Review on Retrofitting & Rehabilitation of Elevated Water Tank by using SAP 2000

S. A. Kumbhar[1] G. V. Bunage[2] R. S. Taware[3] A. S. Kolekar[4] A. I. Gaikwad[5]
[1,2,3,4,5]UG Student
[1,2,3,4,5]Department of Civil Engineering
[1,2,3,4,5]Dattakala Group of Institution Faculty of Engineering, Maharashtra, India

Abstract— Elevated water tanks are one of the most necessary lifeline structures in earthquake prone regions. In major cities and additionally in rural areas elevated water tanks forms an integral part of water supply scheme. These structures has massive mass concentrated at the highest of slender supporting structure thus these structures are especially vulnerable to horizontal forces due to earthquake. Analysis of elevated tank is done by SAP2000. During this paper elevated storage tank of staging height 12m is taken into account with capacity 70 m3. Analysis has been done using SAP-2000. The Rehabilitation of the existing damaged Elevated storage reservoir with pile foundation is employed during this work to judge the effectiveness of retrofitting techniques, known as FRP wrapping. Economic aspects square measure studied for various innovative water tanks staging systems with reference to typical frame type and shaft kind staging of ESR. Concrete elevated water tanks are important structures that are expected to stay functional when severe earthquake so as to serve water system network. Throughout earthquake activity the liquid exerts impulsive and convective pressures (sloshing) on the walls and bottom of tank.

Key words: Rehabilitation, FRP, SAP2000, Retrofitting

I. INTRODUCTION

For water supply and fire protection elevated water tanks are used commonly. Due to earthquake this structure may get fail. Therefore the analysis of elevated tank must be carefully performed, so that safety can be assured when earthquake occurs and the tanks remain functional even after earthquake. The staging of elevated water tank get more sensitive due to irregular shape of water tank and it may get fail especially due to an earthquake. Elevated water tanks are considered as important services in many cities to fulfill demands. Their safety performance during strong earthquakes is of critical concern. They should not fail after earthquake, so that they can be with standing to meet the needs like domestic and fire. Many studies has been done on the seismic behavior, analysis, and design of tanks, particularly ground water tanks. Up to now more studies has been done on elevated water tank. As per the study of past earthquake, structure of elevated water tank has become weak and their seismic behavior has not been convenient being damaged, because of lifeline structures failure, such as elevated tanks with insufficient seismic resistance, firefighting and other emergency response efforts can be hindered (e.g., experiences from Chile 1960, 1978 Izu-Oshima and Miyagi, 1971 San Fernando, and 1987 Whittier earthquakes). There have been numerous studies analyzing and investigating the dynamic behavior of fluid storage tanks, however, most of these studies have focused on the ground level cylindrical tanks, very few studies have concentrated on the behavior of elevated tanks as shown in fig 1.1. Therefore, the attention is generally focused on the dynamic behavior of the fluid and its effect on (staging) the support structure. Most studies investigating the behavior of elevated tanks are summarized below. A model including an analysis of a variety of elevated rigid tanks undergoing translation and rotation was developed by Haroun and Ellaithy. Due to occurrences of earthquake in Gujarat (Bhuj, twenty six Jan 2001) tank that were wont to designed by IS 1893-1984 is revised by new IS 1893-2002. During this code the worth of response reduction issue (R), Sa/g and variety of zone is completely different. Because of revise IS code, their unstable behavior, in post elastic region might be quite completely different. Thus, albeit each the codes area unit given constant kind of structure, their unstable response might be quite {different totally completely different completely different} which can end in different level of residual malleability (IS1893-2002). Aim of the current study is to bring out the variations in unstable behavior of column- beam frame of Elevated tank in IS1893-1984 and IS1893-2002 and to quantify their strength and supply necessary strengthening of structure to take care of practicality. [14]

A. Design of Water Tank

Elevated water tanks include large water mass at the highest of a slender staging that are most crucial thought for the failure of the tank staging throughout earthquakes. Elevated water tanks are essential and strategic structures and injury of those structures throughout earthquakes could endanger drinking water supply, cause to fail in preventing massive fires and substantial economic loss. Since, the elevated tanks are often employed in unstable active regions conjointly hence; seismic behavior of ESR should be investigated intimately. Because of the shortage of information of supporting system a number of the tank were folded or heavily damages. therefore there's need to specialize in seismic safety of lifeline structure exploitation with relation to alternate supporting system that are safe throughout earthquake.1.3 Seismic Analysis of Elevated Water Tank

Seismic safety of liquid storage tanks is of right smart importance. Water storage tanks should stay purposeful within the post-earthquake period to confirm potable facility to earthquake-affected regions and to cater the requirement for firefighting. Industrial liquid containing tanks might contain extremely toxic and combustible liquids and these tanks should not lose their contents throughout the earthquake. Thus seismic analysis of tank is incredibly necessary. Seismic analysis of elevated tank concerned two varieties of analysis.

1) Equivalent Static analysis of elevated water tanks.
2) Dynamic analysis of elevated water tanks.

B. Equivalent Static Analysis of Elevated Water Tanks

Equivalent static analysis of elevated water tanks is that the typical analysis supported the conversion of unstable load in equivalent static load. IS: 1893- 2002 has provided the method of study of elevated tank for unstable loading. Traditionally, unstable masses were taken as equivalent static accelerations that were changed by numerous factors, counting on the location's seismicity, its soil properties, the natural frequency of the structure, and it's supposed use. Elevated tank is studies for each the condition i.e. tank full condition and tank empty condition. For each the condition, the tank is idealized by one- mass structure. For equivalent static analysis, water- structure interaction shows, each water and structure succeed a choose at constant time thanks to the idea that water is stuck to the instrumentation and acts as a structure itself and each water and structure has same stiffness. The response of elevated water tanks obtained from static analysis shows the high value. That's why for giant capacities of tanks, static response don't seem to be precise. If we tend to analyze the elevated tank by static methodology and style by constant, we tend to recover from stabilized or say over strengthened section however it will be uneconomical. That's why static systems of planning of elevated water tanks don't seem to be helpful in unstable zones. And hence, IS code provision for static analysis is restricted for little capacities of tanks only. Dynamic response of elevated water tanks is difficult to define, as behavior of tank is unpredictable. Dynamic analysis of liquid storage tank may be a advanced drawback involving water- structure interaction. Supported varied analytical, numerical and experimental studies, straightforward spring- mass models of tank- liquid system are developed to calculate the fluid mechanics forces. Throughout the earthquake, water contained within the tank exerts forces on tank wall yet as bottom of the tank. These fluid mechanics forces ought to consider within the analysis additionally to fluid mechanics forces.

C. New & Emerging Technologies for Retrofitting & Repairs:

To meet up the wants of advance infra-structure new innovative materials/ technologies in applied science business has begun to operate of the various structures. With structures turning into old and also the increasing bar for the made buildings the recent buildings have begun to Show a heavy need of further retrofits to extend their durability and life. Several environmental and natural disasters, earthquake being the foremost moving of all, have additionally created a requirement to extend the current safety levels in buildings. The understanding of the earthquakes, world over, is increasing day by day and so the unstable demands imposed on the structures get revised frequently. Similarly, the {design the planning the look} methodologies evolve with the growing analysis within the space of unstable engineering and bound fashionable recent design philosophies, like soft story structures, aren't any longer considered acceptable for earthquake resistant style. Several of the prevailing lifeline structures were analysed, designed and elaborated as per the recommendations of the current codes. Such structures create a requirement to undergo Re-evaluation method. Such structures overtimes might not qualify to current unstable needs and so, retrofitting of those structures is important. The retrofitting is one in all the simplest choices to create AN existing inadequate building safe against future probable earthquake or alternative environmental forces. There square measure several alternative factors, considered in deciding for any retrofitting strategy.

The following are some reasons that may need retrofitting:

1) Building that are designed considering gravity loads only.
2) Development activities within the field of Earthquake Resistant design (EQRD) of buildings and different structures result into change in design ideas.
3) Lack of timely revisions of codes of practice and standards.
4) Lack of revisions in seismic zone map of country.
5) In cases of alterations in buildings in seismic prone space i.e. increase in variety of story, increase in loading category etc.
6) In cases of degradation of earthquake (EQ) forces resistant level of building e.g. Decreases in Strength of construction material owing to decay, fire damage, and settlement of foundations.
7) The standard of construction really achieved is also under what was originally planned.
8) Lack of understanding by the designer.
9) Improper designing and mass distribution on floors.

Many choices for retrofitting a structure area unit possible; those which are used historically for a long time currently like addition of latest shear walls, addition of infill walls, addition of wing (Side)walls, addition of buttresses, jacketing of reinforced concrete members, support, sleeping, steel collars, casing, building up, bonding steel plates or steel Jacketing. However, with increase in analysis and introduction of latest materials and technology there are new ways in which of retrofitting the structure with several extra advantages. Introduction of fiber reinforced composites being one in all them. It's proved to be a promising material and technology in repair and retrofitting.

II. LITERATURE REVIEW

This chapter presents a review of relevant research in retrofitting and rehabilitation of the structure. The main objective of the literature review is to explore studies related to retrofitting and rehabilitation of reinforced cement concrete elevated water tank by using various methods. Most of literature has been referred from the books, seminars, thesis conference proceeding, journals handbooks on liquid storage tank. Also the some literature has been referred from the international standards such as ACI, ATC-40, IS code and FEMA-356 etc.

A. Rivews

Applied Technology Council[1] (1996): The document provides analytical procedures for evaluating the seismic performance of existing buildings. Simplified nonlinear analysis methods are provided. Use of nonlinear procedures in general has been discussed and capacity spectrum method is introduced. Although the methods mentioned in the document are not intended for new buildings, the analytical

procedures are applicable to new structures as well. The analytical procedures incorporated in the methodology accounts for post elastic deformations of the structure by using simplified nonlinear static analysis methods. By using static pushover analysis method lateral force resisting capacity of structure is obtained. Verification of acceptable performance by a comparison of available capacity and demand on structure is also presented. A detailed description of each the three primary elements of the nonlinear static analysis procedure are given. The step-by-step development of capacity curve of a structure, various alternative methods to determine displacement demand by use of reduced demand spectra or target displacement are also explained. Various methods described in the document are explained through various explanatory examples.

Verulkar[2] (2005): The aim of this study was to assess the differences in seismic behavior of staging frame used in water tanks and building frames by using pushover analysis. A detailed procedure for pushover analysis is given. In order to assess the seismic behavior of staging frame and building frame, effects of various structural features on the capacity curves are examined. As the first step, contribution of strength and stiffness of masonry infill panels are removed from the building which is then followed by removal of floor diaphragm, except at the top. In the next step, load distributed at each storey level in building, is applied at the top of the frame. These step by step changes in the building frame are studied in terms of seismic behaviour with the help of pushover analysis. Pushover analysis of four typical tank staging with different configurations is also performed. Seismic behavior of these tank staging are observed to be different than that of buildings in terms of sequence of hinge formation and existing ductility.

Inel and Ozmen[3] (2006): This paper discusses the effects of plastic hinge properties on nonlinear response of reinforced concrete buildings. The paper discusses the results of pushover analysis with default and user defined hinge properties. Four and seven storey buildings are considered and a study is carried out with the help of SAP 2000. The paper gives details of reinforcement as well as other structural features of the building under consideration. The study gives emphasis on the comparison of pushover curves with different plastic hinge lengths and other parameters such as spacing of transverse reinforcement are also included in the study. It has been observed that plastic hinge length and spacing of transverse reinforcement does not affect the base shear capacity of the structure but they have considerable effects on displacement demands. The paper concludes that default hinge properties of SAP 2000 may lead to less accurate results if not used cautiously. In case of evaluation of the capacities of existing buildings, use defined hinge properties should be preferred which will give much more reliable results.

Kadid and Boumrkik[4] (2008): Kadid is aimed at evaluating the performance of the framed structures under future expected earthquakes. Need was felt to evaluate the performance of structures after Boumerdes (2003) earthquake which devastated a large part of Algeria. It is stated that pushover analysis is a viable method to the damage vulnerability of buildings. The paper explains pushover analysis of three framed buildings with 5, 8 and 12 stories representing low, medium and high rise buildings respectively. The study is carried out using general finite element software SAP 2000. The results show that capacity spectrum intersects the demand spectrum near elastic range of the response which shows that margin of safety against collapse is high and sufficient strength and displacement are in reserve. The paper finally concludes that behavior of properly designed reinforced concrete framed structures is adequate for desired ground motion.

Ayazhussain Jabar at el[5]. (2012): In empty condition, higher base shear for cross bracing pattern in Loma Prieta time history. For Kobe earthquake, lower base shear and overturning moment in cross bracing and radial bracing pattern severally in empty condition. Just in case of half- full condition, lowest base shear and overturning moment for Radial Bracing in Loma Prieta and Kobe earthquake intensity respectively. For basic staging overturning moment is highest in half-full condition for Loma Prieta having high PGA value. Just in case of Full condition, highest base shear is obtained for radial bracing in Imperial Valley having low PGA price. Roof displacement is significantly decreases with increase in PGA price of earthquake time history and additionally noted higher value in Imperial Valley.

Gaikwad Madhukar V. at el[6].(2013): Gaikwad Madhukar states that the earthquake Impulsive pressure is usually larger than Convective pressure for little capacity tanks, however it's vice-versa for tanks with large capacities. Hence Static analysis for big capacities tanks is uneconomical as all the water mass acts itself as a convective. This statement denotes that if large capacities tanks square measure designed by static methodology distortion within the instrumentation is seen at constant time of collapse of staging. Large capacities square measure liable of manufacturing high stresses on the wall and therefore the slabs of the instrumentation, if the hydraulics factors square measure neglected throughout the analysis they will have an effect on smartly and collapse of the structure will takes place.

M.V.Waghmare at el[7].(2013): The most of the failures of enormous tanks when earthquakes was suspected to possess resulted from the dynamic buckling caused by overturning moments of seismically induced liquid inertia and surface slosh waves. Usually if the tank is worked up due to earthquake ground motion the displacement of water within the tank depends upon the quantity of water contained in it. Usually if the tank is worked up due to earthquake ground motion the displacement of water within the tank depends upon the quantity of water contained in it. Sloshing of water in tank depends not only on the quantity of water in tank however also on staging height and h/D ratio combination of elastic modal properties of frames. Two strategies to produce a target for displacement management of pushover analysis were tested within the study. The study clearly identifies the limitations of pushover analysis.

Pavan S. Ekbote at el[8] (2013): Base shear is additional for hexagonal & Radical bracings of Full tank condition than 0.5 Full and Empty condition. Over-turning moment will increase as bracing level will increase for various varieties of bracings. Over-turning moment is additional hexagonal & Radical bracings of Full tank condition than 0.5 Full and Empty condition. Bending Moment deep down of column goes on decreasing as level of

bracing will increase for various bracing types. Story displacement goes on decreasing as level of bracing will increase and hexagonal & radical type bracing provides less story displacement as compared to different bracing types. Throughout the earthquake Impulsive pressure is usually bigger than Convective pressure for small capability tanks, however it's vice-versa for tanks with massive capacities.

B. Concluding Remark

From the above literature review it's found that:

1) The value Impulsive pressure is always greater than Convective pressure for small capacity tanks. 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 takes place.
2) The most of the failures of large tanks after earthquakes was suspected to have resulted from the dynamic buckling caused by overturning moments of seismically induced liquid inertia and surface slosh waves.
3) Base shear is more for Hexagonal & Radical bracings of Full tank condition than Half Full and Empty condition. Over-turning moment increases as bracing level increases for different types of bracings.
4) For Kobe earthquake, lower base shear and overturning moment in cross bracing and radial bracing pattern respectively in empty condition. In case of half- full condition, lowest base shear and overturning moment for Radial Bracing in Loma Prieta and Kobe earthquake intensity respectively.
5) The Maximum displacement in the height of the structure in nonlinear dynamic analysis, considering the soil condition, happens in the joint of the supporting system to the container.
6) In stiff and relatively soft soils, system's maximum displacement occurs in the joining place of the supporting system to the container and the softer the soil, the system's maximum displacement happens in the system's roof level.
7) It has been observed that plastic hinge length and spacing of transverse reinforcement does not affect the base shear capacity of the structure but they have considerable effects on displacement demands.

C. Scope of the Present Work

From the literature review it is clear that pushover analysis is being increasingly used to assess the seismic performance of reinforced concrete structures, particularly, in inelastic range. This analysis also helps in assessing the ductility available in the structure. Pushover analysis helps in assessing capacities of structures which are otherwise designed using codal provisions (i.e. linear analysis). In codal provisions, generally, response reduction factor is used to arrive at design seismic forces. Codes also provide RC detailing approaches so as to attain required ductility. It is seen that for same type of structure, the value of response reduction factor is different for IS1893-1984 and IS 1893-2002. For example, in IS1893-2002; the response reduction factor(R) is different for different structure. This point out that even for same type of structure the value of seismic force is different in IS 1893-1984 and IS 1893-2002. Hence the strengthening requirement of structure to satisfy the earthquake force is different. In this paper find out the seismic force by using IS 1893-2002 and compare with IS1893-1984 and provide strengthening requirement of structure to satisfy the earthquake force. With this in view, and recognizing that pushover analysis can provide insight into actual capacity of structure, in this project work, pushover analysis of elevated water tank is done and compared to judge if they show different types of ductility.

III. Methodology

A. Seismic Analysis of Elevated Water Tank

Seismic safety of liquid storage tanks is of significant importance. Water storage tanks should stay useful within the post-earthquake amount to ensure potable facility to earthquake-affected regions and to cater the requirement for fireplace fighting. Industrial liquid containing tanks could contain extremely toxic and inflammable liquids and these tanks should not lose their contents throughout the earthquake. Thus unstable analysis of storage tank is extremely important. Unstable analysis of elevated storage tank concerned two types of analysis.

1) Equivalent Static analysis of elevated water tanks.
2) Dynamic analysis of elevated water tanks.

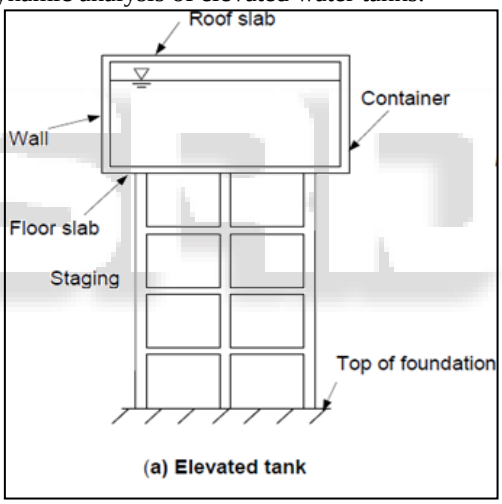

Fig. 1: Component Part of Elevated Water Tank

1) Analysis by using SAP 2000

The package used for this study is SAP 2000. It's product of Computers and Structures, Berkeley, USA. SAP 2000 is employed for analyzing general structures together with bridges, stadiums, towers, industrial plants, offshore structures, buildings, dam, soils etc. it's a totally integrated program that permits model creation, modification, execution of research, style improvement, and results review from among one interface. SAP 2000 may be a standalone finite component based mostly structural program for analysis and style of civil structures. It offers Associate in Nursing intuitive, however powerful computer program with several tools to assist in fast and correct construction of models, at the side of refined technique required doing most advanced projects. SAP 2000 is objecting based mostly, that means that the models are created with members that represent physical reality. Results for analysis and style are reported for the general object, providing information that is each easier to interprets and in line with physical nature.

B. New & Emerging Technologies for Retrofitting & Repairs:

To meet up the necessities of advance infra-structure new innovative materials/ technologies in civil engineering trade has began to the operate of the various structures. With structures changing into recent and also the increasing bar for the created buildings the recent buildings have began to Show a heavy need of extra retrofits to extend their durability and life. Several environmental and natural disasters, earthquake being the most affecting of all, have additionally made a desire to extend the current safety levels in buildings. The understanding of the earthquakes, world over, is increasing day by day and thus the seismic demands imposed on the structures get revised frequently. Similarly, the {design the planning the look} methodologies evolve with the growing research within the space of seismic engineering and bound popular recent design philosophies, like soft story structures, are not any longer considered acceptable for earthquake resistant style. Several of the prevailing lifeline structures were analyzed, designed and detailed as per the recommendations of the prevailing codes. Such structures create a desire to undergo Re-evaluation method. Such structures frequently might not qualify to current seismic necessities and thus, retrofitting of those structures is essential. The retrofitting is one among the simplest choices to form associate degree existing inadequate building safe against future probable earthquake or different environmental forces. There are several different factors, considered in decision making for any retrofitting strategy.

The following are some reasons that may need retrofitting:

1) Building which are designed considering gravity loads only.
2) Development activities in the field of Earthquake Resistant Design (EQRD) of buildings and other structures result into change in design concepts.
3) Lack of timely revisions of codes of practice and standards.
4) Lack of revisions in seismic zone map of country.
5) In cases of alterations in buildings in seismic prone area i.e. increase in number of story, increase in loading class etc.
6) In cases of deterioration of earthquake (EQ) forces resistant level of building e.g. Decreases in Strength of construction material due to decay, fire damage, and settlement of foundations.
7) The quality of construction actually achieved may be lower than what was originally planned.
8) Lack of understanding by the designer.
9) Improper planning and mass distribution on floors. Design the FRP as per ACT-40

1) Recent Retrofitting Methods

There are several relatively new technologies developed for seismic Retrofitting that are supported "Response control". These techniques includes providing additional damping exploitation dampers (Elastic-plastic dampers, friction dampers, tuned mass and tuned liquid dampers, viscous-elastic dampers, lead extrusion dampers etc.) and techniques like base isolation that are introduced to require care of seismic management as shown in fig. 2.

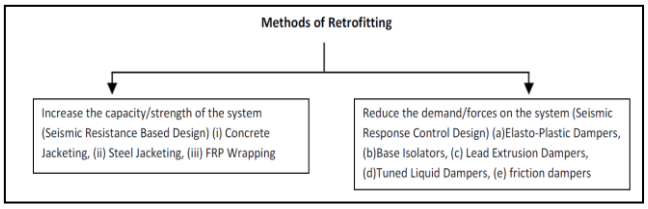

Fig. 2: Methods of Retrofitting

C. Static Pushover Analysis of Water Tank

Pushover Analysis choice can permit engineers to perform pushover analysis as per FEMA -356 and ATC-40. Pushover analysis could be a static, nonlinear procedure using simplified nonlinear technique to estimate seismic structural deformations. It's associate progressive static analysis wont to verify the force-displacement relationship, or the capability curve, for a structure or structural element. The analysis involves applying horizontal masses, in a much prescribed pattern, to the structure incrementally, i.e. pushing the structure and plotting the whole applied shear force and associated lateral displacement at every increment, till the structure or collapse condition. The nonlinear static pushover procedure was originally developed and suggested by two agencies specifically, Federal Emergency Management Agency (FEMA) and Applied Technical Council (ATC), under their seismic rehabilitation programs and tips. This is often enclosed within the documents, FEMA356 and ATC40.

1) AFEMA356

The primary purpose of FEMA356document is to produce technically sound and nationally acceptable tips for the unstable rehabilitation of buildings. The rules for the unstable rehabilitation of buildings are supposed to function a prepared tool for style professionals for carrying out the planning and analysis of buildings, a reference document for building regulatory officers, and a foundation for the longer term development and implementation of building code provisions and standards.

2) ATC40

Seismic analysis and retrofit of concrete buildings commonly referred to as ATC40 was developed by the Applied Technology Council (ATC) with funding from the California Safety Commission. Though the procedures suggested during this document are for concrete buildings, they are applicable to most building types. ATC40 recommends the subsequent steps for the complete method of analysis and retrofit: Initiation of a project: determine the primary goal and potential scope of the project.

3) Selection of qualified professionals

Select engineering professionals with a demonstrated experience in the analysis, design and retrofit of buildings in seismically hazardous regions. Experience with PBSE and nonlinear procedures are also needed.

4) Performance Objective

Choose a performance objective from the options provided for a specific level of seismic hazard.

Review of building conditions: perform a site visit and review drawings.

IV. CONCLUSIONS

After reviewing it has been concluded that damaged water tank lose its concrete strength and as per original design it

require to improve quality and serviceability of tank by retrofitting of tank .The life of the elevated water tank will be improved by providing the proper retrofitting and will be economical. The elevated water tanks performance will be improved by retrofitting. This can be analyzed by SAP2000.

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