tanks. This project gives in brief, theory, design and analysis of the INTZE type water tank. The main objective of this paper is to give best estimates of the required quantity of concrete and steel for a given water holding capacity. Preparing the design, estimation, costing, analysis of designs and cost comparison of output graphs for various inputs is included in this report.

III. REMARKS

- Thalapathy.M and et.al and Sk.Naseema and et.al press on that structure are to be modeled for forces irrespective of type of liquid stored.
- M.Bhandari and Karan Deep Singh suggested that limit state method is more cost effective in terms of amount of materials and formwork used as compared to working stress method.
- M. Bhandari and et.al,Abba Mas'ud Alfanda and et.al has been observed that Circular-shaped tank consumes less quantity of material as well as formwork in comparison with Square and Rectangular ones.
- Harry W. Shenton III, and Francis P. Hampton express that the isolated elevated tank are compared to the corresponding fixed-base tank design indicate that seismic isolation is effective in reducing the tower drift,

- base shear, overturning moment, and tank wall pressure for the full range of tank capacities.
- Bugatha Adilakshmi and et.al suggested that Hybrid design method consisting of LSM for structural elements and WSM for tank is advocated for optimization.
- The need to carry out further research for designing earthquake resistant overhead water tank is underlined by Ranjit Singh Lodhi and et.al & Dr. R. B. Khadiranaikar and et.al in their study.

A. Scope of current work is to assess and validate the following

- To present the comprehensive literature survey and its critical study on ESR subjected to static and dynamic loading.
- From the in depth literature study it is observed that no any work has been carried out yet over ERS resting on sloping ground, hence the study is being undertaken to assess the behavior of ERS on sloping ground profile.
- The obvious question that emerges out from the study of IS: 3370:2009 and other research scholars that when LSM is both safe and economical then why the WSM method is still retained in the code as parallel design procedure.

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