NEAR EAST UNIVERSITY

INSTITUTE OF GRADUATE STUDIES

DEPARTMENT OF CIVIL ENGINEERING

Comparative Study of Analysis Rectangular and Circular Underground Water Tanks

M.Sc. THESIS

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Nicosia

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Approval

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Titled "**Comparative Study of Analysis Rectangular and Circular Underground Water Tanks**" and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Educational Sciences.

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Mohamed Abdinur MOHAMED

25/06/2023

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Abstract

Comparative Study of Analysis Rectangular and Circular Underground Water Tanks

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This research addresses the growing challenges faced by the world's water systems, including pollution, diminishing resources, and the impact of climate change. It focuses on the planning and evaluation of underground water storage systems as a solution to ensure access to clean drinking water. The study proposes effective strategies for designing, capacity planning, water quality management, operation, and environmental impact assessment of underground water tanks. The behavior of rectangular and circular tanks is analyzed using the guidelines provided by ACI-350-06, utilizing both equivalent lateral forces and response spectrum analysis based on NCSC2015. The study is conducted as a case study in Lefkoşa, Northern Cyprus. The results obtained provide valuable insights into the performance of underground water tanks. A comparison between rectangular and circular tanks reveals that circular tanks exhibit higher story displacement values, while rectangular tanks experience greater base shear due to seismic forces. Circular tanks also demonstrate higher hoop tension and compression, indicating greater expansion and contraction under internal and external pressures. Additionally, rectangular tanks experience higher bending moments, whereas circular tanks undergo higher axial forces and shell stress. The findings highlight the crucial role of tank shape and analysis method in assessing the structural behavior of underground water tanks. The research contributes to the development of sustainable and reliable water storage systems to meet the increasing demand for clean drinking water. Based on the results, the study recommends circular underground water tanks for larger capacities compared to rectangular tanks.

Keywords: Underground, Water tank**,** Rectangular, Circular, ETABS, Northern Cyprus

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List of Abbreviations

ACI-350-06: Code Requirements for Environmental Engineering Concrete Structures

UWT: Underground water tank

ACI 318-14: American Concrete Institute Code no. 318 in the year 2014

NCSC2015: North Cyprus seismic code in the year 2015

RSM: Response spectrum method

EQLF: Equivalent lateral method

ETABS: Extended Three-Dimensional Analysis of Building System

IS: Indian Standard

USGS: United State Geological Survey

SEI: Structural Engineering Institute

RC: Reinforced Concrete

SAP: Structural Analysis Program

STAAD pro: Structural Analysis and Design Program

URWT: Underground rectangular water tank

UCWT: Underground circular water tank

CHAPTER I

Introduction

The world's water systems are facing pressure as they provide for both ecosystems and a growing human population. Lakes, rivers, and aquifers are diminishing or becoming highly polluted. Wetlands across the globe have almost disappeared. Agriculture is the biggest consumer of water, with much of it wasted due to inefficiencies. Climate change is causing shifts in weather and water distribution, resulting in water shortages, droughts, and floods in different areas.

All life on Earth depends on water. Since it sustains healthy ecosystems for food production, human and animal health, hydropower generation, and industry, to name just a few of its essential services for human well-being, water may both promote and delay economic development depending on its availability. Water availability is influenced by the quantity of physically accessible water as well as by how it is managed, stored, and distributed among different consumers. It covers topics such as water recycling and reuse, as well as management of surface water, soil water, and groundwater (UNESCO and UN-Water, 2020).so that there is need to design and analysis Reinforced concrete water tanks(RC).

Water tanks are containers for storing liquids. The water in these vessels is typically for human consumption. As long as civilization has existed, water tank systems have been necessary.

There are different types of water tanks according to position are underground water tank, ground water tank and elevated water tank. There are two common shapes which are rectangular and circular, this study concerned about comparative analysis of rectangular and circular underground water tanks.

Underground water storage tanks serve as below-ground containers for storing potable drinking water, sewage, and collected rainfall. These tanks are typically constructed from reinforced concrete and can be either rectangular or round in shape. Whether you refer to them as water tanks or water cisterns, as long as water is being stored underground, these tanks fulfill that purpose. Primarily, underground tanks are utilized to collect and retain runoff from various surfaces like open grasslands, hillsides, residential areas, roads, walkways, paved and unpaved regions. They enable the underground storage of rainwater, wastewater, and potable drinking water. The essential components of these underground tanks are the base slab, side walls, and roof slab. One significant advantage of underground water tanks is their cooler temperature, which results in less water evaporation compared to above-ground tanks. Unlike other structures, subterranean water tanks experience diverse types of loads, often encountering lateral or horizontal pressures from the surrounding soil, the water within the tank, or any other retained liquid.

The two primary loads that pose the greatest risk to an underground water tank constructed with reinforced concrete (RC) are internal water pressure and external soil pressure. Internal water pressure refers to the weight of the water contained within the tank, exerting a substantial force on its walls and base. Conversely, external soil pressure is the force exerted by the surrounding soil on the tank, which can vary based on soil type and tank burial depth. To ensure the tank's structural integrity, engineers must meticulously analyze and incorporate these loads into the tank's design. Key factors considered include dimensions, reinforcement, and anchorage to appropriately withstand the effects of both internal water pressure and external soil pressure.

Figure 1

Earth pressure and Water Pressure Loads by AUTOCAD

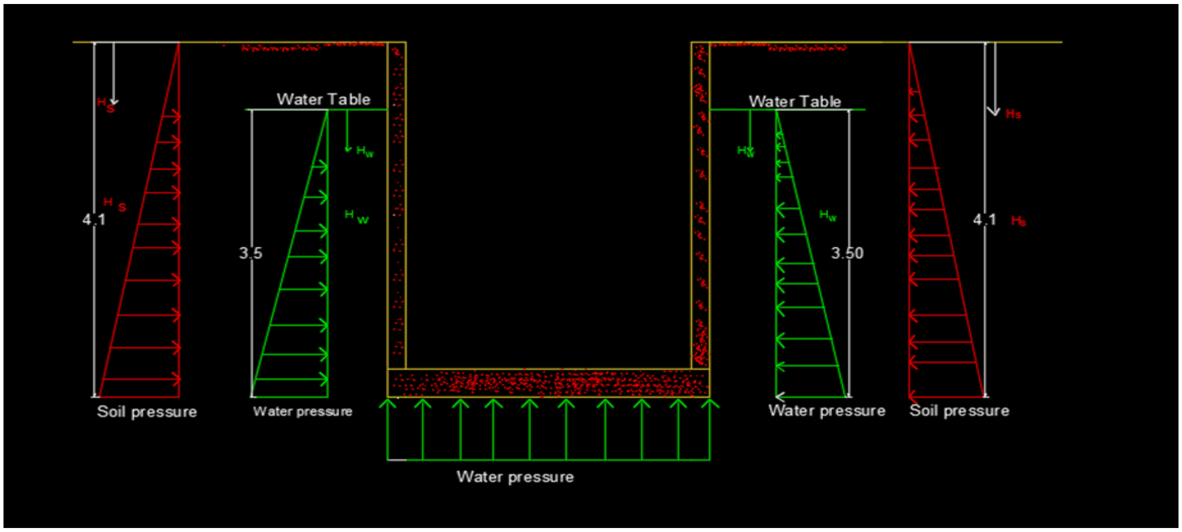
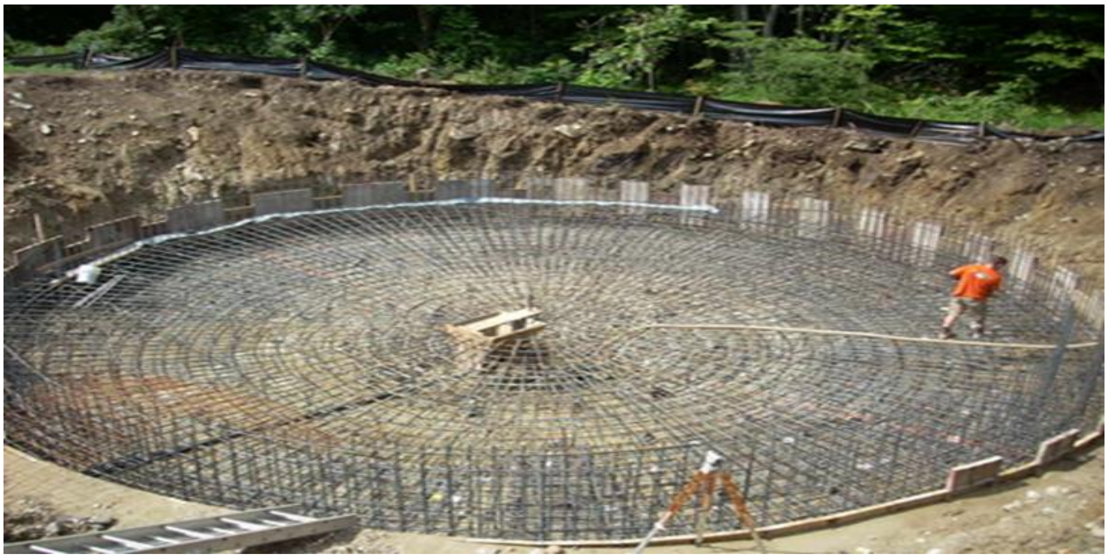


Figure 2

Rectangular Underground Water Tank

Figure 3

Circular Underground Water Tank



Problem statement

Water is universally recognized as a vital source of sustenance for all living beings, as it plays an indispensable role in maintaining a healthy lifestyle. Access to clean drinking water is a fundamental requirement for the well-being of humans. In light of the fact that life cannot be sustained without water, the demand for safe and pure drinking water is on the rise. Therefore, it is of paramount importance to ensure that water is stored and distributed in a clean and efficient manner. This makes the topic of planning and evaluating underground water storage systems an intriguing and significant area of study.

Objectives of the study

- ✓ To study the guidelines for the design of liquid retaining structure according to Code Requirements for Environmental Engineering Concrete Structures (ACI-350-06).
- ✓ To analyze the rectangular and circular underground water tank
- ✓ To compare the behavior of rectangular and circular shape of underground water tank
- ✓ To perform linear static and linear dynamic method using ETAB V.18 software.
- ✓ To explore the variation in the results obtained.

Research questions

1. How does the behavior of rectangular underground water tanks differ from circular underground water tanks?
2. How do the results obtained from linear static and linear dynamic methods using ETAB software V.18 compare in analyzing underground water tanks?
3. What are variations observed in the results obtained from analysis of underground water tanks using different methods and software?

Significance of the study

The analysis of rectangular and circular underground water tanks are compared in this study.

Limitation of the study

The study's focus is solely on the behavior of rectangular and circular underground water tanks, ignoring other tank types, construction costs, maintenance needs, variations in soil properties, and possible limitations of the software used (ETAB V.18) in accurately capturing all aspects of tank behavior.

CHAPTER II

Literature Review

Overview

This chapter includes several prior studies and academic research works mostly on Comparative Study of Analysis Rectangular and Circular Underground Water Tanks. These papers and works have been reviewed as part of this study.

In their 2021 study report, Wagh et al. presented the design of an underground rectangular water tank that they evaluated using STAAD-Pro. Compared to other structures, underground water tanks are subjected to unique types of loads, mostly experiencing horizontal or lateral stresses due to the combined pressure of the soil, water, and other stored liquids. The underground water tank's side walls will undergo more pressure at the bottom and less pressure as they ascend. The structural members were analyzed and designed in accordance with standard criteria using IS-456:2000 & SP-16. The Limit State Method was used for analysis. Unless otherwise specified in the particular design elements, M20 grade concrete and Fe 415 steel were the materials utilized.

In a recent study conducted by Latha, M. S. (2021), the analysis and design of rectangular and circular overhead water tanks using ETABS software were examined. The tanks were subjected to dynamic analysis to evaluate their ability to resist lateral loads. The design process involved manual application of the working stress method. In accordance with IS codes, the tanks were subjected to dead load, live load, wind load, and seismic load. The study focused on various aspects such as story drift, displacement, stiffness, deflection, base shear, storey shear, area of steel, and hoop tension for both circular and rectangular water tanks. A comparative analysis was conducted to compare the performance of the two tank shapes. The results revealed that circular water tanks are more suitable for larger capacities, whereas rectangular tanks are more appropriate for smaller capacities. Additionally, rectangular tanks were found to be more cost-effective for larger capacity requirements.

Tripathi et al. (2020) presented a research paper on the seismic evaluation of an underground (UG) water tank with a reinforced concrete staging structure. To reduce the impact and repercussions of seismic waves, the structure was designed in compliance with the requirements of the IS code. The evaluation involved detailed finite element modeling of the UG water tank using SAP 2000 software for various seismic intensities and nonlinear dynamic analysis. The study's findings demonstrate how the shape of the tank deflects depending on whether it is full or empty. It is vital to use the time history approach to ensure protection from earthquake forces. The UG water tank has a rectangular design and a capacity of 80,000 liters, with dimensions of 6m by 4m by 3.5m. Seismic analysis was performed using both IS: 456 2000 and IS: 1893 2002. After configuring the necessary structure, time history data of the 2015 April 25 (LAMJUNG, NEPAL) earthquake (7.8) were assigned. The time history analysis was a practical and essential tool for selecting and designing a better structure while ensuring safety in accordance with the IS Code. When the structure was analyzed using various time history data, distinct deflected form modes for the UG reservoir's empty and full tanks were obtained.

Dubey et al. (2021) conducted research with the primary objective of comparing the output outcomes of underground water tanks that were subjected to soil-structure interaction and seismic stress. To comply with IS 1893 part 2-2014, the researchers used ETABS17 to model the tank with finite elements under two different soil conditions: high compressibility clay (CL) and high compressibility silt (MH). According to IS 1893-Part-1-2016, CL was categorized as medium or stiff earth, and MH was classified as soft soil. ETABS designated the soil pressure and water pressure as non-uniform shell loads on the walls of the underground water tank (UGT), which were designed to withstand a non-uniform load of 30 kN/m2 of water pressure and 27 kN/m2 of earth pressure. The researchers considered two alternative soil types, medium stiff (CL) and soft soil (MH), for the seismic zone-3 investigation in accordance with IS1893-Part 1-2016. The soil dynamic pressure for CL soil was found to be 94.18 kN/m2 and 75.34 kN/m2. The results showed that considering seismic forces is beneficial for subterranean water tanks. When seismic forces were taken into account, the moments in the base walls, both along X and Y, were greater than those in the walls of the present tank. Shear forces became more dominant and tended to alter the slab thickness when seismic forces were considered.

Nimade et al. (2018) conducted a study in which they built a finite element model of an underground water tank using STAAD Pro software. The study aimed to analyze the behavior of the tank at various L/B ratios. The node displacement and stress patterns were analyzed for different L/B ratios while considering the tank's empty and full water level scenarios. This was done to establish the base pressure and plate moments of the subterranean water tank construction. The study found that the center shear stresses in the X direction (SQX) in the tank wall decreased as the length to width ratio increased. The stressors fluctuated slightly when the L/B ratio was between 1 and 1.5, but showed greater fluctuations between 2 and 3. As the L/B ratio increased, the center shear stresses in the Y direction (SQY) in the tank wall also decreased. However, there was no change until the L/B ratio reached 1.5. After that, the stresses at L/B ratios of 2 and 3 rapidly decreased. The main top strains in water tank walls decreased at a rate of 10% when the L/B ratio increased from 1.2 to 1.5, to 2, and then to 3. At an L/B ratio of 3, there was a 60% reduction in bottom stresses in the tank walls, but there was no noticeable difference when the L/B ratio increased from 1 to 2.

In 2018, a research paper was published by Shinde which investigated the computer-aided design of an underground water tank. The paper provided information on the basic deflection requirements, shell stresses, and joint reactivity for the structure of the underground water tank under both full and empty water levels. It also included a comparison between the manual analysis and design of the underground water tank and the outcomes of the STAAD Pro and SAP 2000 software design programs. The results of the study showed that the deflection calculation in the manual design and the deflection findings from the STAAD Pro and SAP2000 software were almost identical. Additionally, the shell stresses for both full-water and full-empty conditions were within the permissible limit, which was not greater than 7000 kN/m2, and the results from the two software programs were generally consistent. However, unsatisfactory results were obtained when the tank's diameter was smaller.

The study conducted by Iqbal et al. (2015) investigates the influence of design parameters on the response of underground water tanks. The authors consider structural parameters such as the length-height ratio, width-height ratio, wall thickness, and soil density. They employ the Finite Element Method (FEM) using SAP2000 analysis software to evaluate the response characteristics of the tanks. The authors select a series of underground water tanks with varying parameters and analyze them by changing one parameter at a time while keeping others constant. The response characteristics studied are the maximum horizontal and vertical moments for the long and short walls of the tanks. The results obtained from the analyses are presented in graphical form, demonstrating the relationship between the design parameters and the response characteristics of the tanks. The research by Iqbal et al. contributes to understanding the structural behavior of underground water tanks and emphasizes the importance of design parameters in influencing their response. The findings from this study can inform future improvements in the design and performance of such structures.

Dr. Ramakrishna Hegde, Yogesh G, and Sanjay Chawhan (2018) conducted a comparative study on circular and rectangular tanks. Their research concluded that circular tanks require a lesser amount of construction materials compared to rectangular tanks, making them more cost-effective. The study highlighted the preference for circular tanks in areas where water availability is limited to the monsoon season. The findings of this research contribute to the understanding of tank construction choices and their suitability for specific conditions.

Hegde, D. R., Yogesh, G., and Chawhan, S. (2018) this study examines the ideal operational requirements for water tanks that are both rectangular and circular. In this project, a tank with a 21000 liter capacity is used for design. The study concentrated on a number of variables, including maximum stress, hoop tension, steel area, and formwork for both circular and rectangular water tanks. Rebars, cement, sand, aggregate, and formwork are used in the building of water tanks, and these materials are included in prepared drawings. At the conclusion of the experiment, it is found that less materials overall were needed to build a circular tank than a rectangular tank.

CHAPTER III

Methodology

Overview

In this chapter, the study area is introduced, focusing on Comparative Study of Analysis RC Rectangular and Circular Underground Water Tanks .The models and codes used to define limitations and variables impacting the analysis results are also discussed.

Case study

Cyprus, the third largest Mediterranean island, has a semi-arid climate and spans approximately 9251km2. It is home to around 1,200,000 people, with about 30% residing in north Cyprus, totaling approximately 37,000 individuals. Prior to 2015, the island primarily depended on ground and surface water for its water supply. However, water from dams and aquifers in north Cyprus, particularly in Kyrena and Guzeyelyurt, now supplement this source. (Nazari Chamaki et al. (2022).

Lefkoşa, the capital of Northern Cyprus, is among six cities in the area. The rising population, urbanization, and industrialization will boost the demand for water. Currently, the water department in North Cyprus provides around 6,673,439 m3 of water each year to the municipalities of Lefkoşa. The daily consumption per person ranges from 128 to 145 liters, emphasizing the pressing need to implement solutions for the water scarcity issue in Lefkoşa, Northern Cyprus. (Zachariadis, 2010).

This research is conducted at Near East University in Lefkoşa, Northern Cyprus.The geotechnical investigations were carried out at the NEU campus located North of Nicosia. In North Cyprus, the predominant soil types are clays, alluviums, and clay stones, leading to construction challenges. The main issues involve weak, compressible, and less durable silty-clayey soils, along with the swell-shrink behavior of over-consolidated swelling soils. Landslides commonly occur on steep slopes formed by clay formations. Swelling clays also cause extensive damage to buildings and infrastructure, including major roads and highways throughout the country (Atalar, 2006).

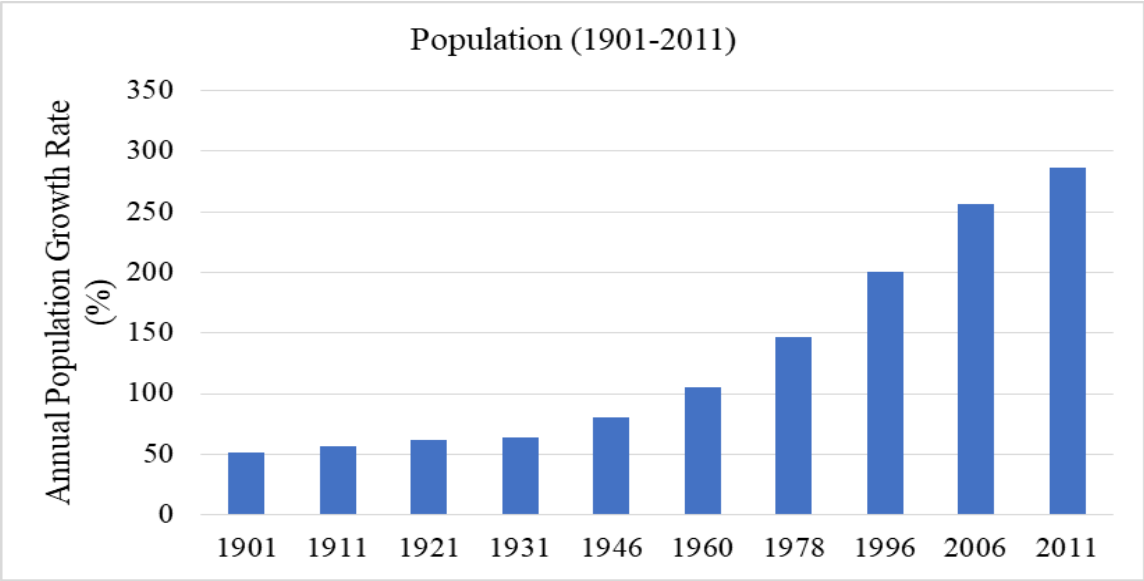
Figure 4

Districts of North Cyprus until 2016 (Districts of Northern Cyprus, 2019)

Source: Districts of Northern Cyprus Wikipedia (Text) CC BY-SA

Figure 5

Population (1901-2011)



Source: Statistical year book, 2020 Turkish Republic of Northern Cyprus

Table 1

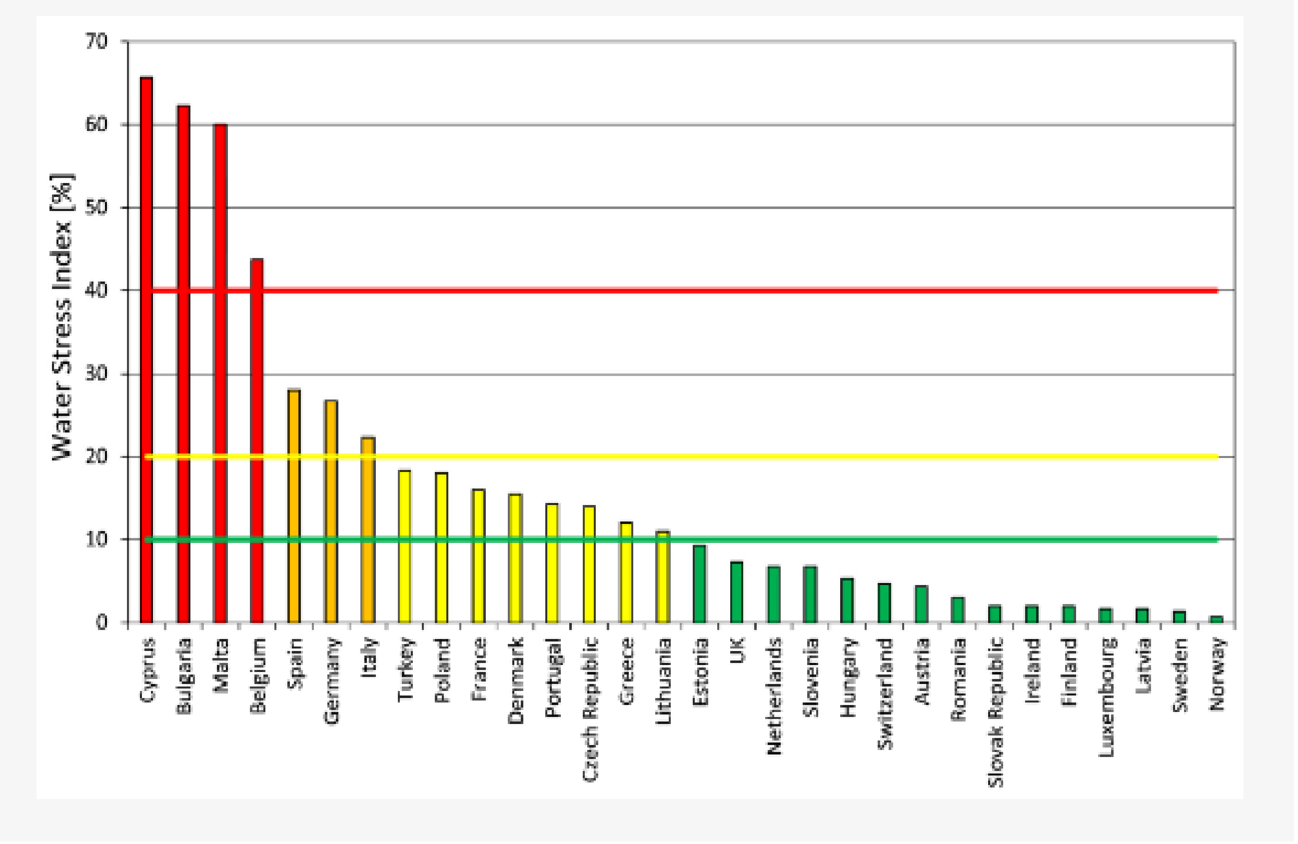
The largest last 10 years of earthquakes in Cyprus (GSD)

Years	**Location**	**Magnitude**
2023	Northwest of Paphos	4.5
2022	west of Nicosia	6.6
2021	Near Larnaka	4.9
2020	Eastern Mediterranean	5.2
2019	Eastern Mediterranean	4.2
2018	Eastern Mediterranean	4.6
2017	Eastern Mediterranean	4.8
2016	Eastern Mediterranean	4.7
2015	Nisi Geronissos	5.2
2014	Eastern Mediterranean	4.7

Source: https://www.volcanodiscovery.com/earthquakes/cyprus/largest.html

Figure 6

Water Stress Index for European Countries



Source: Sofroniou, A., & Bishop, S. (2014). Water scarcity in Cyprus.

Methodology

In this study, the focus lies on investigating the behavior of rectangular and circular underground water tanks when subjected to different loading conditions. The aim is to compare the strength and stability of concrete for both tank shapes. The analysis is carried out based on the guidelines provided by the ACI-350-06 Code Requirements for Environmental Engineering Concrete Structures. To conduct the analysis, the finite element software ETABS 2018 is utilized.

Initially, the analysis is performed on a rectangular underground water tank with a capacity of 500m3. The tank has specific dimensions, measuring 15.3 meters in length, 10.05 meters in width, and 4.1 meters in height. Subsequently, a circular water tank with a diameter of 14 meters and the same capacity is also analyzed, and a comparison of parameters is made. The seismic analysis is conducted according to the guidelines outlined in the NCSC-2015 North Cyprus Seismic Code. For this case study, the location selected is Lefkoşa, situated in northern Cyprus. The considered loads include dead load, live load, earth pressure, water pressure, and seismic load.

Table 2

Material Properties

Weight per unit volume of concrete, γ_c	25 kN/m^3
Weight per unit volume of steel, γ_{st}	78.5 kN/m^3
Modulus Elasticity of Steel, E_{st}	200,000MPa
Modulus Elasticity of concrete, E_c	25743 MPa
Compressive strength of concrete, f_c	30 MPa
Yield strength of Steel, f_y	420 MPa
Live Load	2.4 kN/m^2
Dead Load	1.2 kN/m^2
Soil bearing capacity	16 t/m^3
Angle of internal friction	26°
Soil unit weight	2.2 t/m^3
Soil site class	Group C

Design Concept

Member Size

Initial measurements were conducted to analyze the components of the underground water tanks in the building, including walls, slabs, beams, and columns. The sizes of the walls, slabs, and beams were initially calculated, while the dimensions of the columns were estimated based on the loads transmitted by the slabs and beams due to factors such as live loads, dead loads, water pressure, soil pressure, and seismic loads. The appropriate sizes for the members were determined, and the thickness (h) was computed in accordance with ACI 318-14. This calculation involved referring to sections 8.3 and 9.3 in tables 2 and 3, which specify the minimum thickness required to control deflection

According to ACI-350 the wall 3m height or taller which are in contact of water the minimum thickness is 300mm.

Table 3.

Minimum Thickness of Two-Way Slab with All Sides a Beam

$\alpha_{fm} \leq 0.2$	8.3.11 applies		(a)
$0.2 < \alpha_{fm} \leq 2.0$	Greater of	$\dfrac{l_n\left(0.8 + \dfrac{fy}{1400}\right)}{36 + 9\beta(\alpha_{fm} - 0.2)}$	(b)
		125	(c)
$\alpha_{fm} > 2.0$	Greater of	$\dfrac{l_n\left(0.8 + \dfrac{fy}{1400}\right)}{36 + 9\beta}$	(d)
		90	(e)

Where:

a_{fm} is the average value of a_f for all beams on edges of a panel

l_n is the clear span in the long direction, measured face-to-face of beams (mm).

β is the ratio of clear spans in long to short directions of slab.

Table 4.

Minimum Depth of Non- Prestressed Beams

Support condition	Minimum h
Simply supported	l/16
One end continuous	l/18.5
Both ends continuous	l/21
cantilever	l/8

Columns of Sizing

The initial step in assessing the internal column, which carried the greatest load, involved calculating its tributary area prior to determining the size of the column. To calculate the load being transported, the tributary region was multiplied by the combined dead and live loads of the column. Subsequently, the necessary amount of concrete required to withstand the estimated force was determined, taking into consideration the durability of concrete and steel. To accommodate the irregularity of the column, appropriate overall strength reduction factors were employed, providing an added level of safety. As per the ACI code, the column's gross area was computed using the following equation.

$$\emptyset Pu = \emptyset[0.85 fc'(Ag - Ast) + fyAst]$$

Where $\emptyset \boldsymbol{r}$ is the component that reduces strength.

For a rectangular cross-section, taken as 0.65 and 0.80
$\emptyset$ Pu is the computed force, Ag is the column's gross area, Ast is the steel's area, taken as 0.002Ag, and fy is the concrete's tensile strength, $\boldsymbol{fc'}$ is Concrete's compressive strength

Table 5.

Section dimensions of Rectangular and circular underground water tanks

Section names	**dimensions**
Wall thickness	300mm
Roof slab	150mm
Bottom slab	200mm
Beam	200mm*300mm
Column	300mm*300mm

Loads

Load Patterns

` The study focuses on various loads, including water pressure, soil pressure, dead load, live load, and seismic load. Dead load signifies the weight of the structure itself and is automatically computed using the ETABS software. Super dead load accounts for additional loads caused by finishing materials and partition walls, and it is considered as 1.2 kN/m² in this research. Live load represents temporary loads on the structures and is assumed to be 2.4 kN/m² for all floors. Water pressure is calculated to be 41 kN/m², while soil pressure is taken as 35.2 kN/m². The minimum design values for dead and live load are determined based on the ACI code.

Load Combination

Typically, a load combination consists of different types of loads, such as water pressure, soil pressure, live loads, dead loads, and seismic loads. These loads are combined together to create a design that ensures structural strength. The load combinations are formulated following the guidelines provided by ACI-350-06, and the specific combinations are listed below.

$U=1.4(D+F)$

$U=1.2(D+F+T) +1.6(L+H) +0.5(L_r \text{ or } S \text{ or } R)$

$U=1.2D+1.6(L_r \text{ or } S \text{ or } R) +1.6(L+H) + (1.0L \text{ or } S \text{ or } 0.8W)$

$U=1.2D+1.6W+1.0L+0.5(L_r \text{ or } S \text{ or } R)$

$U=1.2D+1.2F+1.0EL+1.6H+1.0L+0.25S$

$U=0.9D+1.2F+1.6W+1.6H$

$U=0.9D+1.2F+1.0E+1.6H$

L=Live load

L_r=Roof load

D=Dead load

E=Load effects of earthquake

R=Rain load

S=Snow load

F=Loads due to weight and pressure of water

H= Loads due to weight and pressure of soil

CHAPTER IV

SEISMIC ANALYSIS METHODS

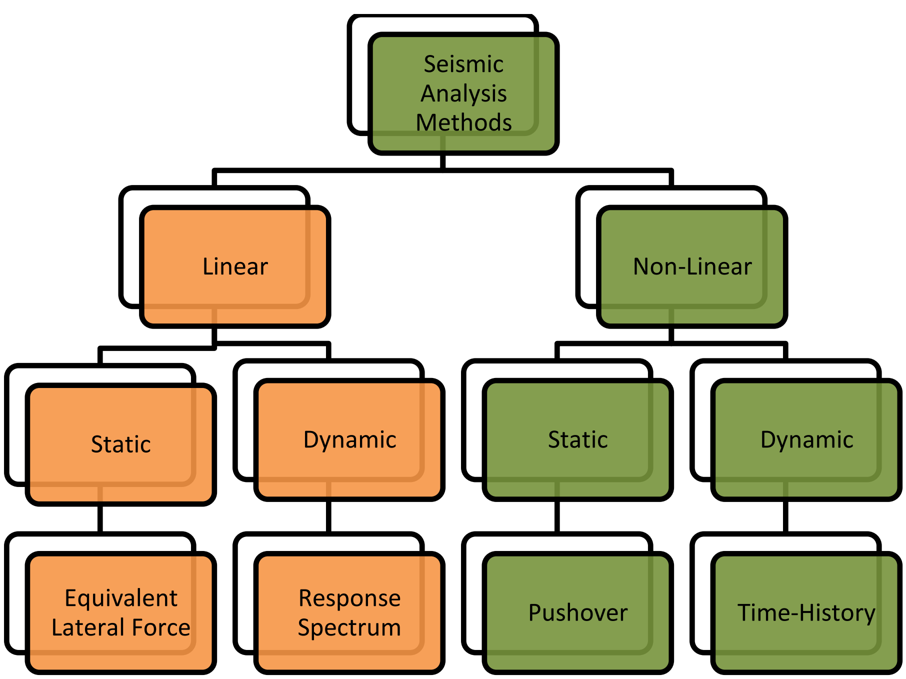
Overview

This chapter provides an overview of seismic analysis methods and demonstrates the process of determining design forces for various patterns using ETABS.

Seismic analysis is a crucial aspect of structural engineering that involves assessing the response of a structure of earthquake forces. By conducting engineers can ensure that a building can withstand the potential seismic forces it may encounter. ETABS, popular structural engineering software, stands for Extended Three Dimensional Analysis of Building Systems. It offers a range of tools and features for performing comprehensive structural analysis and design. In this chapter, the focus is on utilizing ETABS to determine the design forces for different seismic patterns a through seismic force it may encounter.

Figure 7

Seismic analysis methods



Linear static method

The linear static analysis relies on strength assessment, where the structural components' elastic capacity exceeds the loading conditions. It evaluates the adequacy of each component through demand-capacity (DC) ratios based on strength. This approach is considered the simplest and least time-consuming because it utilizes only the elastic stiffness characteristics of the model.

Linear dynamic method

Response Spectrum Analysis (RSA) is a method used to evaluate the potential seismic response of an elastic structure by examining its natural vibration modes. By analyzing the structure's dynamic behavior, RSA helps us understand its maximum response to earthquakes by quantifying pseudo-spectral acceleration, displacement, or velocity. This analysis takes into account the structural period, a specified time history, and damping level to calculate these response quantities. The primary purpose of RSA is to aid in decision-making processes, particularly when it comes to selecting the appropriate structural type based on dynamic performance considerations. By performing response spectrum analysis during the preliminary design phase, engineers can incorporate specific structural performance objectives to ensure effective decision-making. This enables them to assess the structure's ability to withstand seismic loads and make informed choices regarding its design and construction. In summary, response spectrum analysis is a valuable tool that allows engineers to assess the seismic response of a structure and understand its dynamic behavior. By incorporating performance objectives, this method facilitates decision-making processes, enabling engineers to select the most suitable structural type and ensure effective design and construction.

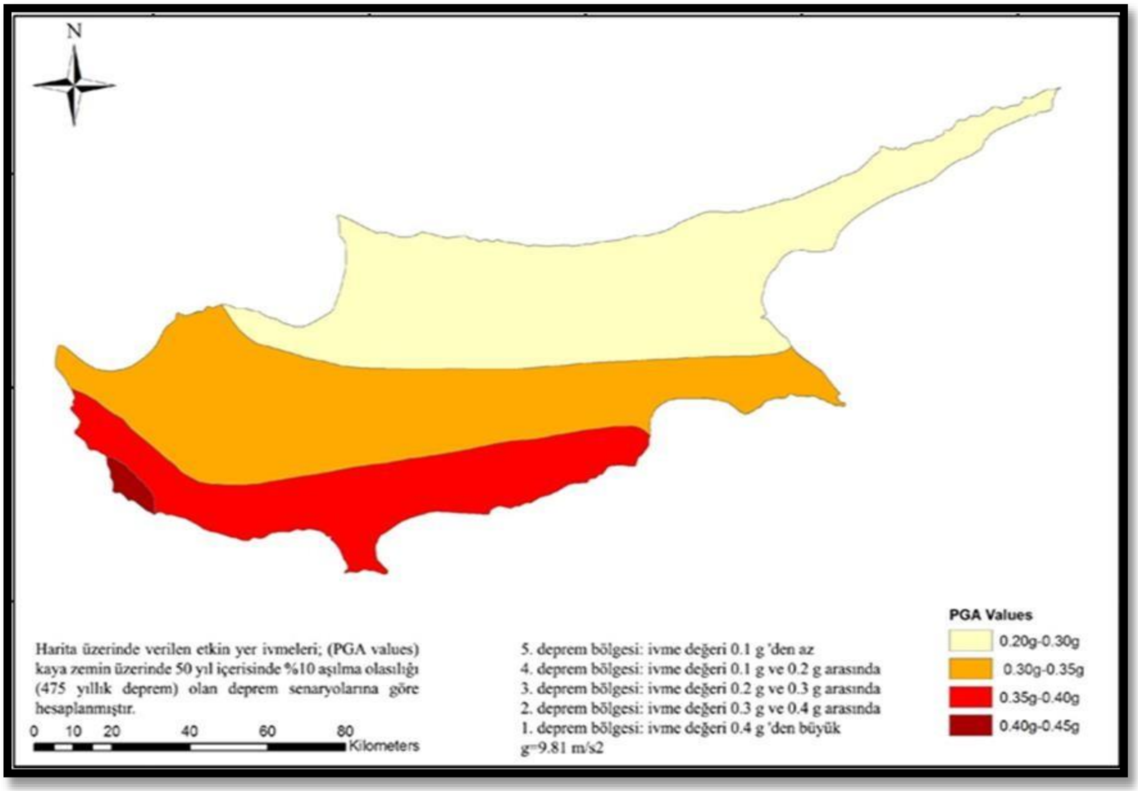
Table 6.

Effective ground acceleration coefficient (Chamber of Civil Engineers, 2015)

Seismic zone	**A_o**
1	0.40
2	0.30
3	0.20
4	0.10

Figure 8

Seismic map zones according to NCSC2015



Source: NCSC2015 (Chamber of Civil Engineers, 2015)

Seismic zoning map presented in Figure 8 has been customized for the northern region of the island. Specifically, it depicts the seismic hazard levels for Nicosia city, with a Peak Ground Acceleration (PGA) value ranging from 0.2 to 0.3 g, as stated by the Chamber of Civil Engineers in 2015.

Table 7.

Building importance factor (Chamber of Civil Engineers, 2015)

Purpose of Occupancy or Type of Building	***Importance Factor (I)***
1. Buildings required to be utilized after the earthquake and buildings containing hazardous materials **a)** Buildings required to be utilized immediately after the earthquake (Hospitals, dispensaries, health wards, fire fighting buildings and facilities, PTT and other telecommunication facilities, transportation stations and terminals, power generation and distribution facilities; governorate, county and municipality administration buildings, first aid and emergency planning stations) **b)** Buildings containing or storing toxic, explosive and flammable materials, etc.	1.5
2. Intensively and long-term occupied buildings and buildings preserving valuable goods **a)** Schools, other educational buildings and facilities, dormitories and hostels, military barracks, prisons, etc. **b)** Museums	1.4
3. Intensively but short-term occupied buildings Sport facilities, cinema, theatre and concert halls, etc.	1.2
4. Other buildings Buildings other than above defined buildings. (Residential and office buildings, hotels, building-like industrial structures, etc.)	1.0

Table 8.

Structural system behavior factors(R)

BUILDING STRUCTURAL SYSTEM	Systems of Nominal Ductility Level	Systems of High Ductility Level
(1) CAST-IN-SITE REINFORCED CONCRETE BUILDINGS		
(1.1) Buildings in which seismic loads are fully resisted by frames............	4	8
(1.2) Buildings in which seismic loads are fully resisted by coupled structural walls............	4	7
(1.3) Buildings in which seismic loads are fully resisted by solid structural walls............	4	6
(1.4) Buildings in which seismic loads are jointly resisted by frames and solid and / or coupled structural walls............	4	7
(2) PREFABRICATED REINFORCED CONCRETE BUILDINGS		
(2.1) Buildings in which seismic loads are fully resisted by frames with connections capable of cyclic moment transfer	3	7
(2.2) Single-storey buildings in which seismic loads are fully resisted by columns with hinged upper connections	—	3
(2.3) Prefabricated buildings with hinged frame connections in which seismic loads are fully resisted by prefabricated or cast – in – situ solid structural walls and / or coupled structural walls.	—	5
(2.4) Buildings in which seismic loads are jointly resisted by frames with connections capable of cyclic moment transfer and cast-in-situ solid and / or coupled structural walls	3	6

Table 9.

The spectrum characteristic periods (Chamber of Civil Engineers, 2015)

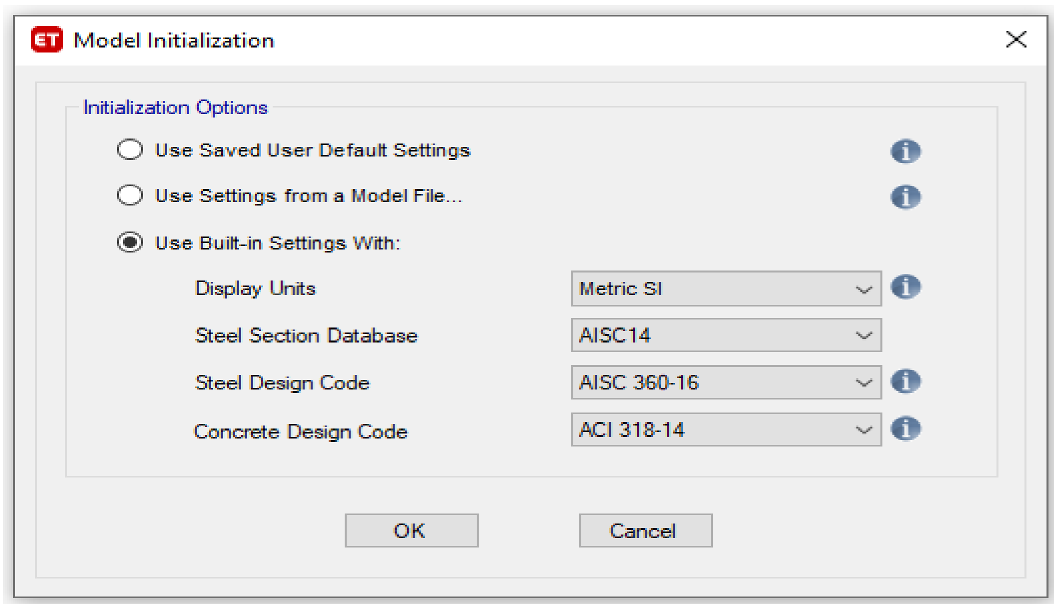
Local site class accordingNCSC2015	**T_A (second)**	**T_B (second)**
Z1	0.1	0.3
Z2	0.15	0.4
Z3	0.15	0.6
Z4	0.20	0.6

Modeling Using ETABS

Model Initialization

Figure 9

Choice of the unit and ACI code

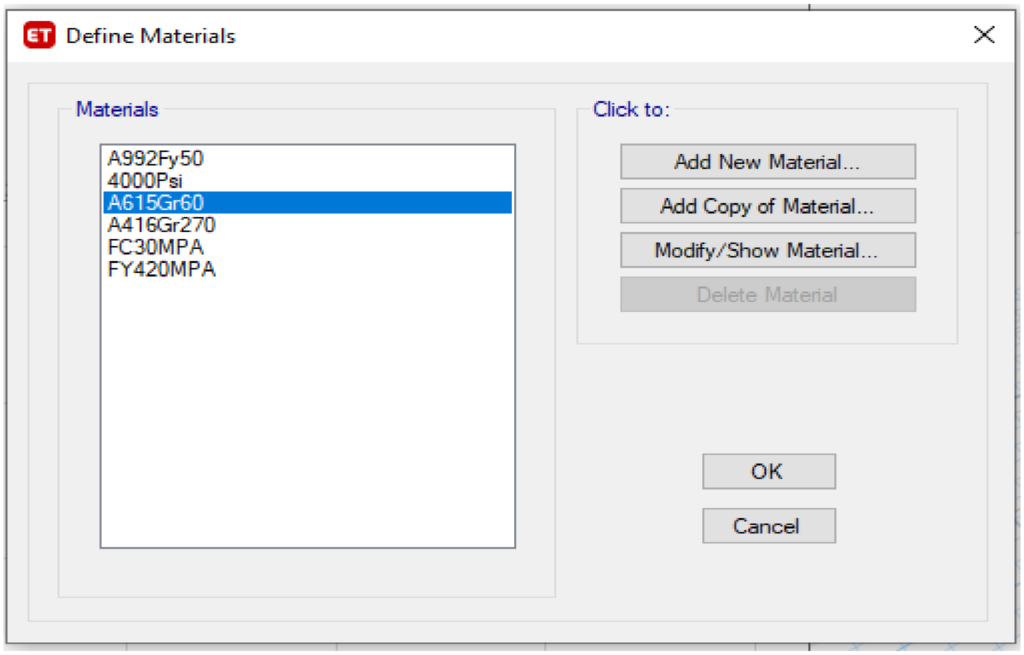


Define Material Properties

ETABS incorporates the necessary provisions for adhering to maximum material strength restrictions during the design of columns, beams, slabs, and beams subjected to torsion. When the material properties exceed these limitations, ETABS mandates that the input material strengths be designated as the upper bounds. Nevertheless, it is crucial for users to diligently verify that the minimum strength criteria are met, thereby ensuring compliance with the required standards.

Figure 10

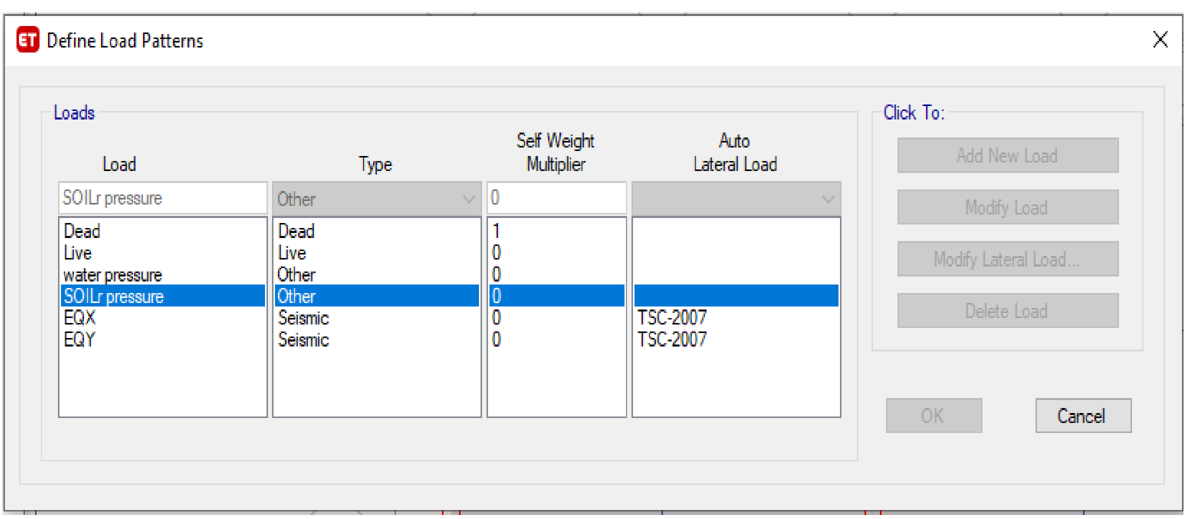
Material properties of Rectangular (URWT) and Circular Underground Water Tanks (UCWT) in ETABS



Define Loads Patterns

Figure 11

Load patterns of Rectangular (URWT) and Circular Underground Water Tanks (UCWT) in ETABS

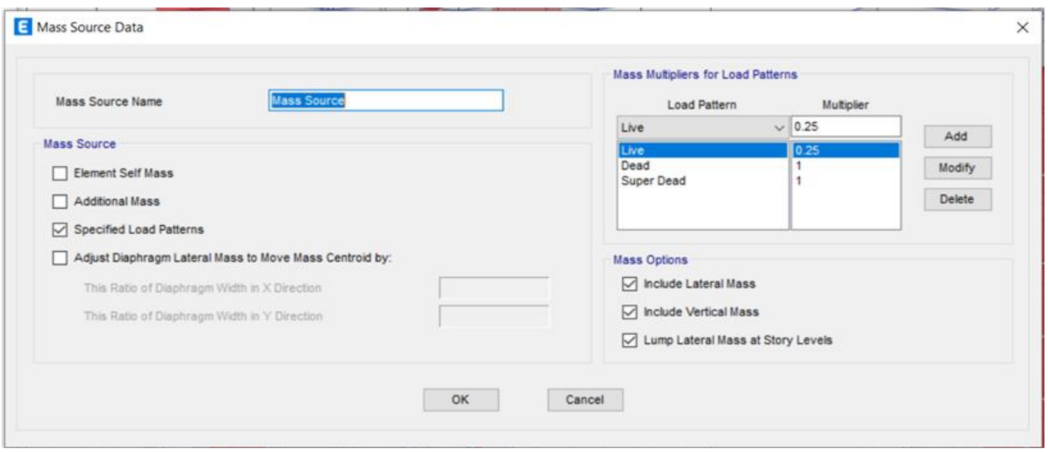


Mass Source Date

Based on volume and material density, mass values for structural components are calculated. Mass is automatically focused at joint sites after being computed by the load pattern under the constraints of the code. Regardless of whether there is only dead load or dead load plus some live load.

Figure 12

Mass source of Rectangular (URWT) and Circular Underground Water Tanks (UCWT) in ETABS

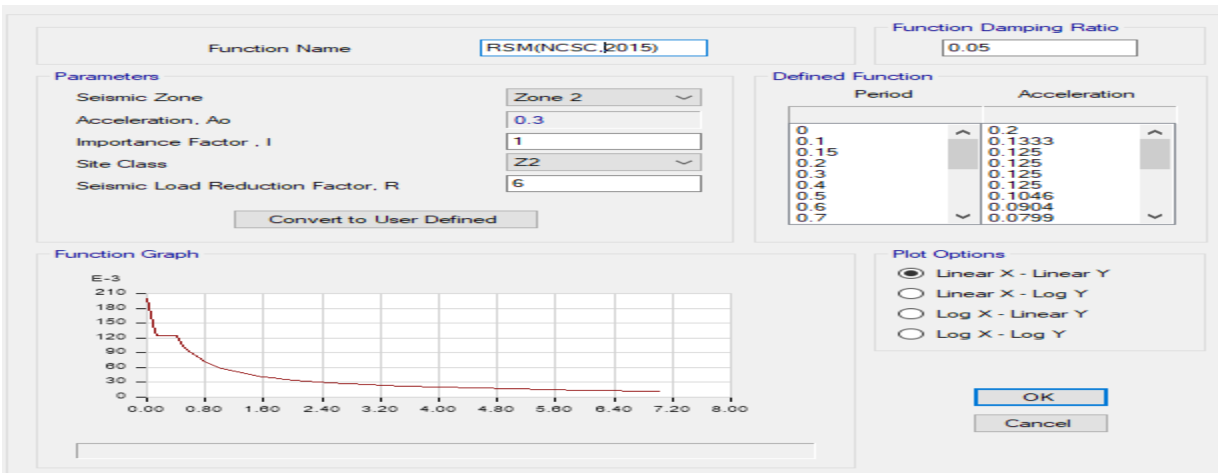


Response Spectrum Function

The figure illustrates the response spectrum curve created by the ETABS

Figure 13

Response spectrum function definition according to NCSC, 2015



Scale factor

Figure 14

Scale factor in ETABS

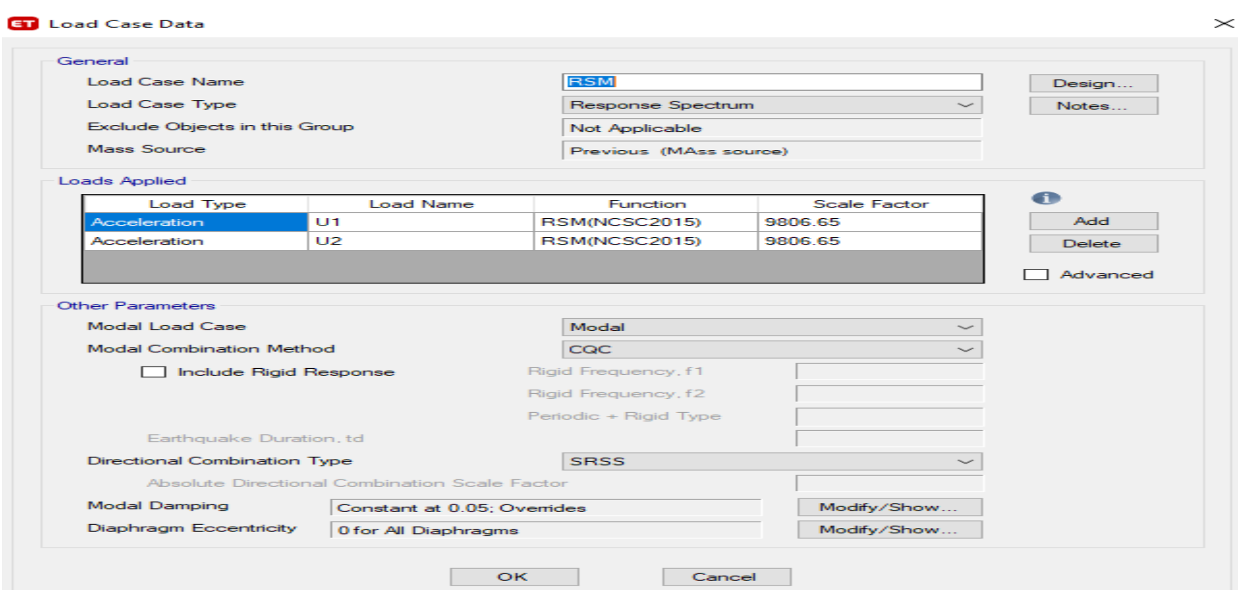


Figure 15

Seismic load in X-direction by ETABS

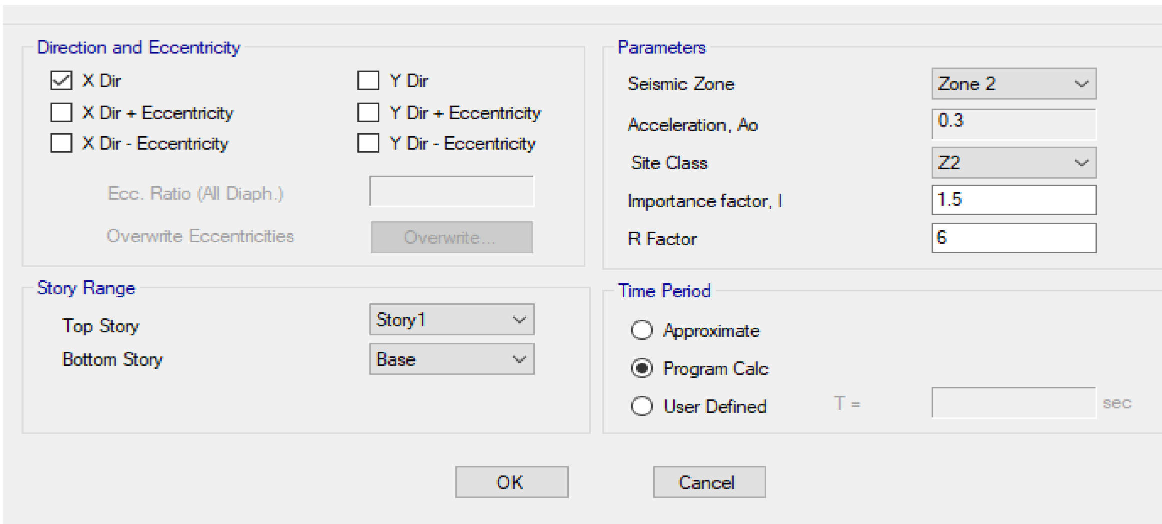


Figure 16

Seismic load in Y-direction by ETABS

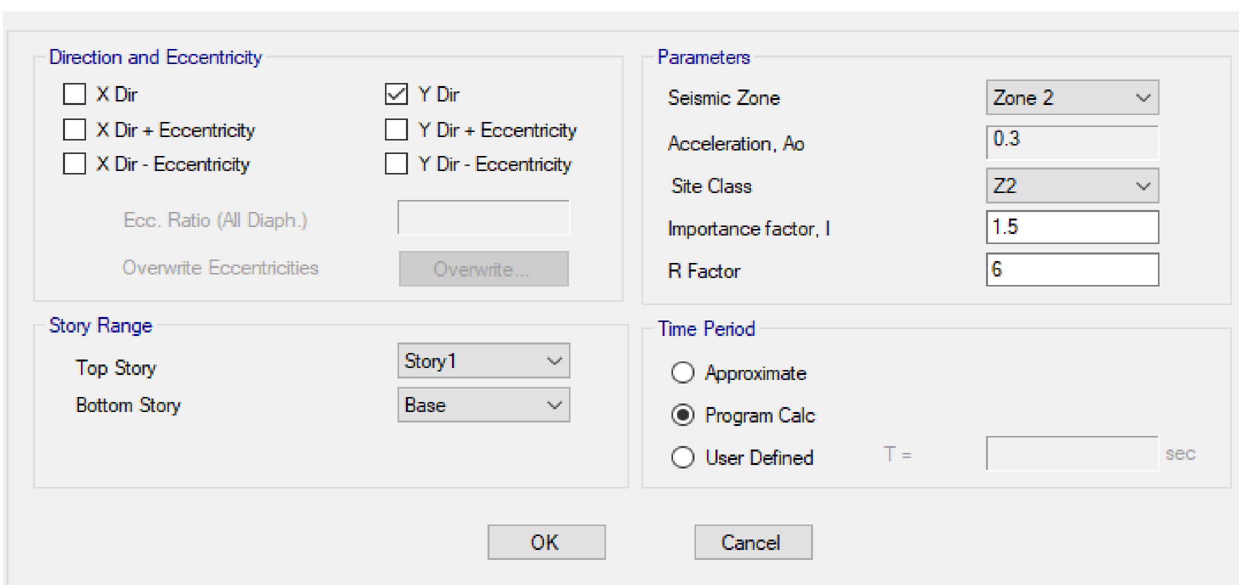


Figure 17

Plan for Underground Rectangular Water Tank by ETABS

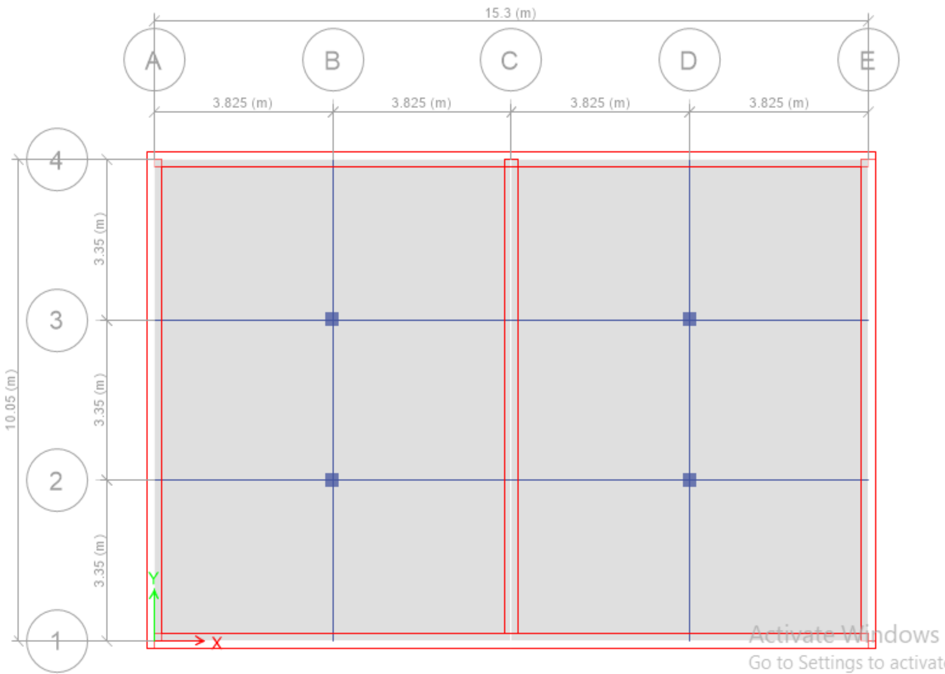


Figure 18

Three Dimensional views for Underground Rectangular Water Tank by ETABS

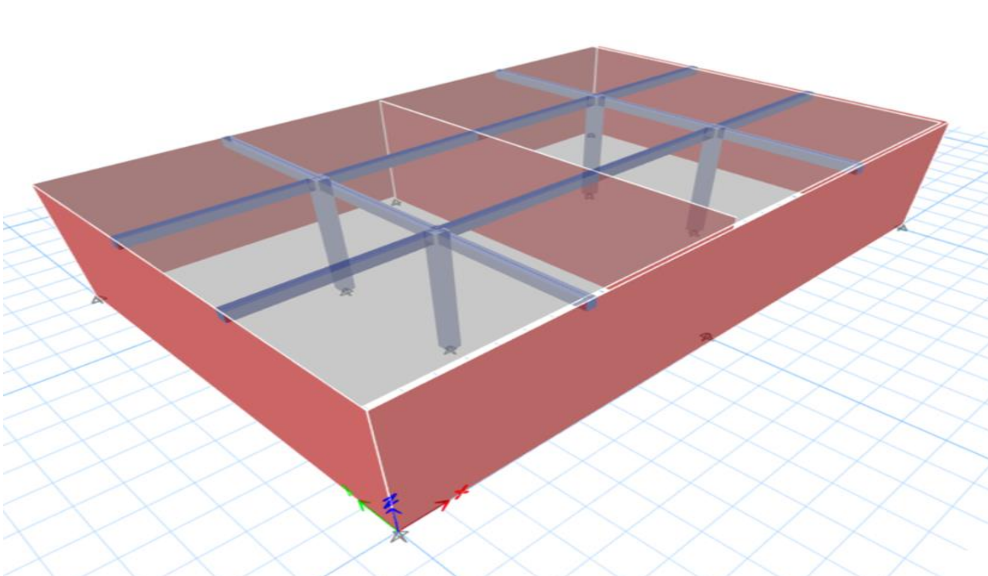


Figure 19

Plan for Underground Circular Water Tank by ETABS

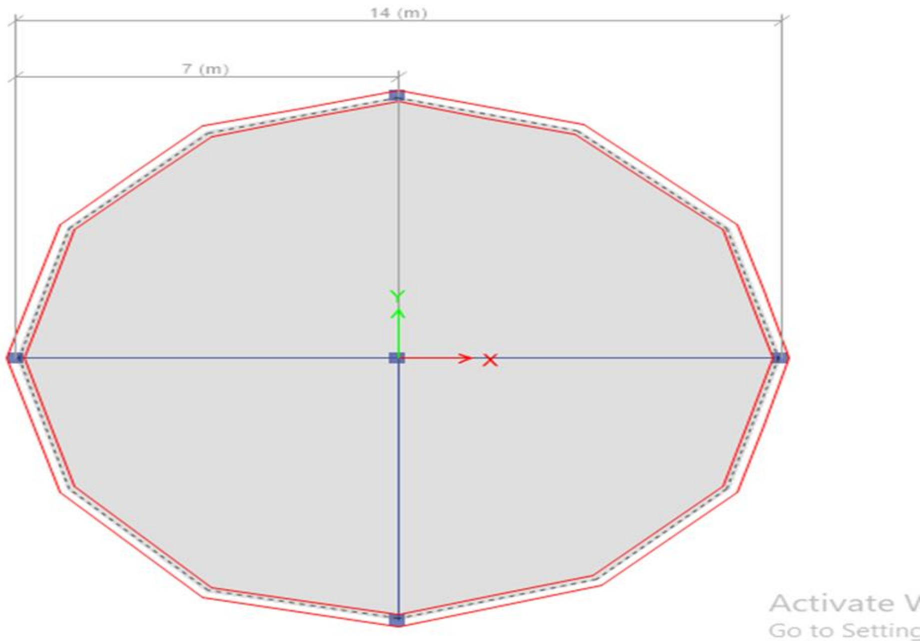


Figure 20

Three Dimensional views for Underground Circular Water Tank by ETABS

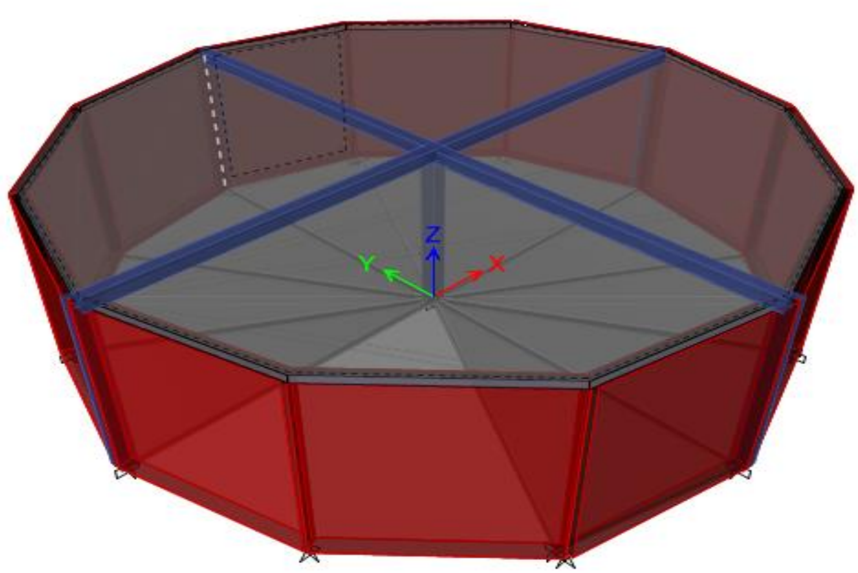


Figure 21

3D Mode shape for Rectangular Water Tank in ETABS

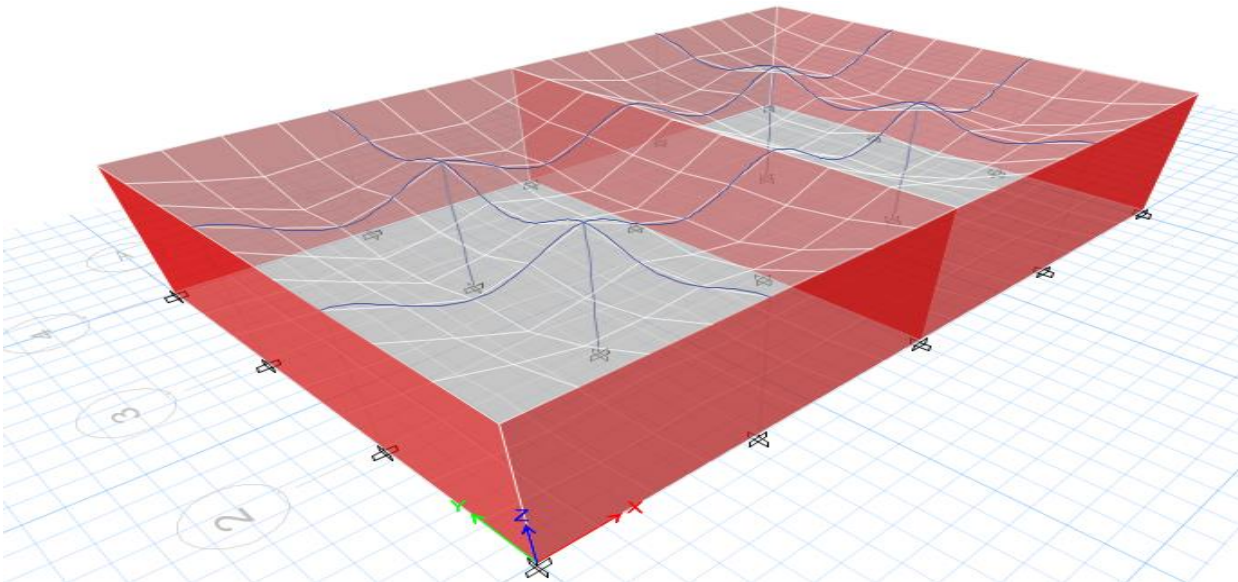


Figure 22

RC Modeling Result for Rectangular Water Tank.

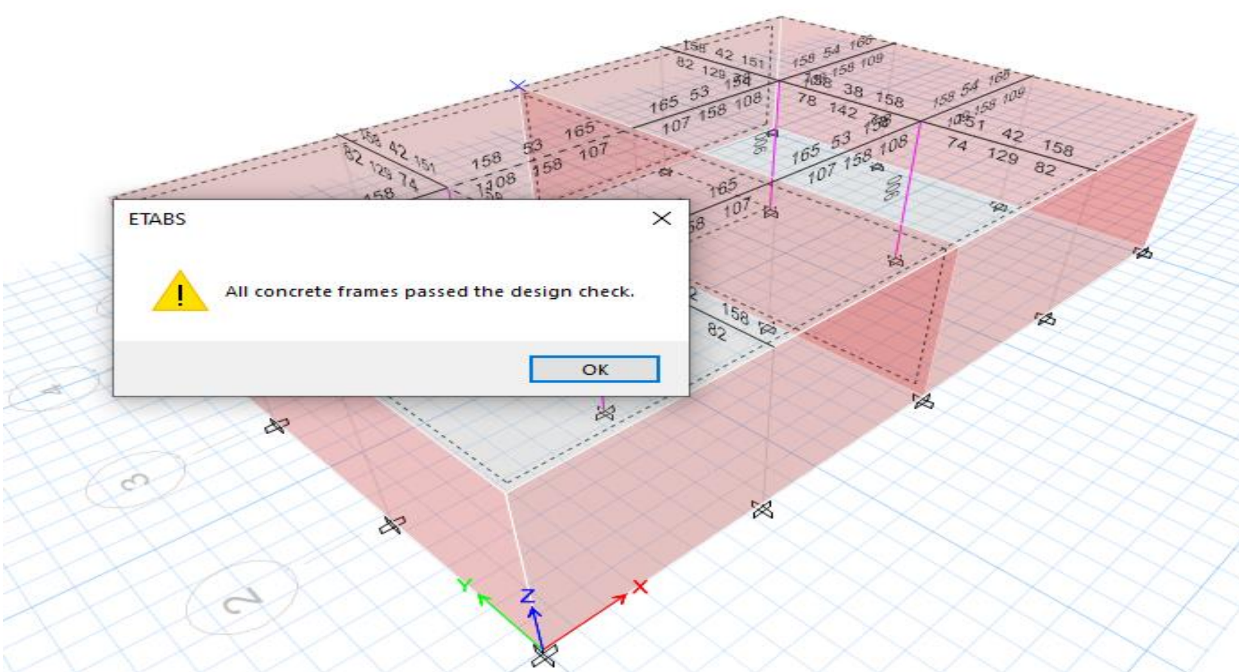


Figure 23

3D Mode shape for Circular Underground Water Tank in ETABS

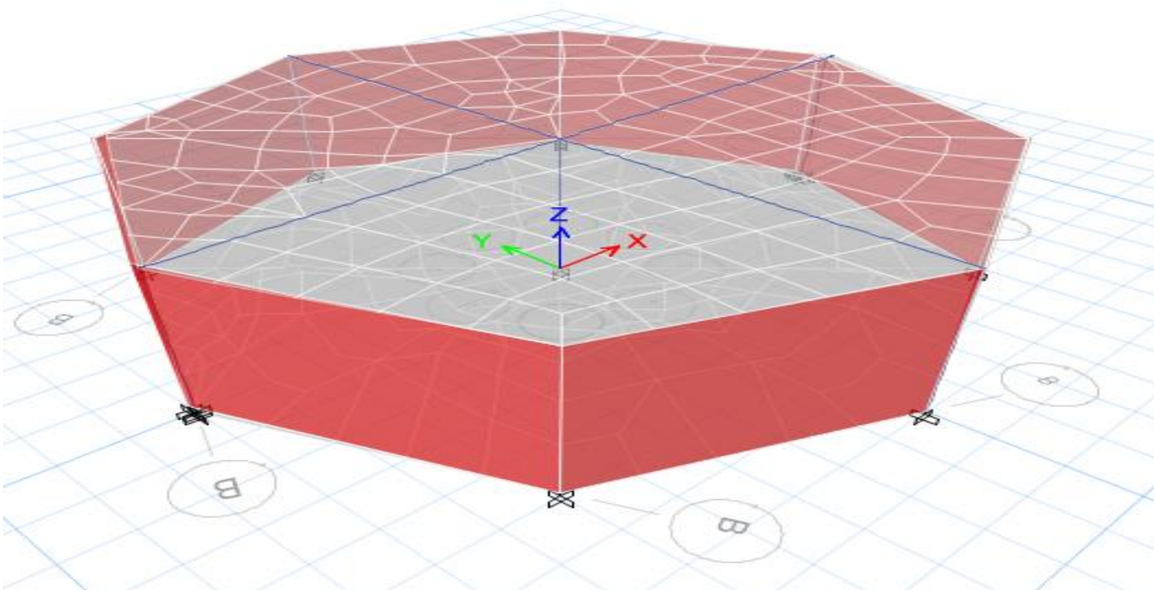


Figure 24

RC Modeling Result for Circular Water Tank

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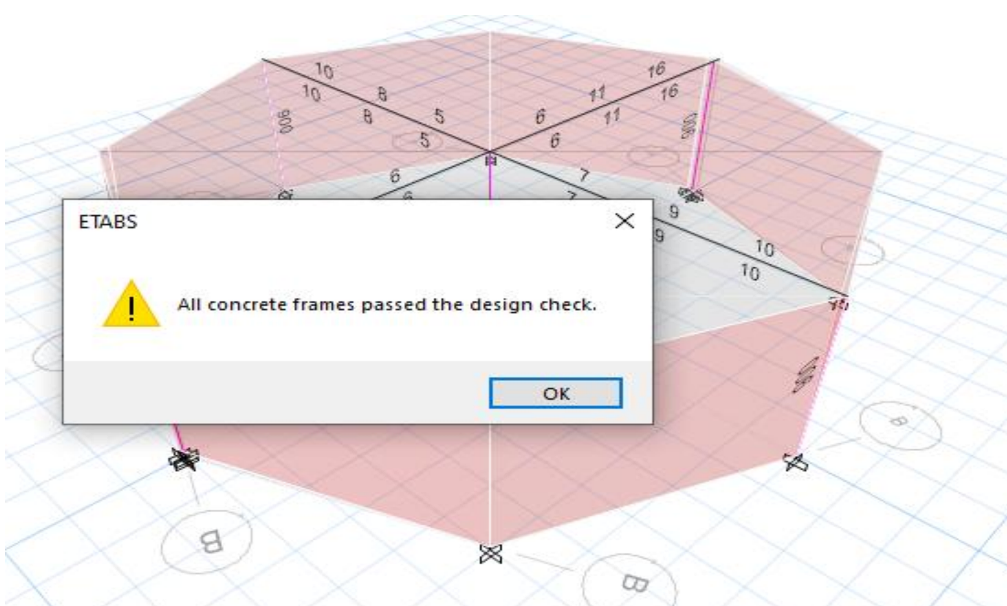


CHAPTER V

Result & Discussion

Overview

The study utilized ETABS software to analyze rectangular and circular underground water tanks according to ACI code and NCSC, 2015. Various parameters such as story displacement, base shear, hoop stresses, bending moments, shell stresses and axial loads were considered. Both linear static and linear dynamic analyses were performed using the working stress method. The obtained results were graphed and thoroughly examined.

In my study, a comparison was made between the results obtained and the findings from relevant literature. Specifically, there were notable similarities between my study and Latha M. S. (2021) in terms of parameters such as base shear, story shear, displacement, axial force, moments, and hoop tension. Similarly, Hegde, D. R., Yogesh, G., and Chawhan, S. (2018) showed similarities in parameters such as maximum stress and hoop tension. However, one significant difference in my study was the use of two different seismic methodologies, RSM and ELF based on NCSC, 2015, whereas the other literature utilized a single seismic method based on Indian codes.

Figure 25

Displacement for the ELFM and RSM in X-direction

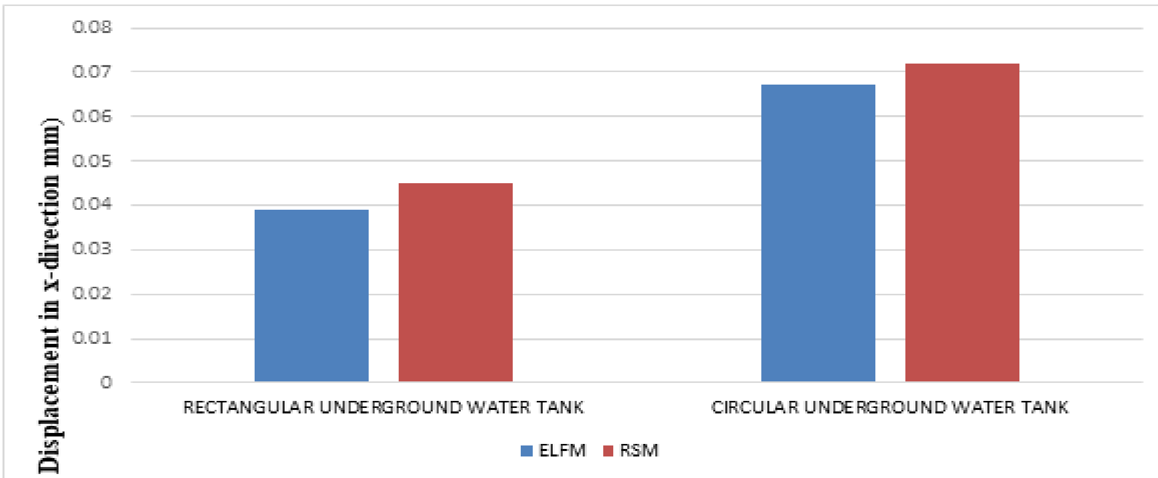
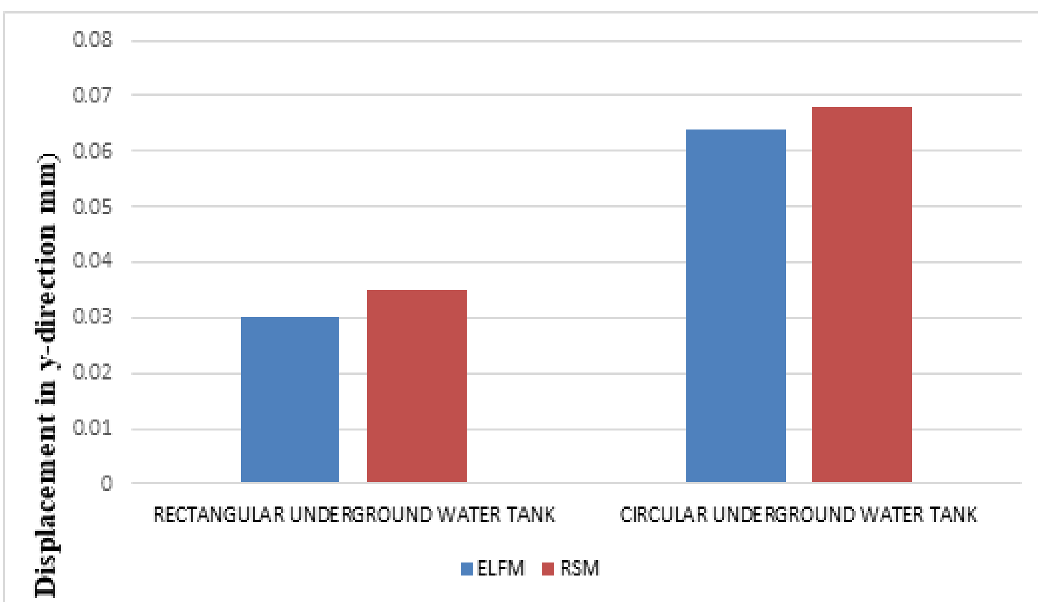


Figure26

Displacement for the ELFM and RSM in Y-direction



Story displacement is the total displacement of the story with respect to ground.

Figure 25 and 26 shows the story displacement for ELFM and RSM in X and Y direction.

Compering both underground water tanks the circular water tank as maximum story displacement value. The comparing both linear and dynamic methods the RSM show greater displacement value in both directions.

Figure 27

Base shear for the ELFM and RSM in X-direction

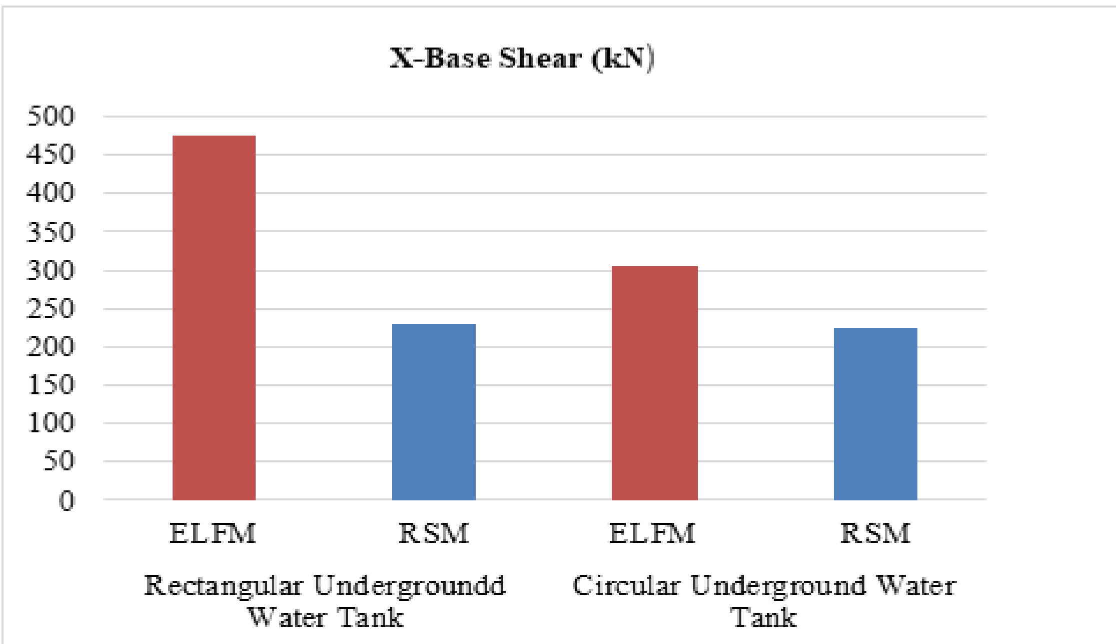
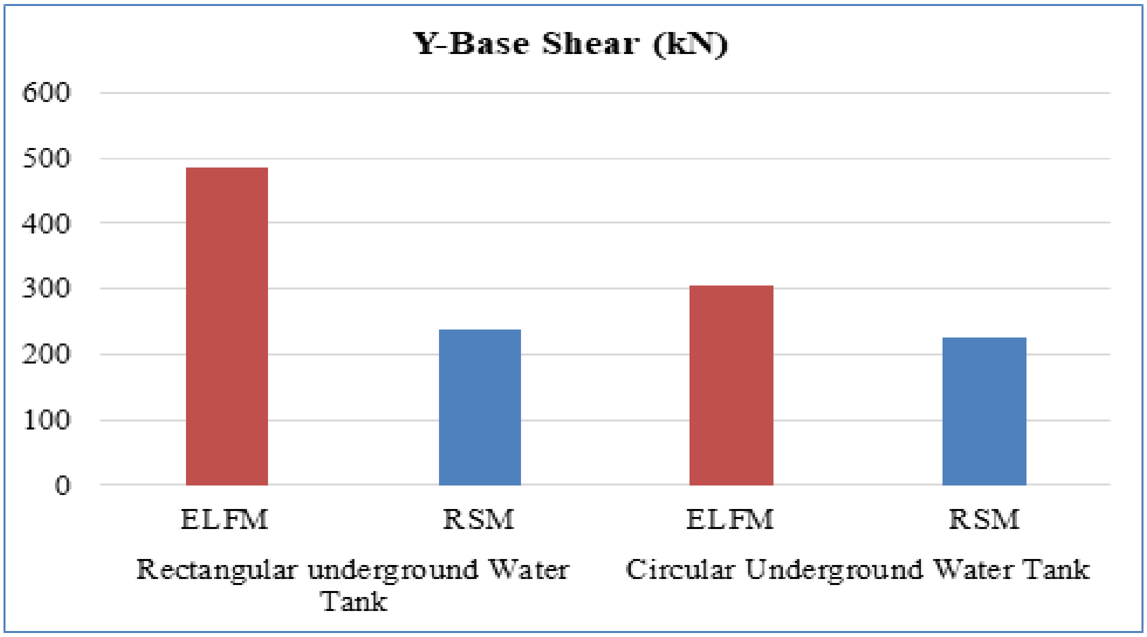


Figure 28

Base shear for the ELFM and RSM in Y-direction



The base shear is expected lateral forces on structure base due to seismic actives. Figure 27 and 28 present the base shear obtained from ELFM and RSM specifically in the x and y directions. When comparing the two underground water tanks, it observed that the rectangular water tank exhibits the maximum base shear value. This suggests that rectangular tank experiences higher lateral forces compared to the circular tank.

Furthermore, when comparing the results obtained from both linear and dynamic methods (ELFM and RSM), it’s found that the ELFM yields larger base shear of tank’s base in response to the applied loads. These finding highlight the significance of considering the shape and analysis method employed in assessing the base shear for underground water tanks.

Figure 29

Hoop tensions for the Rectangular Underground Water Tank and Circular Underground Water Tank

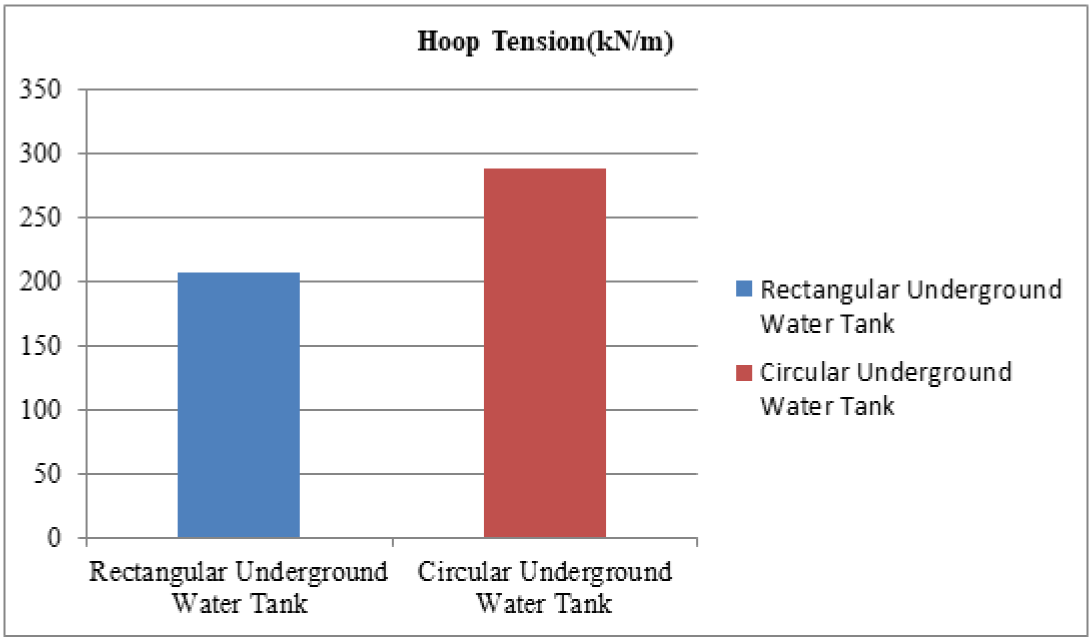
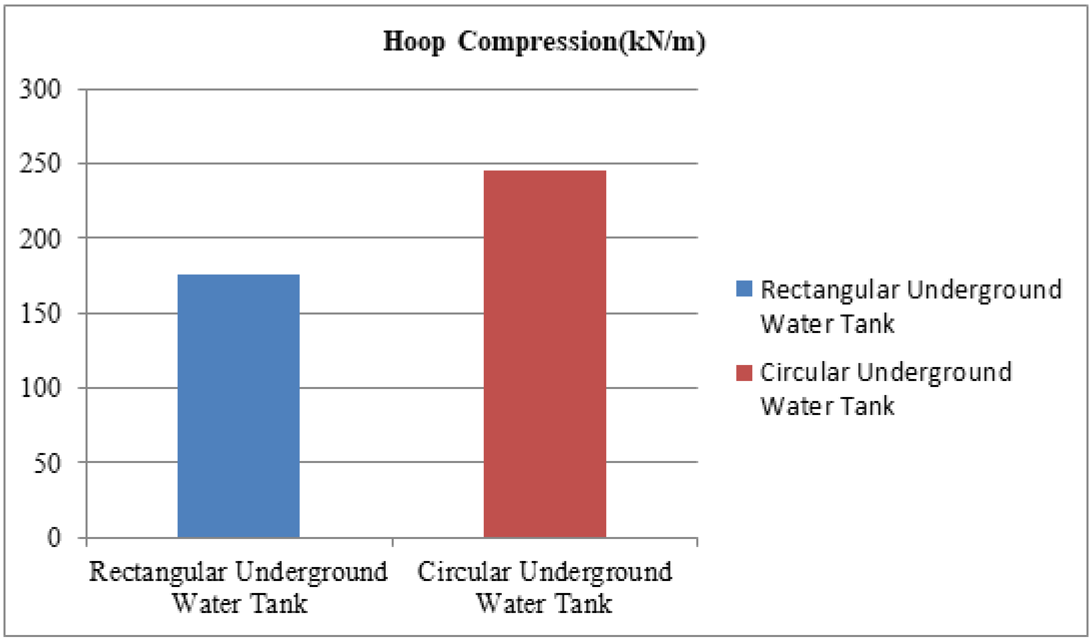


Figure 30

Hoop Compressions for the Rectangular Underground Water Tank and Circular Underground Water Tank.



The circular underground water tank exhibits higher values of hoop tension compared to the rectangular tank. This indicates that the circular tank experiences grater stretching or expansion of its shell due to internal water pressure. Additionally, the circular tank demonstrates greater hoop compression compared to the rectangular tank. This implies that the circular tank experiences more contraction or compression of its shell due to external soil pressure exerted on it.

Figure 31

Bending moment for the ELFM and RSM in X-direction

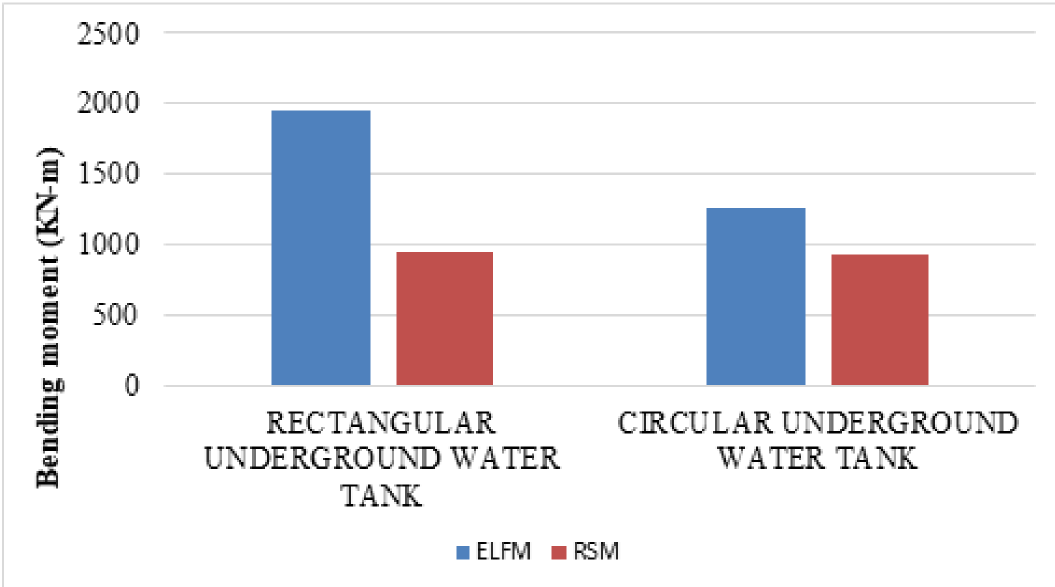


Figure 32

Bending moment for the ELFM and RSM in Y-direction

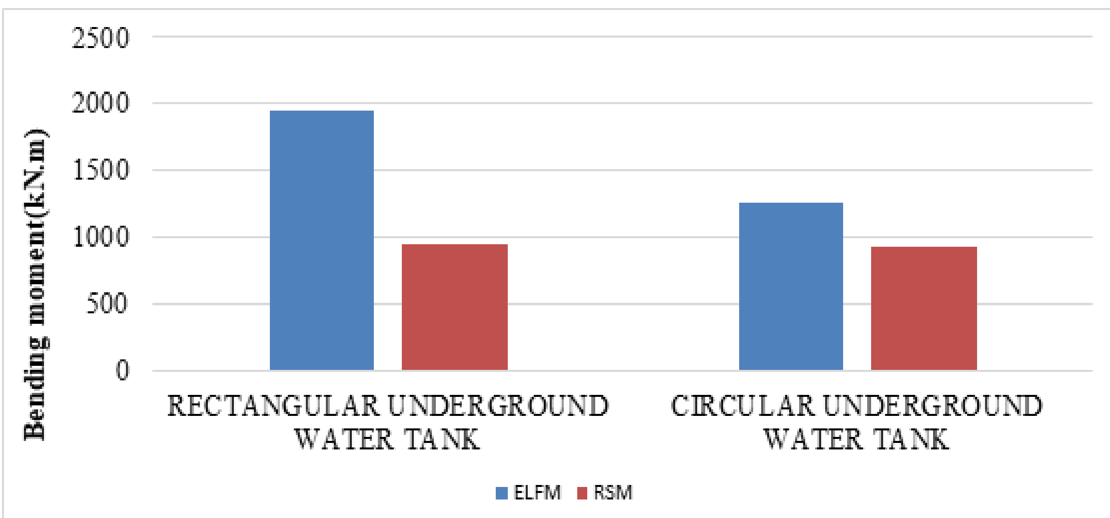
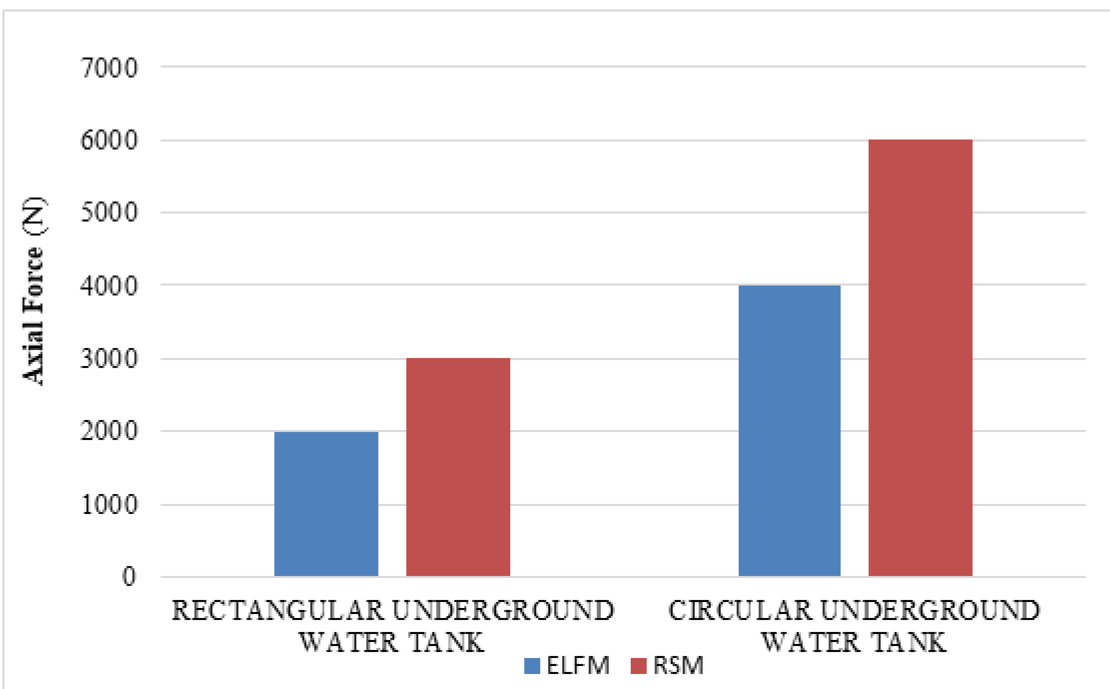


Figure 31 and 32 present the bending moment obtained from ELFM and RSM specifically in the x and y directions. When comparing the two underground water tanks, it observed that the rectangular water tank exhibits the maximum bending moment. This suggests that rectangular tank experiences higher bending forces compared to the circular tank.

Furthermore, when comparing the results obtained from both linear and dynamic methods (ELFM and RSM), it’s found that the ELFM yields larger bending moments in response to the applied loads. These finding highlight the significance of considering the shape and analysis method employed in assessing the bending moment for underground water tanks.

Figure 33

Axial forces for the Rectangular Underground Water Tank and Circular Underground Water Tank.

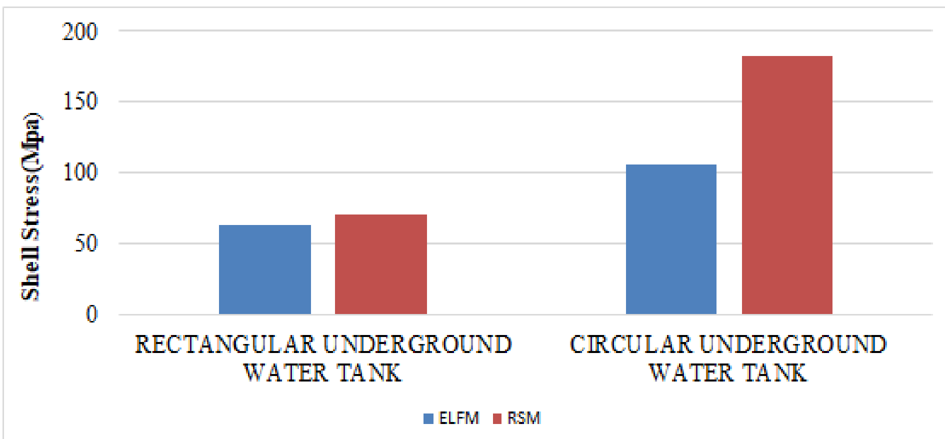


It is observed that the circular water tank experiences a higher axial force compared to the rectangular water tank. This indicates that the circular tank is subjected to greater axial loads, which act along the central axis of the tank. The axial force primarily results from the internal pressure exerted by the water within the tank.

Circular tanks distribute the internal pressure more uniformly along the shell, resulting in higher axial forces. In contrast, rectangular tanks may have concentrated stress areas, particularly at the corners and along the longer walls, which can lead to lower overall axial force values.

Figure 34

Shell Stresses for the Rectangular Underground Water Tank and Circular Underground Water Tank



The results indicate that:

Circular underground water tanks experience higher stress magnitudes compared to rectangular tanks. The response spectrum method (RSM) yields significantly higher stress values for both tank shapes compared to the equivalent lateral force method (ELFM). The circular tank experiences a much larger difference in stress magnitudes between RSM and ELFM compared to the rectangular tank. These findings suggest that circular tanks are more susceptible to higher stress levels, and the choice of analysis method significantly impacts the stress results, particularly for circular tanks.

CHAPTER VI

Conclusion and Recommendation

This research aimed to investigate and propose effective strategies for planning and evaluating underground water storage systems, focusing on design, capacity, water quality management, operation, and environmental impact. The study compared the behavior of rectangular and circular underground water tanks under various loading conditions, utilizing the ACI-350 and the finite element software ETABS 2018. The results and discussions revealed several important findings. The circular water tank exhibited higher story displacement compared to the rectangular tank, indicating greater overall displacement. The rectangular tank experienced higher base shear, implying higher lateral forces during seismic activity than the circular tank. Regarding hoop tension and compression, the circular tank showed higher tension caused by internal water pressure and greater compression from external soil pressure compared to the rectangular tank. The rectangular tank demonstrated higher bending moments, indicating greater bending forces than the circular tank. Additionally, the circular tank experienced higher axial forces due to a more uniform distribution of internal pressure along the shell. These findings emphasize the importance of considering the tank's shape and analysis method when evaluating different parameters of underground water tanks. The research provides valuable insights into the behavior and performance of rectangular and circular tanks, facilitating the design and evaluation of sustainable and reliable water storage systems to meet the growing demand for clean drinking water.

Future Recommendation

- ✓ Investigate alternative tank shapes beyond rectangular and circular designs, considering their structural behavior, water storage capacity, and cost-effectiveness.

- ✓ Evaluate different construction materials and structural designs for underground water tanks to enhance their strength, durability, and seismic resistance.

- ✓ Conduct comprehensive studies to evaluate the environmental impact of underground water storage systems. Investigate the potential effects on groundwater resources, soil stability, and surrounding ecosystems.

- ✓ Compare the Study of Analysis of Rectangular and Circular Underground Water Tanks considering Different Soil Types.

References

Ajagbe, W. O., Ilugbo, E. O., Labiran, J. O., & Ganiyu, A. A. (2015). Analysis and Design of a Fully Submerged Underground Water Tank Using the Principle of Beam on Elastic Foundation. In *UITECH Conference* (pp. 1-10).

Atalar , C., Durgunoğlu, H. T., Das, B. M., Hacıalioğlu, E., Akol, A., & Tozan, H. (2006, November). Site Investigations at Near East University-Cyprus. In *Proceedings of the International Conference New Developments in Geoenvironmental and Geotechnical Engineering, Incheon, Republic of Korea* (pp. 350-361).

Azgar, M., & Smruthi, N. R. (2017). Design of Circular Water Tank by Using STAAD PRO Software. *International Journal of Scientific Engineering and Technology Research*, *6*(29), 5642-5650.

Bhende, A. A., & Jamale, P. B. (2022). Comparative Analysis of Different Shapes of Underground Water Tank. *International Journal of Modern Developments in Engineering and Science*, *1*(5), 19-21.

Chamber of Civil Engineers. (2015). *KKTC Deprem Bölgelerind Yapılacak Binalar Hakkında Yönetmelik.* Lefkoşa: Inşaat Mühendisleri Odasi Chamber of Civil Engineers.

Dubey, R., Singh, V., & Panday, V. (2021). Seismic Analysis of Underground Water Tank Considering Soil Structure Interaction. *International Journal of Engineering Research and Applications*, *11*(10), 21-25.

Gadekar, D., & Patel, R. (2022). Design and Analysis of Under Ground Water Tank Considering Different Fill Conditions Using STAAD. PRO.

Hegde, D. R., Yogesh, G., & Chawhan, S. (2018). Comparative Study On Rectangular And Circular Water Tank Using Staad Pro Software. *International Research Journal of Engineering and Technology*, *5*(11), 1319-1323.

Kapadia, I., Patel, P., Dholiya, N., & Patel, N. (2017). Design, Analysis and Comparison of Underground Rectangular water tank by using STAAD Provi8 software. *International Journal of Scientific Development and Research (IJSDR)*, *2*(1), 2455-2631.

Latha, M. S. (2021). Comparison of Analysis between Rectangular and Circular Overhead Water Tank. *Applied Research on Civil Engineering and Environment*, *2*, 77-95.

Nazari Chamaki, F., Jenkins, H., Hashemipour, M., & Jenkins, G. P. (2022). Wastewater Reuse to Mitigate the Risk of Water Shortages: An Integrated Investment Appraisal. *Water*, *14*(23), 3859.

Nimade, A., Soni, N., Varma, G., Joshi, V., & Chaurasia, S. (2018). Parametric Study of Underground Water Tank using FEM. *International Journal of Science Technology & Engineering*, *4*(9), 94-98.

Shinde Suraj Parbat, Prof.Kulkarni V.P,"Design Of Underground Water Tank By Using Staad- Pro And E-Tabs Software", International Journal Of Engineering Sciences & Research Technology, ISSN: 2277-9655

Sofroniou, A., & Bishop, S. (2014). Water scarcity in Cyprus: a review and call for integrated policy. *Water*, *6*(10), 2898-2928.

Tripathi, S., Dubey, A., & Maurya, M. C. Time History Analysis of Underground Water Tank for Different Seismic Intensity. *International Journal of Science and Research (IJSR) ISSN*, 2319-7064.

Wagh, K. K., Ghuge, A. K., Gaidhane, D. N., & Gandhe, G. R. Design and Analysis of underground water tank by using Staad Pro· 2021. 5. 3.· Design and...

Zachariadis, T. (2010). Residential water scarcity in Cyprus: Impact of climate change and policy options. *Water*, *2*(4), 788-814.

APPENDICES

Appendix A

MINISTRY OF LABOUR AND SOCIAL SECURITY BUILDING, SOILINVESTIGATION REPORT

JEOLOJİ VE MADEN DAİRESİ
JMD
LEFKOŞA - 1974

KKTC
Çevre ve Doğal Kaynaklar Bakanlığı
Jeoloji ve Maden Dairesi

'ÇALIŞMA VE SOSYAL GÜVENLİK BAKANLIĞI BİNASI' ZEMİN ETÜD RAPORU

Hazırlayan

Hatice KAŞER
Jeoloji Yüksek Mühendisi

KASIM, 2007
Lefkoşa

Temel Zeminine Ait Mekanik Parametreler:

1. İnceleme alanı **2. Derece** deprem bölgesindedir.
2. Temel zemin grubu **(C)**
3. Yerel zemin sınıfi **(Z_2)**
4. Zeminin spekturum karakteristik periyotları **T_A=0.15sn, T_B=0.40sn**
5. Kayma dalgası hızı **200-400 m/s** alınabilir.
6. Deprem hesaplarında kullanılacak etkin yer ivmesi katsayısı **A_0 = 0.30** 'dur.
7. Yatak Katsayısı **K_0=2000 ton/m^3**
8. Bina önem katsayısı **I=1.4**

Hatice Kaşer

Jeoloji Yüksek Mühendisi

Appendix B

A.Calculating Slab Thickness of two-way slab

L=3.825m, FY=420MPa, Fc=30MPa,

Design of beam Section:

Minimum depth of beam according to ACI-318-14-19 Table 9.3.1.1 is:

H=L/18.5= 3825mm/18.5 = 207.7mm ≈210mm

H=b (1.5)=210/1.5, b=140mm
Beam section = (140mm*210mm)
But I decide = (200mm*300mm) for safety

For depth of Slab with beam we assume depth of slab is 200mm that is required for determining the moment of inertia of the slab that required in the (α_f) equation for determining the slab thickness.

$$\alpha f = \frac{E_{cb} I_b}{E_{cS} I_S}$$

I_{beam} (for edge)= $(bh^3/12)*1.5$

$=200*300^3/12*1.5=6.75*10^8 mm^4$

I_{beam} (interior)= $(bh^3/12)*2=200*300^3/12*2=9.0*10^8 mm^4$

$I_{slab}= b_s*h^3/12$

I_{slab}(edge)= $3825*200^3/12=25.5*10^8 mm^4$

I_{slab}(interior)=$5000*200^3/12=25.5* 10^8 mm^4$

α_{f1}(edge)= $6.75*10^8 mm^4/25.5* 10^8 mm^4=0.264$

$\alpha_{f(}$interior$_{)}$= 9.0*10^8mm^4/25.5* 10^8mm^4=0.352

$\alpha_{f(total)}$=(0.264+0.352)/2=0.308 $\leq\alpha_f\leq$2 so use table8.3.1.1:

H_{slab}=114mm≤ assumed (200mm)

But I decide for safety 150mm

B. Wall net maximum pressure and area steel calculation

When tank is full and surrounding area is dry

h=4.1m

Ka=$\frac{1-sin\,\theta}{1+sin\,\theta}$

Ka=$\frac{1-sin\,\theta}{1+sin\,\theta}$

$\gamma_{s=}$ assumed 22 kN/m^3

$\gamma_{w=}$10 kN/m^3

θ=26

Net maxim pressure=water pressure-soil pressure

$\gamma w_* h_-$ ka$_*$ γs*h

10 kN/m^3*4.1m-0.39*22 kN/m^3*4.1m=5.882 kN/m^2

Maximum bending moment= wl^2/15

(5.882 kN/m^2) (4.1)^2 /15=6.59 kNm

Mu= Φ*As*FY $(d - \frac{As-fy}{2*0.85fcb})$ =As=60mm^2

Minimum area of steel=0.003*300*1000=900m^2

C. Calculation hoop stresses

Circular hoop tension

HT= (P) (D/2)

HT= ($41KN/m^2$) (14m/2) =287KN/m

As= ($287*10^3$)/150=$1914mm^2$

Rectangular hoop tension

HT= (P) (L/2)

HT= ($41KN/m^2$) (10.05m/2) =206KN/m

As=$206*10^3$)/150=$1374mm^2$

Circular hoop compression

HT= (P) (D/2)

HT= ($35.178KN/m^2$) (14m/2) =246KN/m

Rectangular hoop compression

HC= (P) (L/2)

HC= ($35.178KN/m^2$) (10.05m/2) =176KN/m

D. Response Spectrum Method According to NCSC2015

In NCSC2015, the ordinate of the elastic response spectrum can be found by Equation

$Spa(T) = A(T).\ g\ R\text{a}\ (T)$

Where,

- ✓ A(T) refers to the spectral acceleration coefficient
- ✓ Ra(T) refers to the earthquake load reduction factor
- ✓ g is the gravitational acceleration The spectral acceleration coefficient, A(T) is considered to be the basis for the expectation of seismic load and can be calculated as the
- ✓ Following: $A(T) = A0\ I\ S(T)$

  Where,

- ✓ A0 is the coefficient of effective ground acceleration
- ✓ I is the importance factor
- ✓ S(T) is the spectrum coefficient

The importance factor, I is specified according to structure's function as shown in Table 7

The spectrum coefficient, S(T) depends on the local site conditions and the building's natural period, T.

S(T) can be calculated by the following:

$(T) = 1 + 1.5\, T/\, TA \qquad 0 \leq T \leq TA$

$(T) = 2.5 \qquad TA < T \leq TB$

$(T) = 2.5\, (\frac{TB}{T})^{0.8} \qquad TB < T$

Where,

TA and TB are the spectrum characteristic periods in seconds.

Table 9 gives TA and TB values depending on local soil classes.

Soil types according to NCSC2015 are given in Table 9 depending on shear wave velocity (m/s), while local site classes are presented in Table 9

Appendix C

ETAB Modeling Result

A. Deflection Results of Rectangular Underground water tank

Figure 35

Deflection due to dead load

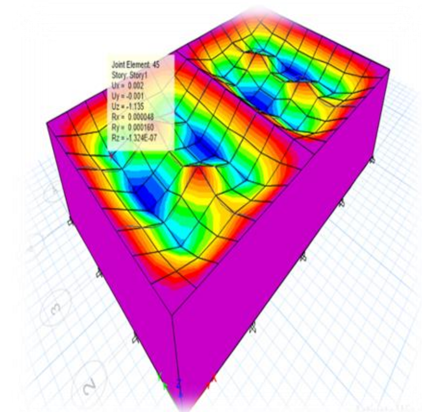


Figure 36

Deflection due to water

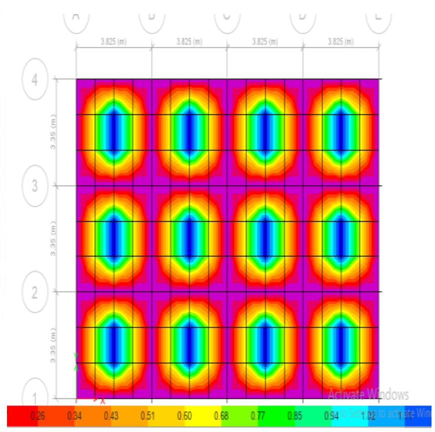


Figure 37

Deflection due to soil load

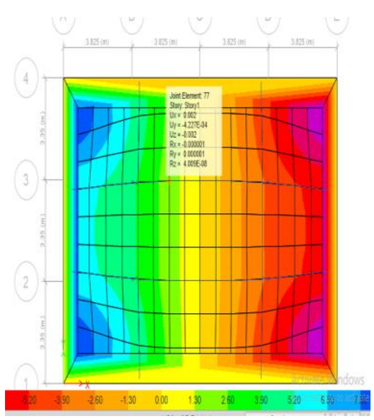


Figure 38

Deflection due to RSM

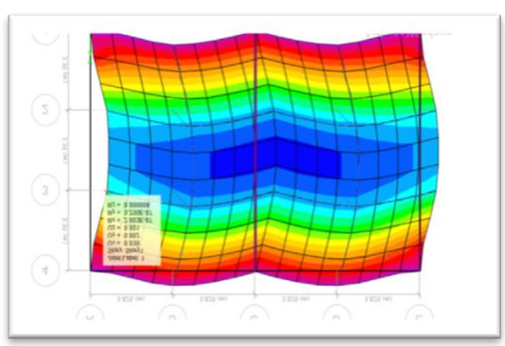


Figure 39

Deflection due to EQX

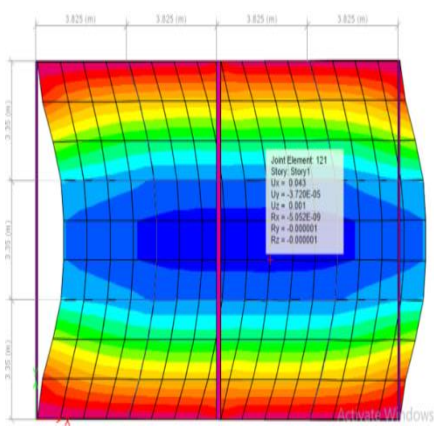
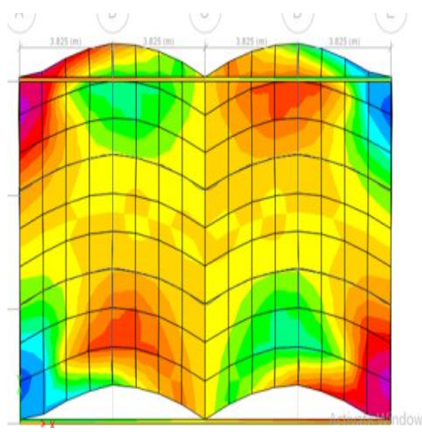


Figure 40

Deflection due to EQY



B. Deflection Results of Rectangular Circular water tank

Figure 41

Deflection due to water

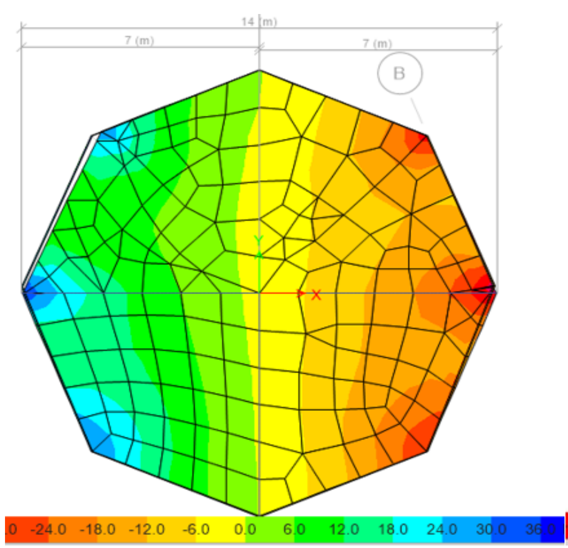


Figure 42

Deflection due to soil

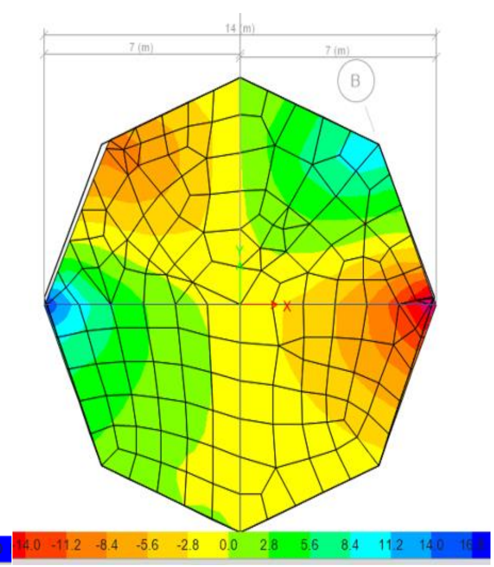


Figure 43

Deflection due to RSM

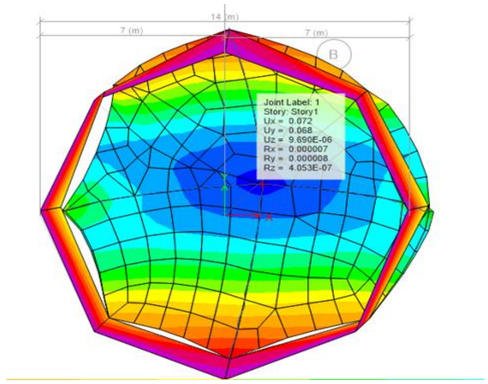


Figure 44

Deflection due to EQX

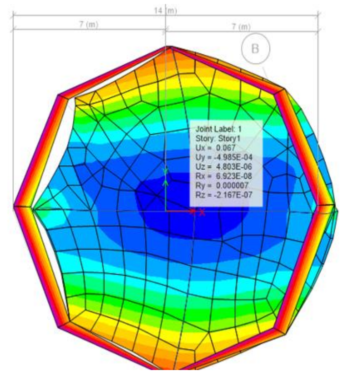
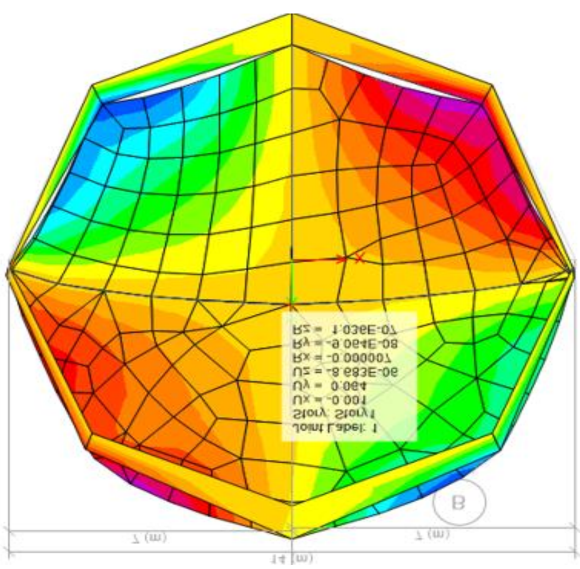


Figure 45

Deflection due to EQY

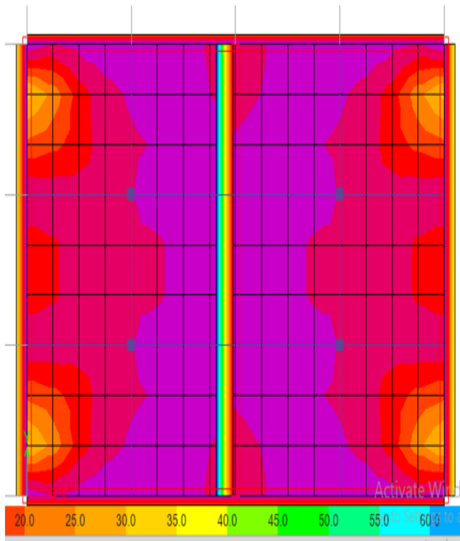


C.Shell Stress Results of Rectangular Underground water tank

Figure 46 *Figure 47*

Shell stress due to RSM Shell stress due to

EQX



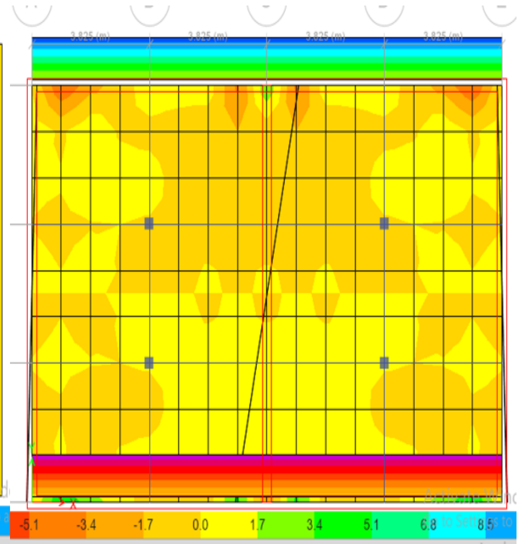
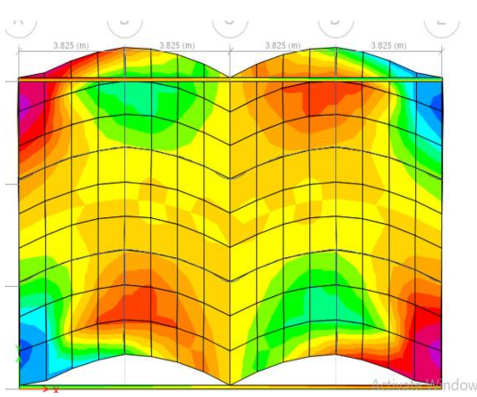


Figure 48 Figure 49

Shell stress due to EQY shell stress due to water



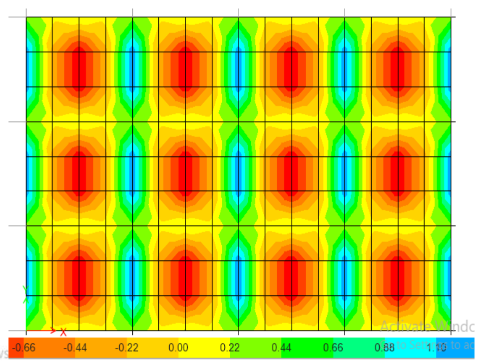
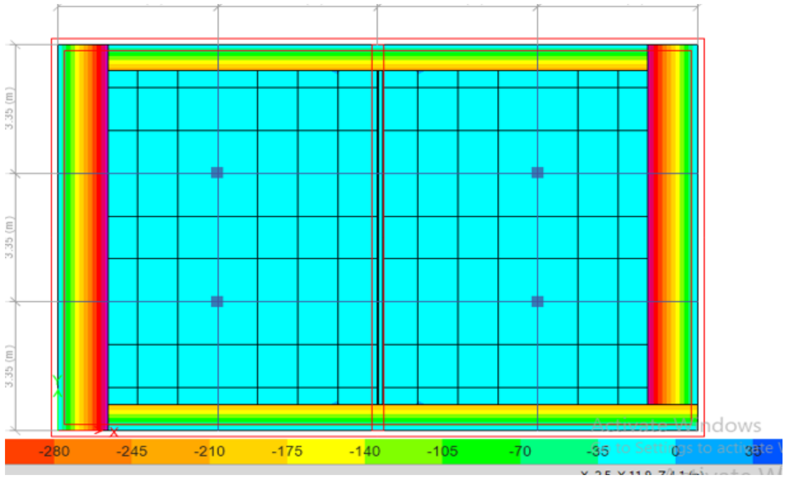


Figure 50

Shell stress due to Soil



D. Shell Stress Results of Circular Underground water tank

Figure 51

Shell stress due to RSM

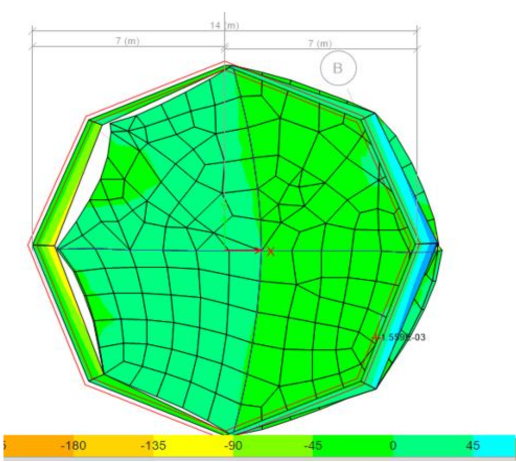


Figure 52

Shell stress due to EQX

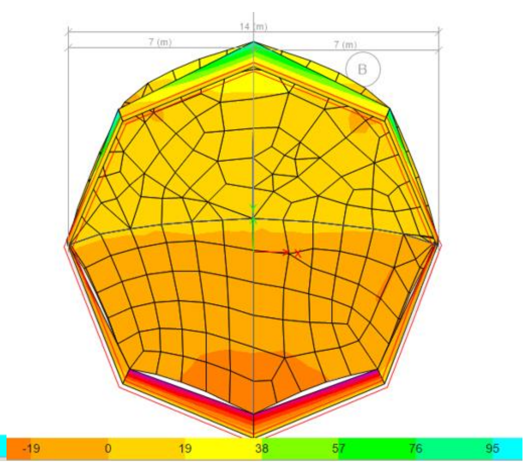


Figure 53

Shell stress due to EQY

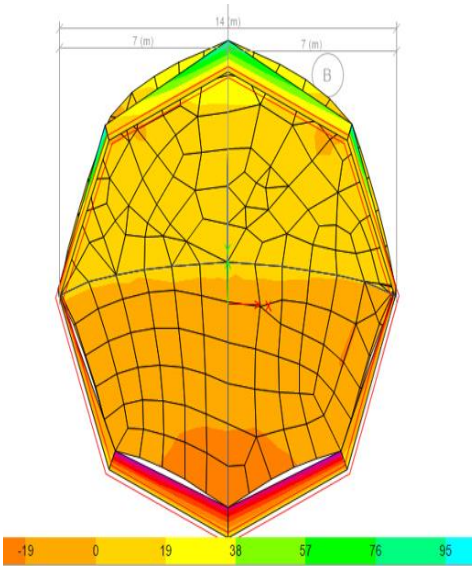


Figure 54

shell stress due to soil

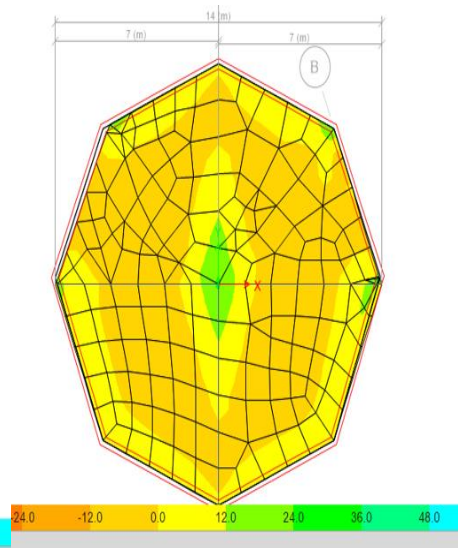
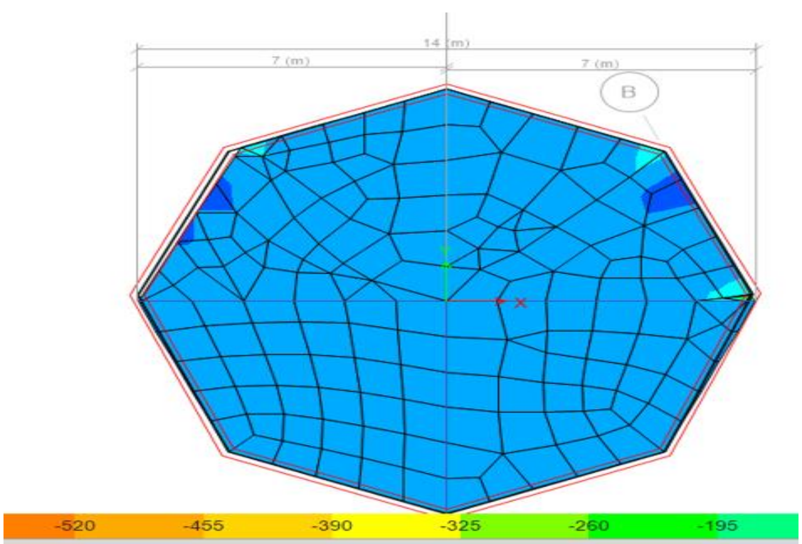


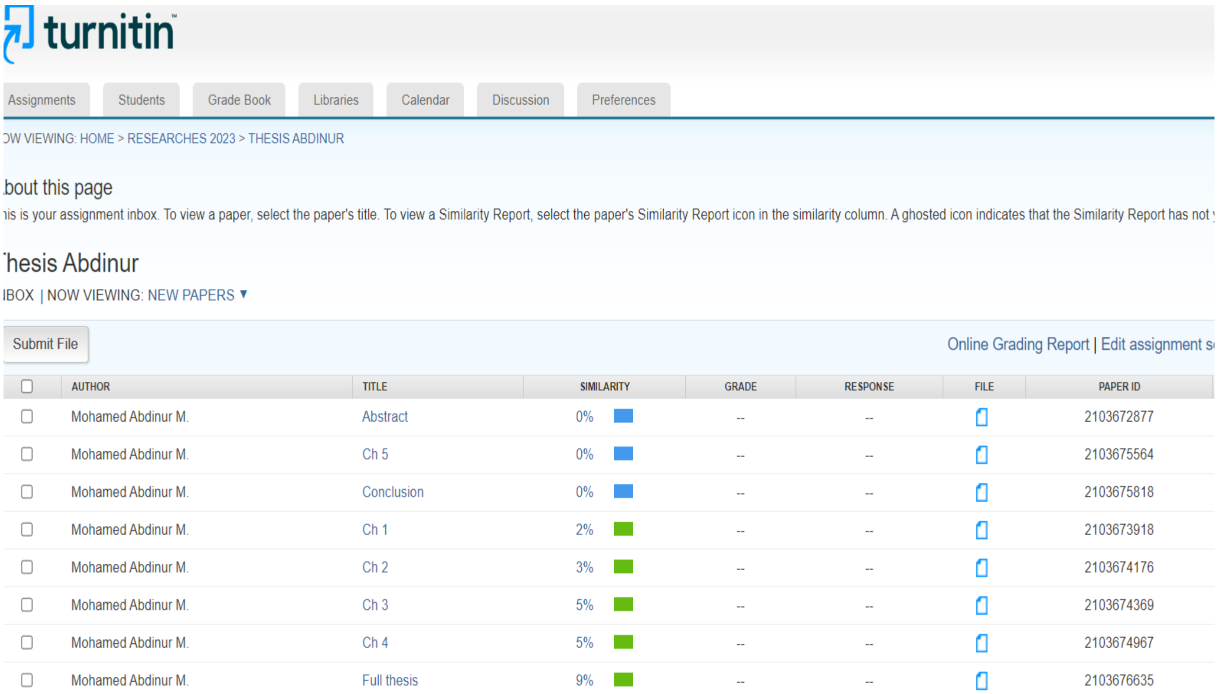
Figure 55

Shell stress due to water



Appendix D

Turnitin Similarity Report



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Thesis supervisor: Assoc.Prof.Dr. Rifat Reşatoğlu

Appendix E

Ethical Certificate

25.06.2023

<u>ETHICS LETTER</u>

TO GRADUATE SCHOOL OF APPLIED SCIENCES

REFERENCE: MOHAMED ABDINUR MOHAMED (20215618)

The aforementioned candidate is one of the Master's students in the field of Civil Engineering.

He is working on a thesis under my supervision, entitled "**Comparative Study of Analysis Rectangular and Circular Underground Water Tanks**". The work is based on modeling Rectangular and Circular Underground Water Tanks.

The building type selected in this study is Underground Water Tank.

The Underground Water Tanks were modeled by using software program called ETABS v18.

Sincerely yours,

Assoc. Prof. Dr. Rifat RESATOGLU

(Supervisor)

Civil Engineering Department,

Faculty of Civil and Environmental Engineering