بسم الله الرحمن الرحيم

Palestine Polytechnic University

College of Engineering

Civil Engineering Department

Graduation Project

" Structural design of a commercial warehouse building, topped with two independent villas"

Project Team:

Duaa Shaher Hanini **Hadeel Sameeh Jabari** **Ghadeer Emad Saleh**

Supervisor:

Eng. Sufian AL Turk

Hebron-Palestine

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This project Submitted to the College of Engineering in partial fulfillment of the requirements for the degree of Bachelor's degree in Civil Engineering Branch of Building Engineering.

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In accordance with the recommendation of the project supervisor and acceptance of all examining committee members, this project has been submitted to the Department of Civil Engineering in the College of Engineering in partial fulfillment of the department's requirements for the degree of Bachelor of Building Engineering.

Signature of Project Supervisor

Name……………………………

Signature of Department Chairman

Name ………………………………..

2022 – 2023

الإهداء

إلهي لا يطيب الليل إلا بشكرك ولا يطيب النهار إلا بطاعتك ولا تطيب اللحظات إلا بذكرك ولا تطيب الآخرة إلا بعفوك ولا تطيب الجنة إلا برؤيتك

الله سبحانه جل في علاه جل جلاله..

إلى من بلغ الرسالة وأدى الأمانة ونصح الأمة إلى نبي الرحمة ونور العالمين ، معلم البشرية ومنبع العلم سيدنا محمد صلى الله عليه وسلم..

إلى من حاكت سعادتي بخيوط منسوجة من قلبها يا بسمة الحياة وسر الوجود يا من كان دعائها سر نجاحي وحنانها بلسم جراحي وركع العطاء أمام قدميها..

أمي الغالية..

إلى من أحمل اسمه بكل فخر ومن استلمت منه قيم الإنسانية وعلمتني ارتقي سلم الحياة بحكمة وصبر ستبقى كلماتك نجوم أهتدي بها اليوم وفي الغد وإلى الأبد يا صاحب القلب الكبير

والدي..

إلى رياحين حياتي يا من تطلعتم إلى نجاحي بنظرات الأمل ورافقتهم منذ أن حملت حقائب صغيرة

أخوتي..

إلى من معهم وبرفقتهم سرت وكانوا على طريق النجاح والخير وأمضيت معهم ذكريات الأخوة

الذين تسكن صورهم وأصواتهم أجمل لحظات الأيام التي عشتها

أصدقائي..

إلى من هم أفضل منا جميعا الذين رووا بدمائهم ثرى فلسطين

كل الشهداء..

إلى من عشقوا الحرية وخاضوا بأمعائهم حربا من اجلك

اهدي هذه الثمرة المتواضعة لك

قدسي..

واخيراً وليس اخراً إلى جميع الأساتذة في دائرة الهندسة المدنية والمعمارية الذين لم يبخلوا بنصائحهم وتوجيهاتهم علينا

فريق المشروع

ACKNOWLEDGEMENT

It has been a great opportunity for us to gain a lot of knowledge through working on this project, But the successful completion of any task would be incomplete without mention of the people Who made it possible. For that we would like to thank everyone who helped, supported, and encouraged us: starting with Palestine Polytechnic University, Engineering College, and Civil Engineering Department, including all members of the helpful and reverend staff for providing us with everything we need to complete our graduation project.

Special thanks to our supervisor, Eng. Sufyan alturk made an effort to encourage us to do a great job, providing our team with valuable information and advice to be better every time. We thank you for the constant support and pleasant communication, which greatly affects our feeling of interest in what we are working on, who was the guiding light every step of the way we worked on this project.

We also extend our thanks to our dear colleagues who, without their presence, would not have felt the pleasure of research, nor the sweetness of positive competition.

In conclusion, we would like to thank our fathers, mothers, and brothers who had the greatest role in reaching what we have reached, and perhaps we will fulfill their right by achieving their satisfaction.

" Structural design of a commercial warehouse building, topped with two independent villas"

Supervisor: Eng. Sufian AL Turk

Project Team:

Duaa Shaher Hanini Hadeel Sameeh Jabari Ghadeer Emad Saleh

ABSTRACT

The safe structural design of a commercial warehouse building with offices, topped by two villas on most of its area with part remaining as a common space between the two villas.

The two villas are identical, each consisting of two floors, a separate staircase and a common elevator.

The design is challenging due to the extremely poor red soil, the existence of water in deep soil layers, the large height of the commercial floor, the area requirements for truck movement, the large distances in the project, and locations of planted columns.

In this project, we use safe and economical solutions such as using piles for the design of foundations to a depth of 10 meters underground with strong type of concrete, using one-way solid slab for the commercial floor with 35 cm slab thickness and dropped beams. finally, using ribbed slab for the villas floors in addition to planting columns in suitable locations.

Through the results, we expect to produce a distinctive structural design that meets the requirements of the structural design code ACI 318, the requests of the owner, safety requirements in the warehouse floor such as ventilation and firefighting system. Also, the requirements of the architectural beauty of the villas.

" التصميم الإنشائي لمبنى مستودع تجاري تعلوه فيلتان مستقلتان "

إشراف: م. سفيان الترك.

فريق العمل:

دعاء شاهر الهنيني هديل سميح الجعبري غدير عماد صالح

الملخص - ABSTRACT(ARABIC)

التصميم الإنشائي الآمن لمبنى مكون من مستودع تجاري بداخله مكاتب ، تعلوه فيلتان على معظم مساحته مع بقاء جزء منها كمساحة مشتركة بين الفيلتين. الفيلتان متطابقتان، كل واحدة تتكون من طابقين ومطلع درج منفصل والمصعد مشترك.

يمثل التصميم تحديًا بسبب التربة الحمراء السيئة للغاية ، ووجود المياه في طبقات التربة العميقة ، والارتفاع الكبير للأرضية التجارية ، ومتطلبات توفير مساحة لحركة الشاحنات ، والمسافات الكبيرة في المشروع ، ومواقع الأعمدة المزروعة.

في هذا المشروع، نستخدم حلولاً آمنة واقتصادية مثل استخدام الخوازيق لتصميم الأساسات حتى عمق 10 أمتار تحت الأرض مع نوع قوي من الخرسانة ، باستخدام بلاطة باتجاه تحميل واحد للطابق التجاري بسماكة 35 سم وجسور مسقطة. أخيرًا استخدام بلاطة معصبة لأرضيات الفيلات بالإضافة إلى زراعة الأعمدة في المواقع المناسبة.

من خلال النتائج نتوقع إنتاج تصميم إنشائي مميز يلبي متطلبات كود التصميم الإنشائي ACI 318 وطلبات المالك ومتطلبات السلامة في المستودع مثل نظام التهوية ومكافحة الحرائق. كذلك متطلبات الجمال المعماري للفلل.

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- **Ac =** area of concrete section resisting shear transfer.
- **As =** area of non-prestressed tension reinforcement.
- **A_s`=** area of non-prestressed compression reinforcement.
- **Ag =** gross area of section.
- **Av =** area of shear reinforcement within a distance (S).
- **At =** area of one leg of a closed stirrup resisting tension within a (S).
- **b =** width of compression face of member.
- **bw =** web width, or diameter of circular section.
- **C_c =** compression resultant of concrete section.
- **C_s =** compression resultant of compression steel.
- **DL =** dead loads.
- **d =** distance from extreme compression fiber to centroid of tension reinforcement.
- **Ec =** modulus of elasticity of concrete.
- **f_c` =** compression strength of concrete.
- **fy =** specified yield strength of non-prestressed reinforcement.
- **h =** overall thickness of member.
- **Ln =** length of clear span in long direction of two- way construction measured face-to-face of supports in slabs without beams and face to face of beam or other supports in other cases.
- **LL =** live loads.
- **Lw =** length of wall.
- **M =** bending moment.
- **Mu =** factored moment at section.
- **Mn =** nominal moment.
- **Pn =** nominal axial load.
- **Pu =** factored axial load
- **S =** Spacing of shear in direction parallel to longitudinal reinforcement.
- **Vc** = nominal shear strength provided by concrete.

- **Vn** = nominal shear stress.
- **Vs** = nominal shear strength provided by shear reinforcement.
- **Vu** = factored shear force at section.
- **Wc** = weight of concrete.
- **W** = width of beam or rib.
- **Wu** = factored load per unit area.
- **Φ** = strength reduction factor.
- ε_c **=** compression strain of concrete = 0.003.
- ε_s **=** strain of tension steel**.**
- $\acute{\varepsilon}_s$ **=** strain of compression steel.
- **ρ** = ratio of steel area .

CHAPTER 1

" INTRODUCTION"

1.1 INTRODUCTION.

1.2 PROJECT OBJECTIVES.

1.3 PROJECT PROBLEM.

1.4 WORK PROCEDURE.

1.5 PROJECT SCOPE.

1.6 TIME LINE.

1.7 PROGRAMS USED IN THE PROJECT.

Figure 1:Expressive Image

1.1 INTRODUCTION

Engineering is the best way to harness natural resources to serve humanity.

In other words, it is the art of applying scientific principles and life experiences to our lives to improve the things we use or the facilities we live in. In general, it is the body that combines the available technical tools, activities and knowledge. It is the professional activity that uses imagination, wisdom and intelligence in the application of science, technology, mathematics and practical experience in order to be able to design, produce and manage processes that suit the needs of mankind.

Civil engineering affects many of our daily activities: the buildings we live in and work in, the transportation facilities we use, the water we drink, and the drainage and sewage systems that are necessary for our health and well-being, so civil engineering in general is the only way to make the world a more suitable and suitable place to live in.

Building engineering in particular is the engineering that takes care of providing the required housing with the required specifications, the required quality, and the resources available to each individual in the community , and it is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including public works such as roads, bridges, canals, dams, airports, sewage systems, pipelines, and construction components of buildings and railways.

1.2 PROJECT OBJECTIVES

After completing this project, we hope to achieve the following objectives:

1. Obtaining experience in solving the problems of each project in particular.
2. Improving the ability to choose the appropriate structural system for the project and distributing its structural elements on the plans, taking into account preserving the architectural character.
3. Gaining experience in reaching the best safe and economical design.
4. Using structural design programs and comparing them with theoretical solutions.

1.3 PROJECT PROBLEM

The design is challenging due to the very poor red soil, the presence of water in the deep soil layers, the large height of the commercial floor, the area requirements for truck traffic, the large distances in the project, and the locations of the pillars planted.

In this project, we use safe and economical solutions such as using piles for the design of foundations to a depth of 10 meters underground with a strong type of concrete, using a one-way solid slab for the commercial floor with a 35 cm slab thickness and dropped beams. Finally, use ribbed slabs for the villa floors in addition to planting columns in suitable locations.

And also determining the loads on it and then determining its dimensions and designing the necessary armament for it, taking into account the safety factor of the origin, and then the executive plans of the structural elements that were designed will be made, to get this project out of the proposal space into implementation.

1.4 WORK PROCEDURE

To achieve the objectives of the project, the following steps were taken:

1. The architectural study in which the site, building plans and floor heights were studied.
2. Structural planning of the building, in which the type of slab is selected and the location of columns, beams and shear walls is determined, taking into account the architectural design.
3. A structural study in which all structural members are identified and the different loads are indicated
4. was appreciated.
5. Analysis and design of the elements according to the ACI code using software and theoretical solutions.
6. Preparing construction drawings for all the elements in the building.
7. Writing a project where all these stages are presented in detail.

1.5 PROJECT SCOPE

This Project contains the following chapters:

CHAPTER 1: General introduction.

CHAPTER 2: Architectural description of the project.

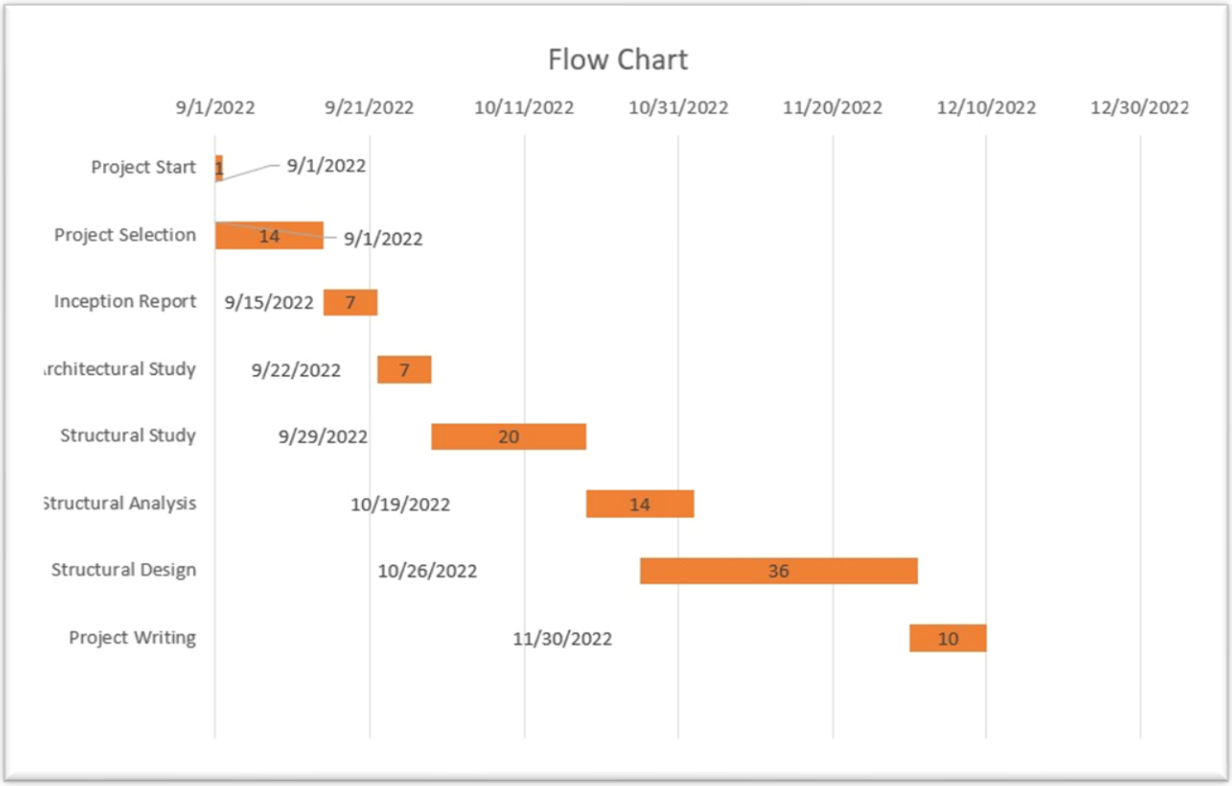
CHAPTER 3: General description of the structural elements.

CHAPTER 4: Structural analysis and design of all structural elements.

CHAPTER 5: Results and Recommendations.

1.6 TIME LINE

Table 1: Time Line



1.7 PROGRAMS USED IN THE PROJECT

1. Adoption of the American code in the various structural designs (ACI-318-19).
2. Using analysis and structural design programs such as (Atir12, Safe, Etabs, SAP2000)
3. Other programs such as Microsoft office Word, Power Point, Excel.
4. Autocade.
5. Google Earth p

CHAPTER 2

" ARCHITECTURAL DESCRIPTION "

Figure 2: The Architectural form of the project

2.1 INTRODUCTION

Architecture is considered an art, talent, and idea, which derives its fuel from what God has bestowed upon the architect from the talents of beauty. With these talents, he moved from the life of the caves to the best form of luxury, taking advantage of the beauty God gave him of this picturesque nature, and if every art or science has controls and limits, architecture is not subject to any limitation or restriction, as it oscillates between imagination and reality. The result may be buildings of extreme simplicity and beauty.

The design process for any facility or building occurs through several stages until it is completed to the fullest, starting with the architectural design stage. The initial installation of the facilities, achieving the required spaces and dimensions, and in the process lighting, ventilation, movement, mobility, and other functional requirements are also studied.

Architectural designs should be easy to deal with and understand the various events and other things of importance that give a clear view of the project thus it will be possible to locate the columns and other structural elements in the structural design process that aims to determine the dimensions of the structural elements and their characteristics depending on the different loads that are placed on them. Transported through these elements to the foundations and then to the soil.

2.2 GENERAL IDENTIFICATION OF THE PROJECT

The owner of this project is one of the major merchants in Hebron.

Because of the nature of his work in merchandise trade, he needs a wide and safe area and has safety requirements such as ventilation and firefighting system. As well as the requirements of architectural beauty for storage, transportation, loading and housing, so he went to a request from the engineers to construct this building on the land owned by him, who is located in the city of Hebron.

The building consists of three layers above the ground ,the ground floor consists of a cargo storage area with a large area with offices equal to 808.1562 m^2, and the first floor consists of two identical villas with an area equal to 591.3941 m^2, with the remaining part as a common area between the two villas with an area of 154.5497 m^2, the second floor of the two villas, each with an area of 503.7341 m^2.

The two villas are identical, each one consists of two floors, a separate staircase, and a common elevator, with an area of 68.2328 m^2.

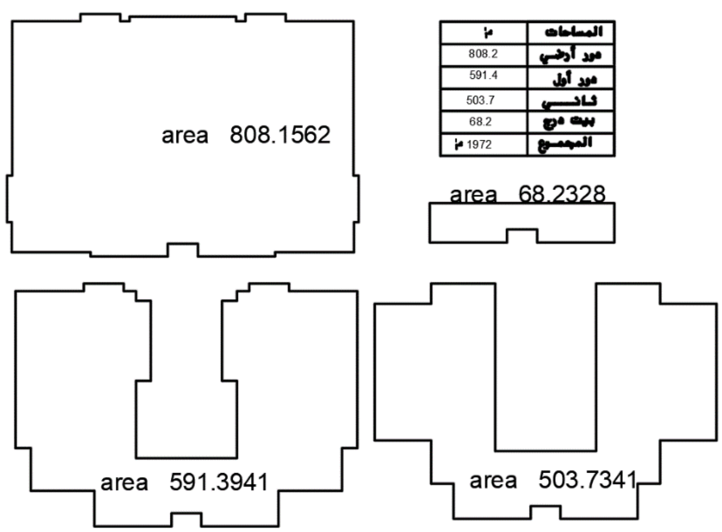


Figure 3: Building Areas

2.3 GENERAL SITE DESCRIPTION:

Figure 4: Site Location

2.4 FLOORS DESCRIPTION

The project consists of three floors with a variety of services. It is a commercial warehouse building, surmounted by two villas in most of its area, with part of it remaining as a common space between the two villas. The architectural distribution of these facilities is characterized by the complexity and asymmetry between the floors, the wide spaces, and the recesses in the walls of the building, and this led to difficulty in the structural design of the project.

2.4.1 GROUND FLOOR:

(Level + 0.00 m) with an area of 808.15 m^2.

The ground floor consists of a large cargo storage area with offices as shown in the figure (5).

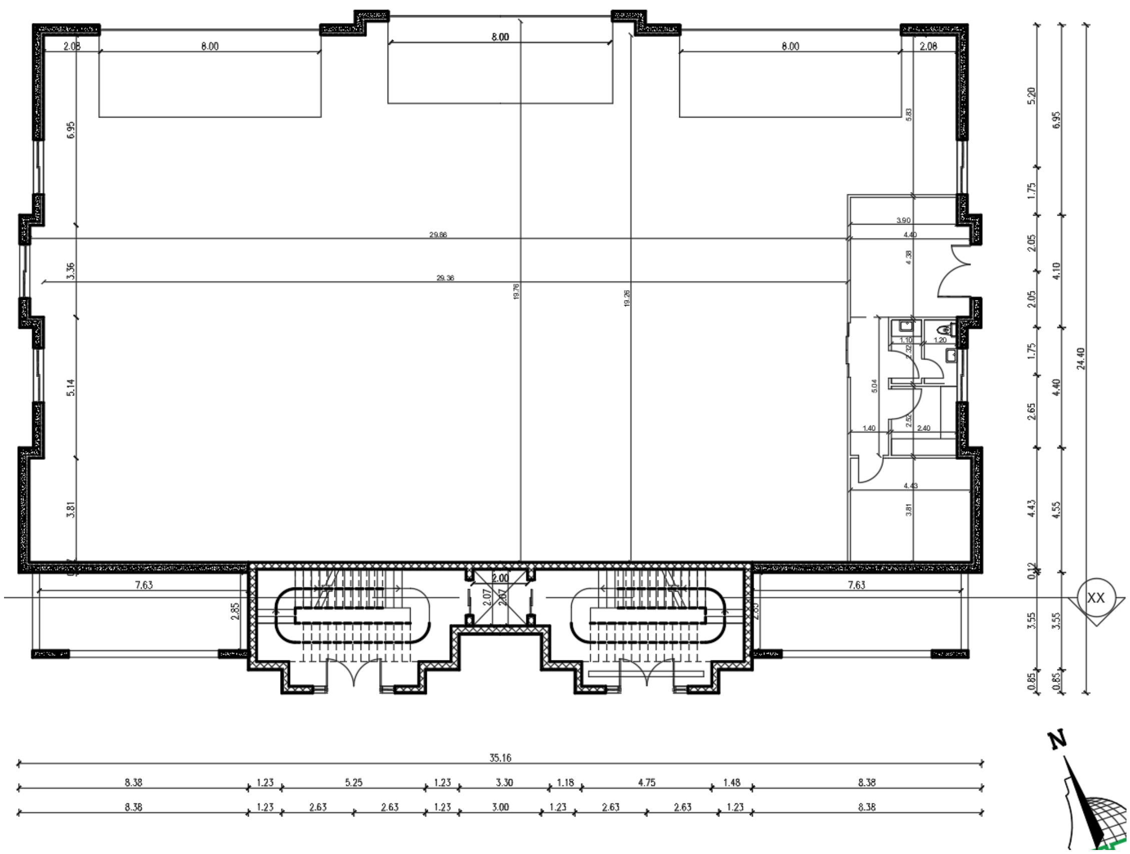


Figure 5: Ground Floor Plan

2.4.2 First Floor:

(Level + 7.37 m) with an area of 591.3941m^2.

The first floor consists of two identical villas with the remaining part as a common area between the two villas as shown in Figure (6).

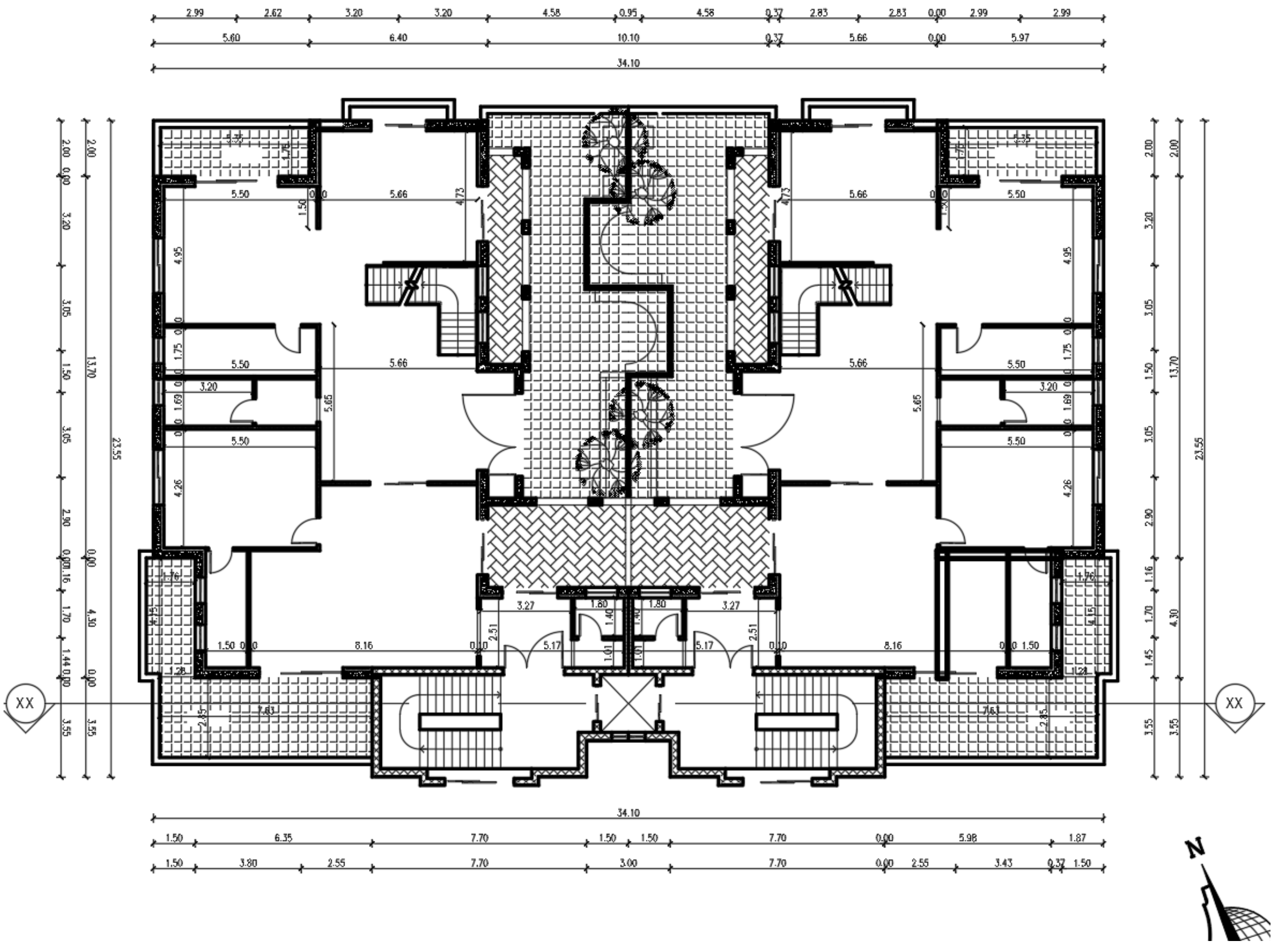


Figure 6: First Floor Plan

2.4.3 Second Floor:

(Level + 10.7 m) with an area of 503.7341 m2.

The second floor of the two villas as shown in Figure (7).

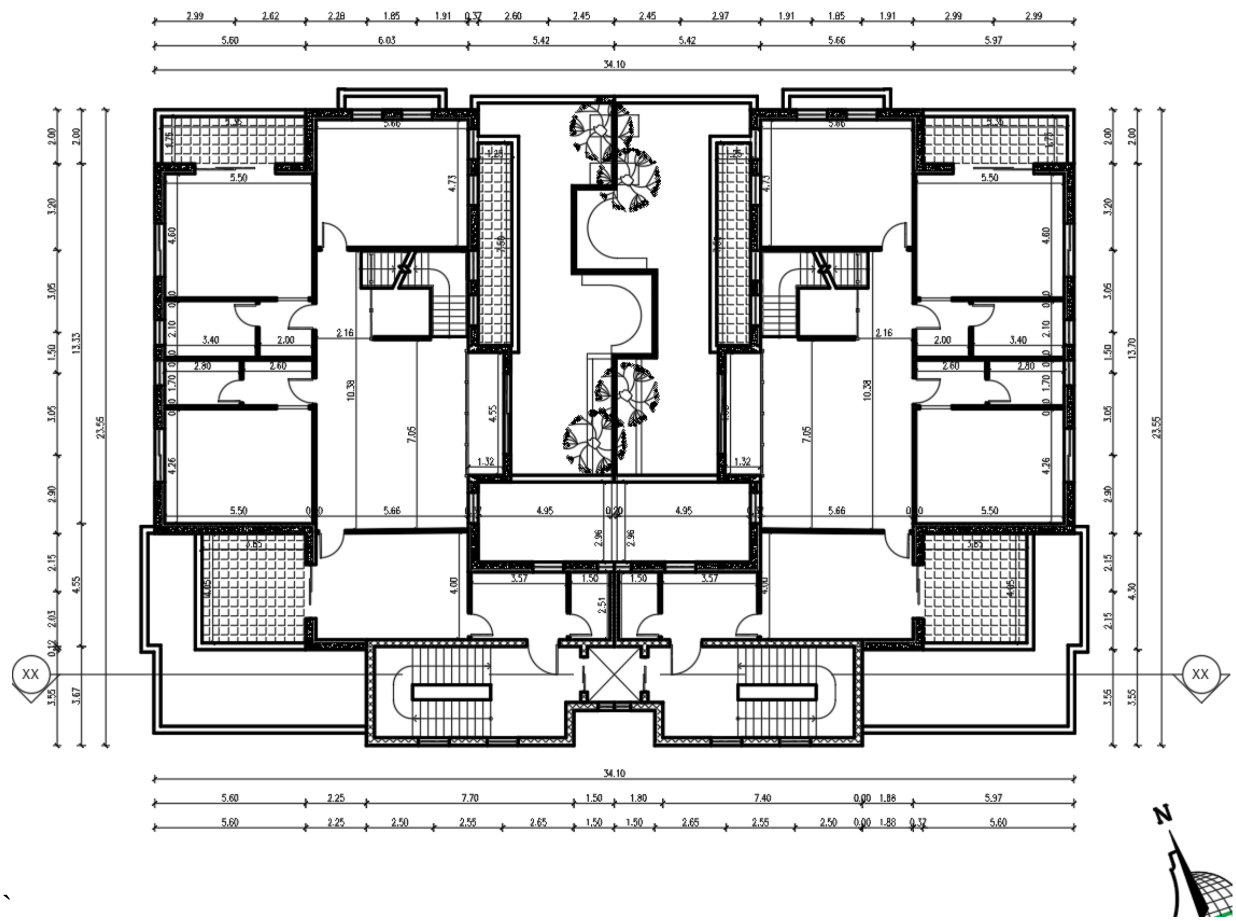


Figure 7: Second Floor Plan

2.5 ELEVATIONS DESCRIPTION

The following is a description of different elements and components of the project elevations :

2.5.1 North Elevation:

The northern elevation shows the main entrance to the storage as shown in Figure (8) .

Figure 8: North Elevation

2.5.2 South Elevation:

The southern elevation shows the main entrance to the two villas by a separate staircase and a common elevator, as shown in the figure (9).

Figure 9: South Elevation

2.5.3 East Elevation:

The eastern elevation shows the secondary entrance to the stores, which is the entrance to the offices, as shown in Figure (10).

Figure 10 :East Elevation

2.5.4 West Elevation:

The western elevation shows the facade opposite the entrance to the offices,

as shown in Figure (11).

Figure 11: West Elevation

2.6 DESCRIPTION OF MOVEMENT AND ENTRANCES

2.6.1 On The Ground Floor:

The entrance and spaces in the storage area are designed to allow the movement of large trucks to enter and exit the warehouses and load and unload products with ease and safety, as the dimensions of the entrance doors are 7.6 m , and the length of the storage is 19.26 m, with a height of 6.37 m.

Another entrance to the offices was designed inside the storage to facilitate movement for office workers without exposing them to danger while loading and unloading products.

2.6.2 On The First Floor:

A separate entrance was designed for each of the two villas through a separate staircase that connects to the first and second floors and the roofs, and a common elevator that contains a separate door for each villa.

2.6.3 On The Second Floor:

The entrances are designed on the second floor in both villas through an internal staircase that connects from the first floor, in addition to the possibility of entering through the entrance of the stairs and the common elevator.

CHAPTER 3
" STRUCTURAL DESCRIPTION "

3.1 INTRODUCTION.

3.2 THE AIM OF THE STRUCTURAL DESIGN.

3.3 LOADS ACTING ON THE BUILDING.

3.4 SCIENTIFIC TESTS.

3.5 STRUCTURAL ELEMENTS OF THE BUILDING.

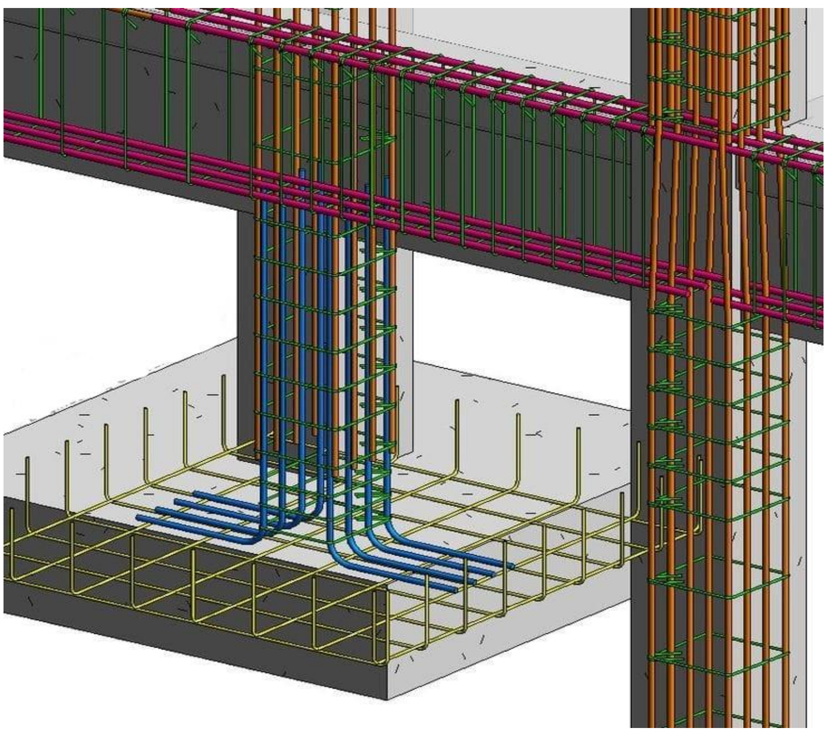


Figure 12: Expressive Image

3.1 INTRODUCTION

Structural design is a methodical investigation to get the economical specification of a structure or a structural element to carry the predicted load safely. With the application of structural design, we can obtain the required size, grade, reinforcement, etc. Of structural members to withstand the internal forces calculated from the structural analysis.

If the structure is not designed properly including proper selection of materials and technology or if the structure that we have designed is subjected to excessive load than the specified limit then it will probably fail to perform its intended function with possible damage both to structure and life, including complete damage.

3.2 THE AIM OF THE STRUCTURAL DESIGN

The following aims must be taken into consideration:

1. Ensure structural safety, which implies providing adequate stiffness and reinforcements to contain deflections and cracks.
2. Durability: The structure should last for a reasonable period.
3. Produce a structure that is capable to resist all applied loads without failure during its service life.
4. Obtain the economical dimensions of structural members. As any engineer can always design a massive structure, which has more than adequate stability, strength, and serviceability, but the ensuing cost of the structure may be exorbitant.
5. Stability to stop overturning, slipping, or buckling of the frame, or sections thereof, under load motion.
6. Investigate the strength and rigidity of structures.

3.3 STAGES OF STRUCTURAL DESIGN

Structural design stages can be divided into two main stages:

3.3.1 The First Stage:

It is the preliminary study of the project in terms of the nature and size of the project, in addition to understanding the project from all its various aspects, determining the building materials that will be approved for the project, then making the basic structural analyzes of this system, and the expected preliminary dimensions of it.

3.3.2 The Second Stage:

It is represented in the structural design of each part of the structure, in a detailed and accurate manner, according to the structural system that was chosen and the necessary structural details for it in terms of drawing horizontal projections, vertical sectors, and details of the reinforcement steel.

3.4 LOADS ACTING ON THE BUILDING

The loads to which the building is exposed are divided into different types, which are as follows:

3.4.1 Dead Load:

They are the loads resulting from the self-weight of the main elements that make up the structure, permanently and steadily, in terms of size and location, in addition to additional parts such as the various internal partitions and any mechanical works or additions that are carried out permanently and steadily in the building, and they can be calculated by determining the dimensions of the structural element, and the densities Its constituent materials, and Table (2) shows the specific densities of the materials used in the project.

Table2 :T The Specific Densities Of The Materials

MATERIALS USED	SPECIFIC DENSITIES USED (kN/m^3)
Reinforced concrete	**25**
Tiles	**23**
Mortar	**22**
Plaster	**22**
Sand Fill	**17**
Hollow block	**10**

Partition = 1.5 kN/m^2

3.4.2 Live Load:

In this project, all slabs are loaded with a residential load, in addition to the open terrace area, which has a different load, as it is an area in which various activities can be held, such as gatherings of people, parties, and others.

Live load values are chosen according to the Jordanian code tables:

Table 3 : Live Load From Jordanian Code

نوع المبنى		الاستعمال	الحمـل الموزع	الحمل المركز البديل
عـام	خاص	الاشغـال	كن/م٢	كن
المبانـي الخاصة والسكنية.	النوع الأول : مباني الشقق السكنية التي لا يزيد ارتفاعها عن ثلاثة طوابق ولا يزيد عدد الشقـق التي يمكن الوصول إليها من خلال درج مشترك عن أربع شقق للطابق الواحد.	جميع الغرف بما في ذلـك غـرف النـوم والمطـابخ وغرف الغسيل وما شـابه ذلك (All Usages).	2.0	1.4

Table 4 : Live Load From Jordanian Code

الجدول (٣-١-ب)

تابع الأحمال الحية للأرضيات والعقدات

نوع المبنى		الاستعمال	الحمـل الموزع	الحمل المركز البديل
عـام	خاص	الاشغـال	كن/م٢	كن
تابع المبانـي الخاصة والسكنية	تابع النوع الثالث:	المراجل والمحركات والمراوح وماشابـه ذلك.	7.5	4.5
		قاعات الرقص والمـساحات المشتركة دون مقاعد ثابتة.	5.0	3.6

Table 5 : Live Load For Stairs From Jordanian Code

النوع الثاني : المباني التي لا ينطبـق عليهـا مـا ورد في النـوع الأول و البـسيونات والمبـاني المخصـصة لاقامـة الضيوف.	غرف النوم.	2.0	1.8
	الحمامات.	2.0	–
	الطعام وردهات الاستراحة والبليارد و.	2.0	2.7
	الممرات والمداخل والأدراج و بـسطات الأدراج والممرات المرتفعة الموصـلة بين المباني.	3.0	4.5

3.4.3 Snow Load:

Snow loads depend on the height of the area above sea level, and the shape of the roof.

Table 6: Snow Loads

SNOW LOADS (KN /M²)	HEIGHT OF BUILDING ABOVE SEA LEVEL (H) (M)
0	**h < 250**
(h-250) / 1000	**500 > h > 250**
(h-400) / 400	**1500 > h > 500**
(h – 812.5)/ 250	**2500 > h > 1500**

The height of the building above sea level = (950 m), according to the third item, the snow loads were calculated as follows:

S.L = $h - 400/400$ = $950 - 400/400$ = **1.4 KN/m^2**

3.4.4 Earthquake Loads:

Earthquakes result from horizontal and vertical vibrations, due to the relative movement of the rocky layers of the earth, which results in shear forces that affect the facility, and these loads must be taken into account when designing in order to ensure the building's resistance to earthquakes in the event that they occur and thus reduce potential damages as a result of an earthquake.

It will be resisted in this project by the shear walls distributed in the building based on its structural calculations. For which it will be used, to avoid the effects of earthquakes, such as:

• The limits of the building's validity for operation (Serviceability) in terms of avoiding any excess deflection) and avoiding cracks that negatively affect the required architectural appearance.

• The shape and aesthetic aspects of the establishment.

3.5 SCIENTIFIC TESTS

Soil geotechnical examinations are the first step that is carried out before the structural design of the building. The type of soil at the site and its bearing capacity will determine the type of foundation suitable for the building.

Soil testing can be divided into two main components:

- Field soil sampling and analysis
- Lab tests

In this project, the site soil is weak and has a low bearing capacity. We also find rocks at a depth of 10 meters below the ground surface. Therefore, the foundations proposed for this project are piles.

3.6 STRUCTURAL ELEMENTS OF THE BUILDING

3.6.1 Slabs:

After studying the building architecturally and structurally, the following types of slabs were used in the design:

- **One-way solid slab**

  A one-way slab is a type of concrete slab in which loads are transferred in one direction to the supporting beams and columns. Therefore, the bending occurs in only one direction. It is used in areas that are highly exposed to live loads.

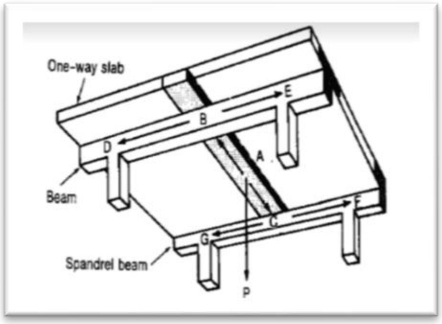


Figure 13: One-Way Solid Slab

- **Two-way solid slab**

  A slab supported on all four edges with an aspect ratio of longer to shorter theoretical span less than ≤2.00

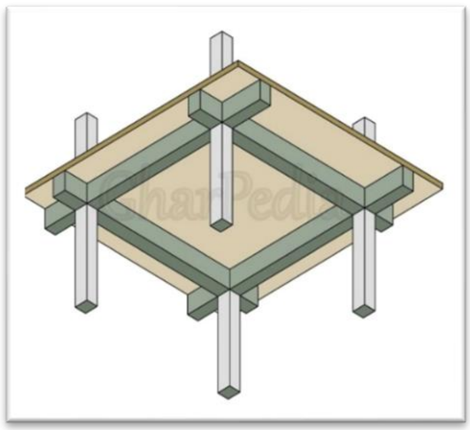


Figure 14: Two-Way Solid Slab

- **One-way ribbed slab**

  It's the most common system used in Palestine. It consists of a row of bricks followed by the rib, and the reinforcement is in one direction

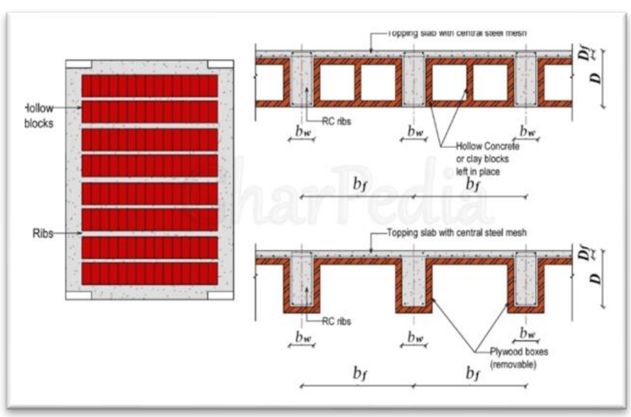


Figure 15: One-Way Ribbed Slab

3.6.2 Beams:

Beams act as structural elements that transfer loads from the slab to columns. They are typically horizontal members. In our project we used these types:

- Rectangular beams
- T-section beams
- Upward beams

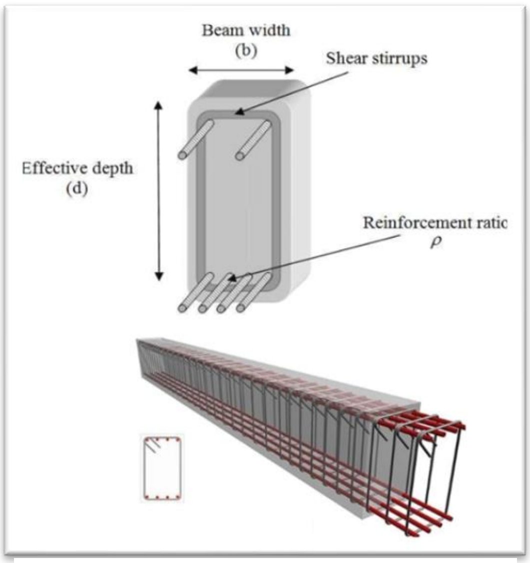


Figure 16: Rectangular Beam

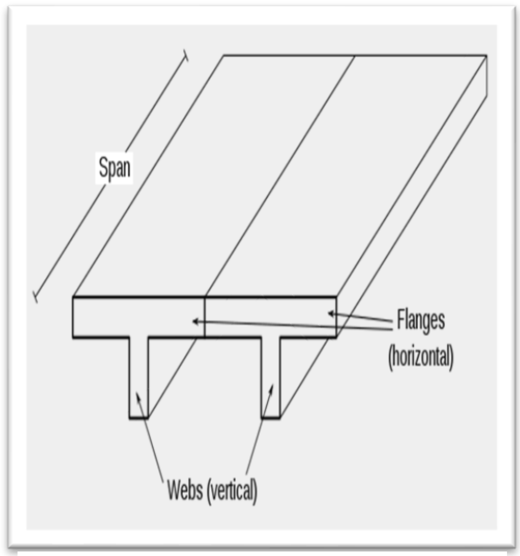


Figure 17: T-section Beam

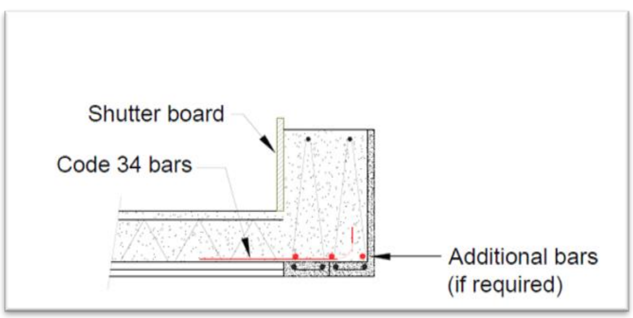


Figure 18: Upward Beam

3.6.3 Columns:

Columns act as a structural element that transfers loads from the slab, (i.e., roof, upper floor) to the foundation and finally to the soil under a structure. In our project we use:

- Continues columns
- Planted columns
- Steel columns

Figure 19: Continues Columns

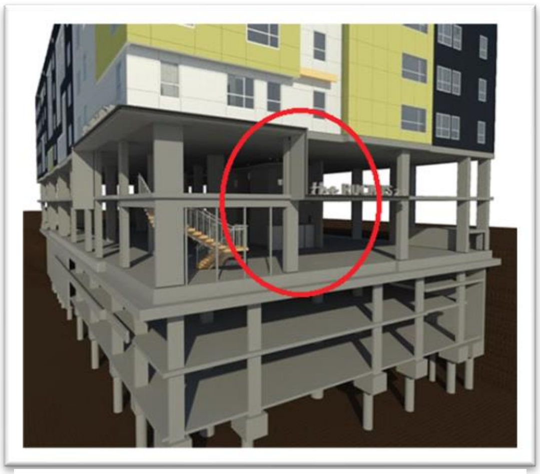


Figure 20: Planted Columns

Figure 21: Steel Columns

3.6.4 Foundations:

The foundations are the first thing that begins to be implemented when building, but they are designed after designing all the basic elements in the building, as the foundations transfer loads from columns and load-bearing walls to the soil in the form of strength and pressure.

In our project, the site soil is weak and has a low bearing capacity. We also find rocks at a depth of 10 meters below the ground surface. Therefore, the foundations proposed for this project are piles.

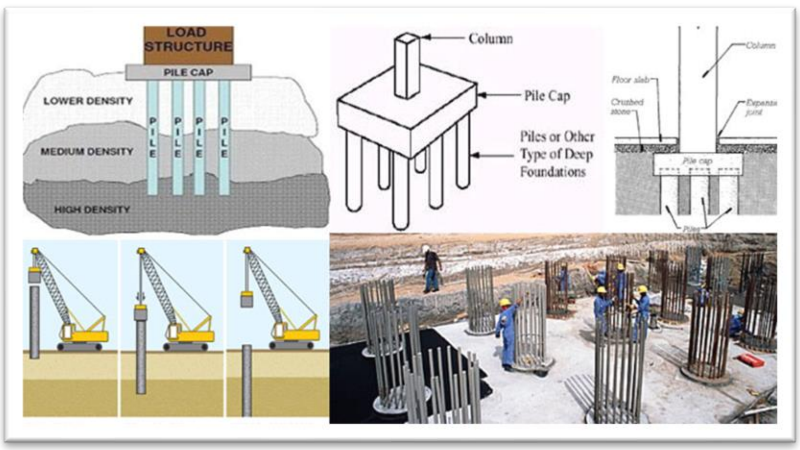


Figure 22: Pile Foundation

3.6.5 Shear Walls:

Shear walls are the walls that resist horizontal forces such as wind forces and earthquakes, and be in the walls of the stairwell and the walls of the elevators

In our project we used:

- Continues shear wall (staircase)

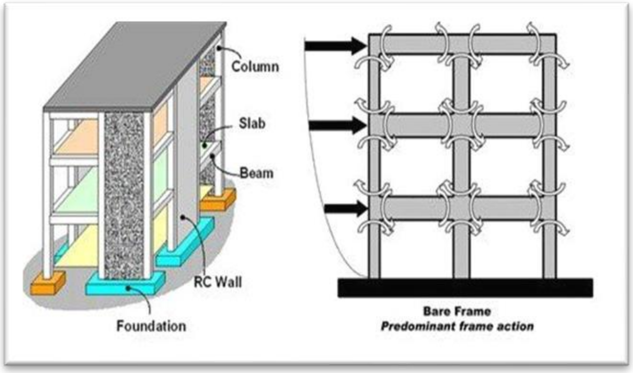


Figure 23: Shear Wall

3.6.6 Stairs:

The staircase is an architectural element in the building to move between two levels or move between floors

In our project, there are two stairs and they are:

- The staircase that allows movement from the storerooms to the roof
- An internal staircase that moves from the first floor of the villa to the second floor

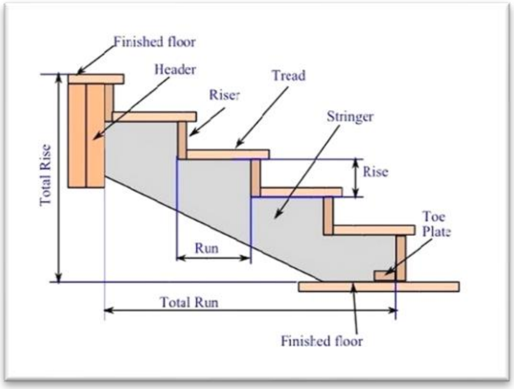


Figure 24: Stairs

CHAPTER 4
" STRUCTURAL ANALYSIS AND DESIGN"

4.1 INTRODUCTION

Normal plain concrete can withstand compressive stress but does not do well with tensile and stresses such as those caused by wind, earthquakes.

Reinforced concrete contains steel embedded in the concrete so the two materials complement each other to resist forces such as tensile, shear and compressive stress in the concrete structure.

In this project, there are many types of slabs such as “one-way ribbed slab”, They would be analyzed and designed by using finite element method of design, with aid of a computer program called "Beam D- Software” to find the internal forces, deflections and moments for ribbed slabs, and then handle calculation would be made to find the required steel for all members.

4.2 DESIGN METHOD AND REQUIREMENTS

The design strength provided by a member is calculated according to the requirements and assumptions of ACI-code (318-19).

4.2.1 Ultimate Strength Design Method:

In this method, the reinforced concrete structure is designed beyond the elastic region. the working dead load and live load are multiplied by a factor of safety. the section designed to fail at factored load. failure at factored load means the section exceeds the elastic region to ultimate strength then failure.

The computation of this strength takes into account the nonlinear stress-strain behavior of concrete. The strength design method is expressed by the following,

Strength provided ≥ strength required to carry factored loads.

4.2.2 Materials:

Reinforced Concrete: B300 , $f_{\acute{c}}$ = 24 N/mm^2 (Mpa)

Reinforcement Rebars: f_y = 420 N/mm^2 (Mpa)

4.3 FACTORED LOAD

The structure may be exposed to different loads such as dead and live loads. The value of the load depends on the structure type and the intended use. The factored loads on which the structural analysis and design is based for our project members, is determined as follows:

$$q_u = 1.2DL + 1.6LL \quad \ldots\ldots\ldots \; ACI - 318 - 14\ (9.2.1.)$$

Where;

q_u: Ultimate Load (KN)

D_L: Dead Load (KN)

L_L: Live Load (KN)

4.4 DETERMINATION OF SLAB THICKNESS

Minimum Thickness of Non prestressed Beam or One-Way Slabs Unless Deflections are Calculated. **(**ACI-Code-318-19**)**

Table 7 : Check Of Minimum Thickness Of Structural Member.

Minimum Thickness (h)				
Member	**Simply supported**	**One end Continuous**	**Both end continuous**	**Cantilever**
Solid one way slabs	**L/20**	**L/24**	**L/28**	**L/10**
Beams or ribbed one-way	**L/16**	**L/18.5**	**L/21**	**L/8**

4.4.1 One-Way Solid Slab Thickness:

The final thickness of the slab will be determined based on the deformation that will be calculated through the design programs because the slab is originally one-way, but due to the difference in its behavior in some areas, the loads may be distributed in both directions.

4.4.2 One-Way Ribbed Slab Thickness:

- **First Floor**

  The maximum span length for one end continuous (for ribs):

  h_{min} for one-end continuous = L/18.5

  = 577 /18.5 = **31.2 cm.**

  The maximum span length for both end continuous (for ribs):

  h_{min} for both-end continuous = L/21

  = 577/21 = **27.5 cm.**

- **Second Floor**

  The maximum span length for one end continuous (for ribs):

  h_{min} for one-end continuous = L/18.5

  = 560 /18.5 = **31 cm.**

  The maximum span length for both end continuous (for ribs):

  h_{min} for both-end continuous = L/21

  = 560/21 = **27 cm.**

  The maximum Cantilever span length (for ribs):

  h_{min} for Cantilever = L/8

  = 135/8 = **16.9 cm.**

Selected a preliminary slab thickness of the ribbed slabs thickness = 32 cm.

4.5 DESIGN OF TOPPING IN SECOND FLOOR

Consider the Topping as strip of (1m) width, and span of mold length with both ends fixed in the ribs.

Dead Load For 1m strip = (0.08×25×1) + 1 = **3 KN/m**

Live Load For 1m strip = 2 KN/m^2 × 1 = **2 KN/m**

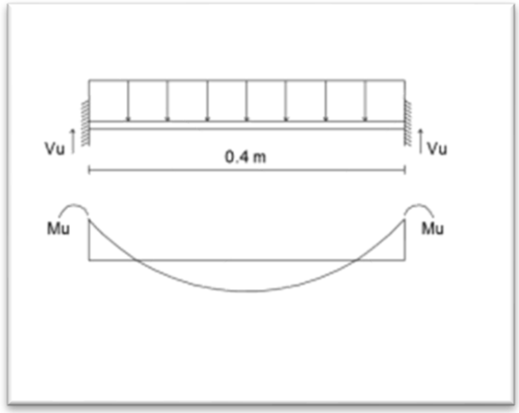


Figure 25: Topping Load

- ✓ Factored load:

W_u= 1.2 ×3 + 1.6×2 = 6.8 KN/m

- ✓ Check the strength condition for plain concrete:

$\emptyset M_n \geq M_u$, where $\emptyset$= 0.55

$M_n = 0.42\ \lambda \sqrt{f_c'}\ S_m$ .... **(ACI 22.5.1, equation 22-2)**

$$S_m = \frac{b.h^2}{6} = \frac{1000.80^2}{6} = 1066666.67\ mm^2$$

$\emptyset M_n$ =0.55×0.42×1×$\sqrt{24}$ ×1066666.67 ×10^{-6} =1.2 KN.m

$M_u = \frac{W_u L^2}{12} = 0.091\text{KN. m}$ (negative moment)

$M_u = \frac{W_u L^2}{24} = 0.045\text{ KN. m}$ (positive moment)

$\emptyset M_n >> M_u = 0.091\text{ KN. m}$

No reinforcement is required by analysis. According to ACI 10.5.4, provide As_{min} for slabs as shrinkage and temperature reinforcement.

$\rho_{shrinkage}$= 0.0018

$A_s = \rho \times b \times h_{topping}$ =0.0018 ×1000×80 = 144 mm^2/m strip.

Step (s) is the smallest of:

1. 3h = 3×80 =240 mm …… ***control***
2. 450 mm.
3. S =$380\left(\frac{280}{f_s}\right) - 2.5C = 380\ \left(\frac{280}{\frac{2}{3}(420)}\right) - 2.5\ \times 20 = 330$ mm

Take ∅ 8 @ 200 mm in both direction, S = 200 mm <S_{max} = 240 mm … OK

4.6 DETERMINATION OF SLABS LOADS

4.6.1 One-Way Ribbed Slab.

- **First Floor**

Table 8 : Dead Load First Floor With One-Way Ribbed Slab.

Parts of Rib	Density	D_L (KN/m)
RC. Rib	25	**0.24*0.12*25= 0.72**
RC.Topping	25	**0.08*0.52*25 = 1.04**
Plaster	22	**0.03*0.52*22 = 0.3432**
Block	10	**0.4*0.24*10= 0.96**
Sand Fill	17	**0.07*0.52*17= 0.6188**
Tiles	23	**0.03*0.52*23 = 0.3588**
Mortar	22	**0.03*0.52*22 =0.3432**
Partition	-	**1.5*0.52 =0.78**
		$\sum$ = 5.2 KN/m

Nominal Total Dead load = **5.2KN/m/rib**

Nominal Total Live load = 2* 0.52 = **1.04 KN/m/rib**

- **Second Floor**

Table 9 : Calculation Of The Total Dead Load For One-Way Rib Slab.

Parts of Rib	Density	D_L (KN/m)
RC. Rib	25	**0.24*0.12*25= 0.72**
RC. Topping	25	**0.08*0.52*25 = 1.04**
Block	10	**0.4*0.24*10= 0.96**
Plaster	22	**0.03*0.52*22 = 0.3432**
		$\sum$ = 3.06 KN/m/rib

Additional Super dead loads **= 1 KN/m^2**

Nominal Total dead load = 3.06 +(1*0.52) **= 3.58 KN/m/rib**

Nominal Total Live load = 2×0.52 = **1.04 KN/m/rib**

4.6.2 Solid Slab.

- **Ground Floor**

Table 10 : Calculation Of The Total Dead Load For Solid Slab.

Parts of Rib	Density	D_L (KN/m)
Plaster	22	**0.0*22 = 0.66**
Sand Fill **Tiles** **Mortar**	17 23 22	**0.07*17= 1.19** **0.03*23 = 0.69** **0.03*22 = 0.66**
Partition	-	**1.5**
		$\sum$ = 4.7 KN/m^2

Super Dead load = **4.7 KN/m^2**

Live Load for Terrace area = **5 KN/m^2**

Live Load for residential area = **2 KN/m^2**

4.7 DESIGN OF SECOND FLOOR ONE-WAY RIBBED SLAB(R6)

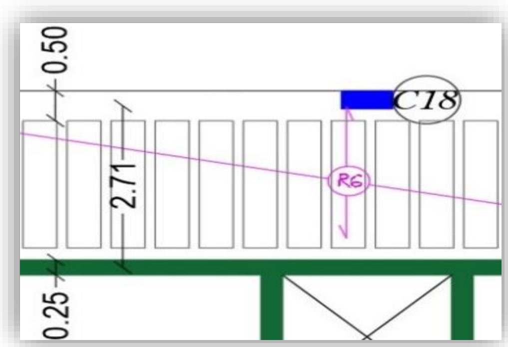


Figure 26: Rib Location

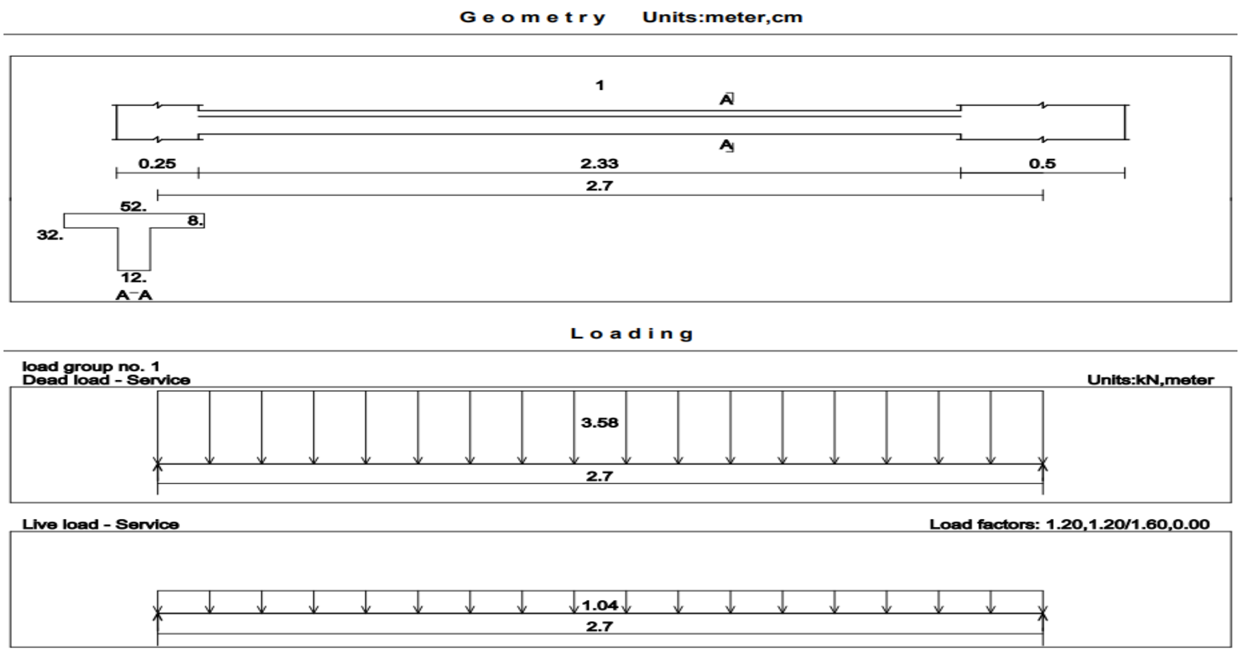


Figure 27: Rib Geometry and loading

- ✓ **Material:**

concrete B300 Fc' = 24 N/mm^2

Reinforcement Steel Fy = 420 N/mm^2

- ✓ **Section:**

b =12cm b_f= 52 cm

h =32cm T_f = 8 cm

4.7.1 Design For Flexure:

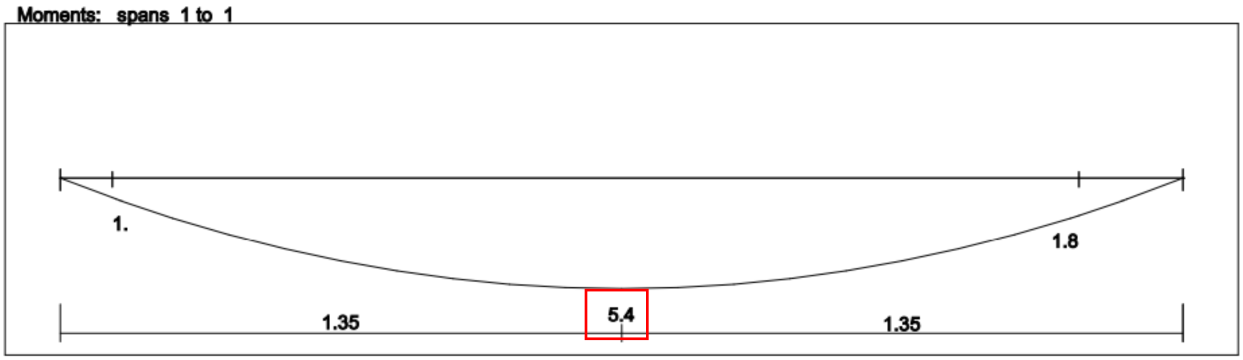


Figure 28: Moment Envelope

✓ Factored load:

W_u= (1.2 ×3.58) + (1.6×1.04) = **5.96 KN/m**

✓ Moment calculation:

$$M_u = \frac{WL^2}{8} = \frac{5.96\times 2.7^2}{8} = \mathbf{5.43\ KN.m}$$

✓ Design for positive moment (M_u=5.43 KN.m)

Assume bar diameter Ø**10** for main reinforcement.

Assume bar diameter Ø**10** for stirrups.

$$D = 320 - 20 - 10 - \frac{10}{2} = 285 \text{ mm}$$

Check if $a > h_f$:

$$\overline{Mn_f} = 0.85 f_{\acute{c}}\, b\, h_f (d - \frac{h_f}{2}) = 0.85 \times 24 \times 520 \times 80 \times (285 - \frac{80}{2}) \times 10^{-6} = 208 \text{ KN.m}$$

$\overline{Mn_f} \gg M_u$ …. $\boldsymbol{a < h_f}$ ➡ **The section is as rectangular section**

$R_n = \frac{M_u}{\emptyset b d^2} = \frac{4.044\times10^6}{0.9\times520\times285^2}$ = 0.1428 Mpa

m = $\frac{f_y}{0.85 f\acute{c}}$ = $\frac{420}{0.85\times24}$ = 20.58

$\rho = \frac{1}{m}(1 - \sqrt{1 - \frac{2\times m\times R_n}{f_y}}) = \frac{1}{20.58}(1 - \sqrt{1 - \frac{2\times20.58\times0.1}{420}})$ = 0.00034

$A_s = \rho \times b \times d$ = 0.00025× 520 × 285 = 50.58 mm^2

$A_{s_{min}}$ = $0.25 \times \frac{\sqrt{f\acute{c}}}{f_y} \times b_w \times d \ \geq \ \frac{1.4}{f_y} \times b_w \times d$

$A_{s_{min}}$ = $0.25 \times \frac{\sqrt{24}}{420} \times 120 \times 285 \ \geq \ \frac{1.4}{420} \times 120 \times 285$

$A_{s_{min}}$ = 99.73 mm^2 $\leq$ 114 mm^2 **…… Control**

$A_s = 48.61\ mm^2 < A_{s_{min}} = 114\ mm^2$ ➡ **Design for minimum reinforcement.**

<u>Use 2∅10</u> with $A_{s_{provid}} = 157.07\ mm^2 > A_{s_{min}} = 114\ mm^2$

Check for strain ($\varepsilon_s \geq 0.005$):

$a = \frac{A_s\times f_y}{0.85\times f\acute{c}\times b} = \frac{157.07\times420}{0.85\times24\times520}$ = 6.216 mm

$c = \frac{a}{0.85} = \frac{6.216}{0.85}$ =7.313 mm

$\varepsilon_s = 0.003\left(\frac{d-c}{d}\right)$ = 0.003 $(\frac{285-7.313}{285})$ = 0.00292> 0.005 **OK.**

4.7.2 Design For Shear:

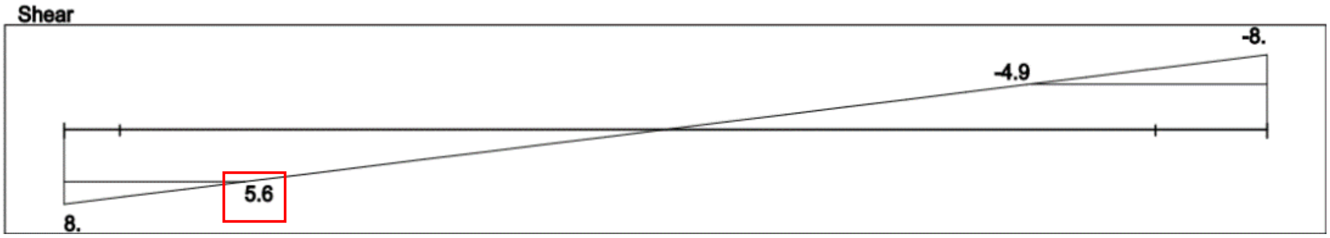


Figure 29: Shear Envelope

✓ $(V_{u,d} = 5.6\ KN)$

d = 320 − 20 − 10 − $\frac{10}{2}$ = 285 mm

$\emptyset V_c = \emptyset\ \frac{1.1}{6} . \lambda . \sqrt{f\acute{c}} . b_w . d$ = 0.75 . $\frac{1.1}{6}$. 1 . $\sqrt{24}$. 120 . 285 . 10^{-3} = 23.037 KN

$\frac{1}{2} \emptyset V_c = \frac{1}{2} \times 23.037$ = 11.518 KN

Check for Cases: -

Case 1: $V_u \leq \frac{\phi V_c}{2}$.

$V_u = 6.6\ KN < \frac{1}{2} \emptyset V_c = 11.518\ KN$ → **So, no shear reinforcement is provided.**

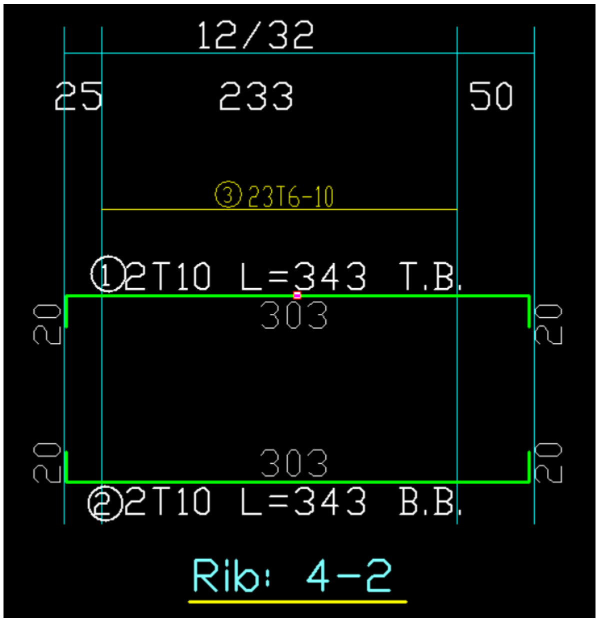


Figure 30 : Reinforcement Of Rib6 In Second Floor

4.8 DESIGN OF ONE-WAY SOLID SLAB

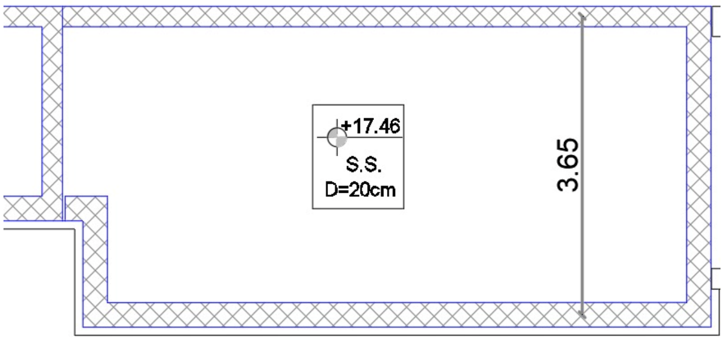


Figure 31:Solid Slab

- h (min) = L/20 = 3.65/20 = 18.3 cm

  Take h = 20cm

- Assume bar diameter Φ 12 for main reinforcement.

  d = h – cover- $\frac{db}{2}$ = 200 – 20- $\frac{12}{2}$ = 174 mm

Dead loads: W_{DL} = γ * h= 25* 0.2 = 5 KN/m^2

Live load: snow load = 1.4 KN/m^2

water tanks = 10 KN/ m^2

Total live load = 1.4 + (10*1) = 11.4 KN/m^2

W = 1.2*5 + 1.6*11.4= 24.24 KN/m^2

$M_u = \frac{W*L^2}{8} = \frac{24.24*3.65^2}{8} = 40.36$ KN.m /m

$M_n = \frac{M_u}{\emptyset} = \frac{40.36}{0.9}$ = 44.85 KN.m /m

$R_n = \frac{M_u}{\emptyset b d^2} = \frac{40.36\times10^6}{0.9\times1000\times174^2} =$ 1.48 Mpa

m = $\frac{f_y}{0.85 f_ć} = \frac{420}{0.85\times24}$ = 20.58

$\rho = \frac{1}{m}(1 - \sqrt{1 - \frac{2\times m\times R_n}{f_y}}) = \frac{1}{20.58}(1 - \sqrt{1 - \frac{2\times20.58*1.48}{420}})$ = 0.00366

$\boldsymbol{A_s = \rho \times b \times d}$ **= 0.00366× 1000 × 174 = 637 mm²**

$A_{s_{min}}$ = 0.0018 * 1000 * 200 = 360 mm^2/m

$A_s = 2018.4\, mm^2/m > A_{s_{min}} = 360\, mm^2$/m **Design for** $\boldsymbol{A_s = 637\, mm^2/m}$

Use $6\emptyset 12$ with $A_{s_{provid}} = 678\, mm^2/m > A_{s_{min}} = 360\, mm^2/m$

Step (s_{max}) is the smallest of **:**

- 3h = 3*200 = 600 mm
- 450mm
- s = $380\,(\frac{280}{\frac{2}{3}*400})$ – (2.5*20) =349 mm but,

s ≤ 300*($\frac{280}{420}$) = 200mm

Take s= 150mm < $\boldsymbol{s_{max}}$ = 200 mm

∴ For Main Reinforcement use Φ12/15 cm, As, prov = 7.533 cm^2/m

- $\boldsymbol{A_s}$**(Temperature and shrinkage) =** $\boldsymbol{A_{s_{min}} = 360\, mm^2}$

Take 5Φ10 /m

Step for Temperature and shrinkage is the smallest of

- 5h = 5*200= 1000 mm
- 450mm

Take S = 150 mm < Smax = 450mm

∴ For Temperature and shrinkage use Φ10/15 cm

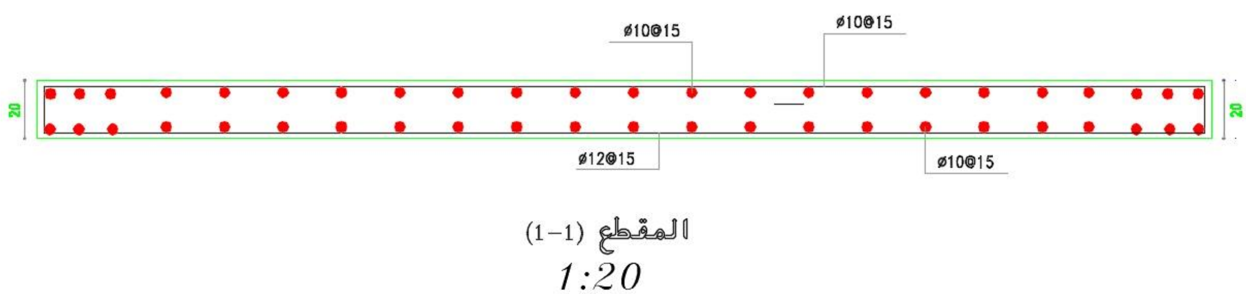


Figure 32: section for solid slab

4.9 DESIGN OF SECOND FLOOR BEAM(B8)

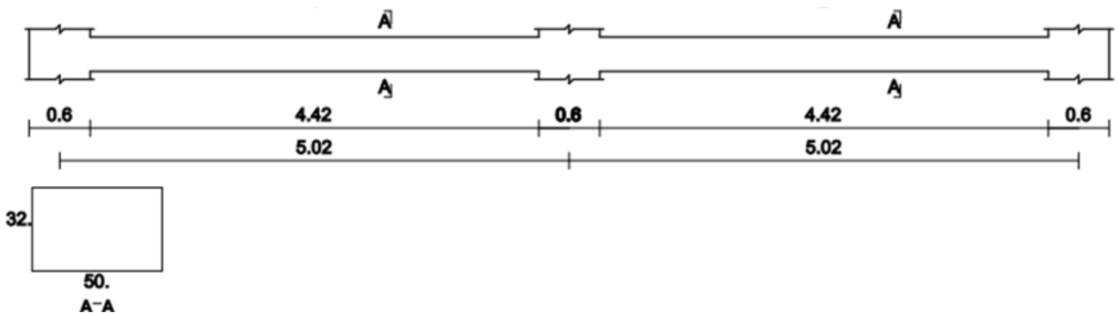


Figure 33: Beam8 Geometry

- Material:

concrete B300 Fc' = 24 N/mm^2

Reinforcement Steel Fy = 420 N/mm^2

- Section:

B = 50 cm

h =32 cm "choose h= 32cm, for deflection requirement's L/240"

According to ACI-Code-318, the minimum thickness of no prestressed beams or one-way slabs unless deflections are computed as follow:

h_{min} for one end cont. = L/18.5

=502 /18.5 = 27.1cm.

Select Total depth of beam h= 32cm.

✓ Loads acts on beam B8:

- Own weight of the beam = Sectional Area × γ concrete = 0.5*0.32 *25 = 4/2= 2 kN/m
- Reactions from (rib6): D.L = 4.83/0.52 = 9.29 kN/m

  L.L = 1.4/0.52 = 2.69 kN/m

- Parapet Load = 7.5 kN/m

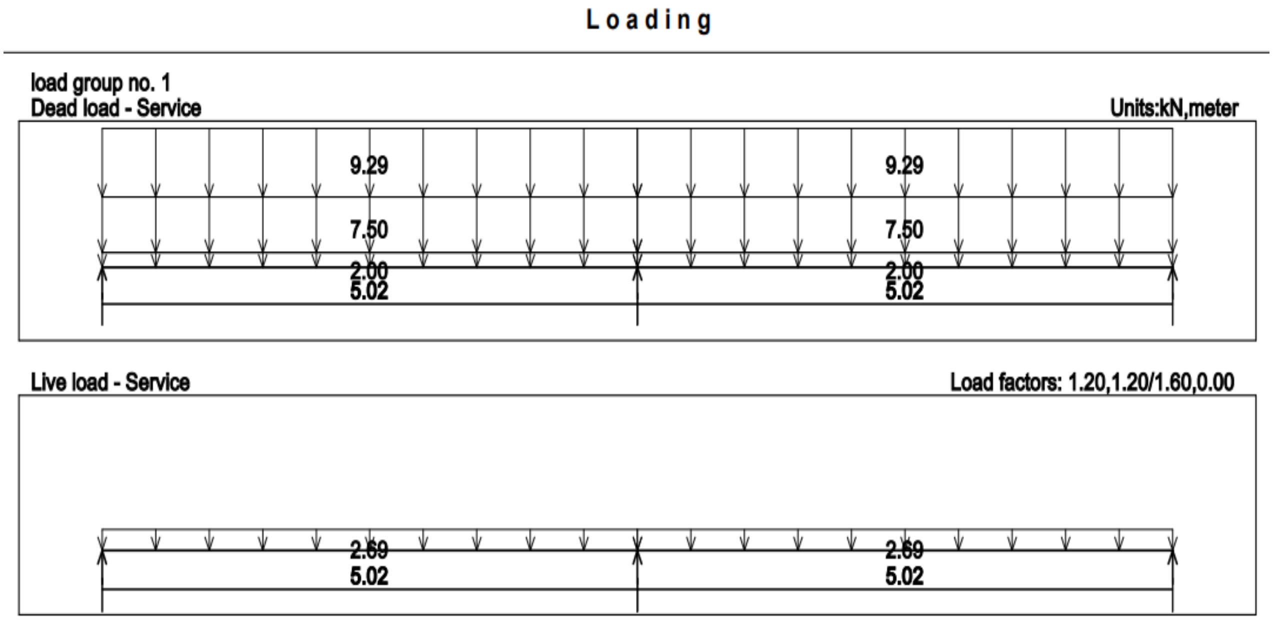


Figure 34:Loads Acts On Beam B8

4.8.1 Design for flexure:

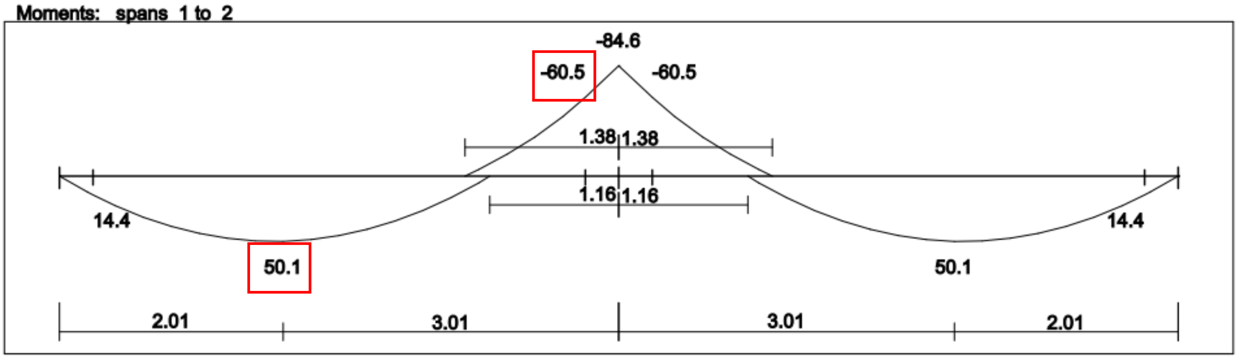


Figure 35: Moment Envelope

✓ ***(Mu_{max} = -60.5 kN.m)***

Assume bar diameter **Ø16** for main reinforcement.

Assume bar diameter **Ø10** for stirrups.

d = depth - cover – diameter of stirrups – (diameter of bar/ 2)

$=320 - 40 - 10 - \frac{16}{2} = 262$ mm

$C_{max} = \frac{3}{7} * d = \frac{3}{7} * 262 = 112.29$ mm.

$a_{max} = \beta_1 * C_{max} = 0.85 * 112.29 = 95.44$ mm.

$M_{n\,max} = 0.85 * f_c' * b * a * (d - \frac{a}{2})$

$= 0.85 * 24 * 0.5 * 0.09544 * (0.262 - 0.09544/2) * 10^3$ =208.59 KN.m

$\varepsilon_s = 0.003 * \frac{d-c}{c} = 0.003 * \frac{262-112.3}{112.3} = 0.004$

$\Phi = 0.65 + \frac{250}{3} * (0.004 - 0.002) = 0.82$

$\phi\, Mn_{max} = 0.82 * 208.59 = 171.04$ KN.m

$\rightarrow$ Mu = 60.5 KN.m < $\phi\, Mn_{max}$ = 171.04 KN.m

∴Singly reinforced concrete section.

✓ Maximum positive moment $Mu^{(+)}$ = 50.1 kN.m

Mn = Mu /ϕ = 50.1 / 0.9 = 55.666 kN.m

m=20.58

$R_n = \frac{M_n}{b*d^2} = \frac{55.666*10^6}{500*(262)^2}$ = 1.6 MPa

$\rho = \frac{1}{20.58}\left(1 - \sqrt{1 - \frac{2*1.6*20.58}{420}}\right) = 0.00402$

$A_s = \rho * b * d = 0.00402*500*262 = 527.75\ mm^2$

$$As_{min} = \frac{\sqrt{f_c'}}{4\,(f_y)} * b * d \;\; \geq \frac{1.4}{f_y} * b * d$$

$$= \frac{\sqrt{24}}{4*420} * 500 * 262 \;\; \geq \frac{1.4}{420} * 500 * 262$$

= 382.0 mm^2 < 436.67 mm^2 …. As, min = 436.67 mm^2

A_s = 527.75 mm^2 > As, min = 436.67 mm^2 **OK**

Use 4 ϕ14 …. As= 615.75 mm^2 for bottom reinforcement

Check for strain:-($\varepsilon_s \geq 0.005$)

Tension = Compression

A_s * Fy = 0.85 * f_c' * b * a

615.75* 420 = 0.85 * 24 * 500* a

a = 26.38 mm.

f_c' = 24 MPa< 28 MPa→ β_1 = 0.85

$c = \frac{a}{\beta_1} = \frac{26.38}{0.85}$ = 31.035 mm.

d=320 – 40 – 10 – $\frac{14}{2}$ = 263 mm

$\varepsilon_s = \frac{d-c}{c} * 0.003 = \frac{263-31.035}{31.035} * 0.003 = 0.0224 > 0.005$ ∴ **ϕ =0.9 … OK**

✓ Maximum Negative moment $Mu^{(-)}$ = -60.5 KN.m

Mn = Mu /ϕ = 60.5 / 0.9 = 67.222 kN.m

D = 262mm → bar diameter Ø16.

m = 20.58

$R_n = \frac{M_n}{b*d^2} = \frac{67.222*10^6}{500*(262)^2}$ = 1.95 MPa

$\rho = \frac{1}{20.58}\left(1 - \sqrt{1 - \frac{2*1.95*20.58}{420}}\right)$= 0.0049

$A_s = \rho$ * b *d =0.0049*500*262 = 643.40 mm^2

As, min = 436.67 mm^2

A_s = 643.4 mm^2 > As, min = 436.67 mm^2

Use 4 Φ16 …. As= 804.23 mm^2 for Top reinforcement.

Check for strain:-($\varepsilon_s \geq$ 0.005)

Tension = Compression

A_s * Fy = 0.85 * f_c' * b * a

804.23* 420 = 0.85 * 24 * 500* a

a = 33.12 mm.

f_c' = 24 MPa< 28 MPa→ β_1 = 0.85

$c = \frac{a}{\beta_1} = \frac{33.12}{0.85}$ = 38.96 mm.

$\varepsilon_s = \frac{d-c}{c}$ * 0.003 = $\frac{262-38.96}{38.96}$ * 0.003 = 0.0172 > 0.005 ∴ **ϕ =0.9 … OK**

4.8.2 Design for Shear:

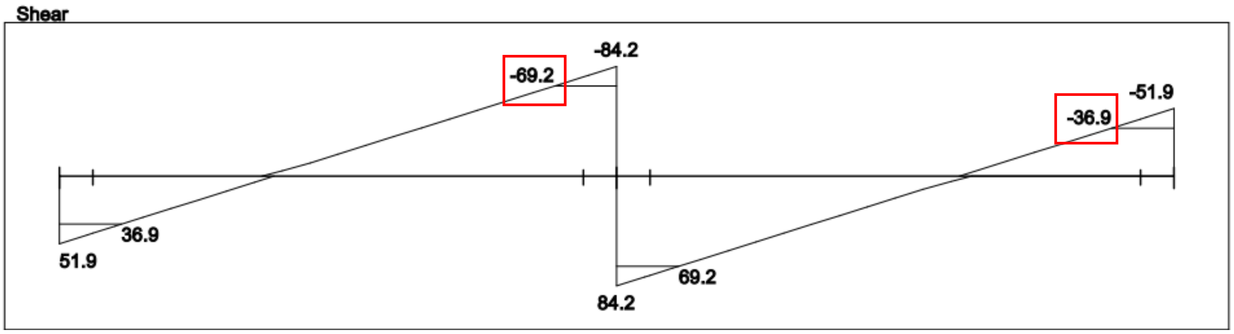


Figure 36: Shear Envelope

✓ $(V_{u,d} = 69.2\ KN)$

$\phi Vc = \phi * \frac{\sqrt{f_c'}}{6} * b * d = 0.75 * \frac{\sqrt{24}}{6} * 500 * 262 * 10^{-3} = 80.22$ KN.

$\frac{\phi V_c}{2} = \frac{80.22}{2} = 40.11$ KN

Check For Cases:-

Case1: $V_u \leq \frac{\phi V_c}{2}$

69.2 > 40.11

∴ Case (1) is NOT satisfied

Case 2: $\frac{\phi V_c}{2} < V_u \leq \phi V_c$

40.11 < 69.2 < 80.22

∴ Case (2) is NOT satisfied

Case 3: $\phi V_c < V_u \le (\phi V_c + \phi Vs_{min})$

$\phi\ Vs_{min} \ge \frac{\phi}{16}\sqrt{f_c'} * b_w * d = \frac{0.75}{16}\sqrt{24} * 0.5 * 0.262 * 10^3 = 30.08$ KN.

$\ge \frac{\phi}{3} * b_w * d = \frac{0.75}{3} * 0.5 * 0.262 * 10^3 = 32.75$ KN …. **Control**.

$\therefore \phi Vs_{min} = 32.75$ KN.

$\phi V_c + \phi Vs_{min} = 80.22 + 32.75 = 122.97$ KN.

$\phi V_c < V_u \le (\phi V_c + \phi Vs_{min})$

$80.22 < 69.2 \le 122.97$ …. **OK**

∴ Case (3) is satisfied → $\left(\frac{Av}{S}\right) = \frac{Vs}{(fy_t * d)}$

$Vs = \left(\frac{Vu}{\phi} - Vc\right)$

$Vs = \left(\frac{69.2}{0.75} - \frac{80.22}{0.75}\right) = 14.69$ KN

Try 2 Φ 10 = 2 * 78.5 = 157 mm^2.

$\frac{2*78.5}{S} = \frac{14.69 * 10^3}{(420 * 262)} \rightarrow s = 1176$ mm

$s \le \frac{d}{2} = \frac{262}{2} = 131$ mm …. CONTROL

≤ 600 mm.

∴ Use Φ10 @ 10 cm 2Leg.

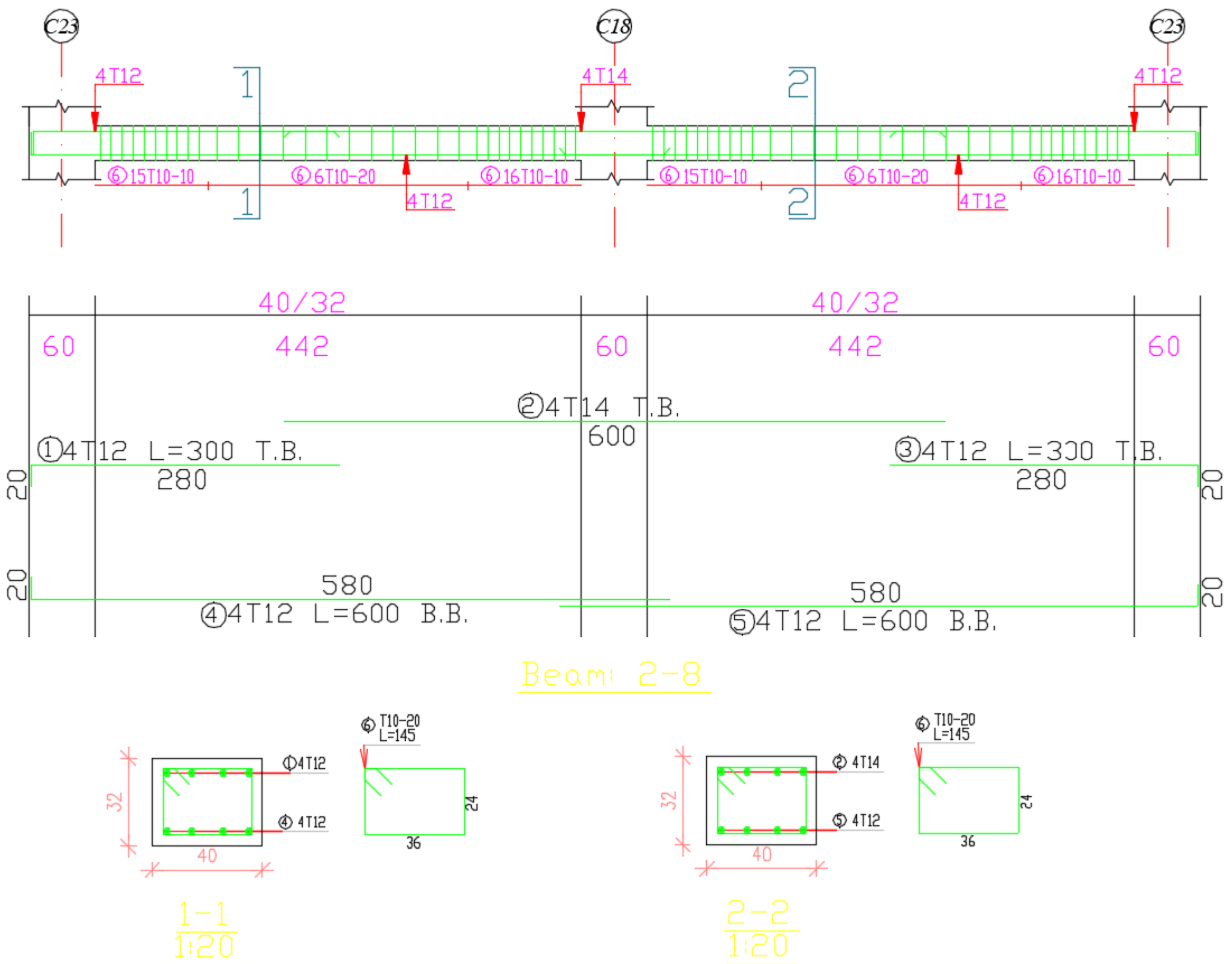


Figure 37 : Reinforcement Of Beam8 In Second Floor

4.10 DESIGN OF COLUMN (C7):

- **Load Calculation:**

Service Load:

DL=480.72 KN

LL=114.33 KN

Factored Load:

Pu= 1.2DL + 1.6LL

Pu= (1.2× 480.72) + (1.6× 114.33) = 759.5 KN

- **Dimensions of Column:**

Pu = 759.8 KN

Pn = $\frac{Pu}{\phi} = \frac{759.8}{0.65}$ = 1168.9 KN ……….. ϕ=0.65 For Tied Column

Assume $\rho g = 1.0$ %

$Pn = 0.8 \times Ag\{0.85 \times fc' + \rho g(fy - 0.85fc')\}$

$1168.9 \times 10^3 = 0.8 \times Ag\{0.85 \times 24 + 0.01(420 - 0.85 \times 24)\}$

$Ag = 59891.99 mm^2 = 598.92 cm^2$

∴Select 60×30cm with Ag = 1800 cm^2.

- **Check Slenderness Effect:**

For braced system if $\lambda \leq 34 - 12\frac{M1}{M2} \leq 40$, then column is classified as short column and slenderness effect shall not be considered.

$$\lambda = \frac{Klu}{r}$$

Where :

Lu: Actual unsupported length = 3.03 m

K: effective length factor (K= 1 for braced frame).

R: radius of gyration → for rectangular section = $\sqrt{\frac{I}{A}}$ =0.3 h

System about X

$\rightarrow \lambda = \frac{1*3.03}{0.3*0.6} = 16.83$

$\lambda \leq 34 - 12(1) = \mathbf{22} \leq 40$

System about Y

$\rightarrow \lambda = \frac{1*3.03}{0.3*0.6} = 16.83$

$\lambda \leq 34 - 12(1) = \mathbf{22} \leq 40$

$\lambda = 16.83 > 22 \therefore$

∴ Short Column , So Slenderness effect will not be considered.

✓ **Calculation of Require d Reinforcement Ratio:**

$\phi Pn = 0.65 \times 0.8 \times Ag\{0.85 \times fc' + \rho g(fy - 0.85fc')\}$

$\phi Pn = 0.65 \times 0.8 \times 300 \times 600\{0.85 \times 24 + \rho g(420 - 0.85 \times 24)\}$

ρg = -0.03< ρg_{min}=0.01

$\therefore \boldsymbol{Take\ \rho g = 0.01}$

As_{req}= 0.01×300×600= 1800 mm^2

Use Φ 14 >> $\#\ of\ bar = \frac{1800}{153.9} = 11.69\ bars$

∴ Use 12Ø 14 with As =1846.8 mm² >As $_{req}$ = 1800 mm²

✓ **Check spacing between the bars :**

$$S = \frac{600-2*40-2*10-6*14}{5} = 83.4\ mm$$

S = 83.4 mm $\geq 40mm$

$\geq 1.5db = 21\ mm$

$\geq \frac{4}{3}\ M.A.S$

✓ **Determination of Stirrups Spacing:**

According to ACI :

$\text{Spacing} \leq 16 \times d_b(\text{Longitudinal. bar. diameter}) = 16 \times 1.4 = 22.4$ cm.

$\text{Spacing} \leq 48 \times d_t(\text{tie. bar. diameter}) = 48 \times 1.0 = 48\text{cm}.$

$\text{Spacing} \leq \text{Least. dim e nsion} = 30$ cm

∴ Select Ø 10/20cm

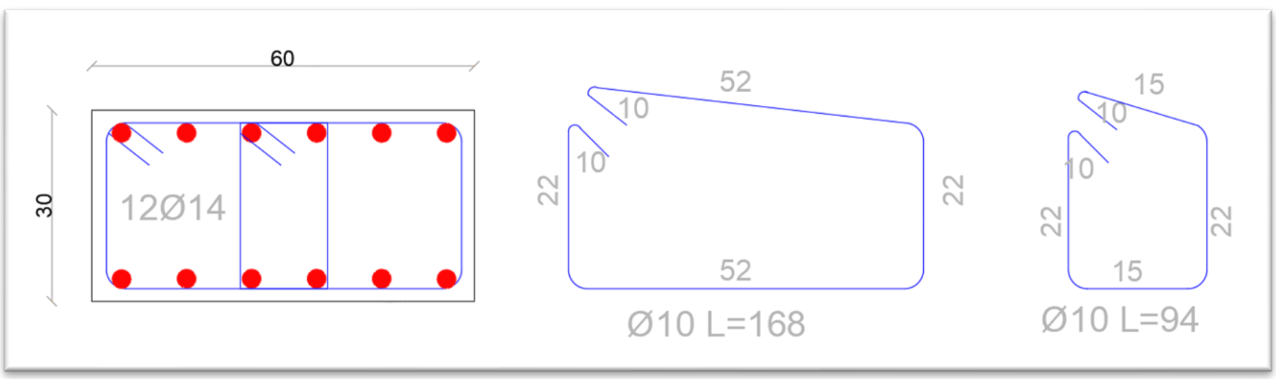


Figure 38: Section of Column

4.11 DESIGN OF STAIR :

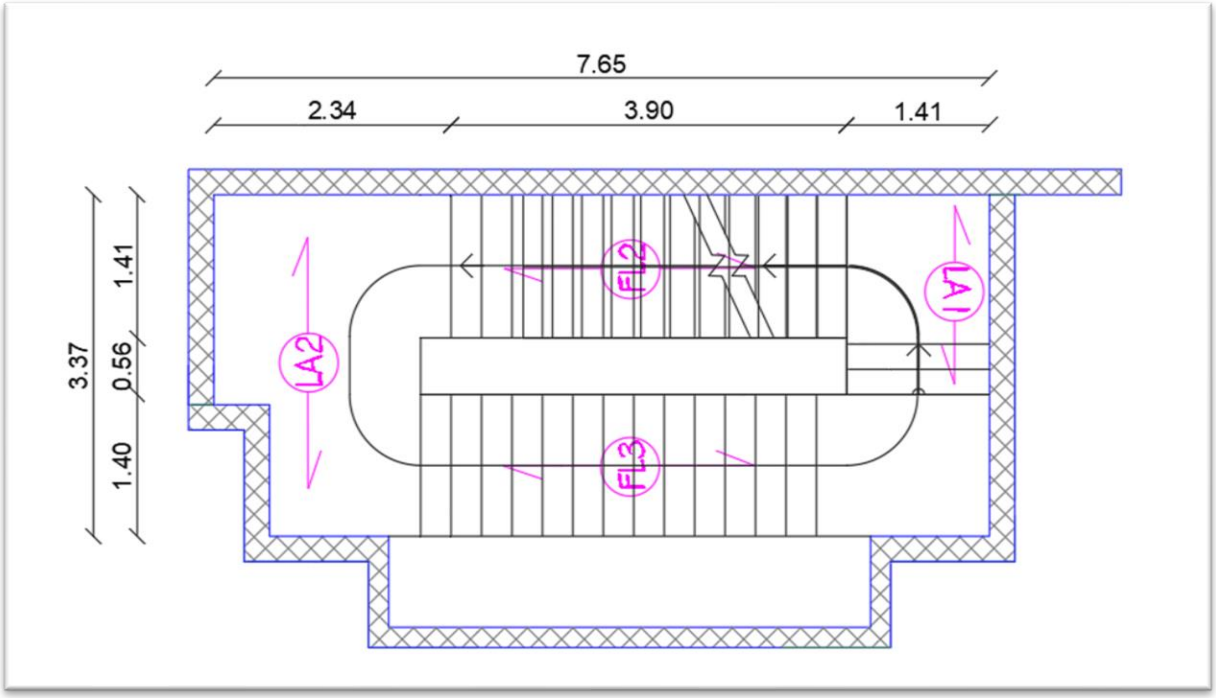


Figure 39: Stair Top View

4.11.1DESIGN OF FLIGHT:

✓ **Determination of Thickness:-**

h_{min} = L/20

h_{min}= 390/20 = 19.5 cm

∴ Select h = 20 cm, but shear and deflection must be checked

The Stair Slope :

Angle (α): tan(α) = 17.3/30 → α = 30°

✓ Load Calculation:

Table 11: Load Calculation For Flight.

N0.	Parts Of Flight	Calculation
1	**Flight**	(0.2 × 25× 1)/ cos(30) = 5.77 KN/m
2	**Plaster**	(0.03 × 22× 1)/ cos(30) = 0.762 KN/m
3	**Mortar**	$(0.03\times22\times1)\times(\frac{0.173+0.3}{0.3})$ = 01.041 KN/m
4	**Stair Steps**	$(\frac{25}{0.3})\times(\frac{0.173\times0.3}{2})$= 2.163 KN/m
5	**Tiles**	$(0.03\times23\times(\frac{35+15}{30})$ = 1.203 KN/m
		SUM= 11.41 KN/m

Live Load = **3KN/m^2**

Factored Loads :

Wu= 1.2 ×11.41 + 1.6×3 = 18.5 KN/m

$$Vu = \frac{18.5\times3.9}{2} = 36.1\ KN$$

Moment Calculation:

$$Mu = 36.1\times((3.9/2)+0.8) - (18.5\times(\frac{1.95^2}{2}))$$

Mu = 64.1 KN.m

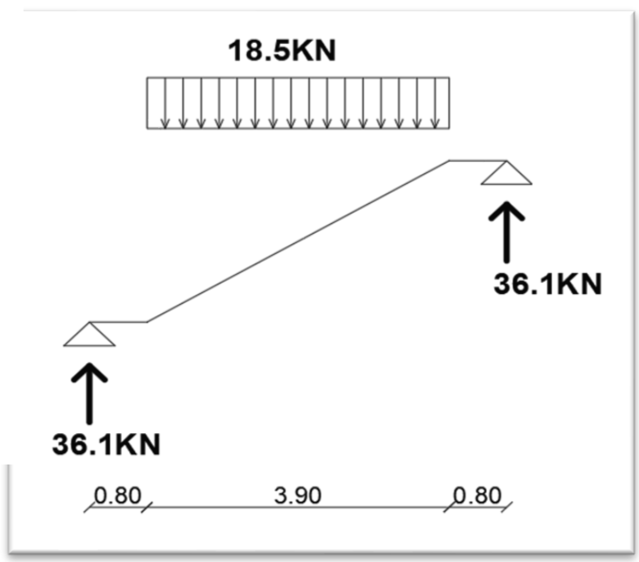


Figure 40: Statically System and Loads Distribution of Flight.

- **Design For Shear For Flight (Vu=36.1 KN):**

Assume bar diameter Ø 14 for main reinforcement

$d = h - 20 - \frac{d_b}{2}$

$d = 200 - 20 - \frac{14}{2} = 173$ mm

$Vc = \frac{1}{6} \times \sqrt{24} \times b_w \times d$

$Vc = \frac{1}{6} \times \sqrt{24} \times 1000 \times 173 = 141.25$ KN

$ØVc = 0.75 \times 141.25 = 105.94\ KN > Vu\ max = 36.1$ KN

∴ No Shear Reinforcement is Required

- **Design For Bending Force (Mu=64.1 KN.m)**

$Mn = \frac{Mu}{Ø} = \frac{64.1}{0.9} = 71.22$ KN.m

$m = \frac{f_y}{0.85 \times f_ć} = \frac{420}{0.85 \times 24} = 20.6$

$Rn = \frac{71.22 \times 10^6}{1000 \times 173^2} = 2.38$ MPa

$\rho = \frac{1}{20.6} \times (1 - \sqrt{1 - \frac{2 \times 2.38 \times 20.6}{420}}) = 0.006$

$As_{req} = 0.006 \times 1000 \times 173 = 1045.4\ mm^2$

$As_{min} = 0.0018 \times 1000 \times 200 = 360\ mm^2$

∴ Select Ø12/100 mm with As = 1131 mm^2 > As req= 1045.4 mm^2 …. For Main Reinforcement

- **Check For Spacing :**

1- $S = 3h = 3*200 = 600$ mm

2- $S = 450$ mm

3- $S = (380\times(\frac{280}{(\frac{3}{4}\times 420)})) - 2.5\times 20 = 330$ mm

But $S \le 300\ (\frac{280}{(\frac{3}{4}\times 420)}) = 300$ mm …….. Control

$S = 100$ mm $<$ $S = 300$ mm ……. OK

$As_{(T\&SH)} = 0.0018\times 1000\times 200 = 360\ mm^2$

∴ Select Ø10/200 mm with As = 395 mm^2 > As req= 360 mm^2

- **Check For Strain:**

$a = \frac{As.f_y}{0.85\times b\times f_{\acute{c}}} = \frac{1113\times 420}{0.85\times 1000\times 24} = 23.28$ mm

$c = \frac{a}{0.85} = \frac{23.28}{0.85} = 27.4$ mm

$\varepsilon_s = 0.003\times(\frac{d-c}{c}) = 0.003\times\frac{173-27.4}{27.4} = 0.0159 > 0.005$ ……… **Ø = 0.9 (OK)**

4.11.2 DESIGN OF LANDING:

Determination of Thickness:-

h_{min} = L/20

h_{min}= 337/20 = 16.85 cm

∴ Select h = 20 cm, but shear and deflection must be checked

Load Calculation

Table 12: Load Calculation For Landing (La2).

N0.	Parts Of Landing	Calculation
1	Tiles	(0.3 × 23× 1) = 0.7 KN/m
2	Mortar	(0.07 × 17× 1) = 1.19 KN/m
3	Slab	(0.25× 25× 1) = 6.25 KN/m
4	Plaster	(0.02 × 22× 1) = 0.40 KN/m
		SUM= 8.94 KN/m

Live Load = **3KN/m^2**

Factored Load :

Wu= 1.2 ×8.94 + 1.6×3 = 15.53 KN/m

Factored Load From Flight :

$W_{LA2} = \frac{W_{F1}}{L} = \frac{36.1}{1.4}$ = 25.8 KN

R = $\frac{15.53 \times 3.37}{2}$ + 25.8 ×1.4 = 62.3 KN

$Mu = 62.3 \times 1.685 - 15.53 \times \frac{1.685^2}{2} - 25.8 \times 1.4 \times (\frac{1.4}{2} + 0.28)$ = 47.5 KN.m

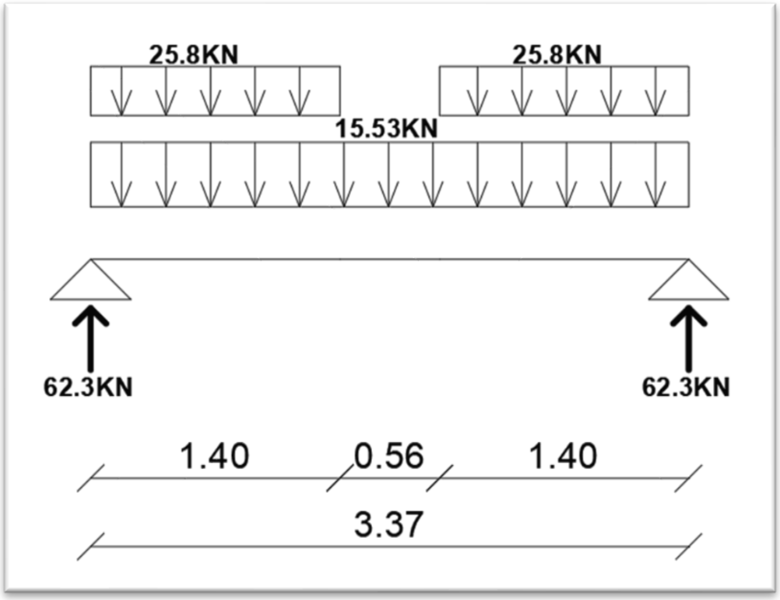


Figure 41: Statically System And Loads Distribution 0f Landing (LA2)

- **Design For Shear For Landing (Vu=62.3 KN):**

Assume bar diameter Ø 14 for main reinforcement

d = h – 20 – $\frac{d_b}{2}$

d = 200 – 20 – $\frac{14}{2}$ = 173 mm

Vc = $\frac{1}{6}\times\sqrt{24}\ \times b_w \times d$

Vc = $\frac{1}{6}\times\sqrt{24}$ × 1000 × 173 =141.25 KN

ØVc = 0.75× 141.25 = 105.94 KN > Vu max = 62.3 KN

∴ No Shear Reinforcement is Required

- **Design For Bending Force (Mu=47.5 KN.m)**

Mn = $\frac{Mu}{Ø}$ = $\frac{47.5}{0.9}$ = 52.81 KN.m

m = $\frac{f_y}{0.85 \times f\acute{c}}$ = $\frac{420}{0.85 \times 24}$ =20.6

Rn = $\frac{52.81 \times 10^6}{1000 \times 173^2}$ = 1.76 MPa

$\rho = \frac{1}{20.6} \times (1 - \sqrt{1 - \frac{2 \times 1.76 \times 20.6}{420}}) = 0.004388$

As_{req}= 0.004388×1000×173= 759.28 mm^2

As_{min}= 0.0018×1000×200= 360 mm^2

∴ Select Ø12/100 mm with As =791.7 mm^2 > As req= 559.9 mm^2 …. For Main Reinforcement

- **Check For Spacing :**

4- S = 3h = 3*200 = 600 mm

5- S = 450 mm

6- S= (380× ($\frac{280}{(\frac{3}{4} \times 420)}$)) − 2.5 × 20 = 330 mm

But S ≤ 300 ($\frac{280}{(\frac{3}{4} \times 420)}$) = 300 mm …….. Control

S = 250 mm < S = 300 mm ……. OK

$As_{(T\&SH)}$= 0.0018×1000×200= 360 mm^2

∴ Select Ø10/200 mm with As = 395 mm^2 > As req= 360 mm^2

- **Check For Strain:**

a = $\frac{As.f_y}{0.85 \times b \times f\acute{c}}$ = $\frac{791.7 \times 420}{0.85 \times 1000 \times 24}$ = 16.3 mm

c = $\frac{a}{0.85}$ = $\frac{16.3}{0.85}$ = 19.18 mm

$\varepsilon_s = 0.003 \times (\frac{d-c}{c}) = 0.003 \times (\frac{173-19.18}{19.18}) = 0.024 > 0.005$ ……… **Ø = 0.9 (OK)**

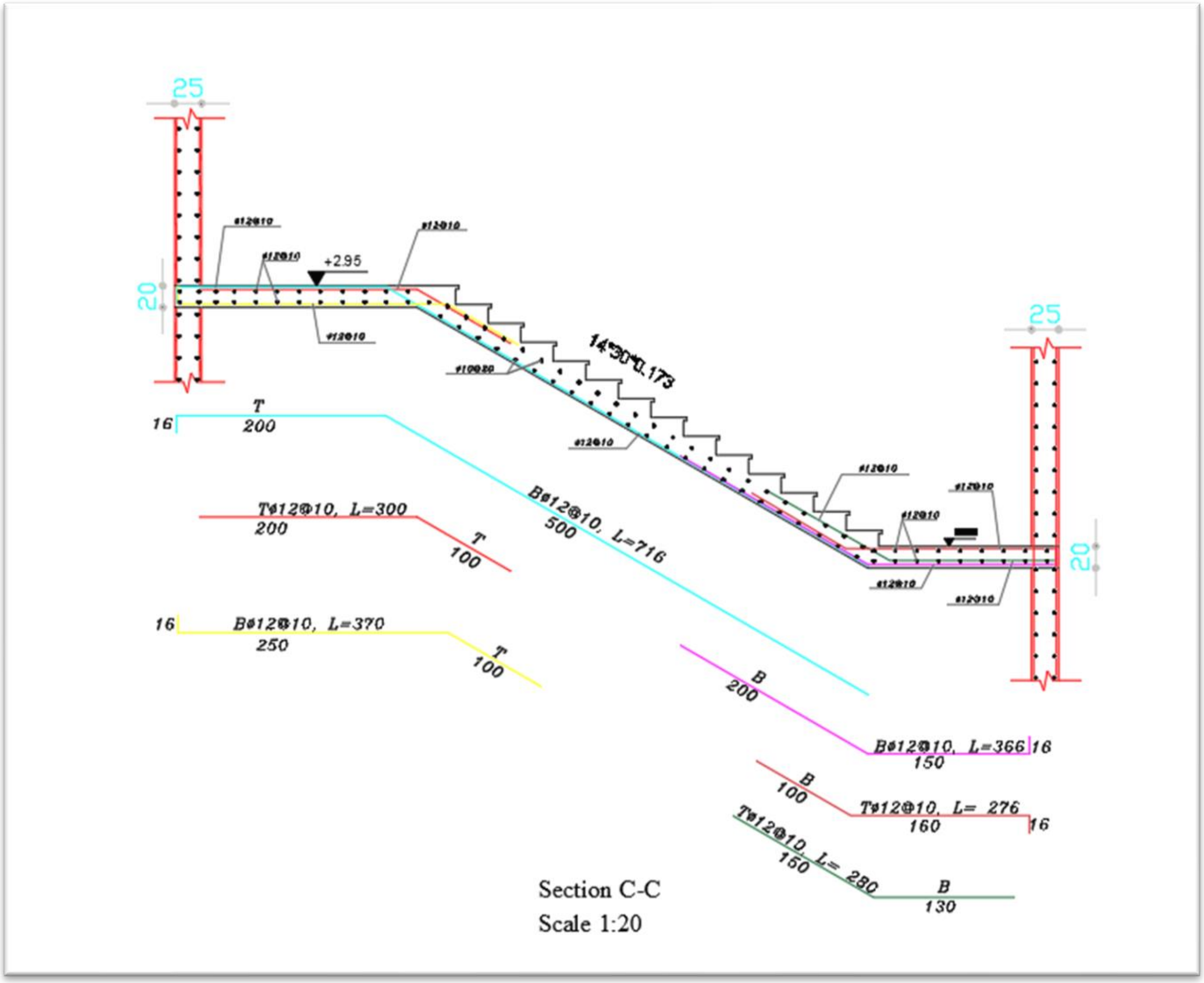


Figure 42: Section Of Stair

4.12 DESIGN OF SHEAR WALL

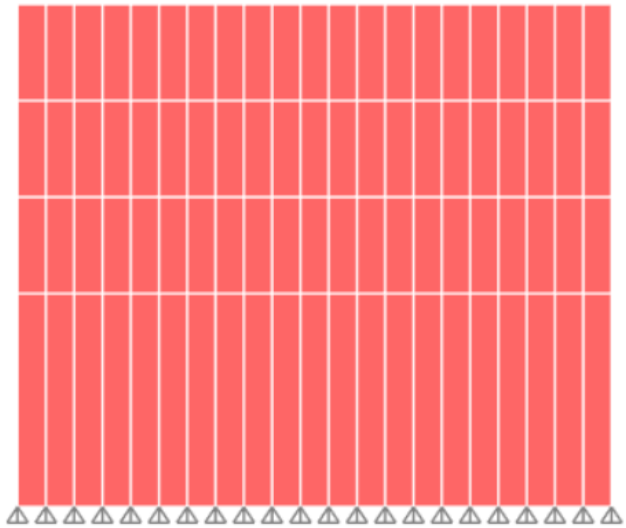


Figure 43: Shear Wall.

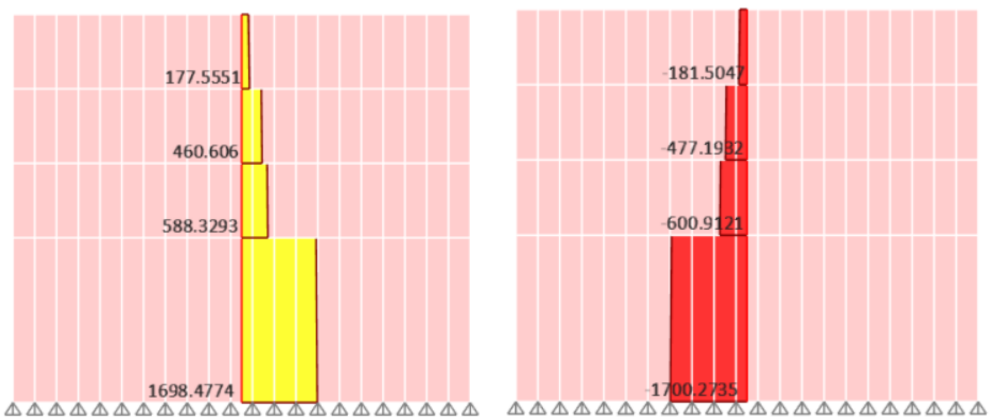


Figure 44: Shear Diagram of Shear Wall.

✓ **Material and Sections:- (From Shear Wall)**

⇒ concrete B300 Fc' = 24 N/mm^2

⇒ Reinforcement Steel Fy = 420 N/mm^2

⇒ Shear Wall Thickness h = 25 cm

⇒ Shear Wall Width Lw = 20.4 m

⇒ Shear Wall Height Hw = 19.74 m

✓ Design of Horizontal Reinforcement:-

$\sum Fx = Vu = 1700\ KN$

The critical Section is the smaller of:

$\frac{lw}{2} = \frac{20.4}{2} = 10.2m.$

$\frac{hw}{2} = \frac{19.74}{2} = 9.87m$

$storyheigh(Hw) = 7m.\ldots Control$

$d = 0.8 \times Lw = 0.8 \times 20.4 = 16.32m$

$$\emptyset V_{nmax} = \emptyset \frac{5}{6}\sqrt{f_c{}'}hd$$
$$= 0.75 * 0.833 * \sqrt{24} * 250 * 16320 * 0.001 = 12487.4\ KN > V_u = 1700KN \ldots OK$$

is the smallest of : V_c

$1 - V_c = \frac{1}{6}\sqrt{f_c{}'}hd = \frac{1}{6}\sqrt{24} * 250 * 16320 * 0.001 = 3331.30KN$ …….. Control

$2 - V_c = 0.27\sqrt{f_c{}'}hd + \frac{N_u d}{4l_w} = 0.27\sqrt{24} * 250 * 16320 * 0.001 + 0 = 5396.715KN$

$$3 - V_c = \left[0.05\sqrt{f_c} + \frac{l_w\left(0.1\sqrt{f_c{}'} + 0.2\frac{N_u}{l_w h}\right)}{\frac{M_u}{V_u} - \frac{l_w}{2}}\right]hd$$

$M_u = 4777.55\ KN.m\ @\ critical\ section = 7m$

$$\frac{M_u}{V_u} - \frac{l_w}{2} = \frac{4777.55}{1700} - \frac{20.4}{2} = -7.389\ (-ve\ value) \ldots canceled$$

$V_c = [0.05\sqrt{24} + 0]250 * 16320 * 0.001 = 999.39\ KN$

Vc =$999.39KN$

Vu = 1700 KN > $\frac{1}{2}$ * 0.75*999.39 = 374.77 KN

Needs reinforcement

$\emptyset * vc + \emptyset vs = vu$
$\emptyset * vs$=vu-$\emptyset * vc$
Vs=vu/$\emptyset - vc$

Vs=(1700/0.75)-999.39= 1267.276 KN

$\frac{A_{vh}}{s_h} = \frac{vs}{fyd} = \frac{1267.276}{420*16320} =$ 0.00018 mm^2/ m < ρ = 0.0025

- Maximum spacing is the least of:

$\frac{Lw}{5}$ = $\frac{20400}{5}$ = 4080 mm
3*h = 3*250 = 750 mm

450 mm ……. Control

ρ = 0.0025

Try Ø10 ($A_S = 78.5\ mm^2$) two layers

$\rho = \frac{A_{vh}}{hS_h} = \frac{2*78.5}{250S_h}$ =0.0025

S_h= 252.48mm

→ use Ø10@200 mm in tow layer

✓ Design of Vertical Reinforcement:-

$\frac{h_w}{Lw} = \frac{19.74}{20.4} = 0.967$

ρ = 0.0025+(2.5-$\frac{h_w}{Lw}$)*(ρ -0.0025)>0.0025
ρ = 0.0025+(2.5-0.967)*(0.00018 -0.0025) = -1.05
So , ρ = 0.0025

- Maximum spacing is the least of :

$\frac{Lw}{3}$ = $\frac{20400}{3}$ = 6800 mm
3*h = 3*250 = 750mm
450 mm ……. Control

Try Ø10 ($A_S = 78.5\ mm^2$) two layers

$\rho = \frac{A_{vh}}{hS_h} = \frac{2*78.5}{250S_h}$ =0.0025

S_h= 252.48mm

→ use Ø10@200 mm in tow layer

✓ Design of Bending Moment:-

Mu = 7654.2 $KN.m$

$$A_{st} = \left(\frac{20400}{200}\right) * 2 * 78.5 = 16014\, mm^2$$

$$w = \left(\frac{A_{st}}{L_w h}\right)\frac{f_y}{f_c{}'} = \left(\frac{16014}{20400 * 250}\right)\frac{420}{24} = 0.0549$$

$$\alpha = \frac{P_u}{l_w h f_c{}'} = 0$$

$$\frac{C}{l_w} = \frac{w + \alpha}{2w + 0.85\beta_1} = \frac{0.0549 + 0}{2 * 0.0549 + 0.85 * 0.85} = 0.06596$$

$$\emptyset M_n = \emptyset\left[0.5 A_{st} f_y l_w (1 + \frac{P_u}{A_{st} f_y})(1 - \frac{c}{l_w})\right]$$

$$= 0.9[0.5 * 16014 * 420 * 20400(1 + 0)(1 - 0.06596)] = 57670.86\ KN \geqq 7654.2\ KN.m$$

Mub = Mu-ØMn = 7654.2 - 57670.86 = −50016.66 KN.m

X≥ $\frac{lw}{600*\frac{\Delta h}{hw}} = \frac{20400}{600*0.967}$ =35 mm

Lb≥ $\frac{X}{2} = 17.58\ mm$

Since Smallest value of Lb & Mub not requires Boundary.

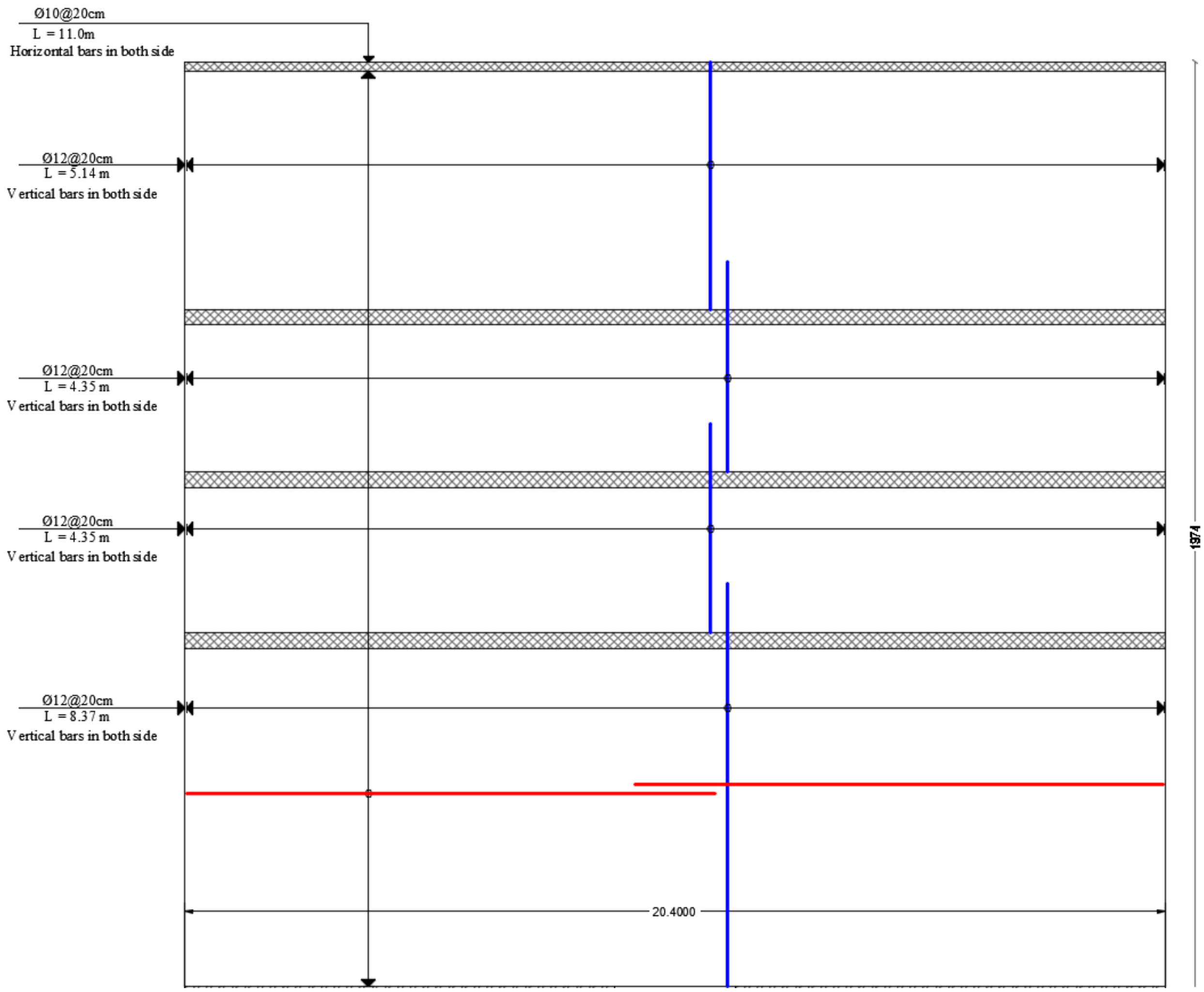


Figure 45: Shear Wall.

CHAPTER 5
" RESULTS AND DISCUSSION "

5.1 INTRODUCTION .

In this project, architectural plans were obtained that lacked many things, and the construction plans were prepared in a detailed, accurate, and clear manner to facilitate the construction process. This report provides an explanation of all the architectural and construction design steps for the building.

5.2 RESULTS..

1. Every student or structural designer must be able to design manually so that he can have experience and knowledge in using computerized design programs.

2. Among the factors that must be taken into account are the natural factors surrounding the building, the nature of the site, and the impact of natural forces on the site.

3. One of the most important steps of the structural design is how to link the different structural elements through the holistic view of the building and then divide these elements to design them individually and learn how to design, taking into account the circumstances surrounding the building.

4. The value for soil bearing strength is 200KN/m2.

5. The Ribbed Slab system has been used in many knots due to the nature and shape of the structure, and the Solid Slab system has been used in the staircase and ground floor areas, due to its being more effective than nerve knots in carrying and resisting concentrated loads .

5.3 RECOMMENDATIONS.

This project has played a major role in expanding and deepening our understanding of the nature of construction projects with all their details, analyzes and designs, where we would like here - through this experience - to present a set of recommendations, which we hope will benefit and advise those who plan to choose projects of a structural nature.

In the beginning, all architectural plans must be coordinated and prepared, so that the building materials are chosen with the construction system of the building determined. At this stage, comprehensive information must be available about the site, its soil, and the bearing strength of the soil of the site, through a geotechnical report specific to that area, after that the Determining the locations of load-bearing walls and columns in full coordination and coordination with the architectural engineering team. At this stage, the structural engineer tries to obtain as much reinforced concrete walls as possible, so that they are distributed in a regular or semi-regular manner throughout the building; To be used later in resisting earthquake loads and other horizontal forces.

5.4 REFERENCES.

1. كود البناء الأردني , كود الأحمال والقوى , عمان , الأردن : مجلس البناء الوطني الأردني 2006 م
2. Adoption of the American code in the various structural designs (ACI-318-19).
3. Google Earth pro.

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