Comparison Between Time History Method And Response Spectrum Method For Dynamic Analysis Of Elevated Water Tank

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Abstract- *Elevated water tanks play a crucial role in public water distribution systems, providing storage and pressure necessary for water network systems. However, these structures have demonstrated poor seismic performance in past earthquakes, highlighting the need for comprehensive research to understand their nonlinear seismic behavior. This study employs a finite element method to investigate the nonlinear seismic response of reinforced concrete (RC) pedestals in elevated water tanks. A wide range of practical tank sizes and pedestal heights and diameters are included in the research to establish a comprehensive database for seismic response factors. Pushover analysis is conducted to construct pushover curves, determine over strength and ductility factors, and assess the influence of parameters such as fundamental period and tank size on the seismic response of elevated water tanks. A probabilistic method is implemented to verify seismic performance and determine response modification factors. The study also examines the impact of wall openings on the seismic response characteristics of elevated water tanks. Furthermore, the effect of axial compression on the shear strength of RC pedestals is evaluated and compared to nominal shear strength standards. This abstract encapsulates the comprehensive investigation conducted in this thesis, which aims to shed light on the intricate dynamics of elevated water tanks under seismic loading conditions, offering crucial insights for enhancing their seismic resilience and structural performance.*

Keywords- Water tank, time history analysis, response spectrum analysis, dynamic analysis, RCC, etc.

I. INTRODUCTION

1.1 Introduction

Elevated Water Tank is the public water distribution system;elevated water tanks are frequently utilized. Water tanks are critical components of the lifeline system, and their seismic safety is critical owing to post-earthquake functioning requirements. Elevated water tanks, also known as elevated service reservoirs (ESRs), are made comprised of a container and a tower (also called as staging). The use of staging in the form of a reinforced concrete shaft and a reinforced concrete column-brace structure is widespread. The column- brace frame staging system is basically a 3D reinforced concrete structure that supports the container and resists lateral stresses caused by earthquakes or wind.

The purpose of this research is to identify and quantify the variations in seismic behavior of column beam (Building) and column-brace (Staging) frames in the post-elastic zone. Nonlinear dynamic analysis is also used to highlight variations in the nonlinear dynamic behavior of different kinds of frames. The structure is exposed to monotonically increasing lateral pressures with an invariant height-wise distribution until a goal displacement is achieved in time history analysis. First, a two- dimensional or three-dimensional model is constructed, including bilinear or trilinear load- deformation diagrams of all lateral force resisting components, and gravity loads are applied.Elevated water tanks are often utilized as part of a lifeline system in public water distribution systems. Seismic safety of water tanks is critical due to post-earthquake functioning requirements.

Elevated water tanks are generally used being an important part of a lifeline system. Due to post earthquake functional needs, seismic safety of water tanks is of most important. In major cities and also in rural areas elevated water tanks forms an Integral part of water supply system. The elevated water tanks must remain functional even after the earthquakes as water tanks are most essential to provide water for drinking purpose. These structures have large mass concentrated at the top of slender which have Supporting structure and hence these structure are especially vulnerable to horizontal forces due to Earthquakes.


Fig 1. 1:Bending Shear Failure in beam

So far, there has been no experimental test program (such as shaking table) that has studied the nonlinear response of RC pedestals to the strong ground motions. The number of numerical studies is also very few and mainly limited to only one or two elevated water tanks with certain tank weight and pedestal dimensions. This is despite the fact that elevated water tanks have a wide range of tank sizes and pedestal heights which may result in considerably different seismic response behaviors.

Furthermore, some of the design equations and requirements existing in the current codes are adopted from ACI 318-08 for designing components such as shear walls which are similar to RC pedestals. In addition, in some specific design features such as openings, the current code has adapted materials from ACI 307 (chimneys) and ACI 313 (silos). This shows the need to further evaluate some of the code requirements and equations. Poor performance in previous earthquakes, lack of experimental results, and importance of these structures as lifelines, very limited numerical studies, and evaluation of certain parts of the current code are the main drivers that necessitate a comprehensive study on the nonlinear performance of RC pedestals.

This study aims to fill this gap and investigate various aspects of nonlinear response behavior of RC pedestals by employing a finite element approach. All practical tank sizes and pedestal height and diameters are included in this research in order to define a comprehensive database for the seismic response factors of elevated water tanks. In addition, special topics such as effect of wall openings and shear strength of RC pedestals will be addressed and discussed. Various analysis methods such as pushover and incremental dynamic analysis (IDA) will be employed to serve this purpose. Other than deterministic approaches, a probabilistic method is implemented as well to study the collapse probability of the RC pedestals under different conditions. The outcomes of this research will help better understand the actual nonlinear seismic response of elevated water tanks.

Elevated water tanks are employed in water distribution facilities in order to provide storage and necessary pressure in water network systems. These structures have demonstrated poor seismic performance in the past earthquakes. In this study, a finite element method is employed for investigating the nonlinear seismic response of reinforced concrete (RC) pedestal in elevated water tanks. A combination of the most commonly constructed tank sizes and pedestal heights in industry are developed and investigated. Pushover analysis is performed in order to construct the pushover curves, establish the over strength and ductility factor, and evaluate the effect of various parameters such as fundamental period and tank size on the seismic response factors of elevated water tanks. Furthermore, a probabilistic method is implemented to verify the seismic performance and response modification factor of elevated water tanks. The effect of wall openings in the seismic response characteristics of elevated water tanks is investigated as well. Finally, the effect of axial compression on shear strength of RC pedestals is evaluated and compared to the nominal shear strength from current guideline and standards.

1.2 Overview of Dynamic Analysis

Dynamic analysis is an important tool in structural engineering for evaluating the behaviour of structures under changing dynamic loads. While classic static analysis techniques give information about a structure's reaction to static loads, dynamic analysis expands this knowledge to include dynamic loading circumstances such as seismic occurrences, wind forces, and mechanical vibrations. Dynamic analysis is important because it can properly forecast structural reaction, evaluate structural stability, and assure the safety and serviceability of civil infrastructure. Engineers may improve structural performance and resilience by modelling real-world dynamic events, identifying possible vulnerabilities, optimising structural design, and implementing mitigation strategies. Dynamic analysis plays a crucial role in understanding the behavior of structures subjected to dynamic loads such as earthquakes, wind, and vibrations. This analysis provides valuable insights into the structural response, ensuring the safety, efficiency, and reliability of various engineering systems. In this article, we will explore the concept of dynamic analysis, its significance, different types, steps involved, applications, challenges, and more. Structures are constantly exposed to various dynamic forces, and it is vital to evaluate their response to such loads. Dynamic analysis is a branch of structural engineering that focuses on studying the behavior of structures under dynamic conditions. Unlike static analysis that considers the equilibrium of forces, dynamic analysis takes into account the time-dependent effects on structures.

1.3 Water Tank

Water storage tanks are used to store water for fire protection and potable drinking water within a designated area or community. Elevated tanks allow the natural force of gravity to produce consistent water pressure throughout the system. Based on the intended application and needs of the distribution area, elevated water tanks can be engineered using a broad range of shapes, sizes, and materials. Storage tanks are among the most important structures that serve multiple purposes for society and industry, generally tanks are used to store chemicals, oil, liquefied gas, also to store water for supplying to households as drinking purpose, for industries as a coolant and irrigational water for agricultural farming in some areas, also they use for firefighting and for emergencies.
One of the basic needs of all human being is water, so for that need there are various types of water tank depending upon their size, shapes and position.

I. Depending upon shape there are Intze, Circular, Conical, and rectangular water tank.
II. Depending on position there are Elevated, Underground and Ground supported water tank.
III. Depending on material there are Reinforced concrete, steel and Prestressed concrete tanks.

1.3.1 Elevated water tank

Water is human basic needs for daily life. Sufficient water distribution depends on design of a water tank in certain area. An elevated water tank is a large water storage container constructed for the purpose of holding water supply at certain height to pressurization the water distribution system. Many new ideas and innovation has been made for the storage of water and other liquid materials in different forms and fashions. There are many different ways for the storage of liquid such as underground, ground supported, elevated etc. Liquid storage tanks are used extensively by municipalities and industries for storing water, inflammable liquids and other chemicals. Thus Water tanks are very important for public utility and for industrial structure. Elevated water tanks consist of huge water mass at the top of a slender staging which are most critical consideration for the failure of the tank during earthquakes. Elevated water tanks are critical and strategic structures and damage of these structures during earthquakes may endanger drinking water supply, cause to fail in preventing large fires and substantial economical loss.

From all types of water tank elevated water tank which is also called as Elevated Service Reservoir (ESR) typically comprises of a container and a supporting tower (also called as staging) cover large area of distribution of water and ESR are specially constructed to maintain high pressure during supply of water at required locations. These tanks are most prone to get affected by earthquake forces, since large concentrated fluid mass is at the top which is supported by some staging system.

Fig 1: Elevated water storage tanks (ESR)

In general, there are three kind of water tanks-tanks resting on ground, underground tanks and elevated tanks among them elevated intze tank are considered in this study. Elevated Intze type tanks having a container at its top and it was supported over various type of staging as shown in Figure-1, a) Shell type staging, b) R.C.C Moment resisting Frame type staging, c) Steel Staging, d) Masonary Pedestal, R.C.C Frame type staging with bracing, Composite staging etc.

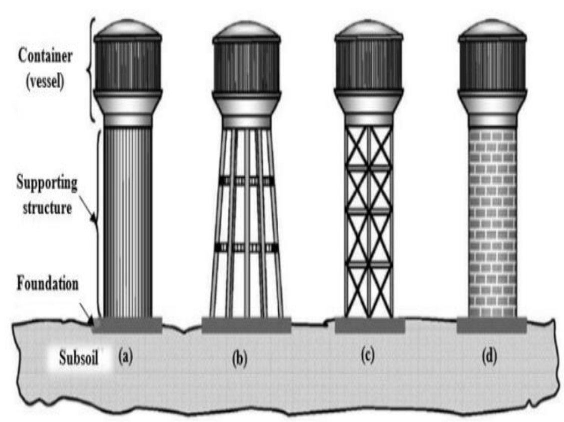


Fig 2: Different Staging Systems

Elevated water tanks are clearly displayed in public spaces, visible from both close and far distances. In India, the Intze style of overhead water tank is widely utilised. A significant number of overhead water tanks are now employed to supply water for public consumption. They are frequently used as markers in the landscape. As a result, the container's shape and form, as well as the supporting structure, must be given careful consideration from an aesthetic standpoint. Water storage tanks should stay operational in the postearthquake period to guarantee that earthquake-affected areas have access to drinkable water and to meet firefighting demands. Industrial liquid storage tanks may contain highly hazardous and combustible substances, and the contents of these tanks should not be lost in the event of an earthquake. Several big high water tanks were badly damaged during the earthquakes, but others were unharmed. The motion of the water relative to the tank, as well as the motion of the tank relative to the ground, must be considered while analysing the dynamic behaviour of such tanks. Because it is intended for wind and seismic pressures, the existing design of supporting structures for elevated water tanks is particularly sensitive to lateral forces caused by an earthquake. Water tanks can be damaged in many components for a variety of causes, including incorrect structural configuration design, inferior materials and workmanship, reinforcement corrosion, wind forces, earthquake forces, and so on. The lateral force design parameters in the zone of strong seismic activity are more or less governed by earthquake forces because of the enormous mass, especially when the tank is full. Total tank collapse must be prevented in the worst-case scenario. Some damage (repairable) may, nevertheless, be acceptable.

1.4 Time History Method for Dynamic Analysis

Time history analysis is a numerical simulation method employed to predict the dynamic response of structures by considering the actual time-varying loads applied to them. Unlike simplified static analysis, which assumes that loads act instantaneously and remain constant throughout, it takes into account the changing nature of forces over time. The most challenging part is the development of the time history curve for the analysis. Variation of the ground acceleration is required for the analysis.

The objectives of this study encompass three main goals. Firstly, it aims to analyze an elevated water tank using both the time history analysis method and the response spectrum method. Secondly, it seeks to compare the responses yielded by these two methods, providing insight into their respective strengths and weaknesses. Lastly, the study endeavors to compare responses of different bracing of water tank to seismic load and identify the suitable bracing system for resting the seismic load efficiently conducted in ETABS software. Through these objectives, the study aims to contribute to a deeper understanding of the structural behavior of elevated water tanks under seismic loading conditions.

II. LITERATURE REVIEW

SnehaGovindrao Mane, Dr. S. S. Angalekar "Seismic analysis of Water tank at different storey height ofthe Buildingandtocheckfluidsloshingeffect."(2022)

The current study is the extension of the "environmental floor" concept, where installing the DOSIWAMsystem at intermittent levels of a multistoried building is carried out. The water coming out of this tank hasvery low BOD, so the water becomes suitable for reuse in gardening, irrigation, and firefighting operations. Anovel approach was used, combining the CFD software and structural analysis software to check the sloshingeffect.Thisispartof a research effortdedicated todevelopingaCAE(ComputerAidedEngineering)methodology. The project's objective was to check the effect of the storage tank on the environmental floor.Thus, a storage tank and a water tank with an aspect ratio close to 1 can be safely provided. The difference intime period of the water tank and the structure was found to reduce the effect of sloshing. Hence, the StoragetankoftheDOSIWAMsystemcanbesafelyinstalledonthe structure.

W. A. Adil, M. A. Baluch et.al "Effect of Different Column Arrangements on Structural Behavior of SquareOverheadWaterTankbyResponseSpectrumAnalysis "(2022)

Overhead water tanks are involved in the important structures of any industrial areas and societies etc. Watertanks should remain in the functional condition during and after an earthquake or in any other emergency. Theintension of researchersisvery limited tostructural analysisand design of overhead water tankswhereastanks are very important structures. In this study, the author investigated the effectof differentcolumnarrangements on the structural behavior of square overhead water tank in terms of Base Shear, Time Period,Axial Force, and Main Column Moment according to the seismic zone 2A of Building Code of Pakistan byResponse SpectrumAnalysis usingSAP2000.

Boggula Rajesh, G. Sreekanth "Design and analysis of diffrent water tanks by considering slab wall and capacity in seismic zones" (2022)

Elevated water tanks subjected to dynamic loads supported on RC framed structure and concrete shaft structure with varying capacity and located in different seismic zones. The history of the earthquake demonstrates that it has inflicted numerous losses to the life of people in its active time.These structures have a large concentration on slender support structures and are at risk of horizontal forces due to the earthquake in specific. They are essential elements in municipal water deliver hearth combating structures and in many commercial centres for garage of water. Hence increased water tanks ought to continue to be functional even after the earthquake. In this study guide seismic analysis of improved square water tank is achieved according with IS: 1893-1984 (i.e. Lumped mass version) and IS: 1893-2002 (Part-2) draft code (i.e. Two mass version).The structures are analysed with different simulated soft ware's Staad-pro and E-tabs. The results are compared for optimal value analysis in particular forces.

KrushnarthChondikar "Design of Overhead Tank with Carbon Fibre/Fiber Rebar as Reinforcement and Time History Analysis using STAAD-Pro software." (2022)

The Construction and Design industry is always trying to find new and better technologies, ways, materials and equipment. One such technology/material is the using Carbon Fibre/fiber as Reinforcement for design the structure which is a new material in this industry that brings alternative for steel in the designing of the structure and offers design opportunities to enhance the performance of the structure with encouraging innovation. The use of this material in designing of the structure reflects economical. In present work, design of the overhead tank using carbon fibre/fiber as reinforcement, has been checked against the several loads, time history analysis and the maximum considered level criteria by performing the linear and nonlinear procedures with the help of STAAD-Pro software. In further work, the performance of overhead tank using carbon fibre/fiber as reinforcement will be checked at the several loads, time history analysis and the maximum considered level criteria.

Nasser Dine HadjDjelloul,, Mohamed Djermane "Non-linear numerical study of the dynamic response of elevated steel conical tank under seismic excitation" (2022)

Elevated cylindrical and conical steel tanks are widely used to conserve water or chemical liquids. These important structures are required to stay protected and operative at any time. The wall angle inclination of conical tank part, as well as the presence of the vertical earthquake component, can cause damage to this structure and even lead to its failure. The purpose of this study is to examine the effect of the wall angle inclination of the tank and the vertical earthquake acceleration component on the nonlinear dynamic stability of the elevated steel conical tanks under seismic excitation. The elevated steel conical tank is simulated utilizing the finite element analysis method using ANSYS software. The fluid-structure interaction is considered using a suitable interface that allows the fluid to apply hydrodynamic pressures on the structure. Three different models, namely Model – A-30°, Model –B-45°and Model –C-60°were investigated; it has been concluded that the impact of inclination of the tank wall significantly affects the nonlinear stability of the elevated steel conical tank. While considering the vertical ground acceleration, inclination plays a significant role in the design of this type of structures. Therefore, it should be appropriately included in the seismic analysis of elevated steel conical tanks to satisfy the safety of the elevated steel conical tank response under seismic loading.

Latha M. S. "Comparison of analysis between Rectangular and Circular overhead water tank" (2021)

The study predicts the analysis and design of the rectangular and circular overhead water tank using ETABS software. The water tank is modeled and analyzed by using dynamic analysis to resist lateral loads and design is made using working stress method manually. Dead load, live load, wind load and seismic loads are applied based on IS codes. The behavior of structure for the parameters like Story drift, displacement, stiffness, deflection, storey shear, base shear, area of steel and hoop tension for circular and rectangular water tank are studied and then comparison of the results is made between circular and rectangular overhead water tank. By this study we say that the circular water tank is suitable for larger capacity and rectangular is suitable for smaller capacity and it is economical for larger capacity.

TayyabaAnjum, Mohd. Zameeruddin "Evaluation of Efficacy of the Elevated Water Tank Under the Seismic Loads" (2021)

Elevated water storage tanks are the lifeline structures in urban areas that should remain serviceable during and after a seismic event. Experience learned from the past earthquakes worldwide showed that elevated water tanks were heavily damaged or collapsed during a seismic event. This failure attributes to the deficiency and misjudgment in the analysis and design aspects. Design procedures available in the present seismic codes indirectly address the inelastic behavior, and they showed the overestimates of the actual strength. Proper selection of a staging system and engineering demand parameters are the key elements of the elevated water reservoir design. In the present work, we performed a nonlinear time history analysis on the models prepared about the data of existing elevated water tanks available within the Nanded region (Maharashtra-India). The obtained engineering demand parameters were used to predict the efficacy of elevated water tanks.

III. METHODOLOGY

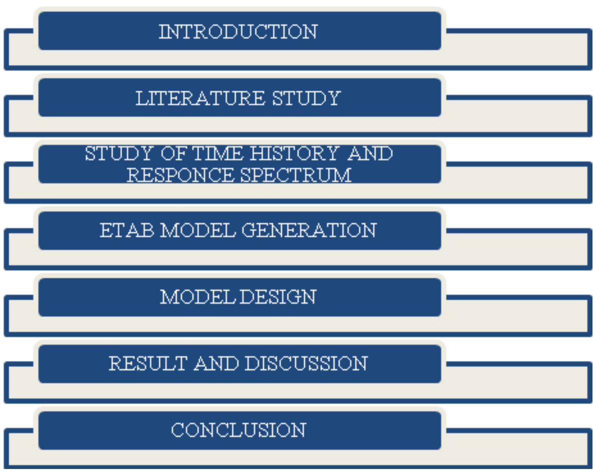


Fig 3: flowchart

3.1 Introduction

The seismic parameters obtained from the non-linear time history analysis of the elevated water tank provide valuable insights into its dynamic behavior and response to seismic loading conditions. Through meticulous analysis and interpretation of these parameters, engineers can better understand the structural performance and resilience of the tank under seismic events. The ground acceleration, velocity, and displacement recorded during the analysis serve as critical indicators of the seismic forces acting on the structure. By examining these parameters, engineers can assess the severity of the seismic excitation and its impact on the tank's stability and integrity. Additionally, studying the response of the tank under both full and empty conditions provides valuable data for evaluating the effects of water mass and storage levels on its dynamic behavior. seismic parameters such as storey displacement, base shear, and nodal displacement offer detailed insights into the distribution and magnitude of forces within the structure. These parameters help identify potential areas of vulnerability and deformation, allowing engineers to implement targeted design modifications or reinforcement measures to enhance the tank's seismic resistance.

3.2 Time History Analysis

It is an analysis of the dynamic response of the structures at each increment of time, when its base is subjected to a specific ground motion time history. In this method, the structure is subjected to real ground motion records. This makes this analysis method quite different from all of the other approximate analysis methods as the inertial forces are directly determined from these ground motions or in forces are calculated as function of time, considering dynamic properties of building structures.

In this method of dynamic analysis, instead of going through a process of determining aresponse spectrum for a given ground motion and then applying the results to given structure,itispossiblebyusingcomputerstoapplytheearthquakemotiondirectlytothebaseofagiven structure. Instantaneous stresses throughout the structure are calculated at small intervalof time for full duration of the earthquake or significant portion of it. The maximum stress inany member that occur the earthquake can then be found by scanning the output records andthedesignreviewed. Theprocedureusuallyincludesthefollowingsteps:

Theearthquakerecord is selected which represent the expected earthquake. The record is digitized as a seriesof small time interval of about 1/4 to 1/25 of a second with given levels of accelerationoccurring for each interval. The digitized record is applied to the model as acceleration at thebaseofstructure.

Theaccelerationandrelativedisplacementofthelumped massesaretranslated into member stresses. The maximum values can then be found by scanning of eachoutput record. This process automatically included various modes of vibration and combinestheir effects as they occur, thus eliminating the uncertainties of combining the modes whichare inherent to the spectrum analysis Response spectrum technique is a simplified case ofmodal analysis. The modes of vibration are determined in period and shape in the usual wayand the maximum response magnitude corresponding to each mode is found by reference to aresponse spectrum. An arbitrary rule is then used for superposition of the maximum responsein various modes. The resultant moments and forces in the structure correspond to envelop ofmaximum values rather than as set of simultaneously existing values. The response spectrummethod has the great virtues of speed and cheapness. This technique is strictly limited to alinear analysis because of the use of superposition. Simulations of nonlinear behavior havebeenmadeusingpairsof response spectra,onefor deflectionand oneforacceleration.

IV. MODELING

4.1Problem Statement

The specifications for the structure include eight columns with a diameter of 300 mm each supporting a tank with a diameter of 7 m. The load on the top dome is 4 KN/m, while the load attributed to the ring beam is 1.5 KN/. Each column sustains a load of 528.48 KN, with a total structure height reaching 16.2 m. These dimensions and load distributions delineate the physical parameters and loading conditions for the design and analysis of the structure.

4.2 Modelling

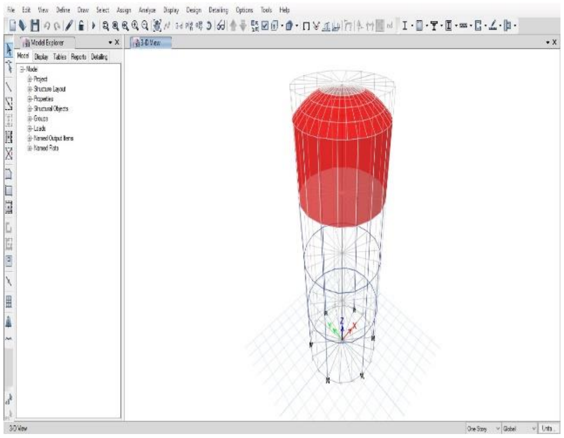


Fig 4: Cross Bracing with Circular water tank

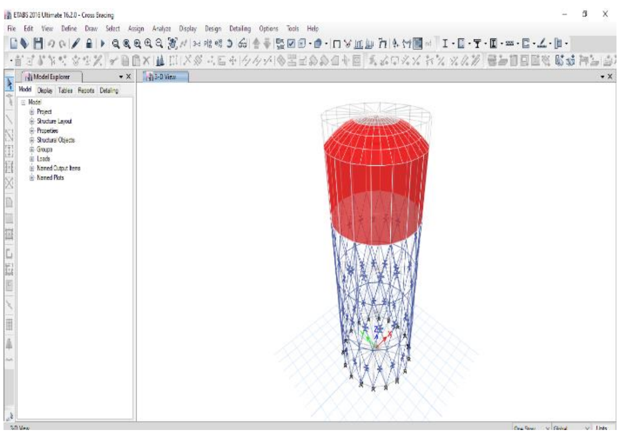


Fig 5: Cross Bracing with Circular tank

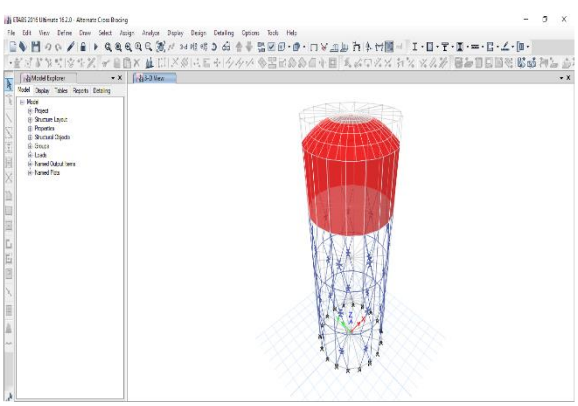


Fig 6: Alternate Cross Bracing with Circular tank

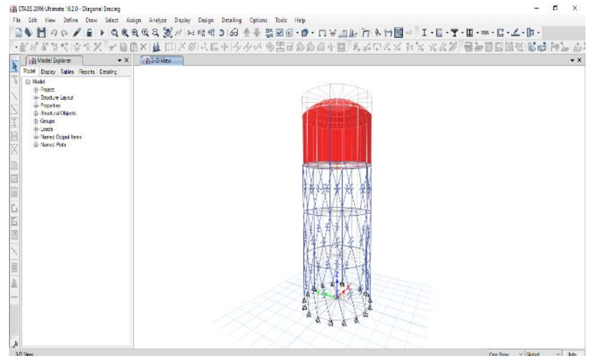


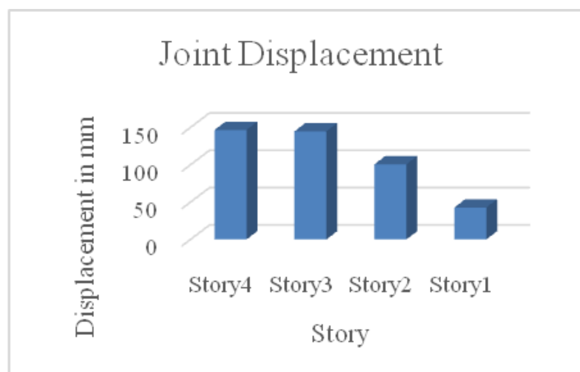
Fig 7: Diagonal Bracing with Circular tank

V. RESULT AND DISCUSSION

5.1 Introduction

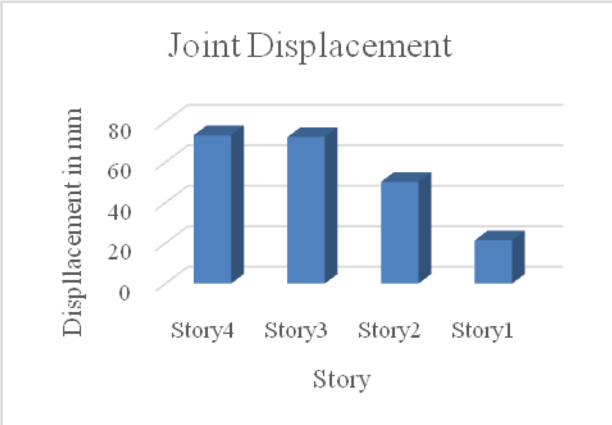
This chapter delves into the dynamic analysis of an elevated water tank using both the time history method and the response spectrum method. Various structural parameters such as joint displacement, story drift, frequency, and time period are studied. Additionally, the influence of different bracing configurations including Cross Bracing, Alternate Cross Bracing, and Diagonal Bracing is examined to assess their impact on the structural response. Through this comparison, the effectiveness and suitability of each analysis method and bracing type will be evaluated.

5.2 Time history analysis in Joint displacement



Graph 1:Joint displacement with full condition

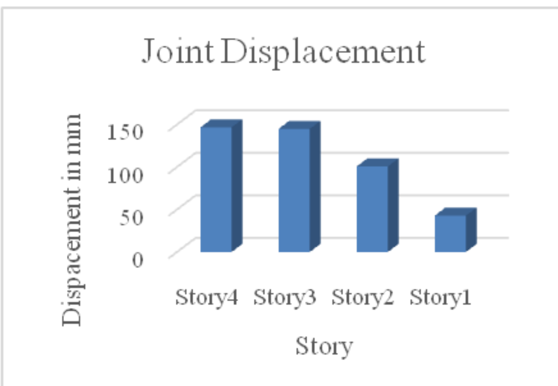
Joint displacement is observed for the time history analysis of a structure under full condition. X axis shows different story and Y axis shows displacements in mm. The minimum displacement occurs at Story1 with 42.756mm, while the maximum displacement is at Story4 with 146.587mm.



Graph 2: Joint displacement with half condition

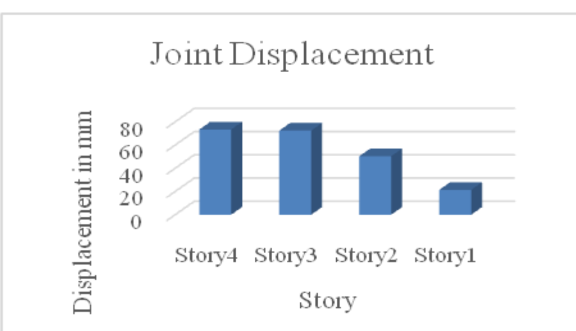
Joint displacement is observed for the time history analysis of a structure under half condition. X axis shows different story and Y axis shows displacements in mm. the maximum displacement is at Story 4 with 73.294 mm, and the minimum displacement is at Story 1 with 21.378 mm.

5.3 Response Spectrum analysis in Joint Displacement



Graph 3:Joint displacement with full condition

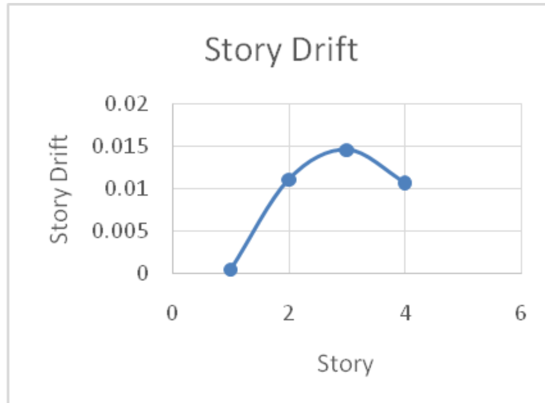
Joint displacement is observed for the Response Spectrum of a structure under full condition. X axis shows different story and Y axis shows displacements in mm. the maximum displacement is at Story 4 with 146.638 mm, and the minimum displacement is at Story 1 with 42.771 mm.



Graph 4:joint displacement with half condition

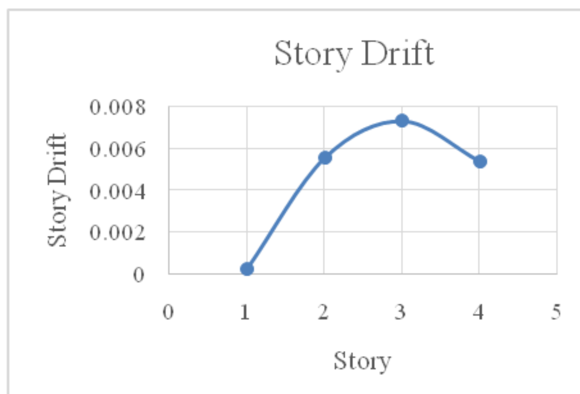
Joint displacement is observed for the Response Spectrum of a structure under Half condition. X axis shows different story and Y axis shows displacements in mm. the maximum displacement is at Story 4 with 73.319 mm, while the minimum displacement is at Story 1 with 21.385 mm.

5.4 Time history in Story Drift



Graph 5:Time history in Story Drift with full condition

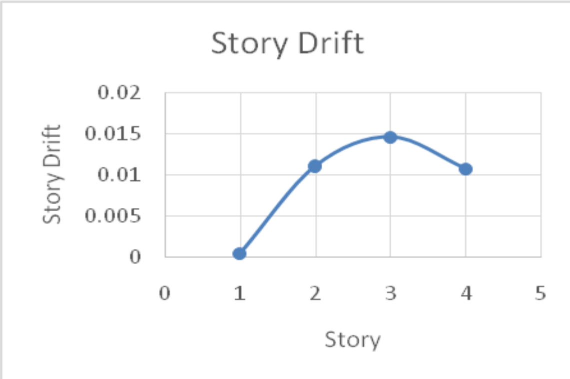
Story Drift is observed for the Time history of a structure under full condition. X axis shows different story and Y axis shows story drift. the maximum story drift occurs at Story 2 with 0.014543, while the minimum is at Story 4 with 0.000459.



Graph 6:Time history in Story Drift with half condition

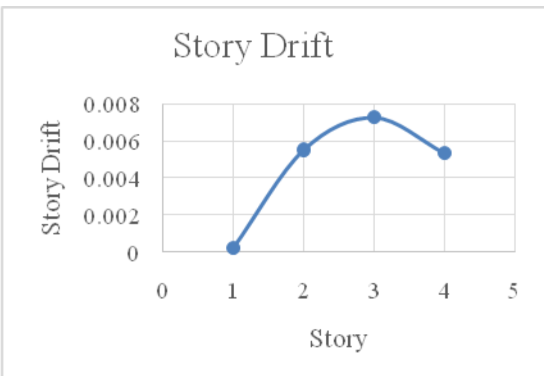
Story Drift is observed for the Time history of a structure under half condition. X axis shows different story and Y axis shows story drift. the maximum story drift is at Story 2 with 0.007271, and the minimum is at Story 4 with 0.00023.

5.5 Response spectrum in Story Drift



Graph 7: Response spectrum in Story Drift with full condition

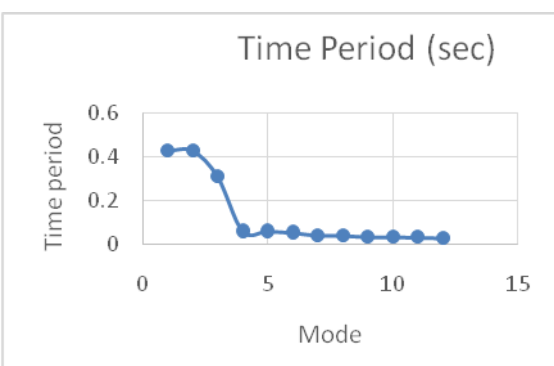
Story Drift is observed for the Response spectrum of a structure under full condition. X axis shows different story and Y axis shows story drift. the maximum story drift occurs at Story 2 with 0.014548, while the minimum is at Story 4 with 0.00046.



Graph 8: Response spectrum in Story Drift with half condition

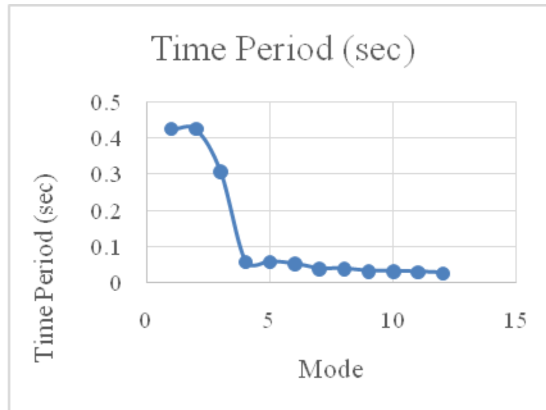
Story Drift is observed for the Response spectrum of a structure under full condition. X axis shows different story and Y axis shows story drift. the maximum story drift is at Story 2 with 0.007274, and the minimum is at Story 4 with 0.00023.

5.6 Time History analysis in Time period



Graph 9: Time History analysis in Time period with full condition

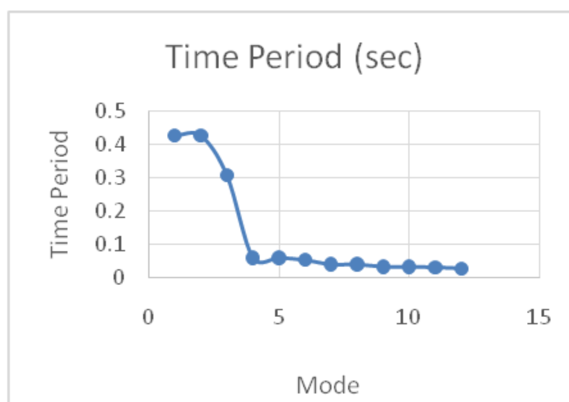
Time period is observed for the Time history of a structure under full condition. X axis shows different modes and Y axis shows time period. the minimum time period is at Mode 4 with 0.058, while the maximum is at Modes 1 and 2 with 0.424.



Graph 10: Time History analysis in Time period with half condition

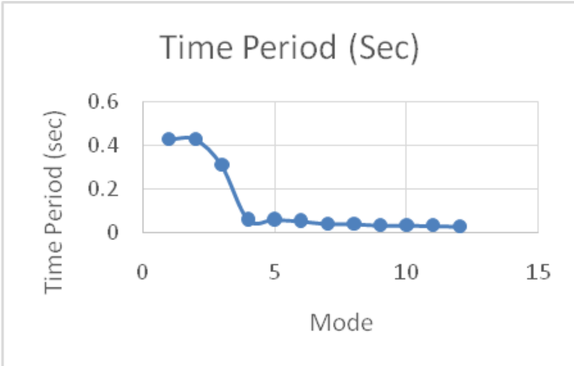
Time period is observed for the Time history of a structure under Half condition. X axis shows different modes and Y axis shows time period. the minimum time period is at Mode 3 with 0.306, while the maximum is at Mode 1 and 2 with 0.424.

5.7 Response Spectrum analysis in Time period



Graph 11: Response Spectrum analysis in Time period with full condition

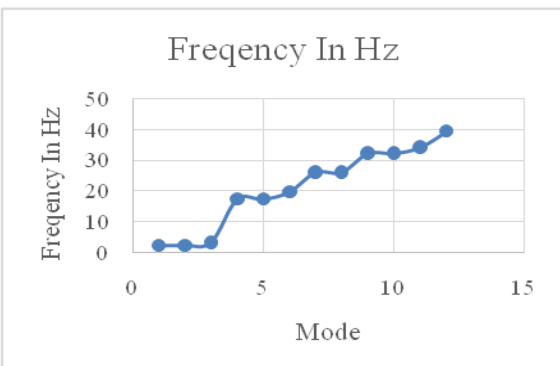
Time period is observed for the Response Spectrum of a structure under full condition. X axis shows different modes and Y axis shows time period. the time period is at both Mode 1 and Mode 2 have the same time period of 0.424 seconds.



Graph 12: Response Spectrum analysis in Time period with half condition

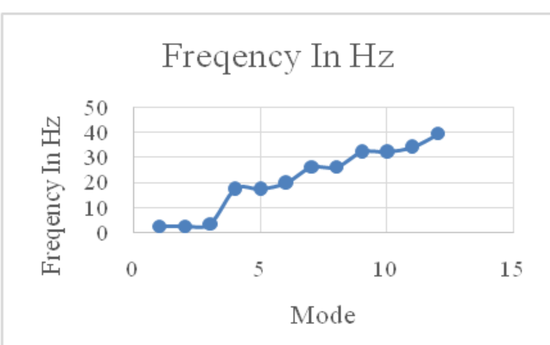
Time period is observed for the Response Spectrum of a structure under half condition. X axis shows different modes and Y axis shows time period. The minimum time period is 0.026 seconds, in Mode 12. And The maximum time period is 0.424 seconds, found in Modes 1 and 2.

5.8 Time History analysis in Frequency



Graph 13: Response Spectrum analysis in Time period with full condition

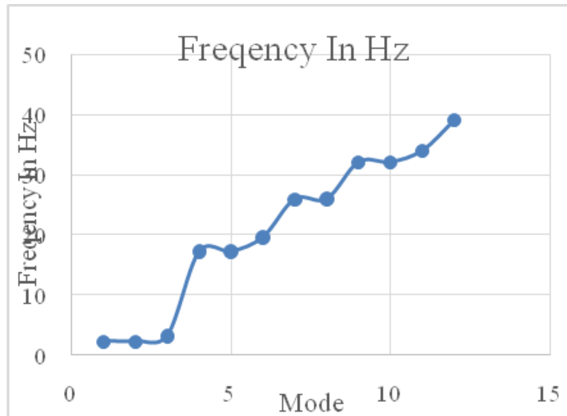
Frequency is observed for the Time History of a structure under full condition. X axis shows different modes and Y axis shows frequencies in Hz. the frequency varies from a minimum of 2.359 Hz in Mode 1 and Mode 2 to a maximum of 39.164 Hz in Mode 12.



Graph 14:Response Spectrum analysis in Time period with half condition

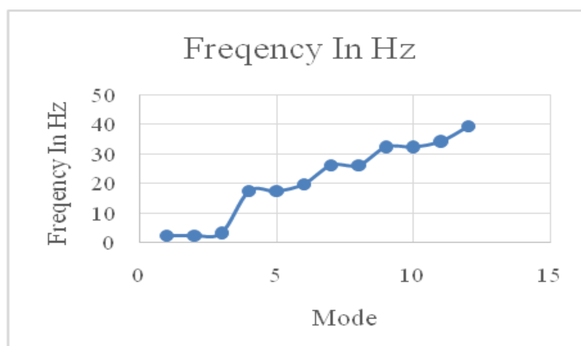
Frequency is observed for the Time History of a structure under half condition. X axis shows different modes and Y axis shows frequencies in Hz. the minimum frequency remains constant at 2.359 Hz for Modes 1 and 2, while the maximum is 39.164 Hz for Mode 12.

5.9 Response Spectrum analysis in Frequency



Graph 15:Response Spectrum analysis in Frequency with full condition

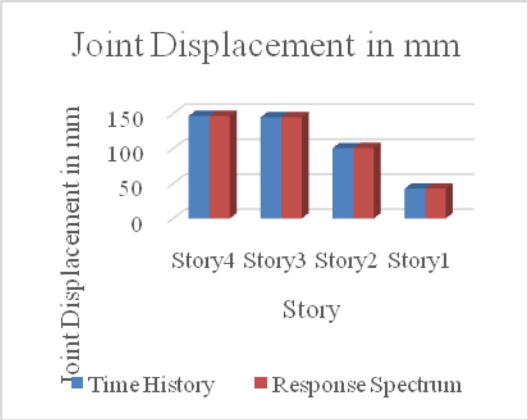
Frequency is observed for the Response Spectrum of a structure under full condition. X axis shows different modes and Y axis shows frequencies in Hz. the frequency ranges from a minimum of 2.358 Hz in Mode 1 and Mode 2 to a maximum of 39.157 Hz in Mode 12.



Graph 16:Response Spectrum analysis in Frequency with half condition

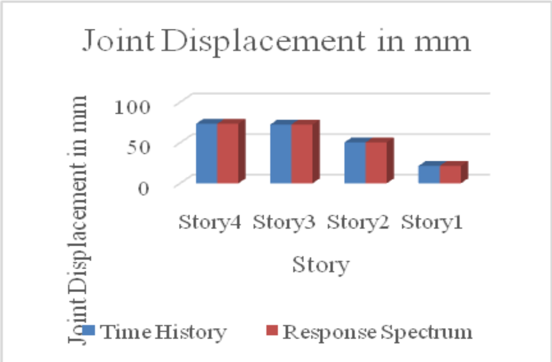
Frequency is observed for the Response Spectrum of a structure under full condition. X axis shows different modes and Y axis shows frequencies in Hz. the frequency ranges from a minimum of 2.358 Hz in Mode 1 and Mode 2 to a maximum of 39.157 Hz in Mode 12.

5.12 Comparison of time history and Response Spectrum



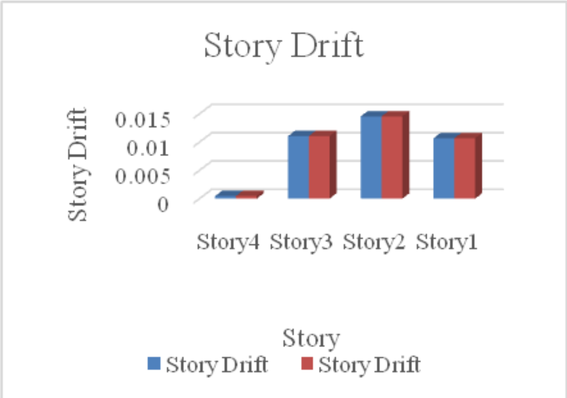
Graph 17:Joint displacement with full condition

Joint displacement is observed for water tank model. It shows a comparison of time history and Response Spectrum of a structure under full condition. X axis shows different story and Y axis shows joint displacements in mm. the highest displacement is 146.638 mm for Story 4 (Response Spectrum), and the lowest displacement is 42.771 mm for Story 1.



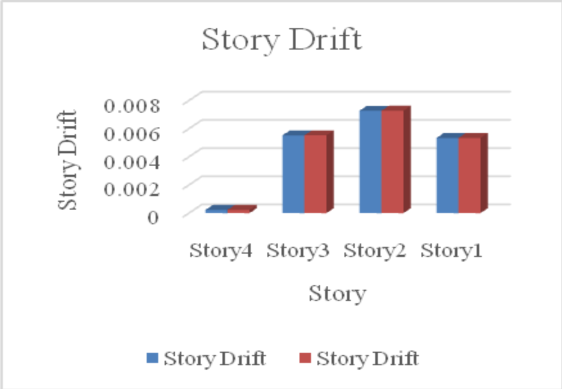
Graph 18:Joint displacement with half condition

Joint displacement is observed for water tank model. It shows a comparison of time history and Response Spectrum of a structure under half condition. X axis shows different story and Y axis shows joint displacements in mm. the highest displacement is 73.319 mm for Story 4, and the lowest displacement is 21.385 mm for Story 1.



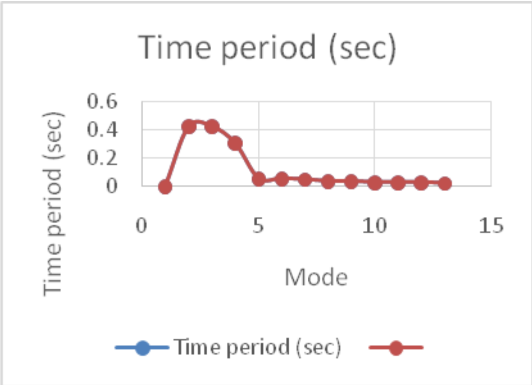
Graph 19: Story Drift with full condition

Story drift is observed for water tank model. It shows a comparison of time history and Response Spectrum of a structure under full condition. X axis shows different story and Y axis shows story drift in mm. The minimum drift at Story 4 with 0.000459 (time history) and 0.00046 (response spectrum), while the maximum drift is at Story 2 with 0.014543 (time history) and 0.014548 (response spectrum).



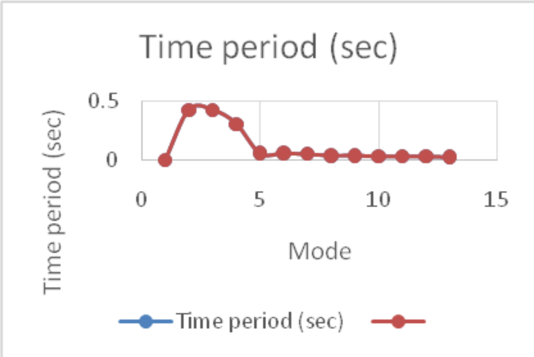
Graph 20:Story Drift with half condition

Story drift is observed for water tank model. It shows a comparison of time history and Response Spectrum of a structure under half condition. X axis shows different story and Y axis shows story drift in mm. The minimum drift is observed at Story 4 with 0.00023, while the maximum drift at Story 2 with 0.007274.



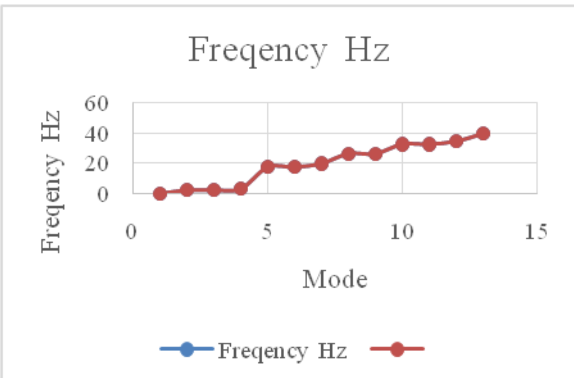
Graph 21:Time period with full condition

Time period is observed for water tank model. It shows a comparison of time history and Response Spectrum of a structure under full condition. X axis shows different mode and Y axis shows Time period in sec. The minimum time periods 0.026 seconds to a maximum of 0.424 seconds.



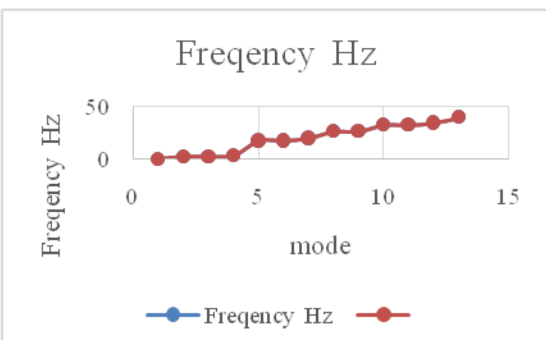
Graph 22:Time period with half condition

Time period is observed for water tank model. It shows a comparison of time history and Response Spectrum of a structure under half condition. X axis shows different mode and Y axis shows Time period in sec. The time periods range from a minimum of 0.026 seconds to a maximum of 0.424 seconds.



Graph 23: Frequency with full condition

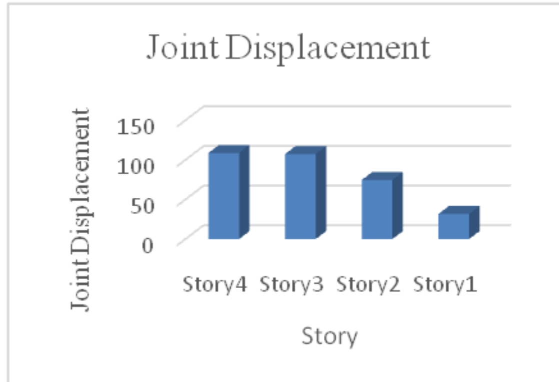
Frequency is observed for water tank model. It shows a comparison of time history and Response Spectrum of a structure under full condition. X axis shows different mode and Y axis shows Frequency in Hz. Frequencies range from a minimum of 2.358 Hz to a maximum of 39.164 Hz.



Graph 24:Frequency with half condition

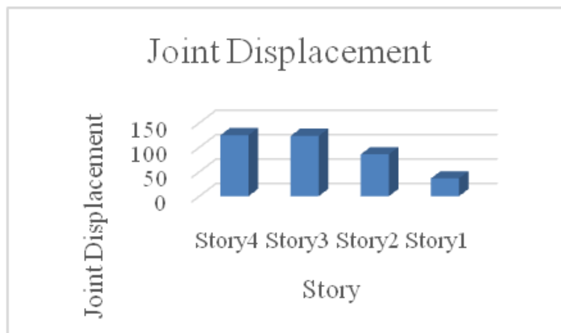
Frequency is observed for water tank model. It shows a comparison of time history and Response Spectrum of a structure under half condition. X axis shows different mode and Y axis shows Frequency in Hz. Frequencies range from a minimum of 2.358 Hz to a maximum of 39.164 Hz

5.13 Different bracing



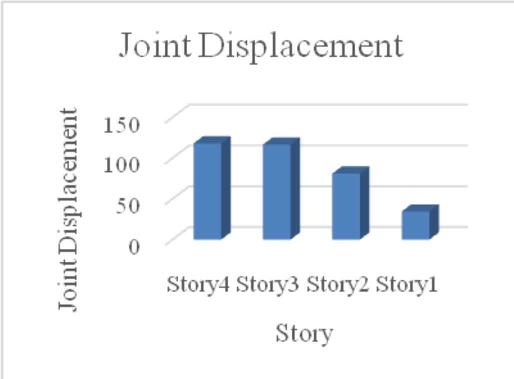
Graph 25:Joint Displacement with Full Condition Cross Bracing

Joint Displacement is observed for Cross Bracing with full condition. x axis showsdifferent stories and y axis shows displacement in millimeters. The minimum displacement is 31.719 for story 1 the maximum displacement is 108.745 for Story4.



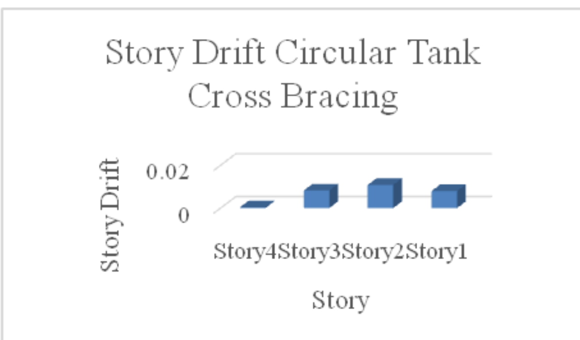
Graph 26: Joint Displacement with Full Condition Alternate Bracing

Joint Displacement is observed for AlternetBracing with full condition. x axis showsdifferent stories and y axis shows displacement in millimeters. The minimum displacement is 36.419 for story 1 the maximum displacement is 124.862 for Story4.



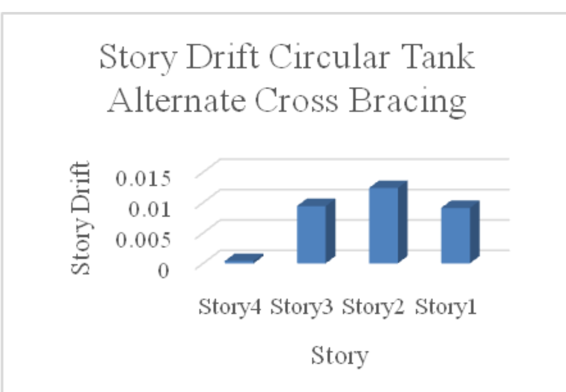
Graph 27:Joint Displacement with Full Condition Diagonal Bracing

Joint Displacement is observed for Diagonal Bracing with full condition. x axis shows different stories and y axis shows displacement in millimeters. The minimum displacement is 34.381 for story 1 the maximum displacement is 117.875 for Story4.



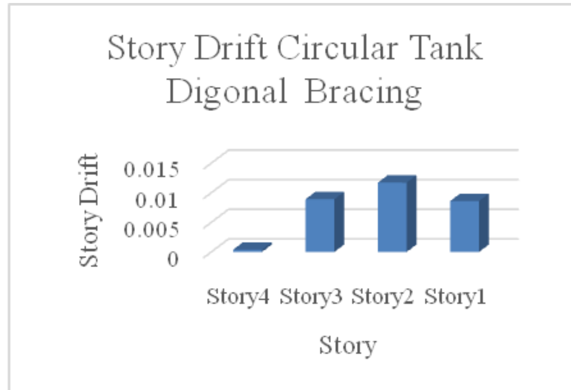
Graph 28:Story Drift with Full Condition Cross Bracing

Story Drift is observed for Cross Bracing with full condition. x axis shows different stories and y axis shows Story Drift in millimeters. The minimum Story Drift is 0.000341 for story 1 the maximum Story Drift is 0.010788 for Story4.



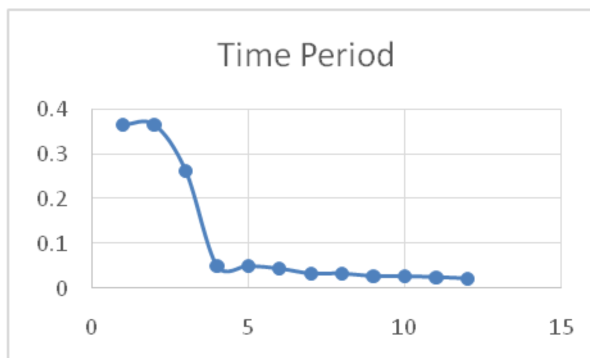
Graph 29:Story Drift with Full Condition Alternet Cross Bracing

Story Drift is observed for Alternet Cross Bracing with full condition. x axis shows different stories and y axis shows Story Drift in millimeters. The minimum Story Drift is 0.000391 for story 4 the maximum Story Drift is 0.012387 for Story2.



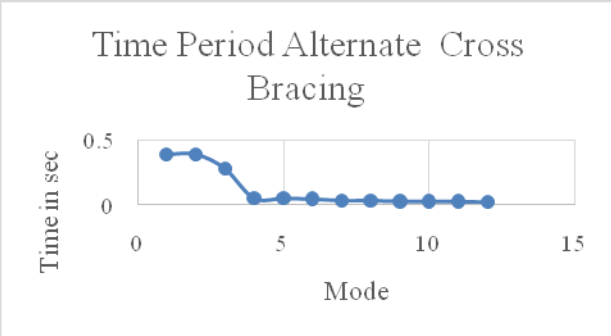
Graph 30:Story Drift with Full Condition Digonal Bracing

Story Drift is observed for Digonal Bracing with full condition. x axis shows different stories and y axis shows Story Drift in millimeters. The minimum Story Drift is 0.000369 for story 4 the maximum Story Drift is 0.011694 for Story2.



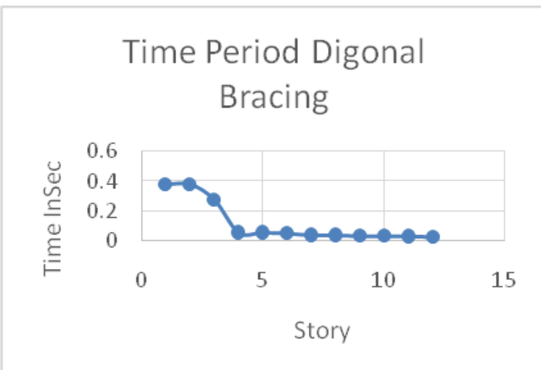
Graph 31:Time period with Full Condition Cross Bracing

Time period is observed for Digonal Bracing with full condition. x axis shows different modes and y axis shows Time Period in seconds. The minimum time period is 0.022 seconds for Mode 12. the maximum time period is 0.365 seconds for Modes 1 and 2.



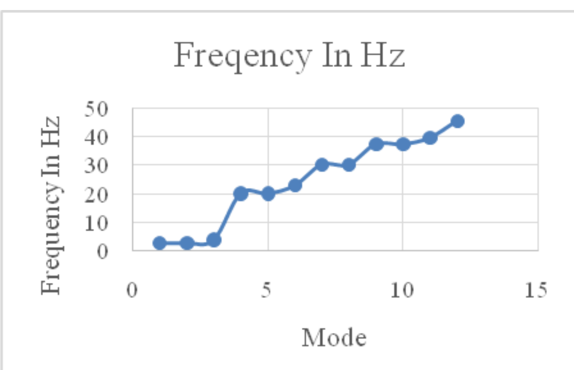
Graph 32:Time period with Full Condition Alternate Cross Bracing

Time period is observed for Alternate Cross Bracing with full condition. x axis shows different modes and y axis shows Time Period in seconds. The minimum time period is 0.024 seconds for Mode 12. the maximum time period is 0.391 seconds for Modes 1 and 2.



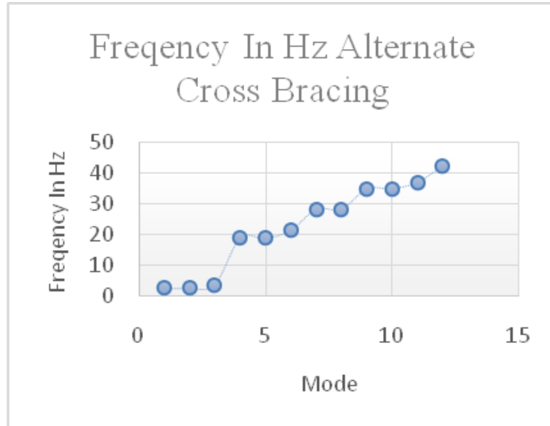
Graph 33:Time period with Full Condition Diagonal Bracing

Time period is observed for Diagonal Bracing with full condition. x axis shows different modes and y axis shows Time Period in seconds. The minimum time period is 0.023 seconds for Mode 12. the maximum time period is 0.38 seconds for Modes 1 and 2.



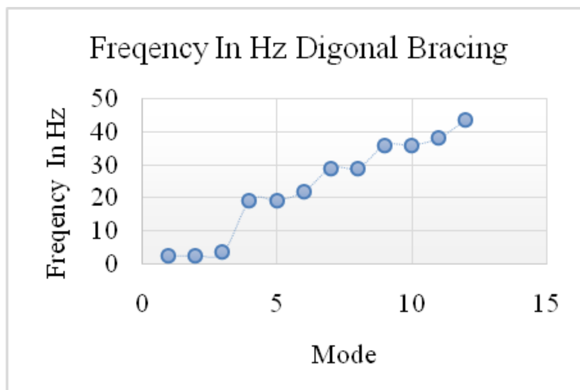
Graph 34:Frequency with Full Condition Cross Bracing

Frequency is observed for Cross Bracing with full condition. x axis shows different modes and y axis shows frequency in seconds. The minimum frequency is 2.739 seconds for Modes 1 and 2. the maximum frequency is 45.47 seconds for Mode 12.



Graph 35:Frequency with Full Condition Alternate Cross Bracing

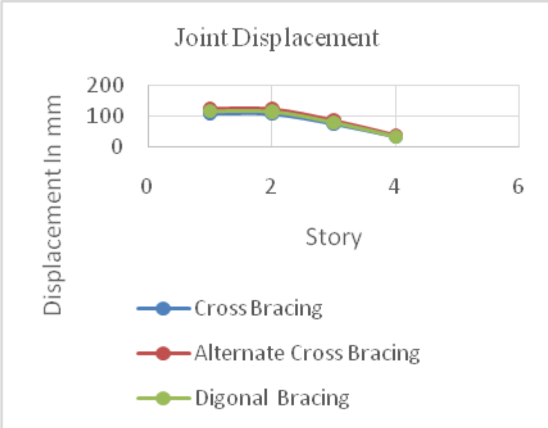
Frequency is observed for Alternate Cross Bracing with full condition. x axis shows different modes and y axis shows frequency in seconds. The minimum frequency is 2.556 seconds for Modes 1 and 2. the maximum frequency is 42.434 seconds for Mode 12.



Graph 36:Frequency with Full Condition Diagonal Bracing

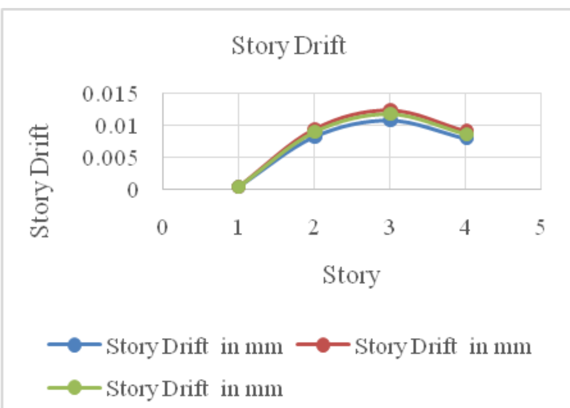
Frequency is observed for Digonal Bracing with full condition. x axis shows different modes and y axis shows frequency in seconds. The minimum frequency is 2.63 Hz for Modes 1. the maximum frequency is 43.674 Hz for Mode 12.

5.14 Comparison of different bracing



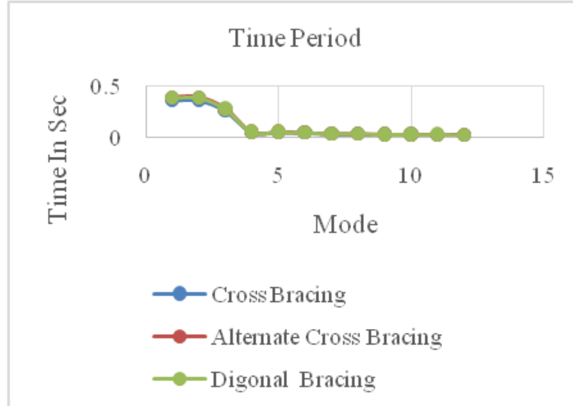
Graph 37:Joint Displacement with Comparison of different bracing

Joint displacement is observed for full condition. It shows a comparison of three bracing Cross, Alternate Cross, Digonal Bracing. X axis shows the different story and Y axis shows displacement in mm. As we can see that Max Joint Displacement is 124.862 mm at Story4 with Alternate Cross Bracing. And Min joint displacement is 31.719 mm at Story1 with Cross Bracing.



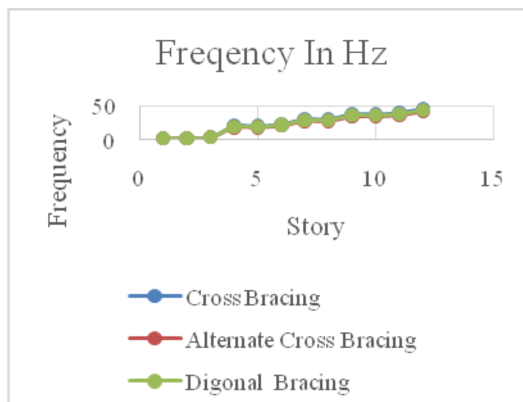
Graph 38:Story Drift with Comparison of different bracing

Story Drift is observed for full condition with a comparison of three bracing types: Cross, Alternate Cross, and Diagonal Bracing. The x-axis represents different stories, while the y-axis shows Story Drift in millimeters (mm). The maximum Story Drift is0.391seconds in Modes 1 and 2 with Alternate Cross Bracing while the minimum Story Drift is 0.022 seconds, observed in Mode 12 with Cross Bracing.



Graph 39:Time Period with Comparison of different bracing

Time Period is observed for full condition with a comparison of three bracing types: Cross, Alternate Cross, and Diagonal Bracing. The x-axis represents mode number, while the y-axis shows Time period in seconds. The maximum time period is 0.391seconds at Modes 1 and 2 with cross bracing while the minimum time period is 0.022 seconds, observed in Mode 12 with Cross Bracing.



Graph 40:Frequency with Comparison of different bracing

Frequency s observed for full condition with a comparison of three bracing types: Cross, Alternate Cross, and Diagonal Bracing. The x-axis represents mode number, while the y-axis shows frequency in (Hz). The minimum frequency is 2.556 Hz in Modes 1 and 2 with Alternate Cross Bracing. The maximum frequency is 45.47 Hz, in Mode 12 with Cross Bracing.

VI. CONCLUSION

The dynamic analysis of elevated water tanks is crucial for ensuring their structural integrity and resilience against various loading conditions. In this study, we employed both the time history method and the response spectrum method to investigate the behavior of such structures under different scenarios. Key parameters such as joint displacement, story drift, frequency, and time period were meticulously examined to gain insights into the structural response. Additionally, we explored the impact of different bracing configurations, including Cross Bracing, Alternate Cross Bracing, and Diagonal Bracing, on the overall performance of the water tank structure. Through a comprehensive comparison of these analyses and bracing types, we aimed to evaluate their effectiveness and suitability in enhancing the structural robustness and stability of elevated water tanks. By shedding light on the dynamic behavior of these structures and the influence of various design choices, this study contributes to advancing our understanding of how to optimize the design and construction of elevated water tanks for improved performance and safety.

Key points of the conclusion:

Analysis of Elevated Water Tank:

- Both Time History Analysis Method and Response Spectrum Method were employed to analyze the dynamic behavior of the elevated water tank.
- Parameters such as joint displacement, story drift, time period, and frequency were investigated for a comprehensive understanding of the structural response.

Comparison of Analysis Methods:

- The comparison between Time History Analysis and Response Spectrum Analysis revealed insights into the structural behavior under seismic loading.
- Joint displacements, story drifts, time periods, and frequencies were compared, showcasing the differences and similarities between the two methods.
- Joint Displacement: The maximum and minimum joint displacements are recorded for different stories and conditions, comparing both time history and response spectrum analyses. The type of bracing also influences these displacements, with different configurations resulting in varying displacement values.
- Story Drift: Similar to joint displacement, story drift is compared under different conditions and bracing types, showcasing the structural response in terms of drift for each story of the tank.
- Time Period: Time period analysis reveals the natural vibration periods of the structure, showing how they vary across different modes and conditions. Again, the choice of bracing affects these periods.
- Frequency: The frequency analysis provides insights into the vibration characteristics of the structure, highlighting the resonance frequencies across different modes and conditions.
- Comparison of Different Bracing: The comparison of different bracing configurations shows how each type influences joint displacement, story drift, time period, and frequency. This comparison helps in understanding the effectiveness of each bracing type in mitigating structural responses.
- Time history analysis provides a detailed account of structural response over time, while response spectrum analysis offers a simplified yet effective approach for seismic evaluation.

Impact of Bracing Configurations:

- Different bracing configurations including Cross Bracing, Alternate Cross Bracing, and Diagonal Bracing were studied to evaluate their influence on the dynamic response of the water tank.
- Joint displacements, story drifts, time periods, and frequencies were compared for each bracing configuration, highlighting their respective strengths and weaknesses.
- The analysis indicated that bracing configurations significantly affect the structural response, with each configuration offering unique advantages in mitigating seismic forces.

Validation of Findings:

- Consistency between the study's results and established literature reaffirmed the validity of the analysis methods and the impact of bracing configurations on the dynamic behavior of elevated water tanks.

Recommendations for Design Practice:

- Based on the analysis results and comparisons, recommendations can be made for designing elevated water tanks to withstand seismic loads effectively.
- Designers may consider employing a combination of analysis methods, such as using time history analysis for detailed assessment and response spectrum analysis for preliminary design evaluations.
- The selection of bracing configurations should be based on specific project requirements, considering factors such as structural performance, construction feasibility, and cost-effectiveness.

In conclusion, the dynamic analysis of elevated water tanks using different methods and bracing configurations provides valuable insights for seismic design and engineering practice, contributing to safer and more resilient infrastructure development.

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