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جامعة النجاح الوطنية
كلية الهندسة وتكنولوجيا المعلومات
قسم الهندسة المدنية

Graduation Project Report

"Analysis And Design of a Reinforced Concrete Water Tank"

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Submitted in partial fulfillment of the requirements for Bachelor degree in Civil Engineering

First Semester 2023/2024

الإهــداء

قال تعالى: " وَفَوْقَ كُلِّ ذِي عِلْمٍ عَلِيمٌ "

الحَمْدُ لِله الذي أنعم علينا بنعم كثيرة ورزقنا من المعرفة والعلم لتكون مشكاةً تضيء الدرب وتعيننا على نوائب الدهر، والصلاة والسلام على سيدنا محمد وخاتم الأنبياء والمرسلين

إلى أمل الحياة ومعناها .. إلى من سهرن الليالي الطوال صاحبات الحنان أمهاتنا الحبيبات

إلى اللذين كافحوا لأجلنا للوصول الى أعلى الدرجات بالأخلاق والعلم..

إلى أرواح أبوينا رحمهم الله وأسكنهم الفردوس الأعلى ..

كما نتقدم بجزيل الشكر والأمتنان الى الدكتور الفاضل منذر ذياب والدكتور عصام جردانة لمساهمتهم في انجاز هذا المشروع .. كما نتوجه بالشكر والتقدير الى صرح جامعة النجاح الوطنية والى طاقمها الرائع , أدامهم الله جميعا سندا لجميع طلاب الجامعة وذخرا لهذا الوطن الذي يضمهم ويصنع من عزيمتهم مستقبل الأمة المشرق..

ABSTRACT

This project focuses on the analysis and design of the foundation system and walls for a reinforced concrete water tower. The foundation of a water tower is critical to ensure stability, durability, and safety throughout its service life. The objective of this study is to develop a comprehensive understanding of the design principles, engineering considerations, and analytical methods required for the foundation system of a water tower. The project begins with a thorough literature review to gather relevant water tower design and foundation engineering information. Various types of foundation systems commonly used for water towers are explored, including spread footings, mat foundations, and piles. Additionally, geotechnical investigations are conducted to assess the soil properties at the project site, enabling accurate analysis of the foundation system.

The analysis phase involves the application of engineering software and structural analysis techniques to evaluate the structural behavior of the foundation system. Load combinations, including dead loads, live loads, wind loads, and seismic forces, are considered to assess the stability and performance of the water tower under different loading scenarios. The effects of settlement, uplift, and lateral movements on the foundation system are also investigated

Based on the analysis results, a design methodology is developed to determine the foundation components' dimensions, reinforcement requirement, and construction specifications. Attention is given to ensuring the structural integrity of the foundation system, considering factors such as soil-bearing capacity, settlement limitations, and structural performance.

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CHAPTER ONE

(INTRODUCTION)

1.1 INTRODUCTION

The foundation of the building is the lower part of it, which is the base on which the building rests on the ground. It is the first part of the concrete structure to be poured on-site directly above the foundation soil. and transfers the structural loads to the supporting soil or rock. In order to put any facility on the ground in a safe manner, we must choose the appropriate type of foundation so as to give it stability and continuity for the longest possible period in the case of normal use or even in conditions of earthquakes, which preserves the lives of its residents.

The foundations are usually embedded in the ground at a depth suitable for construction, and the foundation is chosen according to the type of building, the design method, and the bearing capacity of the soil.

The foundation soil must meet several conditions, durability, balance, stability, and stability.

This means that the function of the foundations is to redistribute the loads on the soil so that they do not collapse and cause a crack, and thus the building collapses.

However, we can judge that foundations are the most important elements of any structure, and without foundations the structure would not rise above the ground.

Foundation design includes several factors to choose the most appropriate type of foundation:

- Soil bearing capacity.
- The geological condition of the soil.
- Depth of foundation for adjacent buildings.
- The load of the structure to be designed.
- Other factors related to the expected stability of the site's soil.

1.2 THE IMPORTANCE OF FOUNDATIONS

Foundations are the most critical part of any structure, as they serve as the base on which the building stands. The foundation of a building is responsible for transferring the load of the structure to the ground and distributing it evenly. A solid foundation ensures that the building is stable, safe, and durable. A poorly constructed foundation can lead to structural damage, collapse, or even endanger lives.

The foundation is the first step in any construction project and must be built correctly to ensure the building's stability and longevity. Properly constructed foundations are essential for the following reasons:

1. Structural Integrity: A solid foundation is critical to the structural integrity of a building. A poorly constructed foundation can cause the building to shift or settle, resulting in structural damage, cracks, or collapse.

2. Safety: A solid foundation ensures that the building is safe for occupants. A weak foundation can result in an unstable structure that can pose a danger to those inside.

3. Longevity: A properly constructed foundation can extend the life of a building. A weak or damaged foundation can cause the building to deteriorate rapidly and require costly repairs.

4. Cost-effectiveness: Building a strong foundation can be more cost-effective in the long run. Investing in a solid foundation can prevent costly repairs and maintenance in the future.

In conclusion, the importance of foundations cannot be overstated in any construction project. A strong foundation is critical to the structural integrity, safety, longevity, and cost-effectiveness of a building. It is essential to invest in a solid foundation to ensure that the building is stable, safe, and durable.

1.3 LOCATION

The location of this project (water tower) is located in Palestine, west bank - Jenin City.

Jenin is located at latitude 32.28 north and longitude 35.18 east Greenwich. It also has coordinates 208 latitudes and 178 longitudes, according to the Palestinian coordinates grid.

Jenin City is located in the northern part of the west bank (far north), It's about 75 km north of the Palestinian capital, Jerusalem.

The water tower is located in the new industrial city of Jenin, and this area is located to the north of the city and is about 4 km away from the city center to the northwest.

Jenin on the map of Palestine

the new industrial city of Jenin

1.4 THE PROJECT

The project is focusing on the design of a water tank including its foundation. The tank project consists of a ground, and an elevated tank (water tower) located in the new industrial city of Jenin. The purpose of the water tower is to provide a reliable and continuous supply of water to the surrounding area. The water tower will have a capacity of 700 cubic meters and the bottom tank have 6000 cubic meters, the tank will be constructed using reinforced concrete. The design of the water tower will take into consideration the local environmental conditions and the specific needs of the surrounding community.

1.5 THE SCOPE

The scope of this project involves designing various foundation alternatives, including isolated footing, combined footing, mat foundation, and pile foundation, and selecting the most suitable foundation for the site. The project will require an assessment of the site's geological conditions, soil bearing capacity, and load requirements to determine the optimal foundation type. Ultimately, the aim is to ensure that the chosen foundation provides the necessary stability and safety for the water tower structure.

CHAPTER TWO

(REVIEW OF SOIL AND FOUNDATION SYSTEM)

2.1 DEFINE OF THE SOIL

soil, the biologically active, porous medium that has developed in the uppermost layer of Earth’s crust. Soil is one of the principal substrata of life on Earth. It is the brittle or crumbly surface layer that covers the Earth's surface.

Soil can be expressed as the (crust or layer) that will be relied upon to bear the loads of buildings and facilities, and which receive loads from the foundations.

The soil and its nature are studied before building on it for several factors:

- Achieving a safe design for the building.
- Choosing the appropriate design and structural system.
- To avoid future defects in the building.

2.2 IMPORTANCE OF SOIL

Among properties of soils highly important in engineering are permeability, strength, compaction characteristics, drainage, shrink-swell potential, grain size, plasticity, and reaction.

Also important are depth to the water table, depth to bedrock, and soil slopes. These properties, in various degrees and combinations, affect construction, structures and foundations.

Soil is one of the three major natural resources, alongside air and water. Soils are complex mixtures of minerals, water, air, organic matter, and countless organisms that are the decaying remains of once-living things. It serves as a natural medium for the plant growth. Soil plays a major role in determining the depth of the foundation required to keep a building safe. Soil sometimes contains water which causes troubles in construction of foundation. Soil testing is extremely important to environmentally sensitive applications in agricultural and constructional fields. In the construction industry, buried cables and pipelines pose as possible threats.

When construction companies are building underground systems, they must pay close attention to the moisture density and thermal conductive properties of the surrounding soil. If a low soil thermal conductivity is noted, cables and pipelines may experience overheating and may potentially combust.

In addition to the importance of soil, its study has a clear impact on making several decisions before construction:

- Select potential residential, industrial, commercial, and recreational areas.
- Evaluate alternate routes for roads, highways, pipelines, and underground cables.
- Plan farm drainage systems, irrigation systems, ponds, and other structures for controlling water and conserving soil.
- Correlate performance of structures already built with properties of the kinds of soil on which they are built, for the purpose of predicting performance of structures on the same or similar kinds of soil in other locations.
- Predict the trafficability of soils for cross-country movement of vehicles and construction equipment.
- Develop preliminary estimates pertinent to construction in a particular area.

2.3 TYPES OF SOIL

Sandy Soils

Sandy soils are free draining, with the largest, but fine and hard particles.

It has a gritty feel. It does not bind very well. It is poor in holding water and easily warms up in the spring season. Sandy soils are very low in nutrients, as they are usually washed away. Its degree of aeration depends on the sizes of the particles, which vary a lot in size, it is usually formed from the weathering or disintegration of bedrock such as shale, limestone, granite and quartz.

Silty soil

This kind is finer, smoother in texture and hold water better than sandy soils. It also holds up nutrients and makes it better for crop cultivation.

Silty soils are heavier than sandy soils, and almost midway between the properties of sandy and clay soils.

It is formed when fine sediments (dust, organic matter and debris) are carried by water or ice and deposited. When silt is deposited and cemented with time, it forms siltstone. Silt particles are so small and not easily seen by the eyes. It leaves a bit of residue after you touch them.

Clay

The particles that make up clay are the finest and they bind very well. It has very little air spaces. Clay very sticky when wet, and can be molded into any shape and form. When they dry, they are rock hard. Clay soils do not drain very well. Clay is believed to form in places where rock is in contact with water, air or steam Example, sediments on sea or lake bottoms may become clay soils with time.

Loamy

This soil is a mixture of sand, clay and silt particles and has the ability to retain water. It is high in calcium, aeration and ideal for most crops and vegetables. It is the soil all farmers dream of, as it is full of nutrients from decomposed organic material. It is soft and easy to cultivate.

Peaty

This soil is acidic and as a result, does not support decomposition very well. It is dark in color, rich in organic material, although contains less nutrients than loamy soils. It retains water very well.

Chalky

This soil is alkaline with a pH of about 7.5. It is not acidic and often stony with chalk or limestone bedrock. It is free draining because of its coarse and stony nature. Not the best for crops to grow in as they lack manganese and iron.

2.4 DEFINISION OF THE FOUNDATION

The foundation is the bottom part of any structure, its main function is to provide a large enough area for a force to spread its load to form-distributed load, which the ground can resist .

A foundation (also called a ground soil) is a structure that transfers loads to the earth Its size depends on the bearing capacity of the soil and the forces applied on it, the forces applied on the foundation are permanent forces as weight of structure, foundation's own weight, furniture and equipment, and variable forces as people, wind and earthquakes, those forces are delivered to the foundation at first then to the soil, thus by knowing those forces we should decide the appropriate type of foundation which is suitable for the site nature and which also deals with problems in this site , and we should design the foundation for those forces in order to achieve resistance , stability and safety of the structure .

The structure makes many effects on the soil depending on the soil nature and the total loads affect the soil, thus we have different types of foundations with different uses.

2.5 PURPOSES OF FOUNDATION

- To support the structure.
- To transmit the superimposed load through side friction and end bearing in case of deep foundations.
- To distribute the total load coming on the structure on longer area so as to bring down the intensity of load at its base below the safe bearing capacity of the subsoil.
- To prepare a leveled and hard surface for concreting and masonry work.

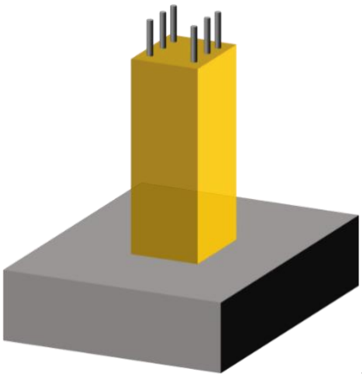
2.6 TYPES OF THE FOUNDATION

Generally, foundation systems are divided into shallow and deep foundations. Shallow foundations are almost always cast against the earth. The site is excavated to relatively shallow depths, underneath the ground elevation. They are easier to construct, cheaper, and, therefore, usually a more popular design option for smaller structures.

- **<u>Shallow Foundations:</u>**

1. Isolated Footings

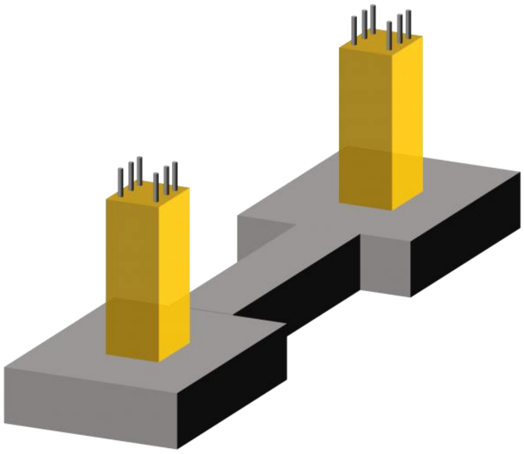
Isolated footings are a type of foundation system used for individual columns or pillars that support the structure. They are the most common type of foundation system used for small buildings, such as houses and low-rise buildings. Isolated footings consist of a reinforced concrete pad that spreads the load of the column over a wider area of the soil. This type of foundation system is cost-effective and easy to construct, but it has a limited load-bearing capacity.



2. Strap Footings

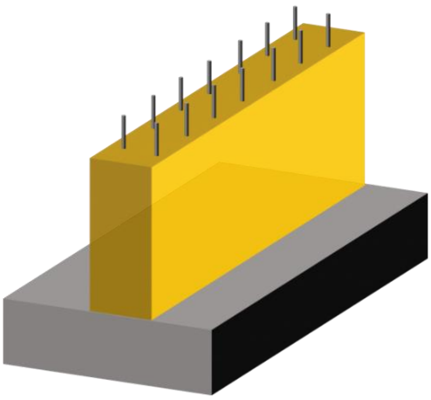
Strap footings, also known as cantilever footings, are two isolated footings connected with a strap beam.

Strap beams commonly connect two footings that support columns resisting significant lateral forces. The central strap beam will help reduce the effects of the lateral load without placing additional gravity pressure onto the soil, which would occur if a combined footing were used.



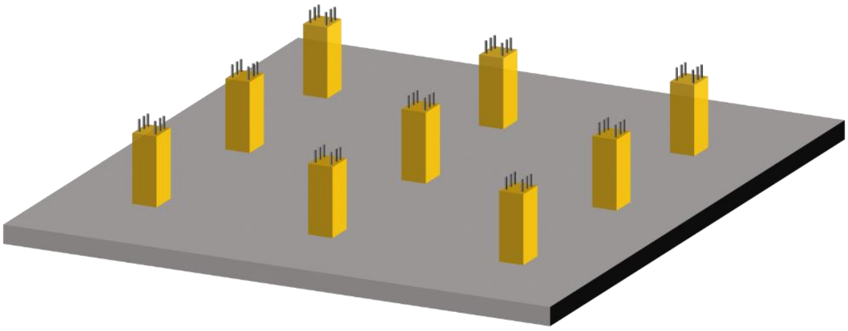
3. Wall Footings

Wall footings are used for load-bearing walls of a structure. They are designed to distribute the load of the wall over a wider area of the soil. Wall footings are deeper than isolated footings and are used for medium to high-rise buildings. They are cost-effective and easy to construct, but they may require more excavation work than other types of foundation systems.



4. Mat Foundations

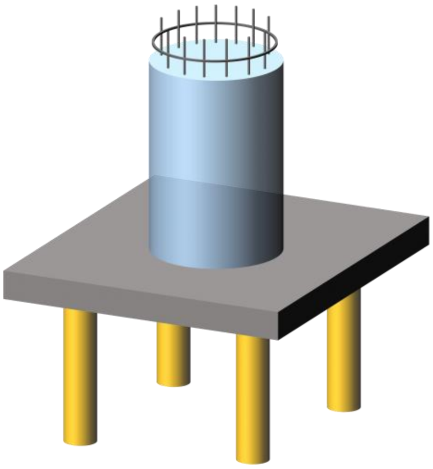
Mat foundations, also known as raft foundations, are used for large and heavy buildings with uneven soil conditions. A mat foundation is a reinforced concrete slab that covers the entire footprint of the building. It distributes the load of the building over a larger area of the soil, reducing the risk of differential settlement. Mat foundations are suitable for high-rise buildings, industrial structures, and areas with poor soil conditions.



- ## Deep Foundations:

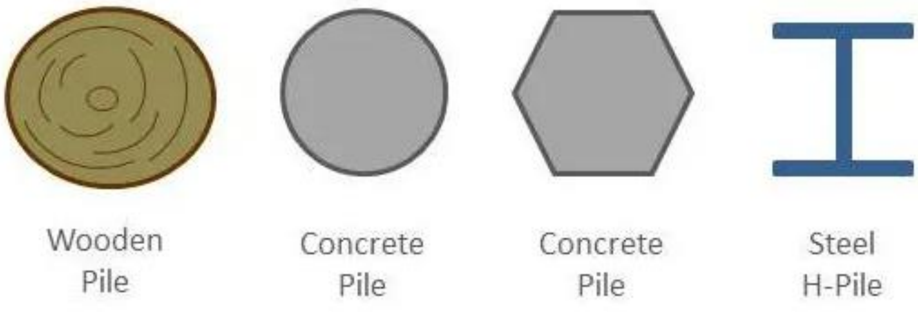
1. Pile Foundation.

Pile foundations are a type of deep foundation system used in construction projects when the soil conditions at the site are too weak or unstable to support the weight of the building. Pile foundations consist of long, slender columns, called piles, that are driven deep into the soil to reach a stronger layer or stratum of soil or rock that can support the load of the building.



- **Materials of Pile Foundation**

Pile foundations can be made of different materials, including steel, concrete, and wood, depending on the specific requirements of the project. The piles can be driven into the soil using a variety of techniques, including driven piles, bored piles, and auger-cast piles.



- **Advantage & Disadvantage:**

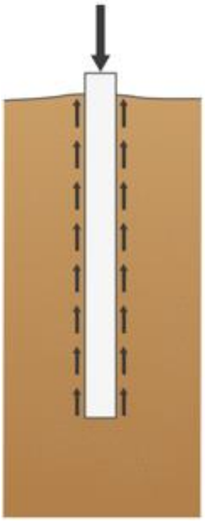
One of the main advantages of pile foundations is their ability to transfer heavy loads from the structure to a more stable layer of soil or rock. This reduces the risk of differential settlement, which can lead to structural damage, and ensures the stability and safety of the building. Pile foundations are commonly used in high-rise buildings, bridges, and structures built on soft or unstable soil.

Pile foundations also have some disadvantages. They can be expensive to install and may require specialized equipment and expertise. The installation of piles can also cause noise and vibration that can be disruptive to nearby buildings and structures. The environmental impact of pile foundations should also be considered, as the installation of piles can disturb the soil and affect local ecosystems.

- **Types of Pile Foundations Based on Construction Method.**

1. End-bearing piles, also known as point-bearing piles, are designed to transfer the load of the structure to a stronger, load-bearing layer of soil or rock located deep beneath the weaker soil. These piles are driven into the ground until they reach the strong, load-bearing layer. The pile is then embedded in the strong layer and the load of the structure is transferred to it.

2. Friction piles, also known as floating piles or cohesion piles, are designed to transfer the load of the structure through the frictional resistance between the surface of the pile and the surrounding soil.



- **How Pile Foundation Are Constructed?**

Pile foundations are constructed using several methods, depending on the type of pile, soil conditions, and load requirements of the structure. Here are some common methods of pile foundation construction:

1. **Driven piles:** This method involves using a pile driver to drive the pile into the ground until it reaches a suitable load-bearing layer of soil or rock. Driven piles are typically made of steel or concrete and can be used for end-bearing or friction piles.

2. **Bored piles**: This method involves drilling a hole in the ground using a drilling rig, and then inserting the pile into the hole. The hole is typically filled with concrete or grout to secure the pile in place. Bored piles can be used for end-bearing or friction piles.

3. **Auger-cast piles**: This method involves using an auger to drill a hole in the ground while simultaneously injecting concrete or grout into the hole to form the pile. Auger-cast piles are typically used for friction piles.

4. **Screw piles:** This method involves using a machine to drive a helical pile into the ground. The pile has a helix-shaped plate at the bottom that provides resistance to the soil, and the pile is screwed into the ground until it reaches a suitable load-bearing layer. Screw piles are typically used for smaller structures or in areas with difficult access.

After the piles are installed, they are typically tested to ensure that they can withstand the load of the structure. The most common method of pile testing is the static load test, where a known load is applied to the pile and the deformation of the pile is measured. If the pile passes the load test, it is considered suitable for supporting the structure.

In summary, pile foundations are a critical component of many construction projects, especially in areas with weak or unstable soil conditions. They provide stability and support to the structure and ensure the safety and durability of the building. However, their installation can be complex and expensive, and their environmental impact should be carefully considered.

CHAPTER THREE
(SITE INVESTIGATION REPORT)

Site Investigation Report

(Proposed Water Tank Structure)

Block No. 2   Parcels No. 25 - Burqin

Jenin – the new industrial area

Requested by:

Mr. Monther Diab

Supervised by:

First Option Engineering Office

Hijjawi Laboratories

March 2023

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1. Introduction

This report is to provide the geotechnical parameters to design the foundation of the proposed Water Tower Structure for Mr. Monther Diab, located at Jenin, Block No.2 and Parcel No.25. The proposed water tank structure will have a plan area of 961 square meters and will have a volume of 6000 m^3 for bottom tank and 700 m^3 for elevated tank.

This report was prepared upon a request by Mr. Monther Diab and supervised by First Option Engineering Office.

2. Purpose

The purpose of this investigation is to determine the following:

- Description of the subsurface soil strata of the site.
- Proposed type and depth of foundations most suitable and practical to be constructed at the proposed site.
- Bearing capacity for the proposed foundation.
- Parameters required for designing retaining walls.
- Geotechnical parameters for seismic design.

3. Procedure

The procedure that was carried out to determine the above purpose was as follows:

- Two boreholes were dug out in the site using soil mechanics boring machine. One borehole was dug to a depth of 12 m, while the rest one borehole was dug out to depth of 8 m. These boreholes gave the opportunity for determining the description of subsurface strata, eye exams, and taking the needed samples for lab tests. Location of boreholes is shown in Figure 1.
- Correlations were used to determine the geotechnical conditions and parameters.

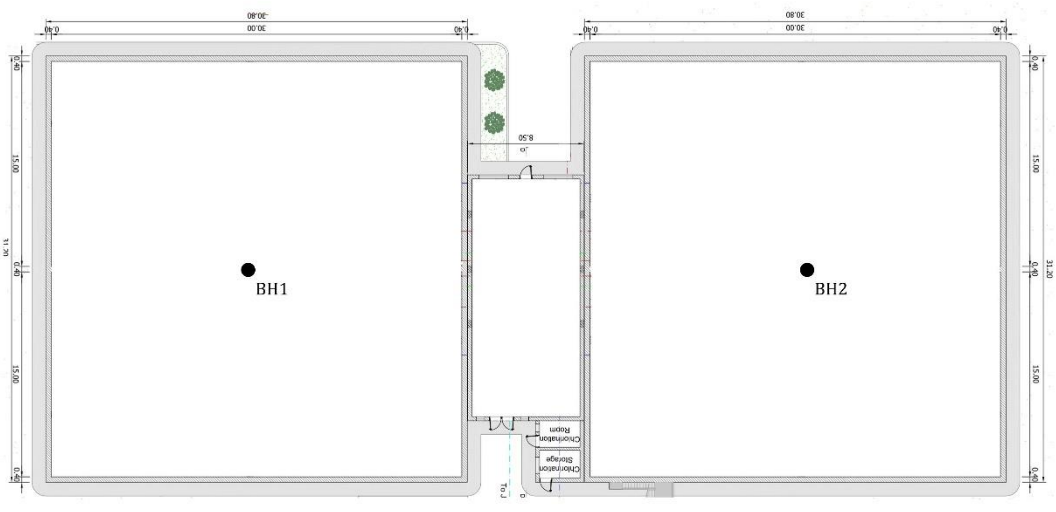

Figure 1 Boreholes' Locations.

4. Geological Condition of Our Region and Climate of the Site (Jenin) :

In order to understand the geological condition of the site, it is recommended to look at the stratigraphy of the whole area. This part of the Middle East which includes Palestine and Jordan reveals similar geological development since most of this land was covered by sea water long time ago. Rock formations from Precambrian, Paleozoic, Mesozoic, and Cenozoic ages are available in different parts of the area. In fact, Cretaceous formations (especially those of the Upper Cretaceous), which are the newest and the latest of the three Mesozoic divisions, are the most common in Palestine including the investigated site. The Upper Cretaceous formation is divided into six different units, the latest of them is the Chalk-Marl unit.

The soils that cover the bedrock are formed by the weathering of various rocks. The most general types of weathering are mechanical and chemical weathering. The soil that is produced by the weathering process of rocks can be transported by physical processes to other places. These soils deposits are called transported soils. In contrast, soils stay in the place of their formation and cover the rock surface from which they derive, are referred to as residual soils.

The Site climate is a Mediterranean climate of a dry summer and mild rainy winter with occasional snowfall. The recorded average of Jenin's rainfall is about 600 mm.

5. Site Description

The soil at the site from a geotechnical point of view consists of Brownish silty clay of high plasticity mixed with pebbles and stones of varying sizes. This type of soil has high swelling potential.

Care should be done to take care of the swelling of this soil. It is necessary to add at least 40 cm of compacted base course to reduce the effect of swelling of soil.

This type of soil may slide when having cuts greater than 2 m. Safety precautions should be taken in this case.

Ground water table was not encountered during the time of investigation (March 2023).

6. Soil Parameters

The following table summarizes the Soil parameters:

BH No.	Sample No.	Depth m	Natural Moisture Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Cohesion kN/m^2	Angle of Internal Friction (φ°)
1	1	0.0 – 2.0	12					
	2	2.0 – 4.0	15	41	18	23	40	8
	3	4.0 – 6.0	20					
	4	6.0 – 8.0	11					
	5	8.0 – 10.0	9					
	6	10.0 – 12.0	9					
2	1	0.0 – 2.0	7	44	22	22	38	10
	2	2.0 – 4.0	12					
	3	4.0 – 6.0	18					
	4	6.0 – 8.0	10					

7. Geotechnical Conditions

According to site description and laboratory test results the following geotechnical conditions prevail :

7.1 Top Soil and Swelling Potential

This type of soil has high swelling potential. Precaution should be taken to overcome problems expected from this expansive soil, such as inserting at least 40 cm of compacted base course. This type of soil may slide when having excavation greater than 2 m. In this case safety precautions should be taken.

7.2 Type of Foundations

Shallow Foundation (strip or mat) is recommended to be used for this site. The site should be improved by at least 60 cm compacted rockfill and 40 cm of compacted base course and in this case the allowable bearing capacity = 200 kN/m^2 (2.0 kg/cm^2) and the foundation depth should be at least 1 m below the existing ground surface.

The value bearing capacity is based on the bearing capacity of the silty clay soil according to the following parameters:

- Cohesion (c) = 39 kN/m^2
- Angle of Internal Friction (φ) = 9°
- Unit Weight = 18 kN/m^3
- Size of Foundation (assumed) 2 x 2 m.
- Depth of Foundation = 1.0 m

Terzaghi Bearing Capacity Equation gives q_{all} = 172 kN/m^2

Vesic Bearing Capacity Equations gives q_{all} = 180 kN/m^2

The recommended allowable bearing capacity q_{all} = 180 kN/m^2

Consider the soil improvement by 40 cm of compacted base course, the allowable bearing capacity becomes = 200 kN/m^2.

Calculation sheet for bearing capacity is shown in the Appendix.

An alternative foundation is Pile Foundation. The capacity of single pile will be given upon request.

7.3 Retaining Walls

The lateral earth pressure behind the retaining wall depends on the type of backfill to be used. For typical backfill soil the coefficient of the lateral earth pressure at rest (K_o) is equal to **0.5.**

Good drainage systems behind the retaining walls with weep holes and perforated drainage pipes have to be provided, so that pore water pressure behind the retaining walls will not develop.

The backfill materials must be adequately selected.

7.4 Seismicity of the Site

Seismic Coefficients According to UBC

Equivalent Linear Static Seismic Lateral Force (ESF)

Seismic Zone Factor (**Z**) (Peak Horizontal Ground Acceleration in study site as a percentage of gravity)	**0.2**
Seismic Source Type	**A**
Seismic Importance Factor	**1.0**
Soil Profile Type	**S_D**
Seismic Coefficient Ca	**0.28**

Seismic Coefficient Cv	**0.4**
Near Source Factor Nv	**1.0**
Near Source Factor Na	**1.0**

Seismic Coefficients According to IBC

Model Response Spectrum (MRS)

Peak Horizontal Ground Acceleration in study site as a percentage of gravity	**0.2**
Soil Profile Type (**Site Class**)	**D**
Mapped Maximum Considered Earthquake MCE spectral response accelerations for short period (0.2 sec.) S_S	**0.53**
Mapped Maximum Considered Earthquake MCE spectral response accelerations for long period (1.0 sec.) S_L	**0.12**
Site Class Coefficient (**Fa**)	**1.37**
Site Class Coefficient (**Fv**)	**2.3**
Design Short Period Acceleration S_{DS}	**0.72**
Design Long Period Acceleration S_{DL}	**0.28**

8. Recommendations

From the above-mentioned geotechnical conditions and parameters, we do recommend the following:

1. Shallow Foundation is recommended for this site after improving the soil by at least 40 cm of compacted base course. In this case the allowable bearing capacity is 200 kN/m^2 (2.0 kg/cm^2). Foundation depth should be at least 1 m from the existing ground surface.
2. An alternative foundation is Pile Foundation. Capacity of piles will be given upon request.
3. Water table was no encountered during drilling of boreholes.
4. A drainage system should be designed and the structure should be isolated properly from surface and internal water.

5. Type I cement (normal Portland cement) may be used in the construction at this site. Common practice of insulation of the underground structures is adequate.
6. No chemical problems are expected neither form the soils nor from the water exiting at this site.
7. If during construction other geotechnical conditions appear, please contact us for remedial measures.

ملخص لأهم نقاط التوصيات:

1- التربة في الموقع تتكون من تربة طينية مخلوطة بحصى ذات معامل لدونة عالي لعمق لنهاية الحفر.

2- هذه التربة لها قابلية عالية للانتفاخ. يجب اتخاذ الاجراءات الاحتياطية للحد من مساوئ التربة المنتفخة. وهنا يجب وضع على الاقل 60 سم دبش مدموك و40 سم من البيسكورس المدموك تحت جميع العناصر الارضية.

3- الاساسات المقترحة هي اساسات سطحية ومقدار تحمل التربة بعد تحسينها كما ذكر اعلاه هو 200 كيلونيوتن/متر مربع (2.0 كغم/سم^2). وعمق التأسيس يجب ان يكون على الاقل 1 متر تحت سطح الارض الحالي.

4- يمكن استخدام اساسات عميقة (piles) في هذا الموقع.

5- التربة الطينية السطحية لها قابلية عالية للانتفاخ. يجب اتخاذ اجراءات وقائية للحد من المشاكل المتوقعة للانتفاخ التربة.

6- في حالة وجود جرفية عميقة فيجب اتخاذ اجراءات السلامة العامة لان هذه التربة لها قابلية عالية للانزلاق. مرفق بعض اجراءات السلامة العامة.

7- يجب مراجعة التقرير كاملا لمعرفة التوصيات والحلول الهندسية الأخرى.

More details in (Appendices A,B,C, and D) in appendix.

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  استطلاع الموقع
- Terzaghi, K., and Peck, R.B. (1967). Soil mechanics in Engineering Practice, Wiley, New York.
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- WinterKorn, H., and Fang H.-Y. (1975). Foundation Engineering Handbook. Van Nostrand, New York.

CHAPTER FOUR

(DESIGN PHILOSOPHY)

4.1 DEFINITION OF CONSTRUCTION TERMINOLOGY FOR THE PROPOSAL WATER TANK TOWER

About the tank, (We are going to focus on the elevated reservoir in this part).

The tank consists of two parts, an upper part through which water is distributed and pumped from the tower, and a lower part of a large size to meet the large stock of water.

<u>Plan</u>

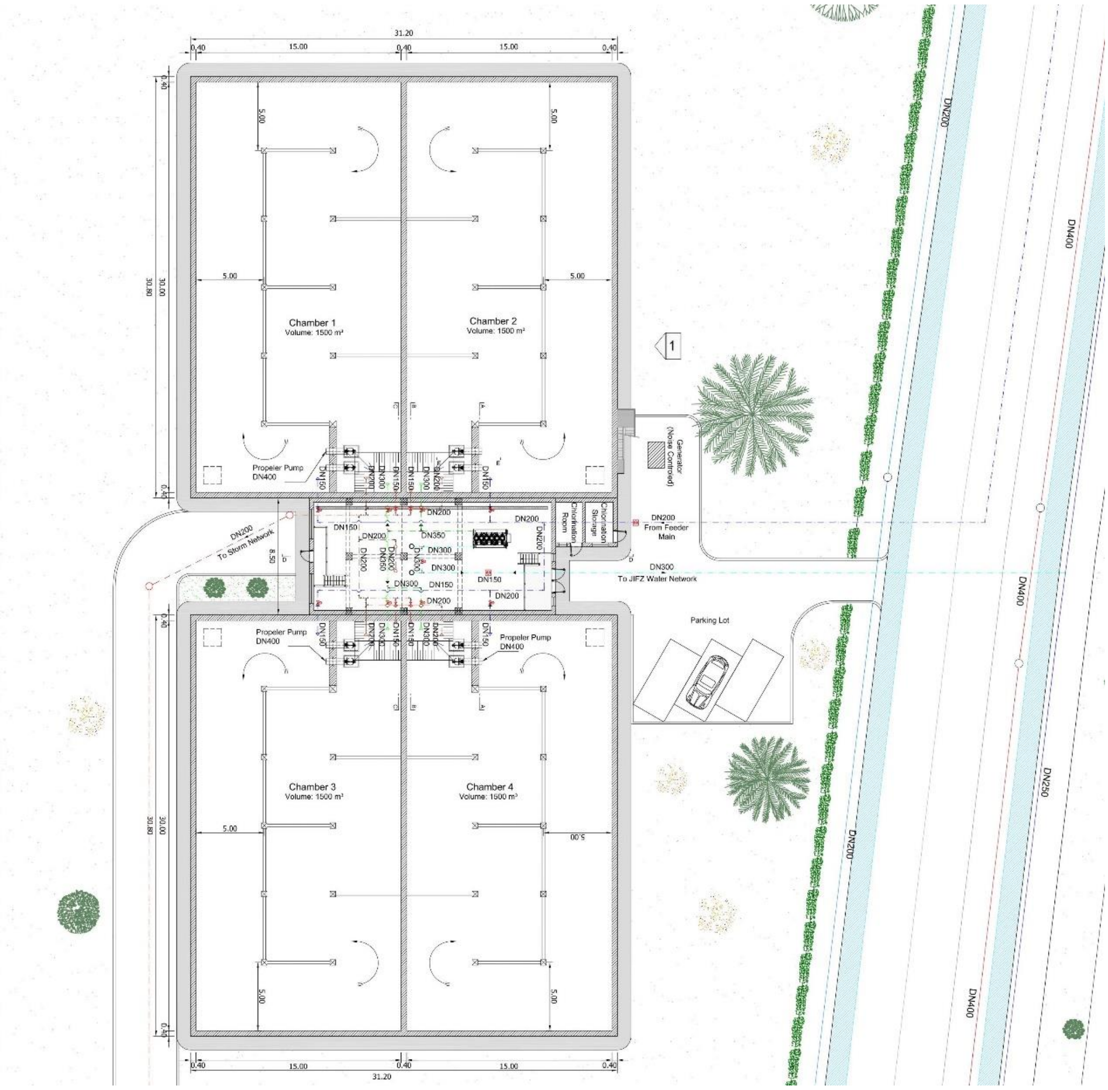


Figure 4.1: Top Plan Project

Dimensions and specifications:

The ETABS program was used for the structural analysis of the water tank, and from it the loads that can be carried by one column and the loads per unit area were obtained.

The required data and structural details of the design were entered as follows:

- Area of all tank base = 2050 m^2
- Area of tower base = 127.5 m^2
- Area of Ground tank base = 1922.5 m^2
- Base elevation: +88.00 AMSL
- Number of columns on tower = 9 Columns
- Ground tank depth = 3.9 m
- Elevated tank (tower) depth = 4.9 m
- Elevated tank dimension: 12.5 m × 12.5 m
- Tank level from ground to the highest point = 29.9 m

More details in (figures 4.1, 4.2) in appendix.

Codes and standards:

Structures are designed by using different practice codes and specifications that control the design processes and variables, and qualify design variables at different loading conditions. The following codes and standards are used:

- ACI 318-19 (American Concrete Institute): building code requirements of structural concrete and commentary.
- IBC - 2015 (International Building Code).
- ASCE 7-16 (American Society of Civil Engineers).

This part of the project will include the analysis and design of the foundations of the upper reservoir, and the analysis and design of the lower reservoir will be completed in the second project.

All loads on the 9 footings were taken into account during the design, including wind, earthquakes, water loads and the reservoir loads.

Loads:

- Gravity loads, including dead, live, and super imposed dead loads.
- Lateral loads, which include seismic loads and wind load

- **Dead load:** structure own weight.
- **Superimposed dead load:** These loads are mainly created by the non-structural elements of the building, such as tiles, stones, partitions, filling materials and plastering and soon.
- **Live Load:** Live load is what is produced during the use of the structure.
- **Seismic loads:** application of an earthquake-generated agitation to a structure.

Material:

They are generally the materials that used to erect the structural of the building.

A - Concrete: It is the binding material that has an ability to resist the compression forces effectively. Also, it provides a very good protection to other structural material such as steel. The concrete compressive strength (f`c) is measured after 28 days of pouring and curing the samples and this strength will differ according to the importance of the structural element.

the modulus of elasticity for concrete (E) can be determined as follows: $E=4700\sqrt{fc}$.

B - Steel: steel is used to give the concrete the strength in tension side, which will make the structure more flexible in addition to reducing the growing cracks in the structural elements.

Materials from ETABS:

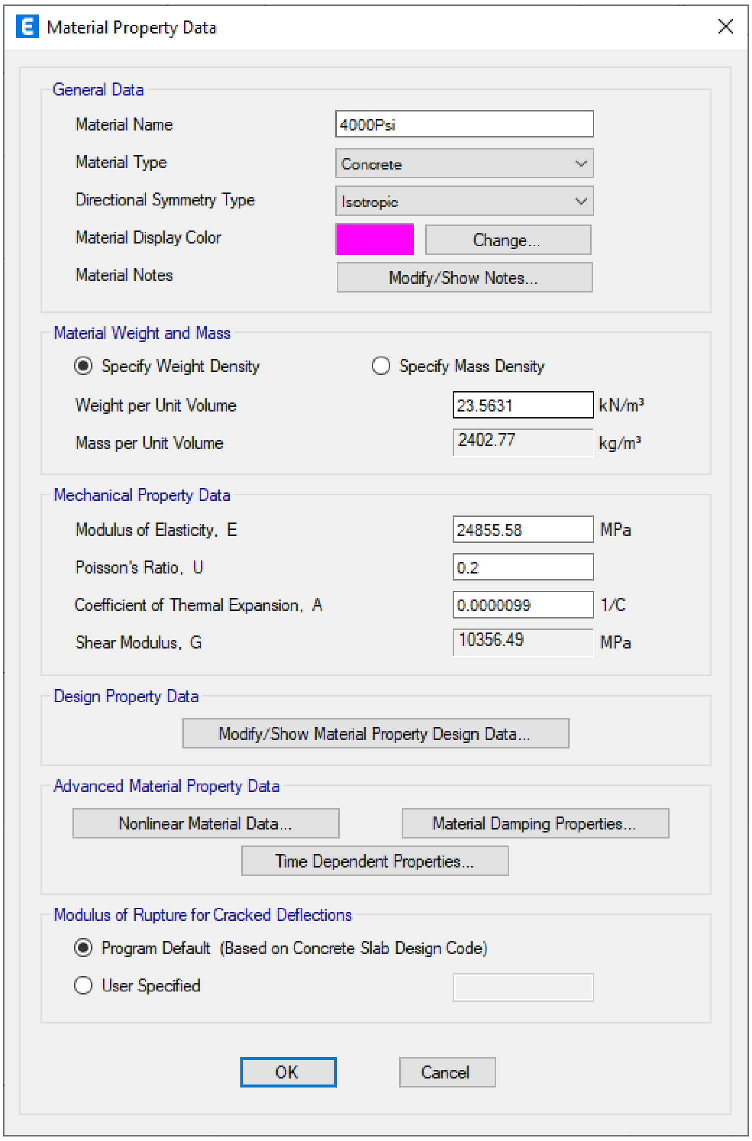


Figure 4.1: Concrete properties

Sections from ETABS:

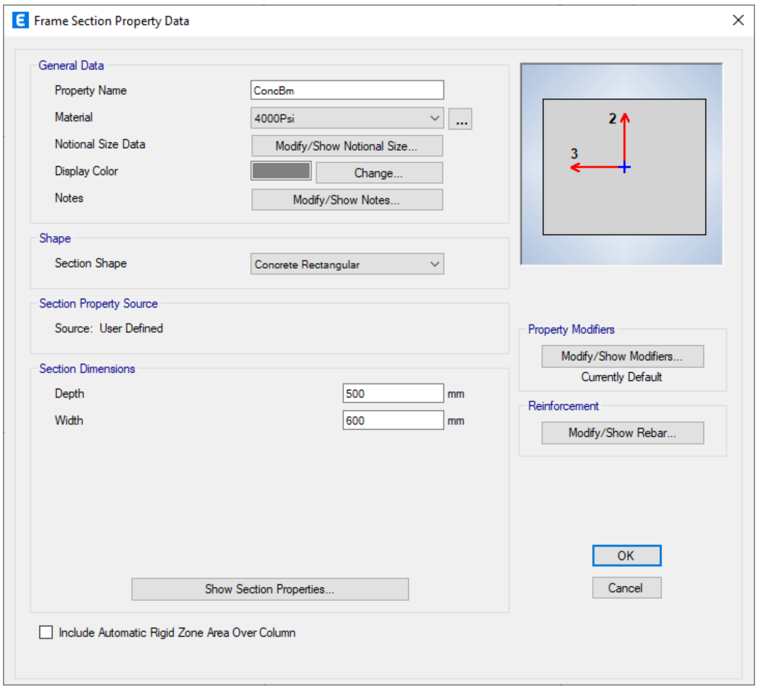


Figure 4.2: Beam Section

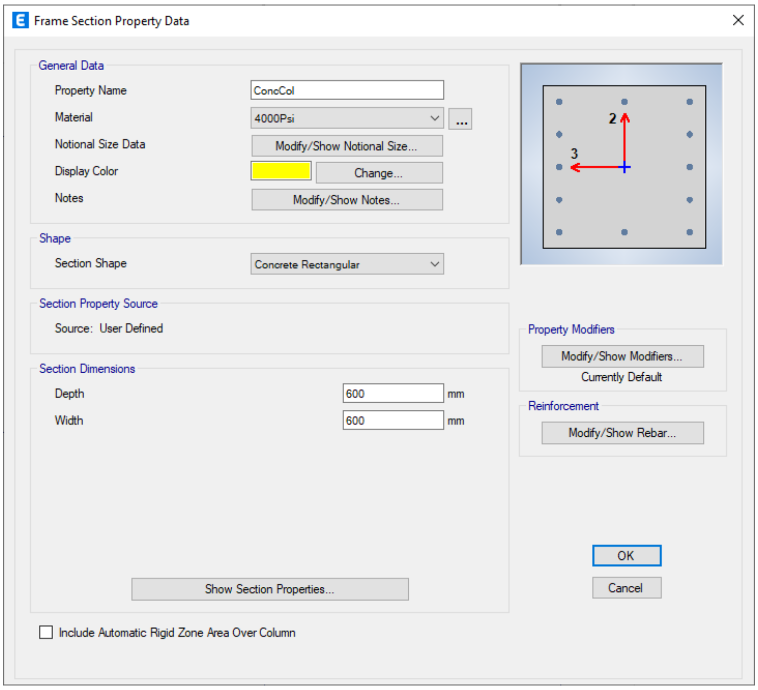


Figure 4.3: Column Section

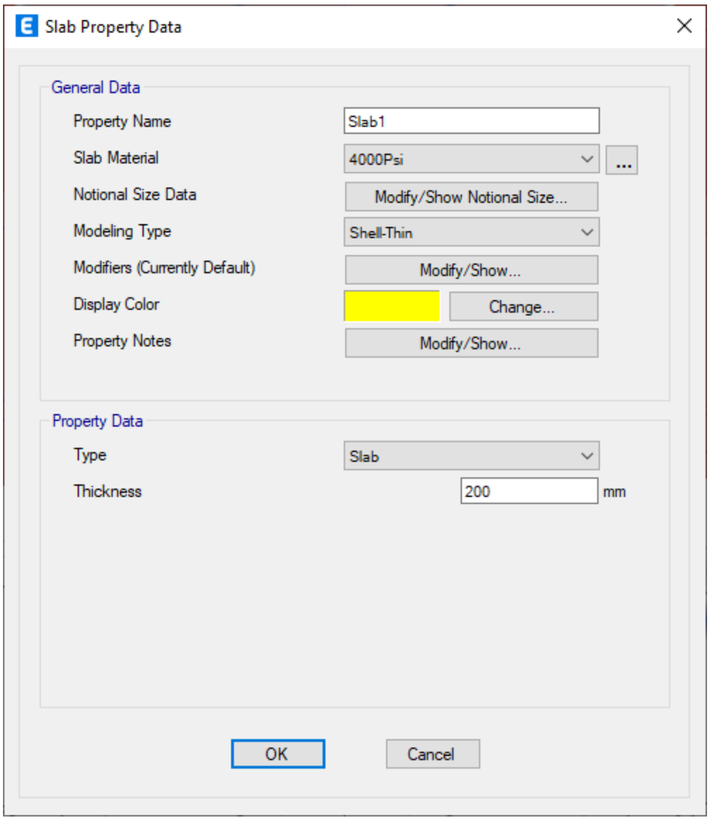


Figure 4.4: Slab Section

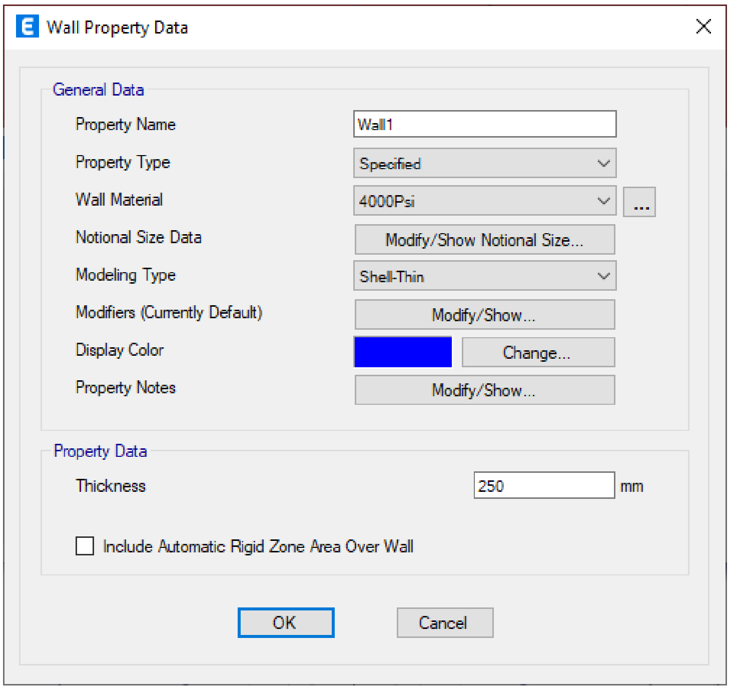


Figure 4.5: Wall Section

4.2 LOADS ON COLUMNS AND ANALYSIS

For elevated reservoir (Water tower):

Dead and Live Load:

Columns	Dead Load	Live Load	Envelope
C10	944.66	642.35	4109.94
C20	1011.10	707.39	4053.24
C30	944.35	642.22	4109.88
C40	1011.07	707.38	4053.26
C50	944.69	642.36	4110.16
C60	1011.08	707.39	4053.25
C70	944.33	642.22	4109.90
C80	1011.12	707.40	4053.24
C90	1088.67	851.29	1362.07

Moments Envelope:

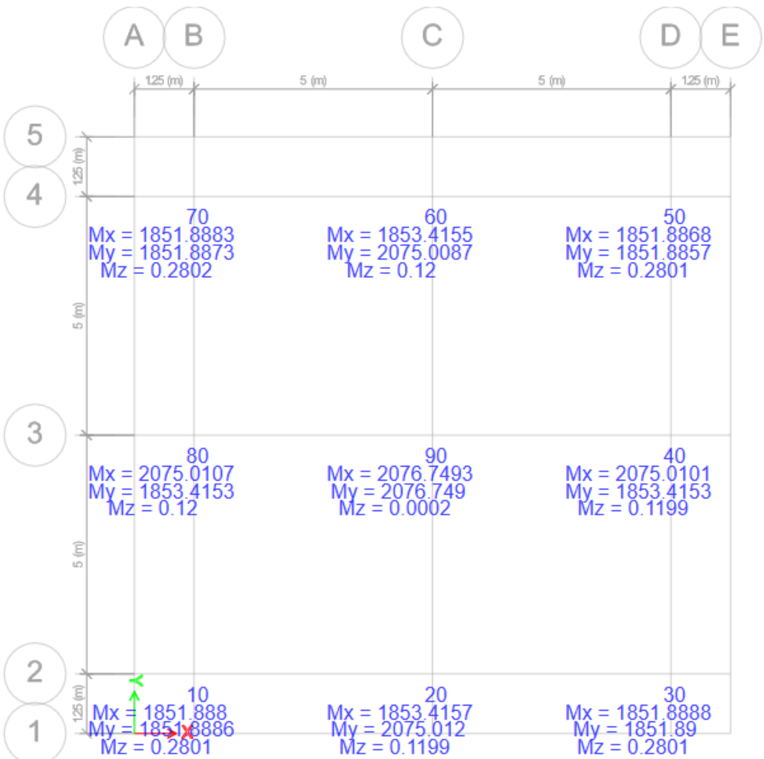


Figure 4.6: Moments Envelope

Loads Envelope:

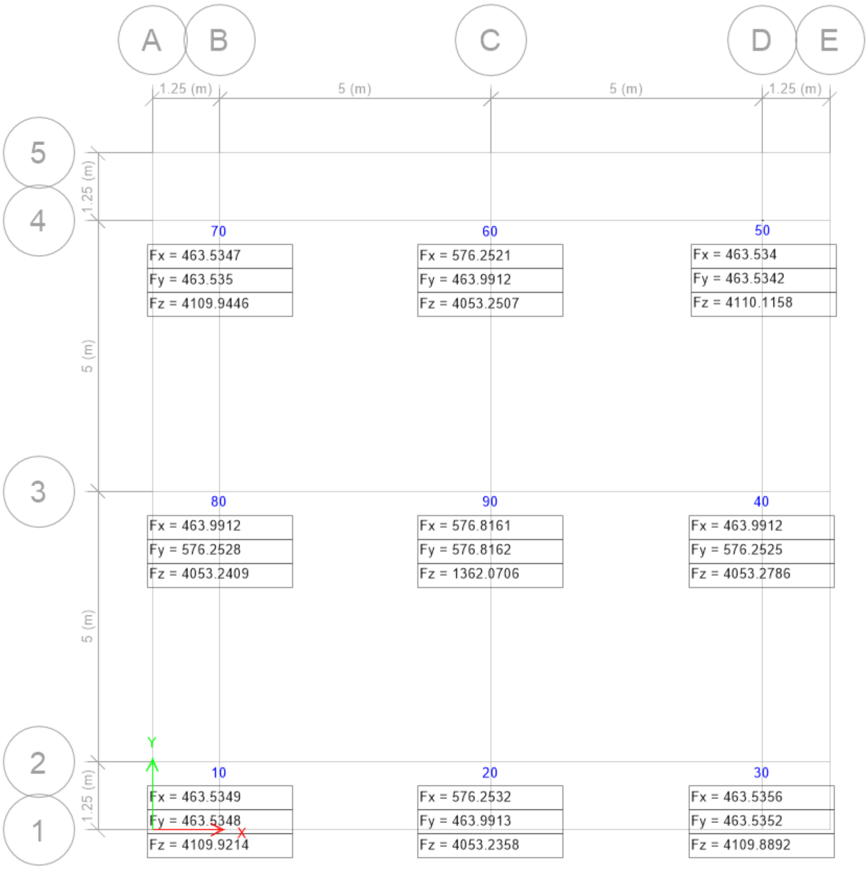


Figure 4.7: Loads Envelope

4.3 FOUNDATION DESIGN

4.3.1 ISOLATED FOOTINGS:

For C50: $Area = \frac{Load}{q_{allowable}} = \frac{4110.12}{200} = 20.55m^2$

$\sqrt{20.55} = 4.6 ..$ choose $\mathrm{B = 5m, L = 5m.}$

Dimension of footing = $5 \times 5\ m$

After a thorough evaluation, it has been determined that the use of isolated single-footing foundation is not suitable for this project due to the 5-meter distance between the columns. This distance would result in an overlap between the footings, creating the risk of differential settlement and potential structural damage. As a result, Mat foundations will be explored as an alternative foundation type for the project.

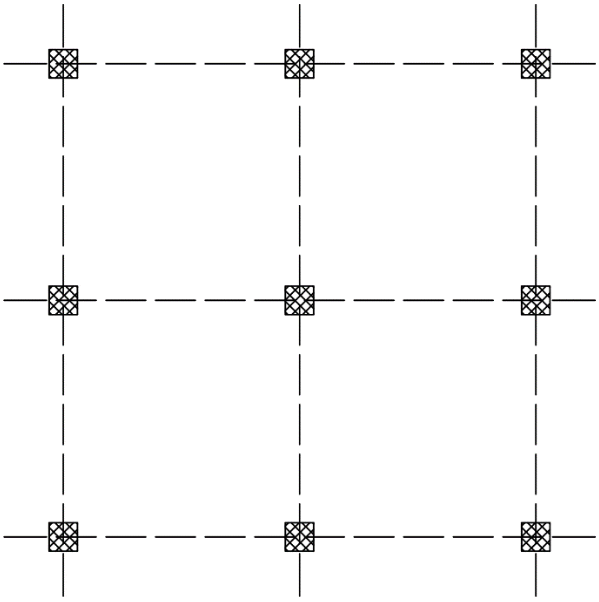


Figure 4.7: Columns Grid

4.3.2 MAT FOUNDATIONS:

Mat foundations, which encompass the entire building footprint, avoid the risk of footing overlap and differential settlement by distributing the structural loads over a wider area. By tying the footings of all columns together into a single unified mat, the foundation system behaves as a coherent whole. This enhanced stability and load distribution make mat foundations well-suited for structures with large spans between columns.

For this project, the use of a mat foundation significantly reduces risks related to footing overlap and settlement issues. It provides a robust foundation solution to support the structural loads of the 5-meter column grid in a safe and economical manner. Mat foundations will undergo further analysis to optimize the design based on the soil conditions and intended building loads.

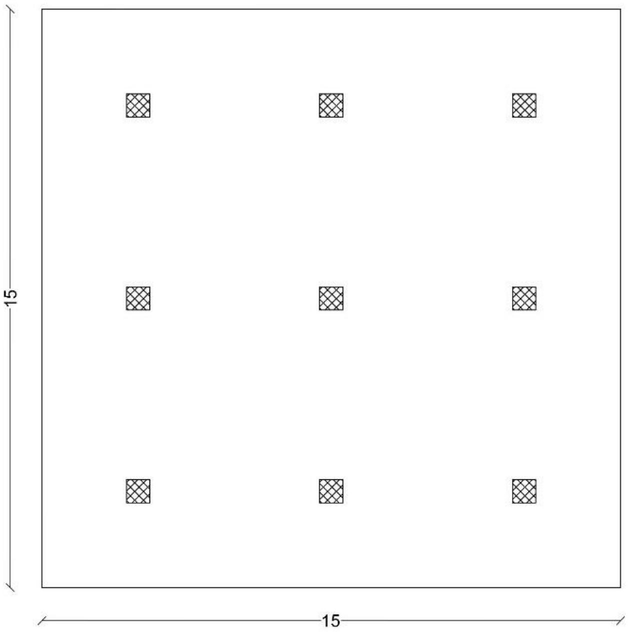


Figure 4.8: Mat Plan Cap Distribution

4.3.3 Piles Foundation:

To provide additional safety, stability and lateral resistance for this structure, pile foundations with 800mm diameter and 12-meter length will be used under each of the 9 columns in conjunction with the proposed mat foundation.

Pile foundations extend into competent soil strata below the mat, anchoring the structure and reducing risks related to shallow soil failure or lateral forces. The piles also help distribute the considerable column loads through weaker near-surface soils into stronger soils at depth, thereby lowering contact pressures on the mat and underlying soils.

By combining mat and pile foundations, this hybrid foundation system harnesses the benefits of both approaches. The mat ties the piles together, reducing differential settlement and providing a uniform bearing surface for the building. The 800mm bored piles in turn enhance the stability and load-carrying capacity of the mat by extending 12 meters deep to competent supporting strata. This interaction results in a robust, cost-effective foundation that satisfies requirements related to bearing capacity, settlement, and lateral load resistance.

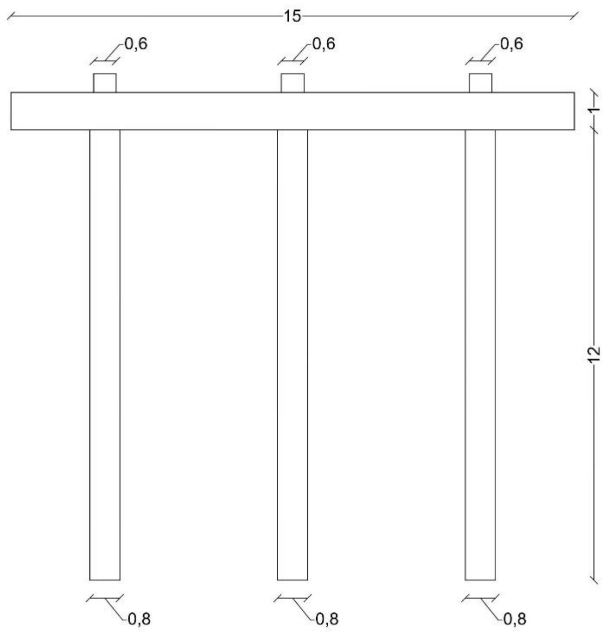


Figure 4.9: Section of Mat foundation with Piles

4.4 CONCLUSION:

Soil-brownish silty clay mixed with stones soil, do soil improvement 60 cm rock and 40 cm base coarse.

We use shallow mat foundation (D=1m) after soil improvement

with piles L=12m, D= 800mm at every Columns footing for increase safety, more stability and resistance lateral moments.

بعض الاجراءات الاحتياطية المقترحة للامان في الموقع

يجب اتخاذ الاجراءات الاحتياطية للامان بالموقع وذلك بسبب وجود حفريات بالموقع وكذلك نوعية التربة، حيث هنالك احتمالات كبيرة لحدوث انهيارات في الموقع. تهدف هذه الاجراءات للحد قدر الامكان من احتمالية حدوث مشاكل في الموقع بسبب عملية الجرف ومن المفضل توفير مهندس امان Safety Engineer وخصوصا للمشاريع الكبيرة، وهي كما يلي:

1. يجب عمل مخطط جرف من قبل مهندس متخصص ومتابعة هذا المخطط وكذلك الاشراف المتخصص على تطبيق المخطط وعملية الجرف.
2. يجب اغلاق الموقع كاملا بجميع محيطة ووضع حواجز بواسطة الواح زينكو ووضع اشارات تحذيرية عليها وتكون عاكسة ليلا وواضحة نهارا.
3. يجب توقف العمل في الظروف المناخية الصعبة، مثل الامطار والثلوج والرياح وغيرها وذلك حتى استقرار الطقس والموقع من اثار هذه الظروف المناخية.
4. يجب ان لا يتم الجرف في فصل الشتاء والامطار خصوصا للمناطق التي فيها تربة غير صخرية او صخرها مفكك.
5. يجب الاسراع في بناء العناصر الانشائية الداعمة للقطع مثل الجدران والطوابق الارضية (basements) وأن يتم ذلك قبل الدخول في موسم الشتاء.
6. يجب عزل منطقة الجرف كليا عن مياه الامطار السطحية. يمكن وضع حاجز من الباطون بارتفاع مناسب لتغيير اتجاه سير المياه السطحية عن الجرفية.
7. يجب وضع اشارات تحذيرية بوجود عمليات جرف في المنطقة على الشارع الرئيسي.
8. يجب وضع نظام للامان للمنطقة والعمال بشكل عام وعمل بوليصة تأمين للمنطقة والجوار والعمال والمارة واتخاذ اجراءات الامان للعمال والزوار أو أي شخص يحتمل وجوده في الموقع أو بالقرب منه.
9. يجب ان يكون العمال مؤهلين فوق السن القانونية ومدربين على تفادي الاخطار في موقع البناء وخصوصا الانهيارات وتوفير مهرب امن لهم واعلامهم بخطورة عملهم. بالاضافة لتجهيزهم

كاملا بادوات وملابس السلامة العامة حسب الموصفات العالمية. يجب التأكد من سلامة الادوات المستخدمة مثل السلالم والسقايل وغيرها ومطابقتها للمواصفات العالمية.

10. يجب توفير انارة كافية في الموقع كله في حالة العمل في ساعات الليل او بعد مغيب الشمس أو في الاماكن التي لا تصلها انارة كافية.

11. التأكد من عدم وجود خطوط مياه أو مجاري في الموقع نفسه أو في الشوارع حوله الملاصقة للموقع. في حالة وجود مثل هذه الخطوط فيجب العمل على نقلها.

12. التأكد من عدم وجود خطوط كهرباء أو تلفون في الموقع أو حوله والقيام بنقل أعمدة التلفون والكهرباء بالقرب من الموقع.

13. عمل بوالص تأمين على العمال والمارة والموقع والمنشآت بالقرب من الموقع من منازل أو شوارع أو غيرها وكذلك التأمين ضد احتمالية حدوث انهيارات وانزلاقات في الموقع أو حوله.

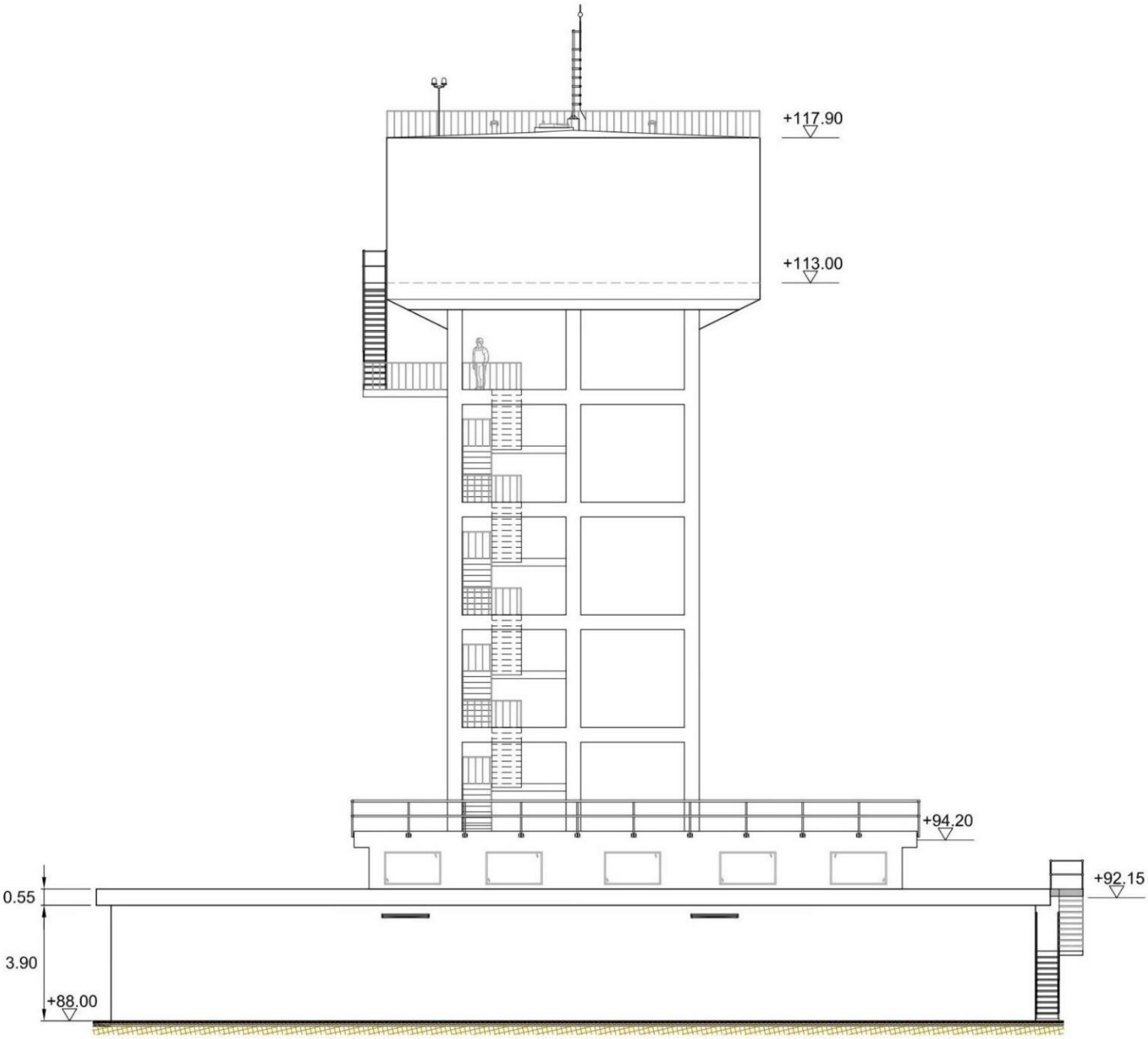
14. هنالك احتمال حدوث انهيار وانزلاقات في الموقع ومحيطه من عملية الجرف. يجب توقع ذلك ووضع خطة طوارئ لدعم الجرفية في حالة حدوث انهيار مثل استخدام مرابيع وغير ذلك.

ملاحظات هامة:

- **يجب اخبارنا بعمليات الجرف الموقع اولا باول، حيث من الضروري قيامنا بزيارة الموقع خلال وبعد كل عملية جرف وخاصة في حالة حدوث انزلاقات او مشاكل تتعلق بعملية الجرف والتربة، وذلك من ضمن متابعة تقرير التربة فقط وتقديم النصح والارشاد فقط اذا كان هنالك حاجة، وليس من باب الاشراف على عملية الجرف حيث ان عملية الاشراف بحاجة لمتابعة خاصة.**
- **في حالة وجود اسفسارات أو حدوث مشاكل تتعلق بعملية الجرف وانشاء الجدران حول الموقع، فيجب مراجعتنا باسرع وقت ممكن للتأكد من اتخاذ الخطوات المناسبة.**

APPENDIX

FIGURE 4.1



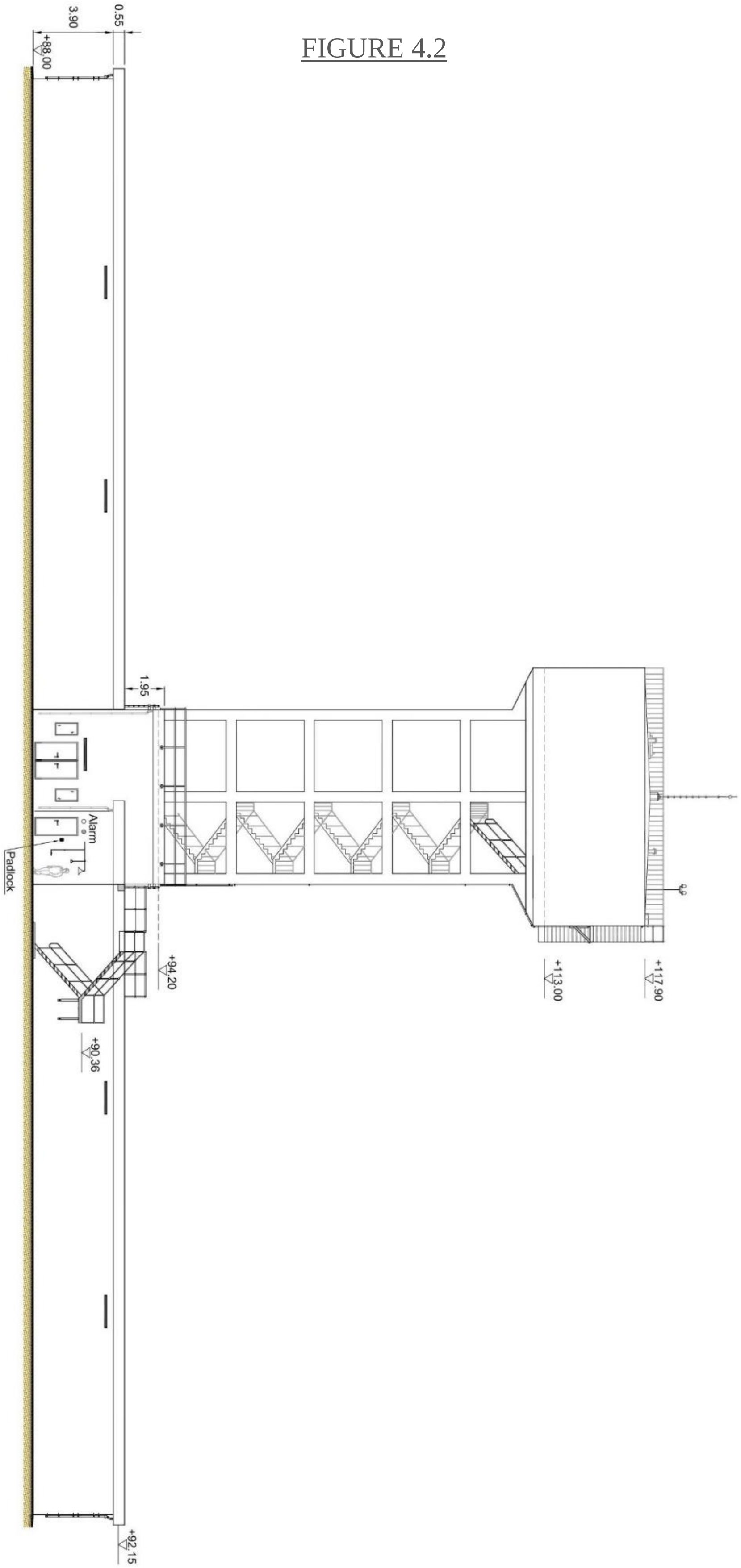


FIGURE 4.2

Appendix A

Borehole Logs

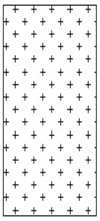
and

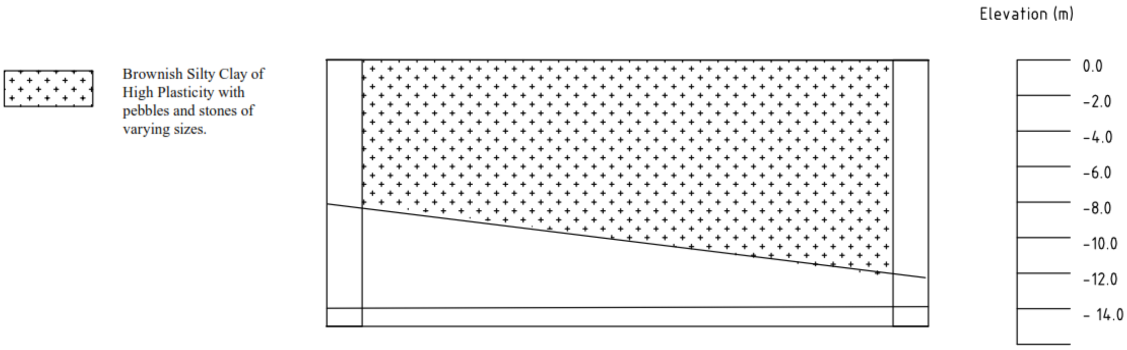
Geological Sections

Project: Proposed Water Tower Structure
Location: Jenin
Client: Mr. Monther Diab, Supervisor: First Option Engineering Office
Date: March 2023
Borehole No. 1
Surface Elevation: 0.0 m (existing ground surface)

No.	Depth m	Sample Type	Symbol	Description of strata	Moisture Content %	Plasticity Index	Strength Parameters
1	0.0 – 2.0	Disturbed		Brownish Silty clay of high plasticity mixed with pebbles and stones of varying sizes.	12	LL = 41 PL = 18 PI = 23	Unconfined compressive strength (c) = 40 kN/m². Angle of Internal Friction (φ) = 8°
2	2.0 – 4.0	Disturbed			15		
3	4.0 – 6.0	Disturbed			20		
4	6.0 – 8.0	Disturbed			11		
5	8.0 – 10.0	Disturbed			9		
6	10.0 – 12.0	Disturbed			9		

Project: Proposed Water Tank Structure
Location: Jenin
Client: Mr. Monther Diab, Supervisor: First Option Engineering Office
Date: March 2023
Borehole No. 2
Surface Elevation: 0.0 m (existing ground surface)

No.	Depth m	Sample Type	Symbol	Description of strata	Moisture Content %	Plasticity Index	Strength Parameters
1 2 3 4	0.0 – 2.0 2.0 – 4.0 4.0 – 6.0 6.0 – 8.0	Disturbed Disturbed Disturbed Disturbed		Brownish Silty clay of high plasticity mixed with pebbles and stones of varying sizes.	7 12 18 10	LL = 44 PL = 22 PI = 22	Unconfined compressive strength (c) = 38 kN/m^2. Angle of Internal Friction (φ) = 10°



Geological Section

Appendix B

Calculation of Allowable Bearing Capacity

BEARING CAPACITY OF SHALLOW FOUNDATIONS
Terzaghi and Vesic Methods

Date	September 22, 2021						
Identification	brownish silty clay mixed with stones wadi soil						
Input			**Results**				
Units of Measurement					Terzaghi		Vesic
	si	SI or E	Bearing Capacity				
				q ult =	517	kPa	540 kPa
Foundation Information				q a =	172	kPa	180 kPa
Shape	sq	SQ, CI, CO, or RE					
B =	2	m	Allowable Column Load				
L =		m		P =	690	kN	720 kN
D =	1	m					
Soil Information							
c =	39	kPa					
phi =	9	deg					
gamma =	18	kN/m^3					
Dw =	20	m					
Factor of Safety							
F =	3						

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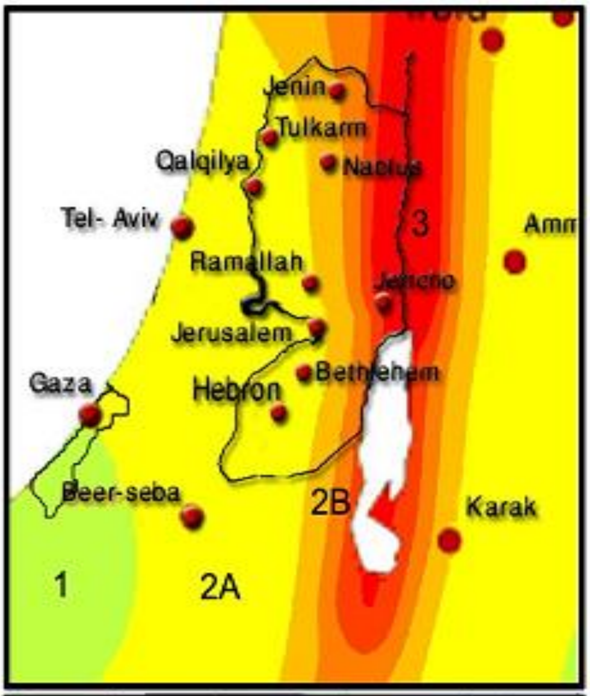
Unit conve	1
Gamma w	9.8
phi (radiar	0.15708
Terzaghi Computations	
a theta =	1.434398
Nc =	9.09
Nq =	2.44
N gamma	0.88
gamma' =	18
coefficient	1.3
coefficient	0.4
sigma zD'	18
Vesic Computation	
Nc =	7.92
sc =	1.28
dc =	1.20
Nq =	2.25
sq =	1.16
dq =	1.11
N gamma	1.03
s gamma =	0.60
d gamma =	1.00
B/L =	1
k =	0.5
W sub f	0

Appendix C

Seismic Zone Factors for Palestine (Z)

Seismic Zone Factor,Z



Zone	1	2A	2B	3
Z	0.075	0.15	0.20	0.3

Appendix D

Laboratory Tests Standards

Laboratory and/or field tests have been used to determine the physical and mechanical properties of the soils and rocks of the proposed site. The following standards have been used to perform the tests:

- ASTM D2216 – 10, Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.
- ASTM D4318 – 00, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
- ASTM D6913 / D6913M - 17 Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis.
- ASTM D7928 – 17, Standard Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis
- ASTM D2938-95(2002), Standard Test Method for Unconfined Compressive Strength of Intact Rock Core Specimens.
- ASTM D2435 / D2435M – 11, Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading.
- ASTM D854 – 14, Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
- ASTM D2166 / D2166M – 16, Standard Test Method for Unconfined Compressive Strength of Cohesive Soil
- B.S. 1377: Part 3: 1990, Test 5, ‘Determination of the sulphate content of soil and ground water’.
- B.S. 1377: Part 3: 1990, Test 7.3, ‘Determination of Acid-soluble chloride content’.

CHAPTER FIVE
(GROUND TANK)

5.1 Introduction

5.1.1 General Background

The foundation is the lower part of structures, which is the base on which the structure rests on the ground. It is the first part of the concrete structure to be poured on-site directly above the foundation soil. and transfers the structural loads to the supporting soil or rock. In order to put any facility on the ground in a safe manner, we must choose the appropriate type of foundation so as to give it stability and continuity for the longest possible period in the case of normal use or even in conditions of earthquakes, which preserves the lives of its residents.

The foundations are usually embedded in the ground at a depth suitable for construction, and the foundation is chosen according to the type of structure, the design method, and the bearing capacity of the soil.

The foundation soil must meet several conditions, durability, balance, stability, and stability.

<u>About MAT foundation:</u> (also called raft foundation), it is a single continuous slab that covers the entirety of the base of a structure. Mat foundations support all the loads of the structure and transmit them to the ground evenly. Soil conditions may prevent other footings from being used. Since this type of foundation distributes the load coming from the building uniformly over a considerably large area, it is favored when individual footings are unfeasible due to the low bearing capacity of the soil.

This chapter is focusing on the design of a foundation for ground water tank.

This tank consists of a ground tank and elevated tank (Which we discussed in the first project). Project is located in the new industrial city of Jenin. The purpose of the water Tank is to provide a reliable and continuous supply of water to the surrounding area. The Elevated tank will have a capacity of 700 cubic meters and the Ground tank have 6000 cubic meters, the tank will be constructed using reinforced concrete.

Total capacity in ground tank and elevated tank = 6700 cubic meters.

5.1.2 About Water Tanks

Tanks can be divided to :

- On-Ground Tanks.
- Underground Tanks.
- Elevated Tanks.

And can be of different shapes :

- Rectangular.
- Circular.
- Irregular.

Standard design water tanks : self-weight, soil pressure, water pressure.

The walls of liquid containing structures ' tanks , shall be designed for seismic dynamics forces in addition to the static pressures of water and soil :

- Inertia forces of walls, Pw and roof, Pr.
- Hydrodynamic impulsive force, Pi.
- Hydrodynamic invective force, Pc.
- Dynamic earth pressure.
- Effective of vertical acceleration.

5.1.3 Project Description

The project involves the design of a reinforced concrete Footings system for a Ground and Elevated Water Tanks , Ground tank is consist of two separate parts, the total net capacity of each part is 3000 cups (m^3), The two parts are similar, have the same details, and are located on the same soil strength, so we will design one part that represents both parts.

The design will be based on the results of our soil report, which we discussed in the first project, the results of which we will attach to this report.

The ground tank consists of two parts, Each part is a tank with an area of 31.20 m × 30.80 m and a capacity of 3000 cups. Each part is divided into two chambers and contains a ripple inhibitor. This system works to prevent water ripple and regulate water flow by reducing the tank area into small sections.

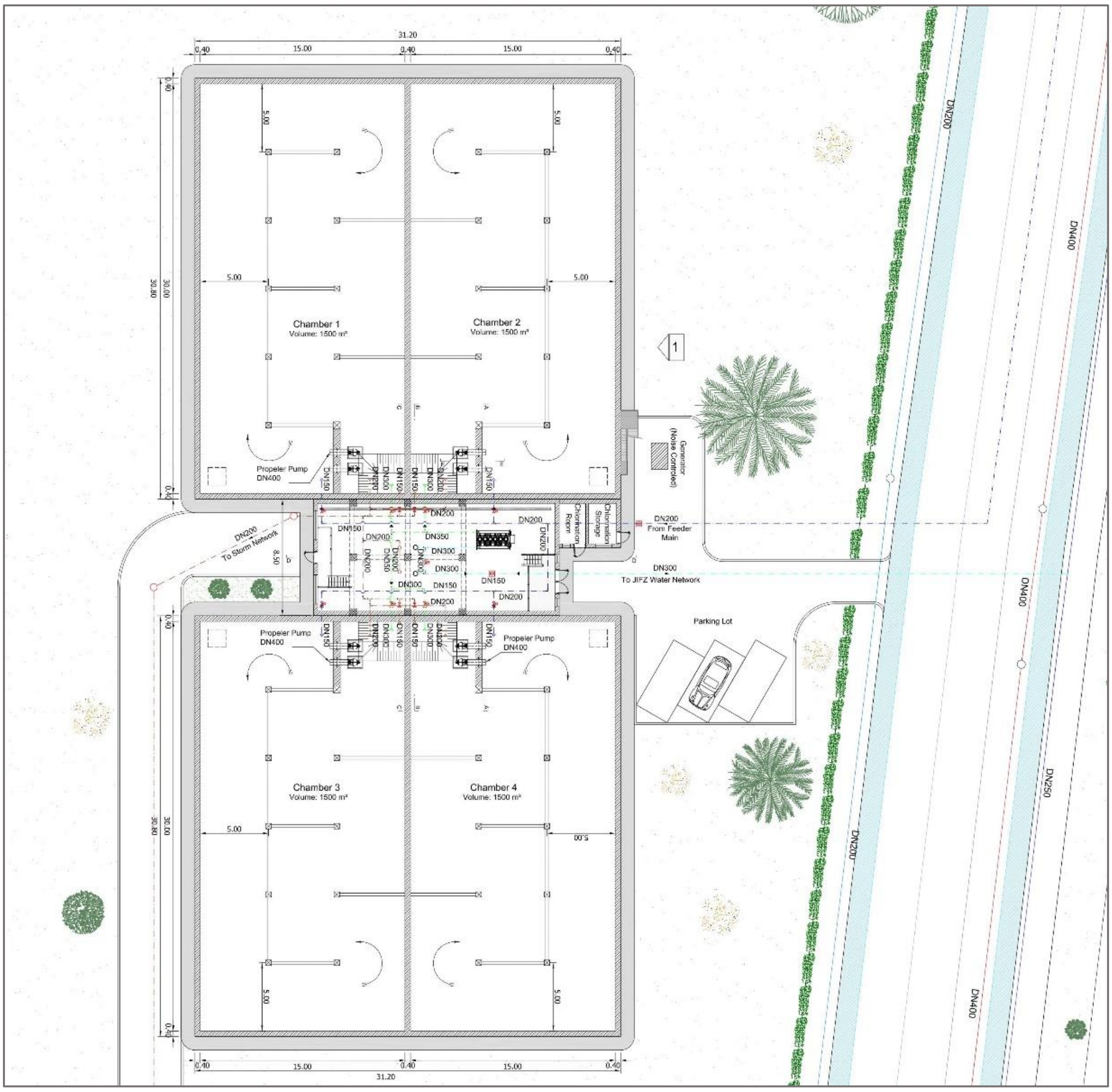


Figure 5.1: The Water Tank Plan.

We will use computer software (ETABS, and AUTOCAD) to Design the structure and verify the analysis and design results using hand calculations.

5.1.4 Codes And Standards

Many codes and engineering references related to the subject of footings and water tank design will be used.

and we will be design according to the system of designing tanks without cracks and according to the new code.

CODES :

- ACI 350-06
- ACI 318-14
- ACI 318-19
- ASCE (American Society of Civil Engineers)

Load Patterns :

D (dead load)

SD (super imposed dead load)

LL (live load)

W (water load)

Water left & Water right

EQx , EQy

Load Combinations :

1.1 (1.4D)

1.1 (1.2D + 1.6L)

Envelope

Service

1.4F (1.4W)

5.2 Modeling

5.2.1 Water Tank Layouts

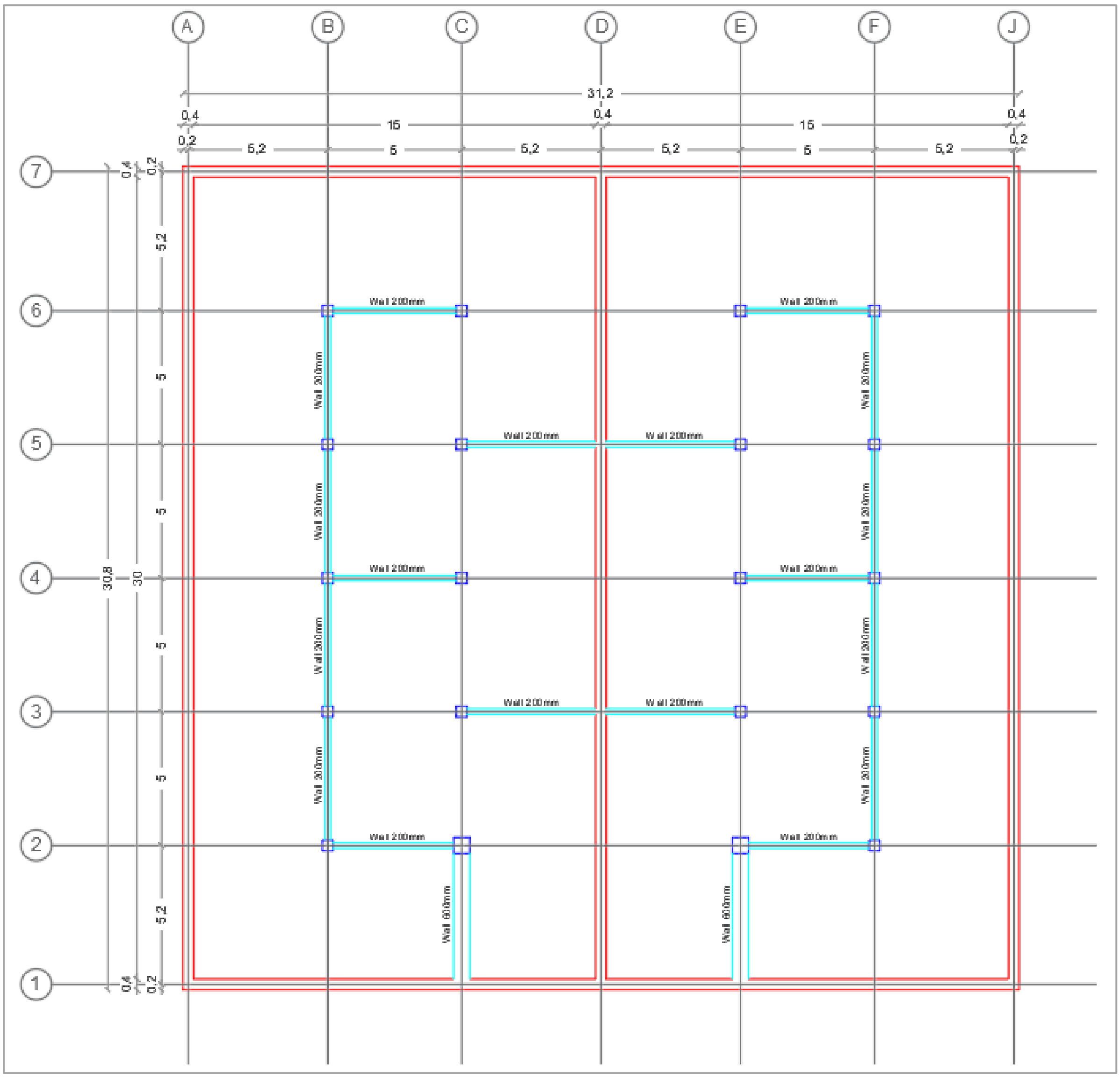


Figure 5.2: Water Tank Layout.

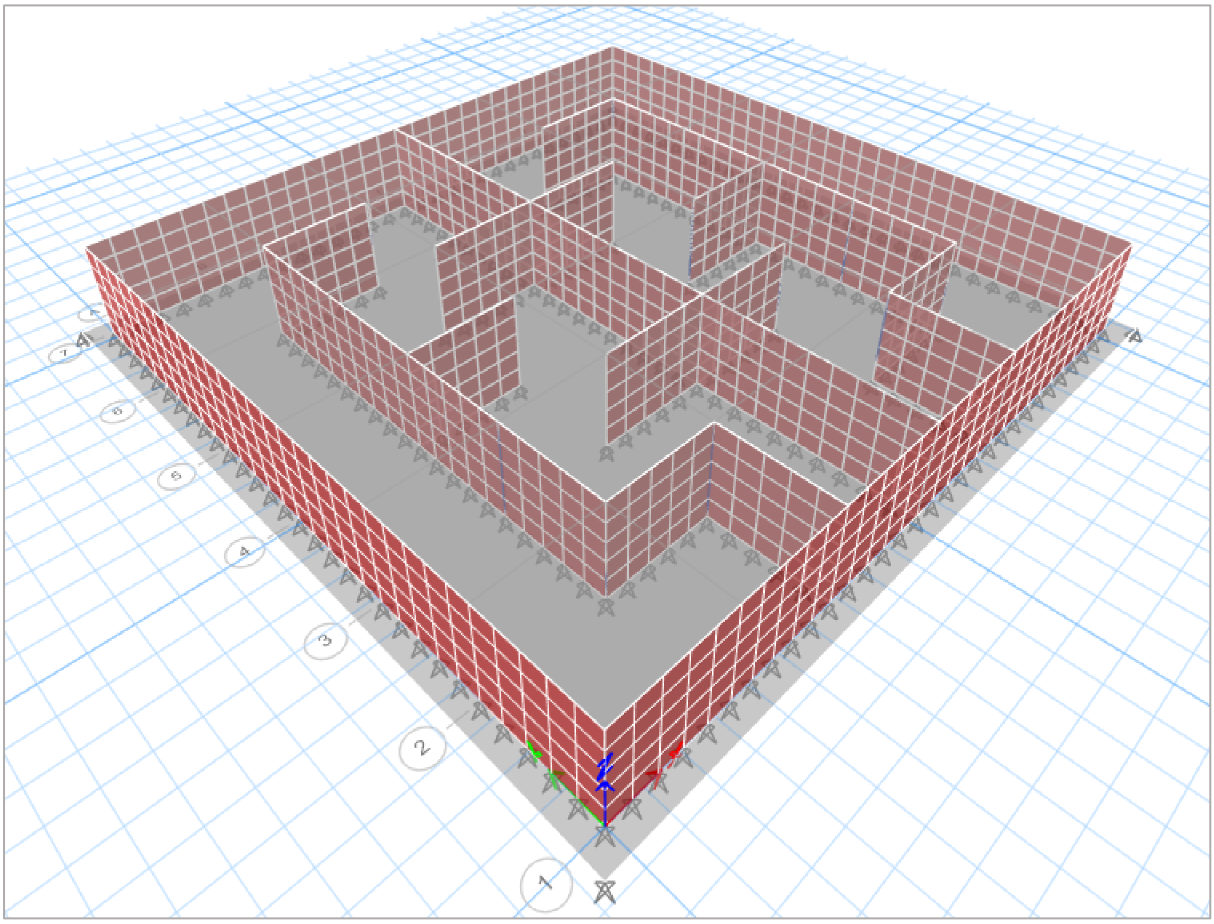


Figure 5.3: 3D Modeling from etabs.

5.2.2 Design Criteria

Design method for walls: Ultimate design method with serviceability check.

Design method for Base: Conventional rigid method.

- $f'c = 28\ MPa.$
- $fy = 420\ MPa.$
- $Tank\ With\ Roof.$
- $Tank\ type : Normal\ Exposure.$
- Base elevation : $+88.00\ AMSL.$
- q_{all} for soil = 200 KN/m^2.

<u>Roof:</u>

SD on roof = 3 KN/m^2.

LL on roof = 2 KN/m^2.

<u>Base:</u>

Water Load = 39 KN/m^2.

With load patterns test left and right.

With Mass source for seismic loads (water and dead).

5.2.3 Preliminary Dimensions

<u>Ground Tank</u>

- $Area\ of\ tank\ (one\ part) = (31.2 \times 30.80) = 960.96\ m^2.$
- $Capacity\ of\ Tank\ (one\ part) = 3000\ cups\ (m^3).$
- $Total\ Height = 4.45\ m.$
- $Depth\ of\ water = 3.9\ m.$

Walls

- $Outer\ Wall\ thickness = 400\ mm.$
- $Inner\ Wall\ thickness = 200\ mm.$
- $Height = 3.9 + 0.2 = 4.1m\ \rightarrow\ 4.1 + 0.35(Edges) = 4.45\ m.$

Roof

- $Roof\ \ thickness = 200\ mm.$

Columns

- $Columns\ used\ : C1, C2.$
- $No. of\ \ columns\ on\ Base = 20\ columns.$
- $C1 :\ 400mm \times 400mm.$
- $C2 : 600mm \times 600mm.$

- Base

The base of the tank is the same as the foundation**.**

5.3 Tank Base (MAT) foundation

A mat foundation, which sometimes referred to as a raft foundation, is a combined footing that may cover the whole area under a structure supporting several columns and walls.

In some conditions where spread footings may cover more than half the building area, mat foundations may prove to be more economical.

The structural design of mat foundation can be carried by two conventional methods: the conventional rigid method and the approximate flexible method.

Finite difference and finite element methods can be used, we use and analysis for conventional rigid method.

The MAT foundation is extended 1.0 m beyond the centers of walls and columns.

- $Base\ Dimension = (32.4 \times 32.8)m.$
- $Area\ of\ Base = 1062.72\ m^2.$
- $Thickness = 600mm.$

5.4 Bearing Capacity

Region : jenin city.

Soil Parameters :

The following table summarizes the Soil parameters:

BH No.	Sample No.	Depth m	Natural Moisture Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Cohesion kN/m^2	Angle of Internal Friction (φ°)
1	1	0.0 – 2.0	12					
	2	2.0 – 4.0	15	41	18	23	40	8
	3	4.0 – 6.0	20					
	4	6.0 – 8.0	11					
	5	8.0 – 10.0	9					
	6	10.0 – 12.0	9					
2	1	0.0 – 2.0	7	44	22	22	38	10
	2	2.0 – 4.0	12					
	3	4.0 – 6.0	18					
	4	6.0 – 8.0	10					

From Soil report, The value bearing capacity is based on the bearing capacity of the silty clay soil according to the following parameters :

- Cohesion (c) = 39 KN/m^2
- Angle of Internal Friction (φ) = 9°
- Unit Weight = 18 KN/m^3
- Depth of Foundation = 1.0 m

Terzaghi Bearing Capacity Equation gives q_{all} = 172 KN/m^2

Vesic Bearing Capacity Equations gives q_{all} = 180 KN/m^2

The recommended allowable bearing capacity q_{all} = 180 KN/m^2

Consider the soil improvement by 40 cm of compacted base course, the allowable bearing capacity becomes = 200 KN/m^2.

∴ q_{all} = 200 KN/m^2 = 200 KN/m/m^2.

Seismicity of the Site :

Seismic Coefficients According to UBC

Equivalent Linear Static Seismic Lateral Force (ESF)

Seismic Zone Factor (**Z**) (Peak Horizontal Ground Acceleration in study site as a percentage of gravity)	**0.2**
Seismic Source Type	**A**
Seismic Importance Factor	**1.0**
Soil Profile Type	**S_D**
Seismic Coefficient Ca	**0.28**
Seismic Coefficient Cv	**0.4**
Near Source Factor Nv	**1.0**
Near Source Factor Na	**1.0**

Seismic Coefficients According to IBC

Model Response Spectrum (MRS)

Peak Horizontal Ground Acceleration in study site as a percentage of gravity	**0.2**
Soil Profile Type (**Site Class**)	**D**
Mapped Maximum Considered Earthquake MCE spectral response accelerations for Short period (0.2 sec.) **S_S**	**0.53**
Mapped Maximum Considered Earthquake MCE spectral response accelerations for long period (1.0 sec.) **S_L**	**0.12**
Site Class Coefficient (**Fa**)	**1.37**
Site Class Coefficient (**Fv**)	**2.3**
Design Short Period Acceleration **S_{DS}**	**0.72**
Design Long Period Acceleration **S_{DL}**	**0.28**

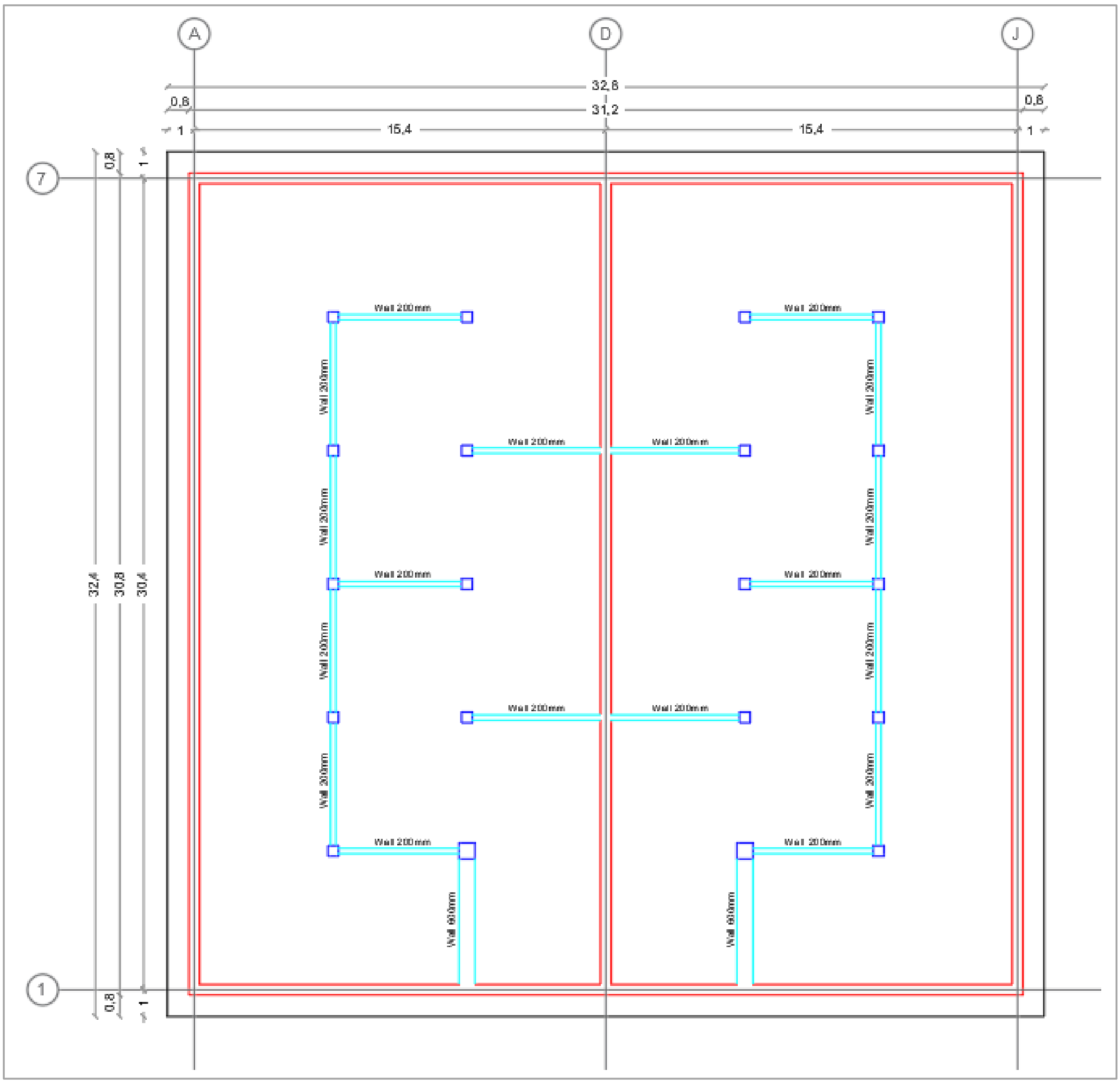


Figure 5.4: Tank Base.

5.5 Analysis And Design

5.5.1 Tank Base (MAT)

Allowable bearing capacity = 200 KN/m^2.

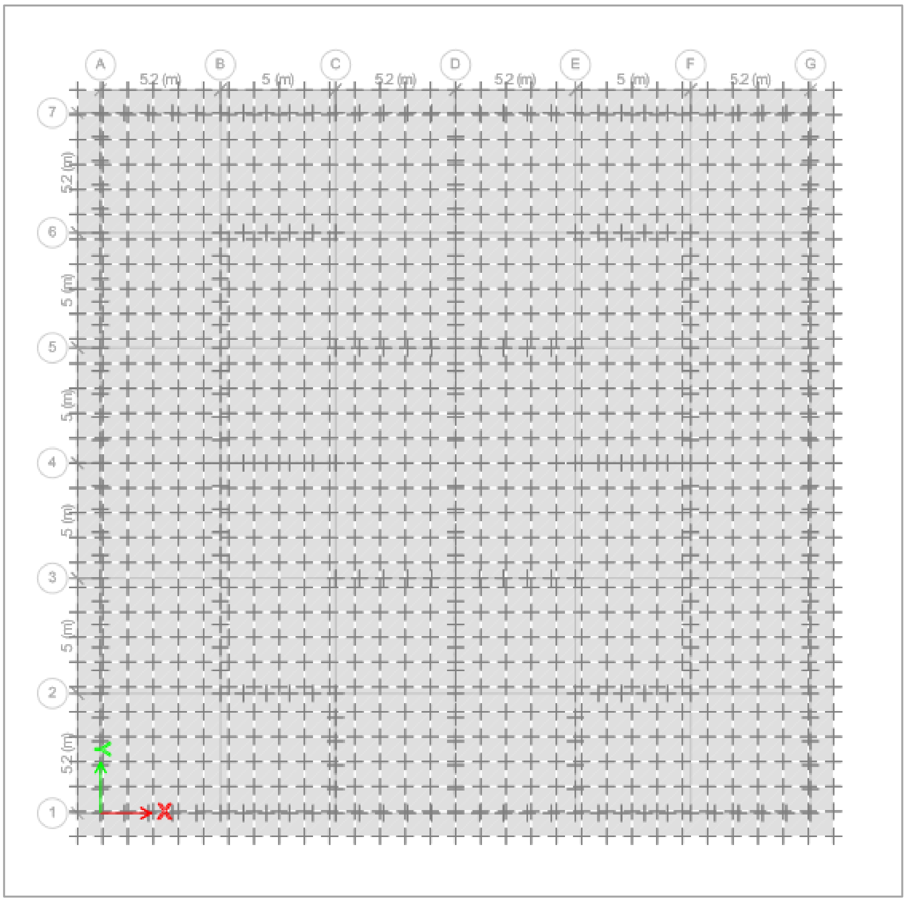


Figure 5.5: MAT Footing from ETABS.

Design thickness:

Try, h = 600 mm.

d = 540 mm.

The MAT foundation is extended 1.0 m beyond the centers of walls and columns.

Add loads on mat footing, W=39 KN/m^2.

Soil pressure:

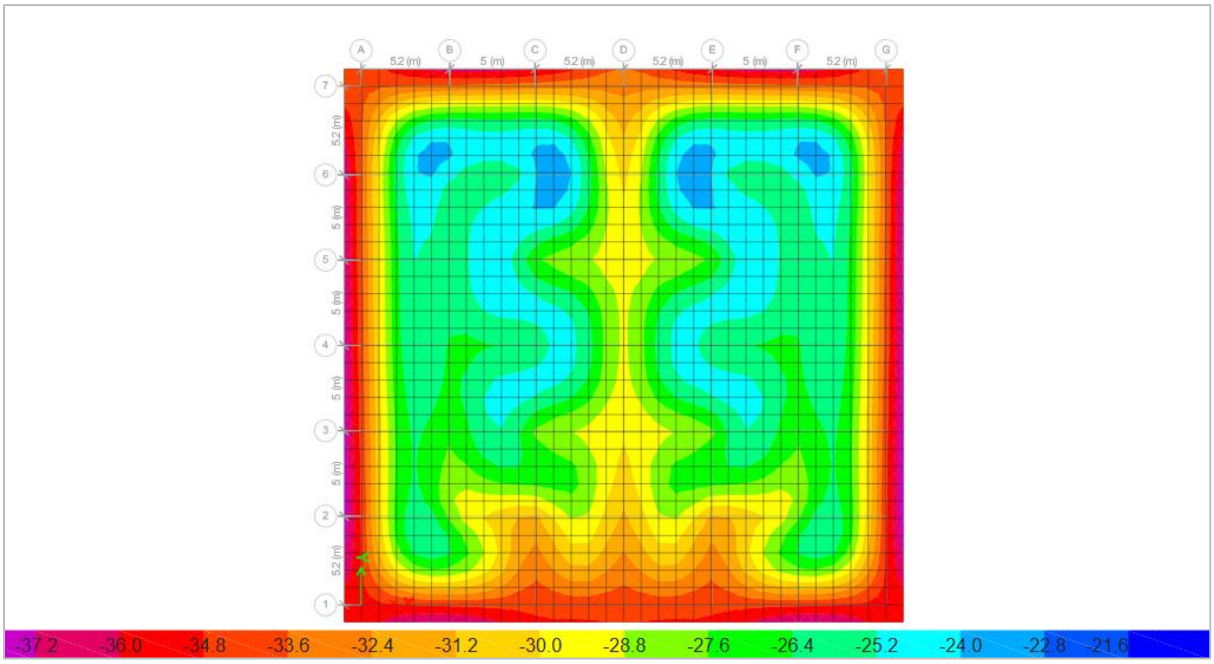


Figure 5.6: Soil pressure under MAT (dead).

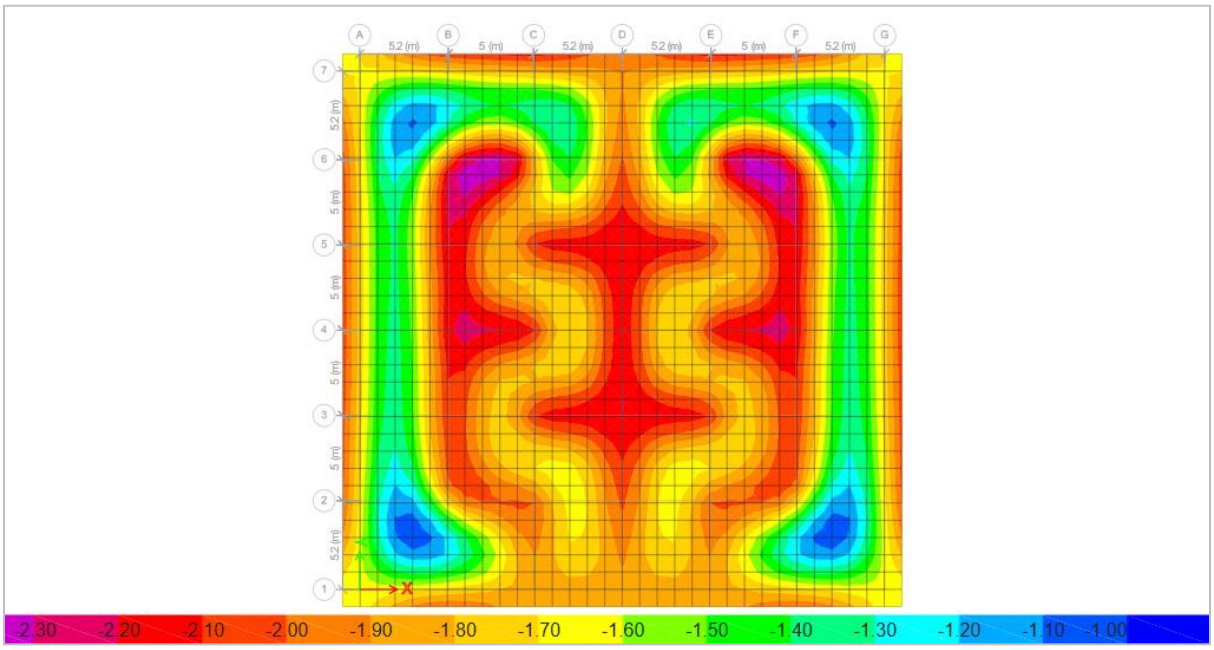


Figure 5.7: Soil pressure under MAT (live).

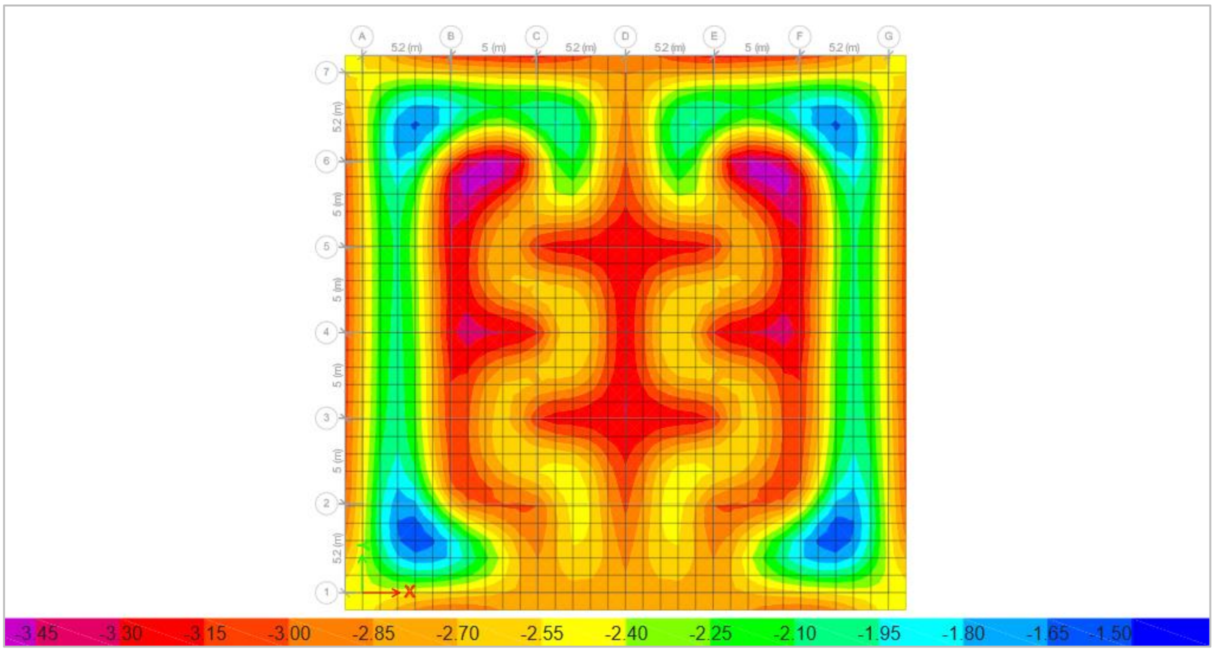


Figure 5.8: Soil pressure under MAT (SD).

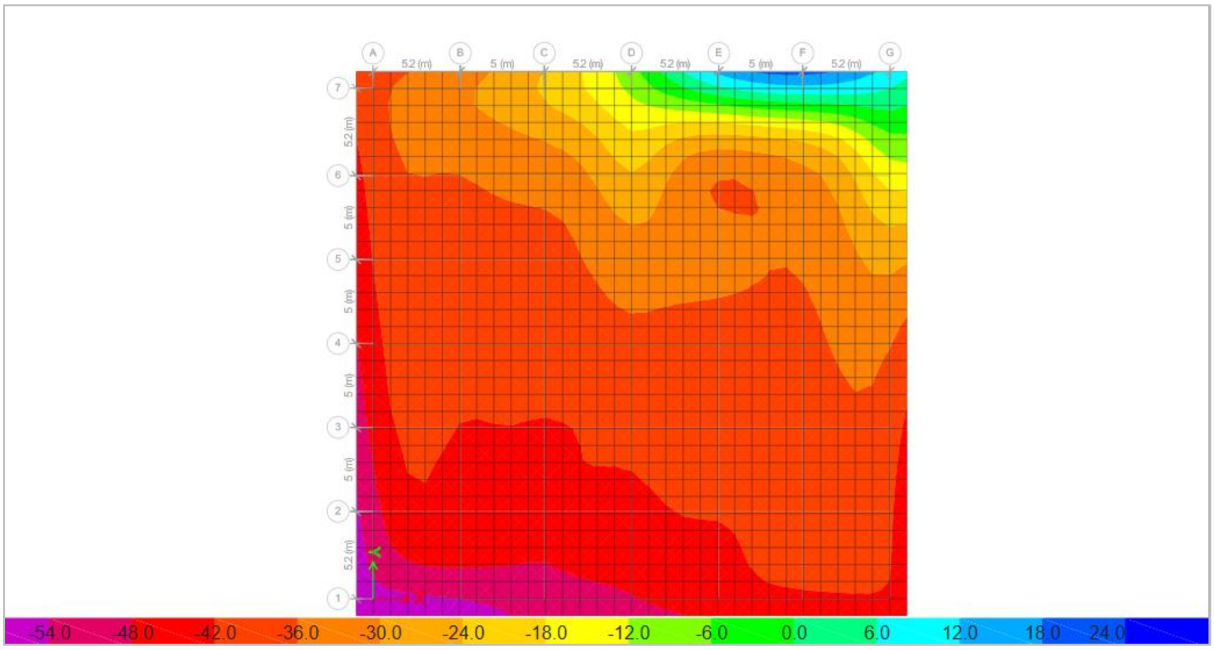


Figure 5.9: Soil pressure under MAT (total water).

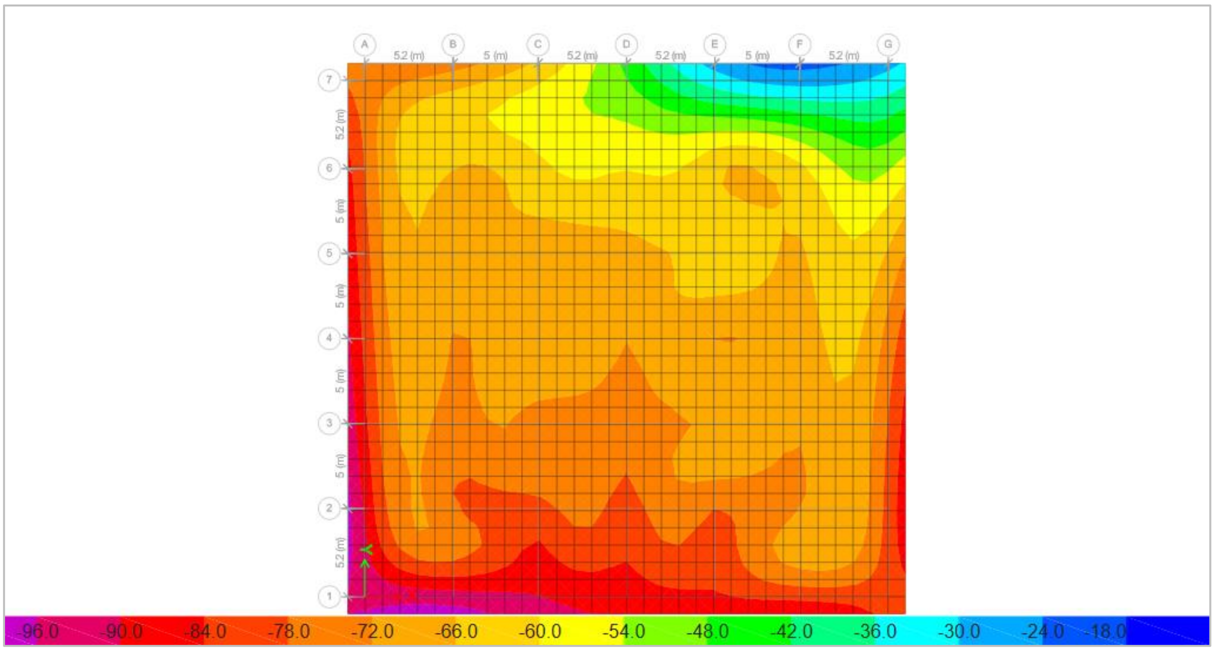


Figure 5.10: Soil pressure under MAT (SERVES).

Upper value of Soil pressure = 96 KN/m^2 < 200 KN/m^2. Then the dimensions are appropriate.

(We can use less thickness of base to be more economical, but this after check shear)..

Check value of soil pressure in service = pressure from (dead + live + SD + water)

= (37.2 + 2.3 + 3.45 + 54) = 96.95 ≈ 96 KN/m^2.

$\therefore OK.$

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For more details in soil pressures on MAT and effect of seismic loads in pages (22-23).

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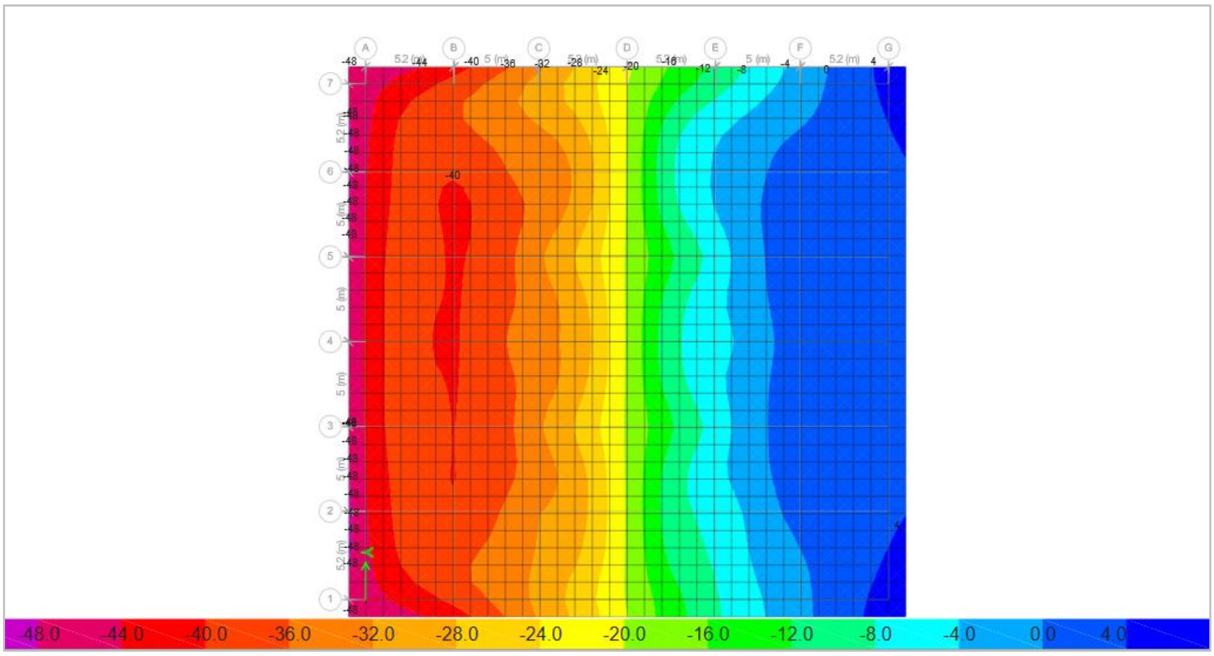
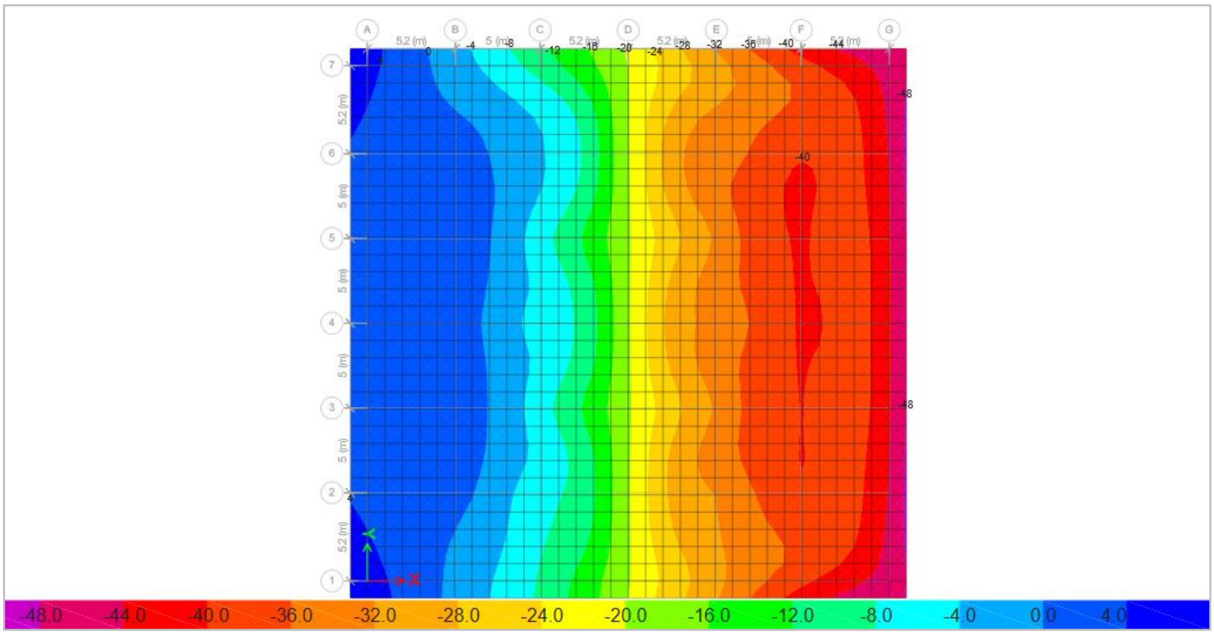
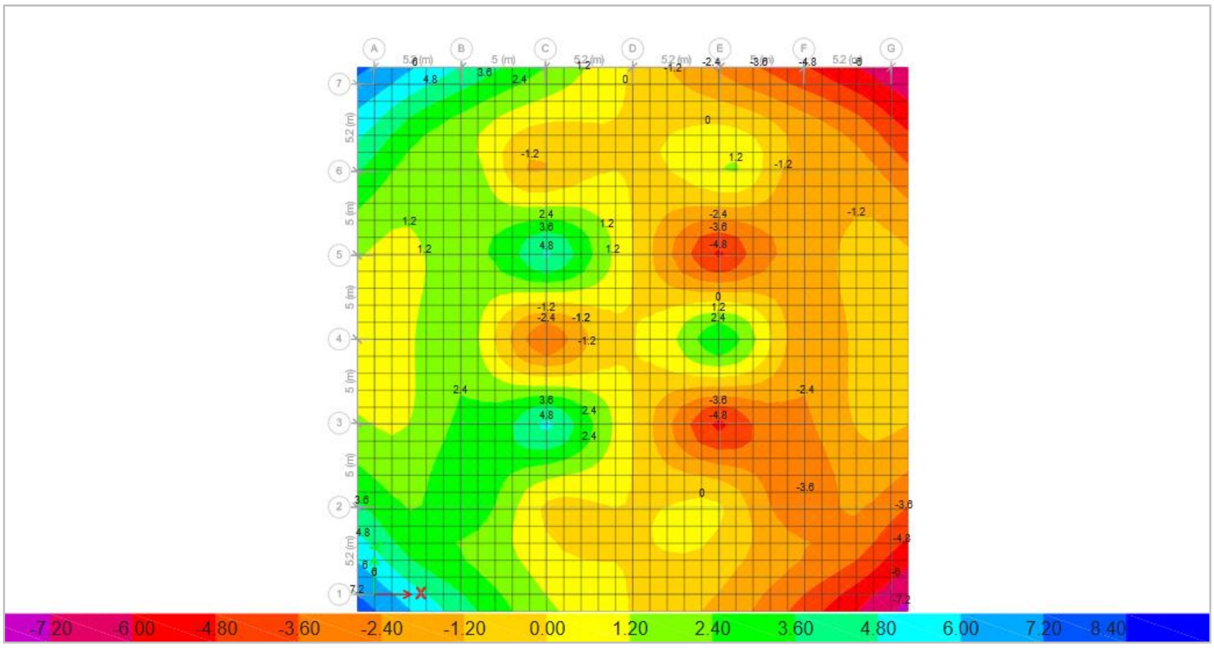


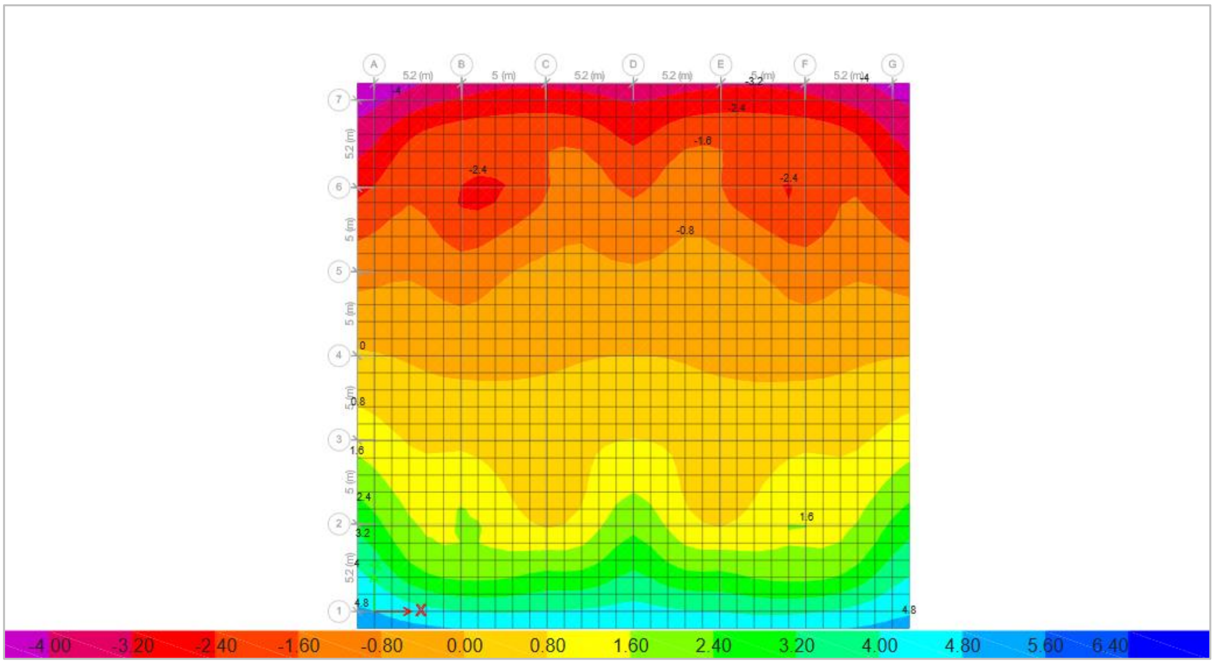
Soil pressure under MAT (water left).



Soil pressure under MAT (water right).



Soil pressure under MAT (Earthquake X).



Soil pressure under MAT (Earthquake Y).

Seismic factors in serves from Codes : ASCE 7-16 and ASCE 22-7.

Base reactions (from loads on the base):

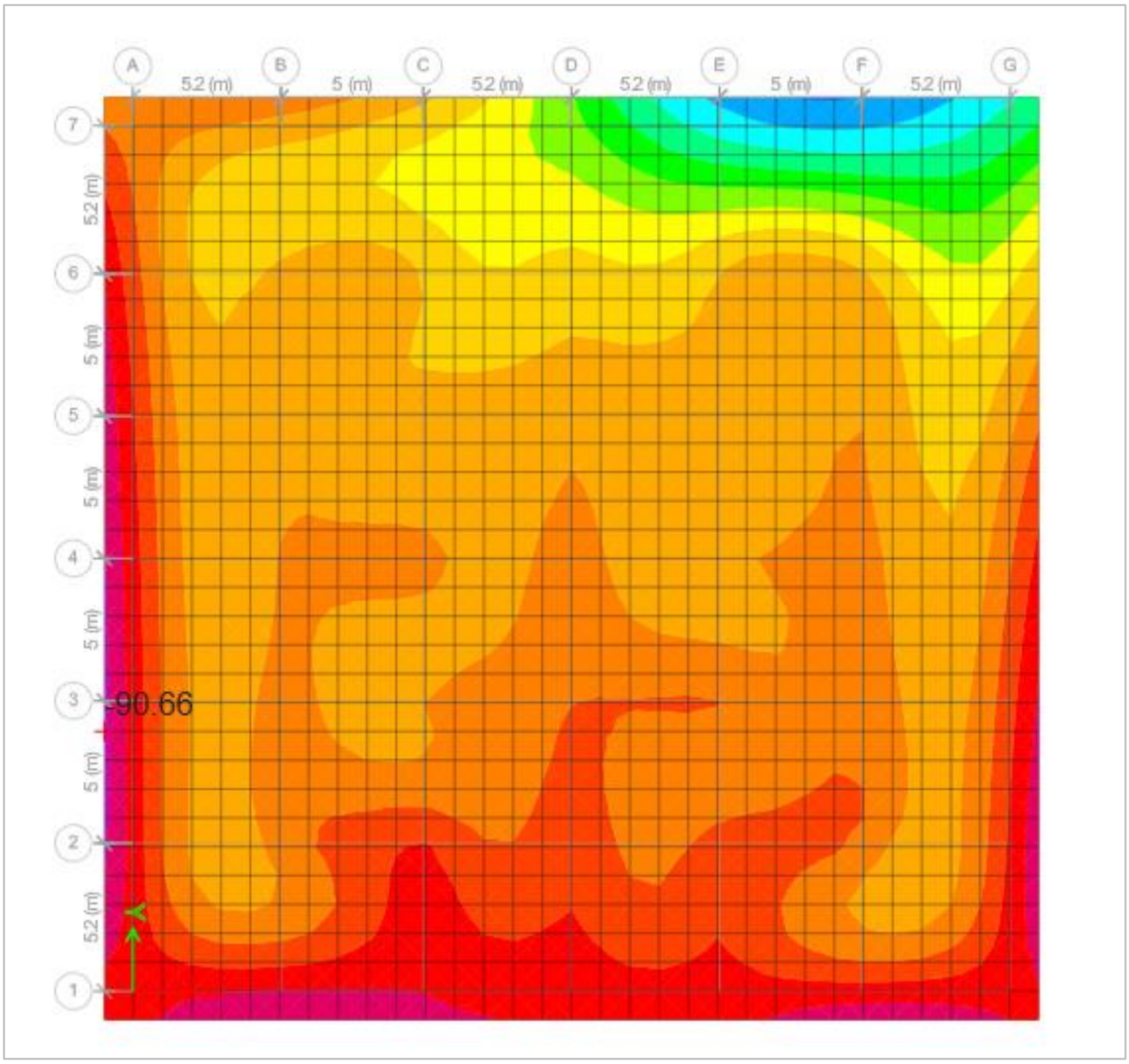
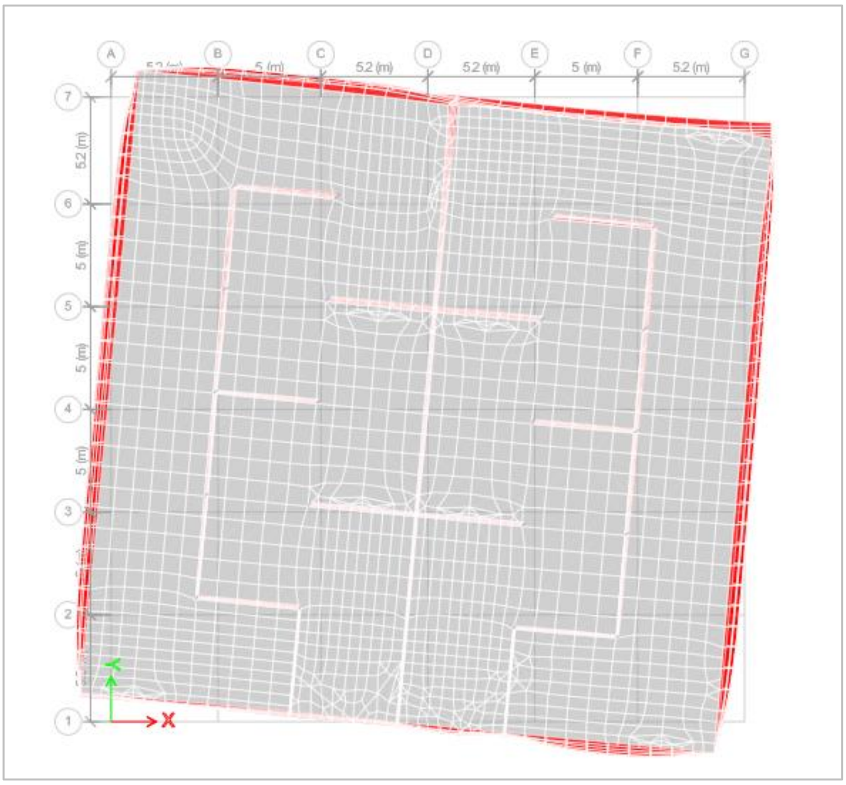


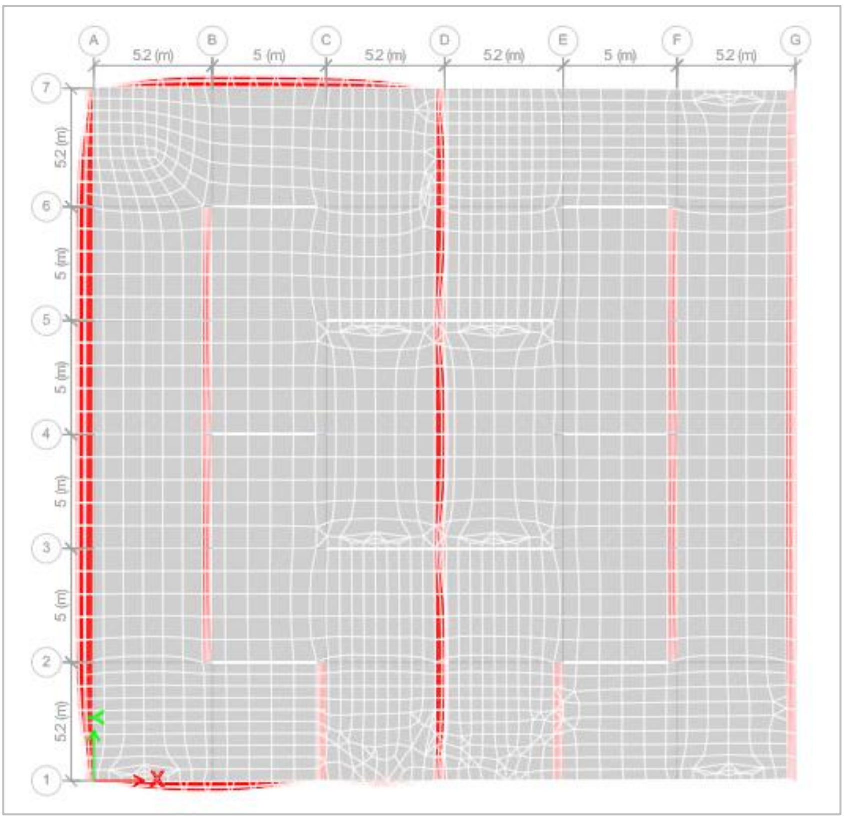
Figure 5.11: Base reaction on MAT (SERVES).

Upper value = 91 kN.

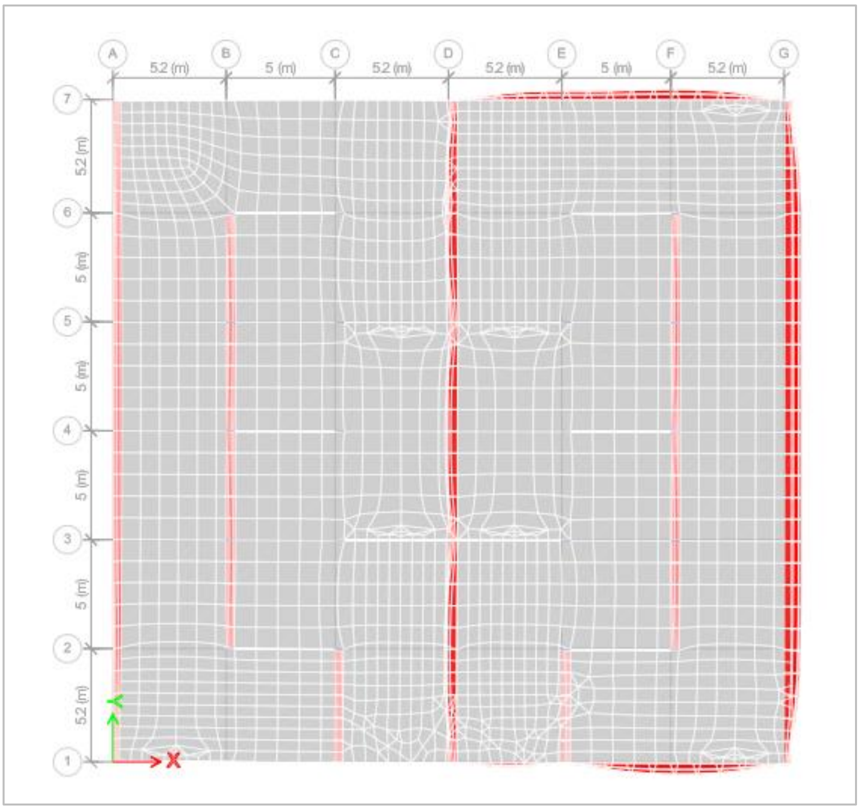
Deformed shapes :



From water



From water left



From water right

CHECKS:

Compatibility Checks:

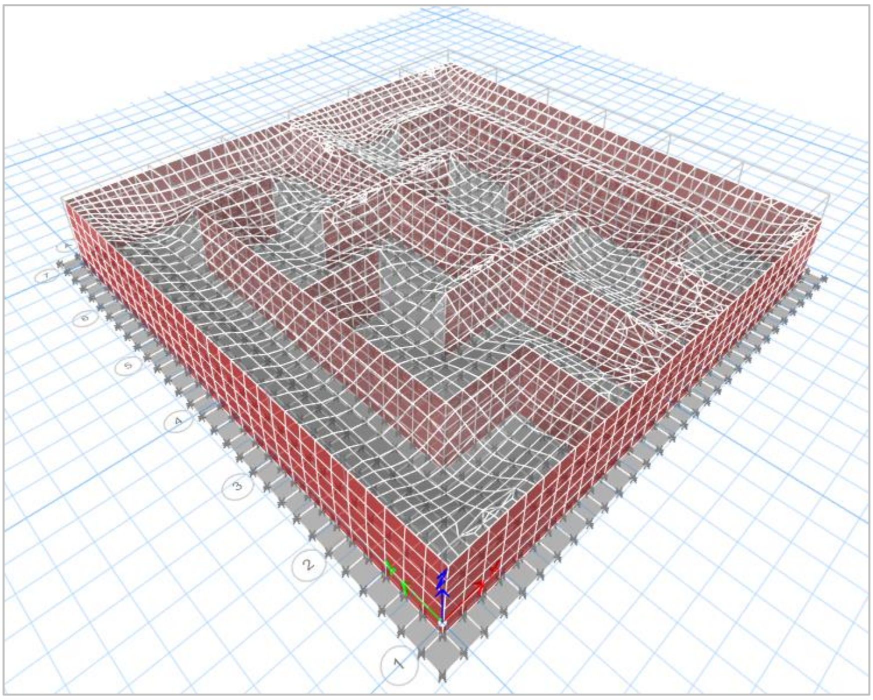
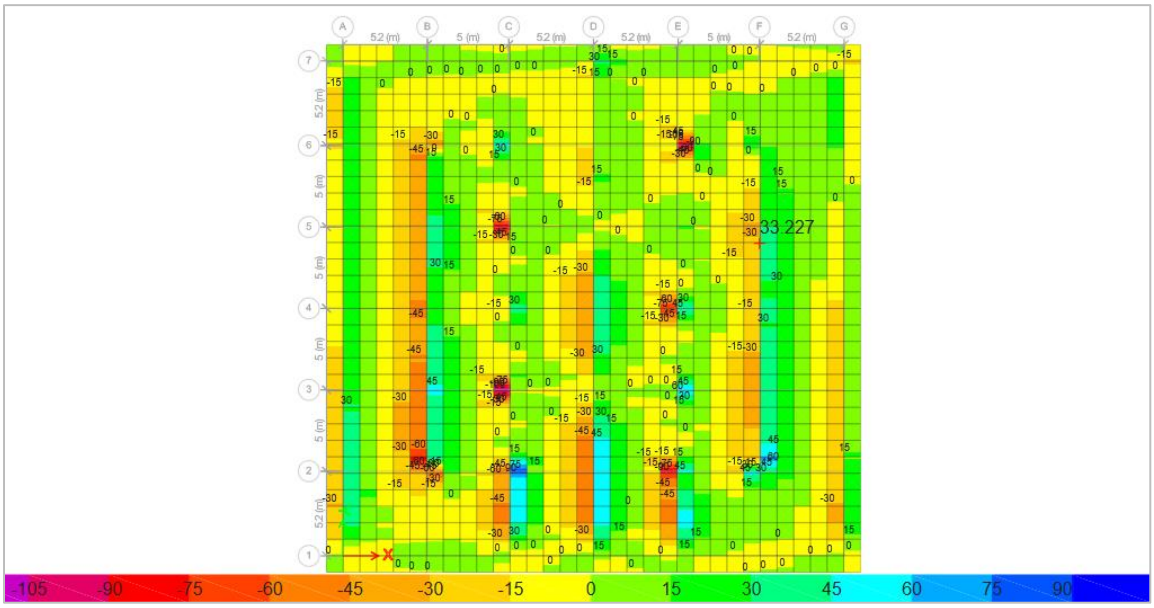


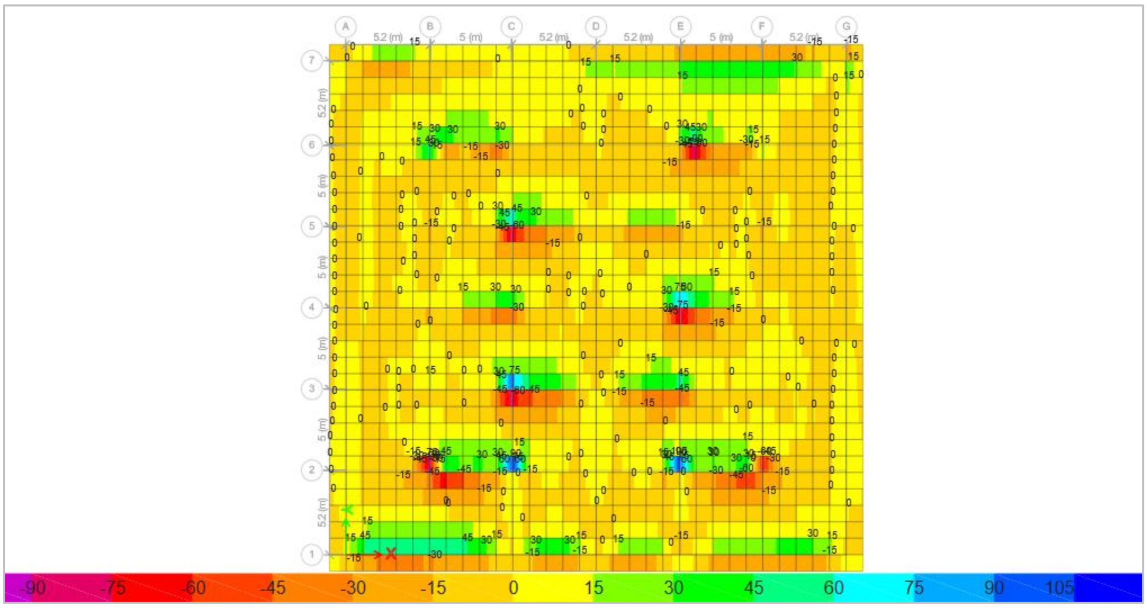
Figure 5.12: Compatibility check (MAT).

All elements work together, OK.

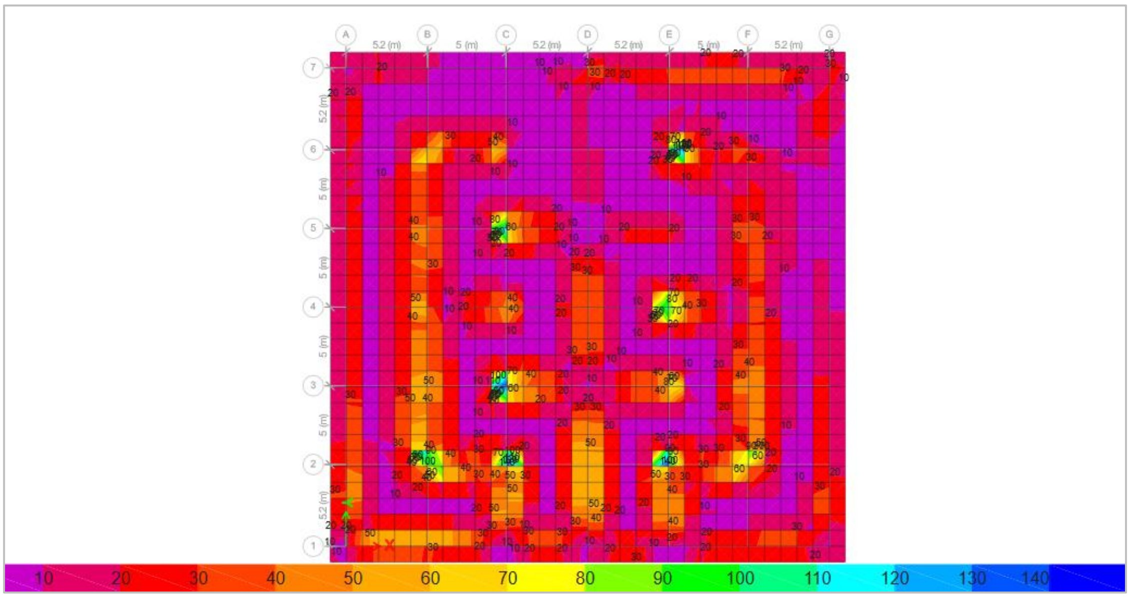
Wide beam shear check:



V13



V23



V max

Vu from ETABS = 140 KN.

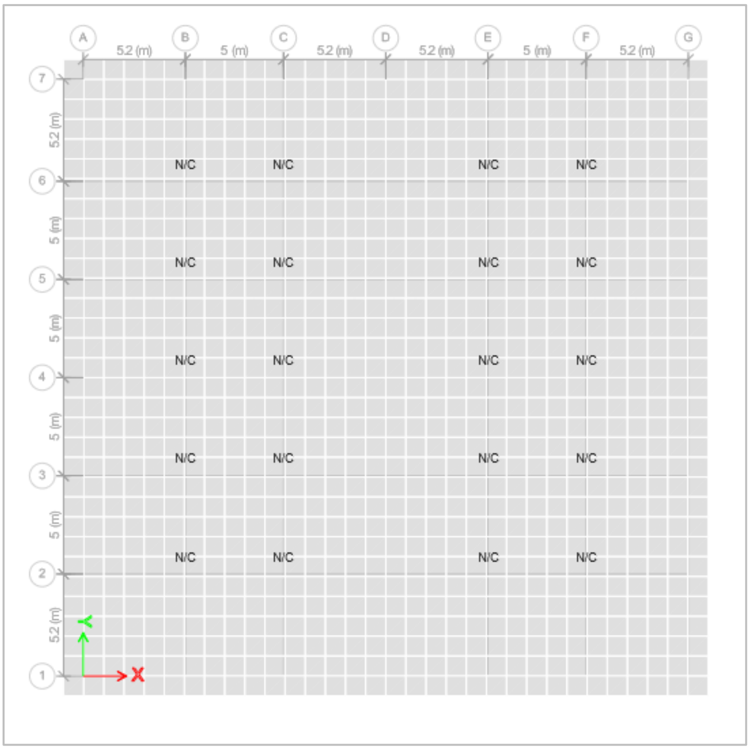
From ACI 318-19: h = 600mm, d = 540mm.

$$\emptyset vc = \frac{(0.75)(1)(1)(0.66)\left(\sqrt{28}\right)\left(0.002^{1/3}\right)(1000)(540)}{1000} = 178.2\ KN \ > \ Vu \ \ OK.$$

$$\emptyset Vc = 0.75 \times \left(\frac{1}{6}\right) \times \sqrt{28} \times 1000 \times 540 \div 1000 = 357.17\ KN > Vu \quad OK.$$

Then the thickness of MAT is Appropriate, and we can minimize thickness to be more economical.

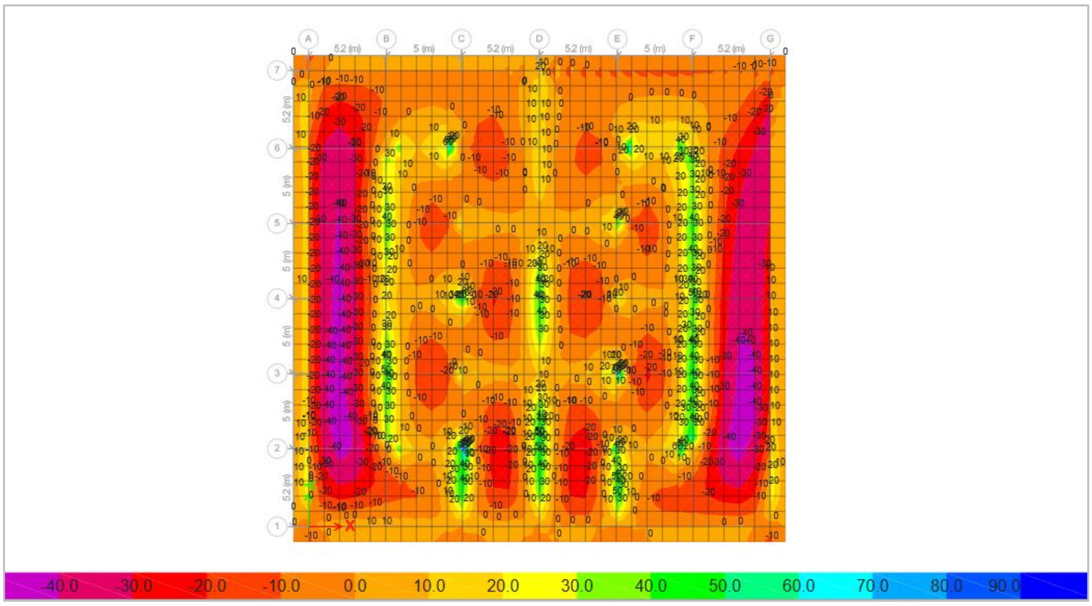
Punching:



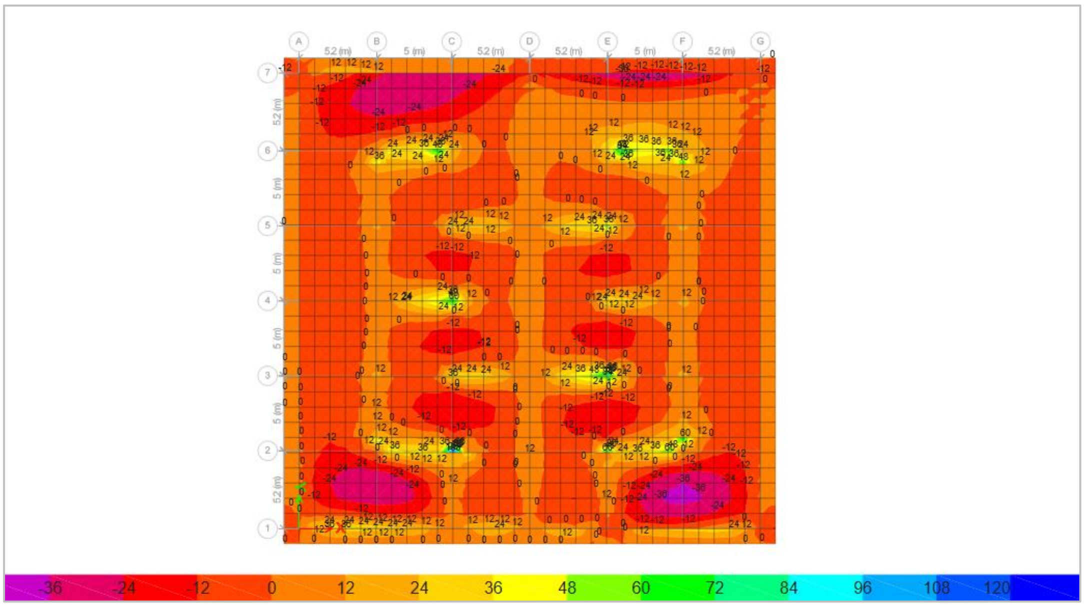
Punching factors = load / capacity

N/C because the columns is connected with shear walls and the effect of punching is small

Moments :



M11



M22

MAT REINFORCEMENT

Design Criteria:

Using code (ACI 318-19).

Tank height = 4.45 m.

Concrete compressive strength $f'c$ = 28 MPa.

Reinforcement steel strength fy = 420 MPa.

<u>BASE</u>

Base Thicknesses = 600 mm, d = 540 mm.

Base Dimension = 32.40 × 32.80 $in\ m$.

Area of Base = 1062.72 m^2.

Load on Base (water load) = 39 KN/m^2.

Type of foundation: shallow foundation, (D_f / B) < 3.

From moment M11,M22, moment values are used to determined required reinforcement for column strip and middle strip in both directions.

Moment values from ETABS:

M11 = 90 KN.m

M22 = 120 KN.m

$$\rho = \frac{0.85 \times 28}{420}\left(1 - \sqrt{1 - \frac{2.61 \times 90 \times 10^6}{1000 \times 540^2 \times 28}}\right) = 0.000821 \ < 0.0033$$

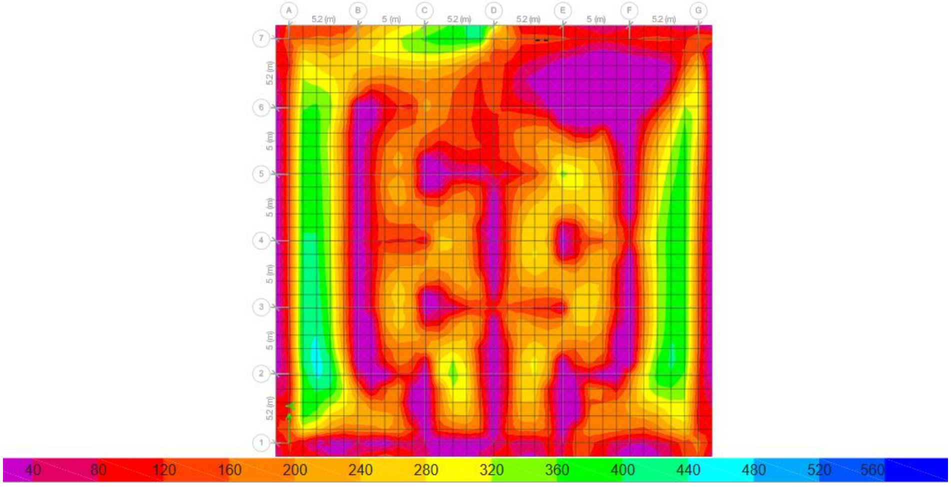
$$\rho = \frac{0.85 \times 28}{420}\left(1 - \sqrt{1 - \frac{2.61 \times 120 \times 10^6}{1000 \times 540^2 \times 28}}\right) = 0.00109 \ < 0.0033$$

Use $\rho\ min = 0.0033$.

$As = \rho \times b \times d = 0.0033 \times 1000 \times 540 = 1780\ mm^2$.

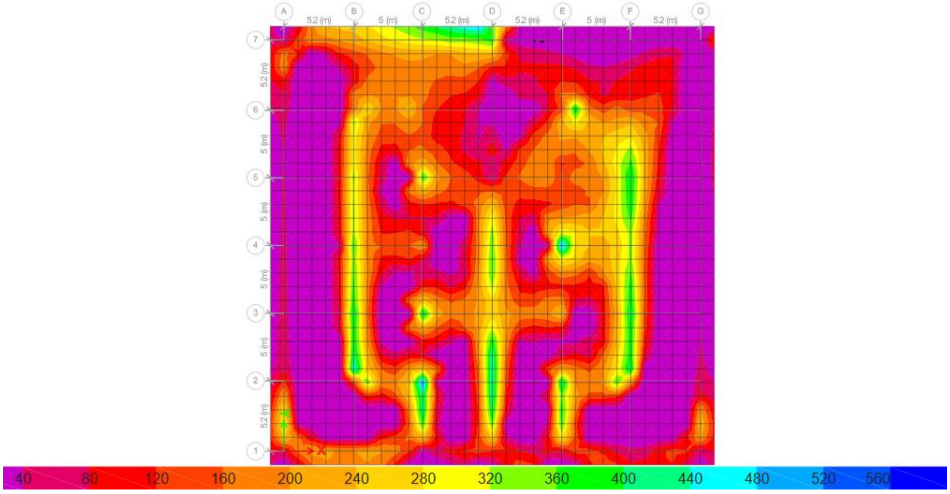
<u>Design flexure in MAT using ETABS in mm^2/m :</u>

Direction 1 – Top Rebar :



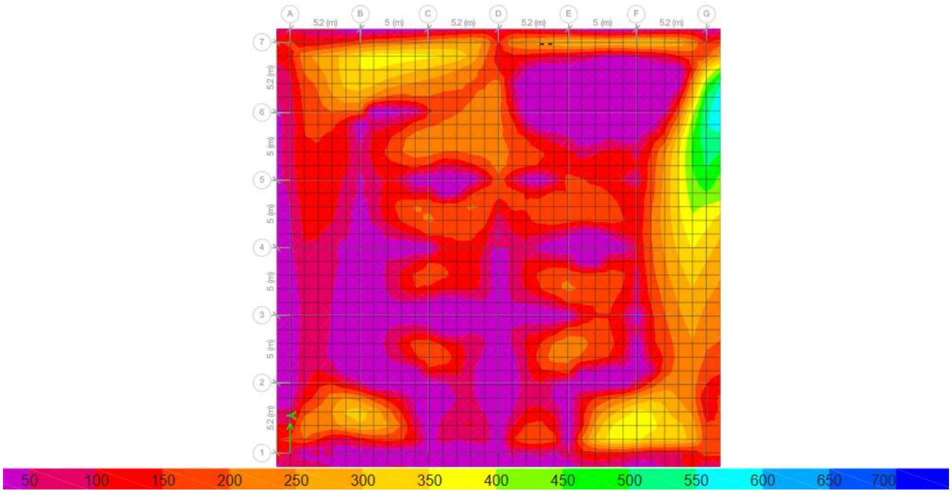
Upper value = 560 mm^2/m.

Direction 1 – Bottom Rebar :



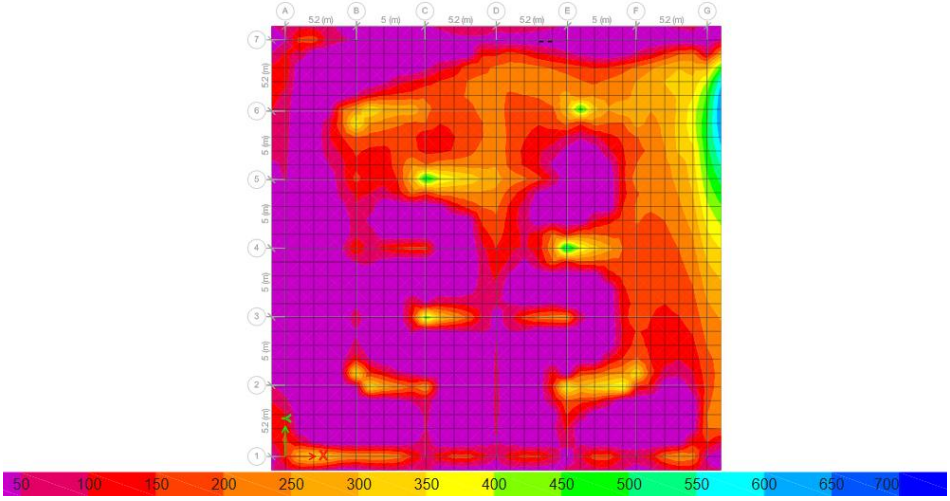
Upper value = 560 mm^2/m.

Direction 2 – Top Rebar :



Upper value = 700 mm^2/m.

Direction 2 – Bottom Rebar :



Upper value = 700 mm²/m.

Upper value from Etabs is 700 mm²/m that is less than minimum steel.

Then we use minimum = 1782 mm²/m.

#	Area of steel mm²/m	Rebar
Top Dir. 1	1780	1Φ20/150mm
Top Dir. 2	1780	1Φ20/150mm
Bot Dir. 1	1780	1Φ20/150mm
Bot Dir.2	1780	1Φ20/150mm

Table 5.1: MAT footing Reinforcement.

SETTLEMENT OF MAT FOUNDATION

From soil report and borehole No.1, the soil below MAT foundation was found to be clayey soil with the following characteristics :

- Liquid limit = 41
- Moisture content = 12%
- Specific gravity = 2.72
- Soil unit weight = 18 KN/m^2.

Base level is 88m after excavated from 89m elevation.

The results of settlement are clear because the soil has been improved using 40 cm of compacted base course under base.

<u>Elastic settlement</u>

Displacement in Z-direction in MAT foundation under effect of service and seismic loads.

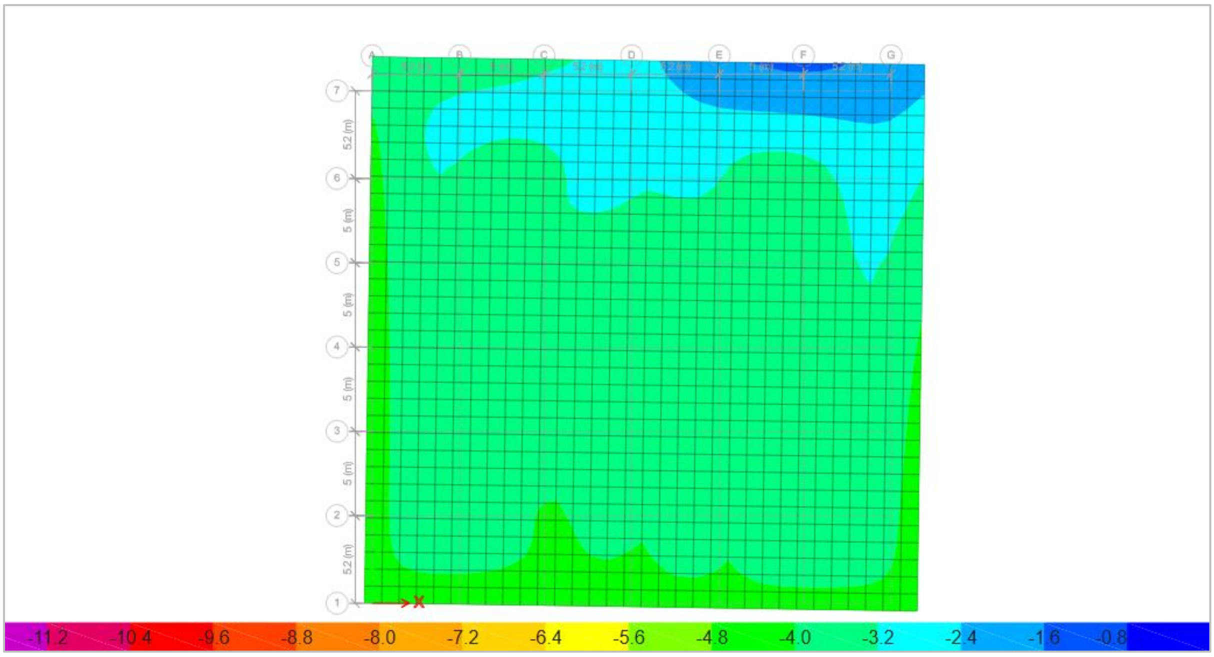


Figure 5.13: Displacement from ETABS.

Elastic settlement = 11.2mm**.**

Max deflection = 5200/240 = 21.67mm.

$\therefore OK$

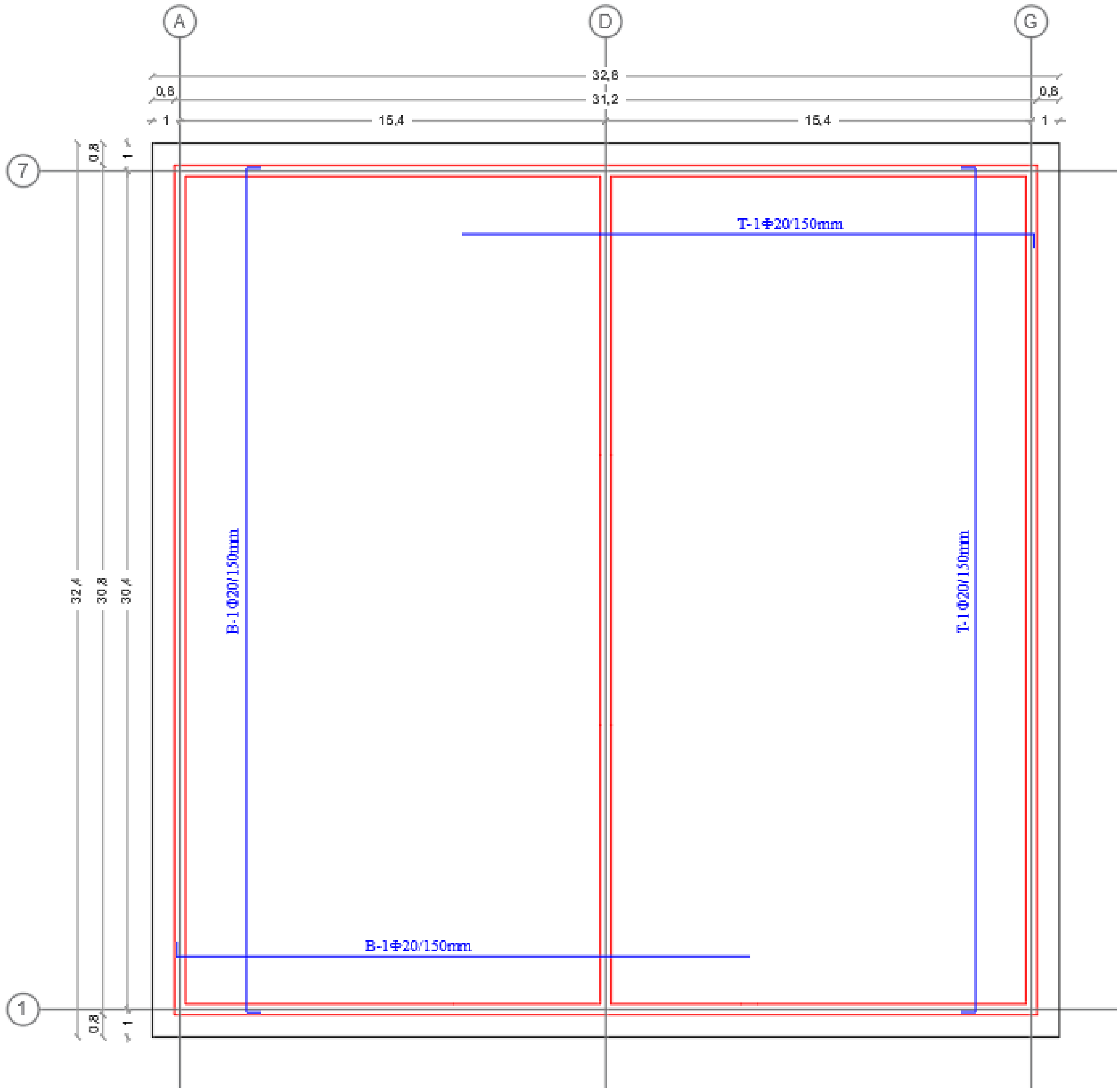


Figure 5.14: Plan In MAT Reinforcement.

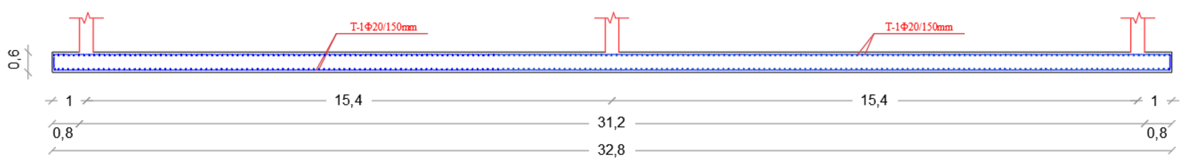


Figure 5.15: Section In MAT Reinforcement.

5.5.2 Walls

This tank is On-Ground Tank, the shape is Rectangular with roof, and its using To provide a reliable and continuous supply of potable water to the surrounding area.

Our tank is classified as (Shallow Water Tank with Roof), Check → $\frac{L1}{H} = \frac{31.2}{4.45} = 7 \ > 4 \ Ok$, then the water loads are transferred in walls in the vertical direction.

Shear and moments for walls:

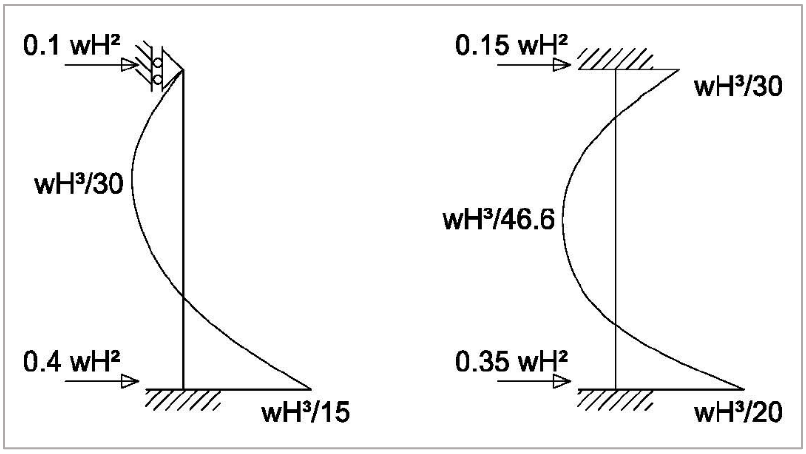


Figure 5.16: shear and moment values (vertical direction).

<u>Design Of Rectangular Water Tanks.</u>

- Length (L_1) & Width (L_2): (31.2 × 30.8) in m.
- Height (H) = 4.45m.
- Roof Thickness = 0.2 m.
- All Wall Thickness = 0.40 m.
- Area Of Part 1 Of Tank = 960 m_2.
- Unit Weight of Water (γw or W) = 10 KN/m^3.
- Soil Allowable Bearing Capacity (q_{all}) = 200 KN/m3.

- $f'c = 28 \ MPa.$
- $fy = 420 \ MPa.$
- Normal exposure.

Vertical Direction:

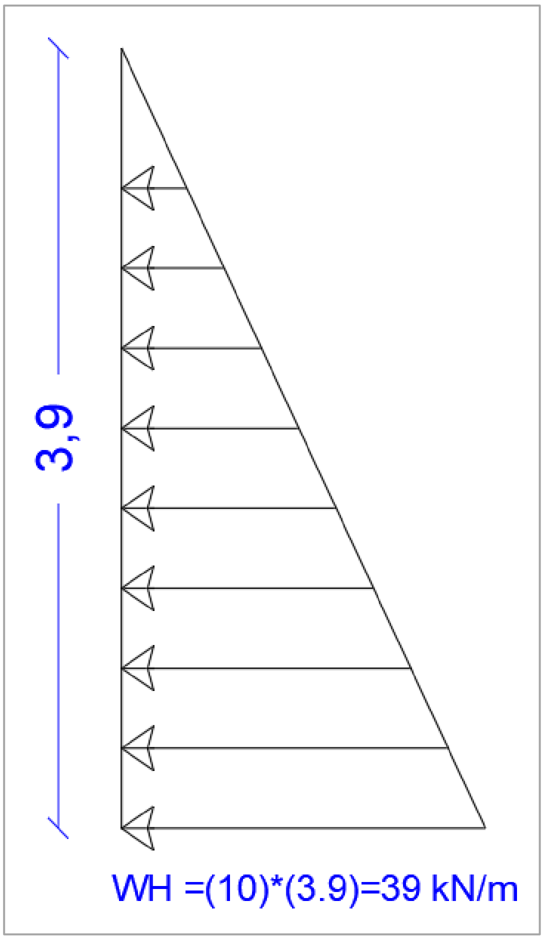


Figure 5.17: Water pressure on tank wall.

Wall thickness = 400mm.

D = 330mm.

In case ' fixed-fixed '

Shear = 0.35 $WH^2 = 0.35 \times 10 \times 3.9^2 = 53.23\ KN$.

Shear = 0.15 $WH^2 = 0.15 \times 10 \times 3.9^2 = 22.81\ KN$.

$$Moment = \frac{WH^3}{20} = \frac{10 \times 3.9^3}{20} = 29.65\ KN.m$$

$$Moment = \frac{WH^3}{30} = \frac{10 \times 3.9^3}{30} = 19.77\ KN.m$$

$$Moment = \frac{WH^3}{46.6} = \frac{10 \times 3.9^3}{46.6} = 12.72\ KN.m$$

Using load combination (1.4F) :

$Vu = 1.4 \times 53.23 = 74.6\ KN.$

$Mu = 1.4 \times 29.65 = 41.5\ KN.m.$

$Mu = 1.4 \times 19.77 = 27.7\ KN.m.$

$Mu = 1.4 \times 12.72 = 17.8\ KN.m.$

Shear in walls (ACI 318-14) :

Check shear in wall:

$\emptyset Vc = 0.75 \times \left(\frac{1}{6}\right) \times \sqrt{28} \times 1000 \times 330 \div 1000 = 218.27\ KN > 74.6\ KN \quad OK.$

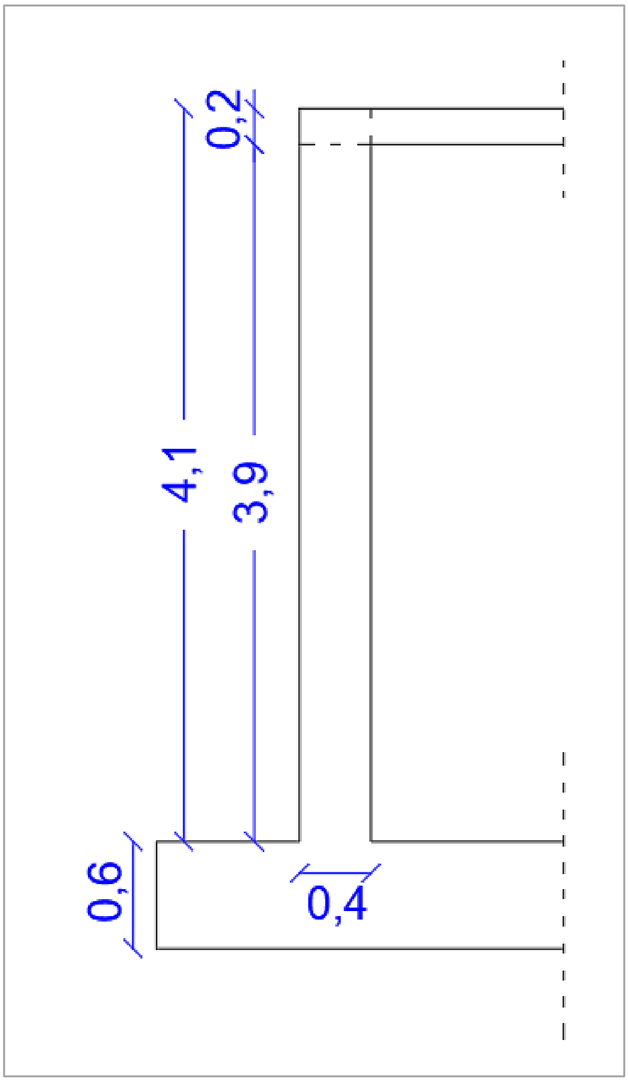


Figure 5.18: Section in wall.

Design for flexure (ACI 350-06 & ACI 318-19):

Using environmental durability factor (Sd).

S=150mm.

$dp = 20$mm.

Thickness of wall (h) = 400mm.

$\beta = 1.2\,, (h = 400 \geq 400)\ OK$.

$$fs = \frac{55880}{\beta\sqrt{(S^2 + 4\left(50 + \frac{dp}{2}\right)^2}} = \frac{55880}{1.2\sqrt{150^2 + 4\left(50 + \frac{20}{2}\right)^2}} = \frac{55880}{225.76} = 242.41\ MPa$$

Check for fs :

$fs \leq 250\ MPa\ \ OK.$

$fs \geq 138\ MPa\ for\ one\ way\ members\ \ OK.$

$fs \geq 165\ MPa\ for\ two\ way\ members\ \ OK.$

$$Sd = \frac{\emptyset fy}{\gamma fs} = \frac{0.9 \times 420}{1.2 \times 242.41} = 1.27$$

$Mu' = 1.27 \times 41.5 = 52.7\ KN.m.$

$$\rho = \frac{0.85 \times 28}{420}\left(1 - \sqrt{1 - \frac{2.61 \times 52.7 \times 10^6}{1000 \times 330^2 \times 28}}\right) = 0.0013\ < 0.0033$$

$\rho \min = 0.0033\ , for\ L > 12m\ \ ,,\ \ use\ \rho = 0.006.$

$As = 1980 mm^2$.

$use\ 1\emptyset 20/150mm\ \ ,\ \ new\ As = 1271.7\ mm^2$. Vertical At Inner side of Wall.

$Mu' = 1.27 \times 17.8 = 22.6\ KN.m.$

$$\rho = \frac{0.85 \times 28}{420}\left(1 - \sqrt{1 - \frac{2.61 \times 22.6 \times 10^6}{1000 \times 330^2 \times 28}}\right) = 0.00055\ < 0.0033$$

$\rho \min = 0.0033\ , for\ L > 12m\ \ ,,\ \ use\ \rho = 0.006$.

$\therefore As = 1980 mm^2$.

$$\rightarrow\ \ As = \frac{0.006}{2} \times 1000 \times 400 = 1200 mm^2$$

$use\ 1\emptyset 16/150mm\ \ ,\ \ new\ As = 1339.73\ mm^2$. Vertical At Outer side of Wall.

Horizontal Direction:

$$Total\ force\ =\ (0.5)(3.9)(3.9)\left(\frac{10\times 3.9}{2}\right)=148.30\ kN$$

$$Total\ moment\ =(148.30)(0.5\times 3.9)=289.18\ kN.m$$

$$Force/m=\frac{148.30}{3.9}=38.03\ kN$$

$$Moment/m\ =\ 289.18/3.9=74.15\ kN\cdot m$$

$$M_u=1.4\times 74.15=103.81\ kN\cdot m$$

$$P_u=1.4\times 38.03=53.25\ kN$$

Design For Flexure

$$M_u=1.27\times 103.81=131.83\ kN\cdot m$$

$$d=330mm$$

$$\rho=0.00329\sim 0.0033$$

$$A_s=1099mm^2$$

Design For Tension

$$A_s=\frac{P}{f_s}=\frac{38.03\times 10^3}{138}=275.57\ mm^2$$

$$Total\ horizontal\ steel\ at\ side\ of\ water\ =A_s=1099+\frac{275.57}{2}=1236.78\ mm^2,$$

$use\ 1\emptyset 16/150mm$. At side of water

$$Minimum\ horizontal\ steel\ =\frac{0.005}{2}\times 1000\times 400=1000\ mm^2$$

$Horizontal\ steel\ at\ outer\ side\ of\ wall\ =1000\ mm^2, use\ 1\emptyset 14/150mm$

Wall Reinforcement:

WALL REINFORCEMENT		
VERTICAL	**Inner Side**	$1\emptyset20/150mm$
	Outer Site	$1\emptyset16/150mm$
HORIZONTAL	**Inner Side**	$1\emptyset16/150mm$
	Outer Site	$1\emptyset14/150mm$

Table 5.2: Wall Reinforcement.

CHAPTER SIX

(ELEVATED TANK)

6. Introduction

6.1.1 General Background

The foundation is the lower part of structures, which is the base on which the structure rests on the ground. It is the first part of the concrete structure to be poured on-site directly above the foundation soil. and transfers the structural loads to the supporting soil or rock. In order to put any facility on the ground in a safe manner, we must choose the appropriate type of foundation so as to give it stability and continuity for the longest possible period in the case of normal use or even in conditions of earthquakes, which preserves the lives of its residents.

The foundations are usually embedded in the ground at a depth suitable for construction, and the foundation is chosen according to the type of structure, the design method, and the bearing capacity of the soil.

The foundation soil must meet several conditions, durability, balance, stability, and stability.

About MAT foundation: (also called raft foundation), it is a single continuous slab that covers the entirety of the base of a structure. Mat foundations support all the loads of the structure and transmit them to the ground evenly. Soil conditions may prevent other footings from being used. Since this type of foundation distributes the load coming from the building uniformly over a considerably large area, it is favored when individual footings are unfeasible due to the low bearing capacity of the soil.

This part is focusing on the design of a foundation for Elevated water tank.

This tank consists of a ground tank and elevated tank (Which we discussed in the first project). Project is located in the new industrial city of Jenin. The purpose of the water Tank is to provide a reliable and continuous supply of water to the surrounding area. The Elevated tank will have a capacity of 700 cubic meters and the Ground tank have 6000 cubic meters, the tank will be constructed using reinforced concrete.

Total capacity in ground tank and elevated tank = 6700 cubic meters.

About Piles Footings: To provide additional safety, stability and lateral resistance for this structure, pile foundations with 700mm diameter and 12-meter length will be used under each of the 9 columns in conjunction with the proposed mat foundation.

Pile foundations extend into competent soil strata below the mat, anchoring the structure and reducing risks related to shallow soil failure or lateral forces. The piles also help distribute the considerable column loads through weaker near-surface soils into stronger soils at depth, thereby lowering contact pressures on the mat and underlying soils.

By combining mat and pile foundations, this hybrid foundation system harnesses the benefits of both approaches. The mat ties the piles together, reducing differential settlement and providing a uniform bearing surface for the building. The 700mm bored piles in turn enhance the stability and load-carrying capacity of the mat by extending 12 meters deep to competent supporting strata. This interaction results in a robust, cost-effective foundation that satisfies requirements related to bearing capacity, settlement, and lateral load resistance.

6.1.2 Project Description

The project involves the design of a reinforced concrete Footings system for a Elevated Water Tank, Which consists of two separate parts, the total net capacity is 700 cups (m^3), The two parts are similar, have the same details.

The design will be based on the results of our soil report, which we discussed in the first project, the results of which we will attach to this report.

In our project, we will extensively utilize various codes and engineering references pertinent to the design of footings and water tanks. Our focus will be on designing tanks that are crack-free, aligning with the latest standards and codes.

Codes:

- ACI 350-06
- ACI 318-14
- ACI 318-19
- ASCE

Load Patterns:

- D (Dead Load).
- LL (Live Load).
- W (Water Load).
- EQ (Earthquake load).

Load Combinations:

- (1.4D).
- (1.2D + 1.6L).
- Envelope.
- Service.
- 1.4F (1.4W).

6.2 Modeling

6.2.1 Water Tank Layouts

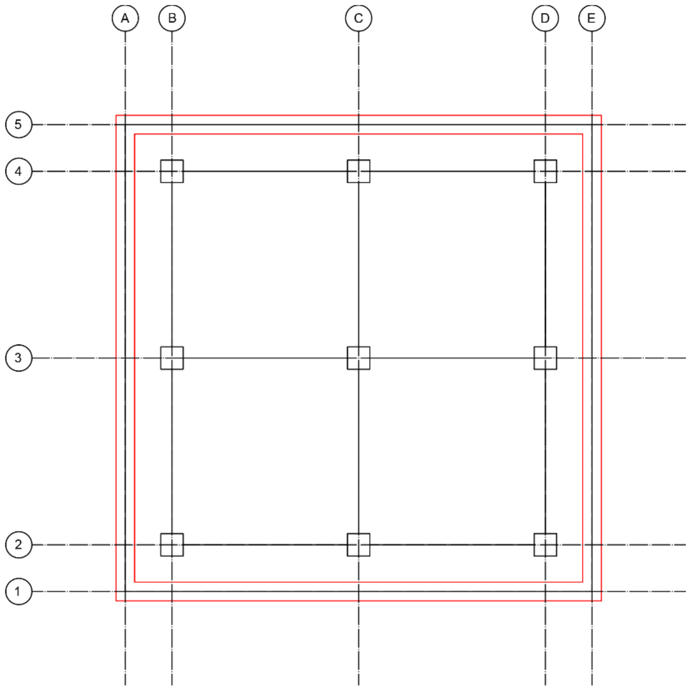


Figure 6.2: Water Tank Layout.

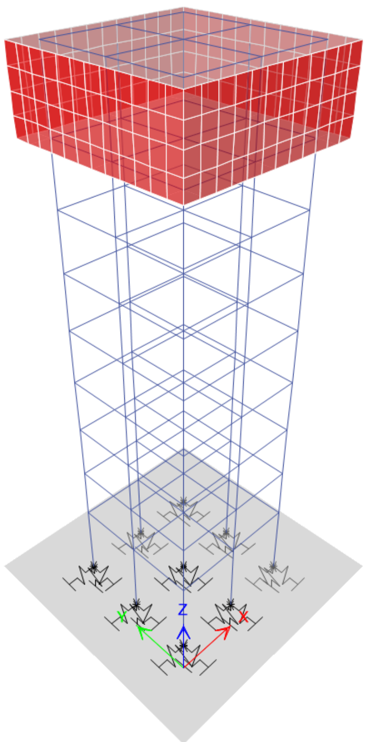


Figure 6.3: 3D Modeling from ETABS.

6.2.2 Design Criteria

Design method for walls: Ultimate design method with serviceability check.

Design method for Base: Conventional rigid method.

- $f'c = 28\ MPa.$
- $fy = 420\ MPa.$
- $Tank\ With\ Roof.$
- $Tank\ type : Normal\ Exposure.$
- $Base\ elevation : +113\ AMSL.$
- $q_{all\ for\ soil} = 200\ kN/m^2.$

6.2.3 Preliminary Dimensions

<u>Elevated Tank</u>

- Area of tank = (12.5×12.5) =156.25 m^2.
- Capacity of Tank = 700 cups m^3.
- Height=4.2 m.
- Depth of water= 4 m.

<u>Walls</u>

- Wall thickness= 250 mm.
- Height= 4m.

<u>Roof</u>

- Roof thickness= 200 mm.

<u>Columns</u>

- Dimension of Column: 600mm×600mm.
- No. of columns on Base: 9 columns.

6.3 Tank Base Foundation

The foundation of an elevated tank plays a crucial role in ensuring the stability and safety of the structure. Elevated tanks, commonly used for water storage, require a foundation capable of supporting not only the weight of the tank itself but also the dynamic loads due to water movement and environmental factors like wind and seismic activities. In this context, a cap with a pile foundation is often employed due to its strength and reliability.

Description of Cap with Pile Foundation

A cap with a pile foundation consists of two main components: the piles and the cap.

Piles: Piles are long, slender columns made of concrete, steel, or timber that are driven into the ground to reach a stable layer of soil or rock. These piles transfer the load from the structure above to the strong soil or rock layers deep underground. The length, diameter, and material of the piles depend on the soil characteristics and the load they need to bear.

Cap: The cap, also known as a pile cap, is a thick concrete mat that rests on top of the piles. It serves as a link between the piles and the structure above. The cap distributes the load from the tank evenly among the piles and provides a stable base for the elevated tank.

Bearing Capacity

From Soil report, the value bearing capacity is based on the bearing capacity of the silty clay soil according to the following parameters:

- Cohesion (c) = 39 KN/m^2
- Angle of Internal Friction (φ) = 9°
- Unit Weight = 18 KN/m^3
- Depth of Foundation = 1.0 m

Terzaghi Bearing Capacity Equation gives q_{all} = 172 KN/m^2

Vesic Bearing Capacity Equations gives q_{all} = 180 KN/m^2

The recommended allowable bearing capacity q_{all} = 180 KN/m^2

Consider the soil improvement by 40 cm of compacted base course, the allowable bearing capacity becomes = 200 KN/m^2.

6.3.1 Mat Foundation

Dimensions and Characteristics

- $Base\ Dimension = 20 \times 20\ m.$
- $Area\ of\ Base = 400\ m^2.$
- $Thickness = 1500\ mm.$

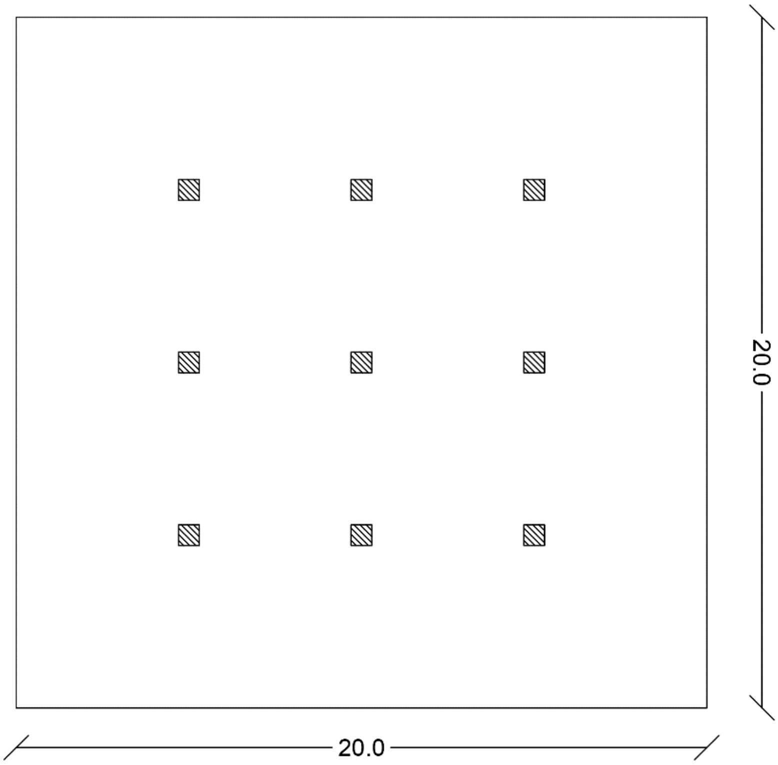


Figure 6.3: Mat Plan Cap Distribution.

Check soil pressure

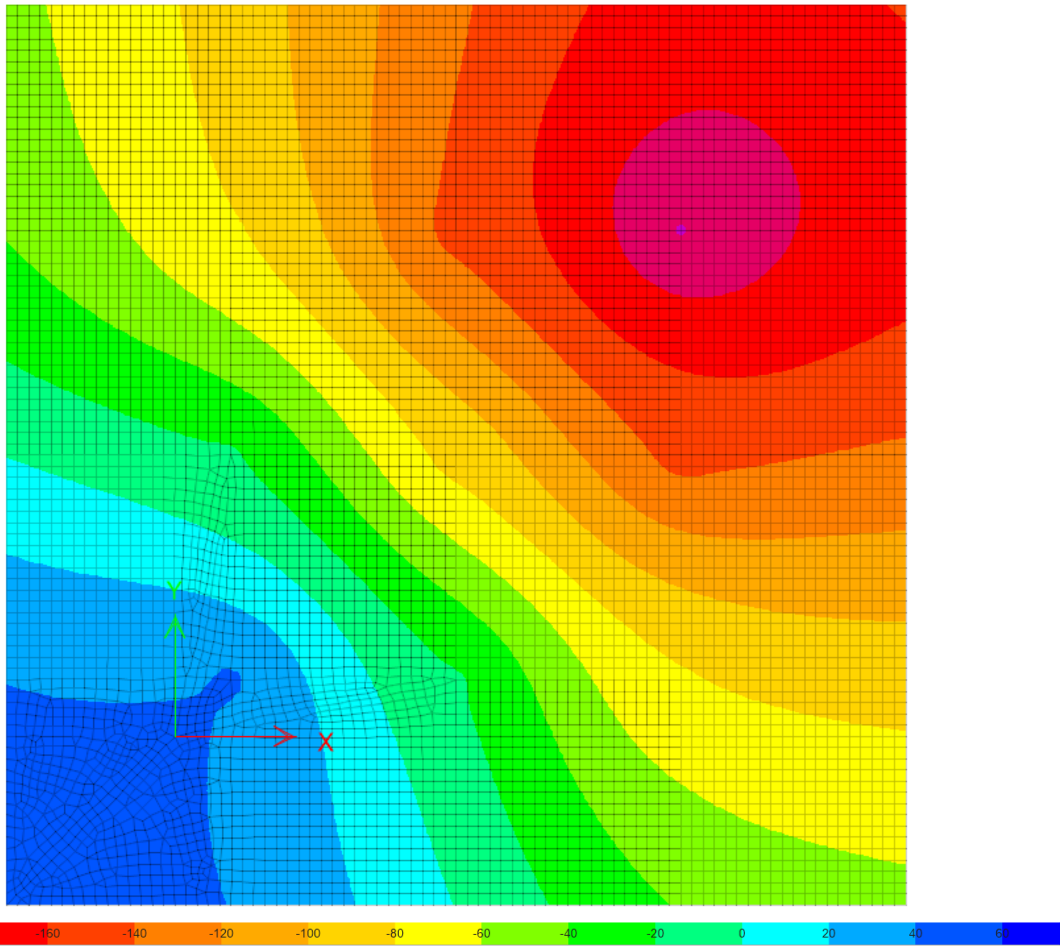


Figure 6.4: Soil Pressure Distribution.

$q_{allowable} = 200kN/m^2$

$q_u = between + 52kN/m^2 \ to \ -126kN/m^2 \ \rightarrow \ 126 < 200 \rightarrow OK.$

The presence of both positive and negative soil pressures can induce overturning moments. To counteract this and enhance stability, incorporating piles into the foundation is essential. Piles transfer loads to deeper, stable soil layers, mitigating the risk of tilting or collapse due to uneven soil pressures.

Check Punching shear

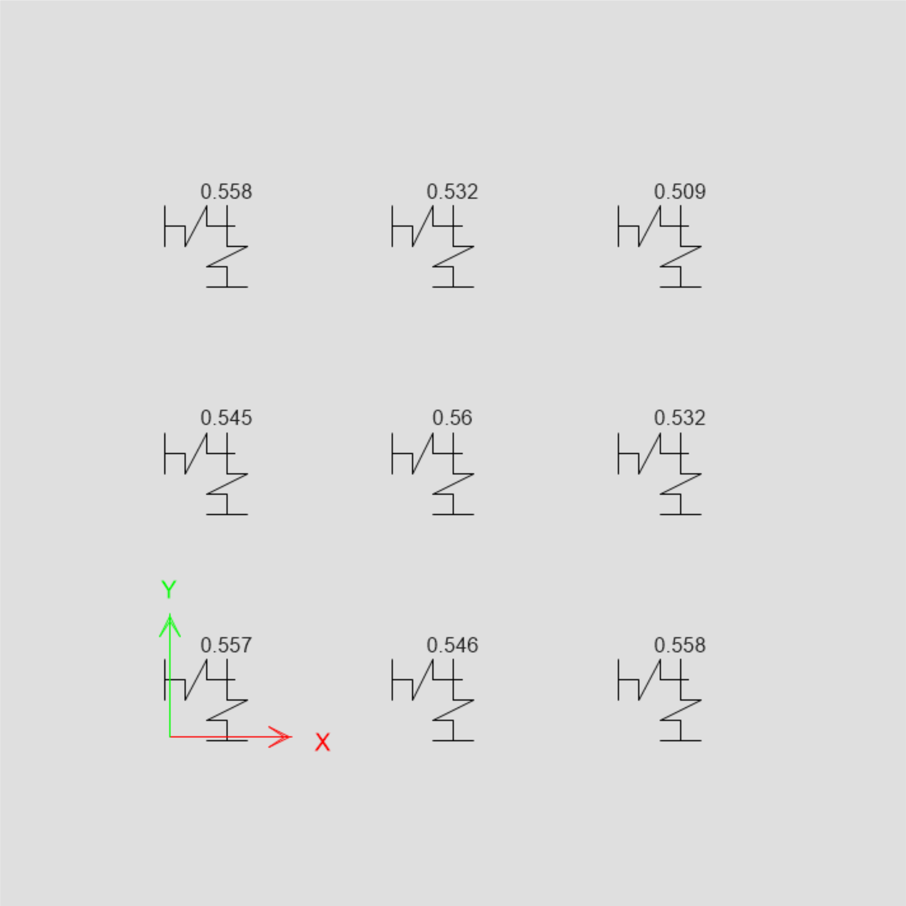


Figure 6.5: Punching shear D/C Ratios.

Ensure that the punching shear values for the mat foundation, as depicted in the image, are all below one. it indicates that the foundation's design is within acceptable limits.

Check One-Way Shear

Assume $d = h - 100\,mm$

$$\emptyset V_c = 0.75 \times 0.66 \times \lambda \times \lambda_s \times \rho^{\frac{1}{3}} \times b \times d \times \sqrt{f_c^{'}}$$

$$\emptyset V_c = 0.75 \times 0.66 \times 1 \times 1 \times 0.002^{\frac{1}{3}} \times 1000 \times 1400 \times \frac{\sqrt{28}}{1000} = 462kN$$

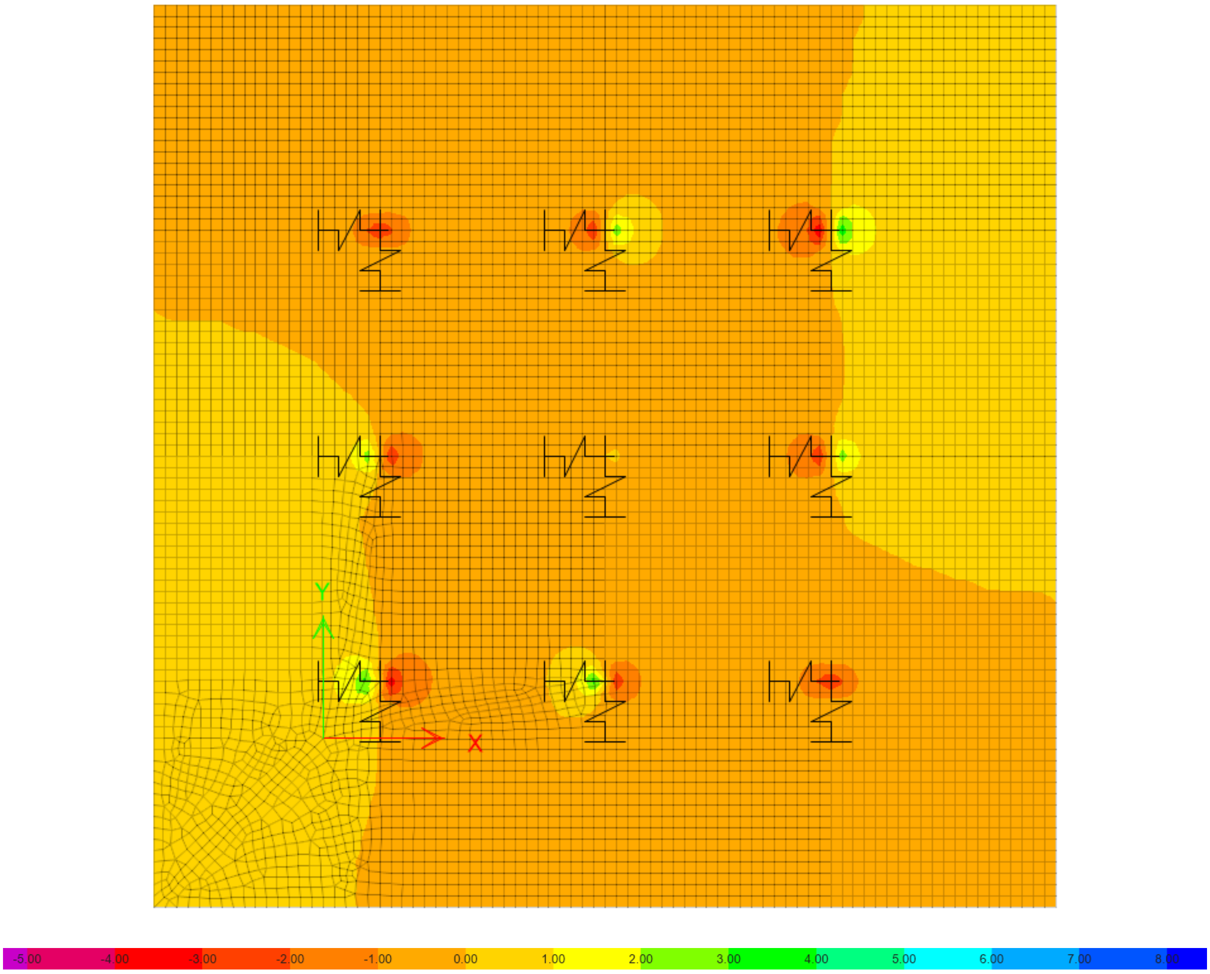


Figure 6.6: One-way shear (V23).

All values of shear values are too small, just near columns accordance of d distance had a high shear value which can be neglected. As a result, no need for shear reinforcement.

Mat Foundation Reinforcement

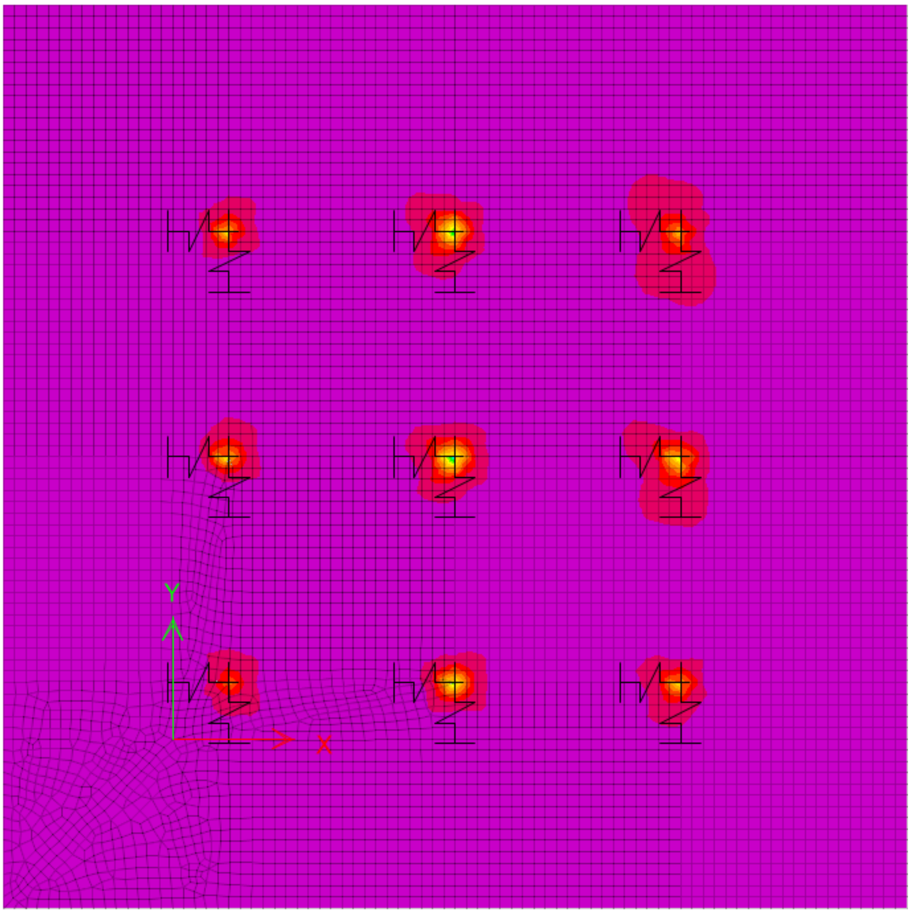


Figure 6.7: Mat foundation reinforcement

	Top	Bottom
Direction-X	1Ø25/150mm	1Ø25/150mm
Direction-Y	1Ø25/150mm	1Ø25/150mm

6.3.1 Pile Foundation

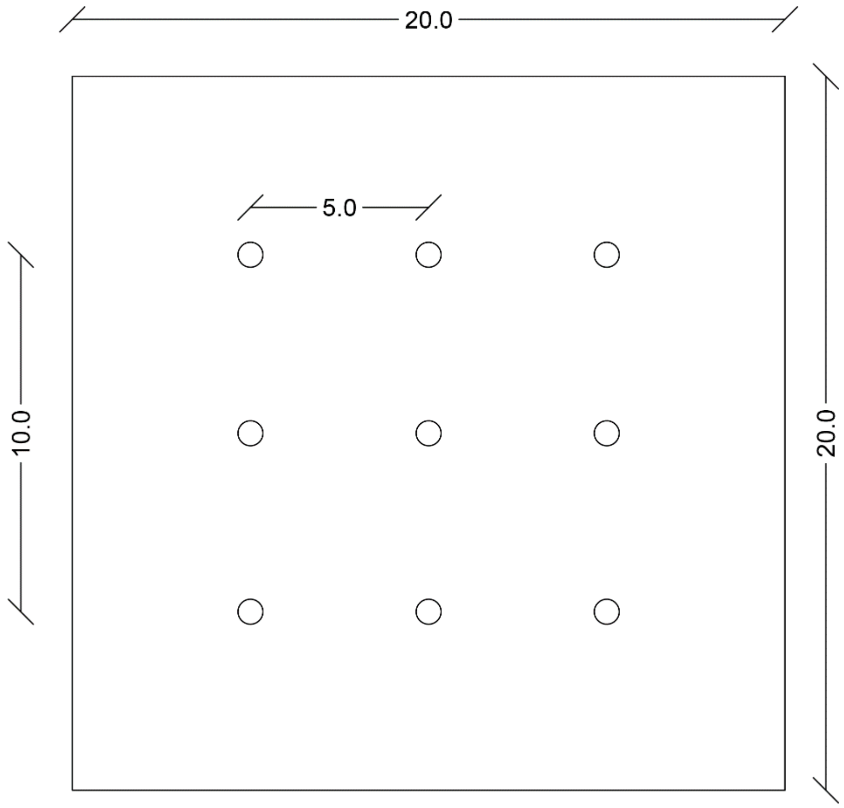


Figure 6.8: Mat foundation with Piles plan

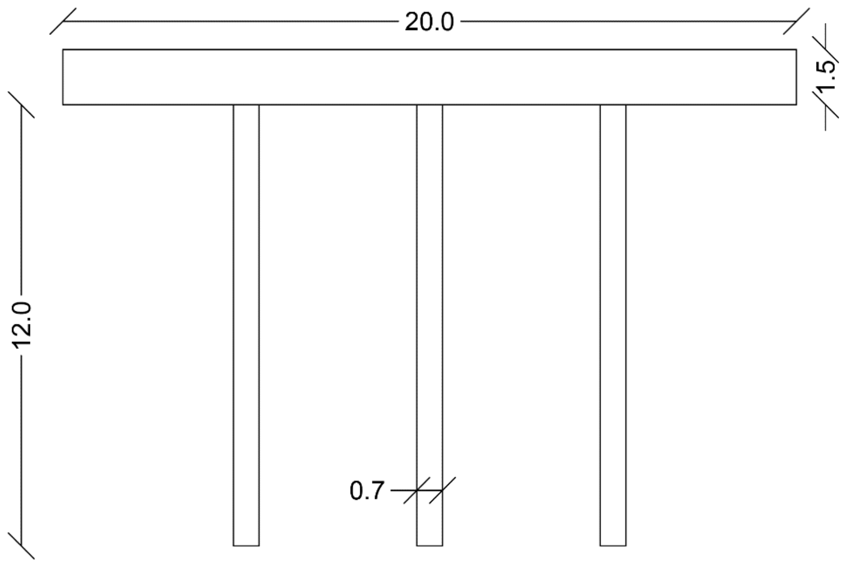


Figure 6.9: section cut for foundation

Piles Specifications:

Diameter = 0.7m, Length = 12m

Group Piles Capacity:

$\sum Q_u = n_1 n_2 [9 A_p c_u + 2(\alpha p c_u L)]$

$\sum Q_u = 3 \times 3[9 \times 0.385 \times 39 + 2 \times (0.74 \times 2.2 \times 39 \times 12)]$

$\sum Q_u = 14930.5 kN$

$FS = 4$

$\sum Q_{allowble} = \frac{14930.5}{4} = 3732.6\ kN$

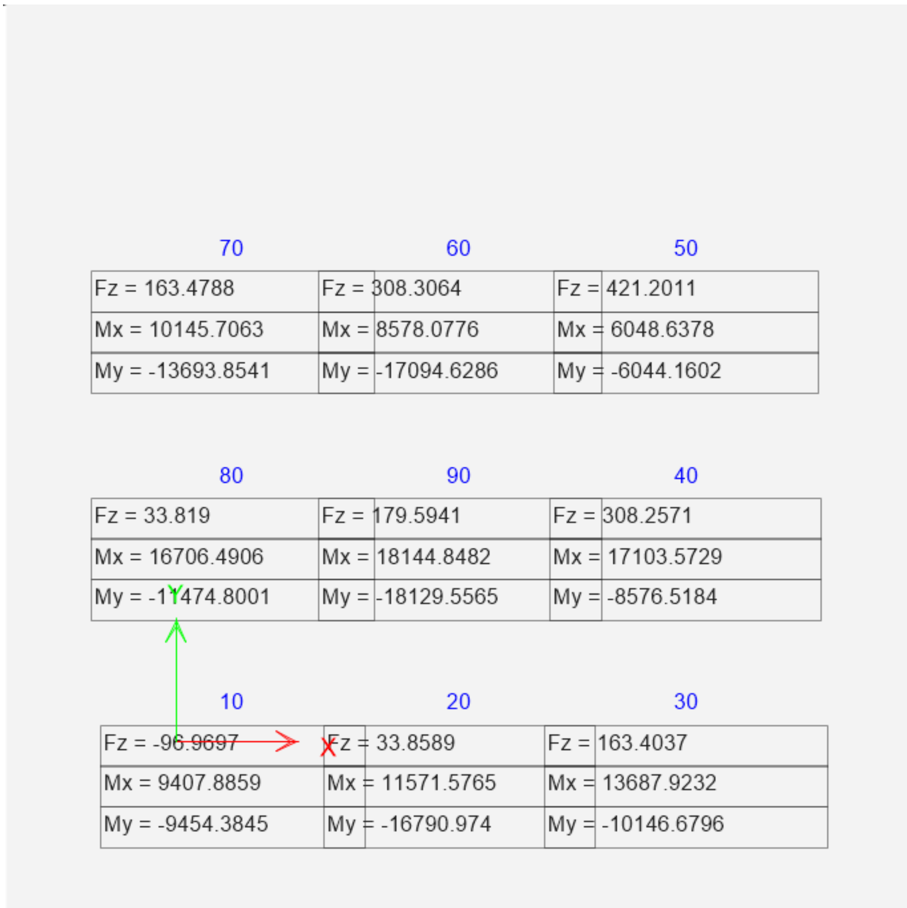


Figure 6.10: Base reaction

$$Piles\ load = 2079 kN$$

$$Since\ 3732.6 > 2079\ \rightarrow safe$$

The pile group's allowable load of 3732.6 kN above the ultimate load of 2079 kN, demonstrating adequate capacity and safety margin for the design.

Piles reinforcement:

Bars: 12Ø25, Spiral: Ø10

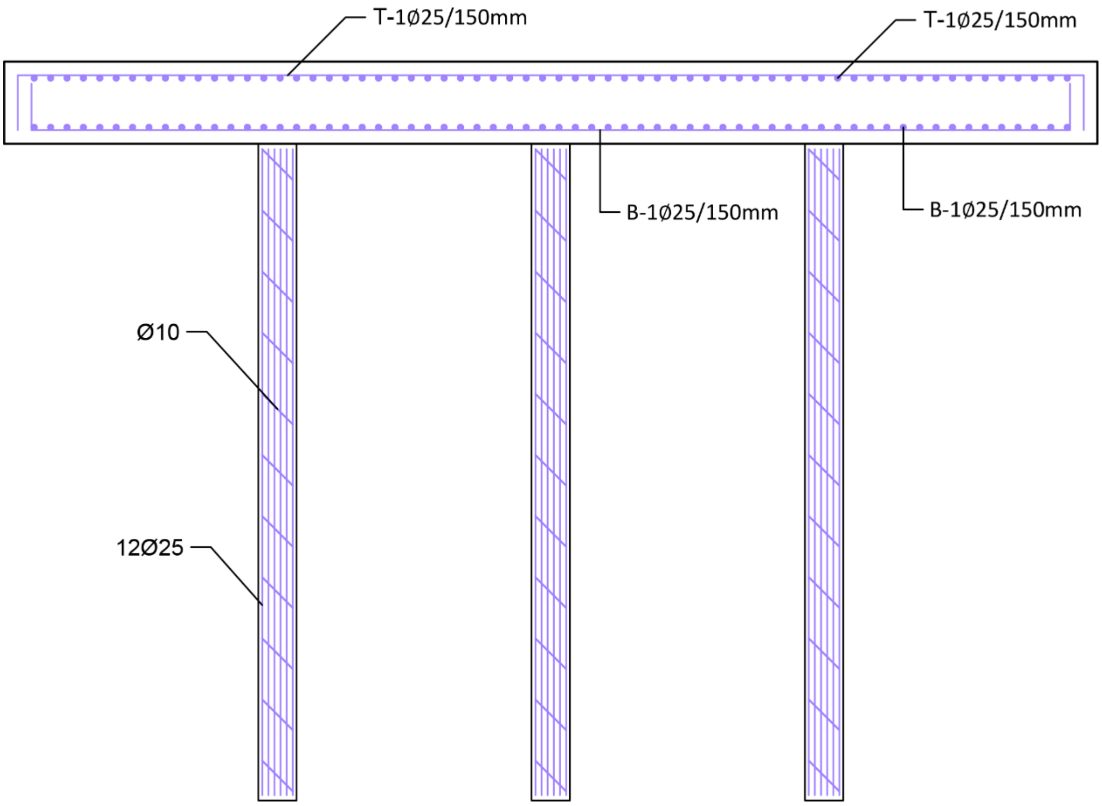


Figure 6.11: section cut reinforcement

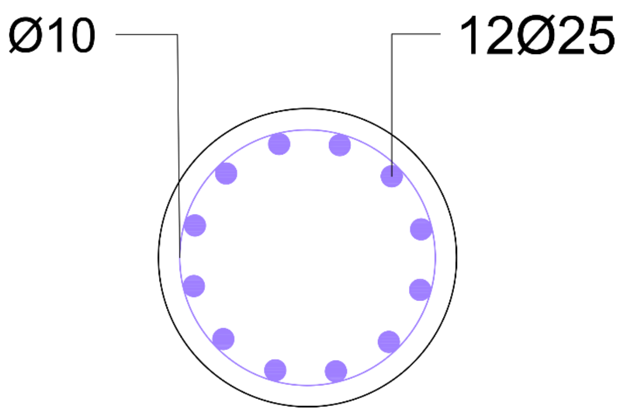


Figure 6.12: Section cut Piles reinforcement

Elastic settlement

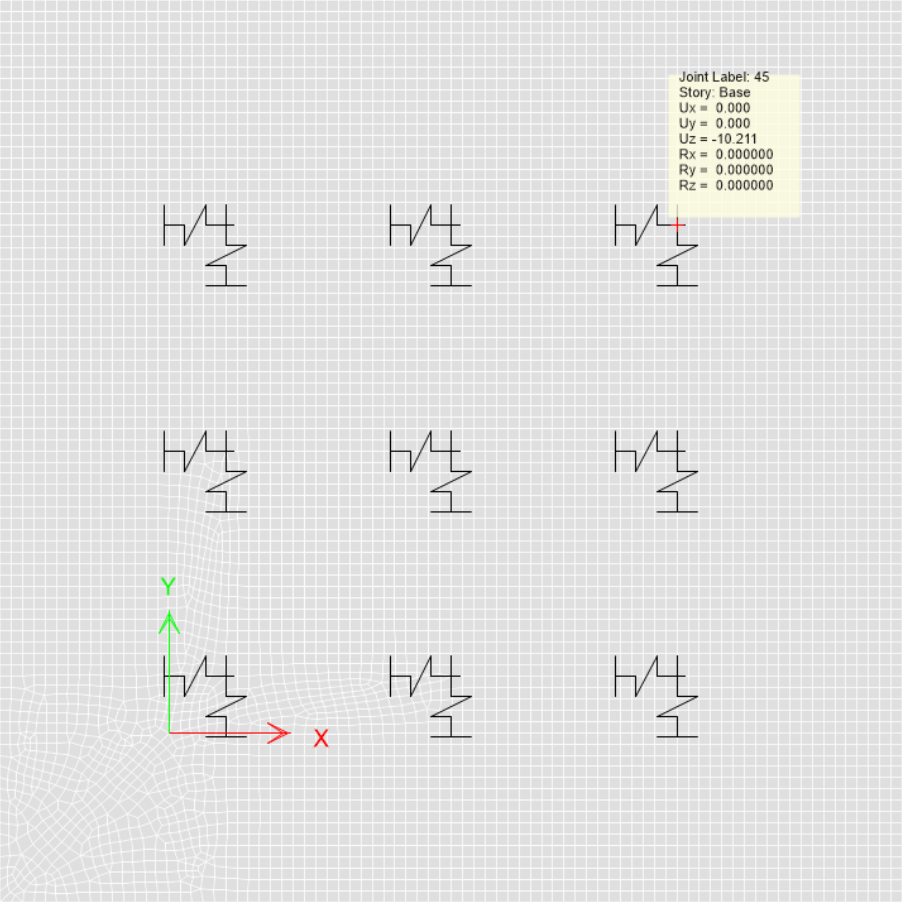


Figure 6.13: Displacement from ETABS.

Elastic settlement = 10.21mm.

The elastic settlement of 10.21 mm is within the acceptable range for pile foundations, indicating satisfactory foundation performance and a good safety margin.