



An-Najah National University
Faculty of Engineering
Civil Engineering Department

GRADUATION PROJECT

*Stadium of Nablus municipal city stands covering
and building parking*

Prepared By:

ZAID ABU-EISHA

DANA BARKAT

Submitted To: ***DR. Monther Diab***

Abstract

This abstract introduces a project centered on revitalizing an existing football stadium to become a cornerstone of urban life and entertainment. The project involves a comprehensive renovation, including the installation of a roof cover to ensure year-round functionality and the enhancement of spectator experience. Challenges such as structural modifications, cost management, aesthetic integration, parking constraints, traffic management, community engagement, and environmental impact are addressed through innovative solutions and community collaboration. The goal is to create a vibrant, inclusive space that not only enriches the fan experience but also contributes positively to the surrounding urban environment. Through strategic planning and implementation, the project aims to transform the stadium into a dynamic hub for sports, culture, and community engagement, revitalizing the urban landscape and fostering a sense of pride and belonging among residents.

The project encompasses the comprehensive enhancement of a football stadium, focusing on both covering the stadium and constructing a multi-level parking facility. The stadium cover is designed to provide optimal shelter from weather elements, enhancing the comfort and overall experience for attendees. This addition ensures that the stadium can be used year-round, regardless of weather conditions. Alongside the stadium cover, constructing a multi-level parking facility to support the stadium's needs. This parking structure will significantly improve accessibility and convenience for visitors, with ample parking spaces designed to accommodate the expected number of attendees.

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Ch1: introduction

1.1 location

1.1.1 Nablus

Nablus is located at the northern part of the West Bank. Nablus is bounded by Jenin from the north, Tulkarem from the northwest bound; Tubas from the north east, Jericho from the east, Ramallah from the south, Salfit and Qalqilya from the west.

Nablus is located in a strategic position between Mount Ebal and Mount Gerizim, it is the capital of the Nablus Governorate and a Palestinian commercial and cultural center, Nablus Governorate has a total area of (607 km²), which forms approximately (11%) of the area of West Bank, has nine distinctive major land use. These include the Palestinian built-up areas, Israeli settlements, closed military areas and military bases, nature reserves, forests and cultivated areas.

The city lies in a strategic position at a junction between two ancient commercial roads; one linking the Sharon coastal plain to the Jordan valley, the other linking The city stands at an elevation of around 550 meters (1,804 ft) above sea level, in a narrow valley running roughly east-west between two mountains: Mount Ebal, the northern mountain, is the taller peak at 940 meters (3,084 ft), while Mount Gerizim, the southern mountain, is 881 meters (2,890 ft)

1.1.2 Nablus municipal stadium

The Nablus Football Stadium is a football stadium in [Nablus, West Bank, Palestine](#). It has a capacity of 4,000. The stadium is home to the city's football club [al-Ittihad](#), which is in the main league in [Palestine](#). The club participated in the [Middle East Mediterranean Scholar Athlete Games](#) in 2000. This stadium, which was constructed in 1950, is the 1st stadium in Palestine, in 2009 it was rebuilt and expanded to meet the FIFA standards. The development of the stadium has made its capacity to be 4,000 and the whole project cost was 1.5 M \$.



Figure 1.1.2.a: Nablus Municipal Stadium

1.2 Preface

The football stadium stands Cover and stadium parking Project represents a transformative endeavor aimed at revitalizing an iconic landmark within the urban landscape. Situated at the heart of the city, the stadium holds a significant place not only in the realm of sports but also as a cultural and social hub for the community. Its importance transcends the boundaries of athletics, influencing various aspects of city life and serving as a symbol of civic pride.

Beyond its role as a venue for sporting events, the stadium acts as a catalyst for economic growth and development, attracting visitors,

businesses, and investment to the surrounding area. It serves as a focal point for tourism, drawing fans from near and far to experience the excitement of live sporting competitions and entertainment events. Additionally, the stadium contributes to the local economy by generating revenue through ticket sales, concessions, and merchandise, bolstering businesses and creating job opportunities within the vicinity.

Moreover, the stadium serves as a platform for cultural exchange and community engagement, bringing people together from diverse backgrounds to share in the collective experience of cheering on their favorite teams and athletes. It fosters a sense of unity and camaraderie among residents, strengthening social bonds and promoting inclusivity and belonging within the community.

Furthermore, the stadium plays a vital role in shaping the urban fabric and identity of the city, serving as a recognizable landmark that symbolizes its spirit and character. Its presence contributes to the vibrancy and dynamism of the surrounding area, enhancing the quality of life for residents and visitors alike.

In light of its multifaceted importance, the renovation and enhancement of the stadium are not merely about improving athletic facilities but about investing in the overall well-being and vitality of the city. By modernizing its infrastructure, enhancing its amenities, and ensuring its usability in all weather conditions, we aim to elevate the stadium to new heights of excellence, cementing its legacy as a cherished asset for generations to come.

Ch2: Methodology

2.1 Site visit

Our team conducted a comprehensive site visit for The football stadium stands Cover and parking. The aim was to assess the current condition of the stadium and evaluate the feasibility of both renovating the existing infrastructure and installing a roof cover to enhance spectator experience and ensure all-weather usability.

The site visit had dual purposes: firstly, to assess the condition of the stadium for potential renovation needs, and secondly, to evaluate the site's suitability for installing a roof cover. The primary objectives included analysing structural integrity, identifying challenges, assessing environmental factors, and gathering data to support the design and construction phases of both projects.

2.1.1 Site Assessment:

1. Structural Assessment:

We conducted a thorough examination of the stadium's structural framework to assess its capacity for both renovation and roof cover installation. This involved inspecting the condition of support columns, beams, and foundation to determine necessary modifications for both projects.

2. Site Conditions:

Evaluation of site conditions, including topography, soil composition, and surrounding infrastructure, was critical for both renovation and cover installation. Factors such as drainage,

accessibility, and safety were considered in the context of both projects.

3. Drainage and Water Management:

Assessing the drainage system was crucial for both projects to prevent water accumulation and ensure proper runoff. We examined existing drainage channels and evaluated their adequacy for both renovation and cover installation.

4. Environmental Impact:

An environmental assessment was conducted to identify potential impacts of renovation and cover installation on the surrounding ecosystem, air quality, and energy consumption. Sustainable design principles were explored to minimize environmental footprint for both projects.

2.2 Data collection

The objective of this data collection effort is to gather relevant information from the Municipal Office of Nablus City to support the planning and implementation of The football stadium stands Cover and parking. Key areas of interest include infrastructure, zoning regulations, transportation, and community engagement.

2.2.1 Data Collected:

1. Stadium Infrastructure:

- Assessment of the existing structural condition of the stadium, including any previous renovation or maintenance efforts.
- Documentation of the stadium's seating capacity, dimensions, and layout.
- Identification of any structural limitations or challenges that may impact renovation or cover installation.

2. Zoning Regulations:

- Review of municipal zoning ordinances and regulations applicable to the stadium site.
- Identification of any zoning restrictions or requirements related to construction, height limits, and land use.

3. Transportation Infrastructure:

- Assessment of the transportation infrastructure surrounding the stadium, including road networks, public transportation routes, and pedestrian access.
- Documentation of traffic flow patterns, congestion points, and existing transportation services during stadium events.

5. Community Engagement:

- Review of past community engagement initiatives related to the stadium, including public consultations, stakeholder meetings, and feedback mechanisms.
- Documentation of community priorities, concerns, and preferences regarding stadium renovation and cover installation.
- Identification of opportunities for community involvement and partnership in the project planning and implementation process.

The data collected from the Municipal Office of Nablus City provides valuable insights into various aspects of the Football Stadium Renovation and Cover Project, including infrastructure, zoning regulations, transportation, and community engagement. This information will inform the development of comprehensive plans and strategies to address key challenges and leverage opportunities for successful project implementation.

Ch3: Objectives

1. Design and Build Parking Services for the Stadium and the surrounding:

An additional objective is to design and construct parking facilities to serve the stadium and the surrounding city. This includes assessing parking demand, identifying suitable locations for parking structures or lots, and designing efficient parking layouts to accommodate stadium attendees and alleviate parking congestion in the

surrounding area. Emphasis will be placed on integrating parking facilities seamlessly into the urban fabric, promoting pedestrian connectivity, and enhancing overall accessibility to the stadium and adjacent amenities. Collaboration with local authorities, urban planners, and transportation agencies will be essential to ensure the success of this objective while meeting the needs of both stadium visitors and the broader community.

2. Covering the Western Amphitheatre:

The primary objective of this phase is to design and implement a roof cover for the Western Amphitheatre of the football stadium. This includes assessing structural requirements, engineering solutions, and aesthetic considerations to provide shelter and enhance spectator experience for attendees seated in the Western section of the stadium. Key goals include ensuring structural integrity, optimizing sightlines, and integrating the cover seamlessly with the existing stadium architecture.

3. Covering the Eastern Amphitheatre:

The secondary objective focuses on covering the Eastern Amphitheatre of the football stadium, mirroring the efforts undertaken for the Western section. This phase involves conducting a thorough assessment of structural requirements, engineering feasibility, and aesthetic integration to provide consistent shelter and improved spectator comfort for attendees seated in the Eastern section of the stadium. Emphasis will be placed on maintaining design

continuity with the Western cover while addressing any unique challenges presented by the Eastern section.

Ch4: Challenges and Opportunities:

4.1 challenges and opportunities identified during site visit

Several common challenges and opportunities were identified during the site visit:

- **Structural Modifications:** Retrofitting the stadium for renovation and cover installation may pose technical challenges and require specialized engineering solutions.
- **Parking Constraints:** Providing adequate parking for stadium attendees poses a significant challenge, particularly in densely populated urban areas. Limited available space and existing parking infrastructure may necessitate creative solutions such as multi-level parking structures, shuttle services from remote parking lots, or partnerships with nearby parking facilities.
- **Parking Building Traffic Management:** The central location of the stadium within the city presents challenges for managing traffic flow and mitigating congestion during events. Coordination with local authorities and implementation of traffic management strategies, such as designated drop-off zones, public transportation incentives, and road closures, will be crucial to ensure smooth ingress and egress for attendees.

- **Cost Management:** Careful cost estimation and budget management are essential for both projects to ensure feasibility and financial sustainability.
- **Aesthetic Integration:** Balancing functional requirements with aesthetic considerations is crucial to ensure that both renovation and cover installation enhance the stadium's visual appeal.

The site visit provided valuable insights into the feasibility and requirements for both renovating the stadium and installing a roof cover. By addressing identified challenges and leveraging opportunities, we aim to develop a comprehensive plan that transforms the stadium into a modern, versatile, and all-weather venue for sports and entertainment.

4.2 Designing challenges

When designing the trusses for stands covering and build Parking Facilities for the Stadium, several potential problems and challenges may arise, including:

4.2.1 Challenges in Designing the stadium cover:

1. Structural Load and Stability:

- Ensuring that the trusses can support the additional load of the roof cover, including dead loads (the weight of the structure itself) and live loads (seismic, snow, wind, and maintenance equipment), is crucial.

- Stability and safety of the overall structure need to be maintained, preventing any risk of collapse or failure.

2. Material Selection:

- Choosing the right materials that provide the necessary strength, durability, and resistance to environmental factors while remaining cost-effective.

- Balancing between lightweight materials for ease of construction and heavy-duty materials for durability.

3. Design Complexity:

- Dealing with complex geometries and ensuring that the truss design is both structurally sound and aesthetically pleasing.

- Balancing architectural design with engineering requirements to maintain the stadium's visual appeal.

4. Environmental Factors:

- Accounting for local environmental conditions such as wind loads, seismic activity, and temperature variations, which can affect the truss design and materials.

- Ensuring proper drainage and waterproofing to protect the structure from weather-related damage.

5. Connection system:

- Addressing the challenges associated with welding, including ensuring the strength and durability of welds in various environmental conditions.

- Managing potential defects such as cracks, weak joints, and misalignments that could compromise the structural integrity of the trusses.

- Ensuring that welds meet stringent quality standards and that the welding process is carried out by skilled professionals to avoid safety risks.

4.2.2 Challenges in Designing the Parking Facilities:

1. space Constraints:

- Limited available land in the densely populated urban centre of Nablus may restrict the size and layout of parking facilities.

- Efficiently using the available space to maximize parking capacity while ensuring ease of access and manoeuvrability.

2. Traffic Flow and Congestion:

- Managing traffic flow in and out of the parking facility to prevent congestion, especially during peak event times.

- Designing entry and exit points that minimize disruption to local traffic patterns.

3. Accessibility:

- Ensuring that parking facilities are accessible to all, including individuals with disabilities, by incorporating ramps, designated parking spaces, and clear signage.

- Facilitating pedestrian access from parking areas to the stadium safely and efficiently.

4. Regulatory Compliance:

- Adhering to local building codes, zoning regulations, and safety standards throughout the design and construction process.
- Securing necessary permits and approvals from municipal authorities.

Addressing these challenges requires a holistic approach, combining innovative engineering solutions, thoughtful urban planning, and sustainable design practices to create a functional, safe, and aesthetically pleasing stadium and parking facilities.

Ch5: Types of parking

Structural parking facilities come in various types, each designed to address specific needs, site constraints, and user requirements. Here are some common types of structural parking:

1. Single-Level Surface Parking:

- Description: The simplest and most common type of parking, typically an open, paved area where vehicles are parked on a single level.
- Advantages: Low construction cost, easy to maintain, quick to build.
- Disadvantages: Requires large amounts of land, not efficient for high-density urban areas.



Figure 5.a: Single-Level Surface Parking

2. Multi-Level Parking Garage:

- Description: A parking structure with multiple levels or floors, either above or below ground.
- Advantages: Maximizes parking capacity in a limited footprint, efficient use of vertical space, can be designed to fit urban environments.
- Disadvantages: Higher construction costs, more complex maintenance and management, longer construction time.



Figure 5.b: Multi-Level Parking Garage

3. Underground Parking Garage:

- Description: Parking structures built below ground level.
- Advantages: Saves surface space for other uses, minimizes visual impact, can be integrated into building basements.
- Disadvantages: Very high construction costs, complex waterproofing and ventilation requirements, challenging excavation processes.

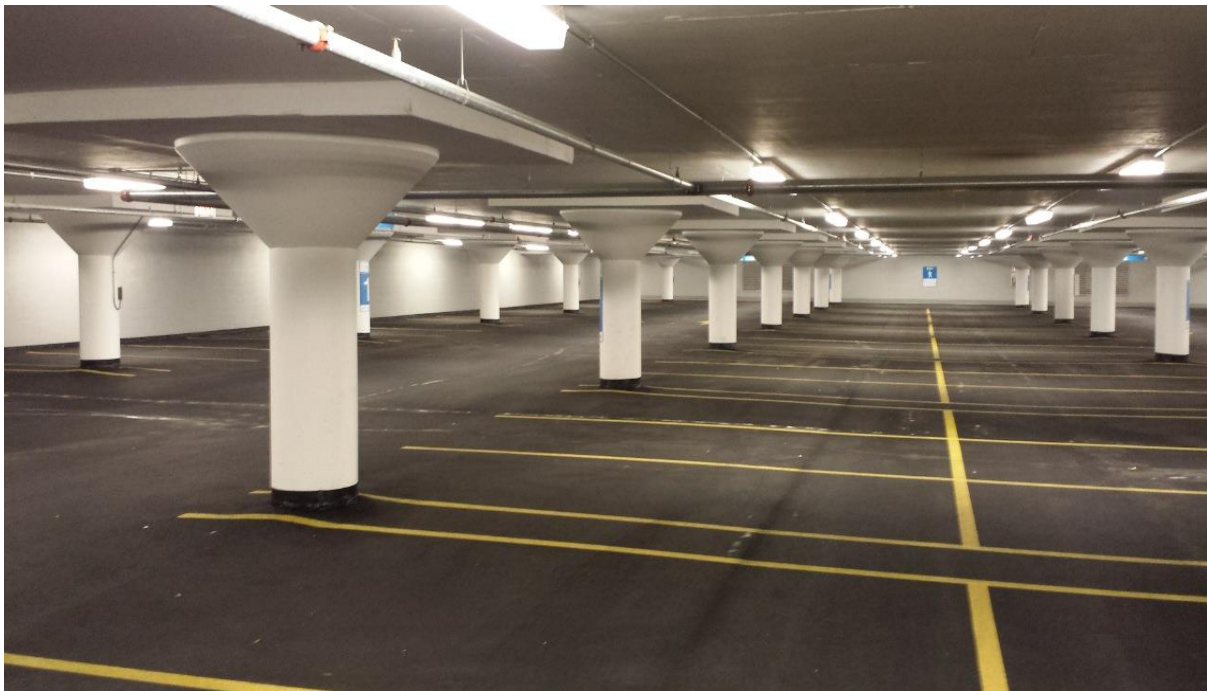


Figure 5.c: Underground Parking Garage

4. Automated (Robotic) Parking System:

- Description: A fully automated system where vehicles are parked and retrieved by mechanical systems without human intervention.
- Advantages: Maximizes space efficiency, can fit more cars in less space, reduces time spent searching for parking spots.
- Disadvantages: High installation and maintenance costs, requires specialized technology, potential for mechanical failures.



Figure 5.d: Automated (Robotic) Parking System

5. Deck Parking:

- Description: Parking on elevated platforms or decks, often found in urban settings.
- Advantages: Efficient use of vertical space, can be integrated into existing urban infrastructure, flexible design.
- Disadvantages: High construction and maintenance costs, potential structural load issues.



Figure 5.e: Deck Parking

Ch6: Parking design

Building a stadium parking facility is a crucial aspect of stadium infrastructure development, as it directly impacts the overall attendee experience, traffic flow, and the surrounding community. Stadium parking not only provides a convenient and safe space for attendees to park their vehicles but also plays a significant role in managing traffic congestion and ensuring efficient access to and from the venue. In this introduction, we will explore the key considerations and steps involved in the process of planning and constructing stadium parking facilities.

6.1 parking capacity

Calculating parking capacity is a fundamental step in the planning and design process of parking facilities, ensuring that adequate parking spaces are available to accommodate the needs of users while maintaining efficient traffic flow and minimizing congestion. Whether for stadiums, commercial developments, or urban areas, understanding the factors involved in determining parking capacity is essential for effective parking management. In this introduction, we will explore the key considerations and methodologies used in calculating parking capacity.

6.1.1 parking capacity demand percentage

Parking capacity calculation begins with an assessment of parking demand, which is influenced by various factors such as the type of development, land use, population density, and transportation patterns. By analyzing these factors, planners can estimate the number of parking spaces required to meet the anticipated demand during peak periods.

6.1.2 Using MetLife Stadium Parking Demand Percentage

MetLife Stadium, located in East Rutherford, New Jersey, has an approximate seating capacity of 82,500 seats and uses a parking demand percentage of around 20%. This percentage is reflective of

the balance between accommodating a large number of attendees and the availability of alternative transportation options, such as public transit and ride-sharing services. Given the comprehensive parking management strategies employed by MetLife Stadium, its demand percentage serves as a reliable benchmark for our calculation.

Nablus municipal Stadium Capacity

- Nablus municipal Stadium Capacity: 4,000 seats
- Parking Demand Percentage (based on MetLife Stadium): 20%

6.1.3 Calculating Parking Capacity

To calculate the parking capacity for our stadium project, we will apply the 20% parking demand percentage to our stadium's seating capacity.

1. Calculate Number of Cars Needed:

$$4,000 * 0.20 = 800 \text{ cars} = 800 \text{ spaces (at least)}$$

6.2 chosen parking type

As previously mentioned, the types of parking facilities include Single-Level Surface Parking, Multi-Level Parking Garages, Underground Parking Garages, Automated (Robotic) Parking Systems, and Deck Parking. We have discussed these types in detail, highlighting their advantages and disadvantages.

For this project, we have chosen the Multi-Level Parking Garage and Multi-Level Underground Parking Garage. The Multi-Level Parking Garage offers significant advantages, including efficient land use by maximizing vertical space and accommodating a large number of vehicles within a smaller footprint. This type also enhances security and provides weather protection for vehicles. Similarly, the Multi-Level Underground Parking Garage preserves surface space for other uses, such as green spaces or additional infrastructure, while still maximizing parking capacity. It offers a discrete solution that minimizes the visual impact of parking facilities on the surrounding area. Additionally, multi-level underground garages can provide a cooler environment, protecting vehicles from extreme weather conditions. Both types of parking solutions enhance the overall functionality and aesthetic appeal of the stadium, catering to the needs of attendees while optimizing available space.

6.3 design of parking facilities – surface car parks

Designing surface car parks involves careful consideration of various factors to ensure efficient use of space, ease of access, safety, and optimal traffic flow. One key aspect of surface car park design is the

angle of parking spaces, which can significantly impact the overall layout and functionality of the parking area. The angles of parking spaces typically range from 30 degrees to 90 degrees, each offering distinct advantages and considerations.

1. 90-Degree Parking:

- Advantages:

- Maximizes the number of parking spaces within a given area.
- Suitable for both one-way and two-way traffic flow.
- Provides the most direct access to parking spaces.
- Easy to navigate and reverse out of for most drivers.

- Considerations:

- Requires more space for maneuvering, particularly in terms of aisle width.
- Not ideal for high-traffic areas due to potential congestion in the aisles.

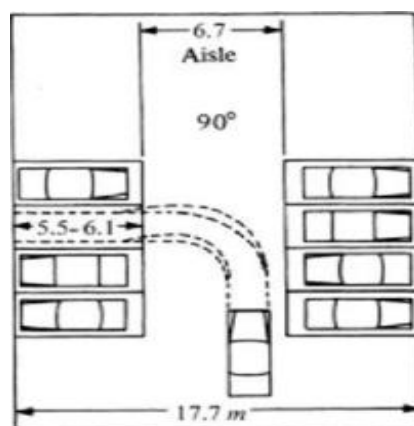


Figure 6.3.a: 90-Degree Parking

2. 60-Degree Parking:

- Advantages:

- Offers a balance between space efficiency and ease of access.
- Reduces the required aisle width compared to 90-degree parking.
- Easier to enter and exit than 90-degree spaces.

- Considerations:

- Slightly fewer spaces per row compared to 90-degree parking.
- More suitable for one-way traffic flow.

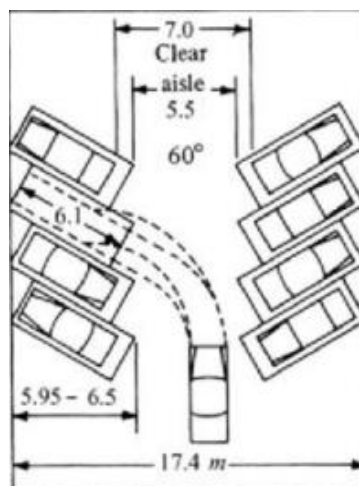


Figure 6.3.b: 60-Degree Parking

3. 45-Degree Parking:

- Advantages:

- Very easy for drivers to maneuver into and out of spaces.
- Requires less aisle width, which can save space.
- Promotes smooth traffic flow, particularly in one-way systems.

- Considerations:

- Fewer parking spaces per row compared to 60-degree and 90-degree parking.
- Ideal for areas where ease of access and quick turnover are priorities.

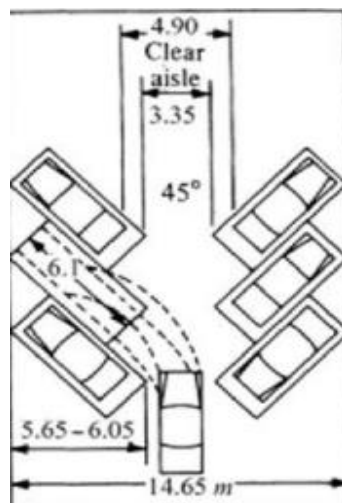


Figure 6.3.c: 45-Degree Parking

4. 30-Degree Parking:

- Advantages:

- Simplest for drivers to enter and exit.
- Requires the least amount of aisle width.
- Facilitates fast and efficient traffic flow.

- Considerations:

- Least efficient in terms of the number of parking spaces per row.
- Best suited for short-term parking or low-traffic areas.

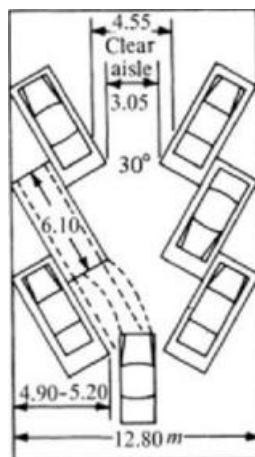


Figure 6.3.d: 30-Degree Parking

6.4 Design Considerations

- Space Dimensions:

- Standard parking space dimensions typically range from 2.4 to 2.7 meters in width and 5.5 to 6.0 meters in length.

- Accessible spaces should be wider to accommodate wheelchair access, typically around 3.6 meters wide.

- Aisle Width:

- Aisle width varies based on the angle of parking spaces. For 90-degree parking, a wider aisle (typically 6.7 meters) is necessary, whereas angled parking spaces (e.g., 45-degree) can function with narrower aisles (e.g., 3.6 to 5.5 meters).

We have chosen 90-degree parking for our project because of its numerous advantages. This configuration maximizes the number of parking spaces within the given area, making the most efficient use of available space. It provides the most direct access to parking spaces, making it easy for drivers to navigate and reverse out. Additionally, 90-degree parking is suitable for both one-way and two-way traffic flow, offering flexibility in design. For our parking spaces, we have selected dimensions of 2.4 meters in width and 5.5 meters in length, ensuring ample room for vehicles. To facilitate smooth and safe traffic flow, we have set the minimum aisle width at 6.7 meters and chosen a two-way traffic flow to enhance accessibility and convenience for users. This design balances space efficiency, ease of access, and user convenience, making it an optimal choice for our parking facility.

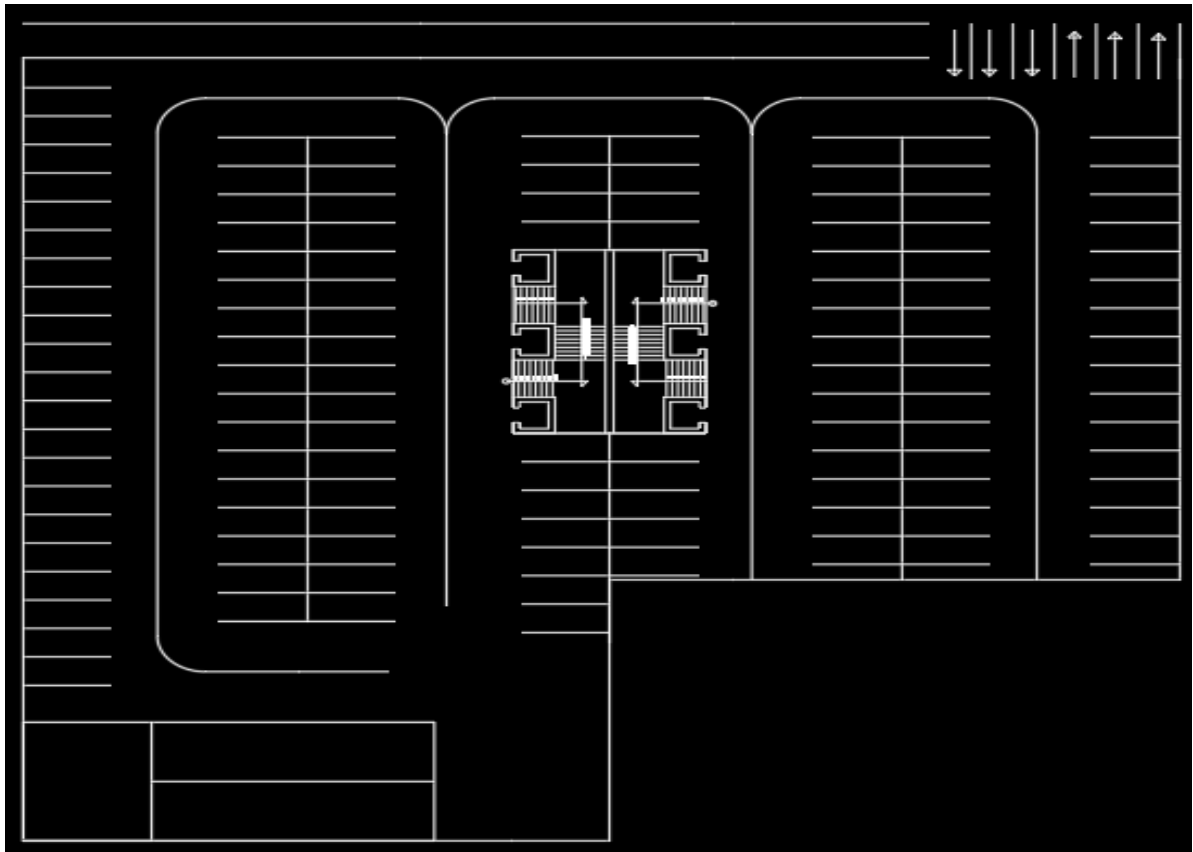


Figure 6.4.a: Design Considerations

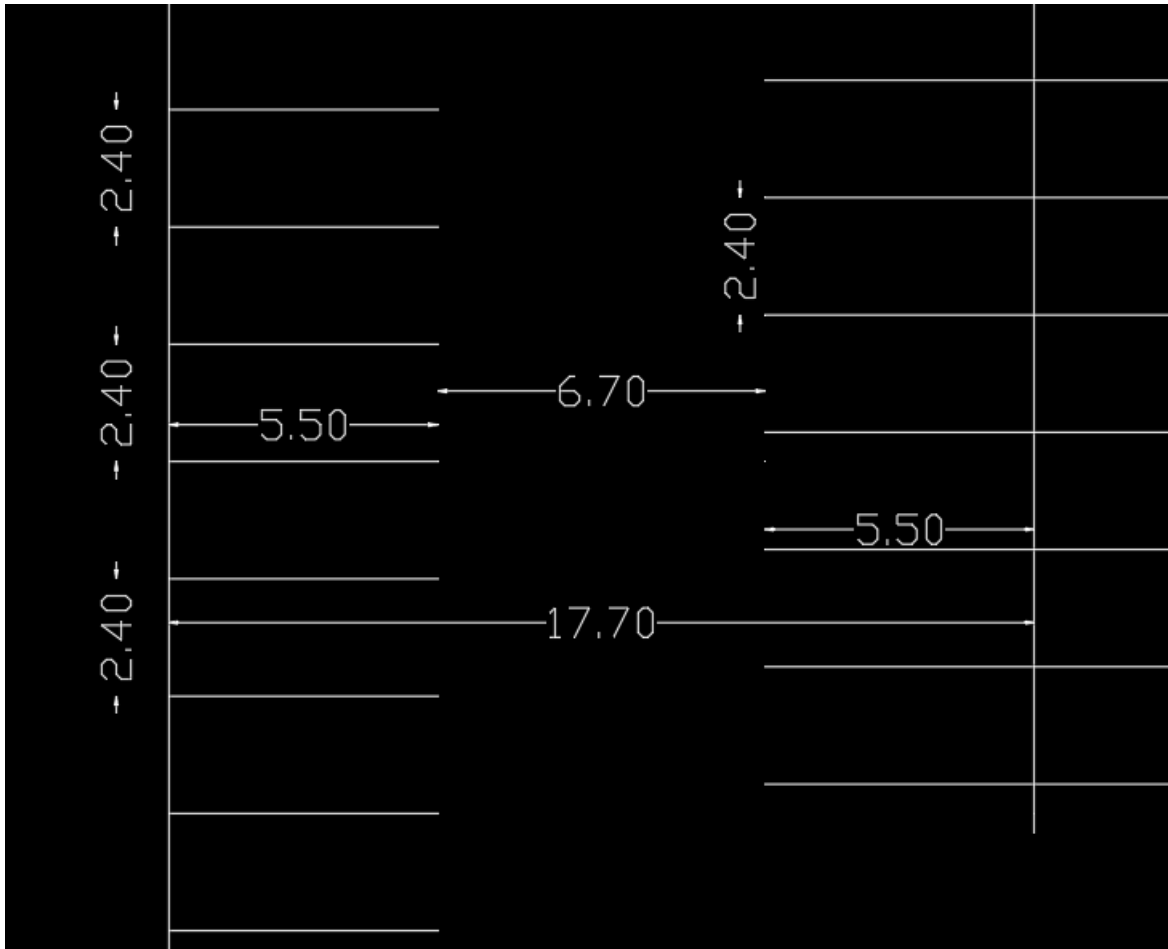


Figure 6.4.b: Space Dimensions

References

Transportation 1

6.5 parking system

To create a simple and efficient entry system for the parking facility, we can implement a ticket-based system with floor and parking space identifiers. Here's how the system would work:

1. Automated Entry Gates:

- Install automated entry gates equipped with ticket dispensers at the entry points.



Figure 6.5.a: Automated Entry Gates

2. Ticket Issuance:

- When a vehicle approaches the entry gate, the driver presses a button to receive a ticket.
- The ticket will have a letter indicating the floor (e.g., A for the ground floor, B for the first floor) and a number indicating the specific parking space (e.g., A23 for ground floor space 23).



Figure 6.5.b: Ticket Issuance

3. Clear Signage and Directions:

- Place clear and visible signage at the entrance and throughout the parking facility to guide drivers. Include lane markings, directional arrows, and entry/exit points.
- Use digital displays to provide real-time information on available parking spaces and their locations.



Figure 6.5.c: Clear Signage and Directions

4. Parking Space Allocation:

- Upon entering, drivers follow the signage to their designated floor.
- Once on the correct floor, additional signs and markings guide them to their specific parking space.

5. Security and Assistance:

- Ensure the presence of security personnel or automated assistance booths at the entry points to help users with any issues or questions they may have.
- Install intercom systems at the entry gates for immediate assistance if needed.

6. Payment Options:

- Pay at Entry:
 - Drivers have the option to pay for parking upon entry. Payment can be made via automated machines at the entry gate using credit/debit cards, mobile payment apps, or cash.
 - After payment, the ticket is validated for exit without additional steps.
- Pay at Exit:
 - Alternatively, drivers can choose to pay when exiting. Upon leaving, they insert their ticket into the exit gate machine, which calculates the parking fee based on the time spent and prompts the driver to make a payment.
 - After payment, the gate opens, allowing the driver to exit the parking facility.

6.5.1 Example Entry Process:

1. Approach the Gate:

- Drivers approach the automated entry gate.

(Refer to figure 6.5.a)

2. Ticket Issuance:

- Drivers press a button on the ticket dispenser to receive a ticket.
- The ticket indicates the designated floor with a letter (e.g., A for the ground floor) and the specific parking space with a number (e.g., A23 for ground floor space 23).

(refer to figure 6.5.b)

3. Enter the Parking Facility:

- The gate opens, and drivers proceed to the designated floor, guided by clear signage and digital displays showing available spaces.



A digital display showing the status of parking spaces. The display is divided into two columns by a vertical line. The left column lists parking lots A, B, C, and D. The right column lists parking lots E, F, G, and H. The word 'LOT' is displayed in blue on the left, and 'Spaces Available' is displayed in green on the right. The status of each lot is shown in green or red text.

LOT	Spaces Available
A	2
B	44
C	Full
D	78
E	90
F	3
G	34
H	Full

Figure 6.5.1.a: digital display

4. Park in Designated Space:

- Drivers park in the allocated space as indicated on their ticket.



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Figure 6.5.1.b: Parking with labelled Spaces

5. Payment Options:

*Pay at Entry:

- Upon entering, drivers can pay for parking at the entry gate using various payment methods. The ticket is then validated for exit.

*Pay at Exit:

- When ready to leave, drivers proceed to the exit gate. They insert the ticket into the exit gate machine, which calculates the fee and prompts for payment. After payment, the gate opens, allowing the driver to exit.

Advantages:

***Efficient Space Management:**

- Pre-designated parking spaces prevent overcrowding and ensure efficient use of available parking areas.

***Clear Guidance:**

- Clear signage and ticket information guide drivers directly to their designated spots, reducing the time spent searching for a parking space.

***Enhanced Security:**

- Controlled entry and exit points improve security by monitoring vehicle movements and preventing unauthorized access.

***Flexible Payment Options:**

- Providing both entry and exit payment options caters to different user preferences, enhancing convenience.

By implementing this ticket-based system with flexible payment options, we can create an organized and user-friendly parking facility that enhances convenience for all users.

6.6 parking layout

After finalizing the design with 90-degree parking, we laid out the columns and achieved a layout with 108 parking spaces per floor. With this configuration, we opted for 7 floors, resulting in a total of 750 parking spaces. Additionally, we dedicated one floor specifically for people with special needs, providing 52 parking spaces with a width of 3.5 meters, along with 35 regular spaces. Therefore, the total number of parking spaces across the 8 floors equals 830, which exceeds the minimum requirement of 800 spaces we initially assumed.

We decided to set the height of each floor at 3 meters. The parking structure is divided into two distinct sections:

1. First Section:

- Consists of 4 floors starting at the level of 104 meters.
- The first floor in this section is dedicated to people with special needs, with 52 specially designed parking spaces and 35 regular spaces.
- These four floors share the same entry and exit points, optimizing accessibility for all users.
- Each section has a ramp with a width of 7 meters and a slope of 8%, and turning radius of 6.5 m, allowing cars to move within their designated sections only.

Grand floor:

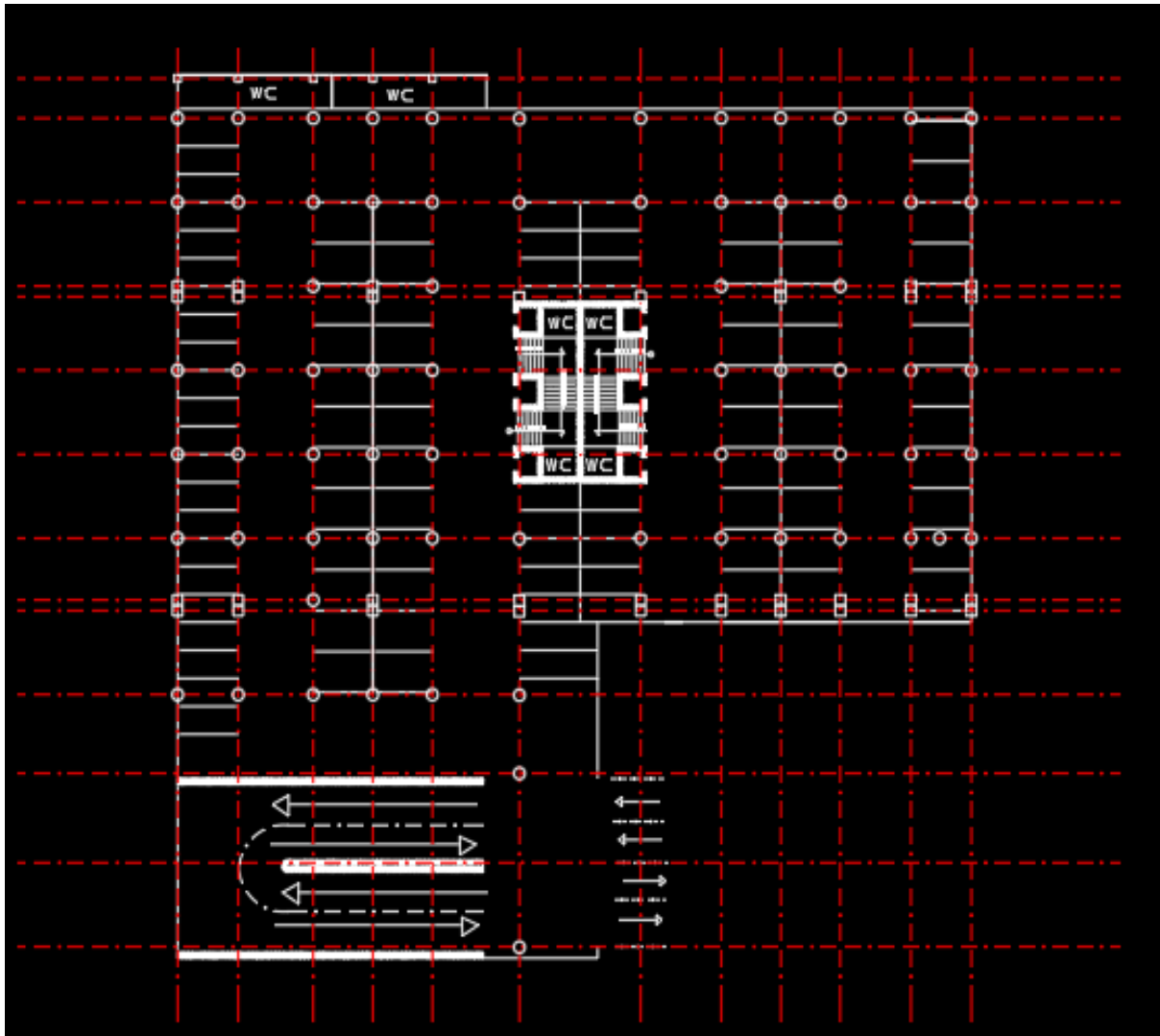


Figure 6.6.a: Grand Floor

1st floor:

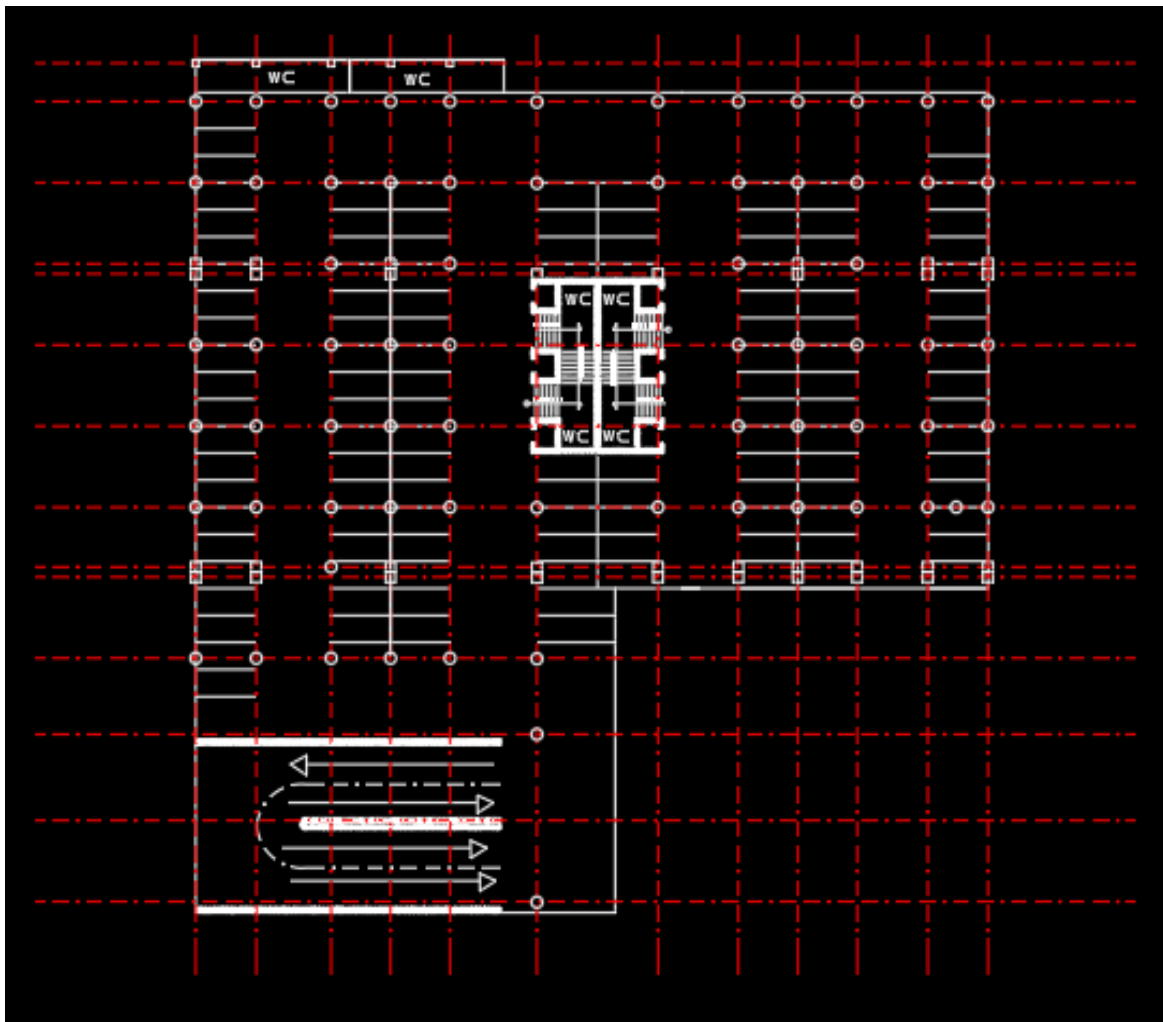


Figure 6.6.b: 1st Floor

2nd floor:

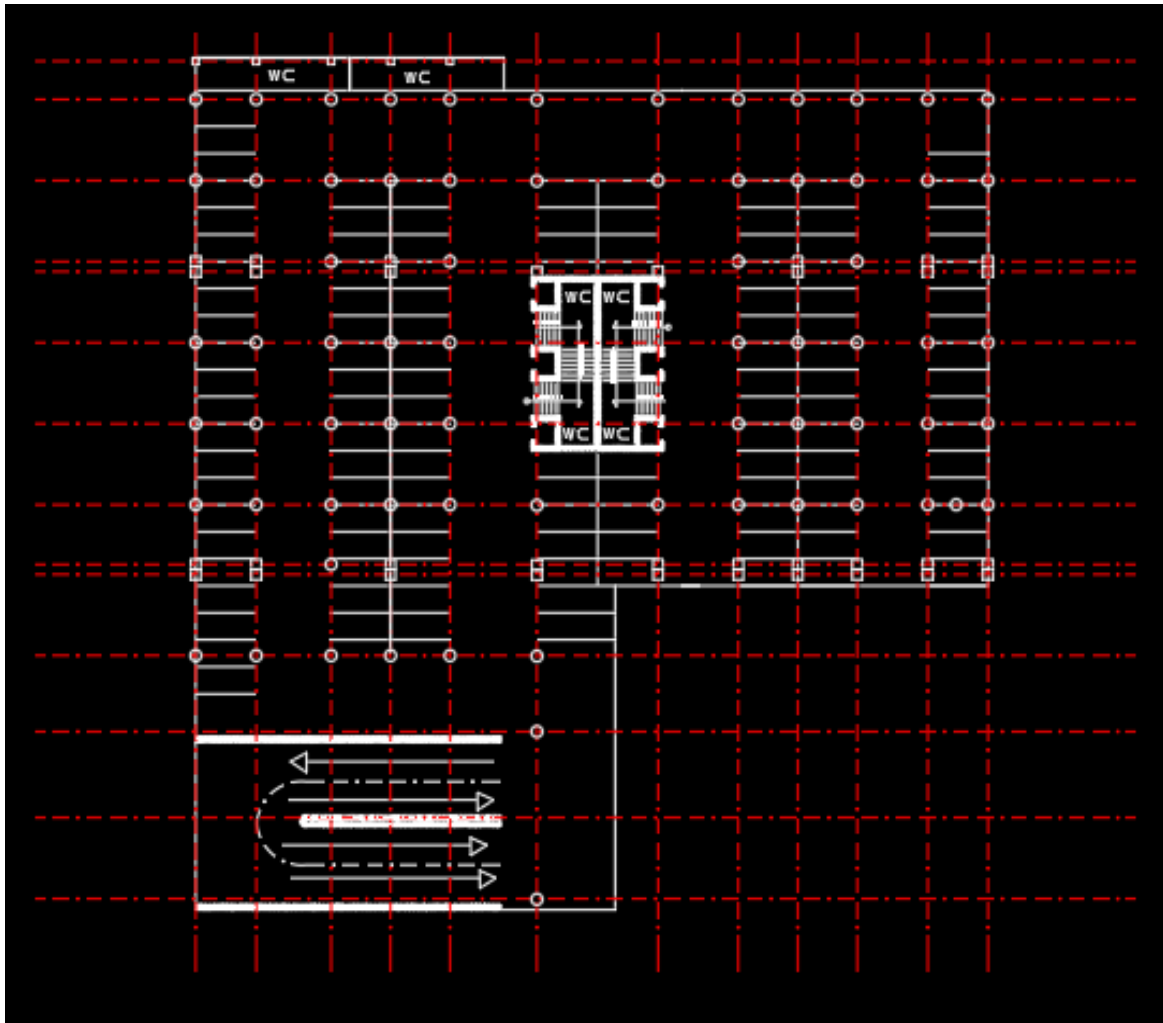


Figure 6.6.c: 2nd Floor

3rd floor:

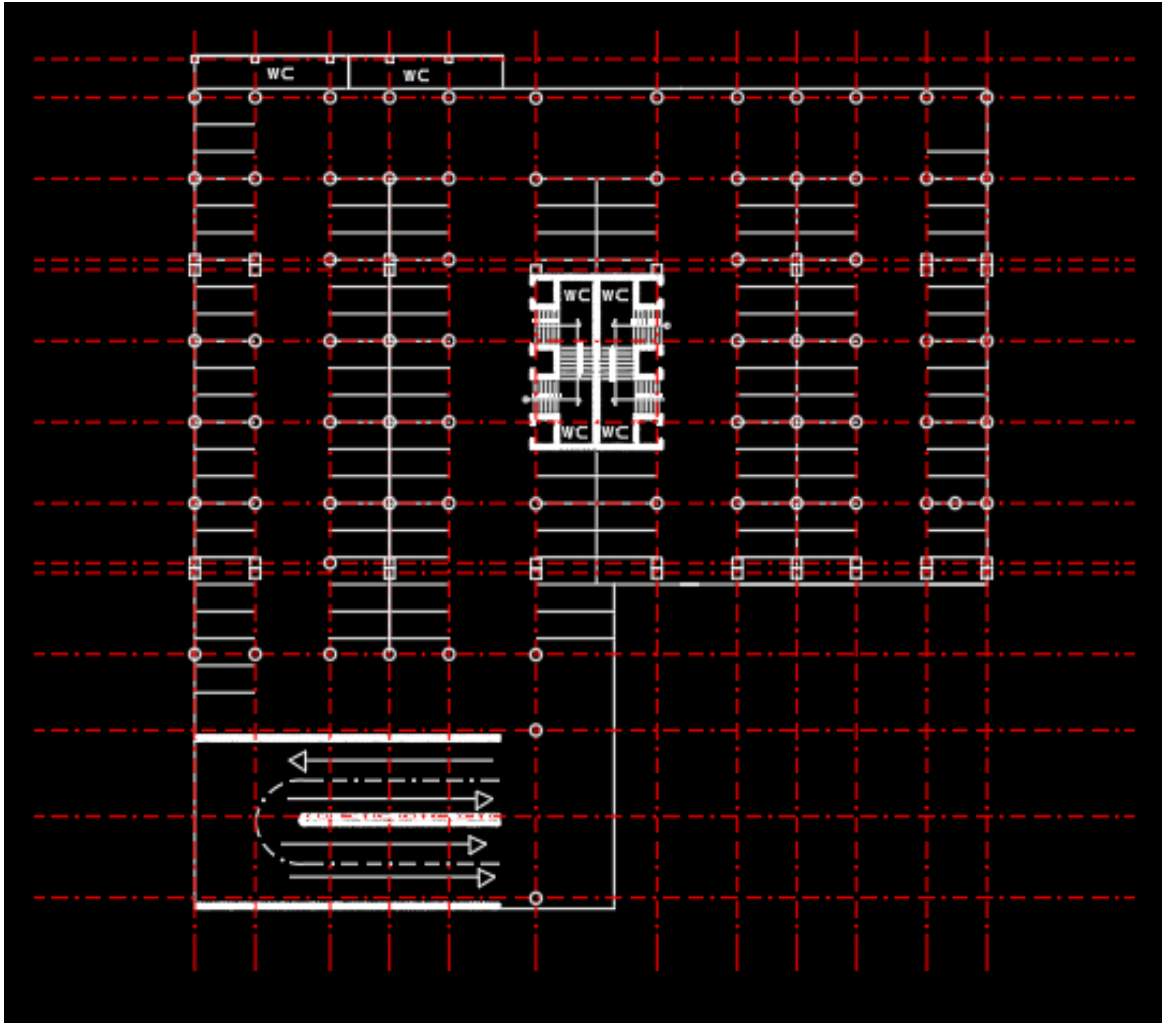


Figure 6.6.d: 3rd Floor

2. Second Section:

- Comprises 4 floors located below the first section, starting at the level of 101 meters.
- These floors are designated for regular parking spaces and have a different entry and exit system from the upper 4 floors.
- Each section has a ramp with a width of 7 meters and a slope of 8%, and turning radius of 6.5 m, allowing cars to move within their designated sections only.

B1 floor:

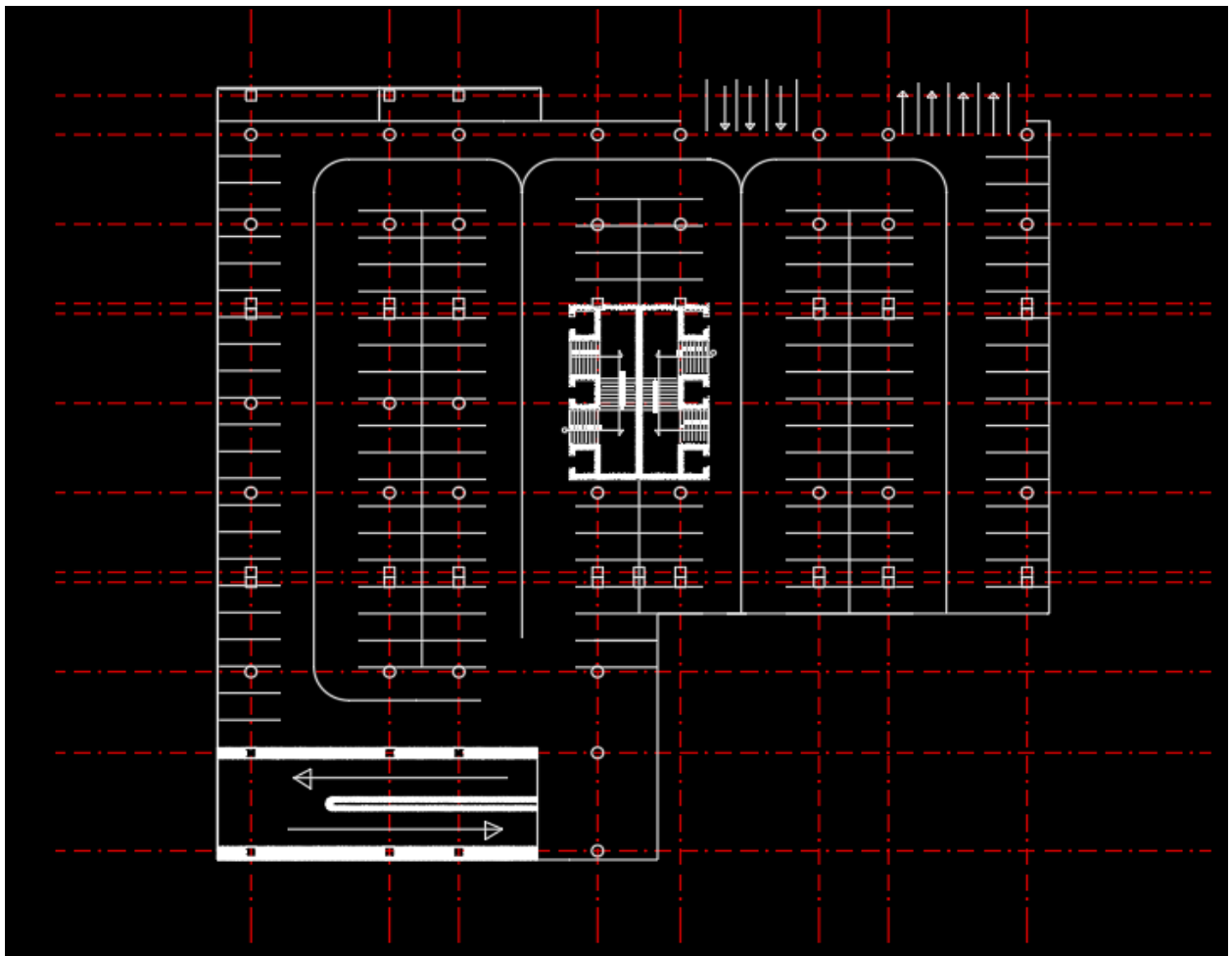


Figure 6.6.e: B1 Floor

B2 floor:

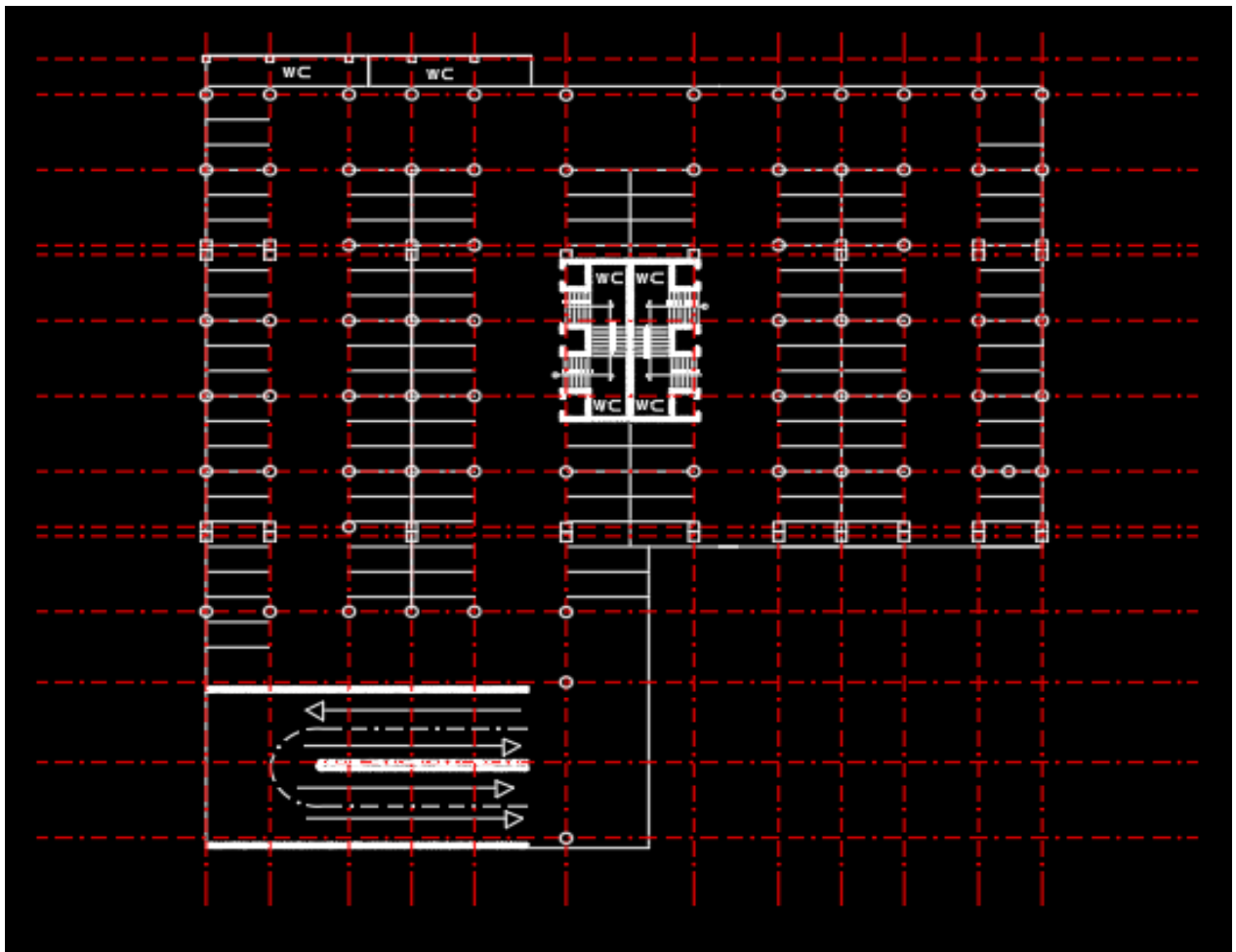


Figure 6.6.f: B2 Floor

B3 floor:

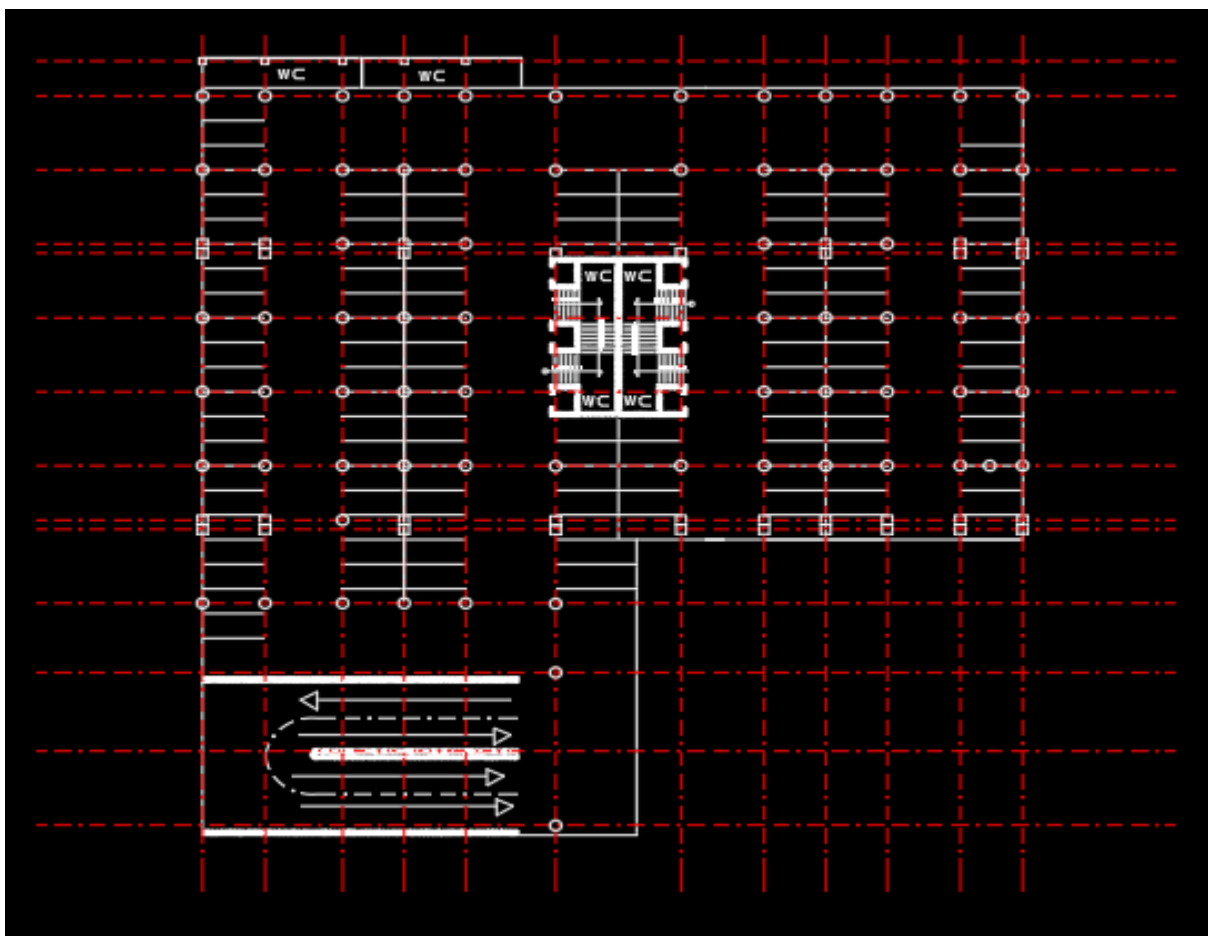


Figure 6.6.g: B3 Floor

B4 floor:

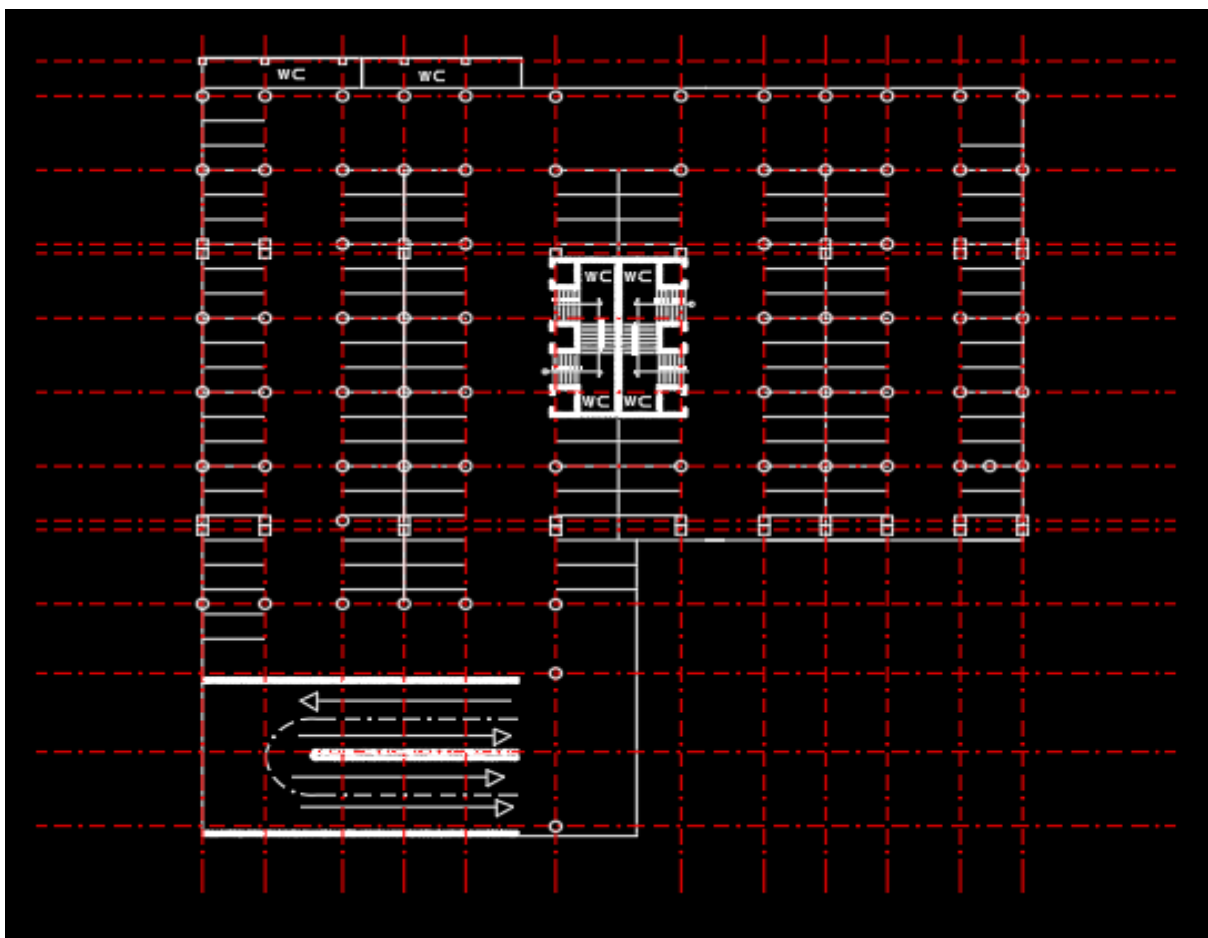


Figure 6.6.h: B4 Floor

Additionally, we have installed 6 elevators with a capacity of 1000 kg each and two staircases with a width of 3 meters each. The elevators and staircases are designed to move across all 8 floors, ensuring convenient vertical transportation and accessibility throughout the parking facility.

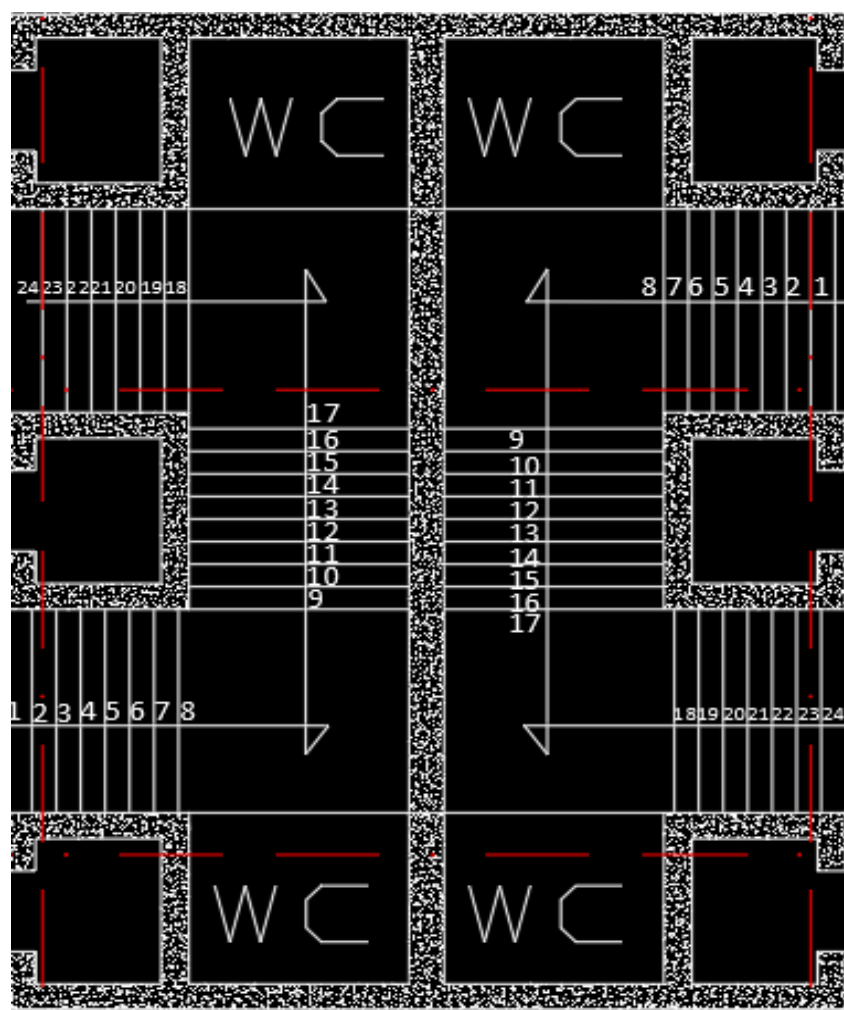


Figure 6.6.i: elevators and staircase

This design ensures ample parking capacity while accommodating special requirements for accessibility and improving overall functionality by providing distinct entry and exit points for different sections of the parking facility.

6.6.1 parking columns layout

In our parking structure design, we utilized two types of columns to optimize functionality and ensure a comfortable experience for users. Circular columns were chosen for the main parking areas to allow for smoother navigation and a more spacious feel, enhancing manoeuvrability for vehicles. For the ramps, bathrooms, staircases, and elevators, we opted for square columns due to their structural robustness and ease of integration with these facilities. Additionally, two square columns were strategically used as expansion joints to accommodate the thermal expansion and contraction of the concrete, which is crucial given the large area of the structure. Expansion joints play a vital role in maintaining the integrity and durability of the building by preventing cracks and other structural damages that can result from temperature fluctuations and other environmental stresses. This thoughtful combination of circular and square columns not only supports the structural needs but also enhances the overall user experience within the parking facility.

Ch7: Stands cover

Football stadiums often use large truss structures to support their roofs. These trusses are designed to span long distances and support the weight of the roof while accommodating various architectural and functional requirements. Some common types of trusses used in covering football stadiums include:

- 1. Warren Truss:** This is one of the most common types of trusses used in stadium construction. It consists of a series of equilateral triangles arranged in a repeating pattern along the length of the truss. Warren trusses are efficient in spanning long distances and are often used in stadium roofs where clear spans are required.

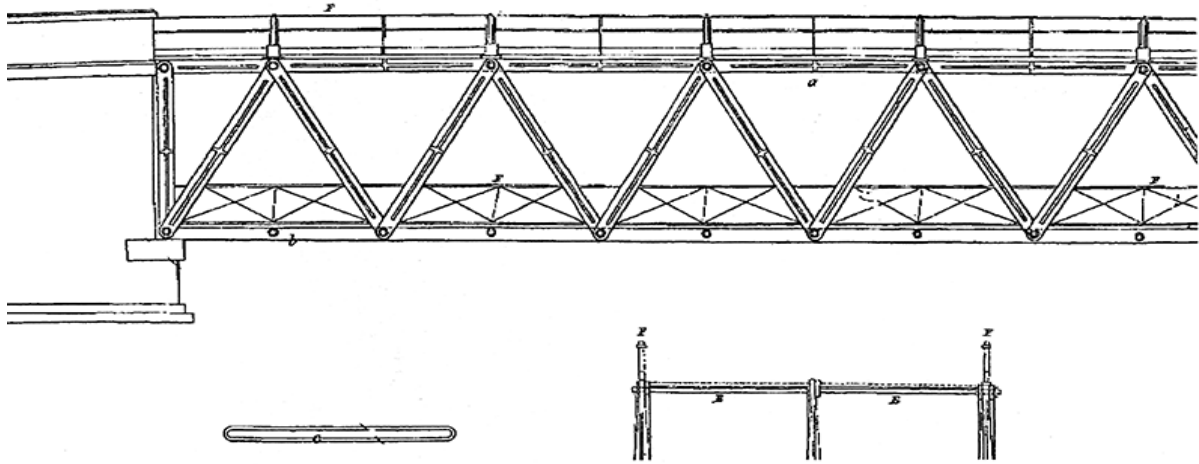


Figure 7.a: warren truss

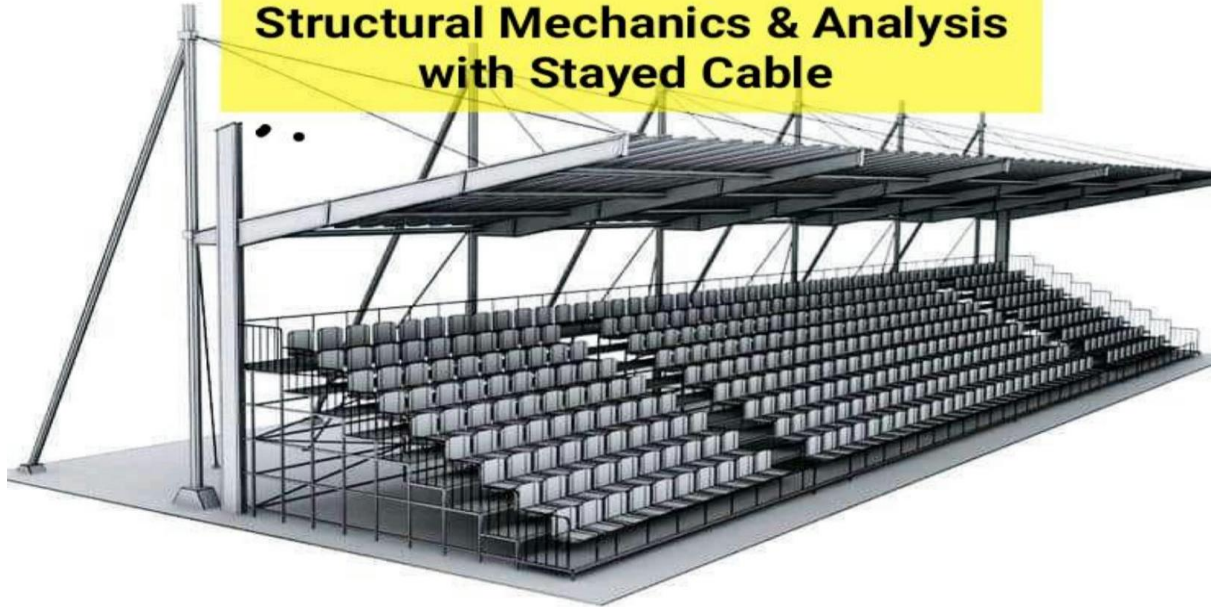
2. Pratt Truss: Similar to the Warren truss, the Pratt truss also consists of diagonal members connected to vertical members. However, in a Pratt truss, the diagonal members slope towards the centre, while in a Warren truss, they alternate in slope direction. Pratt trusses are suitable for medium to long spans and are commonly used in stadium construction.

3. Bowstring Truss: This type of truss is characterized by its arched top chord, resembling the shape of a bowstring. Bowstring trusses are efficient in spanning long distances and are often used in stadiums where a curved roof design is desired.

4. Cantilever Truss: In a cantilever truss, one end of the truss is anchored while the other end extends freely. This type of truss is often used in stadiums where a portion of the roof needs to extend beyond the support structure, providing additional coverage for seating areas without obstructing the view.

GRANDSTAND DESIGN

Cantilever Roof Structural Mechanics & Analysis with Stayed Cable



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Figure 7.b: cantilever truss

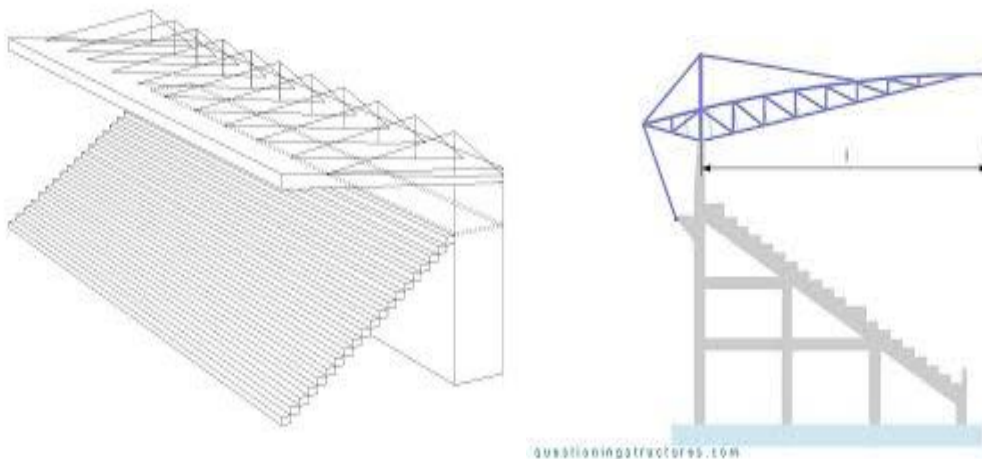


Figure 7.c: cantilever truss

5. Tied Arch Truss: Tied arch trusses consist of an arch-shaped top chord supported by diagonal members connected to a bottom chord. These trusses are suitable for stadiums requiring a visually appealing roof design with large clear spans.



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Figure 7.d: Tied Arch Truss

6. Space Truss: Space trusses are three-dimensional truss structures composed of interconnected triangular elements. They are used in stadium roofs where complex geometries or irregular shapes are desired.

These are just a few examples of the types of trusses commonly used in covering football stadiums. The choice of truss type depends on various factors such as span requirements, architectural design, structural considerations, and budget constraints.

Ch8: parking reinforcement concrete

Parking structures are essential components of modern urban infrastructure, requiring durable, strong, and efficient reinforced concrete (RC) design to withstand heavy loads, environmental exposure, and long-term serviceability demands. The design of reinforced concrete in parking facilities must account for static and dynamic loads from vehicles, as well as factors like temperature variations, moisture, and potential chemical exposure from de-icing salts and vehicle emissions. Proper reinforcement ensures structural integrity, minimizes cracks, and enhances durability, particularly in slabs, beams, and columns, which experience significant flexural and shear stresses. Additionally, parking structures often require expansion joints, proper drainage systems, and corrosion-resistant reinforcement to extend their lifespan and maintain safety. Understanding the principles of parking reinforced concrete design is crucial for engineers to deliver cost-effective and long-lasting solutions.

8.1.1 codes and standards

-**ACI 318-19**, the Building Code Requirements for Structural Concrete, is a widely recognized standard for the design and construction of reinforced concrete structures. This code provides comprehensive guidelines for structural analysis, reinforcement detailing, strength design, and serviceability requirements to ensure safe and durable concrete structures. By using ACI 318-19 in reinforced concrete design, you follow the latest industry standards for load calculations, flexural and shear design, seismic detailing, and durability provisions.

-**ASCE 7-16, ASCE 7-22, and UFC** codes are widely used standards for seismic design, ensuring structures can withstand earthquake forces safely and efficiently. ASCE 7-16 and ASCE 7-22 are part of the Minimum Design Loads and Associated Criteria for Buildings and Other Structures by the American Society of Civil Engineers (ASCE). These codes provide updated seismic hazard maps, site-specific ground motion procedures, and improved guidelines for response spectrum analysis. ASCE 7-22 includes refinements to seismic load combinations, nonstructural component design, and performance-based design approaches.

8.1.2 software programs



SAP2000 is a powerful structural analysis and design software used for modelling complex structures, including buildings, bridges, and industrial facilities. It provides advanced tools for static, dynamic, and seismic analysis, making it ideal for engineers working on steel and concrete structures.



ETABS is specialized for building analysis and design, offering an intuitive interface for modeling multi-story structures. It includes features like automatic wind and seismic load generation, slab design, and integration with building codes, making it a go-to tool for high-rise and commercial building projects.



AutoCAD is a widely used drafting and design software for creating precise 2D and 3D drawings. It is essential for architectural, structural, and engineering plans, enabling efficient detailing, documentation, and collaboration in construction projects.

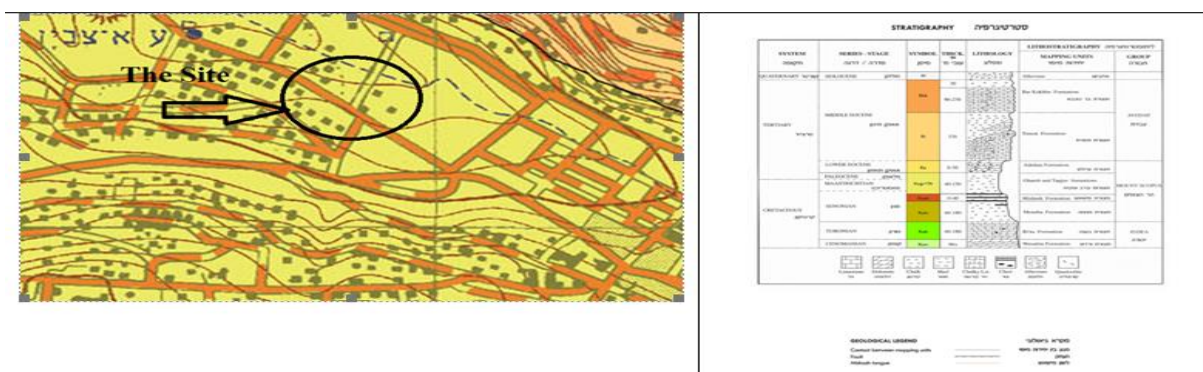
8.1.3 Design criteria:

- eight floors parking building
- floor height = 3.00m
- f'_c for concrete = 32mpa
- f_y for steel = 420mpa
- superimposed dead load = 0.5kn/ m²
- live load = 3.5kn/m²

Ch9 Site Investigation (Jaffa Street – Nablus)

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. Figure 2 below shows the geological map of the site.



Site Description

The soil at the site from geotechnical point of view consists of the following:

- 1- Top soil layer of brownish silty clay soil of high plasticity and high swelling potential. This layer has thickness ranges from 2.5 to 4 m from the existing ground surface.
- 2- Second layer below the top soil layer is very soft Marlstone bedrock formation. This layer extends below the top layer to end of drilling which is 15 from existing ground surface.

The site is excavated to foundation level and it has slopes below the main streets. It is recommended to take safety measures in the site due to deep cuts.

Ground water table was not encountered during the time of investigation (June 2024), however, there is source of water from the southern side of the site and care should be taken to collect the water before entering the site.

6. Soil Parameters

The following table summarizes the Soil parameters:

Bh. No.	Sample No.	Depth m	Description	Natural Moisture Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Cohesion kN/m ²	Angle of Internal Friction (φ°)
1	1	0.0 – 2.0	Brownish silty clay of high plasticity and high swelling		48	24	24	66	
	2	2.0 – 4.0	Brownish silty clay of high plasticity and high swelling						
	3	4.0 – 6.0	Very soft Marlstone Bedrock Formation						
	4	6.0 – 8.0	Very soft Marlstone Bedrock Formation						
	5	8.0 – 10.0	Very soft Marlstone Bedrock Formation						
	6	10.0 – 12.0	Very soft Marlstone Bedrock Formation						
	7	12.0 – 14.0	Very soft Marlstone Bedrock Formation						
2	1	0.0 – 2.0	Brownish silty clay of high plasticity and high swelling		45	25	20	68	
	2	2.0 – 4.0	Brownish silty clay of high plasticity and high swelling						

Bh. No.	Sample No.	Depth m	Description	Natural Moisture Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Cohesion kN/m ²	Angle of Internal Friction (φ°)
	3	4.0 – 6.0	Very soft Marlstone Bedrock Formation						
	4	6.0 – 8.0	Very soft Marlstone Bedrock Formation						
	5	8.0 – 10.0	Very soft Marlstone Bedrock Formation						
3	1	0.0 – 2.5	Brownish silty clay of high plasticity and high swelling		44	26	18	70	
	2	2.5 – 4.0	Very soft Marlstone Bedrock Formation						
	3	4.0 – 6.0	Very soft Marlstone Bedrock Formation						
	4	6.0 – 8.0	Very soft Marlstone Bedrock Formation						
	5	8.0 – 10.0	Very soft Marlstone Bedrock Formation						

The Marlstone bedrock of the site has soft strength. Samples of rocks were tested in unconfined compression machine according to ASTM D2938-95(2002),

Standard Test Method for Unconfined Compressive Strength of Intact Rock Core Specimens and gave unconfined compressive strength ranges as follows:

Borehole No.	Sample No.	Depth m	Sample Type	Unconfined Compressive Strength kN/m ²
1	1	1.0	Block	9000
2	1	1.0	Block	6200
3	1	1.0	Block	12000

7. Geotechnical Conditions

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

7.1 Top Soil and Swelling Potential

The site consists of Marlestone and it has no swelling potential. The site has good layer to construct the foundation on it. The top loose soil should be removed from the site.

7.2 Type of Foundations

Shallow foundation (isolated with strong tie beams, continuous or mat) is recommended to be used for this site. The foundation depth should be inside

marlstone bedrock layer. In this case the allowable bearing capacity = 300 kN/m^2 (3.0 kg/cm^2).

Strong tie beams should be used if isolated footings are used.

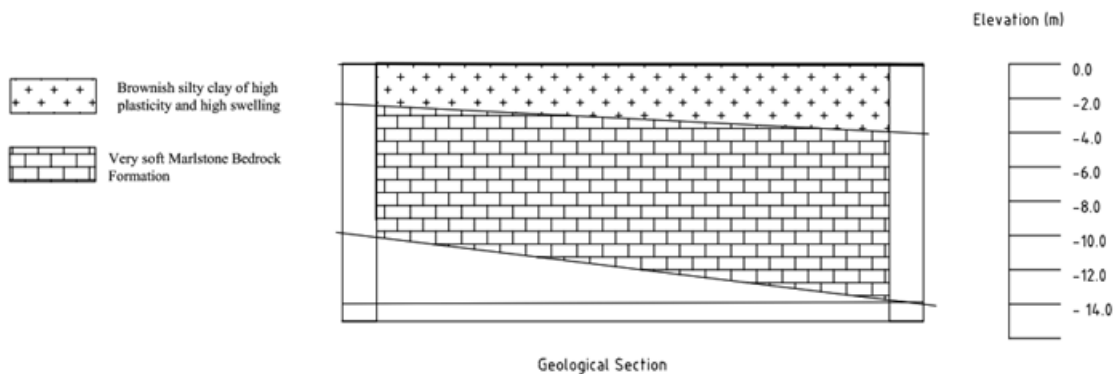
This value is based on the bearing capacity of the Marlstone according to Jordanian Code as follows:

- Unconfined Compressive Strength of Rock (q_u) = 6200 kN/m^2 .
- RQD < 25%
- Depth of Foundation = 1.0 m

According to Jordanian Code, the allowable bearing capacity = $0.05 \times q_u = 0.05 \times 6200 =$

310 kN/m^2 .

Use allowable bearing capacity = 300 kN/m^2 .



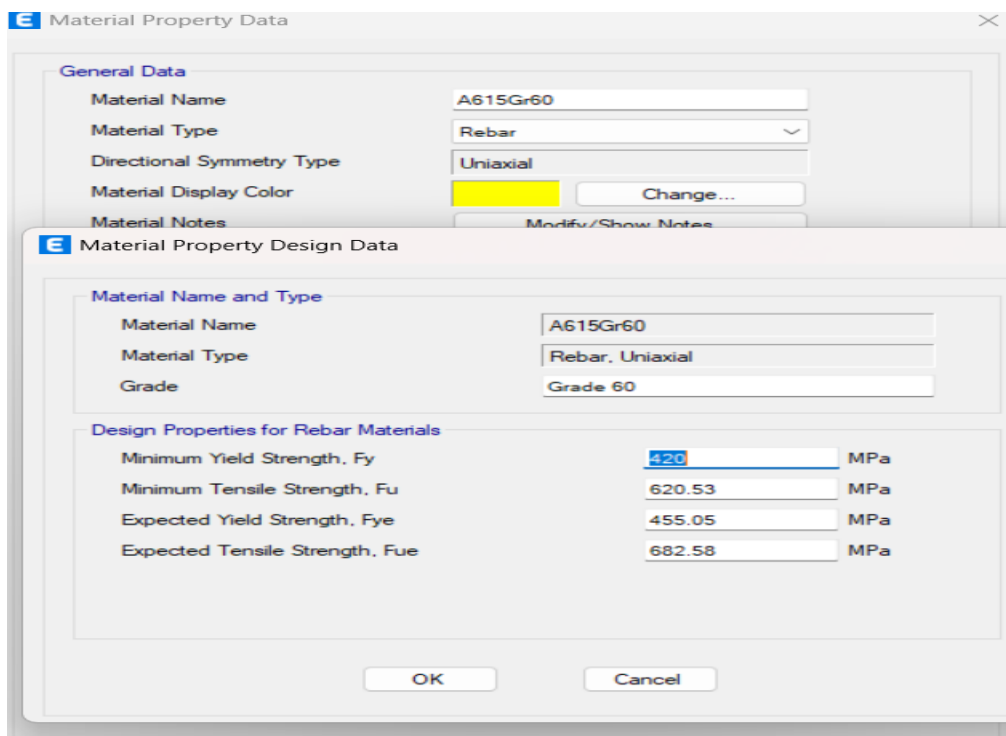
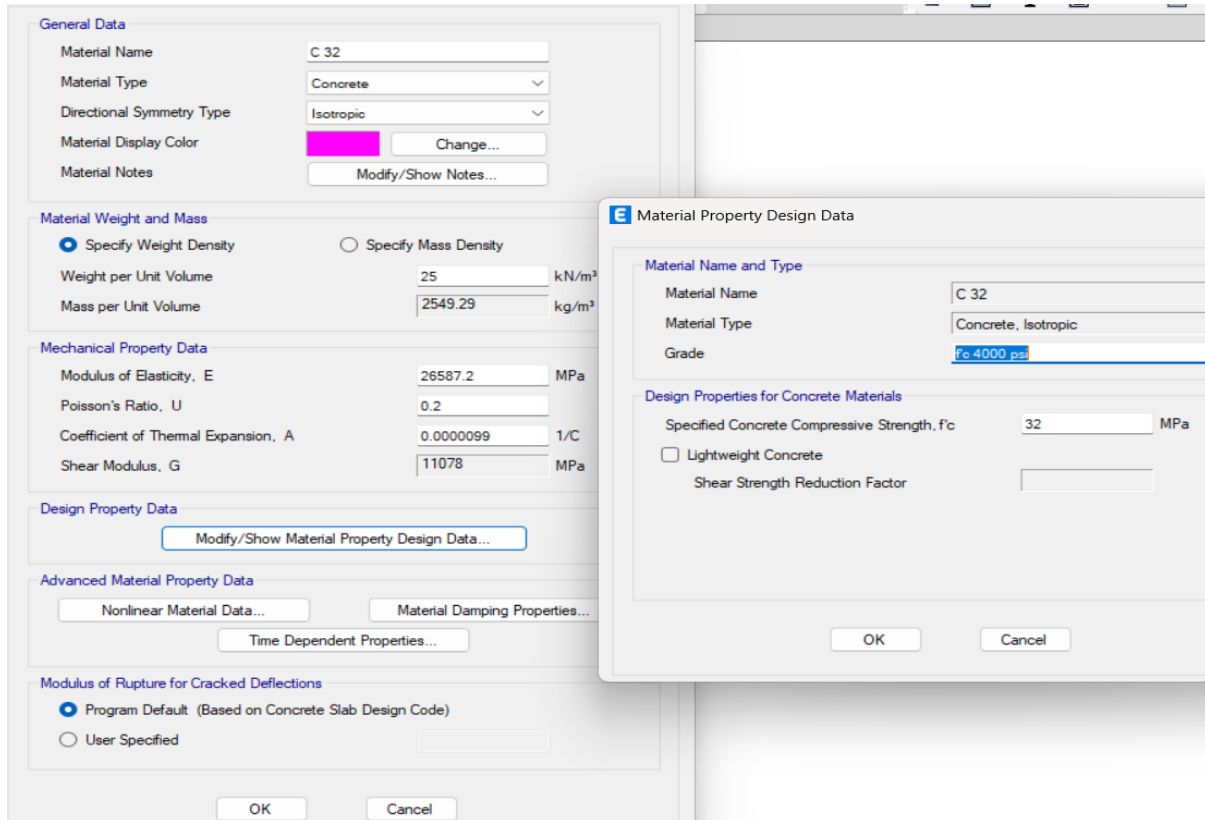
Retaining Walls

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_0) is equal to **0.5 for typical backfill materials (soil unit weight (γ) = 18 kN/m^3 and angle of internal friction (ϕ) = 30°)**

Ch10 Etabs model

10.1 definitions

10.1.1 Material properties



10.1.2 Section properties:

1-columns

General Data

Property Name:

Material: ...

Notional Size Data:

Display Color:

Notes:

Shape

Section Shape:

Section Property Source

Source: User Defined

Section Dimensions

Diameter: mm

Property Modifiers

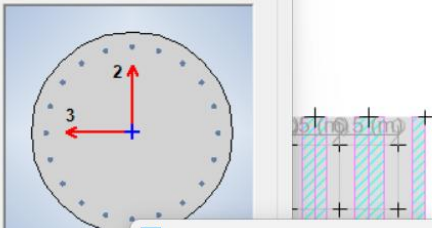
Currently Us

Reinforcement

Property/Stiffness Modification Factors

Property/Stiffness Modifiers for Analysis

Cross-section (axial) Area	<input type="text" value="1"/>
Shear Area in 2 direction	<input type="text" value="1"/>
Shear Area in 3 direction	<input type="text" value="1"/>
Torsional Constant	<input type="text" value="0.7"/>
Moment of Inertia about 2 axis	<input type="text" value="0.7"/>
Moment of Inertia about 3 axis	<input type="text" value="0.7"/>
Mass	<input type="text" value="1"/>
Weight	<input type="text" value="1"/>



E Frame Section Property Reinforcement Data

Design Type

P-M2-M3 Design (Column)

M3 Design Only (Beam)

Rebar Material

Longitudinal Bars: ...

Confinement Bars (Ties): ...

Reinforcement Configuration

Rectangular

Circular

Confinement Bars

Ties

Spirals

Check/Design

Reinforcement to be Checked

Reinforcement to be Designed

Longitudinal Bars

Clear Cover for Confinement Bars: mm

Number of Longitudinal Bars:

Longitudinal Bar Size and Area: ... mm²

Confinement Bars

Confinement Bar Size and Area: ... mm²

Longitudinal Spacing of Confinement Bars (Along 1-Axis): mm

2-Beam

General Data

Property Name: BEAM

Material: C 32

Notional Size Data: Modify/Show Notional Size...

Display Color: Change...

Notes: Modify/Show Notes...

Shape

Section Shape: Concrete Rectangular

Section Property Source

Source: User Defined

Section Dimensions

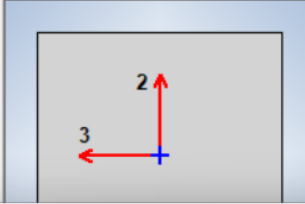
Depth: 500 mm

Width: 500 mm

Property/Stiffness Modification Factors

Property/Stiffness Modifiers for Analysis

Cross-section (axial) Area	1
Shear Area in 2 direction	1
Shear Area in 3 direction	1
Torsional Constant	0.35
Moment of Inertia about 2 axis	0.35
Moment of Inertia about 3 axis	0.35
Mass	1
Weight	1



Frame Section Property Reinforcement Data

Design Type

P-M2-M3 Design (Column)

M3 Design Only (Beam)

Rebar Material

Longitudinal Bars: A615Gr60

Confinement Bars (Ties): A615Gr60

Cover to Longitudinal Rebar Group Centroid

Top Bars: 60 mm

Bottom Bars: 60 mm

Reinforcement Area Overwrites for Ductile Beams

Top Bars at I-End: 0 mm²

Top Bars at J-End: 0 mm²

Bottom Bars at I-End: 0 mm²

Bottom Bars at J-End: 0 mm²

OK Cancel

3-Slab

General Data

Property Name: waffle slab

Slab Material: C 32

Notional Size Data: Modify/Show Notional Size...

Modeling Type: Shell-Thick

Modifiers (Currently User Specified): Modify/Show...

Display Color: Change...

Property Notes: Modify/Show...

Property Data

Type: Waffle

Overall Depth: 300 mm

Slab Thickness: 100 mm

Stem Width at Top: 150 mm

Stem Width at Bottom: 150 mm

Spacing of Ribs that are Parallel to Slab 1-Axis: 750 mm

Spacing of Ribs that are Parallel to Slab 2-Axis: 750 mm

Property/Stiffness Modification Factors

Property/Stiffness Modifiers for Analysis	
Membrane f11 Direction	1
Membrane f22 Direction	1
Membrane f12 Direction	1
Bending m11 Direction	0.25
Bending m22 Direction	0.25
Bending m12 Direction	0.25
Shear v13 Direction	1
Shear v23 Direction	1
Mass	1
Weight	1

4-Shear and Retaining walls

Property/Stiffness Modifiers for Analysis

Membrane f11 Direction	0.7
Membrane f22 Direction	0.7
Membrane f12 Direction	0.7
Bending m11 Direction	0.7
Bending m22 Direction	0.7
Bending m12 Direction	0.7
Shear v13 Direction	1
Shear v23 Direction	1
Mass	1
Weight	1

Property Data

Thickness: 300 mm

Include Automatic Rigid Zone Area Over Wall

Property/Stiffness Modification Factors

Wall Material: C 32

Notional Size Data: Modify/Show Notional Size...

Modeling Type: Shell-Thin

Modifiers (Currently User Specified): Modify/Show...

Display Color: Change...

Property Notes: Modify/Show...

5-Ramp

The image shows two overlapping dialog boxes from a software application. The background dialog is titled 'General Data' and 'Property Data'. The foreground dialog is titled 'Property/Stiffness Modification Factors'.

General Data

Property Name	RAMP
Slab Material	C 32
Notional Size Data	Modify/Show Notional Size...
Modeling Type	Shell-Thick
Modifiers (Currently User Specified)	Modify/Show ...
Display Color	Change...
Property Notes	Modify/Show ...

Property Data

Type	Slab
Thickness	300

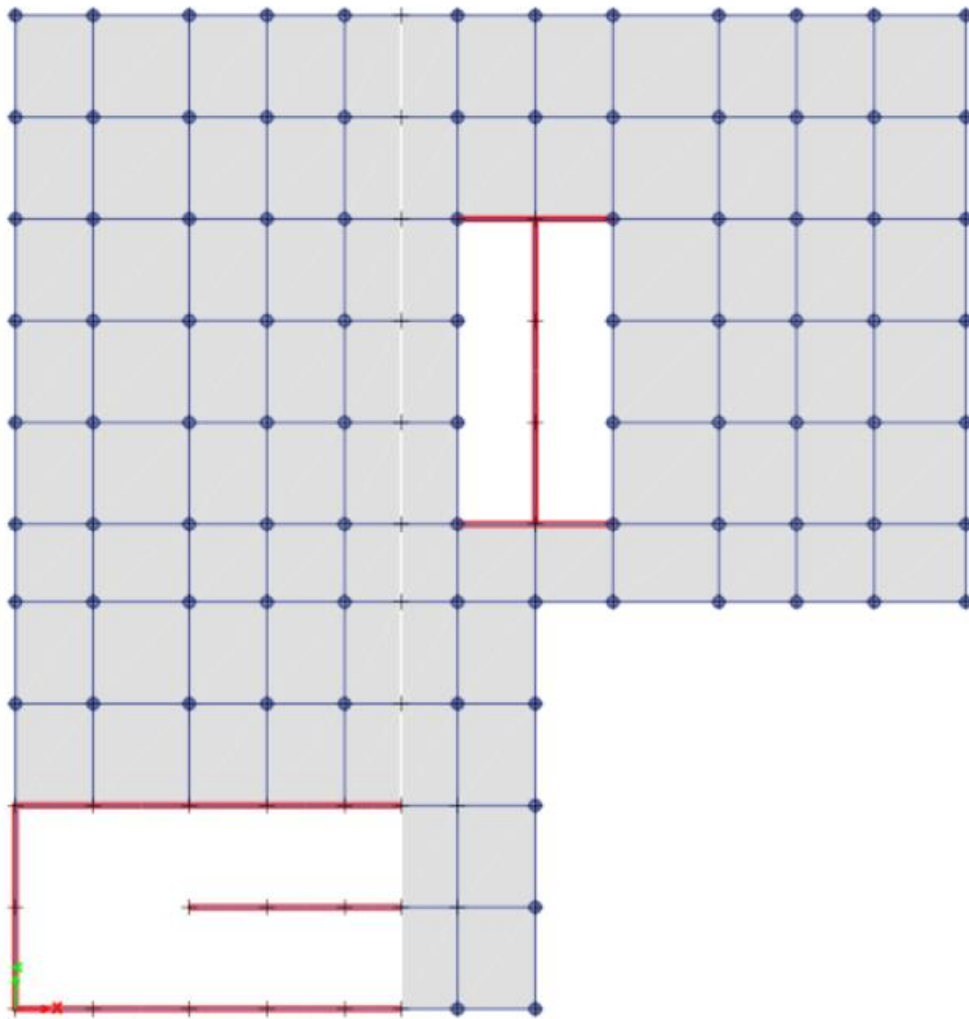
Property/Stiffness Modification Factors

Property/Stiffness Modifiers for Analysis

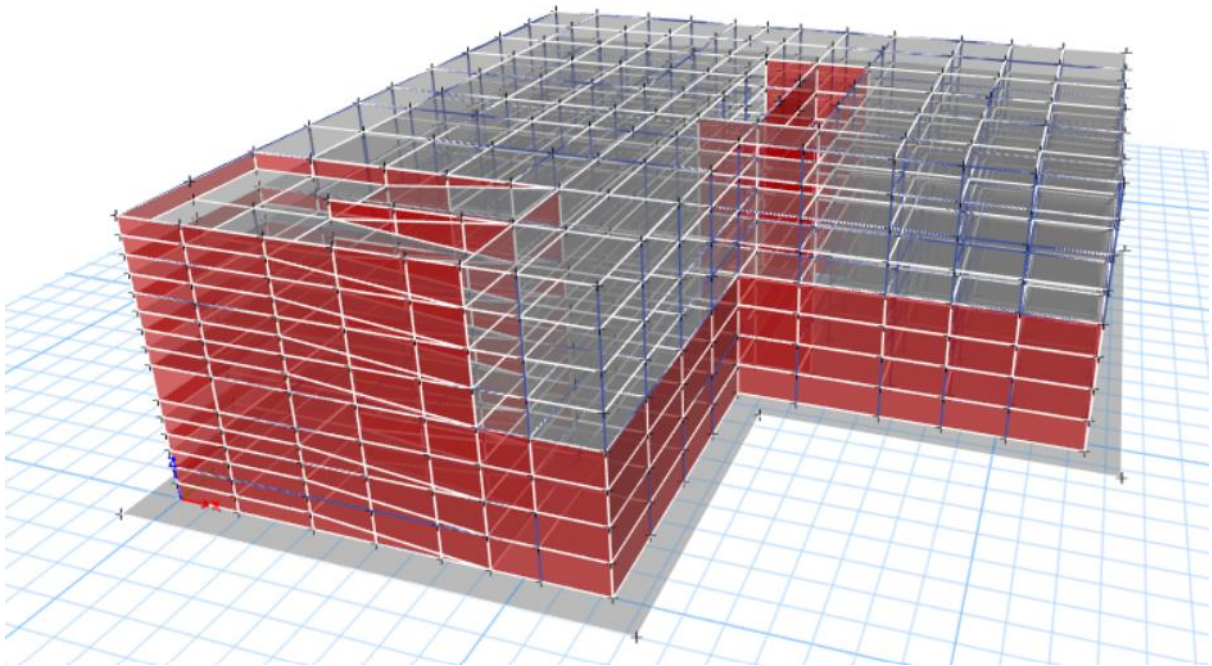
Membrane f11 Direction	1
Membrane f22 Direction	1
Membrane f12 Direction	1
Bending m11 Direction	0.25
Bending m22 Direction	0.25
Bending m12 Direction	0.25
Shear v13 Direction	1
Shear v23 Direction	1
Mass	1
Weight	1

OK Cancel

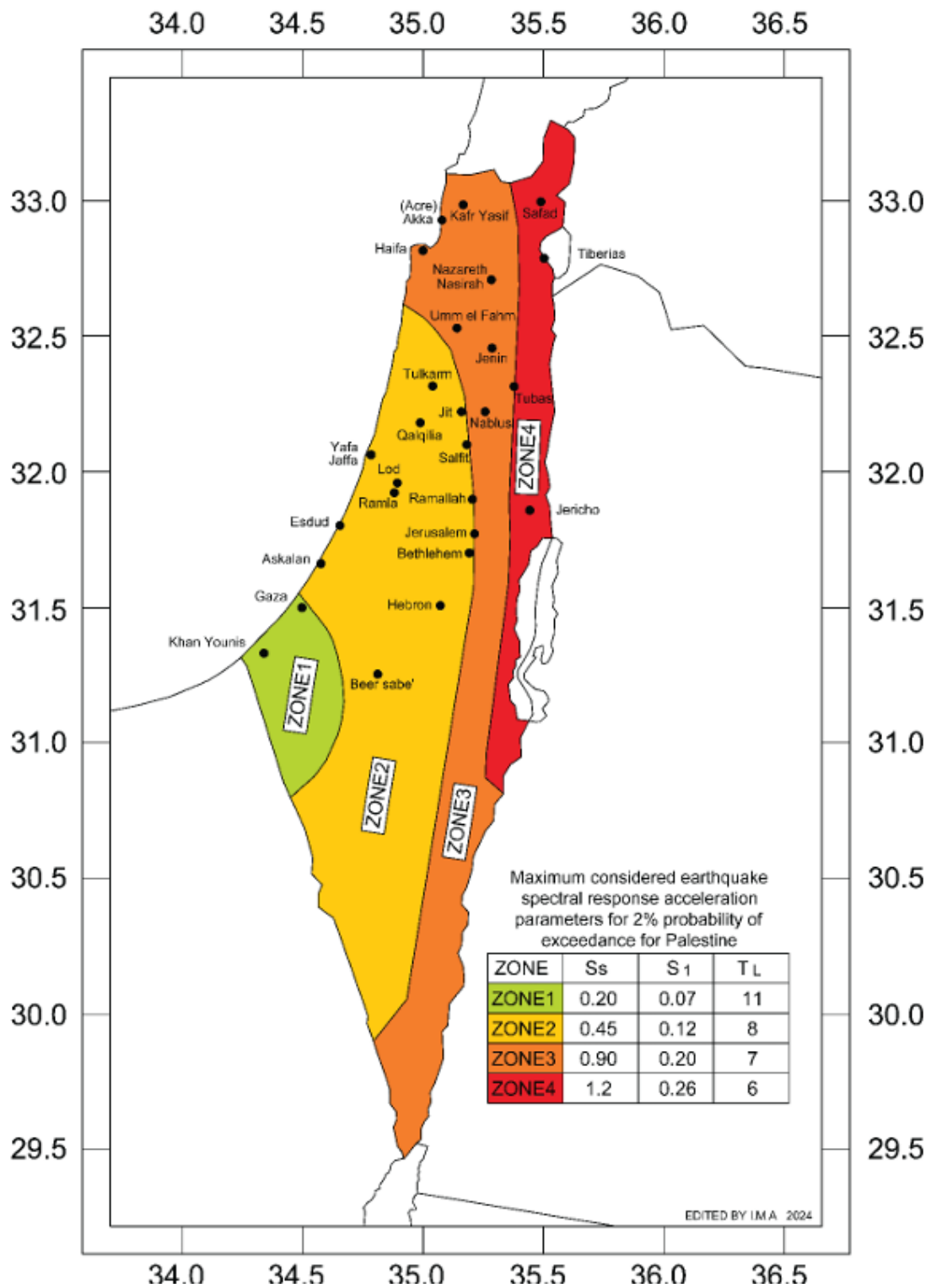
10.2 X-Y Plan



10.3 3-D Plan



Ch11 Define seismic load:



Nablus in zone 3, so $S_s = 0.90$, $S_1 = 0.20$, $T_L = 7$

Risk category III

11.1 Seismic force-resisting system:

For 1st to 4th floors, seismic force-resisting system is special reinforced concrete shear walls with $R=6$; because there are retaining walls around all building and shear walls around elevators and ramps.

For 5th to 8th floors, seismic force-resisting system is dual system (special walls and special frames) with $R=7$; so it's better to design with $R=6$ to be in safe side.

$R=6$

Omega = 2.5

$Cd = 5$

Site class:

According to ASCE 7-16, if the soil properties are not known in sufficient detail to determine the site class, site class D shall be used.

X-direction:

ASCE 7-16 Seismic Loading

Direction and Eccentricity

X Dir Y Dir
 X Dir + Eccentricity Y Dir + Eccentricity
 X Dir - Eccentricity Y Dir - Eccentricity

Ecc. Ratio (All Diaph.) 0.05

Overwrite Eccentricities Overwrite...

Time Period

Approximate Ct (ft), x =
 Program Calculated Ct (ft), x = 0.028; 0.8
 User Defined T = sec

Story Range

Top Story for Seismic Loads Story8
Bottom Story for Seismic Loads Base

OK Cancel

Seismic Coefficients

0.2 Sec Spectral Accel, Ss 0.9
1 Sec Spectral Accel, S1 0.2
Long-Period Transition Period 7

Site Class D

Site Coefficient, Fa 1.14
Site Coefficient, Fv 2.2

Calculated Coefficients

SDS = (2/3) * Fa * Ss 0.684
SD1 = (2/3) * Fv * S1 0.2933

Factors

Response Modification, R 6
System Overstrength, Omega 2.5
Deflection Amplification, Cd 5
Occupancy Importance, I 1

Y-direction:

ASCE 7-16 Seismic Loading

Direction and Eccentricity

X Dir Y Dir
 X Dir + Eccentricity Y Dir + Eccentricity
 X Dir - Eccentricity Y Dir - Eccentricity

Ecc. Ratio (All Diaph.) 0.05

Overwrite Eccentricities Overwrite...

Time Period

Approximate Ct (ft), x =
 Program Calculated Ct (ft), x = 0.028; 0.8
 User Defined T = sec

Story Range

Top Story for Seismic Loads Story8
Bottom Story for Seismic Loads Base

OK Cancel

Seismic Coefficients

0.2 Sec Spectral Accel, Ss 0.9
1 Sec Spectral Accel, S1 0.2
Long-Period Transition Period 7

Site Class D

Site Coefficient, Fa 1.14
Site Coefficient, Fv 2.2

Calculated Coefficients

SDS = (2/3) * Fa * Ss 0.684
SD1 = (2/3) * Fv * S1 0.2933

Factors

Response Modification, R 6
System Overstrength, Omega 2.5
Deflection Amplification, Cd 5
Occupancy Importance, I 1

Ch12 design concrete elements

12.1 beams

Beams are horizontal structural elements that support loads by transferring them to columns or walls. They primarily resist bending, shear, and torsion, making them essential in reinforced concrete and steel structures. Beams come in various types, including simply supported, cantilever, and continuous beams, depending on their support conditions. Proper design ensures they can handle dead loads, live loads, and seismic forces while maintaining stability and durability.

12.1 dimension of beams

12.1.1 depth

Table 9.5 (a) MINIMUM THICKNESS OF NONPRESTRESSED BEAMS OR ONE-WAY SLABS UNLESS DEFLECTIONS ARE CALCULATED

	Minimum thickness, <i>h</i>			
	Simply supported	One end continuous	Both ends continuous	cantilever
member	Members not supporting or attached to partitions or other construction likely to be damaged by large deflections			
Solid one way slabs	L/20	L/24	L/28	L/10
Beams or ribbed one way slabs	L/16	L/18.5	L/21	L/8

Notes:

Values given shall be used directly for members with normal weight concrete and Grade 420 reinforcement. For other conditions, the values shall be modified as follows:

- a) For lightweight concrete having equilibrium density, w_c , in the range of 1440 to 1840 kg/m³, the values shall be multiplied by $(1.65 - 0.0003w_c)$ but not less than 1.09.
- b) For f_y other than 420 MPa, the values shall be multiplied by $(0.4 + f_y/700)$.

$$\text{Depth (H)} = L/18.5 = 7.2/18.5 = 0.40\text{m}$$

$$\text{Take H} = 0.50\text{m}$$

12.1.2 Width:

$$B = L/20 = 7.2/20 = 0.36\text{m}$$

As a factor of safety, we will exceed the dimensions 40%

$$\text{Then; } H = 0.36 * 1.4 = 0.50\text{m}$$

$$B = 500 \text{ mm}$$

The preliminary dimensions of the exterior beams are: **500*500 mm (preliminary)**

12.2 two-way waffle slab

A two-way waffle slab is a reinforced concrete system with a grid of ribs running in both directions, allowing for efficient load distribution across multiple supports. This design enhances structural strength, reduces material usage, and enables long spans with minimal deflection. Commonly used in commercial buildings and large open spaces, two-way waffle slabs provide better seismic performance and can be aesthetically exposed for architectural appeal.

12.2.1 slab thickness

Table 8.9: Preliminary thickness of two-way slabs (Steel yield strength, $f_y = 420\text{MPa}$).

Slab system		Minimum thickness, h_{\min}
Flat Plate	Solid	$L_n/30$
	Voided	$L_n/27$
	Ribbed/Waffle	$L_n/24$
Flat slab	Solid	$L_n/34$
	Voided	$L_n/31$
	Ribbed/Waffle	$L_n/26$
Slab on stiff beams	Solid	$L_n/42$
	Voided	$L_n/38$
	Ribbed/Waffle	$L_n/33$
Slab on hidden beams	Voided	$L_n/31$
	Ribbed/Waffle	$L_n/26$

$$\text{Take slab thickness} = 7200/33 = 218$$

So use 300 mm (preliminary)

12.2.2 Ultimate load calculations

$$W \text{ S.D.} = 0.5 \text{ kn/m}^2$$

$$W \text{ L.L.} = 3.5 \text{ kn/m}^2$$

$$W. \text{ slab} = ((0.75 * 0.75 * 0.30 - 0.6 * 0.6 * 0.2) * 25) / 0.75 * 0.75 = 4.3 \text{ kn/m}^2$$

$$\text{Ultimate load on the slab} = 1.2(4.3 + 0.5) + 1.6(3.5) = 11.36 \text{ kn/m}^2$$

12.3 circular columns

Circular columns are structural elements with a cylindrical cross-section, commonly used in buildings, bridges, and piers. Their shape provides uniform strength and load distribution, making them ideal for resisting axial loads, bending, and seismic forces. Circular columns are often reinforced with spiral or tie reinforcement to enhance ductility and prevent buckling, especially in high-seismic zones. They are also aesthetically appealing and frequently used in architectural and exposed concrete designs.

12.3.1 Columns dimensions:

Assuming moment on columns = 0

Note: design an internal columns and use the dimensions for all columns as a preliminary dimension

Internal column:

$$\text{Tributary area} = 6.75 * 7.2 = 48.6 \text{ m}^2$$

$$\# \text{ of floors} = 8 \text{ floors}$$

$$W_u \text{ slab} = 11.36 \text{ kn/m}^2$$

$$P_u = W_u * \# \text{ of floors} * \text{t. area}$$

$$P_u = 11.36 * 8 * 48.6 = 4417 \text{ kn}$$

$$\Phi P_n = \Phi \lambda (0.85 f'_c (A_g - A_s) + F_y A_s)$$

$$4417 * 10^3 = 0.65 * 0.8 * (0.85 * 32 * (A_g - A_s) + 420 * A_s)$$

$$\text{Assume } p = 0.01 = A_s / A_g, A_s = 0.01 A_g$$

$$A_g = 141898 \text{ mm}^2$$

Assuming circular columns, $d=500 \text{ mm}$

Take **$d=800 \text{ mm}$** (preliminary)

$$A_s = 0.01 * \pi/4 * 800^2 = 5027 \text{ mm}^2$$

Spiral:

$$\rho_s = 0.45 \left(\frac{A_g}{A_{ch}} - 1 \right) \frac{f'_c}{f_{yt}} \quad (6.12)$$

$$\rho_s = 0.008$$

Space between spiral (S):

$$s = \frac{4A_{sp}}{\rho_s D_c} \leq 75 \text{ mm} \quad (6.13)$$

$$S = 54 \text{ mm} \leq 75 \text{ mm}$$

Use spirals $\phi 10 \text{ mm} / 50 \text{ mm}$

12.4.1 columns Check:

Check columns using interaction diagram

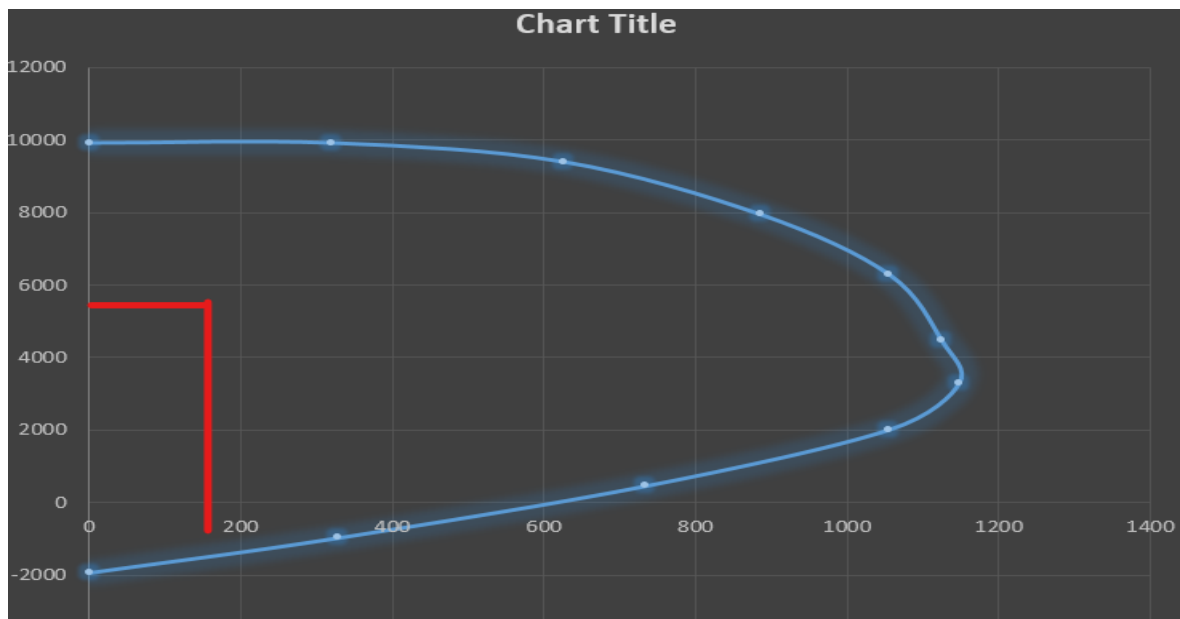
Interior column:

$P = 5210\text{kn}$

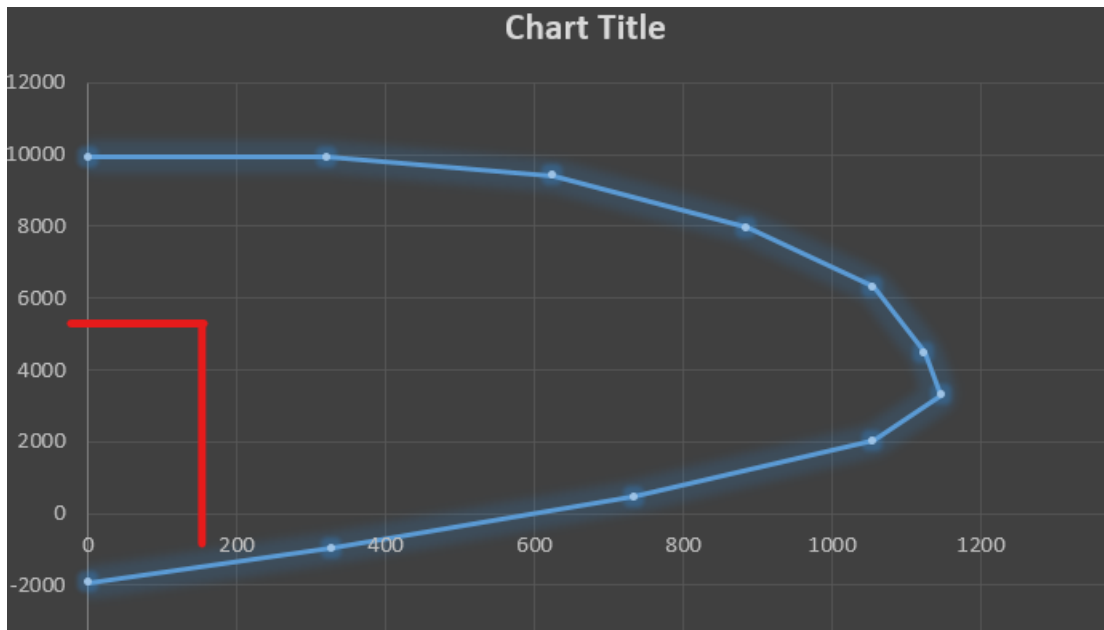
$M_2 = 130\text{kn.m}$

$M_3 = 95\text{kn.m}$

(M2-2) interaction diagram:



(M3-3) interaction diagram:



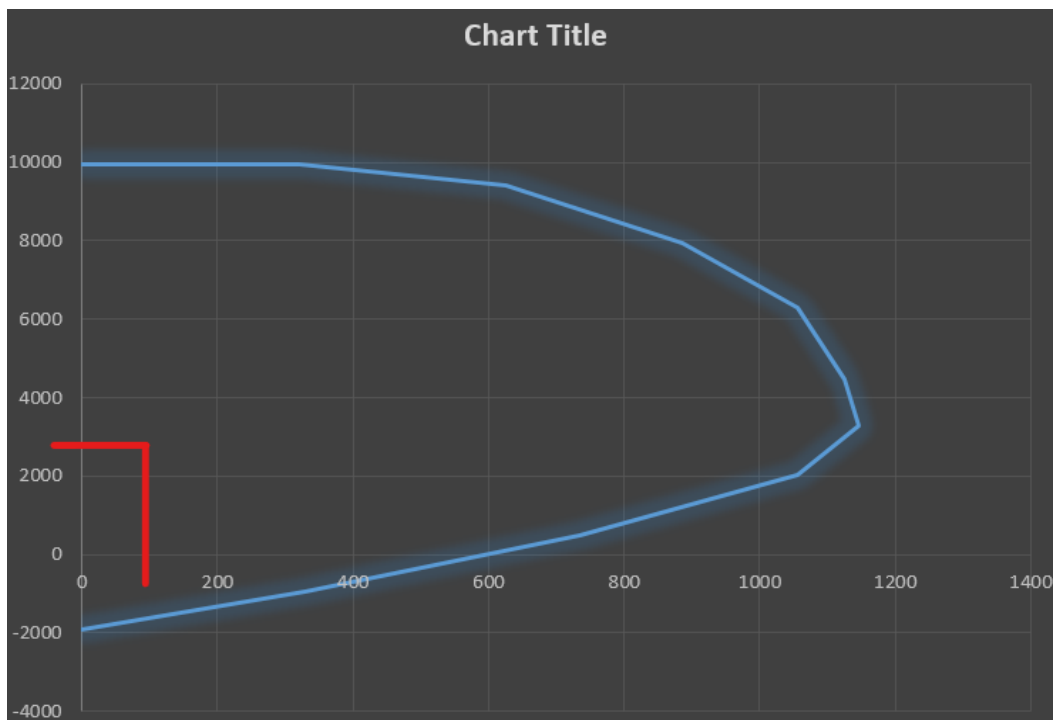
Edge column:

$P = 2505\text{kn}$

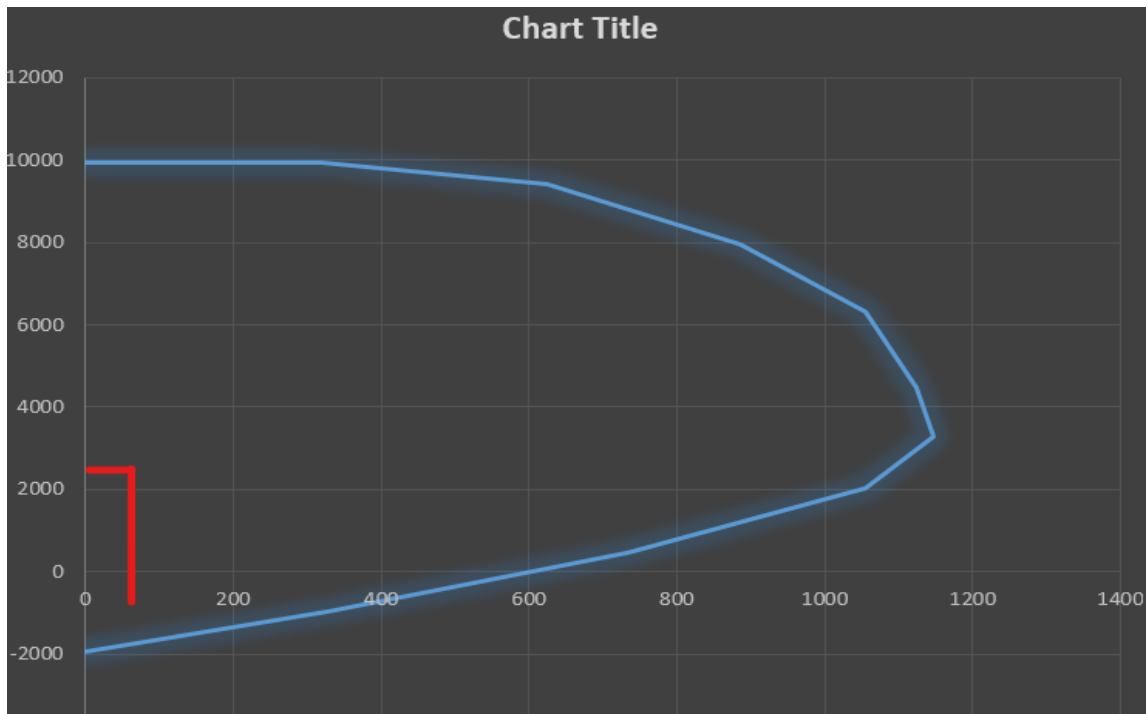
$M2 = 26\text{ kn.m}$

$M3 = 12\text{ kn.m}$

(M2-2) interaction diagram:



(M3-3) interaction diagram:



Corner columns:

Axial and moment forces on the corner columns so small, since it dimensions same as other columns; then it's okay

So; all columns are okay, but we can use less diameter for column, especially both of edge and corner columns.

12.4 Concrete frame design Dimensions check:



Beams and columns dimensions are okay

Ch13 Shell analysis mesh:

For all structural elements use (0.5X0.5) square mesh, To ensure that the mesh joints of adjacent shell elements (such as slabs, walls, or shear walls) are properly connected is essential for accurate load transfer and structural continuity. When mesh nodes are not linked, the elements behave as separate components, leading to incorrect force distribution, stress concentrations, and potential numerical instabilities in the analysis.

Focus on Load Transfer

1. Force and Moment Transfer: Connected meshes allow forces (axial, shear, and bending) to transfer smoothly between elements, ensuring accurate structural response.
2. Prevention of Gaps or Overlaps: Properly meshed shells prevent artificial gaps or overlaps, which can disrupt the load path and create unrealistic stress concentrations.
3. Structural Integrity: Load transfer between connected shells ensures that slabs and walls work together, improving overall stiffness and stability.
4. Numerical Stability: Disconnected meshes may cause singularities in the stiffness matrix, leading to analysis errors or inaccurate deformation results.

Ch14 Deflection Check

Calculating slab deflection is essential to ensure serviceability and structural performance. Deflection is influenced by factors such as slab thickness, material properties, reinforcement, span length, and applied loads. It is typically determined using formulas from ACI 318, finite element analysis, or software like SAP2000 and ETABS. Engineers check both instantaneous and long-term deflections (due to creep and shrinkage) to ensure they remain within permissible limits, preventing issues like cracking and excessive deformation.

The total long-term deflection, Δ_{LT} is given by:

$$\Delta_{LT} = \Delta_L + \lambda_{\infty} \Delta_D + \lambda_t \Delta_{LS} \quad (10.9)$$

where:

Δ_L : immediate live load deflection (The deflection due to the un-sustained part of the live load is considered in this equation).

Δ_D : immediate dead load deflection.

Δ_{LS} : immediate sustained live load deflection.

$\lambda_t, \lambda_{\infty}$: multiplier for additional deflection due to long-term effects, and it is given by:

$$\lambda_t, \lambda_{\infty} = \frac{\xi}{1 + 50\rho'} \quad (10.10)$$

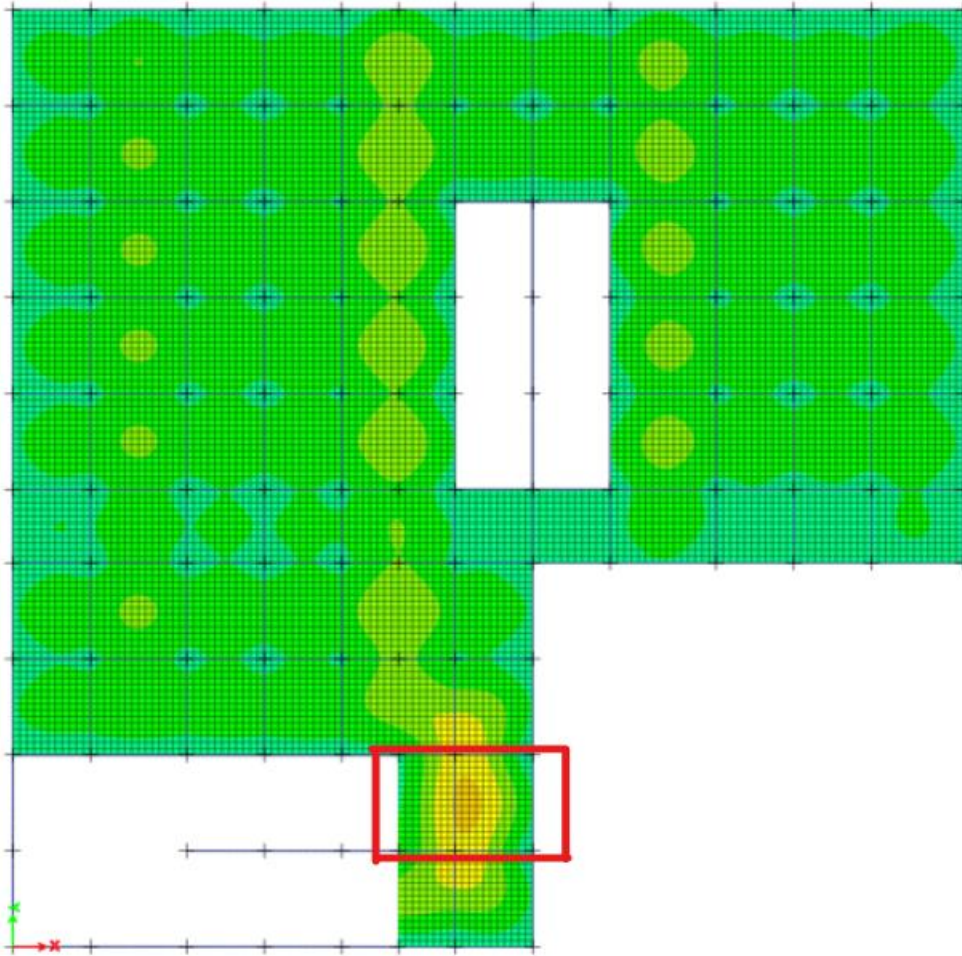
where ρ' (compression steel ratio) shall be the value at midspan for simple and continuous spans, and at support for cantilevers.

Since no sustained live load, $\Delta_{LS} = 0$

$\lambda_{\Delta} = 2$

Maximum deflection is on the 8th floor with $L = 9.5\text{m}$

14.1 deflection for slab



$$\Delta L (\text{un-sustained}) = 10\text{mm}$$

$$\Delta D = 21.15\text{mm}$$

$$\Delta L_t = 10 + 2 \times 21.15 = 52.30\text{mm}$$

Deflection limitation:

Table 10.2: ACI 318-19 Table 24.2.2—Maximum permissible calculated deflections.

Member	Condition		Deflection to be considered	Deflection limitation
Flat roofs	Not supporting or attached to nonstructural elements likely to be damaged by large deflections		Immediate deflection due to maximum of L_r , S , and R	$L/180$ [1]
Floors	Immediate deflection due to L			$L/360$
Roof or floors	Supporting or attached to nonstructural elements	Likely to be damaged by large deflections	That part of the total deflection occurring after attachment of nonstructural elements, which is the sum of the time-dependent deflection due to all sustained loads and the immediate deflection due to any additional live load [2]	$L/480$ [3]
		Not likely to be damaged by large deflections		$L/240$ [4]

for flat roof without partitions under the slab, use $L/180$

$9500/180 = 53\text{mm} > \Delta L_t$; then slab thickness is okay

14.2 deflection for ramp:

Flights:

ΔL (un-sustained) = 4mm

$\Delta D = 10\text{mm}$

$\Delta L_t = 4 + 2 * 10 = 24\text{mm}$

use $L/180$

$10000/180 = 55\text{mm} > \Delta L_t$; then flights thickness is okay

Ramp landing:

ΔL (un-sustained) = 6mm

$\Delta D = 13\text{mm}$

$\Delta L_t = 6 + 2 * 13 = 32\text{mm}$

use $L/180$

$12000/180 = 66\text{mm} > \Delta L_t$; then ramp landing thickness is okay

Ch15 design of slab

15.1 Waffle slab

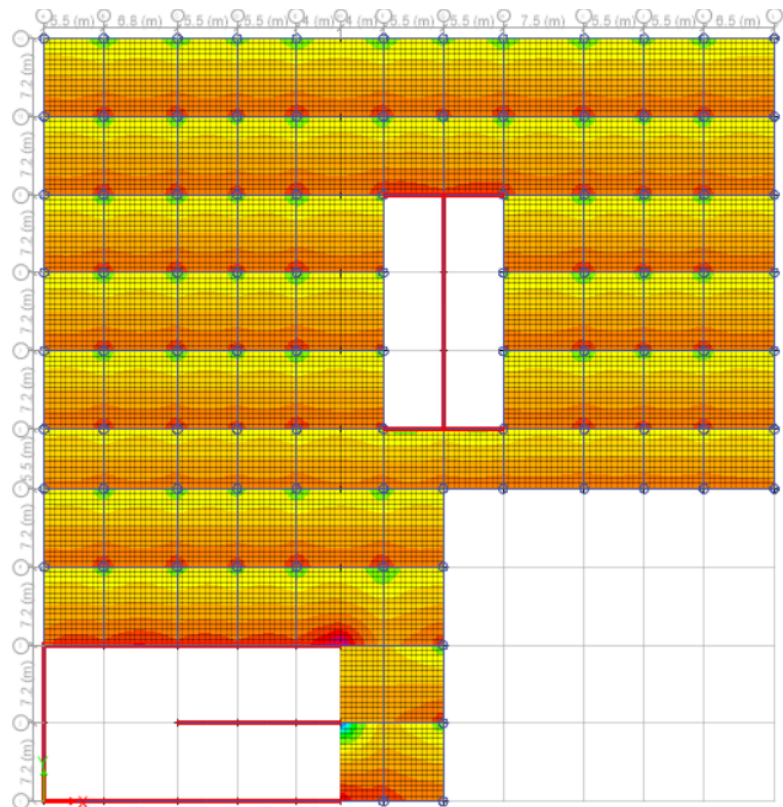
15.1.1 wide beam shear

H= 300mm

D= 240mm

$$\rho_w = 0.0018 \left(\frac{h}{d}\right) = 0.00225$$

$$\phi V_c = \phi \left(0.66 \lambda_s \lambda (\rho_w)^{\frac{1}{3}} \sqrt{f'_c} + \frac{N_u}{6A_g} \right) b_w d = 15 \text{ kn}$$



Vu max.= 50kn > 15kn

$V_s = 35 \text{ kn}$

$A_v/s = V_s/f_{yd}$

For 1 ϕ 10mm, $S = 450\text{mm}$

Since $V_s < 1/3 * f_c^{0.5} * b_w * d$;

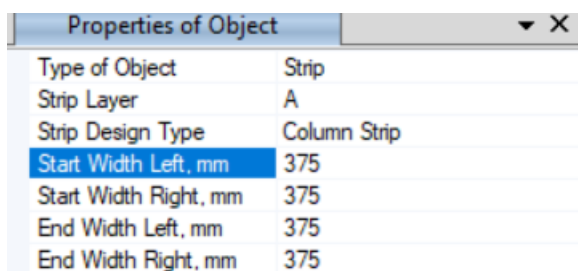
then $S_{\text{max.}} = \text{minimum of } 600\text{mm or } d/2$

$S_{\text{max.}} = 240/2 = 120\text{mm}$, then use 1 ϕ 10mm / 100mm c/c

15.1.2 Design slab for flexural (1st – 8th) floors:

To determine longitudinal bars for a waffle slab, draw design strip that represent the web width of a waffle segments, then replicate the design strip for all waffle segments, and finally choose the best longitudinal bars diameter.

Web width= 750mm



Properties of Object	
Type of Object	Strip
Strip Layer	A
Strip Design Type	Column Strip
Start Width Left, mm	375
Start Width Right, mm	375
End Width Left, mm	375
End Width Right, mm	375

$\rho_{\text{minimum}} = 0.0018$

As minimum = $0.0018 * 1000 * 300 = 540\text{mm}^2$

For one segment of waffle slab $A_{s \text{ min}} = 540 * 750 / 1000 = 405\text{mm}^2$

Note: the main steel put in the stem section for the waffle segment, and use minimum steel for the slab area between stems.

Direction 1(X-direction):

Top steel:

From Etabs, 2 ϕ 12mm is enough as a top steel

As for 2 \varnothing 12mm = 226mm² < As min. = 405mm²

Use 2 \varnothing 16mm

Bottom steel:

From Etabs, 2 \varnothing 12mm is enough as a top steel

As for 2 \varnothing 12mm = 226mm² < As min. = 405mm²

Use 2 \varnothing 16mm

Slab Area between stems:

Thickness = 100mm

Width = 750mm

As = 405, use 1 \varnothing 12mm / 185mm

Direction 1(Y-direction):

Top steel:

From Etabs, 2 \varnothing 12mm is enough as a top steel

As for 2 \varnothing 12mm = 226mm² < As min. = 405mm²

Use 2 \varnothing 16mm

Bottom steel:

From Etabs, 2 \varnothing 12mm is enough as a top steel

As for 2 \varnothing 12mm = 226mm² < As min. = 405mm²

Use 2 \varnothing 16mm

Slab Area between stems (distance = 750mm):

As = 405mm², use 1 \varnothing 12mm / 185mm

15.1.3 Punching shear

No punching shear; because of the internal beams

15.2 Ramp design

15.2.1 Landing

Flexural design:

$A_s \text{ min.} = 0.0018 * 1000 * 300 = 540 \text{ mm}^2$

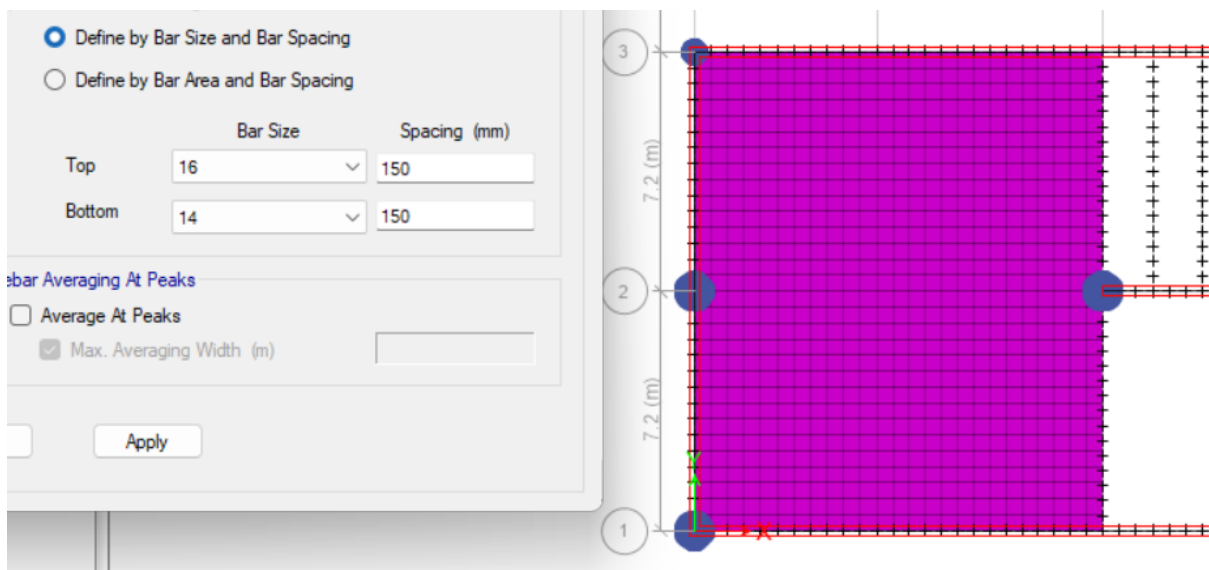
X-direction:

Top steel: 1 ϕ 16mm /150mm

$A_s = 1340 \text{ mm}^2 > A_s \text{ min.} = 540 \text{ mm}^2$; then it's okay

bottom steel: 1 ϕ 14mm /150mm

$A_s = 1026 \text{ mm}^2 > A_s \text{ min.} = 540 \text{ mm}^2$; then it's okay



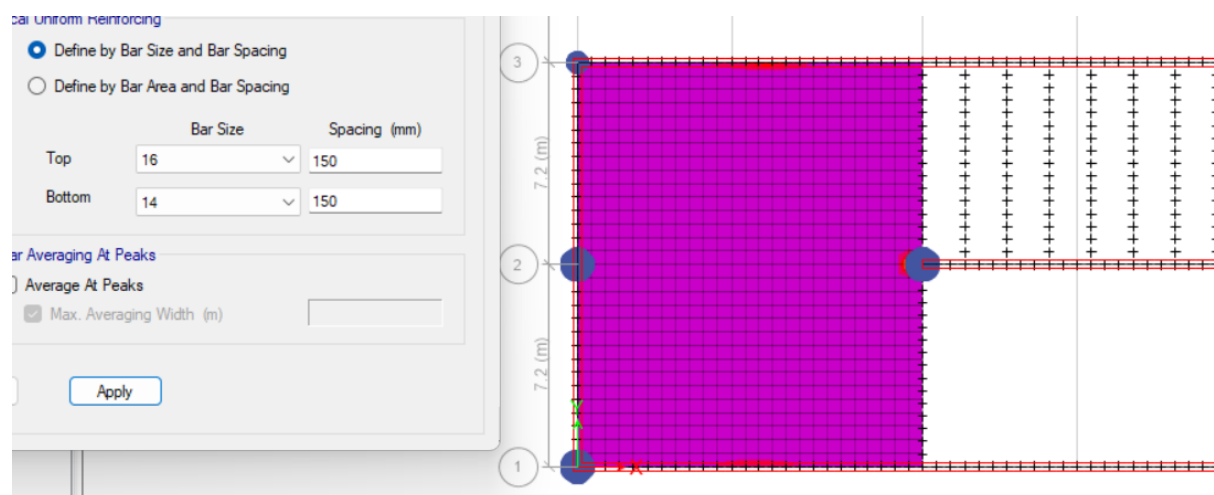
Y-direction:

Top steel: 1 ϕ 16mm /150mm

$A_s = 1340\text{mm}^2 > A_{s \text{ min.}} = 540\text{mm}^2$; then it's okay

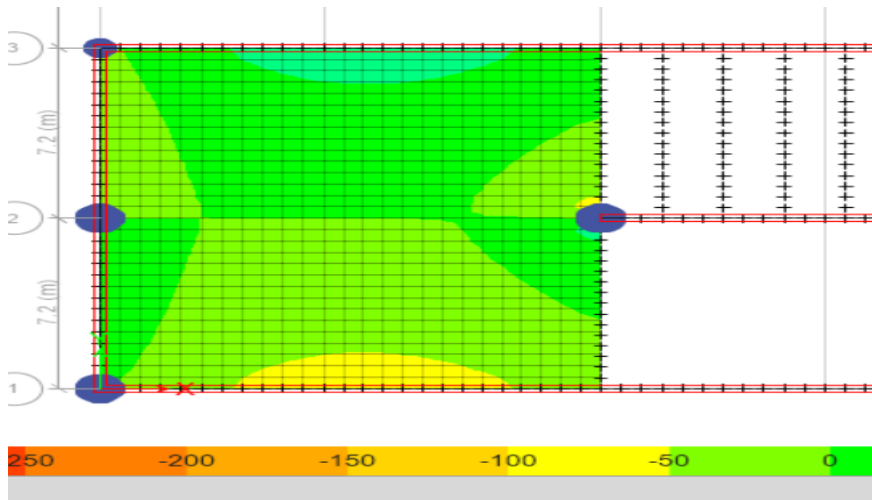
bottom steel: 1 ϕ 14mm /150mm

$A_s = 1026\text{mm}^2 > A_{s \text{ min.}} = 540\text{mm}^2$; then it's okay



Shear check

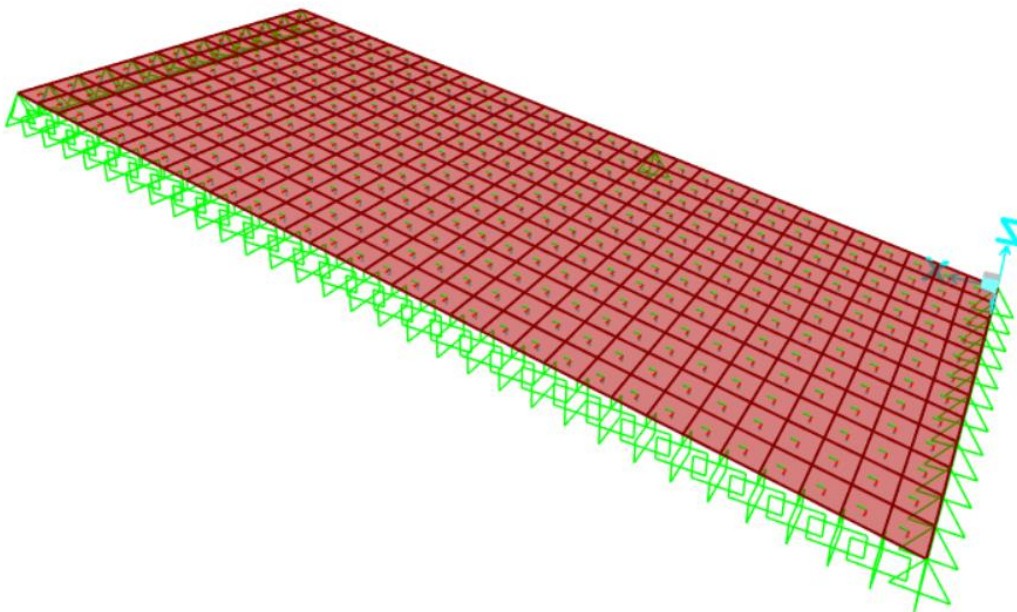
$$\phi V_c = \phi \left(0.66 \lambda_s \lambda (\rho_w)^{\frac{1}{3}} \sqrt{f'_c} + \frac{N_u}{6A_g} \right) b_w d = 102 \text{ kn}$$



$V_u = 75 \text{ kN} < 102$; no need shear reinforcement

15.2.2 Flights

Because the inclined flights, use SAP2000 to design it



Flexural design:

$$A_s \text{ min.} = 0.0018 * 1000 * 300 = 540 \text{ mm}^2$$

X-direction:

Top steel: 1 ϕ 16mm /150mm

$A_s = 1340 \text{ mm}^2 > A_s \text{ min.} = 540 \text{ mm}^2$; then it's okay

bottom steel: 1 ϕ 14mm /150mm

$A_s = 1026\text{mm}^2 > A_{s \text{ min.}} = 540\text{mm}^2$; then it's okay

Y-direction:

Top steel: 1 ϕ 16mm /150mm

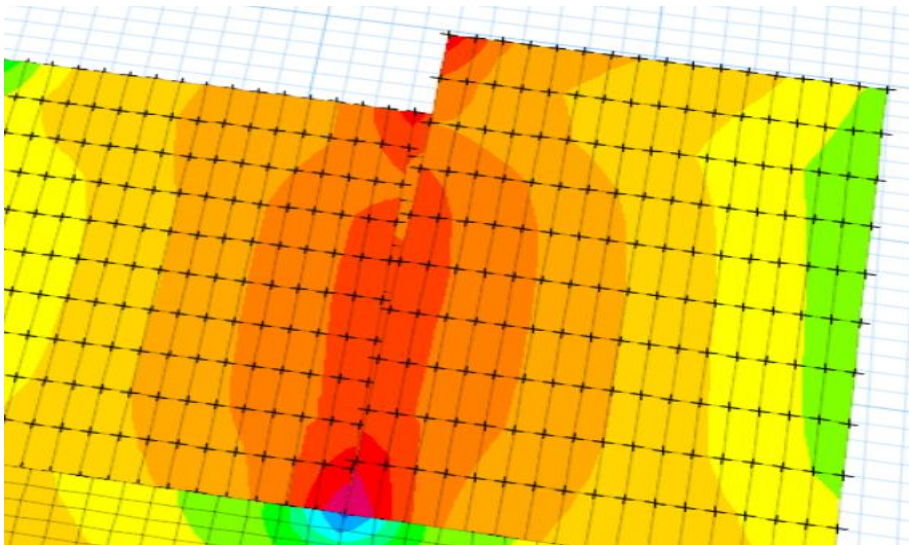
$A_s = 1340\text{mm}^2 > A_{s \text{ min.}} = 540\text{mm}^2$; then it's okay

bottom steel: 1 ϕ 14mm /150mm

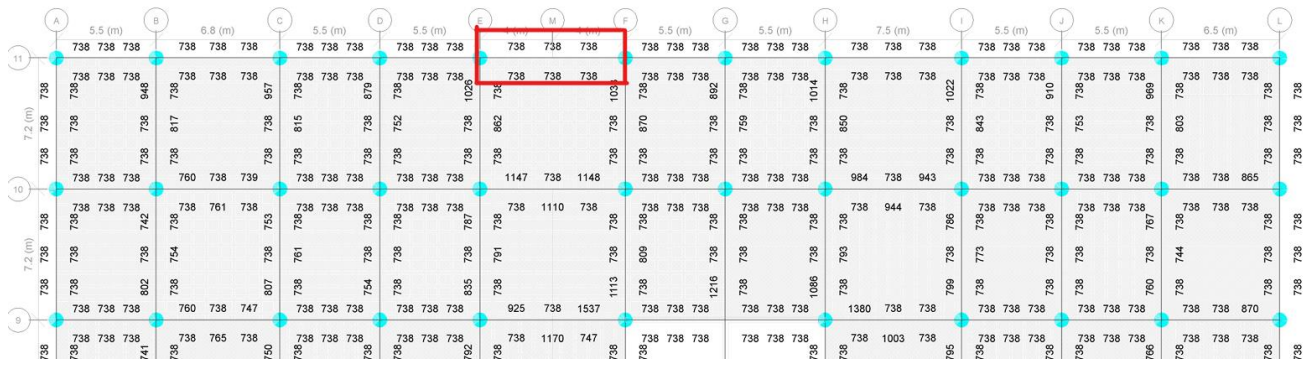
$A_s = 1026\text{mm}^2 > A_{s \text{ min.}} = 540\text{mm}^2$; then it's okay

Shear check

$$\phi V_c = \phi \left(0.66 \lambda_s \lambda (\rho_w)^{\frac{1}{3}} \sqrt{f'_c} + \frac{N_u}{6A_g} \right) b_w d = 102 \text{ kn}$$



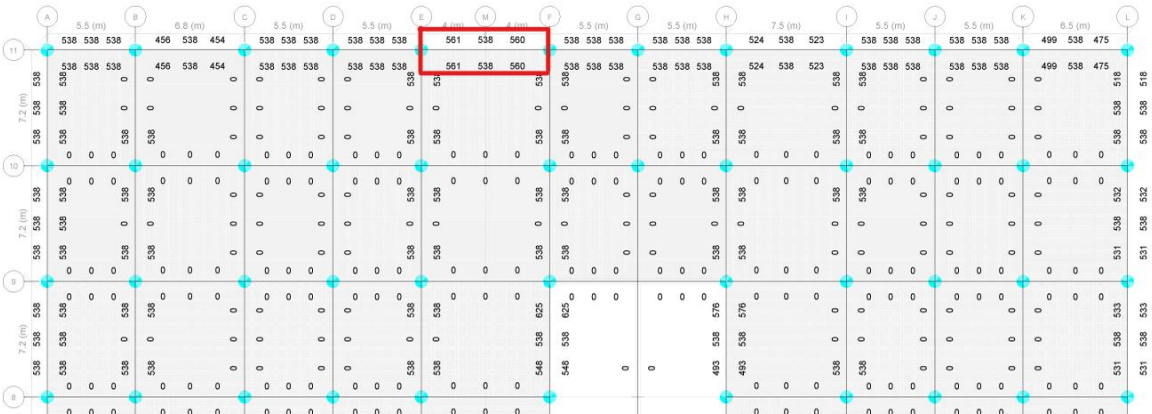
$V_u = 80\text{kn} < 102$; no need shear reinforcement



Design the selected beam as an example:

Maximum top $A_s = 740\text{mm}^2$

Maximum bottom $A_s = 740\text{mm}^2$



Design the selected beam as an example:

Maximum top $A_s = 560 \text{ mm}^2$

Maximum middle $A_s = 560 \text{ mm}^2$

Maximum bottom $A_s = 560 \text{ mm}^2$

Total A_s for the selected beam:

$A_s \text{ top} = 560 + 740 = 1300 \text{ mm}^2$

$A_s \text{ middle} = 560 \text{ mm}^2$

$A_s \text{ bottom} = 560 + 740 = 1300 \text{ mm}^2$

Top steel: 5 ϕ 18mm

Middle steel: 4 ϕ 14mm / two bars on right side and two bars on left

Bottom steel: 5 ϕ 18mm

16.2 Design transverse rebar for beams from shear and torsion:

4th to 8th floors (special frames):

Seismic Requirements

For beams in seismic regions (Special Moment Frames or Special Structural Walls):

1. Critical Zones (within 2d of the ends of beams):

Maximum spacing between $d/4$, 6 inches (150 mm).

This ensures better confinement and shear resistance in regions of high ductility demand.

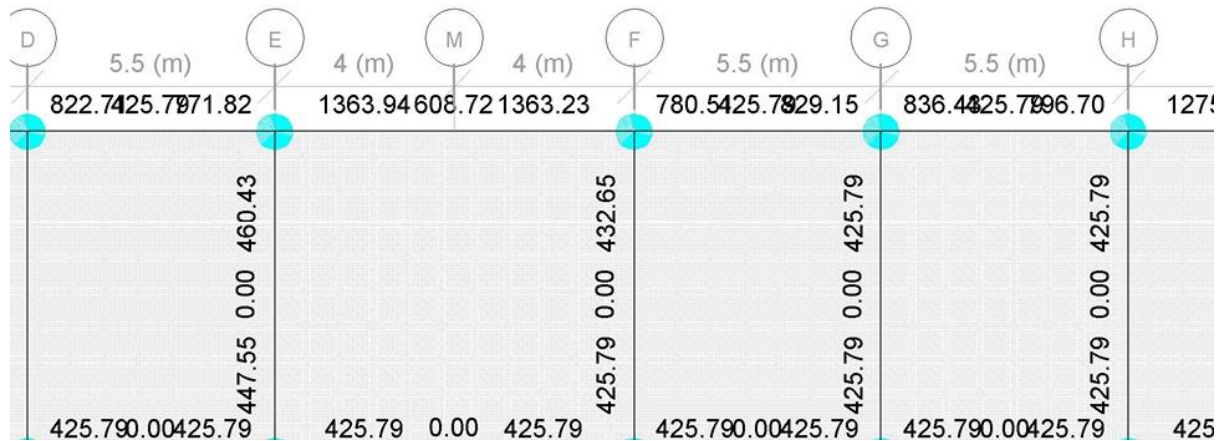
2. Other Regions of Beams:

Maximum spacing between $d/2$ or 12 inches (300 mm).

2 ϕ 10 mm stirrups: $A_v = 235\text{mm}^2$

2 ϕ 12 mm stirrups: $A_v = 340\text{mm}^2$

From beamstransverserebar(shear+torsion)8th.pdf



8th floor from 11E to 11F:

2d = 880mm take it 1m

Stirrups within 1 m from each sides:

$A_v / S = 1364 \text{ mm}^2/\text{m} = 1.364 \text{ mm}^2/\text{mm}$

Using 3 legs ϕ 10 mm, $A_v = 235 \text{ mm}^2$

$S_{\text{max.}} = d/4 = 110 \text{ mm}$, use 100mm

$S = 235/1.364 = 173 \text{ mm} > S_{\text{max.}}$ use $S_{\text{max.}}$

So; 3 legs ϕ 10mm / 10 cm

Stirrups in the middle of span (more than 1 m):

$S_{\text{max.}} = d/2 = 220 \text{ mm}$

$A_v / S = 1364 \text{ mm}^2/\text{m} = 1.364 \text{ mm}^2/\text{mm}$

Using 3 legs ϕ 10 mm, $A_v = 235 \text{ mm}^2$

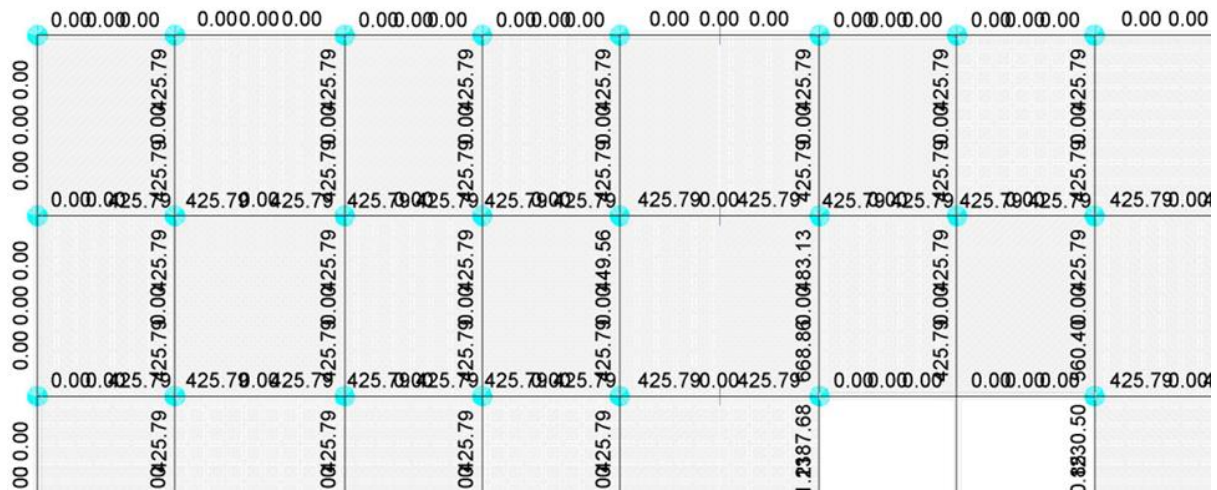
$S = 235/1.364 = 173 \text{ mm} < S_{\text{max}}$

So; 3 legs ϕ 10mm / 17cm

1st to 4th floors:

No special frames because of special walls design

From beamtransverserebar(shear+torsion)3th.pdf



Distance 3 m from each sides

A_v for 2 legs 10 mm stirrups= 157mm²

$S = 157/0.425 = 370\text{mm}$

$S_{\text{max.}} = d/2 = 220\text{mm}$, use 200mm

Use 1 ϕ 10mm / 20cm

Mid span (2 m):

No stirrups needed; so use 1 ϕ 10mm / 40cm

Ch17 Wall design

17.1 retaining walls

Using a selected fill for backfill with unit weight= 18kn/m^2

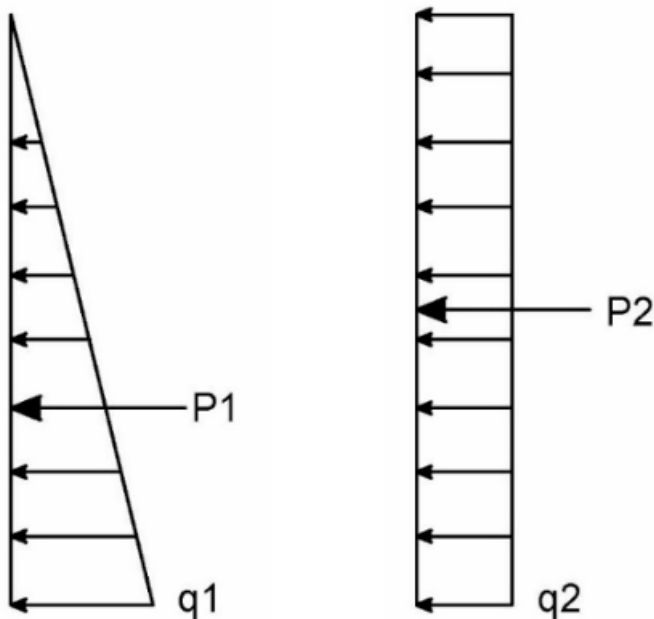
And $\varphi = 30$ degree.

Surcharge load= 10kn/m^2 on three sides of the parking building

Fourth side (west side) no surcharge load.

Retaining walls with surcharge load:

soil load calculations:



For $\varphi = 30$ degree, $h = 3 \times 4 = 12\text{m}$, surcharge load(w)= 10kn/m^2 and $\gamma_s = 18\text{kn/m}^2$

$$K_a = \frac{1 - \sin 30}{1 + \sin 30} = 0.333$$

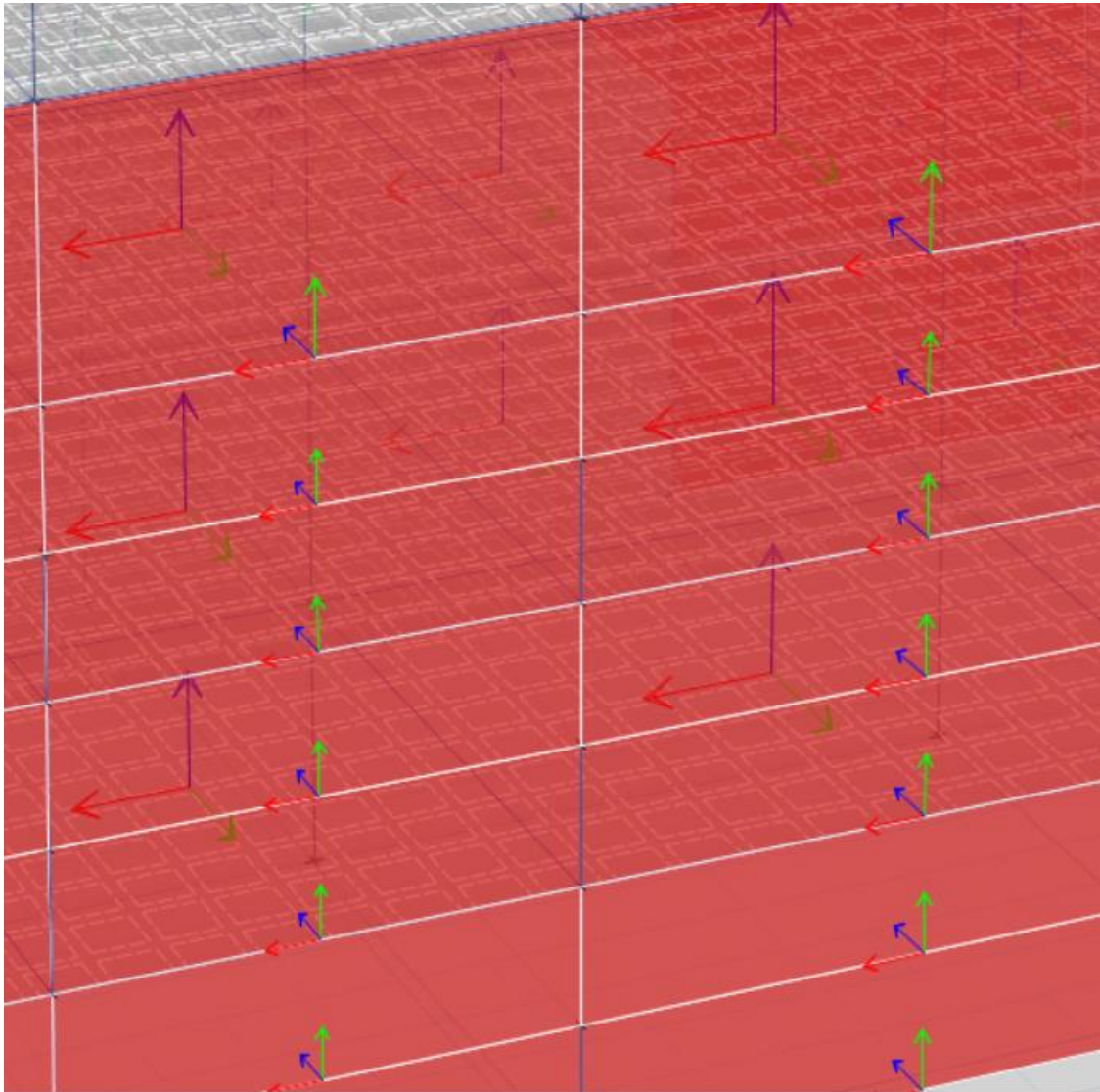
$$Q_1 = \gamma \cdot h \cdot K_a = 18 \cdot 12 \cdot 0.333 = 72\text{kn/m}^2$$

$$Q_2 = W \cdot K_a = 3.33\text{kn/m}^2$$

assign uniform soil load $q = -6Z + 72$

NOTE: - design a strip with 1m width.

First be sure that 3-local axes direction is to inside the building



Then make a rectangular 0.5*0.5 mesh for a 1m strip, then assign the strip for a pier label and finally assign soil and surcharge load.

Surcharge load assign:

Shell Load Assignment - Uniform ✕

Load Pattern Name

Uniform Load

Load kN/m²

Direction

Options

Add to Existing Loads

Replace Existing Loads

Delete Existing Loads

Non-uniform soil load assign:

Shell Load Assignment - Non-uniform ✕

Load Pattern Name

Direction

Restrictions

Use All Values

Zero Negative Values

Zero Positive Values

Non-uniform Load

Load at Point(x,y,z) = Ax + By + Cz + D
x, y and z are in the Global coordinate system

A	<input type="text" value="0"/>	kN/m ³
B	<input type="text" value="0"/>	kN/m ³
C	<input type="text" value="-6"/>	kN/m ³
D	<input type="text" value="72"/>	kN/m ²

Options

Add to Existing Loads

Replace Existing Loads

Delete Existing Loads

In special wall design, use vertical longitudinal bars with hoops to resist axial force and bending moment, and horizontal longitudinal bars to resist shear forces

Vertical longitudinal bars:

As min.= $0.0018 \times 1000 \times 300 = 540 \text{mm}^2$

As from Etabs= 1250mm^2 for both sides

$1250/2 = 625 \text{mm}^2$ for one side

Use 1 \varnothing 12mm / 150mm in each side

Hoops:

For a 300 mm thick special structural wall, if boundary elements are required, hoops will need to be provided within these boundary elements to meet ACI 318-19 requirements.

1-Boundary element width = $2 \times \text{wall thickness} = 600 \text{mm}$

2-Vertical space between hoops, the smallest of:

-0.25 of the boundary element's smallest dimension= $0.25 \times 300 = 75$

- $6 \times$ diameter of the smallest longitudinal= $6 \times 12 = 72 \text{mm}$

-100mm

So; use vertical 70mm as a vertical space

Use 1 \varnothing 10mm / 70mm c/c

Horizontal longitudinal bars:

$$A_s = 0.0025 * 1000 * 300 = 750 \text{mm}^2/\text{m}$$

A_s from Etabs = 750mm²/m for both sides

$A_s = 375 \text{mm}^2/\text{m}$ for one side

Use 1 \varnothing 12mm / 250mm

Maximum distance between horizontal bars:

1) Maximum spacing based on wall thickness:

$$\text{Max spacing} = 300/2 = 150 \text{mm}$$

2) Maximum spacing based on bar diameter:

$$\text{Max spacing} = 6 \times 12 \text{ mm} = 72 \text{ mm}$$

3) Maximum spacing per ACI 318-19:

Max spacing = 300 mm (12 inches).

Use 1 \varnothing 12mm / 70mm

17.2 Shear walls

Use normal wall design, because special retaining walls are much more than shear walls and because the last 4 floors designed as a special frame.

Vertical longitudinal bars:

$A_s = 750 \text{ mm}^2/\text{m}$ for both sides

$A_s = 375 \text{ mm}^2$ for one side

Use 1 \varnothing 12mm/250mm for each side

Horizontal longitudinal bars:

$A_s = 750 \text{ mm}^2/\text{m}$ for both sides

$A_s = 375 \text{ mm}^2$ for one side

Use 1 \varnothing 12mm/250mm for each side

Ch18 Mat foundation

Thickness of mat foundation 600mm

Check wide beam shear:

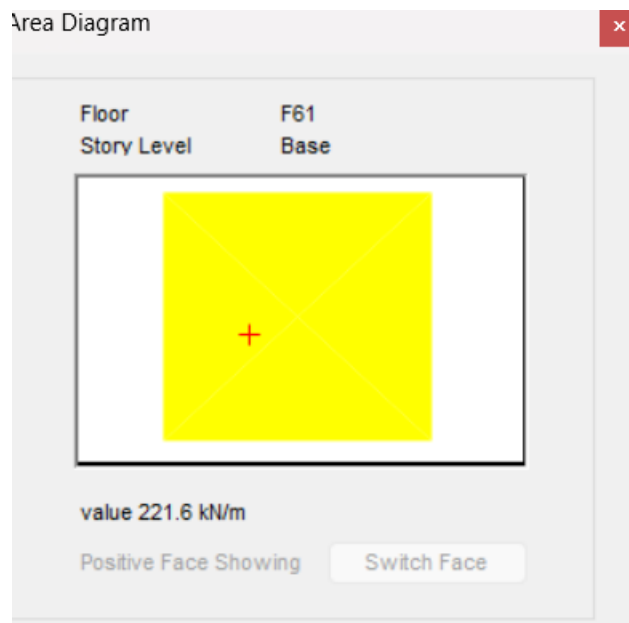
H= 600mm

D= 500mm

$$\rho_w = 0.0018 \left(\frac{h}{d} \right) = 0.00225$$

$$\phi V_c = \phi \left(0.66 \lambda_s \lambda (\rho_w)^{\frac{1}{3}} \sqrt{f'_c} + \frac{N_u}{6A_g} \right) b_w d = 184 \text{kn}$$

Vu = 222kn



Need to increase thickness of mat

Try mat with 700mm thickness

Check wide beam shear:

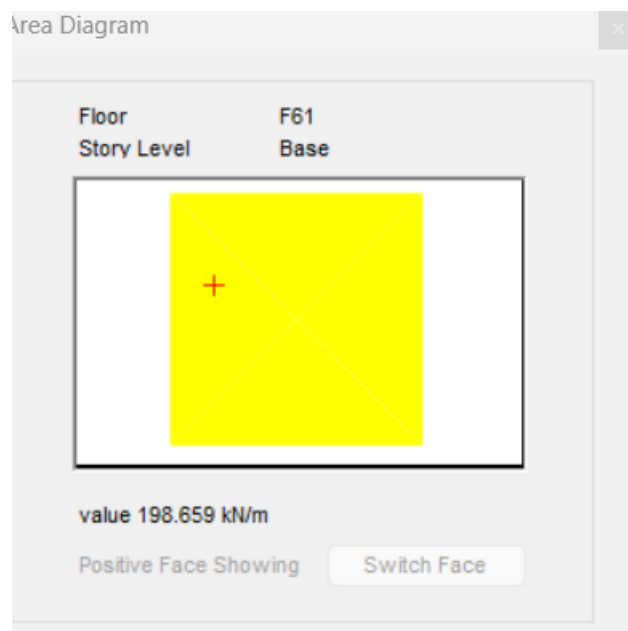
H= 700mm

D= 600mm

$$\rho_w = 0.0018 \left(\frac{h}{d} \right) = 0.0021$$

$$\phi V_c = \phi \left(0.66 \lambda_s \lambda (\rho_w)^{\frac{1}{3}} \sqrt{f'_c} + \frac{N_u}{6A_g} \right) b_w d = 215 \text{ kN}$$

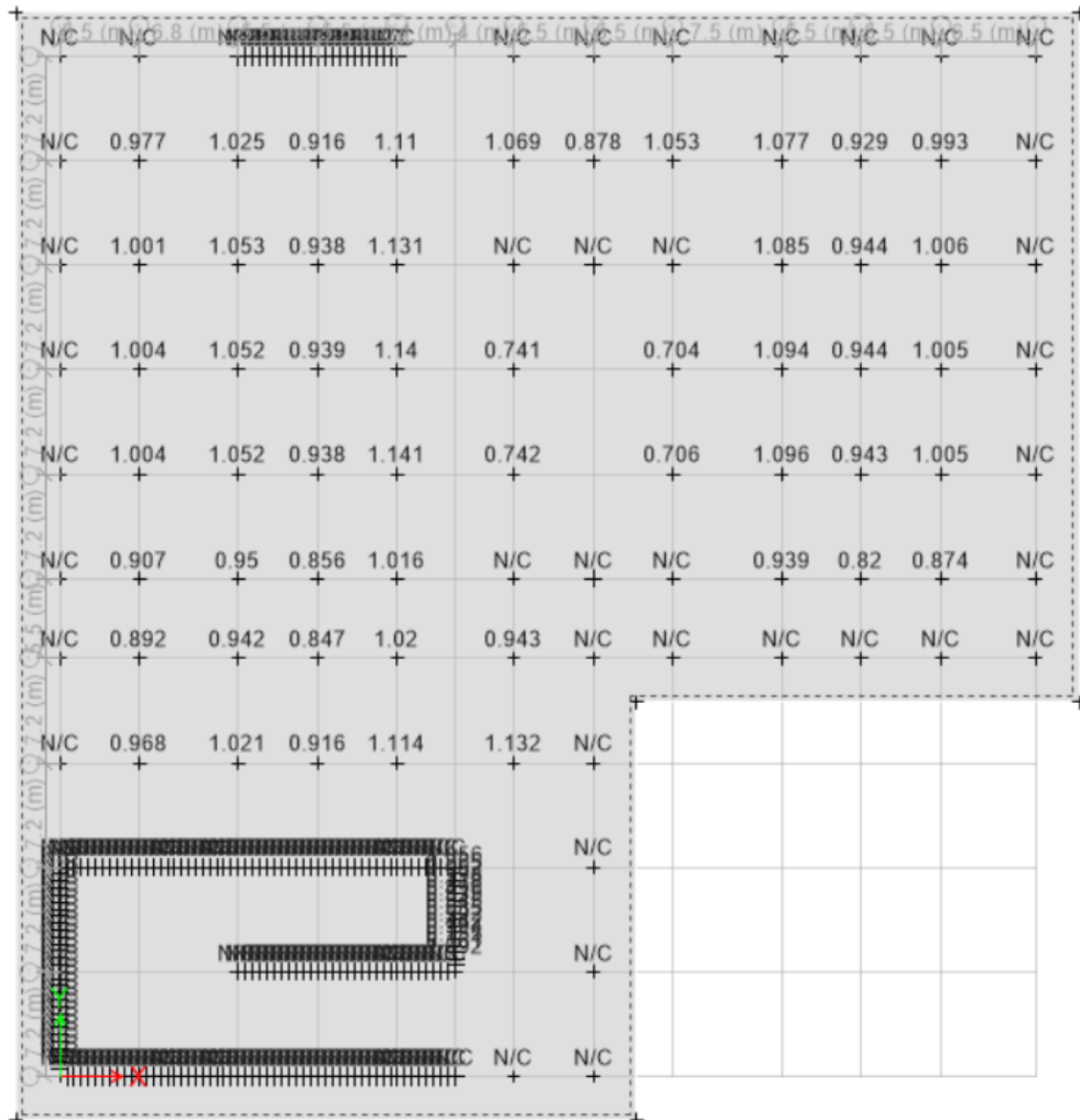
Vu = 200 kN



Since $\phi V_c > V_u$; then no need for shear reinforcement

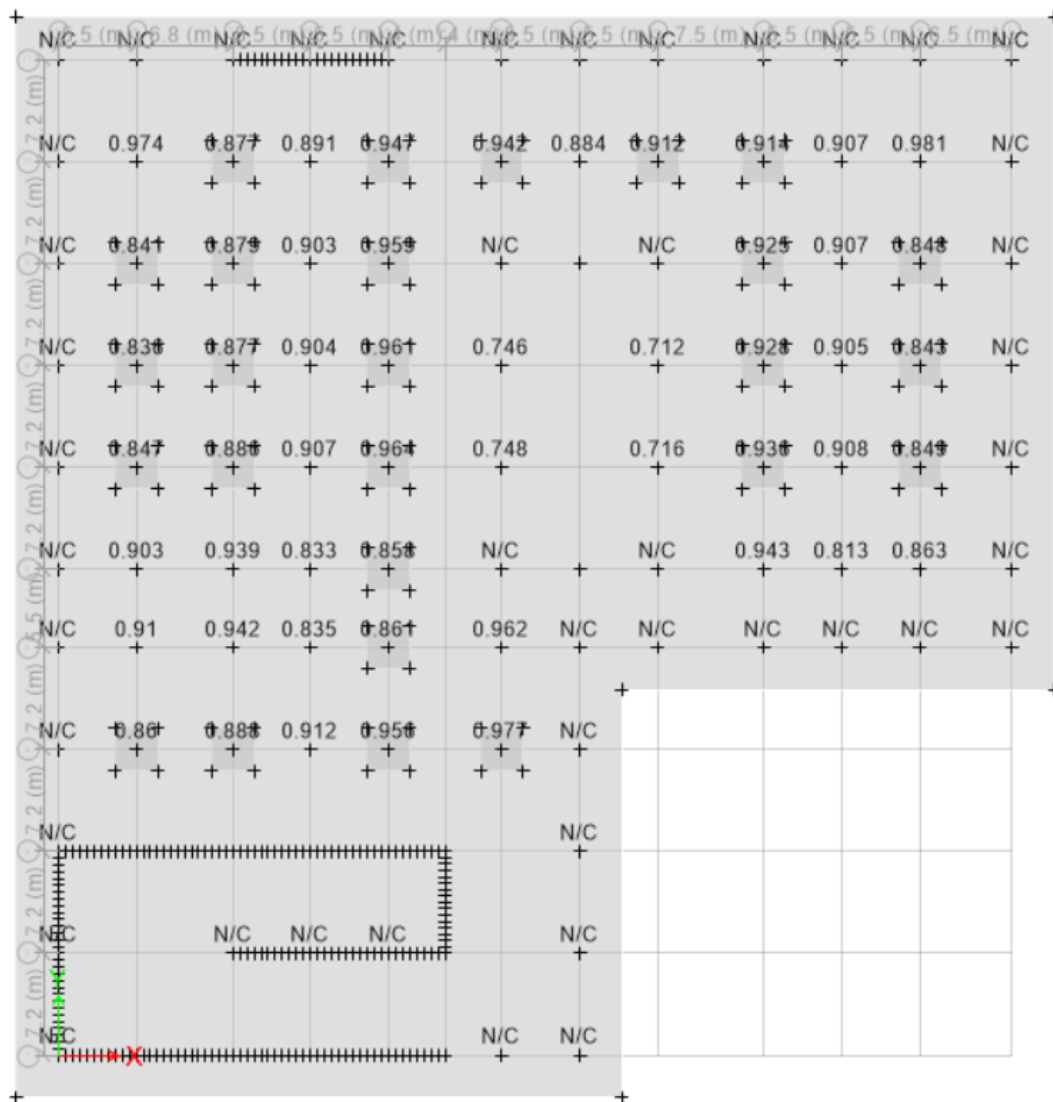
Thickness is ok

Check punching shear:



For demand/capacity ratio more than 1, use drop panels

Using drop panels with 3mX3m and thickness of 800mm:

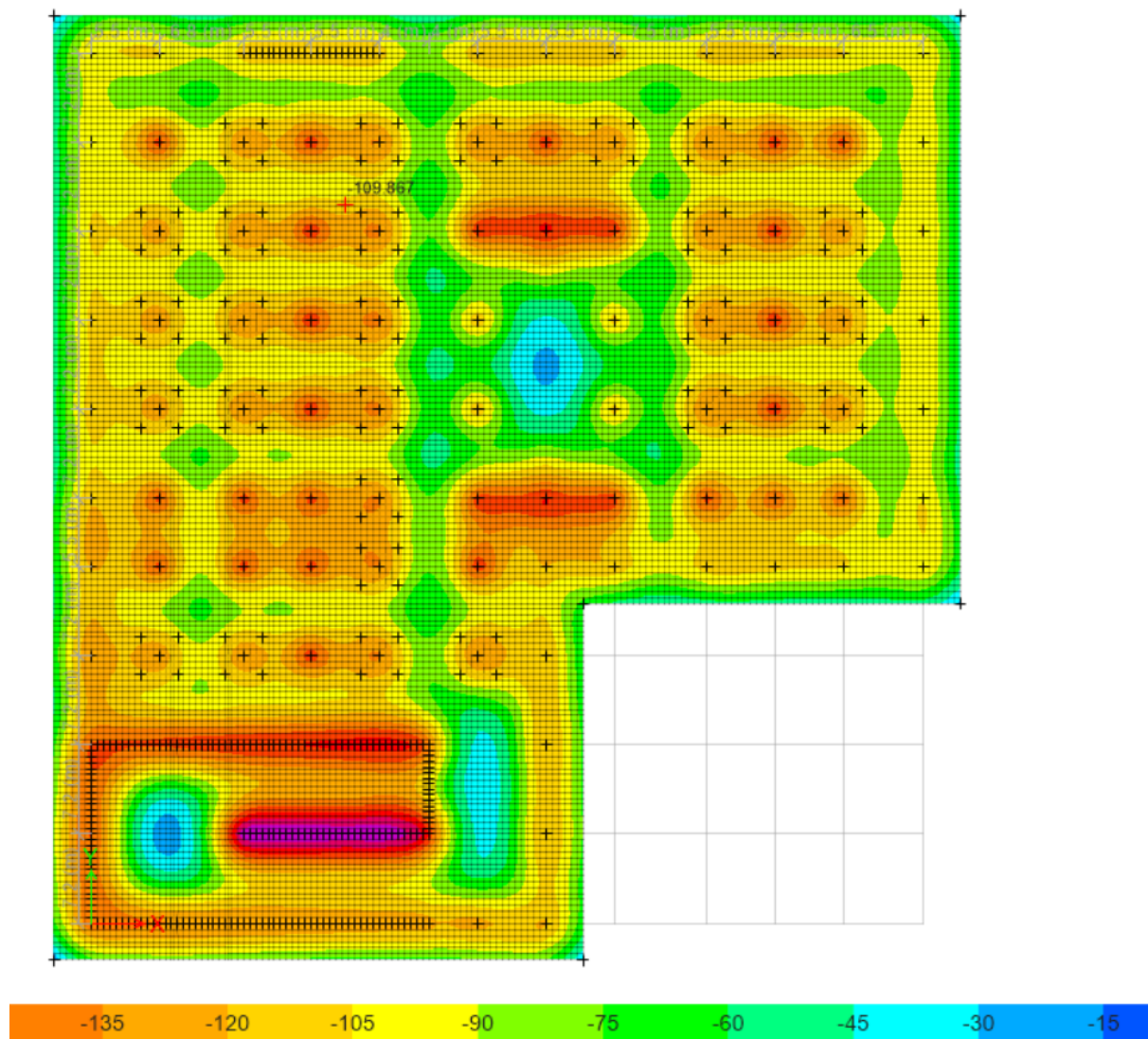


Punching shear is ok

Check soil pressure under footing:

In this check maximum soil pressure must be less than bearing capacity of the soil (300kn/m²), and the values of the pressure should be negative to ensure that the soil exposed to compression from the footing.

Soil pressure from service load combination:



-Maximum value of pressure is 210kn/m² which is less than 300kn/m²; then it's ok

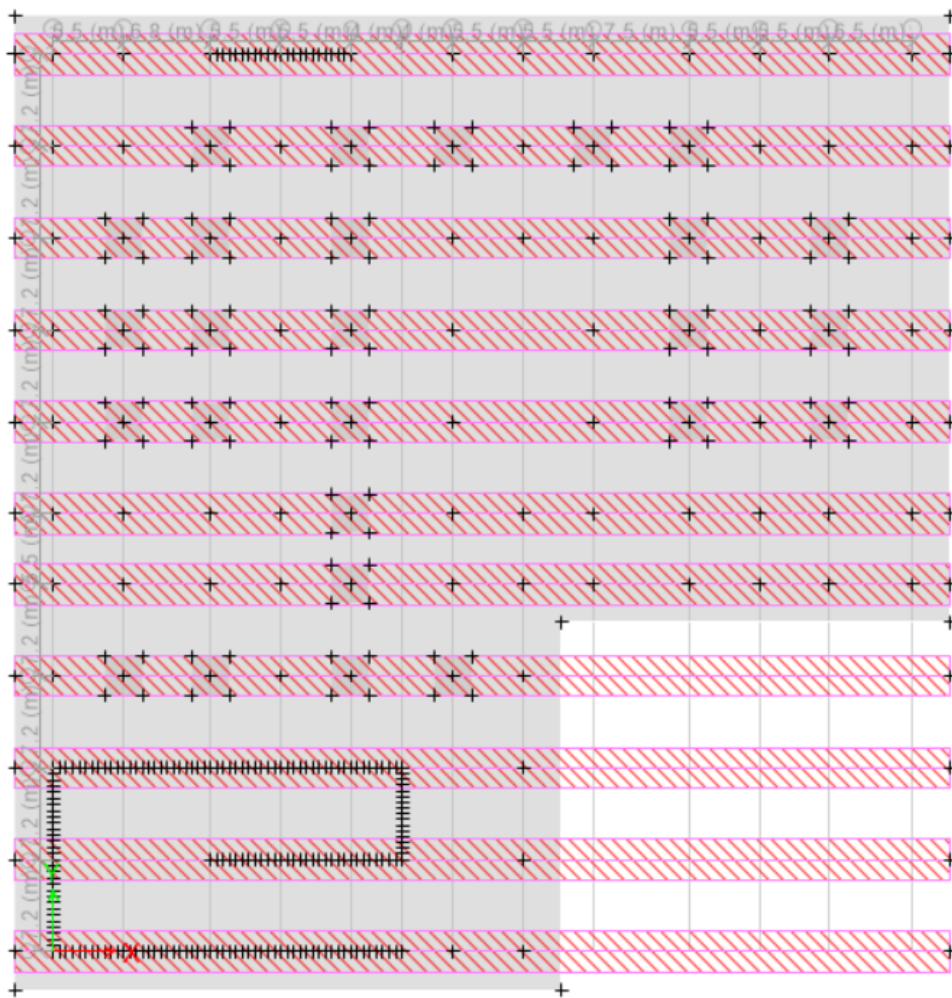
-all pressure values are negative (compression) no tension; then it's ok

Design mat foundation for flexural:

To design mat foundation, draw column and middle strips in each direction (X, Y-direction) and make sure that the steel bars used have an A_s more than A_s minimum.

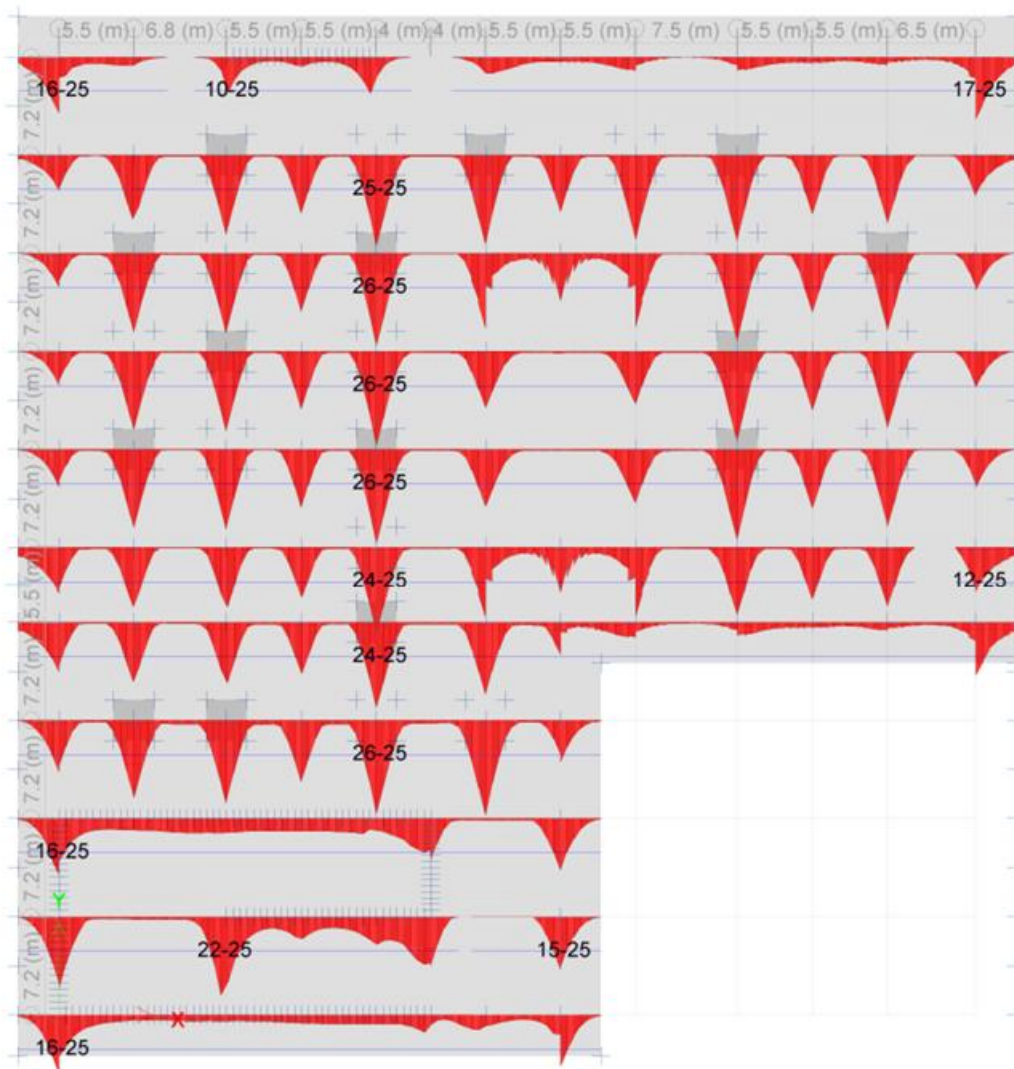
X-direction:

Column strip (3.6m width):



Bottom steel:

Open matrebarX-dir.bottomsteel(column strip).pdf



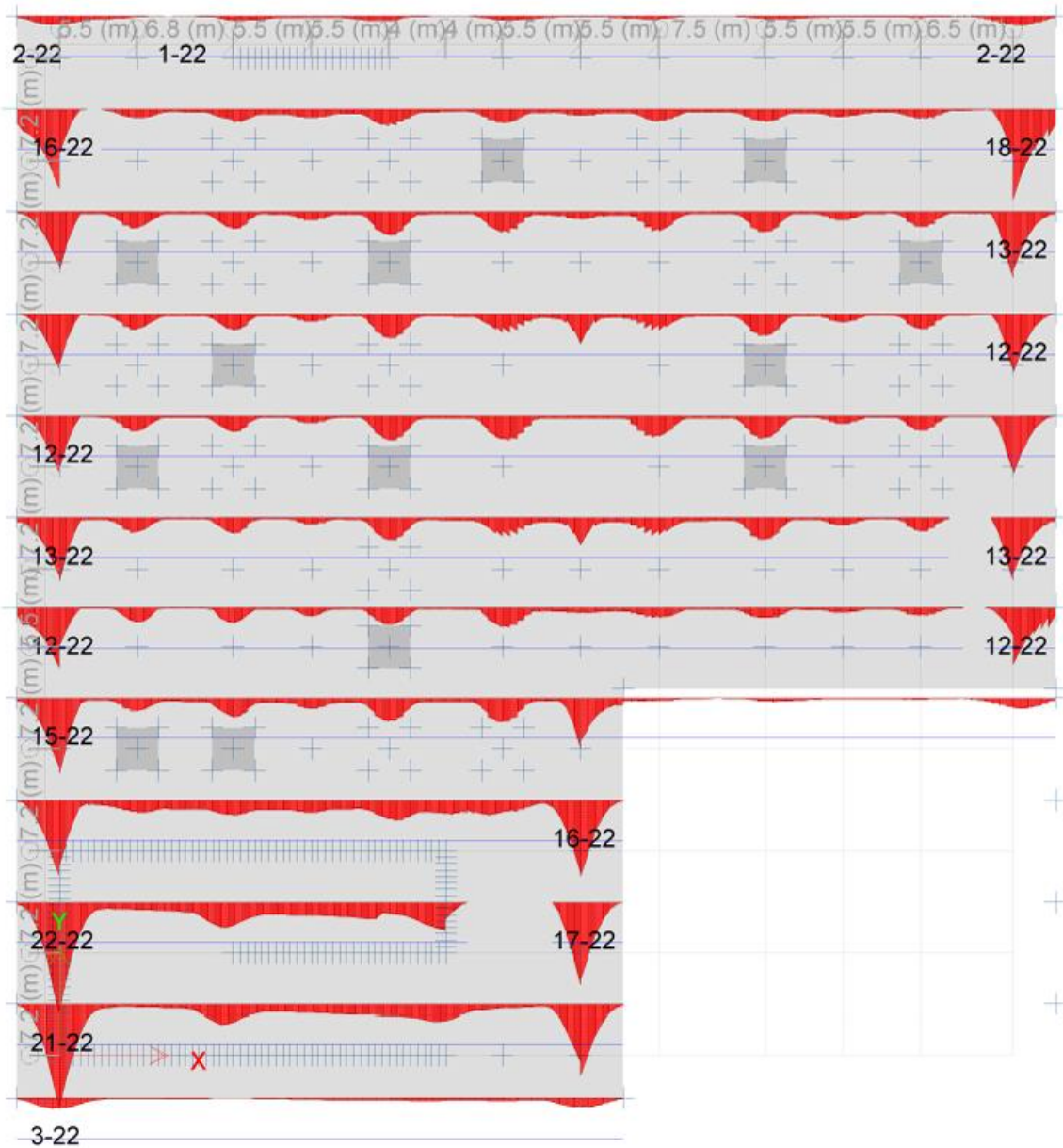
$A_{s \text{ min.}} = 0.0018 * 600 * 3600 = 3888 \text{ mm}^2$

Minimum steel used is 10 ϕ 25mm

As for 10 ϕ 25mm=4900mm² > $A_{s \text{ min.}}$ then; area of steel is good

Bottom steel:

Open matrebarX-dir.bottomsteel(middle strip).pdf

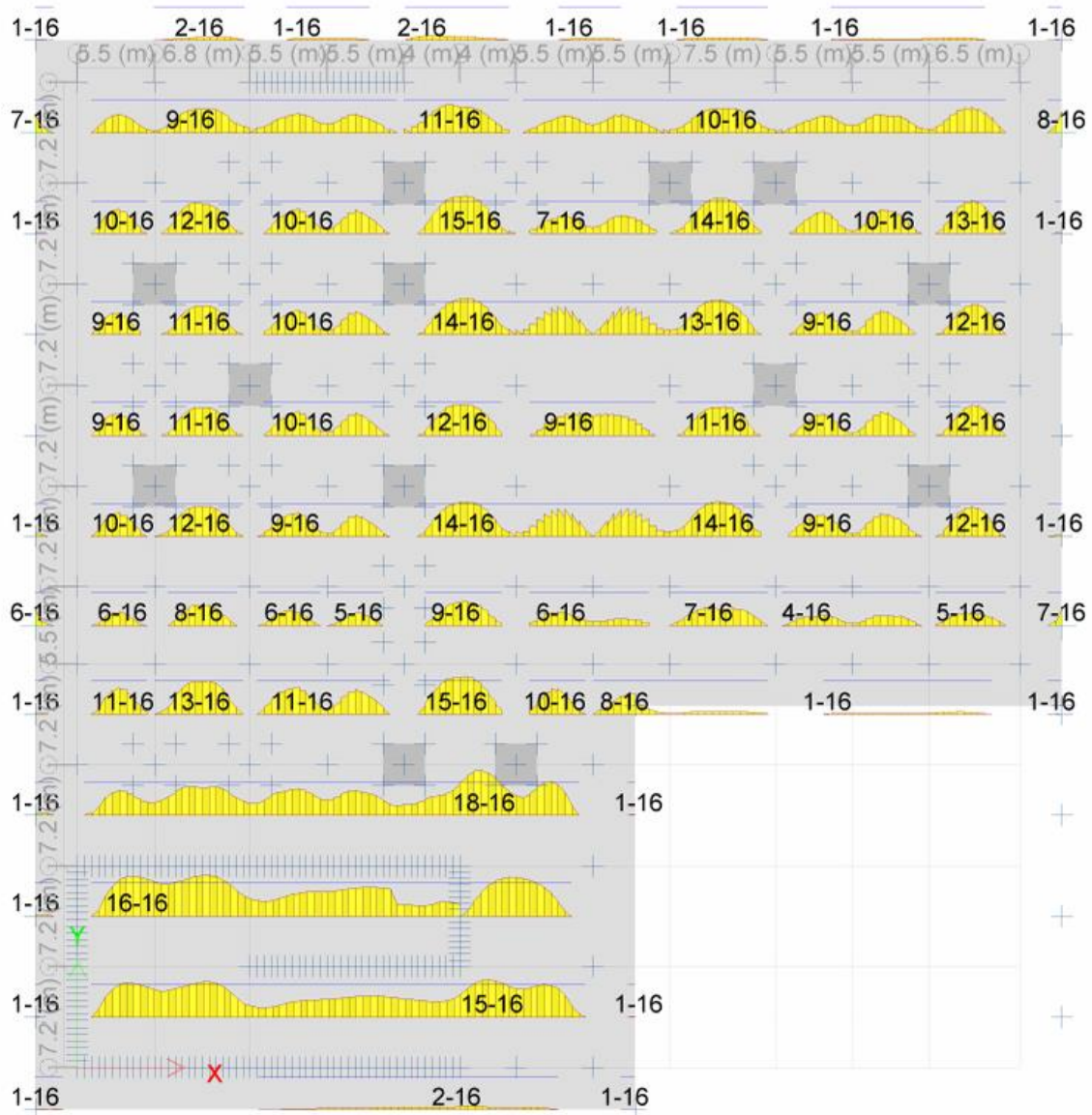


$$A_s \text{ min.} = 0.0018 * 600 * 3600 = 3888 \text{ mm}^2$$

Minimum steel = 11 ϕ 22mm

Top steel:

Open matrebarX-dir.topsteel(column strip).pdf



As min. = $0.0018 \times 600 \times 3600 = 3888 \text{mm}^2$

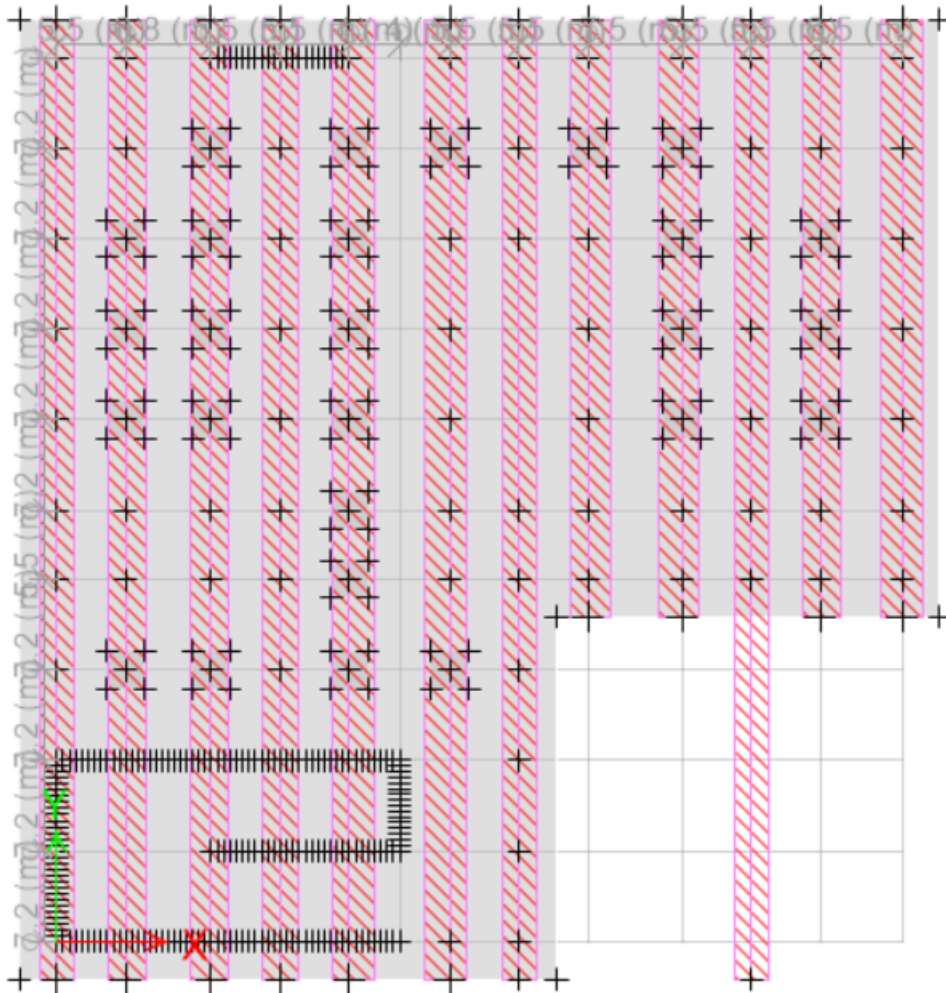
Minimum bars = 20 \varnothing 16mm

Then use 20 \varnothing 16mm for 3.6m width as a top steel

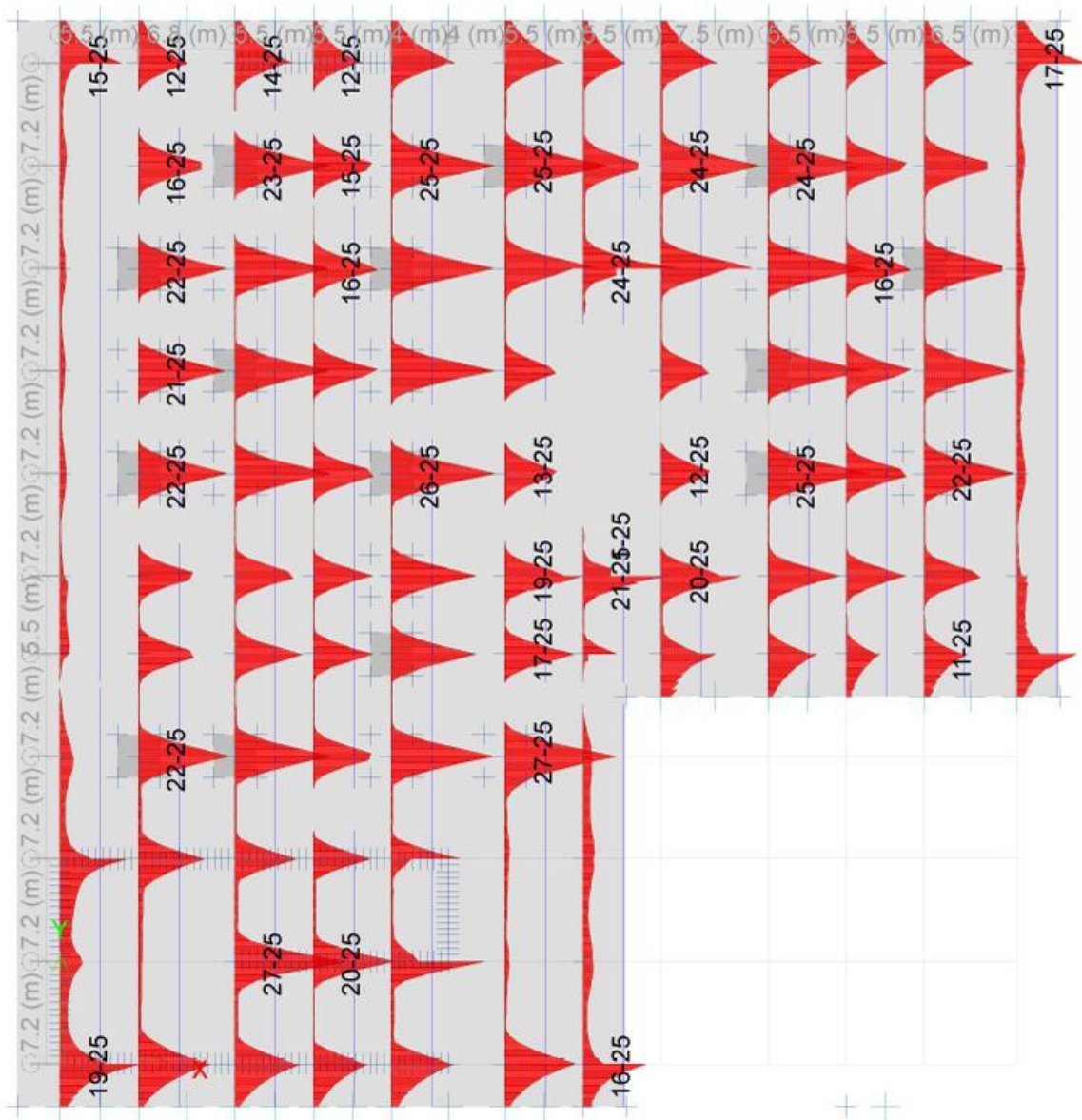
Y-direction:

Column strip:

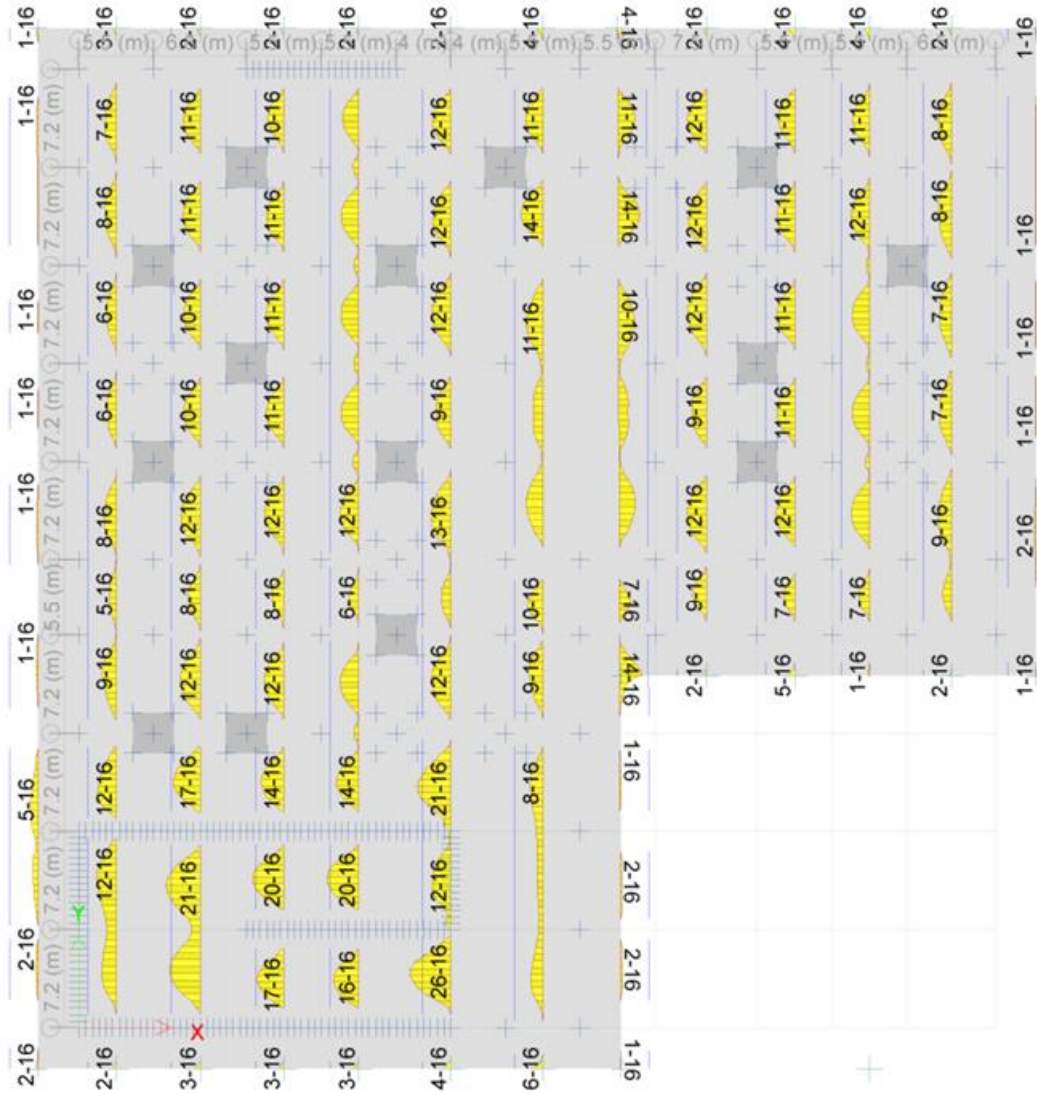
NOTE: variable strips width because of variable span dimensions



Bottom steel:



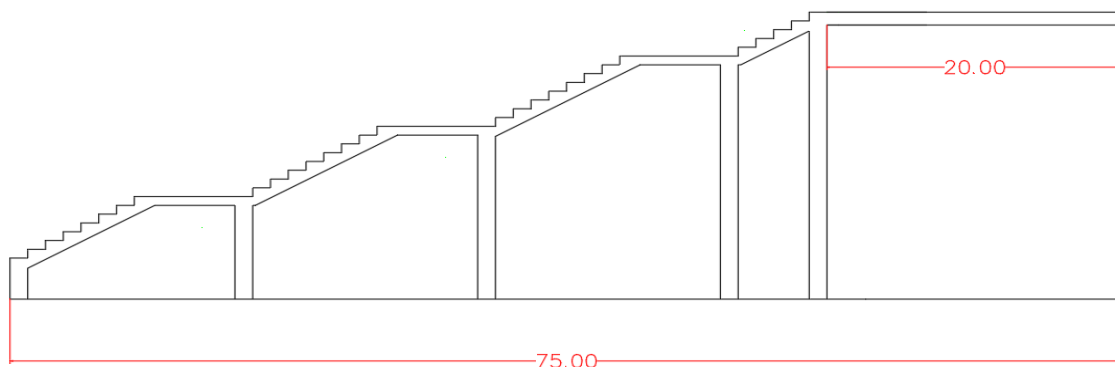
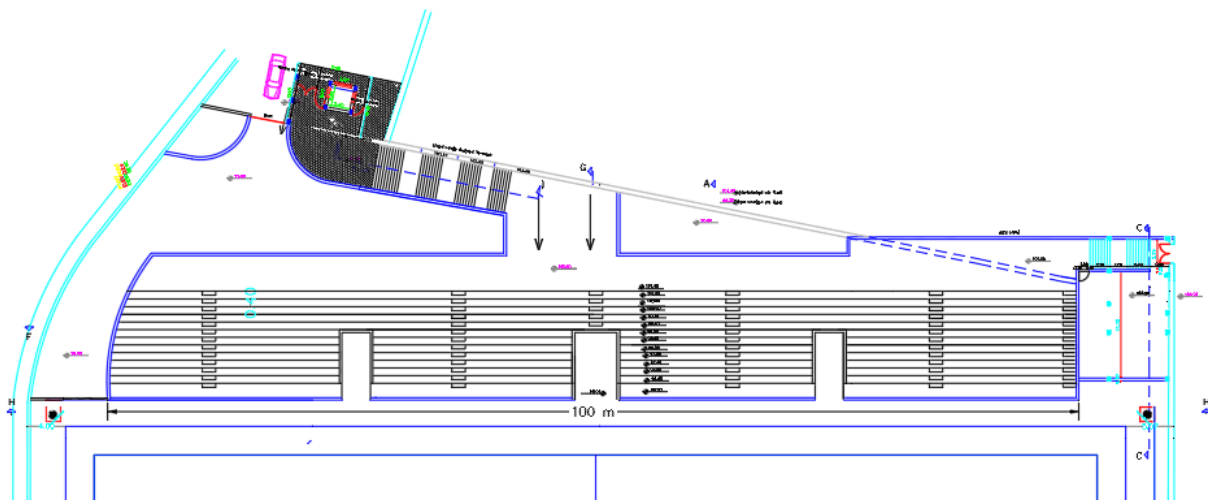
Top steel:



Ch19 Covering Audience Stand

Using a truss steel structure to cover an audience stand is an efficient and durable solution, providing high strength-to-weight ratio, large spans, and aesthetic flexibility. Steel trusses can span long distances with minimal support, ensuring an unobstructed view for spectators while reducing material costs. They efficiently transfer loads to the supporting columns, resisting wind, seismic, and live loads. Additionally, trusses allow for lightweight roofing materials, reducing overall weight and foundation demands. Their modular design also enables easy transportation, assembly, and future expansion, making them ideal for stadiums and outdoor event venues.

19.1 Audience stand plane and dimensions



19.2 codes and standards

-**ASCE 7-10**: for calculating wind load

- **AISC 360-10**: Specification for Structural Steel Buildings, is a widely recognized standard used for the design of steel structures. This code provides guidelines for the design of steel members, including beams, columns, and connections, considering factors like strength, stability, and serviceability. It incorporates modern design philosophies, including limit states design, and helps engineers ensure structural safety and efficiency. By using AISC 360-10, you can develop steel structures that meet the necessary strength requirements while optimizing material use and adhering to the latest industry standards.

19.2.1 Design criteria

- steel grade: A992 Grade 50
- floor height = 12.00m
- mean floor height = 10.00m
- column height = 8.00m
- space between truss = 5.00m
- distance between vertical members = 2.00m

-Warren truss; because it's suitable for:

-Efficient Load Distribution: The Warren truss uses equilateral triangles, allowing for an efficient distribution of loads across the truss, which is especially important for large spans

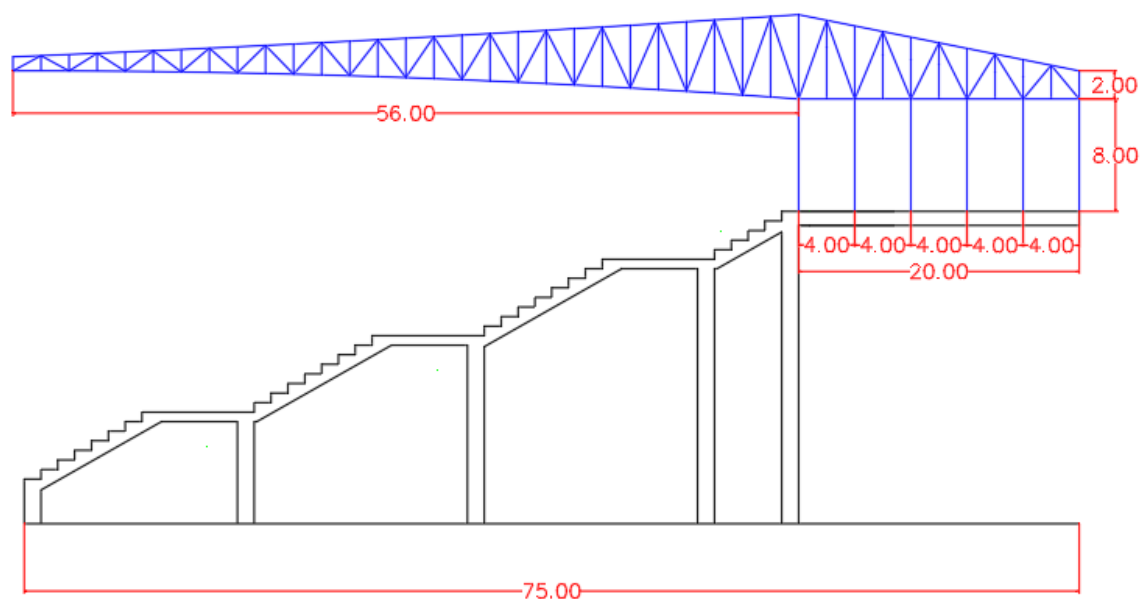
-Lightweight Design: The simple geometry (alternating diagonal members) uses less material than other trusses while maintaining strength.

-Common Use: Often used for long spans in bridges, roofs, and cantilevered structures

19.2.2 Shape of cantilever truss

For 56-meter cantilever truss design, parabolic inclined top chord with a concave upward shape to efficiently shed the weight of water and prevent accumulation. This ensures natural drainage, reducing the risk of ponding and additional loading on the structure. The bottom chord follows a parabolic concave downward shape, aligning with the bending moment distribution to optimize material usage and enhance structural efficiency. This configuration offers several advantages: it reduces overall weight while maintaining strength, minimizes deflections, and enhances stability by efficiently distributing forces. Additionally, the concave upward top chord improves aerodynamic performance, reducing wind-induced stresses, while the concave downward bottom chord maximizes load resistance where it is most needed. Together, these design choices create a lighter, stronger, and more durable cantilever truss, ideal for long-span applications such as audience stands and stadium roofs.

19.2.3 2D Truss Layout:



19.2.4 apply parabolic chord in SAP2000

For top chord draw a curve frame from start to end of the cantilever truss, when click on the end a table will appear:

Curved Frame Geometry

File Edit

Line Object Parameters

Line Object Type: Curved Frame

Curve Type: Parabolic Arc - 3rd Point Coords

Section Property: FSEC1

	X	Y	Z
Start	0.	90.	11.
End	56.	90.	14.
3rd Point	40.	90.	13.

Curve Parameters

Number of Linear Segments: 28 Refresh

Curve Length: 56.0817 T/C Limits...

Line Object Meshing

Keep as Single Object

Break into Multiple Equal Length Objects

Break into Multiple Objects with Equal Projected Length on Chord

Computed Point Coordinates for Linear Segments

Pt.	X	Y	Z
0	0.	90.	11.
1	2.	90.	11.083
2	4.	90.	11.1679
3	6.	90.	11.2545
4	8.	90.	11.3429
5	10.	90.	11.433
6	12.	90.	11.525
7	14.	90.	11.6188
8	16.	90.	11.7143
9	18.	90.	11.8116

Coordinate System: GLOBAL

Units: KN, m, C

Planar View

OK Cancel

Then, choose “parabolic Arc – 3rd point coords”, 3rd point is the center of concave. then, choose number of linear segments 28; because of 56 m span length and 2 m segments length so; $56/2$ is 28 linear segments. Then, copy computed point coordinates for linear segments (Z points) and use these points to draw a special joint these because can't separate the chord to 2m segments because it's not straight (parabolic). Finally, delete the parabolic cord and draw a new one with straight segments between the special joints.

Note: Apply this method for bottom cord

19.3 member's mechanism

1-Bottom Chord (Tension Member)

-**Carries tensile forces** → The bottom chord is mainly in **tension**, resisting the pulling forces caused by loads.

-**Determines truss deflection** → A properly designed bottom chord minimizes sagging and excessive deflection.

-**Works with the top chord** → Together, they form the primary load-carrying system of the truss.

2-Top Chord (Compression Member)

-**Carries compressive forces** → The top chord is in compression, resisting pushing forces caused by loads.

- **Prone to buckling** → Needs bracing to prevent lateral instability.

-**Supports purlins** → Transfers loads from the roof or decking to the truss system.

3-Bracing Between Top Chords (Lateral Bracing)

- **Prevents lateral buckling** → The top chord is under compression, so lateral bracing strengthens it.

-**Increases rigidity** → Helps resist wind loads and asymmetrical forces.

- **Distributes forces more evenly** → Reduces stress concentration at weak points.

4-Bracing Between Bottom Chords

- **Prevents lateral movement** → Keeps the bottom chord stable under tension forces.

- **Reduces dynamic effects** → Improves vibration control, especially in large-span structures.

- **Balances force distribution** → Helps maintain a uniform load path across the truss.

5- Vertical Bracing Between Top and Bottom Chords (Shear Transfer)

- **Transfers forces between compression (top) and tension (bottom) chords.**

- **Reduces bending stress** → Helps the truss handle vertical loads more efficiently.

- **Prevents excessive deflection** → Keeps the structure rigid and balanced.

6-Diagonal Bracing (Main Load-Carrying Braces)

- **Carries shear forces** → Diagonal braces help transfer shear loads across the truss.

-**Reduces bending moments** → Allows the structure to be lighter and more efficient.

- **Improves overall strength** → Without diagonal bracing, the truss would be unstable.

7-Purlins (Roof Load Distribution)

-**Supports the roof panels** → Transfers roof loads (self-weight, snow, wind) to the truss.

-**Provides lateral support to the top chord** → Prevents buckling and improves stability.

- **Connects multiple trusses together** → Distributes loads evenly across the structure.

Each of these components contributes to the overall strength and efficiency of your cantilever truss:

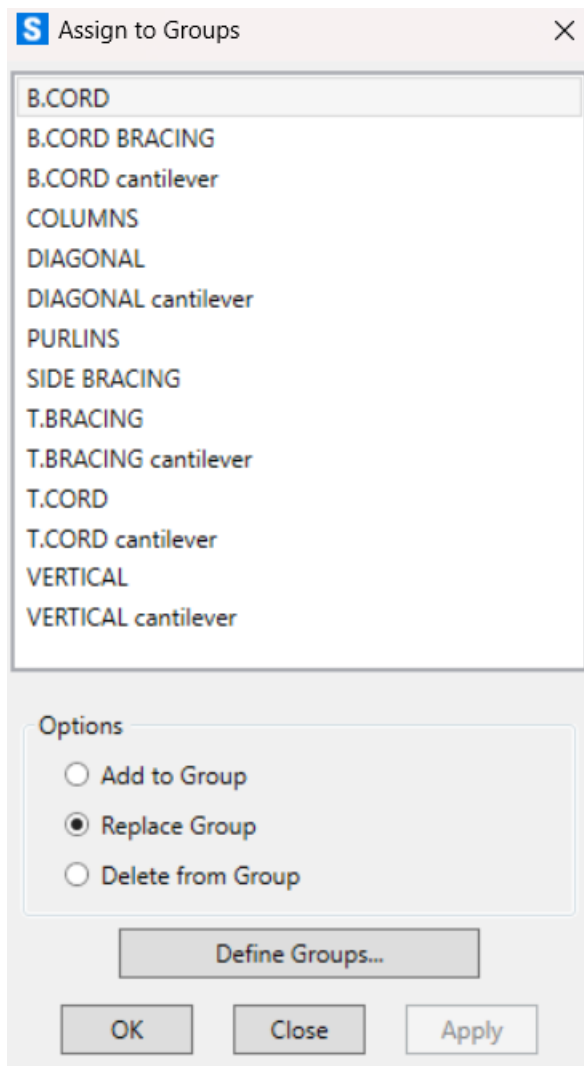
-Bottom chord (tension) and top chord (compression) form the primary load path.

-Bracing (top, bottom, vertical, and diagonal) ensures stability, prevents buckling, and transfers forces efficiently.

-Purlins distribute loads from the roof to the trusses, preventing excessive stress on any single member.

19.4 Sap definitions

19.4.1 Steel member groups



19.4.2 Members section:

Member	Section
Column	HLS
Bottom cord	TUBO
Top cord	TUBO
Cantilever top cord	TUBO
Cantilever bottom cord	TUBO
Vertical	TUBO
Diagonal	TUBO
Cantilever vertical	TUBO
Cantilever diagonal	TUBO
Side bracing	TUBO
Top cord bracing	TUBO
Top cord cantilever bracing	TUBO
Bottom cord cantilever bracing	TUBO
Purlins	UPN

19.4.3 Load on structure

1-Live Load: 1 kN/m² live load for the structure to account for maintenance activities, including the weight of workers, tools, and equipment required for inspections, repairs, and cleaning. This ensures the roof can safely support temporary loads without excessive deflection or structural stress. The selected load follows standard design practices, providing a balance between safety and material efficiency while accommodating potential future maintenance needs.

2-Superimposed dead load: covering roof with 6cm double skin sandwich panel **SD=0.2kn/m2**

3-Snow Load: To be on the safe side, it is recommended to consider a snow thickness of 30 to 50 cm for structural design in Nablus, even though heavy snowfall is rare.

Snow Load Calculation

The weight of snow depends on its density, which varies based on moisture content:

- Fresh dry snow: 1 to 2 kN/m³
- Wet/heavy snow: 3 to 5 kN/m³

For a safe assumption, let's consider:

- 50 cm (0.5 m) of wet snow with a density of 3 kN/m³
- Snow load (kN/m²) = Thickness × Density
- $0.5 \times 3 = 1.5 \text{ kN/m}^2$

Thus, for safe structural design, a snow load of 1.5 kN/m² should be considered.

4-wind load:

-wind speed $V = 140 \text{ km/hr} = 39 \text{ m/s}$

-Wind directionality factor: since the structure is arched roof, then $K_d = 0.85$

-Exposure Category: since the stadium at urban area, take exposure category B

-No changes in topography so $K_{z,t} = 1$

-Guest effect factor G:

$$H_m = 8 + 4/1 = 12 \text{ m}$$

1- $12 \text{ m} < 18 \text{ m}$

2- $12 \text{ m} < 20 \text{ m}$

Then; it's rigid

$$G = 0.85$$

-Internal pressure factor: For open building, $G_{Cpi} = 0$

-velocity pressure exposure coefficient:

Height of structure above ground is 35m, so velocity pressure exposure coefficient **1.04**

-wall pressure coefficient C_p :

Φ for cantilever roof = 3.1 degree

Φ for above columns roof = 11 degree

Wind X:

-On cantilever roof, wind is normal to ridge, and $\varphi = 3.1$ degree

$h/L = 0.25$, so $C_p = -0.9$

$$Q_h = 0.613 * K_{zt} * K_d * K_h * V^2 = 830$$

$$P = Q * G * C_p = -635 \text{ n/m}^2 \text{ take it } -770 \text{ n/m}^2$$

-above columns roof, wind is normal to ridge, and $\varphi = 11$ degree

$h/L = 0.7$, so $C_p = -1$

$$Q_h = 0.613 * K_{zt} * K_d * K_h * V^2 = 830$$

$$P = Q * G * C_p = -710 \text{ n/m}^2 \text{ take it } -770 \text{ n/m}^2$$

Wind Y:

-On cantilever roof, wind is parallel to ridge, and $\varphi = 3.1$ degree

$h/L = 0.14$, so $C_p = -0.9$

$$Q_h = 0.613 * K_{zt} * K_d * K_h * V^2 = 830$$

$$P = Q * G * C_p = -635 \text{ n/m}^2 \text{ take it } -770 \text{ n/m}^2$$

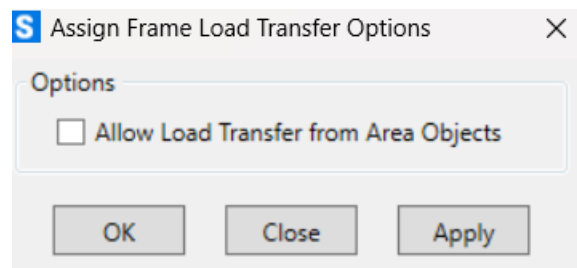
-above columns roof, wind is normal to ridge, and $\varphi = 11$ degree

$h/L = 0.14$, so $C_p = -0.9$

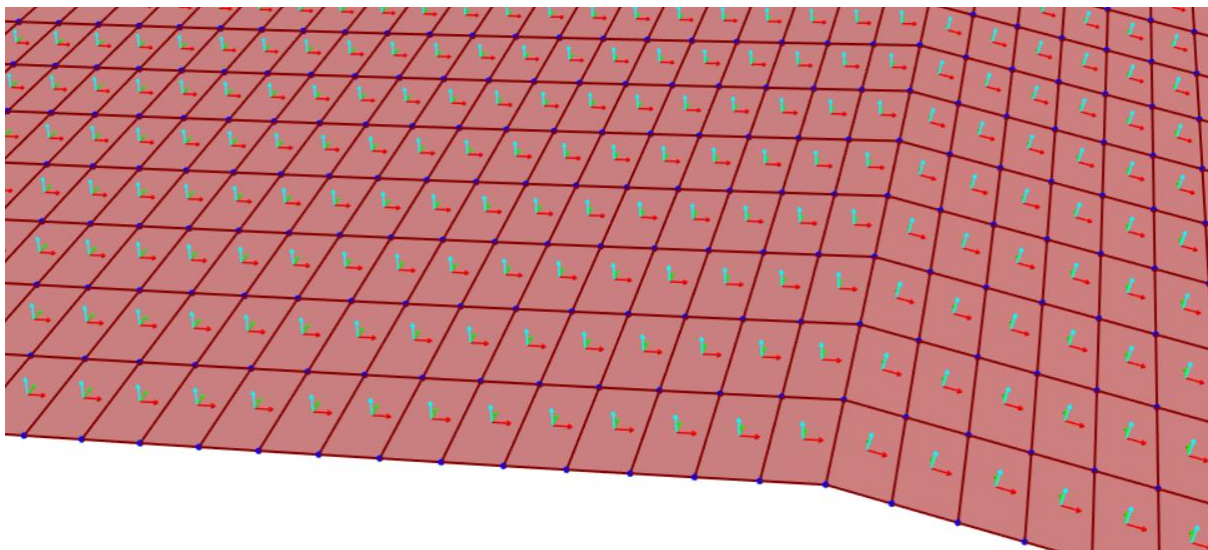
$$Q_h = 0.613 * K_{zt} * K_d * K_h * V^2 = 830$$

$$P = Q * G * C_p = -635 \text{ n/m}^2 \text{ take it } -770 \text{ n/m}^2$$

NOTE: must disable bracing frames from taking load from area.



NOTE: local axis 1 (red axis) must be perpendicular to purlins, because of the load is one way



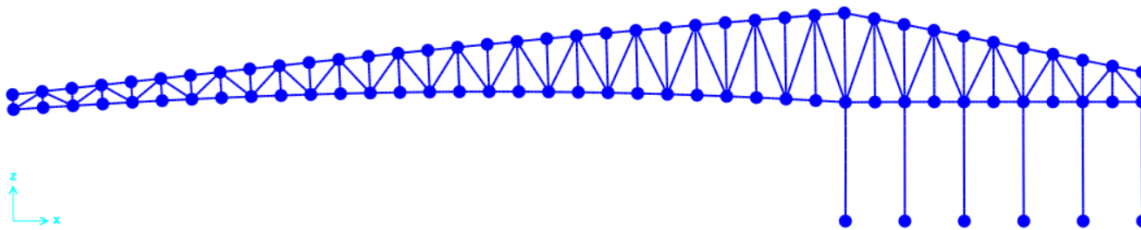
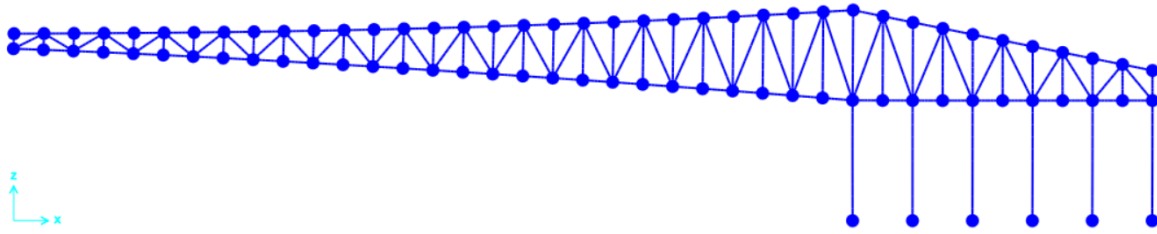
19.4.4 Load combinations:

- 1) $1.4D$
- 2) $1.2D+1.6L+0.5S$
- 3) $1.2D+1.0L+1.6S$
- 4) $1.2D+1.0L+0.5S+1.0W_x$
- 5) $1.2D+1.6S+0.5W_x$
- 6) $0.9D+1.0W_x$
- 7) $1.2D+1.0L+0.5S-1.0W_x$
- 8) $1.2D+1.6S-0.5W_x$
- 9) $0.9D-1.0W_x$
- 10) $1.0D+1.0L$
- 11) $1.2D+1.0L+0.5S+1.0W_y$
- 12) $1.2D+1.6S+0.5W_y$
- 13) $0.9D+1.0W_y$
- 11) $1.2D+1.0L+0.5S-1.0W_y$
- 12) $1.2D+1.6S-0.5W_y$
- 13) $0.9D-1.0W_y$

D=own weight+SD

19.5 Analysis check

19.5.1 compatibility check



19.5.2 Equilibrium check

Tributary area= $5*76=380$ m²

Table1: reaction due to load on roof

load	Value kn/m ²	P (kn) z-direction
Live	1	$1*380 = 380$ -Z
SD	0.2	$0.2*380 =76$ -Z
Snow	1.5	$1.5*380 =570$ -Z
Wind-X	0.77	$0.77*380 = 292.6$ +Z
Wind-Y	0.77	$0.77*380 = 292.6$ +Z

OutputCase	CaseType Text	GlobalFX KN	GlobalFY KN	GlobalFZ KN
SD	LinStatic	-3.019E-12	0	76
LIVE	LinStatic	-1.487E-11	0	380
SNOW	LinStatic	-2.213E-11	0	570
WIND-X	LinStatic	1.176E-11	0	-292.6
WIND-Y	LinStatic	1.176E-11	0	-292.6

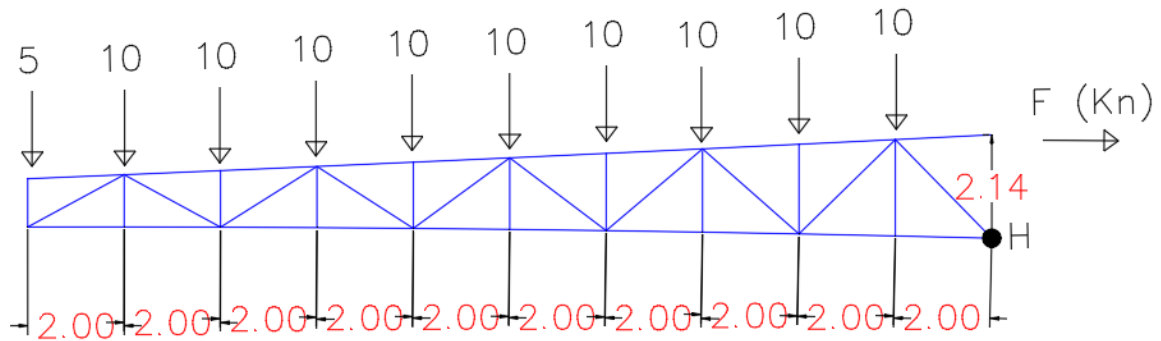
Table2: reaction due to load on roof

Load	Manual	SAP2000	%difference
Live	380 Kn	380	0%
SD	76 Kn	76	0%
Snow	570 Kn	570	0%
Wind-X	292.6 kn	292.6	0%
Wind-Y	292.6 Kn	292.6	0%

%difference= (manual-SAP2000/manual) * 100%, must be less than 5%

19.5.3 internal force check

Manual calculation (due to live load):

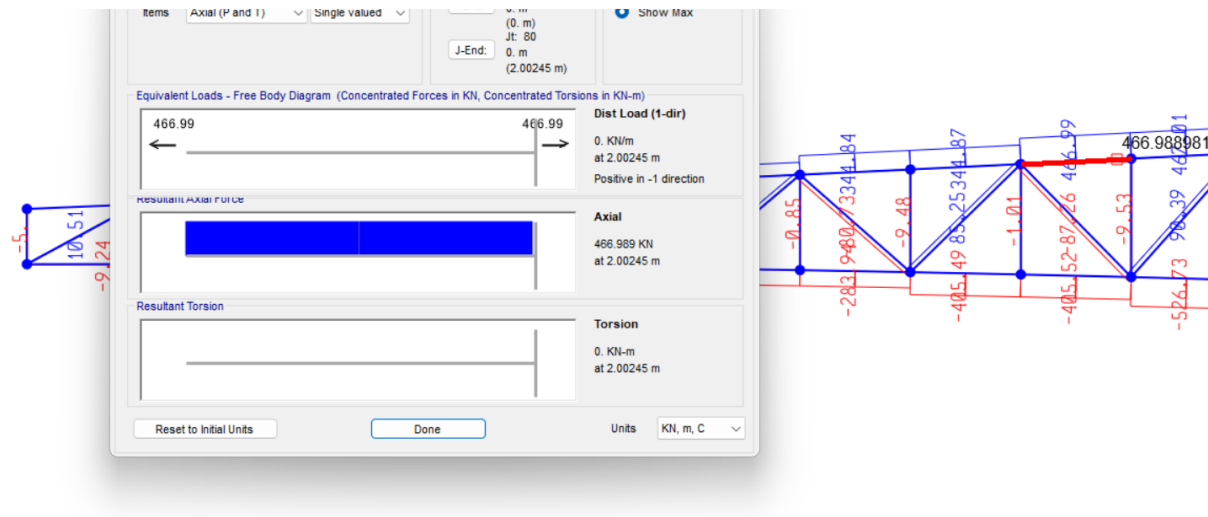


$$\sum M, H=0$$

$$10 \cdot 2 + 10 \cdot 4 + 10 \cdot 6 + 10 \cdot 8 + 10 \cdot 10 + 10 \cdot 12 + 10 \cdot 14 + 10 \cdot 16 + 10 \cdot 18 + 5 \cdot 20 = 2.14 \cdot F$$

$$F = 1000 / 2.14 = 467.3 \text{ Kn}$$

SAP2000 results:



$$\% \text{difference} = (467.3 - 466.99 / 467.3) \cdot 100\% = 0\%$$

19.6 Deflection check

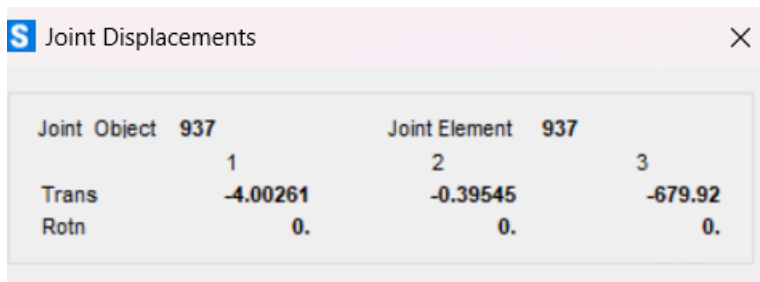
1- Δ from snow or live or wind load for cantilever must be less than $L/180 = 310\text{mm}$

2- Δ from (live + dead) load for cantilever must be less than $L/120=465\text{mm}$

Now we just can check deflection from snow or live or wind load; because until now the section of members undefined so dead load when define sections will change.

Note: check deflection from snow load; because it's larger load

Deflection from snow load:



Joint	Object	937	Joint Element	937
		1	2	3
Trans		-4.00261	-0.39545	-679.92
Rotn		0.	0.	0.

$\Delta = 680\text{mm} > 310\text{mm}$ so, not acceptable

Use tensile cables (100 mm diameter)

Cable Section Data

Cable Section Name: CAB1
Section Notes: Modify/Show...

Cable Material
Material Property: + A992Fy50

Cable Properties
 Specify Cable Diameter: 0.1
 Specify Cable Area: 7.854E-03
Torsional Constant: 9.817E-06
Moment of Inertia: 4.909E-06
Shear Area: 7.069E-03
Modify/Show Cable Property Modifiers...

Units: KN, m, C
Display Color: ■

OK Cancel

Cable tensile capacity:

$$P_n = 0.75 \cdot F_y \cdot A_g$$

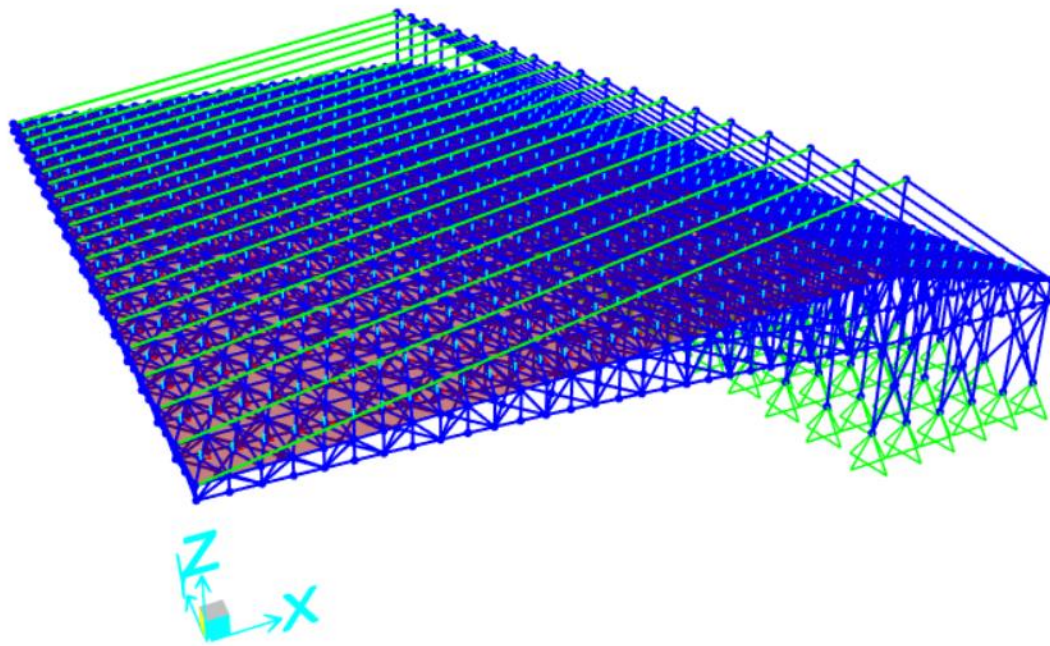
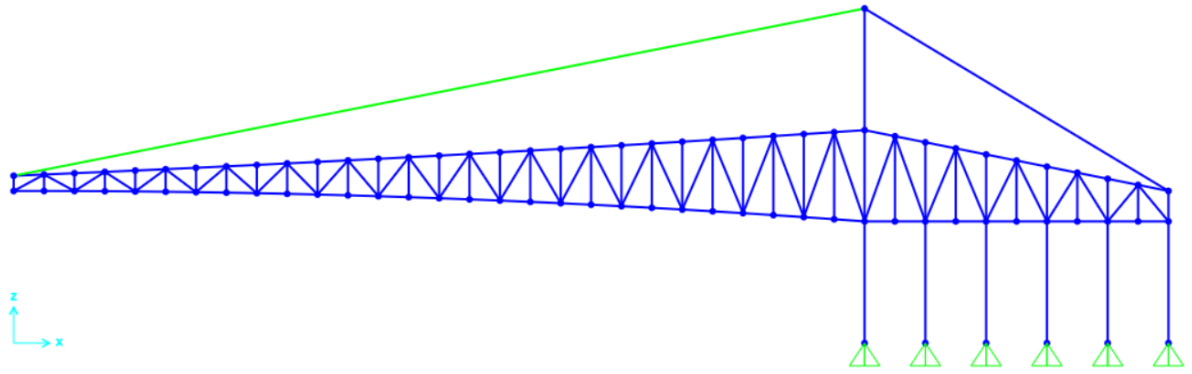
F_y for grade50 = 448 mpa

$$A_g = (3.14/4) \cdot 100^2 = 7854 \text{ mm}^2$$

$$P_n = 2638938 \text{ N} = 2639 \text{ Kn}$$

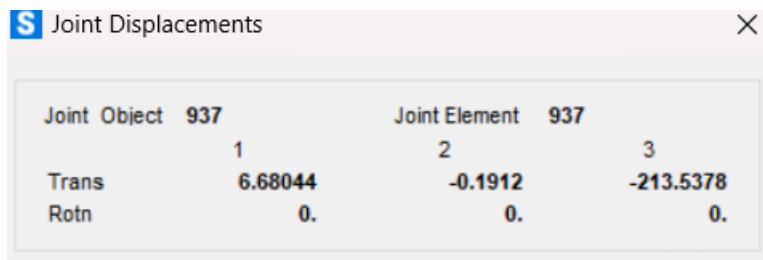
Maximum tension force on cable = 1600 Kn (due to envelope load comb.)

2639 > 1600; then cable is ok



Deflection check:

Due to snow load maximum deflection:



The screenshot shows a window titled "Joint Displacements" with a close button (X) in the top right corner. The window contains a table with the following data:

Joint Object	Joint Element 937		
	1	2	3
Trans	6.68044	-0.1912	-213.5378
Rotn	0.	0.	0.

215 mm < 310mm, then it's okay

19.7 Unbraced length ratio

the unbraced length ratio is a crucial parameter in the buckling analysis of structural members, especially for columns and compression members. It defines the effective length of a member between lateral supports relative to its actual physical length. This ratio is used to calculate the effective length factor (K) and, consequently, the critical buckling load. In SAP2000, users can define different unbraced length ratios for the major (L33) and minor (L22) axes, considering the support conditions and bracing system. Properly setting the unbraced length ratio ensures accurate stability analysis, preventing underestimation of buckling effects and ensuring the design meets safety standards. If the ratio is set incorrectly, it can lead to overestimated load capacity, increasing the risk of failure.

Demand/capacity ratio limit=0.95

Top cord cantilever:

Unbraced Length Ratio (Major)	1.
Unbraced Length Ratio (Minor)	1.
Unbraced Length Ratio (LTB)	1.

bottom cord cantilever:

Unbraced Length Ratio (Major)	1.
Unbraced Length Ratio (Minor)	2.
Unbraced Length Ratio (LTB)	2.

Top cord (columns side):

Unbraced Length Ratio (Major)	1.
Unbraced Length Ratio (Minor)	2.
Unbraced Length Ratio (LTB)	2.

Permanent members frame section

Member	Section
columns	HLS500
Haunch	HE300M , HE300C
B. cord (above columns)	TUBO 220X220X12.5
B. cord bracing (above columns)	TUBO 120X60X3.6
T. cord (above columns)	TUBO 180X180X10
T. cord bracing (above columns)	TUBO 140X70X4
Vertical (above columns)	TUBO 240X240X12.5
Diagonal (above columns)	TUBO 280X140X8
B. cord (cantilever)	TUBO 360X252X14.2
B. cord bracing (cantilever)	TUBO 120X60X3.6
T. cord (cantilever)	TUBO 340X170X10
T. cord bracing (cantilever)	TUBO 360X180X12.5
Vertical (cantilever)	TUBO 80X80X5.4
Diagonal (cantilever)	TUBO 280X196X10
Purlins	UPN 260
Frames cable catchment	TUBO 380X190X10
Frames cable catchment bracing	TUBO 240X240X12.5
Front bracing	TUBO 260X130X7.1
Side bracing for columns	TUBO 380X196X10

SAP2000



All steel frames passed the stress/capacity check.

OK