Palestine Polytechnic University
College of Engineering
Civil Engineering and Architecture Department

Graduation Project

"STRUCTURAL DESIGN OF A RESIDENTIAL VILLA"

Project Team

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This project submitted to the College of Engineering in partial fulfillment of requirements of the Bachelor degree of Civil Engineering

Hebron - Palestine

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The undersigned hereby certify that they have read, examined, and recommended to the Department of Civil Engineering and Architecture in the College of Engineering at Palestine Polytechnic University the approval of a project entitled: **Structural Design of a Residential Villa** , submitted by Mahdi Y. Rajabi and Ribhi M. Haddad for partial fulfillment of the requirements for the bachelor's degree.

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STRUCTURAL DESIGN OF A RESIDENTIAL VILLA

Supervisor : Dr. Hamdi Idais

Project Team: Mahdi Rajabi , Ribhi Haddad

ABSTRACT

This project aims to apply the theoretical knowledge that has been acquired during the years of study through making a complete analysis and design of a 5-story residential villa with an estimated total area of 1325 m^2.

In this regards, the architectural plans of the building were studied. Then structural planning of the building was done, in which the location of columns and beams was determined to fit with the architectural plans. A detailed structural study also was carried out to estimate loads that act on each member using the Jordanian code for gravity loads estimation and (ASCE7-16) code for the definition of lateral seismic loads.

Analysis and design then were done in accordance with ACI 318-14 Building code based on the ultimate strength method for concrete design and working stress method for soil design. That was using structural programs such as Atir BeamD, Found, SP Column, Safe 2016, and Etabs2018. Finally, structural working drawings were prepared to present the reinforcement details of all members.

التصميم الانشائي لمبنى سكني

فريق العمل : مهدي ياسر عطا رجبي , ربحي ماهر الحداد

إشراف : د .حمدي ادعيس

الملخص

يهدف المشروع الى عمل تصميم انشائي لجميع العناصر الانشائية المكونة لفيلا سكنية مكونة من 5 طوابق تقدر مساحتها الاجمالية بـ 1325 م^2. وذلك لما للتصميم الانشائي من اهمية فهو من اهم المراحل التي يمر بها المبنى والتي يتم فيها تحديد اماكن الاعمدة و الانظمة الانشائية لمختلف عناصر المبنى وبذلك يتم تحويل المخططات المعمارية الاولية الى مخططات قابلة للتنفيذ .

وتحقيقا لهدف المشروع تم في البداية دراسة المخططات المعمارية و اختيار انسب الية لتوزيع العناصر الانشائية بما لا يتعارض مع التصميم المعماري للمبنى , ثم تم عمل دراسة انشائية مفصلة تم فيها تقدير الاحمال المتوقعة على جميع العناصر الانشائية بالاعتماد على الكود الاردني والكود الامريكي ASCE-16 لتقدير احمال الزلازل.بعد ذلك تم تحليل وتصميم جميع تلك العناصر بالاعتماد على الكود الامريكي ACI318-14 وباستخدام مجموعة من البرامج الهندسية . وفي النهاية تم إعداد المخططات التنفيذية لجميع العناصر الانشائية المكونة لهيكل المبنى ليصبح المبنى قابلاً للتنفيذ .

اهداء

الى روح الحبيب المصطفى (ﷺ) الذي قال: " من سلك طريقاً يلتمس به علماً سهّل الله له به طريقاً الى الجنة".

الى من تشكل على جبينهِ معنى الحياةِ وغلفتها لآلِئُ الألماس، الى من أفنى وقتَهُ وجهدهُ وقدّم لنا ثمرةَ فؤادهِ وجهدهِ "والدي الكريم".

الى من كان دعاؤها في جوف الليل نوراً يضيءُ السماواتِ والأرض، الى صاحبةِ القلبِ النقيّ " أمي العزيزة".

الى سرّ قوّتنا وقدوتنا يوماً بعد يومْ "اخوتي".

الى من عايشناهم أياماً طويلة، الى من شاركونا الفرحَ والحزنَ الى من أضاءَ ضيائهم قلوبنا وغمروها بكل الحبْ، الى كل "الأصدقاء".

الى من يُضحون باللّحم أطناناً من أجل كرامتنا "أسرانا البواسلْ".

الى من اصطفاهمُ اللهُ ليكونوا في كنفهِ ورعايته "شهدائنا الأبرار".

الى الكادر الاكاديمي في جامعة بوليتكنك فلسطين، الذي ما زال يخرّج ثلة متميزة في شتى الميادين الأكاديمية والعملية.

اليكم جميعاً...

الشكر :

الشكر لله تعالى والثناء عليه.

لقد كانت فرصة عظيمة لنا لاكتساب الكثير من المعرفة من خلال العمل في هذا المشروع ، لكن الإكمال الناجح لأي مهمة سيكون غير مكتمل دون ذكر الأشخاص الذين جعلوها ممكنة .

لذلك نود أن نشكر كل من ساعدنا ودعمنا وشجعنا:

جامعة بوليتكنك فلسطين ، كلية الهندسة ، قسم الهندسة المدنية والمعمارية ، بما في ذلك جميع أعضاء فريق العمل المخلصين والمتعاونين .

شكر خاص لمشرفنا الدكتور حمدي ادعيس ، الذي كان الضوء الموجه في كل خطوة على الطريق أثناء عملنا في هذا المشروع.

شكرًا لجميع المدربين على كل الجهود التي بذلوها لتزويدنا بجميع المعلومات المفيدة ومشاركة معارفهم وخبراتهم لجعلنا مهندسين ناجحين.

وأخيراً نتقدم بجزيل الشكر والامتنان لوالدينا وإخواننا وأخواتنا على صبرهم معنا ومساعدتهم التى كانت وستبقى بلا حدود .

شكرا لكم جميعاً .

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LIST OF ABBREVIATIONS

As	Area Of Non-Prestressed Tension Reinforcement.
As′	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.
d	Distance From Extreme Compression Fiber To Centroid Of Tension Reinforcement.
Ec	Modulus Of Elasticity Of Concrete.
fy	Specified Yield Strength Of Non-Prestressed Reinforcement.
h	Overall Thickness Of Member.
I	Moment Of Inertia Of Section Resisting Externally Applied Factored Loads.
ln	Length Of Clear Span , Measured Face-To-Face Of Supports In Slabs Without Beams And Face To Face Of Beam Or Other Supports In Other Cases.
M	Bending Moment.
Mu	Factored Moment At Section.
Mn	Nominal Moment.
S	Spacing Of Shear Or 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.
ρ	Ratio Of Steel Area.
εc	Compression Strain Of Concrete=0.003mm /Mm
Fsd,r	Total Additional Tension Force Above The Support.
Ved,0	Shear Force At Critical Section.
Vu	Factored Shear Force At Section.
Wu	Factored Load Per Unit Length.
Φ	Strength Reduction Factor.

CHAPTER 1

INTRODUCTION

1.1. General Overview
1.2. Project Problem
1.3. Project Objectives
1.4. Project Scope
1.5. Work Procedure
1.6. Project Timeline
1.7. Programs Used In The Project

1.1 General Overview

Any building is supported by a framed arrangement known as Structure which is a system formed from the interconnection between structural members. The structural design requires an intelligent manner in making decisions regarding the systems of different structural elements and that cannot be achieved by an understanding of basic concepts of structures only. Rather, that understanding must be applied through practice.

From this point of view, a residential villa was chosen to be designed and the reason for choosing this building is because it is the most common and most requested in the engineering labor market, because of the recent tendency of people to live independently .

The building was designed by applying the acquired knowledge in the design of different structural elements to provide a safe design that achieves the required engineering specifications and standards.

1.2 Project Problem

As a result of the variety of construction systems and the need of making a balance between costs and safety in the design, it was necessary to find the most appropriate structural system that satisfies the strength and serviceability requirements for the chosen residential villa .

1.3 Project Objectives

This Project was chosen to achieve the following galls:

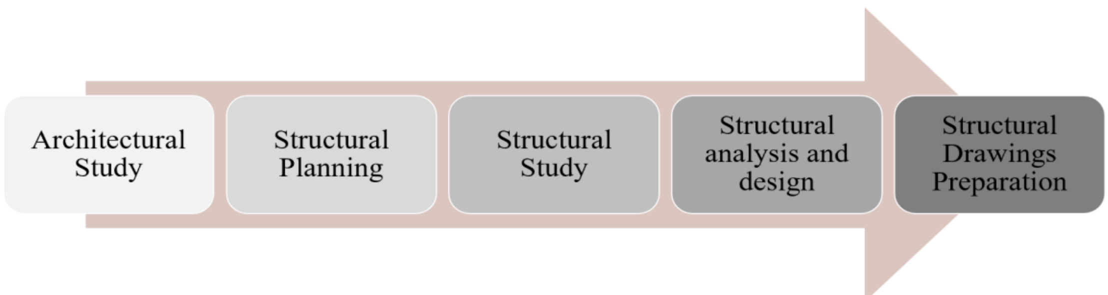
- Correlate the theory that has been gained in the design courses with practical life.
- Increase the ability to choose a suitable structural system of elements that meets design requirements.
- Get experience in dealing with different problems encountered in the design process.
- Practice the structural analysis and design programs as well as theoretical knowledge.

1.4 Work Procedure

To achieve the objectives of the project following steps were followed :

1. Architectural study in which the site, building plans, and elevations were been studied.
2. Structural planning of the building, in which the location of columns, beams, and shear walls was determined to fit with architectural design.
3. Structural study in which all structural members were identified and different loads were been estimated.
4. A complete analysis and design for all elements were done according to the ACI Code.
5. Preparation of Structural drawings of all existing elements in the building.
6. Project Writing in which all these stages were presented in detail.

Figure(1- 1) :Work Procedure



1.5 Project Scope

This Project contains the following Chapters :

CHAPTER 1: A general introduction.

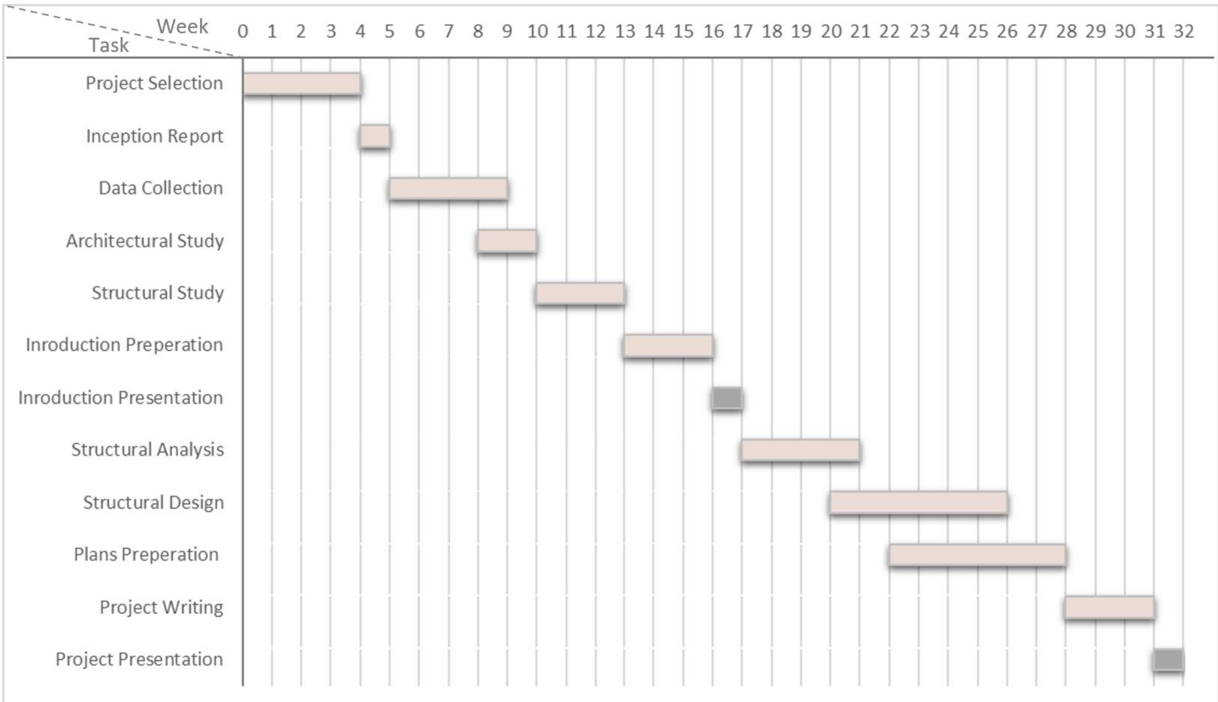
CHAPTER 2: An architectural description of the project.

CHAPTER 3: A general description of the structural elements.

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

CHAPTER 5: Results and Recommendations.

1.6 Project Timeline



Figure(1- 2):Project Timeline

The following chart shows the project plan and timeline :

1.7 Programs used in the project

There are several computer programs used in this project:

1. Microsoft Office: It was used in various parts of the project such as text writing, formatting, and project output.
2. AUTOCAD 2017: for detailed drawings of structural elements.
3. ATIR18: Structural design and analysis of structural elements.
4. SP Column: design of columns.
5. Etabs18: design and analysis of structural elements especially for walls.
6. Safe16: design of combined and matt foundation.

CHAPTER 2

ARCHITECTURAL DESCRIPTION

2.1 Introduction

Building any structure is an integrative process between several engineering specializations and the design process for any building takes place through several stages until it is fully accomplished.

Starting first with the architectural design stage, at this stage, the shape of the structure is determined and take into account the inquiry of the various functions and requirements for which you will create this building, here the initial distribution of the facilities is made, to achieve the required spaces and dimensions, and in this process, lighting, ventilation, movement, mobility, and other functional requirements are also studied.

An architectural study that must precede the start of architectural design must be easy to handle and understand different events that it contains building and functional relations among them, and the nature of the association movement and using these parts, and other things of importance that give a clear view of the project and therefore it will be possible to locate the columns and other structural elements to suit architectural design.

2.2. General Identification of the project

The proposed project is a residential villa with 5 floors ,basement floor is hall for guests, the rest is residential floors

The building is proposed to be built on 900 square meters land. This area of land is sufficient to establish this villa with its own garden, which gives it a character of independence and beauty

Figure (2- 1): 3D shot of the building

2.3 General site description

The proposed project is located in Singer – Dura ,south of hebron , in a residential area with a good infrastructure of roads. It is an easily accessible location with available needed services such as electricity and communications link. The location of the project is clearly shown in Figure (2-1).

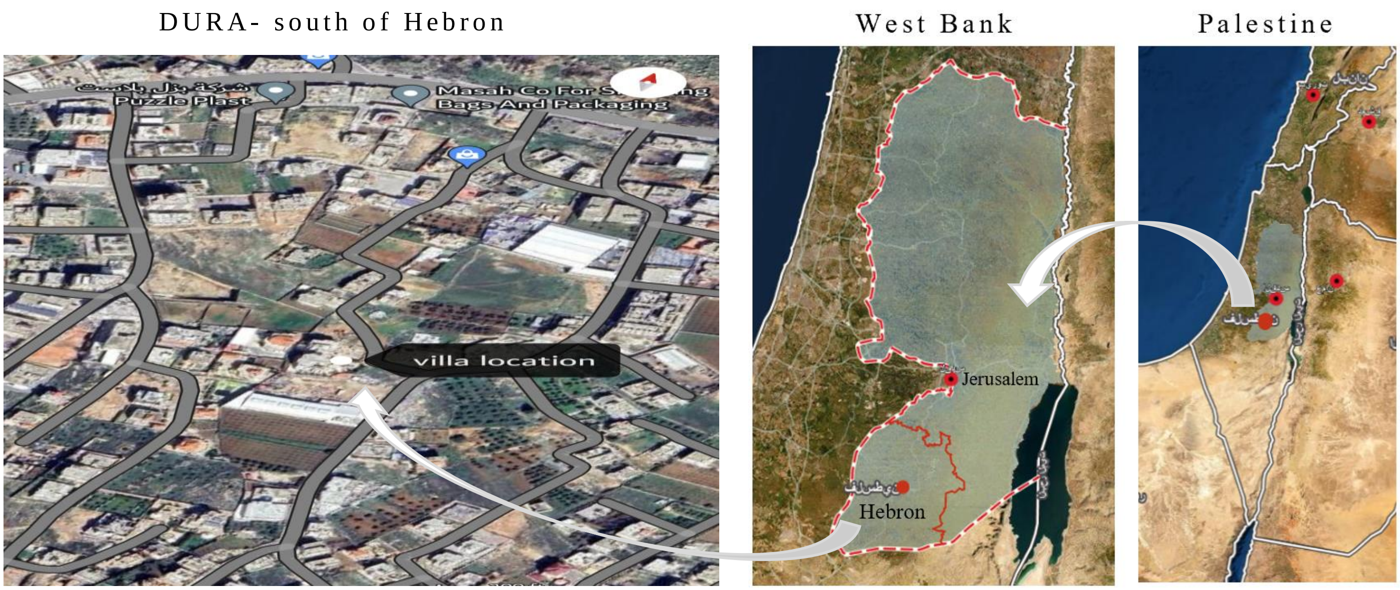


Figure (2- 2): Site Location

2.4 Floors Description

The Project contains three types of floors: Basement, Ground floor, and 3 residential floors with a total area of 1325 m^2. The following is a brief description of each floor.

1. BASEMENT FLOOR

The basement floor level is 0.00 m with the level of Main Street with an area of 272 m^2. It consists of a large hall for guests, a kitchen, a bathroom, and also the stairs leading to the ground floor , in addition to the water well.

The entrance to the basement is from the southeast side of the building ,with another entrance from staircase at the northeast side, Which is clearly shown in figure (2-3).

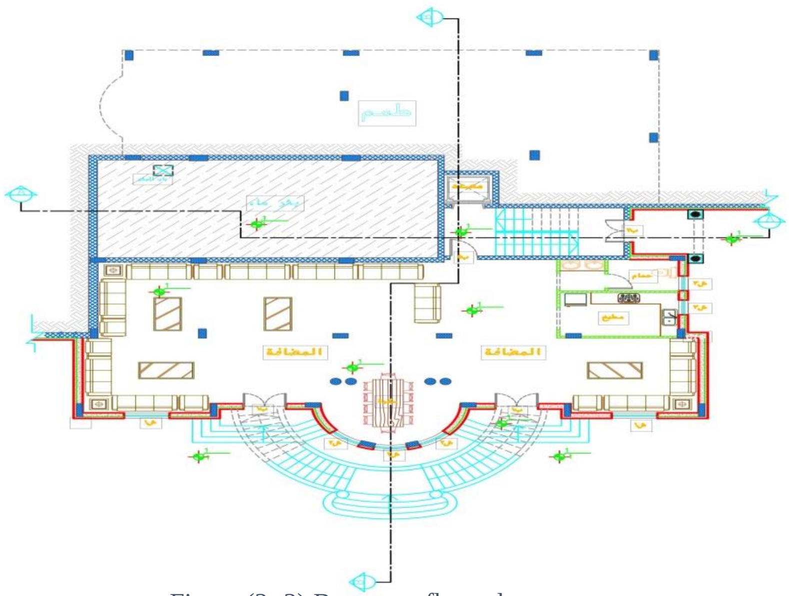


Figure (2- 3):Basement floor plan

2. GROUND FLOOR

It contains main enterance to the villa it is accessed by a beautiful semi-circular staircase and the ground floor is of an area 305 m2. another entrance on the northeastern side leads to access to all floors.

Figure (2-4) shows the plan of the ground floor that shows the entrances to the villa , in addition to the connection between spaces.

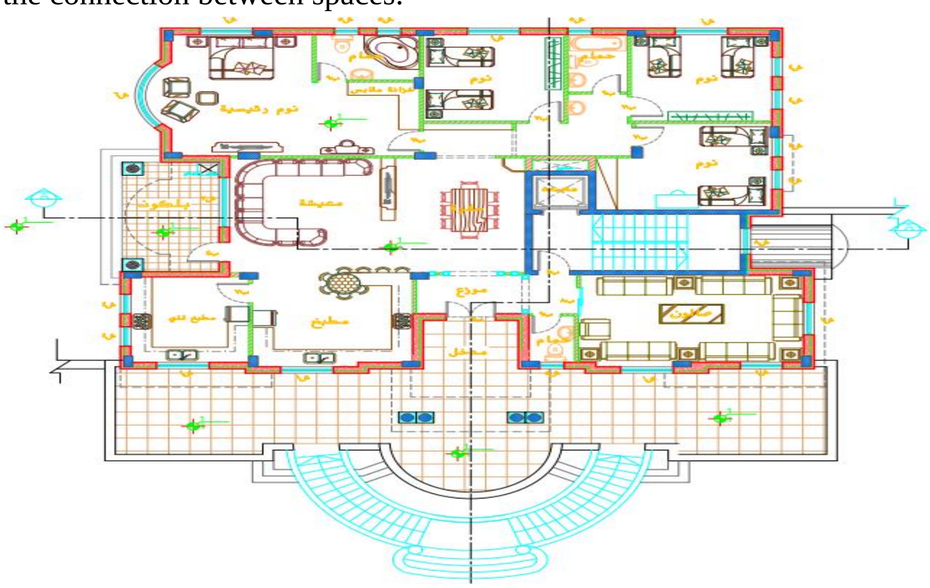


Figure (2- 4):Ground floor Plan

3. 1ST & 2ND FLOORS

There are 2 typical floors, each floor is an independent residential apartment that is accessed by stairs and elevators, the floors come in different areas and shapes to give a beautiful architectural toutch to the villa , areas are $277m^2$ (1st) and $243m^2$ (2nd).

Each floor consists of:

- Entrance
- Guest room
- Dining room
- Kitchen
- Living room
- Master bedroom
- Two bedrooms
- Three bathrooms
- 3 Terrace

Figure (2-5) shows the plan of the typical residential floor on which the entrances appear, in addition to the connection between spaces.

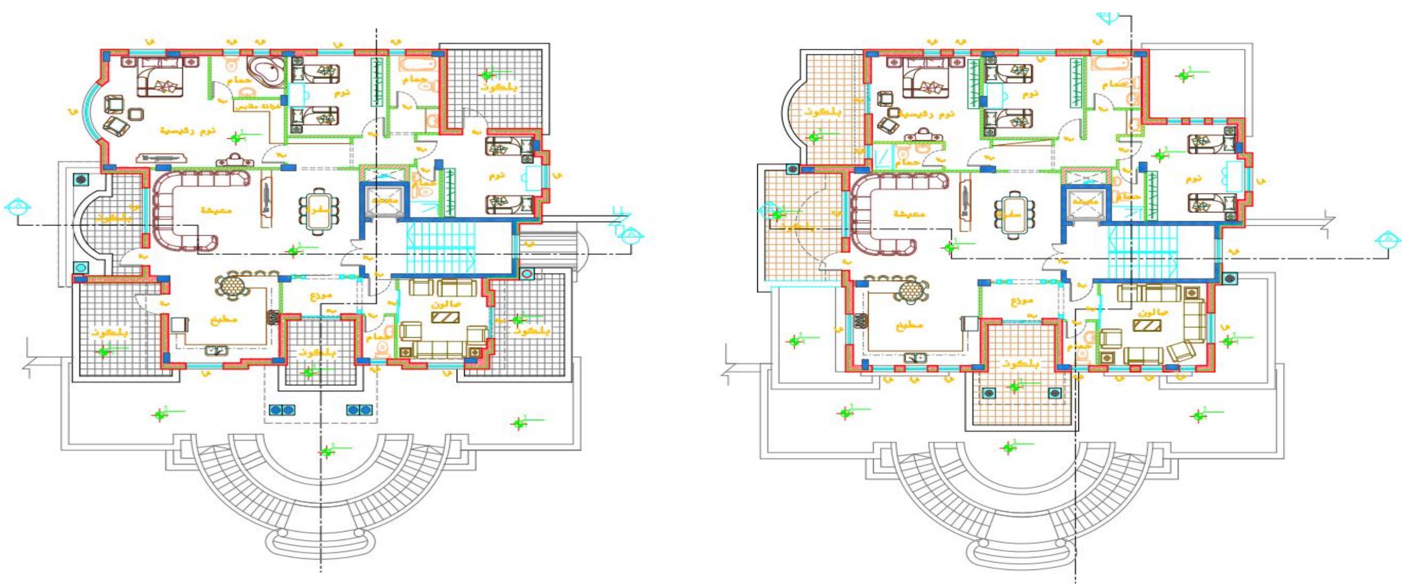


Figure (2- 5): Typical floor Plan

4. 3rd FLOOR (ROOF)

It's also inependent apartment with an area equivalent to 203 m^2. Accessed by stairs or elevator.

Roof floor consist of the following :

- Guest room
- Dining room
- Kitchen
- Living room
- Master bedroom
- Two bedrooms
- 3 bathrooms
- 2 Terrace

Figure (2-6) shows the plan of the Roof floor on which the entrances appear, in addition to the parts of the roof .

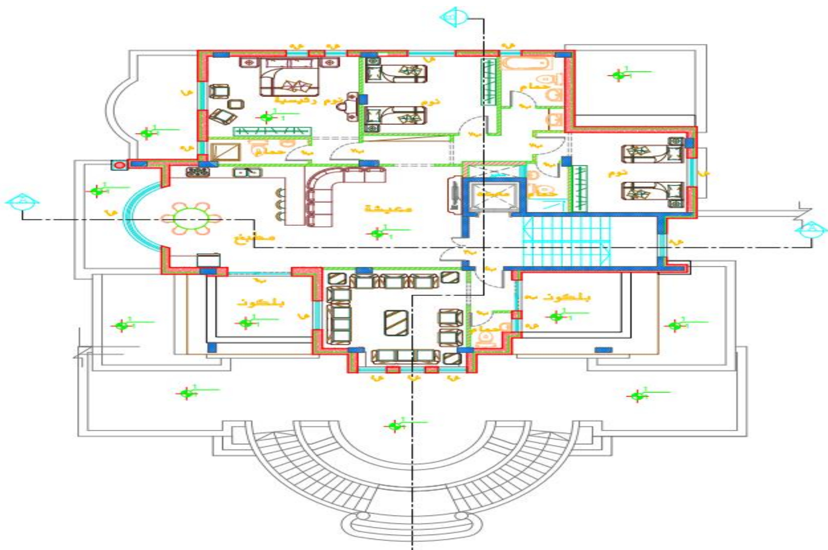


Figure (2- 6):Roof floor Plan

5. MOVEMENT AREAS

This building contains two stairs and one elevator, one of the stairs is the main stair and the other is for the ground floor only .The main stairs and elevator are located on the northeast side, the main staircase is also located in the middle of the building , while the semi-circular stair located ate the front of the villa at the main elevation .

2.5 Elevations Description

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

2.3.1 South East elevation

It's the main elevation contains the entrance to the basement and goround floor. This elevation contain stone coulomns ,it also shows the types of used stone , windows frames and decoration used in the elevation (2-7).

Figure (2- 7):south east elevation

2.3.2 South West elevation

As shown in figure (2-8), this elevation shows the level difference between the basement floor and the ground floor .It shows the circular staircase and shows the enterance that overlooks the garden for the ground floor .

Figure (2- 8):South West elevation

2.3.3 North East elevation:

In this elevation, the architectural beauty appears in the arrangement of openings and the use of different types of stone to distinguish the openings on one hand and to give a unique appearance to the building on the other hand. Furthermore, concrete columns cladded with stones appear in this elevation these columns serve the building structurally. They also add beauty to the building , and shows the traditional staircase reach to all floors.

Figure (2- 9):North East elevation

2.3.4 North west elevation:

This is the backside elevation of the building, it is characterized by its glass and prominent colored stones that give the aesthetic appearance and architectural beauty that reflects the luster of the building. As shown in figure (2-10) cladded concrete columns are appear here too.

Figure (2- 10): North west elevation

2.4 Sections of the building

These sections explain the movement inside the building through the stairs and elevator. It also shows more details for the heights and levels for slabs, windows, and doors. Figures (2-11) and (2-12) shows two sections of the building.

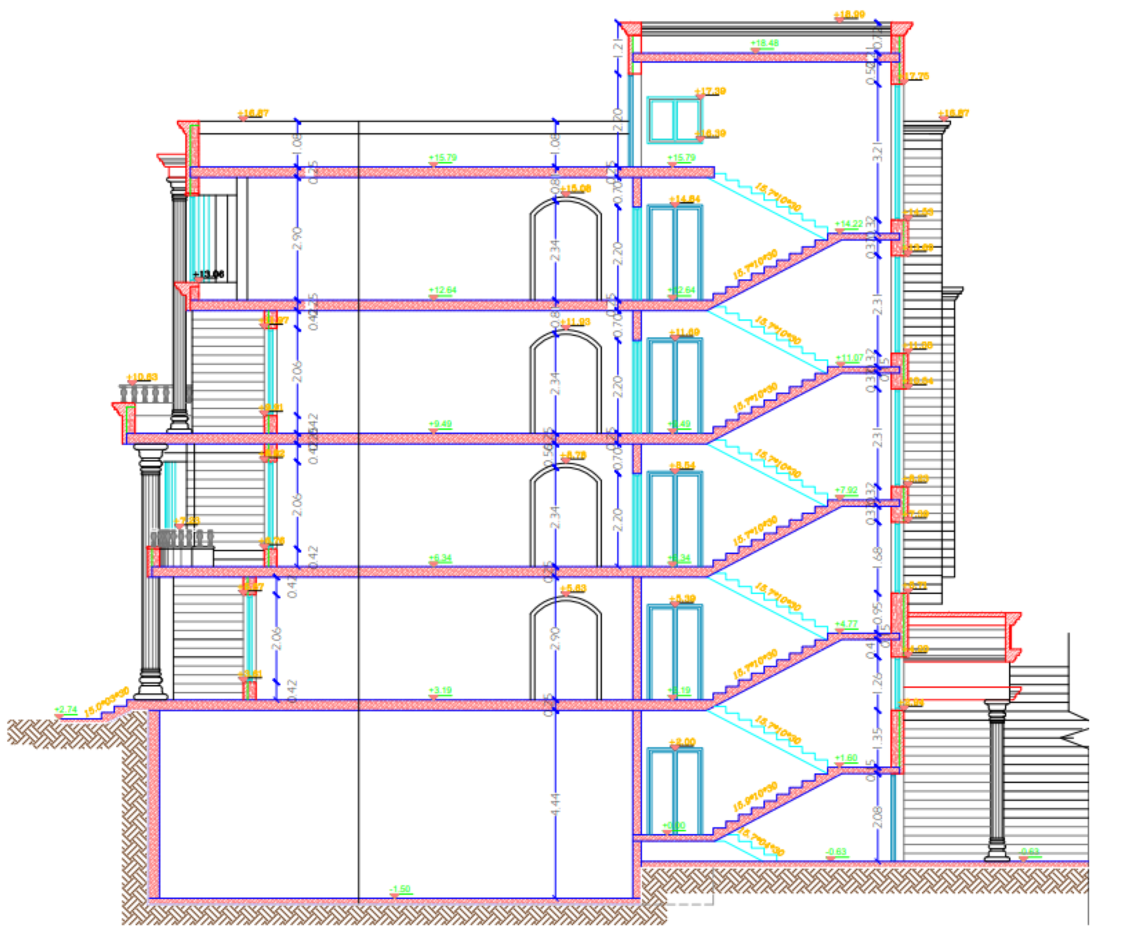


Figure (2- 11):Section A-A

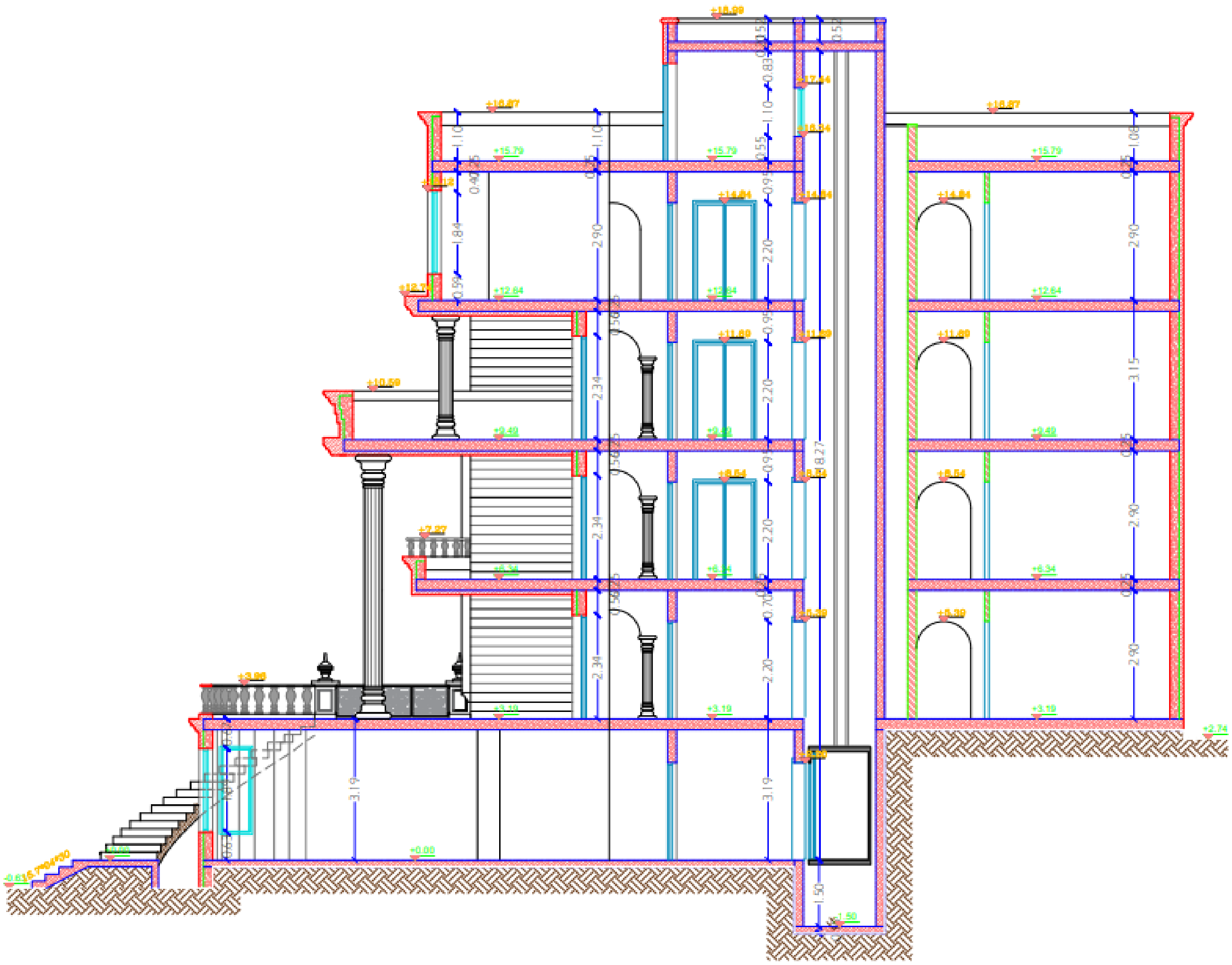


Figure (2- 12):Section B-B

CHAPTER 3

STRUCTURAL DESCRIPTION

3.1 Introduction

After completion of the architectural study of the building, A study of the structural elements was done to determine the optimal structural system for the building to make the best design of all structural elements.

The knowledge of structural elements of any project is essential in the design of reinforced concrete structures. In this chapter, a study of the different structural elements such as columns, bridges, foundations, and other elements was conducted. Also, different loads were estimated in accordance with the requirements, standards, and standard specifications that will be mentioned later.

3.2 The Aim of the Structural Design

The main purpose of structural design is to make a safe, economic, and serviceable design, so In designing a structure the following objectives must be taken into consideration :

1- **Safety**: The structure should be able to carry all expected loads safely, without failure, that is, without breaking or collapsing under the loads.

2- **Durability:** The structure should last for a reasonable period of time.

3- **Stability:** to prevent overturning, sliding, or buckling of the structure, or parts of it, under the
the action of loads.

4- **Strength:** to resist safely the stresses induced by the loads in the various structural members.

5- **Serviceability**: To ensure satisfactory performance under service load conditions - which implies providing adequate stiffness and reinforcements to contain deflections, crack-widths, and vibrations within acceptable limits, and also providing impermeability and durability (including corrosion-resistance), etc.

There are two other considerations that a sensible designer must bear in mind, economy and aesthetics. 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, and the end product, far from aesthetic.

3.3 Scientific Tests

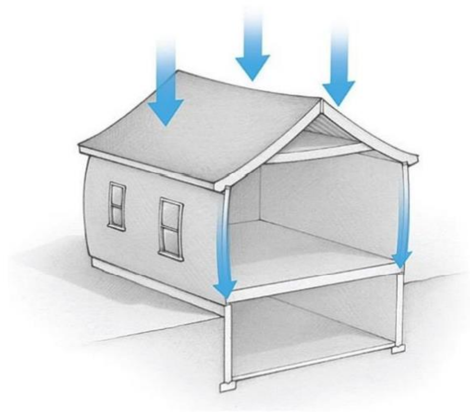
Before the structural study of any building, there is the work of geotechnical studies of the site, which means all work related to exploring the site and studying soil, rocks, and groundwater, then analyzing information and translating it to predict the way the soil behaves when building on it, and the most important thing is to obtaining soil durability (Bearing Capacity) required to design the building's foundations.

3.4 Loads Acting on the Building

Loads that acting on the building must be calculated and selected carefully because any error in identifying and calculating loads reflects negatively on the structural design of various structural elements. The building is exposed to loads of live and dead loads, wind loads, snow loads, and loads of earthquakes.

3.4.1 dead loads

Dead loads consist of the weight of all materials of construction incorporated into the building including but not limited to walls, floors, roofs, ceilings, stairways, built-in partitions, finishes, cladding and other similarly incorporated architectural and structural items, and fixed service equipment including the weight of cranes



Figure(3- 1): Dead Load

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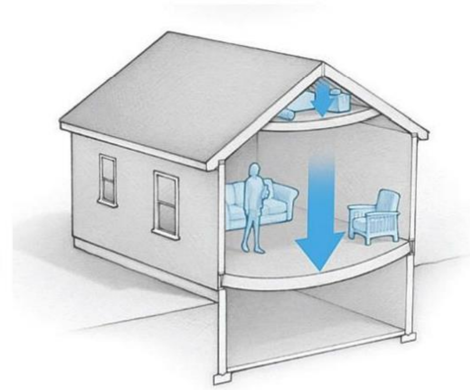
3.4.2 live load

Live loads are those loads produced by the use and occupancy of the building or other structure and do not include construction or environmental loads such as wind load, snow load, rain load, earthquake load, flood load, or dead load.



Figure(3- 2): Live Load

3.3.3 Environmental loads

It is the third type of load that must be taken into account in the design, and these loads are:

1. Wind Loads

They are horizontal forces that affect the building and their effect appears in tall buildings. They are the forces that the wind affects buildings, installations, or parts of, and they are positive if they are caused by pressure and negative if they are caused by tension, and are measured in kilotons per square meter (KN / m2). Wind loads are determined depending on the height of the building above the ground, and the location in terms of surrounding buildings, whether high or low.

Figure(3- 3):Wind Loads

2. Snow

Snow loads can be evaluated based on the following principles:

- Height of the facility above sea level.
- Slope of the roof exposed to snow.

The following table shows the value of snow loads according to the height above sea level, according to the Jordanian code

Figure(3- 4): Snow Loads

Table 3 - 1 The value of snow loads by height above sea level

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

3. SeismicLoads

One of the most important environmental loads that affect the building, which are horizontal and vertical forces that generate torque, and can be resisted by using shear walls designed with thicknesses and sufficient reinforcement to ensure the safety of the building when it is exposed to such loads that must be observed in the design process to reduce Risks and maintenance of the building's performance of its function during earthquakes.

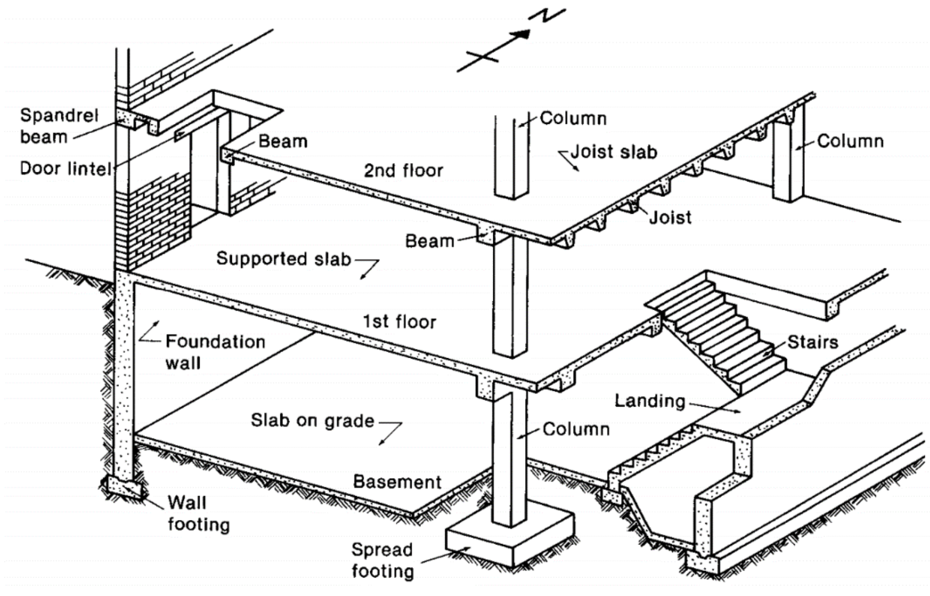
Figure(3- 5):Seismic Loads

4. Shrinkage and expansion loads

As a result of the contraction and expansion of the concrete elements of the building due to the variation in temperature during the seasons of the year, stresses have generated that lead to cracks in the building, where they are avoided and prevented from appearing using the phi 8 reinforcement mesh and also using expansion joints.

3.5 Structural Elements of the Building

All buildings usually consist of a set of structural elements that work together to maintain the continuity of the building and its suitability for human use, The most important of these slabs, beams, columns, and load-bearing walls, etc. are being defined.



Figure(3- 6):Structural elements of a typical RC structure

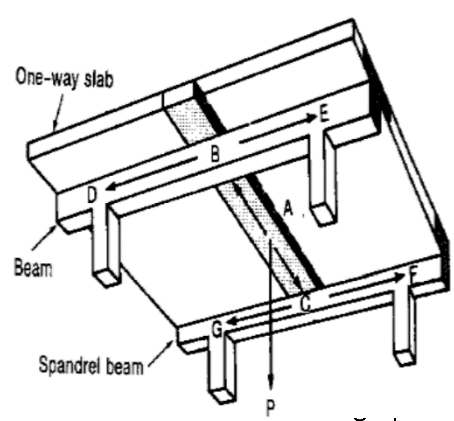
3.5.1 Slabs

Structural elements are capable of delivering vertical forces due to the loads affecting the building's load-bearing structural elements such as beams, columns, and walls, without distortions.

There are many different Structural systems of reinforced concrete slabs, including the following:

3.5.1.1 Solid slab (one or two way)

Solid Slabs are fully customizable concrete slabs of varying width, length, and thickness. They can be used in a variety of applications such as bridges, piers, and building floors. It



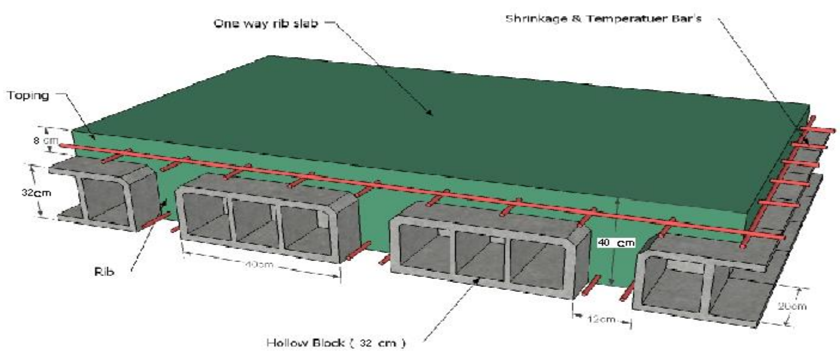
Figure(3- 7): Solid slab

is known that solid slabs should be supported by drop beams.

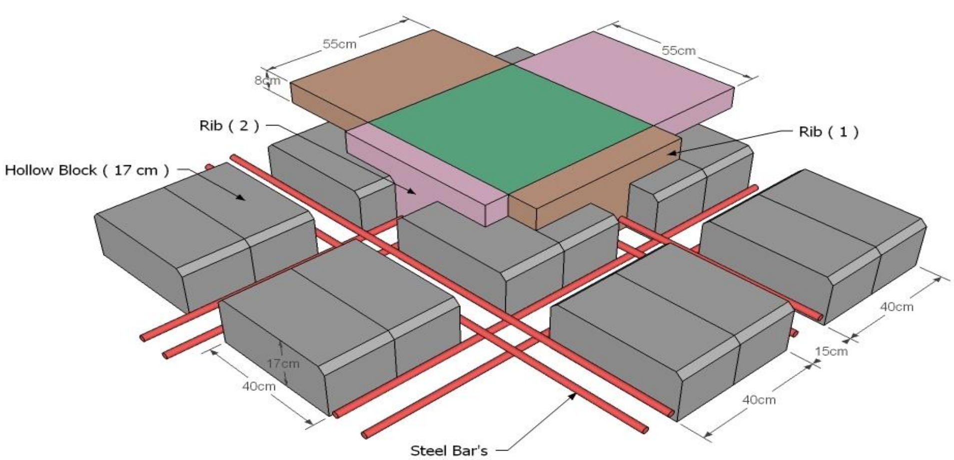
3.5.1.2 Ribbed slab (one or two way)

It’s the most common system used in Palestine. They are made up of wide band beams running between columns with narrow ribs spanning the orthogonal direction. Normally the ribs and the beams are the same depth. A thin topping slab completes the system. It can be designed to carry loads either in one direction only, or in two directions.

Figures (3-8),(3-9) describe one-way and two-way ribbed slabs respectively.



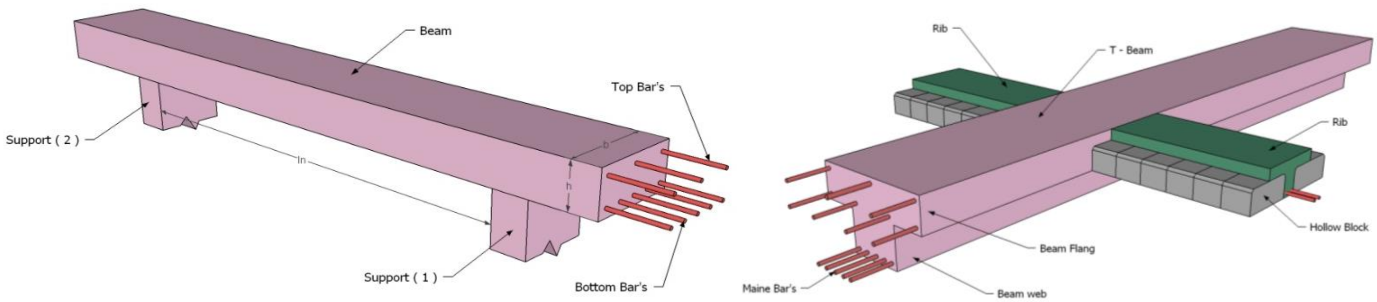
Figure(3- 8):One way ribbed slab.



Figure(3- 9):Two way ribbed slab

3.5.2 Beams

They are basic structural elements in transferring loads from slabs to the columns, and they are of two types, hidden inside the slab and Dropped Beams that emerge from the slab from the

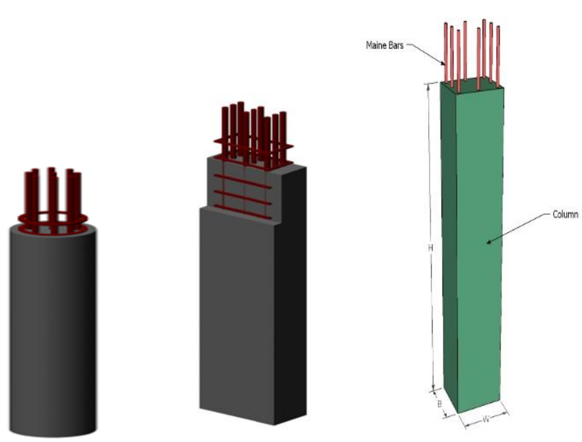


bottom.

Figure(3- 10):Beams

3.5.3 Columns

Columns are the main member in transporting loads from slabs and beams to foundations, and as such, they are a necessary structural component for conveying loads and building stability.



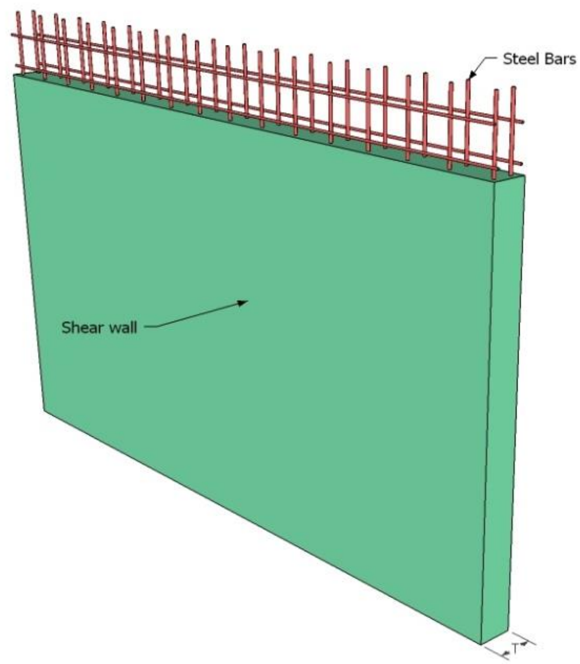
Figure(3- 11):Different types of Columns

Therefore, they must be designed to be able to carry and distribute the loads on them.

3.5.4 Shear walls

They are structural load-bearing elements that resist vertical and horizontal forces located on them and are mainly used to resist horizontal loads such as wind and earthquake forces.

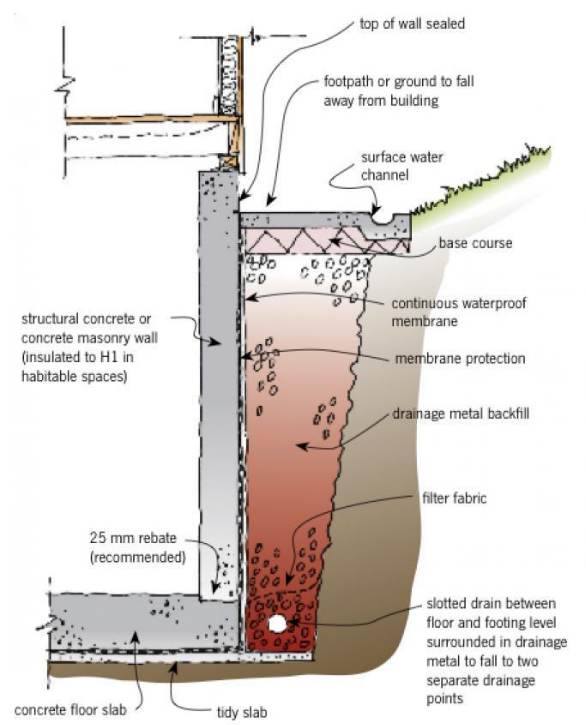
These walls are armed with two layers of steel to increase their efficiency to resist the horizontal forces. The two directions taking into consideration that the distance between the center of resistance formed by the shear walls in each direction and the center of gravity of the building is minimal. And that these walls are sufficient to prevent or reduce the generation of torque waves and their effects on the walls of the building resisting horizontal forces.



Figure(3- 12):Shear wall

3.5.7 Basement walls

A basement wall is a wall that is used on the floor and ceiling to provide support to the side walls as well as to the structure. It handles the pressure of the sidewalls and provides space for living inside the walls. Basement walls bear the load of the whole structure.



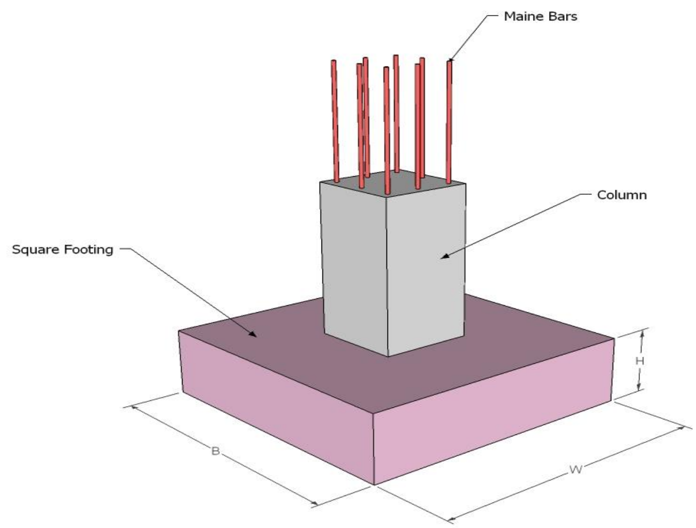
Figure(3- 13): Basemet Wall

3.5.5 Foundations

Although the foundations are the first to start with the construction of the structure, their design takes place after the completion of the design of all structural elements in the building.

Loads act on foundations came from the loads on the slabs which transferred to the beams, then to columns, and finally to foundations. and these loads are the design loads for the foundations.

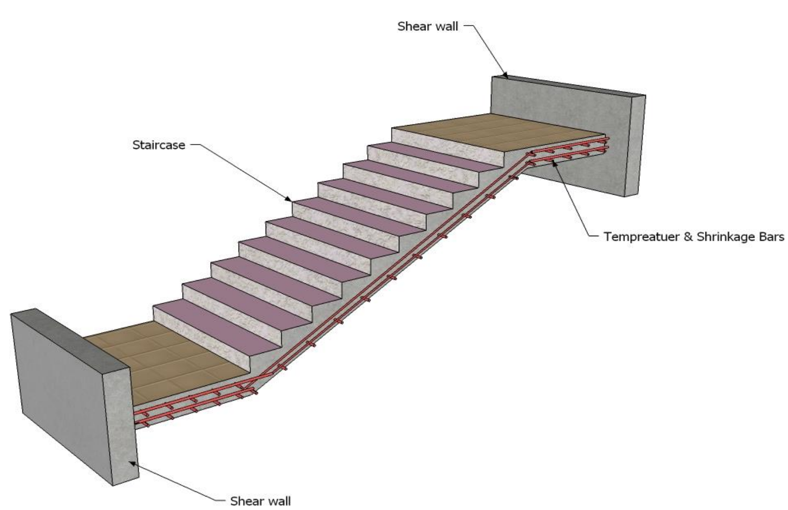
There a many types of foundations that can be used in each project it depends on the type of loads and the nature of the soi in the site.



Figure(3- 14): Isolated Footing

3.5.6 Stairs

Stairs must be provided in almost all buildings. It consists of rises, runs, and landings. The total steps and landings are called a staircase



Figure(3- 15): General Section of stairs

There are different types of stairs, which depend mainly on the type and function of the building and the architectural requirements.

CHAPTER 4

STRUCTURAL ANALYSIS AND DESIGN

4.1. Introduction
4.2. Determination of slab thickness
4.3. Design of one-way ribbed slab
4.4. Design of Beam B3
4.5. Design of Column C11
4.6. Design of Shear Wall
4.7. Design of Basement Wall
4.8. Design of Basement Footing
4.9. Design of Isolated Footing F3
4.10. Design of Stairs

4.1. Introduction

After finishing the structural planning of the building, in which the location of columns and beams was determined. A complete design for all elements was done for flexure, shear, and deflection.

In this chapter, the analysis and design procedure for a sample of each structural element in the building are explained in detail.

The following General considerations are taken throughout the analysis and design processes of this project:

1. All members were designed according to ACI 318-14 Building code.
2. Gravity loads were estimated using the Jordanian code.
3. (ASCE7-16) is used for the definition of lateral seismic loads.
4. The ultimate strength design method is used during the analysis and design of this project.
5. Working Stress Method is used for soil design.
6. The compressive strength of concrete for all elements is B300 which equals to Fc′ = 24 MPa.
7. Yield strength of reinforcing rebars Fy = 420 MPa .

4.2. Determination of slab thickness

The thickness of the one-way ribbed slab is obtained according to the ACI code to achieve deflection requirements. The following table summarizes the determination of thickness for ribs that gives maximum values:

Table(4- 1): Determination of thickness for ribs from maximum values of cases

Supporting type	min. h equation	Rib	Span	min. h (cm)
Simply Supported	L/16	6	1	$= \frac{430}{16} = 26.87$
One end continues	L/18.5	2	1	$= \frac{530}{18.5} = 28.6$
Both ends continuous	L/21	9	2	$= \frac{570}{21} = 27.1$

Since the previous are approximate equations for determination the thickness of a slab ,it will be selected (28cm) and deflection will be checked later.

∴ **Select slab thickness = 28cm with 20cm block & 8cm topping.**

The following figure shows a typical section in a 32cm thick one-way ribbed slab.

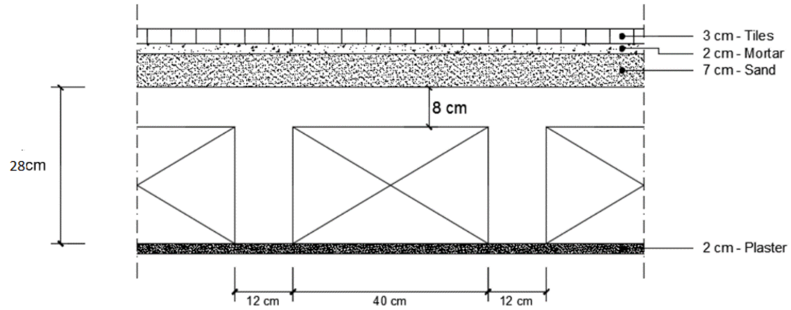


Figure (4- 1) :Typical section of one-way ribbed slab

4.3. Design of one-way ribbed slab

One way ribbed slab Design procedure is explained in the following steps :

4.3.1. Design of topping

Topping in One way ribbed slab can be considered as a strip of 1-meter width and span of hollow block length with both ends fixed in the ribs.

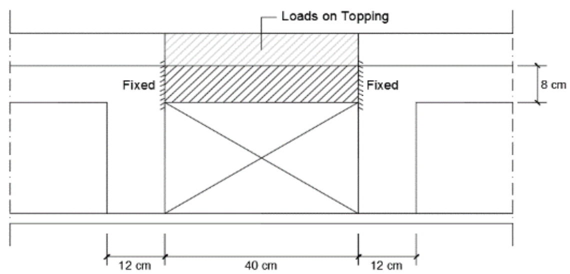


Figure (4- 2):System of topping

4.3.1.1. Calculation of Loads on Topping

Dead loads that act on Topping can be calculated as shown in the following table :

→ Dead Load For 1m strip:

Table(4- 2): Dead Load Calculation for topping

Material	Quality Density (kN/m^3)	Calculation	Dead Load (kN/m)
Tiles	23	= 0.03×23×1	0.69
Mortar	22	= 0.02×22×1	0.44
Sand	16	= 0.07×16×1	1.12
Topping	25	= 0.08×25×1	2
Partitions		= 2.3×1	2.3
∴ Dead Load for 1m strip of topping = 6.55 kN/m			

→ Live Load For 1m strip = **2.0 × 1 = 2.0 kN/m**

→ Factored load (W_u) = 1.2 ×D.L + 1.6 ×L.L = 1.2 * 6.55 + 1.6 * 2.0 = **11.06 kN/m.**

4.3.1.2. Analysis of topping

- $Vu = \frac{W_u \times L}{2} = \frac{11.06 \times 0.4}{2} =$ **2.21 kN**
- $Mu = \frac{W_u \times L^2}{12} = \frac{11.06 \times 0.4^2}{12} =$ **0.147 kN.m**

W_u = 11.06 kN/m

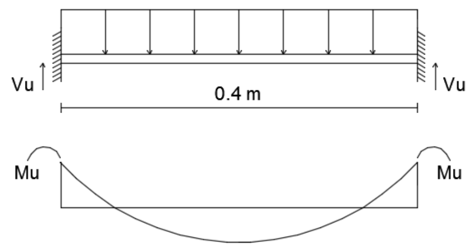


Figure (4- 3):System and analysis of topping

4.3.1.3. Design Strength of topping

→ **Shear Design Strength :**

For Plain concrete section one way shear is calculated using the following equation:

$\Phi . Vc = \Phi \times 0.11 \times \lambda \times \sqrt{Fc'} \times bw \times h$

$\Phi . Vc = 0.6 \times 0.11 \times 1 \times \sqrt{24'} \times 1000 \times 80 =$ **25.87 kN > Vu → SAFE**

→ **Moment Design Strength :**

For Plain concrete section with "b = 1 m & h = 8 cm"

$\Phi . Mn = 0.6 \times 0.42 \times \sqrt{Fc'} \times \frac{b\,h^2}{6}$

$\Phi . Mn = 0.6 \times 0.42 \times \sqrt{24'} \times \frac{1000 \times 80^2}{6} =$ **1.32 kN.m > Mu → SAFE**

∴ **Plain Concrete Section is SAFE #**

But According to ACI , As_{min} shall be provided for slabs as shrinkage and temperature reinforcement.

$\rho_{shrinkage}$ = 0.0018 According to ACI

Minimum (As) = $\rho_{shrinkage} \times Ag$

= 0.0018 × b × h
= 0.0018 × 100 * 8
= 1.44 cm^2/m

Step (s) is the smallest of :
1. 3h = 3×80 =**240 mm** « **controlled**
2. 450 mm.
3. $S = 380(\frac{280}{fs}) - 2.5Cc = 380\left(\frac{280}{\frac{2}{3}*420}\right) - 2.5*20 = 330mm$

But $S \leq 300(\frac{280}{fs}) = 300\ (\frac{280}{\frac{2}{3}*420}) = 300mm$

Take S=200mm < Smax=240mm

∴ **Select Mesh Ø8/20cm in both directions.**

Provided As = $(\pi\times8^2/4)*(100/20) = 2.5\ cm^2/m > min\ As = 1.44\ cm^2/m$

4.3.2. Design of Rib (R2)

Rib(R2)is selected to be designed ,the following figure shows its location in basement floor slab

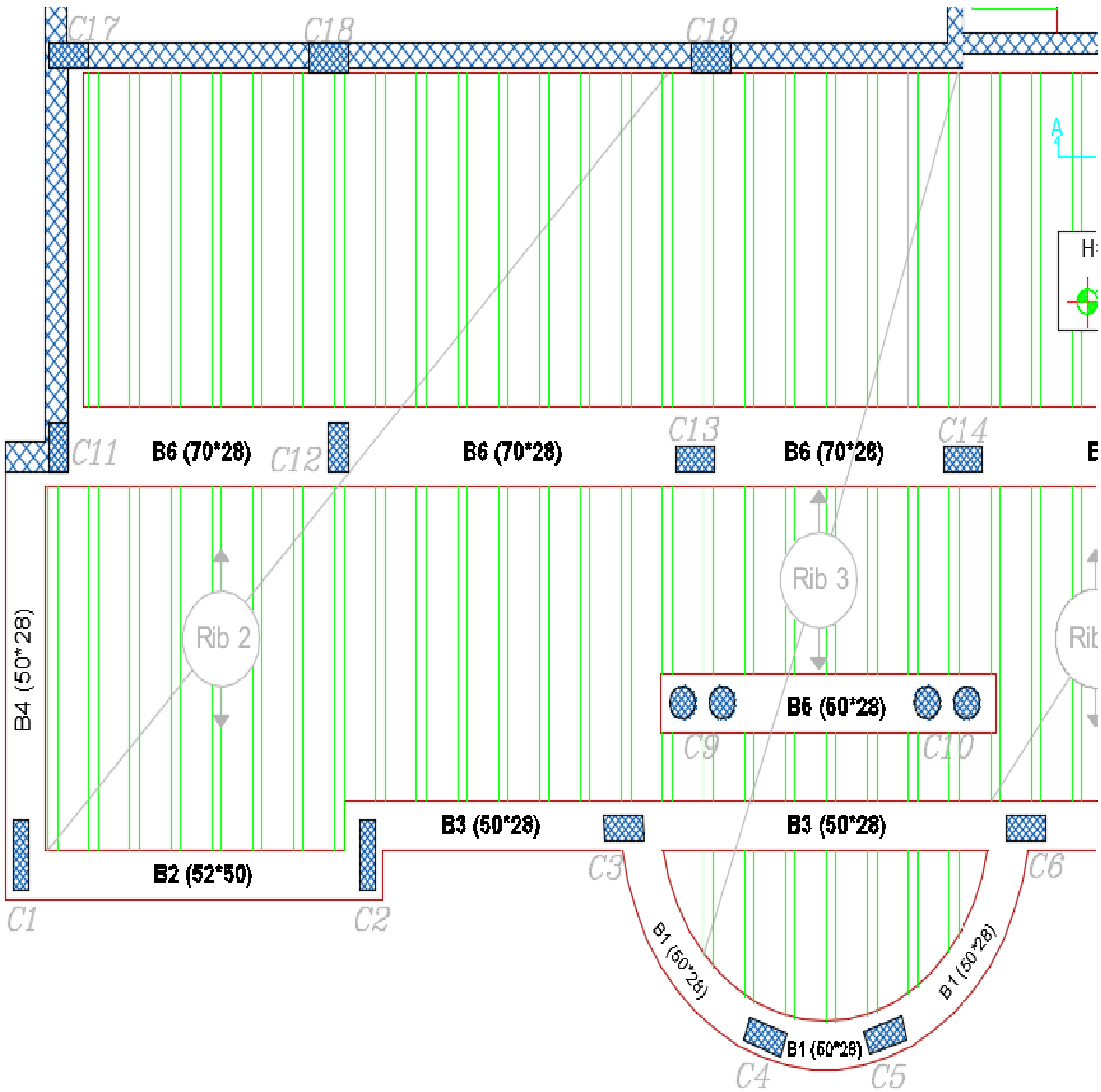


Figure (4- 4):Rib (R2) Location in Ground Floor Slab

4.3.2.1. Rib geometry

Requirements for Ribbed Slab (T-Beam Consideration According to ACI) are as follows :

- $bw \geq 10cm \rightarrow$ **select bw = 12 cm**
- $h \leq 3.5\,bw = 3.5 \times 12 = 42cm \rightarrow$ **select h =28 cm**
- $tf \geq \frac{Ln}{12} \geq 50\ mm \rightarrow$ **select tf = 8cm**

4.3.2.2. Loads Calculation for Rib (R2)

For the one-way ribbed slabs, the total dead load to be used in the analysis and design is calculated as sown in the following table :

→ **Dead loads :**

Table(4- 3):3 Dead Load Calculation for rib (R17)

Material	Quality Density (kN/m^3)	Calculation	Dead Load (kN/m/Rib)
Tiles	23	= 0.03×23×0.52	0.359
Mortar	22	= 0.02×22×0.52	0.229
Sand	16	= 0.07×16×0.52	0.582
Topping	25	= 0.08×25×0.52	1.040
Block	12	= 0.20×12×0.40	0.960
Rib	25	= 0.24 ×25×0.12	0.720
Plaster	22	= 0.02×22×0.52	0.229
Partitions		= 2.3×0.52	1.196
∴ Dead Load =5.315 kN/m/Rib			

→ **Live loads** = 2.0 × 0.52 = **1.04 kN/m/rib**

→ **Factored Load (W_u)** = 1.2×D.L + 1.6×L.L

WuD = 1.2× 5.315 = **6.38 kN/m/rib**

WuL = 1.6*1.04 = **1.66 kN/m/rib**

4.3.2.3. Analysis

Figure (4-5)& (4-6) shows the shear and Moment envelope of the rib (R2) obtained from Atir

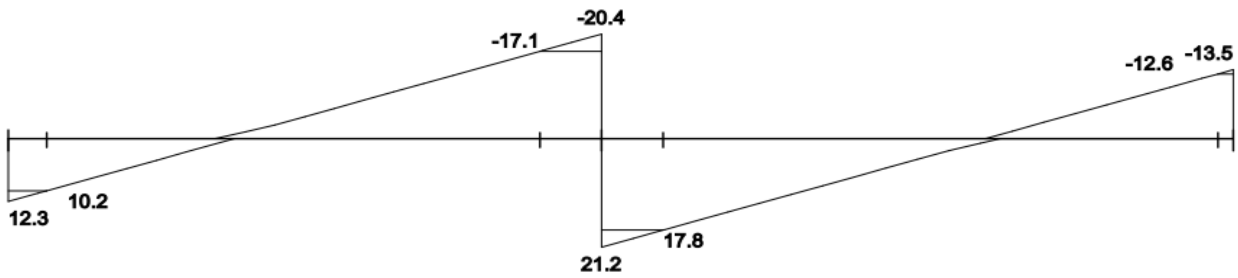


Figure (4- 5):Shear envelope of rib (R2) – [kN]

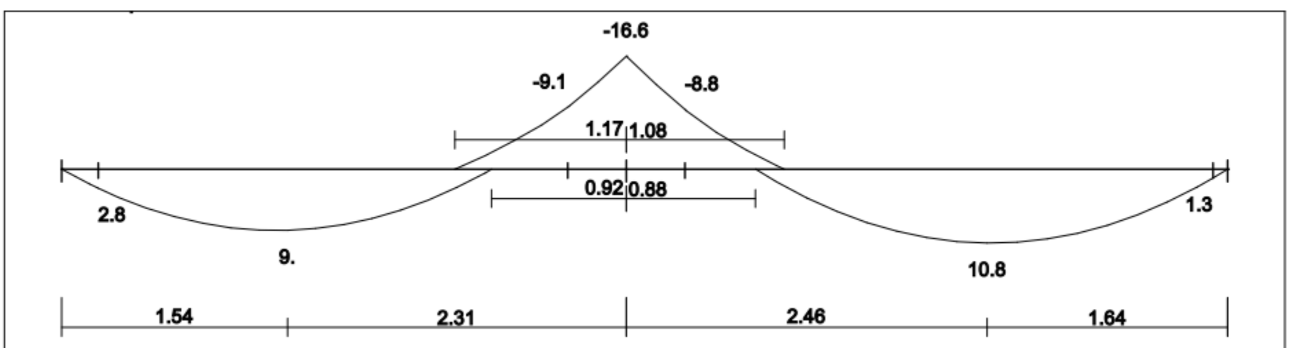


Figure (4- 6): Moment envelope of rib (R2) – [kN.m]

4.3.2.4. Design of Rib for Shear

Shear strength Vc , provided by concrete for the ribs may be taken greater than that for beams. This is mainly due to the interaction between the slab and the closely spaced ribs.

Max. Vu at the critical section at distance d from the face of support is obtained from figure (4-5) , where Vu = 17.8 kN

If $\frac{1}{2}$ Ø.Vc < Vu ≤ Ø.Vc …. No shear Reinforcement is required for slabs .

$$\rightarrow \varnothing .Vc = \varnothing * 1.1 * \frac{1}{6} * \sqrt{Fc'} * bw * d$$

$$= 1.1 * 0.75 * \frac{1}{6} * \sqrt{24} * 120 * 244 * 10^{-3}$$

$$= \mathbf{19.72\ kN}$$

Ø.Vc=**19.72 kN** > Vu max = 17.8 kN … No shear Reinforcement is required .

∴ **Select Ø8/30cm as montage for construction requirements .**

4.3.2.5. Design Rib for Flexure

4.3.2.5.1. Design of Positive Moment – Bottom Reinforcement

Check for chosen effective flange width (***be***) :

According to (ACI 318-14) (be) is the smallest of:
- be ≤ Span/4 ≤ (410/4) = 102.5 cm
- be ≤ 16*hf + bw = 16*8 + 12 = 140 cm
- be ≤ bw + ½ Lc = 12 + ½ * 40 + ½ * 40 = **52 cm** « **Cont.**

⇒ **Design of span 1 - Max Mu^+ = 9 kN.m**

$$d = h - cover - d\ stirrups - \frac{db}{2} = 280 - 20 - 10 - \frac{12}{2} = 244mm$$

1. **Check if (a ≤ t) or (a > t)**

   Assume a=t=8cm

   Ø * Mn = Ø * C or T * (d – ½*t)

   C = (0.85 * Fc' * t * bE)

   Ø * Mn = Ø * C or T * (d – ½*t)

   $= 0.9 * 0.85 * 24 * 80 * 520 * (244 - \frac{80}{2}) *10^{-6}$

   = **155.81 kN.m** > Mu^+ = 9 kN.m

   ∴ **a < t → Compression zone is in the flange**

2. **Design as Rectangular Section with b=be**

   → $m = \frac{Fy}{0.85*Fc'} = \frac{420}{0.85*24} = 20.59$

   → $Rn = \frac{Mu/Ø}{b*d^2} = \frac{9*10^6/0.9}{520*244^2} = 0.323$ MPa

   → $\rho = \frac{1}{m} * (1- \sqrt{1 - \frac{2*Rn*m}{Fy}}) = \frac{1}{20.59} * (1- \sqrt{1 - \frac{2*0.654*20.59}{420}}) = 0.000775$

   → $Asreq = \rho * b * d = 0.000775 * 520 * 244 = 98.36\ mm^2$

3. **Check As min :**

As (min) = $0.25 * \frac{\sqrt{Fc'}}{Fy} * bw * d = 0.25 * \frac{\sqrt{24}}{420} * 120 * 244 = 85.38\ mm^2$

Or

As (min) = $\frac{1.4}{Fy} * bw * d = \frac{1.4}{420} * 120 * 244 =$ **97.6 mm²** « **Controlled**

∴ **Use 2Ø10 with As = 158 mm² > Asreq =98.36 mm²**

4. **Check Strain :**

C=T

0.85*Fc'*a*b=As *Fy

0.85 * 24 * a * 520 = 158* 420

a=6.25 mm ⇒ X = a / β = 6.25 / 0.85 = 7.35 mm

$$\varepsilon_s = 0.003\left(\frac{d-c}{c}\right) = 0.003\left(\frac{244 - 7.35}{7.35}\right) = 0.097 > 0.005 \qquad \mathbf{0k}$$

⇒ Design of span 2 - Max Mu+ = 10.8 kN.m

1. **Check if (a ≤ t) or (a > t)**

Assume a=t=8cm

Ø * Mn = **155.81 kN.m** > Mu^+ = **10.8** kN.m

∴ **a < t → Compression zone is in the flange**

2. **Design as Rectangular Section with b=be**

→ $Rn = \frac{10.8*10^6/0.9}{520*244^2} = 0.387$ MPa

→ $\rho = \frac{1}{20.59} * (1-\sqrt{1-\frac{2*0.387*20.59}{420}}) = 0.000932$

→ Asreq = $0.000932 * 520 * 244 = 118.2\ mm^2$

∴ **Use 2Ø10 with As = 158 mm² > Asreq =118.2 mm²**

3. Check Strain :

C=T

0.85*Fc'*a*b=As *Fy

0.85 * 24 * a * 520 = 158* 420

a=6.25 mm ⇒ X = a / β = 6.25 / 0.85 = 7.35 mm

$$\varepsilon_s = 0.003\left(\frac{d-c}{c}\right) = 0.003\left(\frac{244\ -7.35}{7.35}\right) = 0.097 > 0.005 \qquad \mathbf{0}\boldsymbol{k}$$

4.3.2.5.2. Design of Negative Moment – Top Reinforcement (at support B)

Max Mu^- = -9.1 kN.m
(Compression zone in web ⇒ design as rectangular RC section)

→ rn = $\frac{9.1*10^6/0.9}{120*244^2}$ = 1.41 MPa

→ $\rho = \frac{1}{20.59} * (1- \sqrt{1-\frac{2*1.41*20.59}{420}}) =$ 0.00395

→ Asreq = $\rho * b * d = 0.00395 * 120 * 244 = 102.3$ mm^2

∴ **Select 2Ø10 with As = 158 mm2 > As min = 97.6 mm^2**

→ **Check Strain :**
C=T
0.85*Fc'*a*b=As *Fy
0.85 * 24 * a * 520 = 158* 420
a=6.25 mm ⇒ X = a / β = 6.25 / 0.85 = 7.35 mm

$$\varepsilon_s = 0.003\left(\frac{d-c}{c}\right) = 0.003\left(\frac{244\ -7.35}{7.35}\right) = 0.097 > 0.005 \qquad \mathbf{0}\boldsymbol{k}$$

4.3.2.6. Check Deflection

The value of Deflection should not exceed Δlimit, Which according to ACI Code $= \frac{L}{240}$. The following Table shows values of Δlimit compared with deflection calculated by Atir software .

Table(4- 4):Deflection Check for rib (R17)

Span No.	Span Length (mm)	Δlimit (mm)	ΔCalculated (mm)	Check
Span 1	3850	3850/240 =16.1	3850/320 =12.1	ΔCalculated < Δlimit (OK)
Span 2	4100	4100/240 =17.1	410/4081 =1.00	

4.4. Design of Beam B3

Beam (B3) is selected to be designed , the following figure shows its location in ground floor slab:

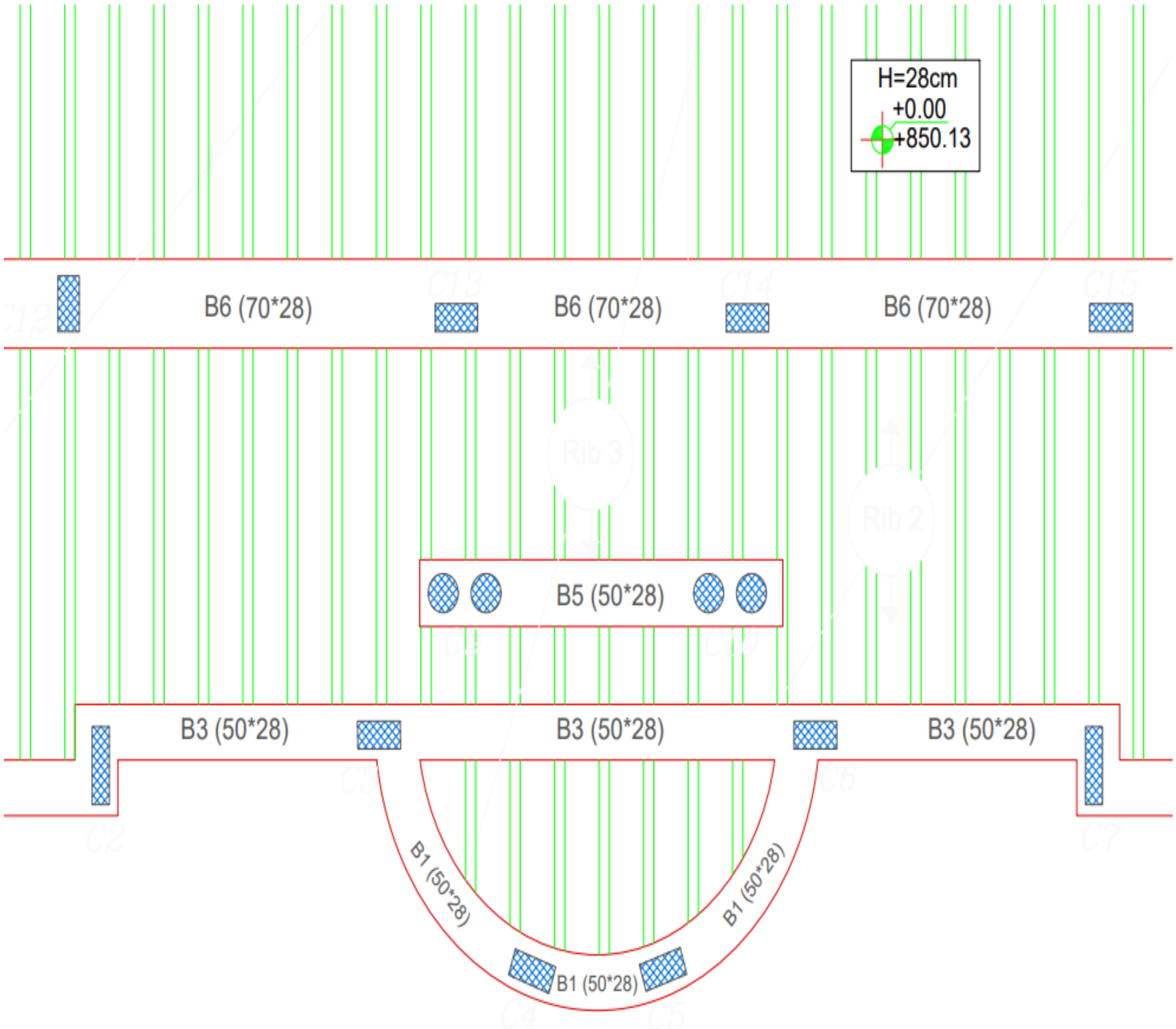


Figure (4- 7):Beam (B3) Location In basement Floor Slab

4.4.1. Load Calculation for beam

The following figure shows the geometry of beam and loads that act on it :

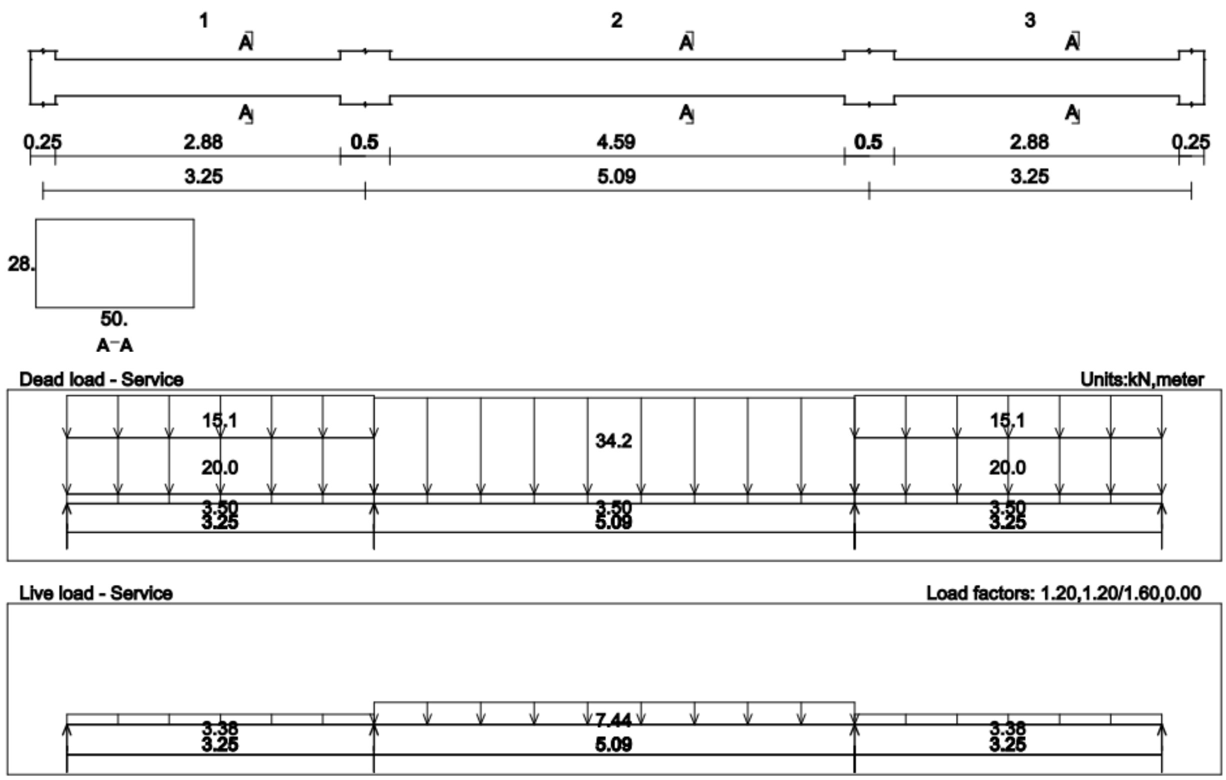


Figure (4- 8) : Beam B3 Geometry and loads

Calculation of Loads that acts on beam B3 :

1. Own weight of the beam :
   Own wt. = 25*0.28*0.50 = **3.5 kN/m**

2. Reactions of ribs that acting on it .
   The following table shows calculation of loads that act on B30 from ribs .

Table(4- 5):Loads on B3 from ribs

	Rib(R2)	Rib(R3)	Rib (R2)
quD(kN/m)	7.87/0.52=15.1	17.83/0.52 = 34.3	7.87/0.52 = 15.1
quL (kN/m)	1.76/0.52 = 3.4	3.87/0.52=7.44	1.76/0.52 = 3.4

4.4.2. Design of beam B3 for Flexure

The following figure shows moment envelope resulted from analysis of beam (B3) using Atir 2018 Software :

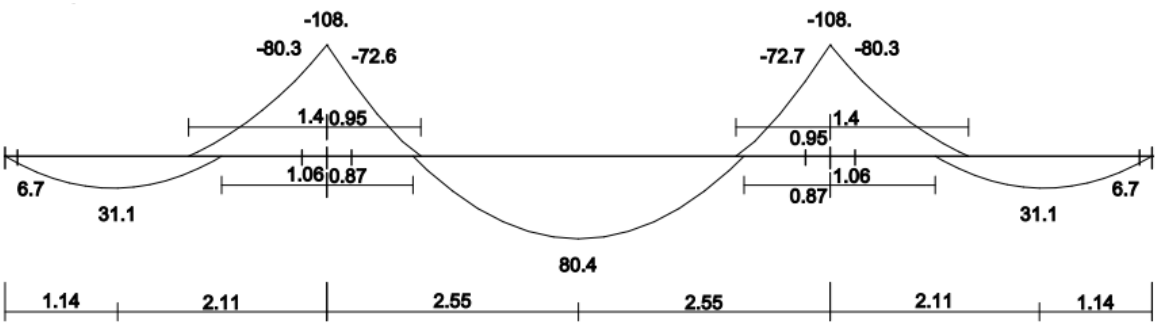


Figure (4- 9):Moment Envelope of beam (B3) – [kN.m]

4.4.3.1 Design of Negative Moment – Top Reinforcement

⇒ **Design of negative moment Mu- = -80.3 kN.m @ support (3)**

1. Check whether the section will be act as singly or doubly reinforced section :

Maximum nominal moment strength from strain condition $\varepsilon_s = 0.004$.

$\boldsymbol{d}$ = 280 – 40 -10 - 20/2 = 220 $\boldsymbol{mm}$

→ Mn req = $\frac{\text{Mu}}{\emptyset}$, Take ∅ = 0.9 for flexure as tension-controlled section.

→ Mn req = $\frac{80.3}{0.9}$ = 89.22 kN.m

→ m = $\frac{Fy}{0.85*Fc'} = \frac{420}{0.85*24}$ =20.59

→ Rn = $\frac{\text{Mn req}}{\text{b}*\text{d}^2} = \frac{89.22}{500*220^2}$ = 3.68 Mpa

$\rightarrow$ $\rho req = \frac{1}{m} * (1- \sqrt{1-\frac{2*Rn*m}{Fy}}) = \frac{1}{20.59} * (1- \sqrt{1-\frac{2*4.23*20.59}{420}}) = 0.0097$

But $\rho max = 0.85 * \frac{Fc'}{Fy} * \beta 1 * \frac{3}{7} = 0.85 * \frac{24}{420} * 0.85 * \frac{3}{7} = 0.01769$

$\therefore$ $\rho req < \rho max$ **...** Design the section as singly reinforced concrete section.

2. **Design the section as singly reinforced concrete section :**
   Assume rectangular & tension control section.
   $\rightarrow$ Asreq = $0.0097 * 500 * 220 = 1067$ mm^2
   $\therefore$ **Select 6Ø16 with As = 1200.6 mm^2 .**

3. **Check As min :**
   As (min) = 0.25 * $\frac{\sqrt{Fc'}}{Fy}$ * bw * d = 0.25 * $\frac{\sqrt{24}}{420}$ * 500 * 220 =320.7 mm^2
   Not less than :
   As (min) = $\frac{1.4}{Fy}$ * bw * d = $\frac{1.4}{420}$ * 500 * 220 = **366.67 mm^2** « **Controlled**
   As = 1200.6 mm^2> Asmin =366.67 mm^2 ... (OK)

4. **Check Strain for Ø and Asmax**
   C=T
   0.85*Fc'*a*b=As *Fy
   0.85 * 24 * a *500 = 1200.6* 420
   a=49.4 mm
   X = a / β = 62 / 0.85 = 58.16 mm
   $\varepsilon_s = \frac{0.003d}{x} - 0.003 = \frac{0.003*220}{58.16} - 0.003 = 0.00835$

   $\therefore$ $\varepsilon_s = 0.00835 > 0.005$ then Ø = 0.9 ... (OK)
   also, $\varepsilon_s = 0.00835 > 0.004$ then As < Asmax ... (OK)

5. **Check for spacing**
   S= $\frac{500-2(40)-2(10)-6(16)}{5}$ = 60.08 mm >25 mm ... (OK)
   > db=16mm ... (OK)

⇒ Design of negative moment Mu- = -80.3 kN.m @ support (2)

Since Mu =80.3 kN.m = Mu @ support 3 ,which was designed as singly reinforced section , then also this section must be designed as singly reinforced concrete section.

→ Mn req=80.3/0.9 =89.2 kN.m

→ m = 20.59

→ Rn $= \frac{\mathbf{89.22}*10^6}{500*220^2}$ = 3.86 MPa

→ $\rho = \frac{1}{20.59} * (1- \sqrt{1 - \frac{2*3.86*20.59}{420}}) = 0.0097$

→ Asreq = $\rho * b * d = 0.00678 * 500 * 220 = 1067$mm^2

∴ **Select 6 Ø16 with As = 1200.6 mm^2**

→ As = 1200.6 mm^2> Asmin =366.67 mm² … (OK)

→ **Check Strain for Ø and Asmax**

C=T

0.85 * 24 * a *500 = 1200.6* 420

a=49.4 mm , X = 37.2 / 0.85 = 58.16 mm

$\varepsilon_s = \frac{0.003*220}{58.16} - 0.003 = 0.00835$

∴ $\varepsilon_s = 0.00835 > 0.005$ *then* Ø = 0.9 … (OK)

also, $\varepsilon_s = 0.00835 > 0.004$ then As < Asmax ... (OK)

→ **Check for spacing:**

S= $\frac{500-2(40)-2(10)-6(16)}{5}$ = 60.08 mm >25 mm … (OK)

> db=16mm … (OK)

4.4.3.2 Design of Positive Moment – Bottom Reinforcement

⇒**Design of span 1 - Max Mu+ = 31.1 kN.m**

Since max Mu in this span < max Mu @ support 3 ,which was designed as singly reinforced section , then also this section must be designed as singly reinforced concrete section.

→ Mn req=31.1 /0.9 =34.55 kN.m

→ m = 20.59

→ Rn $= \frac{34.55*10^6}{500*220^2}$ = 1.42MPa

→ $\rho req = \frac{1}{20.59} * (1- \sqrt{1 - \frac{2*1.42*20.59}{420}}) = 0.00351$

→ Asreq = $0.00351 * 500 * 220 = 385.8$ mm^2

∴ **Select 4Ø12 with As = 452 mm^2**

→ As =452 mm^2> Asmin =366.67 mm^2 … (OK)

→ **Check Strain for Ø and Asmax :**

C=T

0.85 * 24 * a *500 = 452* 420

a=18.61 mm , X = 18.61 / 0.85 =21.9 mm

$\varepsilon_s = \frac{0.003*220}{21.9} - 0.003 = 0.027$

∴ $\varepsilon_s = 0.027 > 0.005$ *then* Ø = 0.9 … (OK)

also, $\varepsilon_s = 0.027 > 0.004$ then As < Asmax ... (OK)

→ **Check for spacing:**

S= $\frac{500-2(40)-2(10)-4(12)}{3}$ = 117.33 mm >25 mm … (OK)

> db=12mm … (OK)

⇒ Design of span 2 - Max Mu+ = 80.4 kN.m

Since max Mu in this span = max Mu @ support 3 ,which was designed as singly reinforced section , then also this section must be designed as singly reinforced concrete section.

→ Mn req=80.4 /0.9 =89.33 kN.m

→ m = 20.59

→ kn = $\frac{89.33*10^6}{500*220^2}$ = 3.69MPa

→ $\rho req = \frac{1}{20.59} * (1- \sqrt{1 - \frac{2*3.69*20.59}{420}}) = 0.00977$

→ Asreq = $0.00977 * 500 * 220 = 1074.9$ mm^2

∴ **Select 6Ø16, with As=1200.6 mm^2.**

→ As =1200.6 mm^2> Asmin =366.67 mm^2 … (OK)

→ **Check Strain for Ø and Asmax :**

C=T

0.85 * 24 * a *500 = 1200.6* 420

a=49.43 mm , X = 49.43 / 0.85 =58.16 mm

$\varepsilon_s = \frac{0.003*220}{58.16} - 0.003 = 0.00835$

$\therefore\ \varepsilon_s = 0.00835 > 0.005$ *then* Ø = 0.9 … (OK)

also, $\varepsilon_s = 0.00835 > 0.004$ then As < Asmax ... (OK)

→ **Check for spacing:**

S= $\frac{500-2(40)-2(10)-6(16)}{5}$ = 60.08 mm >25 mm … (OK)

> db=16mm … (OK)

Design of span 3 - Max Mu+ = 31.1 kN.m

Since max Mu in this span < max Mu @ support 3 ,which was designed as singly reinforced section , then also this section must be designed as singly reinforced concrete section.

→ Mn req=31.1 /0.9 =34.55 kN.m

→ m = 20.59

→ kn = $\frac{34.55*10^6}{500*220^2}$ = 1.42 MPa

→ $\rho req = \frac{1}{20.59} * (1- \sqrt{1-\frac{2*1.42*20.59}{420}}) = 0.00351$

→ Asreq = $0.00351 * 500 * 220 = 385.8$ mm^2

∴ **select 4 Ø12 with As=452 mm^2.**

→ As =452 mm^2> Asmin =366.67 mm² … (OK)

→ **Check Strain for Ø and Asmax :**

C=T

0.85 * 24 * a *500 = 452* 420

a=18.61 mm , X = 18.61 / 0.85 =21.9 mm

$\varepsilon_s = \frac{0.003*220}{21.9} - 0.003 = 0.027$

$\therefore\ \varepsilon_s = 0.027 > 0.005$ *then* Ø = 0.9 … (OK)

also, $\varepsilon_s = 0.027 > 0.004$ then As < Asmax ... (OK)

→ **Check for spacing:**

S= $\frac{500-2(40)-2(10)-4(12)}{3}$ = 117.33 mm >25 mm … (OK)

> db=12mm … (OK)

4.4.4 Design Beam B3 for Shear

The following figure shows shear force envelope resulted from analysis of beam (B3) using Atir 2018 Software :

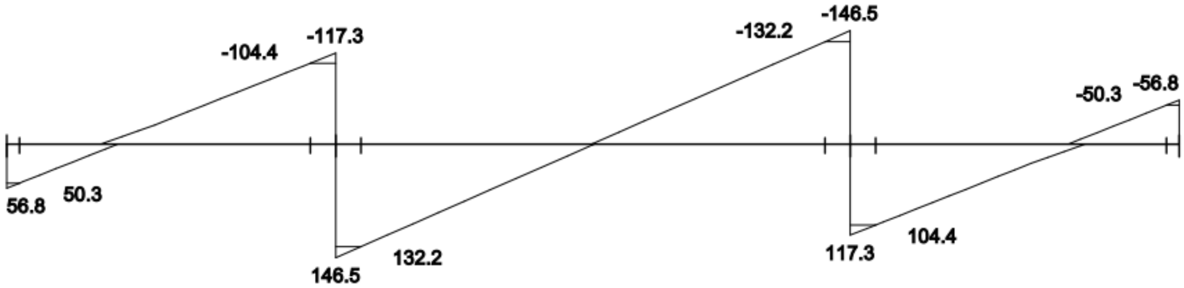


Figure (4- 10):Shear envelope of beam B3 – [kN]

The following are steps of shear force design :

1. **Check for dimensions:**

If Vu max $\leq$ Ø.Vc + Ø $\frac{2}{3}\sqrt{Fc'}$ * bw * d, then section dimensions are adequate. If not, section must be increased.

Overall maximum shear value = 132.2 kN as shown in figure (4-10).

$Ø.Vc = Ø * \frac{1}{6} * \sqrt{Fc'} * bw * d$

$= 0.75 * \frac{1}{6} * \sqrt{24} * 500 * 220 * 10^{-3}$

= **67.36 kN**

$Ø \frac{2}{3}\sqrt{Fc'} * bw * d = 0.75 * \frac{2}{3}\sqrt{24} * 500 * 220 * 10^{-3}$ =**269.44 kN**

$Ø.Vc + Ø \frac{2}{3}\sqrt{Fc'} * bw * d$ = 336.8 kN > Vu max = 132.2 ...(OK)

∴ **Section is adequate .**

2. **Category (III) :**

$Ø.Vc < Vu \leq Ø.Vc + Ø.Vs\ min$

Ø .Vs min is the maximum between :

→ $Ø.Vs\ min = 0.75 \times \frac{1}{16} \times \sqrt{fc'} \times bw \times d = 0.75 \times \frac{\sqrt{24}}{16} \times 500 \times 220 \times 10^{-3}$ = **25.26 kN**

OR

→ $Ø.Vs\ min = 0.75 \times \frac{1}{3} \times bw \times d = 0.75 \times \frac{1}{3} \times 500 \times 220 \times 10^{-3}$ = **27.5 kN** « **Control**.

Ø.Vc + Ø .Vs min = **67.36 + 27.5 = 94.86 kN**

∴ For all shear values that is ≤ 94.86 kN , minimum shear reinforcement is required .

→ Minimum Shear Reinforcement :

$$Sreq = \frac{0.75*Av*Fyt*d}{Ø.Vs\ min}$$

$$\rightarrow Sreq = \frac{0.75*100*420*220}{27.5} = \mathbf{252\ mm}$$

But , **Smax** ≤ d/2 → 220/2 = **110 mm« Cont**

Or , **Smax ≤ 600 mm**

∴ **Select Ø8/10cm ,2legs**

Note :
Assume Ø8 stirrups with 2 legs are used ,
then $Av = 2 * \frac{\pi * 8^2}{4} = 100\ mm^2$

3. Category (IV) :

$$Ø.Vc + Ø.Vs\ min < Vu \leq Ø.Vc + Ø \times \frac{1}{3} \times \sqrt{fc'} \times bw \times d$$

$$\rightarrow Ø \times \frac{1}{3} \times \sqrt{fc'} \times bw \times d = 0.75 \times \frac{1}{3} \times \sqrt{24} \times 500 \times 220 \times 10^{-3} = \mathbf{134.2\ kN}$$

$$\rightarrow Ø.Vc + Ø \times \frac{1}{3} \times \sqrt{fc'} \times bw \times d = \mathbf{202.1\ kN} > Vu\ max = \mathbf{132.2\ kN}$$

$$Sreq = \frac{Av*Fyt*d}{Vs}, \text{ where } Vs = \frac{Vu - Ø.Vc}{Ø} = \frac{132.2 - 67.36}{0.75} = 86.45\ kN$$

$$\rightarrow Sreq = \frac{100*420*220}{86.45*10^3} = \mathbf{127.5\ mm} \text{ « Cont}$$

But , **Smax** ≤ d/2 → 260/2 = **106.9 mm**

Or **Smax ≤ 600 mm**

∴ **Select Ø8/10cm ,2legs**

4.5. Design of Column (C11)

4.5.1. Calculation of Loads act on Column (C11)

Loads acting on columns are obtained from support reaction when analyzing the supported beams.

Loads acting on column (C11) are as follows:

Dead Load = (Service Dead reaction from B4) + (Service Dead reaction from B6) + (Service Dead reaction from B9) +(Service dead reaction from b15)+ (Self weight of the column x 2)

= (48.75) + (74.43) + (57.56) +(78.64)+ (0.5 x 0.25 x 3 x 25 x 2) = 341.49 kN

Live Load =(Service Live reaction from B6) + (Service Live reaction from 9)

=(15.97) + (10.97) =26.94 kN

Factored loads (Pu) = 1.4 DL = 1.4 x 341.49 = **478.086 kN**. << Cont.

OR Pu = 1.2 DL + 1.6 LL = 1.2 x 341.49+ 1.6 x 26.94 = **452.892 kN** .

4.5.2. Calculation of Required Dimension of Column (C11)

Total load Pu =478.086 KN

Pn = 478.086 /(0.65) = 735.51 KN

Assume $\rho g = 1.0\ \%$

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

$735.51 * 10^{-3} = 0.8 * Ag[0.85 * 24 + 0.01 * (420 - 0.85 * 24)]$

$Ag = 0.037\ m^2$

∴**Select 50*25cm with Ag = 1250 cm².**

- **Check Slenderness Effect :**

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

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

***W*here :**

Lu: Actual unsupported (unbraced) length = 2.91 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

$\rightarrow \lambda = \frac{1 * 2.91}{0.3 * 0.25} = 38.8$

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

$\lambda = 38.8 > 22$ ∴ slenderness check .

System about Y

$\rightarrow \lambda = \frac{1 * 2.91}{0.3 * 0.6} = 16.16$

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

$\lambda = 16.16 < 22$ ∴ Short about Y.

4.5.3. Calculation of Required Reinforcement Ratio & Slenderness chek :

Minimum Eccentricity:-

$$ey = \frac{Mux}{Pu} = 0$$

$$\min ey = 15 + 0.03 \times h = 15 + 0.03 \times 250 = 22.5mm = 0.0225m$$

$$ey = 0.0225m$$

Magnification Factor:-

$$\delta_{ns} = \frac{Cm}{1 - \frac{Pu}{0.75P_c}} \ge 1.0 and \le 1.4$$

$$Cm = 0.6 + 0.4\left(\frac{M1}{M2}\right) \geq 0.4$$
$$Cm = 0.6 + 0.4 * 1 = 1 \geq 0.4$$

$$P_{cr} = \frac{\pi^2 EI}{(KLu)^2}$$

$$EI = 0.4\frac{E_c I_g}{1+\beta_d}$$
$$E_c = 4700\sqrt{fc'} = 4700 \times \sqrt{24} = 23025.20Mpa$$
$$\beta_d = \frac{1.2DL}{Pu} = \frac{1.2 * (341.49)}{478.086} = 0.857 < 1$$
$$I_g = \frac{b \times h^3}{12} = \frac{0.50 \times 0.25^3}{12} = 0.000651m^4$$
$$EI = \frac{0.4 \times 23025.2 \times 0.000651}{1+0.857} = 3.22MN.m^2$$
$$P_{cr} = \frac{\pi^2 * 3.22}{(1 * 2.91)^2} = 3.753MN$$
$$\delta_{ns} = \frac{1}{1 - \frac{478.086}{0.75 * 3.753}} = 1.2 \geq 1.0$$

Interaction Diagram:-

$$ey = e_{\min} \times \delta_{ns} = 0.0225 \times 1.2 = 0.027m$$
$$\frac{ey}{h} = \frac{0.027}{0.5} = 0.054$$
$$\frac{\gamma}{h} = \frac{250 - 2*40 - 2*10 - 14}{250} = 0.544$$

From the interaction diagram chart

from chart A9 - a for $\frac{\gamma}{h} = 0.5 \rightarrow \rho g = 0.01$

from chart A9 - b for $\frac{\gamma}{h} = 0.75 \rightarrow \rho g = 0.01$

then for $\frac{\gamma}{h} = 0.544 \rightarrow \rho g = 0.01$

Select reinforcement

$Ast = \rho g \times Ag = 0.01 \times 250 * 500 = 1250mm^2$

Select 10 ϕ14 *with* AS > Ast = 1540mm^2 .

∴ **Use 10 Ø 14 with As = 1540 mm^2 >As$_{req}$ = 1250 mm^2**

- **Check spacing between the bars :**

$$S = \frac{500-2*40-2*10-5*14}{4} = 82.5\ mm$$

S = 82.5 mm $\geq 40mm$

$\geq 1.5db = 21\ mm$

4.5.4. Determination of Stirrups Spacing

According to ACI :

$S \leq 16$ db (longitudonal bar diameter)

S $\leq$ 48dt (tie bar diameter).

S $\leq$ Least dimension.

$\text{Spacing} \leq 16 \times d_b(\text{Longitudinal. bar. diameter}) = 16 \times 14 = 22.4\text{cm}.$

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

$\text{Spacing} \leq \text{Least. dim e nsion} = 25\ \text{cm}$

∴ **Select Ø 10/20cm**

Column (C11) Section is shown in figure(4-11) where bars arrangmenet and stirrups detailing appear :

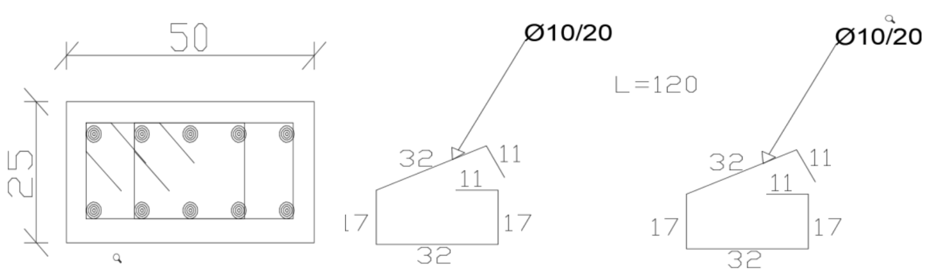


Figure (4- 11): C11 Reinforcement Details

4.6. Design of Shear Wall

Analysis and design were done using ETABS program in which the seismic loads were taken into account. The following is a sample calculation for one of the walls, S.W6

The following data that used in design :

- Shear Wall thickness = h = 20 cm
- Shear Wall length Lw = 2.0 m
- Building height Hw=18.48 m
- Critical section shear : Lw<hw → d =0.8*Lw =1.60 m

4.6.1. Design of Horizontal Reinforcement

Calculation of Shear Strength Provided by concrete Vc:

- Shear Strength of Concrete is the smallest of :

1- $Vc = \frac{1}{6}\sqrt{fc'} \times b \times d$

$$= \frac{1}{6}\sqrt{24} \times 200 \times 1600 = \mathbf{261.28\ kN} \ll \text{Controlled}$$

2- $Vc = \frac{\sqrt{fc'} \times b \times d}{4} + \frac{Nu \times d}{4Lw}$

$$= \frac{\sqrt{24} \times 200 \times 1600}{4} + 0 = 391.92\ kN$$

3- $Vc = \left[\frac{\sqrt{fc'}}{2} + \frac{Lw\left(\sqrt{fc'} + \frac{2Nu}{Lw.h}\right)}{\frac{Mu1}{Vu} - \frac{Lw}{2}}\right] \times \frac{h \times d}{10}$

Where :

- Mu1=246.4 kN.m
- $\frac{Mu1}{Vu} - \frac{Lw}{2} = \frac{246.4}{270.1} - \frac{2}{2} = -0.088 < 0$ → This equation is not applicable .

$\therefore Vc = 261.28$ kN → $\emptyset Vc < Vumax$[1] = 270.1 kN →Horizontal Reinforcement is Required.

$$\rightarrow Vs = \frac{Vu}{\emptyset} - Vc = \frac{270.1}{0.75} - 261.28 = 98.85\ kN$$

$$\rightarrow \frac{Avh}{s} = \frac{Vs}{fy*d} = \frac{98.85*10^3}{420*1600} = 0.147$$

$$\text{but } \left(\frac{Avh}{s}\right)\text{min} = 0.0025*h = 0.0025*200 = \mathbf{0.5} \ll \text{Controlled.}$$

→ Avh : For 2 layers of Horizontal Reinforcement

Select Ø10 :

Avh = 2 *79 = 158 mm^2

$$\frac{Avh}{s} = 0.5 \rightarrow Sreq = \frac{158}{0.5} = 316\ mm$$

Smax= Lw/5 = 2000/5 = 400 mm ≪ Controlled.

= 3h = 3*200 =600mm

$= 45cm \ll$

∴Select Ø10 @ 250 mm at each side .

4.6.2. Design of Vertical Reinforcement

→ Avv = $[0.0025 + 0.5\ (2.5 - \frac{hw}{lw})(\frac{Avh}{Shor*h} - 0.0025)] * h * Sver$

$$\frac{hw}{lw} = \frac{18.48}{2.0} = 9.24 > 2.50$$

→ $\frac{Avv}{Sver} = [0.0025 + 0.5\ (0)(\frac{2*79}{250*200} - 0.0025)] * 200$

∴ $\frac{Avv}{Sver} = 0.5$

Smax = Lw/3 = 2000/3 = 666.67 mm

= 3h = 3*200 =600mm

$= 450\ mm \ll$ Controlled.

Select Ø12 :

Avv = 2 *113 = 226 mm^2

$$\frac{Avv}{s} = 0.5 \rightarrow Sreq = \frac{226}{0.5} = 452\ mm$$

∴Select Ø12 @ 200 mm at each side .

4.6.3. Design of Bending Moment

Moment diagram were obtained from ETABS
Max Mu =606.3 kN.m

→ Part of Moment that resisted through Avv :

Muv =0.9 [0.5*Asv*fy*Lw (1-$\frac{Z}{2\,Lw}$)]

Where :

- Asv=2*113 *$\frac{2000}{200}$ = 2260 mm^2
- $\frac{Z}{Lw} = \frac{1}{2+\frac{0.85*\beta 1*fc'*Lw*h}{Asv*fy}} = \frac{1}{2+\frac{0.85*0.85*24*2000*200}{2260*420}} = 0.10744$

∴ Muv = 0.9 [0.5*2260*420*2000 (1- $\frac{0.107}{2}$)] = 808.39 kN.m

Muv = 808.39 kN.m > Mu =606.3 kN.m

So, Boundary Element is not required. #

4.7. Design of Basement Wall

4.7.1. System and Loads

cThe wall spans vertically and it is considered to be pinned at both ends as shown in figure (4-12) which also illustrate loads that act on the wall.

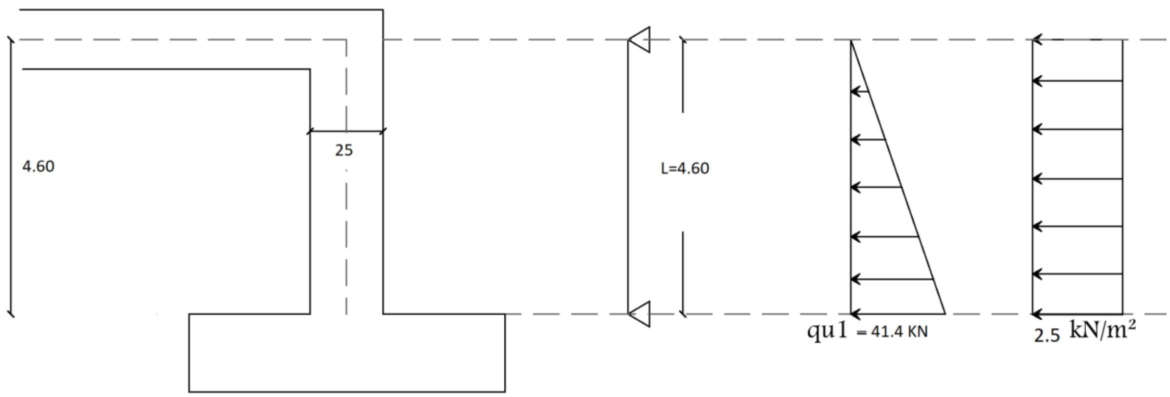


Figure (4- 12):Basement Wall system and loads

The different lateral pressures on a 1m length of the wall are calculated as follows:
$k_o = 1 - \sin 30 = 0.5$
Due to soil pressure at rest : $qu1 = k_o.\gamma.h = 0.5*18*4.6 = 41.4\ kN/m^2$
Due to surcharge : $qu2 = 5*0.5 = 2.5\ kN/m^2$

The following are shear and moment diagrams that obtained from Atir Software.

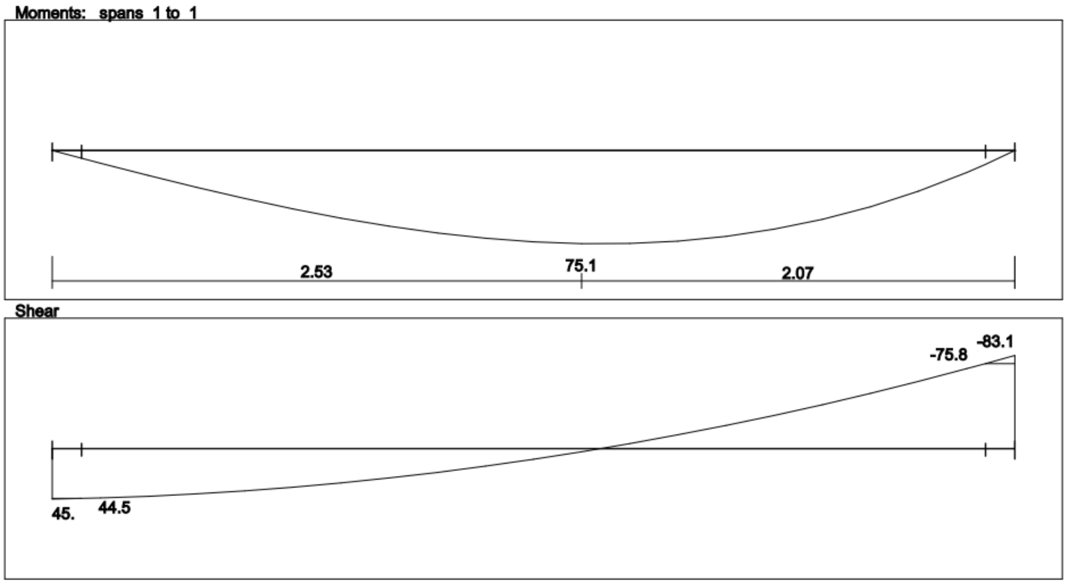


Figure (4- 13): Moment and Shear Envelope of Basement wall

4.7.2. Design of Shear Force

Max value shear force is obtained from figure(4-13) , Vu= 75.8 kN

d=25-2-2 = 21 cm

$Ø * Vc = 0.75 * \frac{1}{6} * \sqrt{24} * 1000 * 210 = 128.59$ kN > Vu

∴ **h=25cm is correct.**

4.7.3. Design of Wall Reinforcement

1. Design of Vertical Reinforcement at Tension Side :

Max value Moment is obtained from figure(4-13) , $Mu = 75.1$ kN.m

→ $m = \frac{420}{0.85*24} = 20.6$

→ Mn = 75.1 /0.9= 83.44 kN.m

→ $Rn = \frac{Mn}{b*d^2} = \frac{83.44 *10^6}{1000*210^2} = 1.892$ MPa

→ $\rho = \frac{1}{20.6} * (1- \sqrt{1 - \frac{2*1.892*20.6}{420}}) = 0.00473$

→ $Asreq = \rho * b * d = 0.00473 * 1000 * 210 = 994.5$ mm^2 /1m

→ As (min) = 0.0012*b*h = 0.0012*1000* 250 = 300 mm^2 /1m < Asreq

∴ Select 7Ø14/m with As = 1078 mm^2 /m > As min

2. Design of Vertical Reinforcement Compression Side:

→ As = As (min) = 300 mm^2

∴ Select **Ø12/20cm with As = 678 mm^2 /m**

3. Design of Horizontal Reinforcement:

→ As = As (min) = 0.001 *1000*250 = 250 mm^2 /m for one layer

∴ Select **Ø10/25cm**

4.8. Design of Basement Footing

Loads that act on Wall footing is obtained from ETABS where :

- qD=140.2kN/m & qL=18.4 kN.m
- Total Service Loads : qtot =65.56+5.15 = 158.6 kN/m
- Total Factored Loads : qu =1.4 *140.2 = 196.28 kN/m

4.8.1. Check if footing width is correct

$\sigma_b = {qtot}/{Areq} \leq \sigma_{b\,(allow\,.\,net)}$

$\therefore\ \mathbf{158.6}/{1.25 * 1.0} = 126.88 < \sigma_{b(allow\,.\,net)} = 400\ kN/m^2$

$\therefore$ **a=1.25m is correct #**

4.8.2. Design of one way shear

→ Assume h =25cm
→ d=500-50-20 = 430 mm
→ Vu=196.28*0.07*1m = 13.74 KN
→ $\varnothing * Vc = 0.75 * \frac{1}{6} * \sqrt{24} * 1000 * 430 = 263.32\ kN > Vu$

$\therefore$ **h =50 cm (SAFE) .**

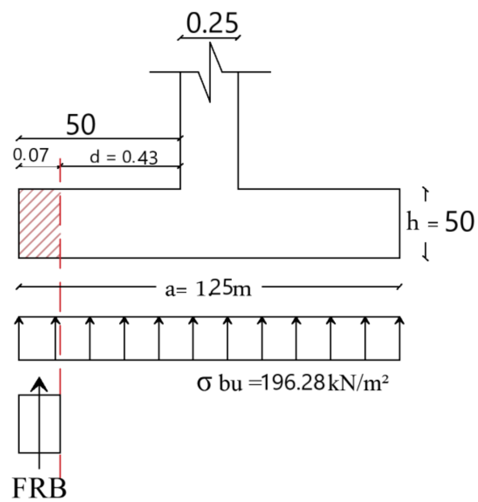


Figure (4- 14): Critical Section of Shear force

4.8.3. Design of Bending Moment

➢ **Main Steel:**

Mu =196.28*0.5*1*(0.5/2) = 24.5kN.m

→ Mn = 24.5 /0.9= 27.23 kN.m
→ $kn = \frac{Mn}{b*d^2} = \frac{6.94*10^6}{1000*230^2} = 0.147\ MPa$
→ $\rho = \frac{1}{20.6} * (1-\sqrt{1-\frac{2*0.147*20.6}{420}}) = 0.00035$
→ $Asreq = 0.00035 * 1000 * 430 = 151\ mm^2/m$

→ $As\ (min) = 0.0018*1000 * 500 = 900\ mm^2/m$

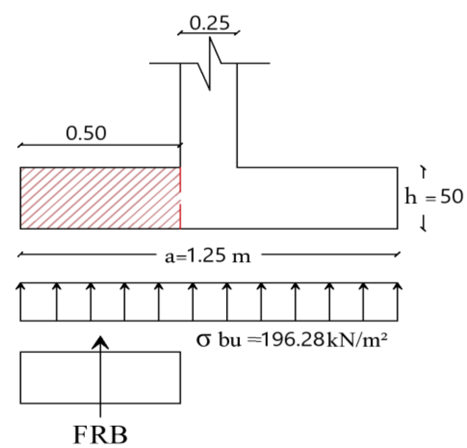


Figure (4- 15):Critical Section of Bending Moment

∴ **Select Ø14/15cm with As = 1078 mm^2 > Asmin=900 mm^2**

➢ **Secondary Steel:**

→ As (min) = 0.0018*b*h = 0.0018*1000 * 500 = 900 mm^2

∴ Select **Ø12/15cm 8Ø12/1m with As = 904 mm^2 > Asmin**

The Following figure shows details of a section taken in a basement wall and its footing.

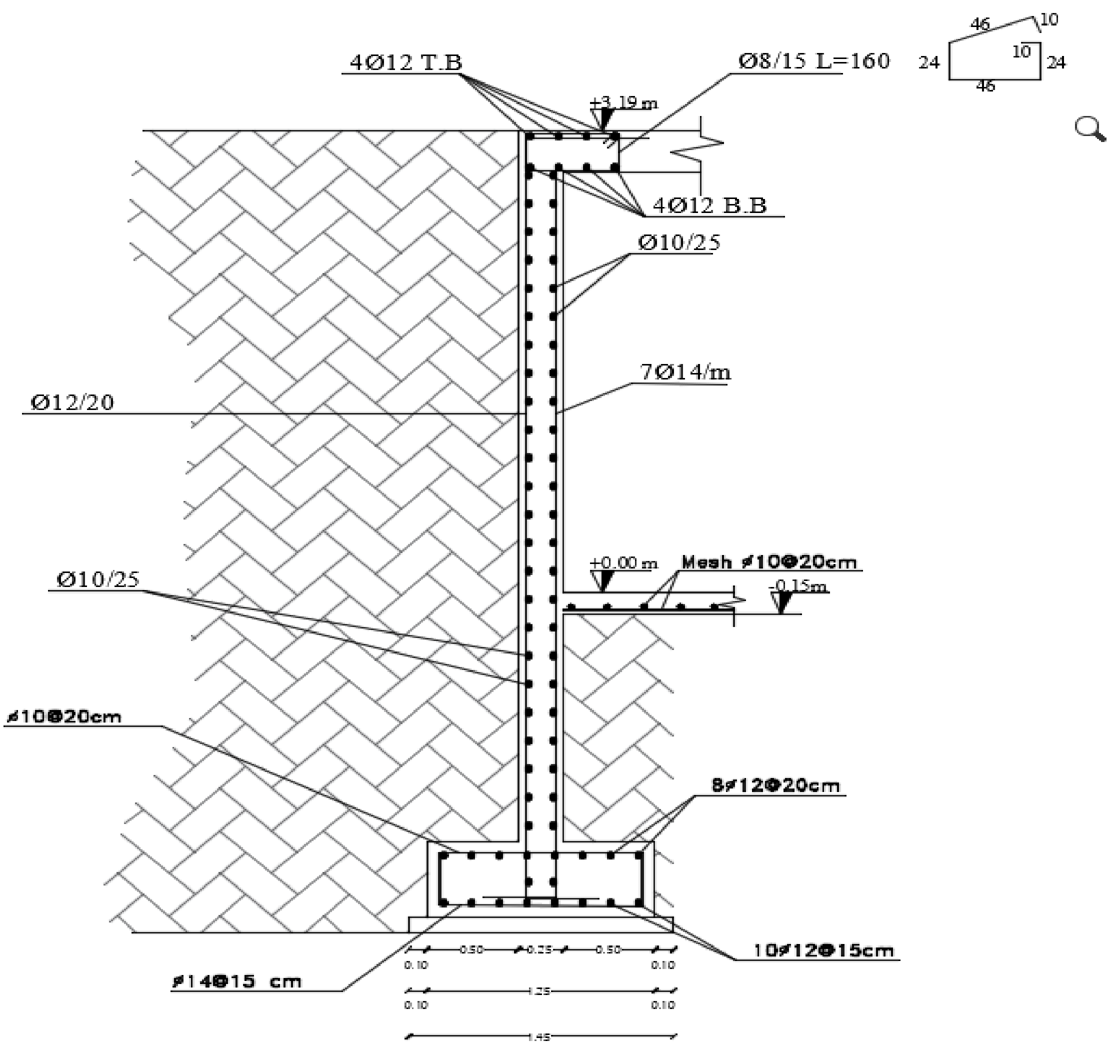


Figure (4- 16): Basement wall Reinforcement Details

4.9. Design of Isolated Footing (F3)

Loads that act on footing F3 are :

- PD =701.15 kN , PL =91.54 kN → Pu = 1.2 * 701.15 + 1.6*91.54 = 987.844 kN

The following parameters are used in design :
- $\gamma_{concrete}$ = 25 kN/m^3
- γ_{soil} = 18 kN/m^3
- σ_{allow} = 400 kN/m^2
- clear cover =75cm

4.9.1.Determination of footing dimension (a)

Footing dimension can be determined by designing the soil against bearing pressure .

→ Assume h = 50 cm

→ $\sigma_{b(allow)net}$ = 400 – 25*0.85 = 378.75 kN/m²

→ $\sigma_{bu(\,allow\,.\,net)}$ = 1.4* 378.75 = 530.25 kN/m²

→ $\sigma_{bu} = {}^{Pu}/_{Areq} \le \sigma_{bu(\,allow\,.\,net)}$

$\therefore\ {}^{987.844}/_{a^2}$ = 530.25 → **a=1.36m** → **Select a=1.45m**

→ $Bearing\ Pressure\ \sigma bu = {}^{Pu}/_{A} = \frac{987.844}{1.45*1.45}$ = **469.84 kN/m^2** ≤ 530.25 kN/m² **…. (SAFE)**

4.9.2. Determination of footing depth (h)

To determine depth of footing both of one and two way shear must be designed.

4.9.2.1. Design of one way shear

→ $d = h - cover - \emptyset = 500 - 75 - 14 = 411\ mm$

→ Vu at distance d from the face of column :

Vu = $FRB = \sigma bu \times 0.566 \times b$

$= 469.84 \times 0.064 \times 1.45 = 43.6\ kN$

→ $\emptyset * Vc = 0.75 * \frac{1}{6} * \sqrt{Fc'} * b * d$

$= 0.75 * \frac{1}{6} * \sqrt{24} * 1450 * 411$ =364.9 kN >Vu

∴ h = 50 cm is correct ✓

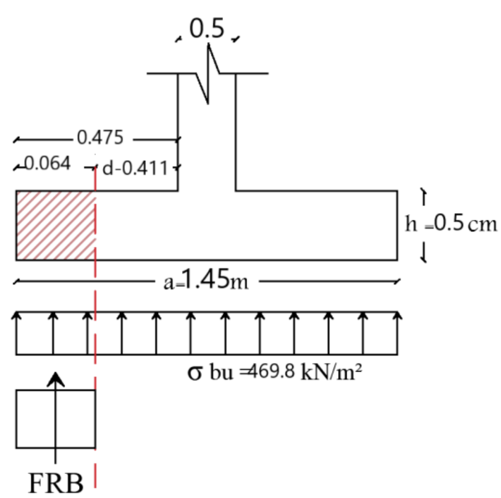


Figure (4- 17): Critical Section of Shear Force

4.9.2.2. Design of Punching (two way shear)

→ $d = 411\ mm$

→ b_o = 2*911+2*661= 3144 mm

→ Bc = 1

→ αs = 40 (interior column)

Vu = 987.84 – (469.8 *0.911*0.661) = **704.94 kN**

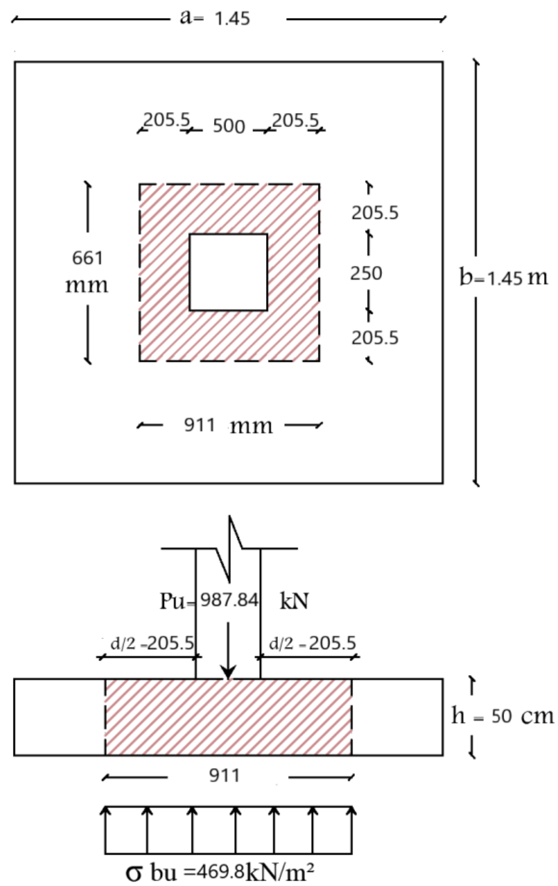


Figure (4- 18):Punching Shear Critical Section

Ø×Vc is the smallest of :

1. $Vc = \left(2+\frac{4}{Bc}\right)\times\frac{\sqrt{fc'}}{12}\times b_o\times d$

$= \left(2+\frac{4}{1}\right)\times\frac{\sqrt{24}}{12}\times 3144\times 411$

$= 3165.19$ kN

2. $Vc = \left(\frac{\propto_s\times d}{b_o}+2\right)\times\frac{\sqrt{fc'}}{12}\times b_o\times d$

$= \left(\frac{40\times 411}{3144}+2\right)\times\frac{\sqrt{24}}{12}\times 3144\times 411$

$= 3813.5$ kN

3. $Vc = 4\times\frac{\sqrt{fc'}}{12}\times b_o\times d$

$= 4\times\frac{\sqrt{24}}{12}\times 3144\times 411=$ **2110.1 kN .. ∢ cont.**

→ Ø×Vc = 0.75 × 2110.1 = **1582.57** kN > Vu = **704.49** kN

∴ **h = 50 cm is correct ✓**

4.9.3.Design of Reinforcement

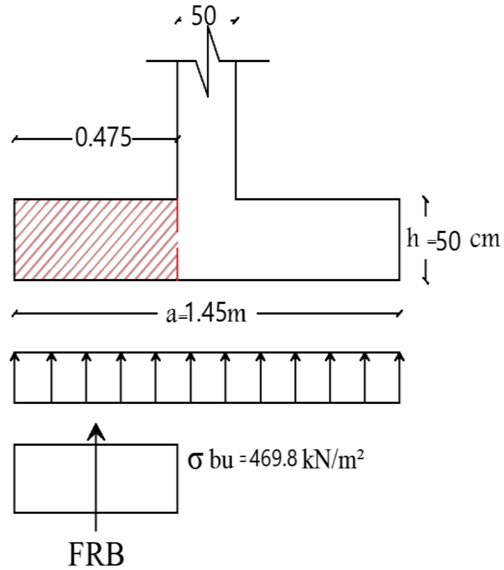


Figure (4- 19):Critical Section of Bending Moment

Mu = 469.84 *0.475*1.45*(0.475/2) = 76.85kN.m

→ m $=\frac{Fy}{0.85*Fc'} = \frac{420}{0.85*24} = 20.6$

→ Mn = 76.85/0.9= 85.39 kN.m

→ Rn $= \frac{Mn/\emptyset}{b*d^2} = \frac{85.39*10^6}{1450*411^2}$ = 0.348 MPa

→ $\rho = \frac{1}{m} * (1- \sqrt{1 - \frac{2*Rn*m}{Fy}})$

$= \frac{1}{20.6} * (1- \sqrt{1 - \frac{2*0.836*20.6}{420}}) = 0.000837$

→ Asreq = $\rho * b * d$ $0.002033 * 1450 * 411 = 499$ mm^2

→ As (min) = 0.0018*b*h =0.0018*1450 *500 = 1305 mm^2

→ Asreq < As (min) , use As min .

∴ **Select for both directions: 9Ø14 with As = 1386 mm^2 > As,min … (ok)**

4.9.4.Design the Connection between Column & Footing

→ **Design of bearing pressure at section of column :**

$\emptyset \times Pnb = 0.65 \times 0.85 \times fc' \times A1 \geq Pu$

$= 0.65 \times 0.85 \times 24 \times 500 \times 250 = 1657.5$ kN > Pu = 987.844 kN

∴ **Dowels are not required to transfer the load between column and footing**

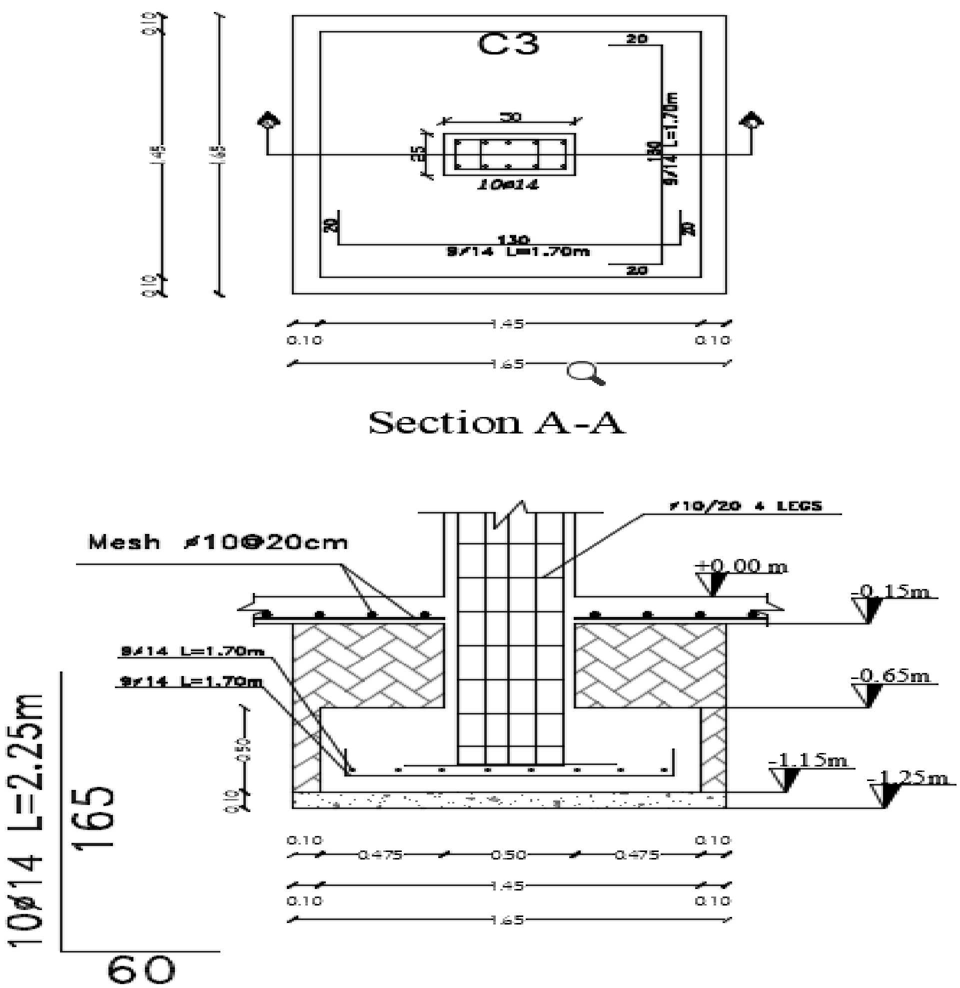


Figure (4- 20):F3 Reinforcement Details

4.10. Design of Stairs

The following figure shows a top view of the stairs :

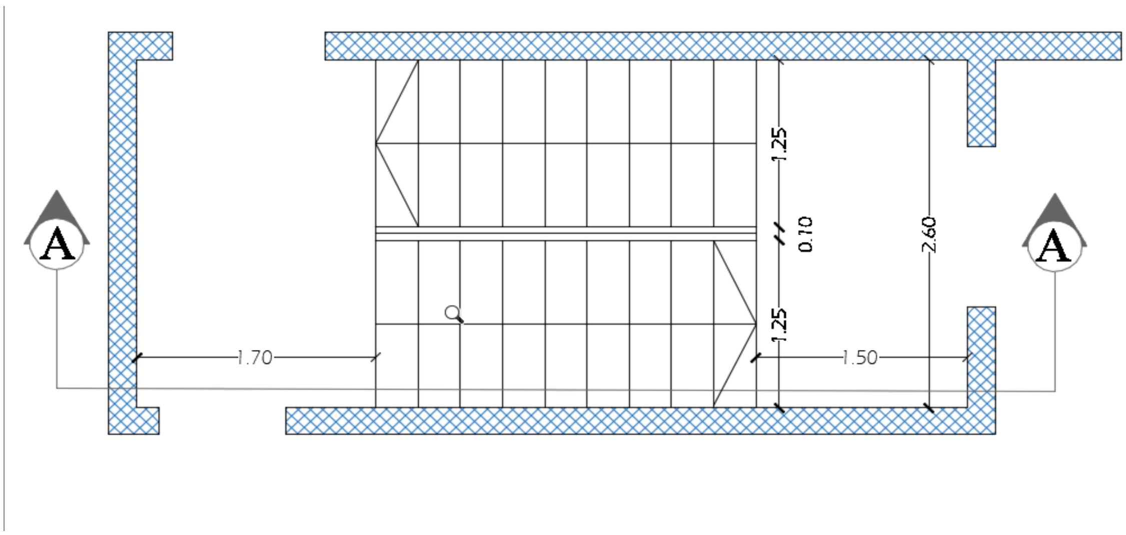


Figure (4- 21): Stairs Top View

4.10.1. Design of flight

The structural system of the flight is shown in figure (4-22) and the following steps explain the design procedure of the flight :

1. **Determination of flight thickness :**

   Limitation of deflection: h ≥ minimum h

   h (min) = L/20 = 350/20 = 17.5 cm

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

   Angle (α): tan(α) = 15.7/30 → α = 27.6°

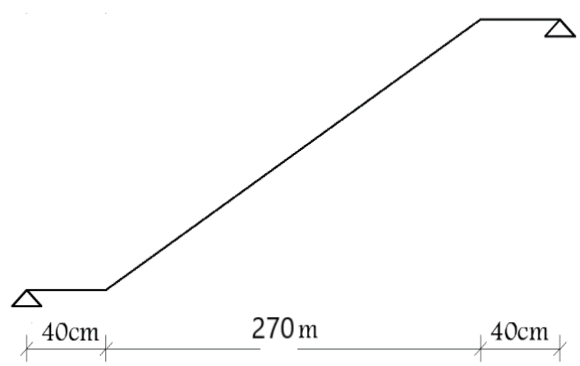


Figure (4- 22): Structural system of flight

2. Loads calculation :

Figure (4-23) shows a section in the flight in which the layers carried by the flight appear.

Table(4- 6): Calculation of Dead Loads that act on Flight

Flight Dead Loads
Flight = (0.15 * 25* 1)/ cos(27.5) =4.23 kN/m
Plaster = (0.03 * 22* 1)/ cos(27.5) =0.75 kN/m
Hor.Mortar =0.03*22*1 =0.66 kN/m
Ver.Mortar = 0.03*22*($\frac{0.157}{0.3}$) = 0.345 kN/m
Hor.Tiles = 0.04*23*($\frac{33}{30}$) = 1 kN/m
Ver.Tiles = 0.03*23*($\frac{0.157}{0.3}$) = 0.36 kN/m
Triangle =0.5*0.157*25 =1.96 kN/m
Sum=9.3 kN/m

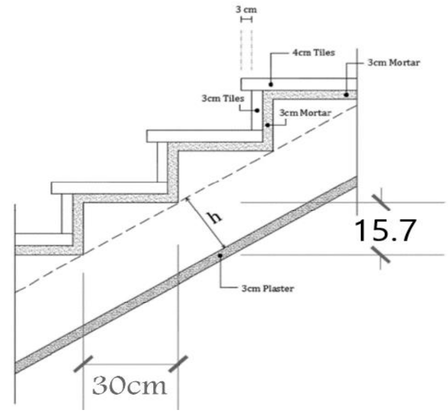


Figure (4- 23): Section of The Flight

Factored Loads :

qu= 1.2 *9.3 + 1.6*2 = 14.36 kN/m

Au= 14.36*2.7/2 = 19.4 kN

3. **Analysis** : The following figures show shear and moment Diagrams resulted from analysis of the flight :

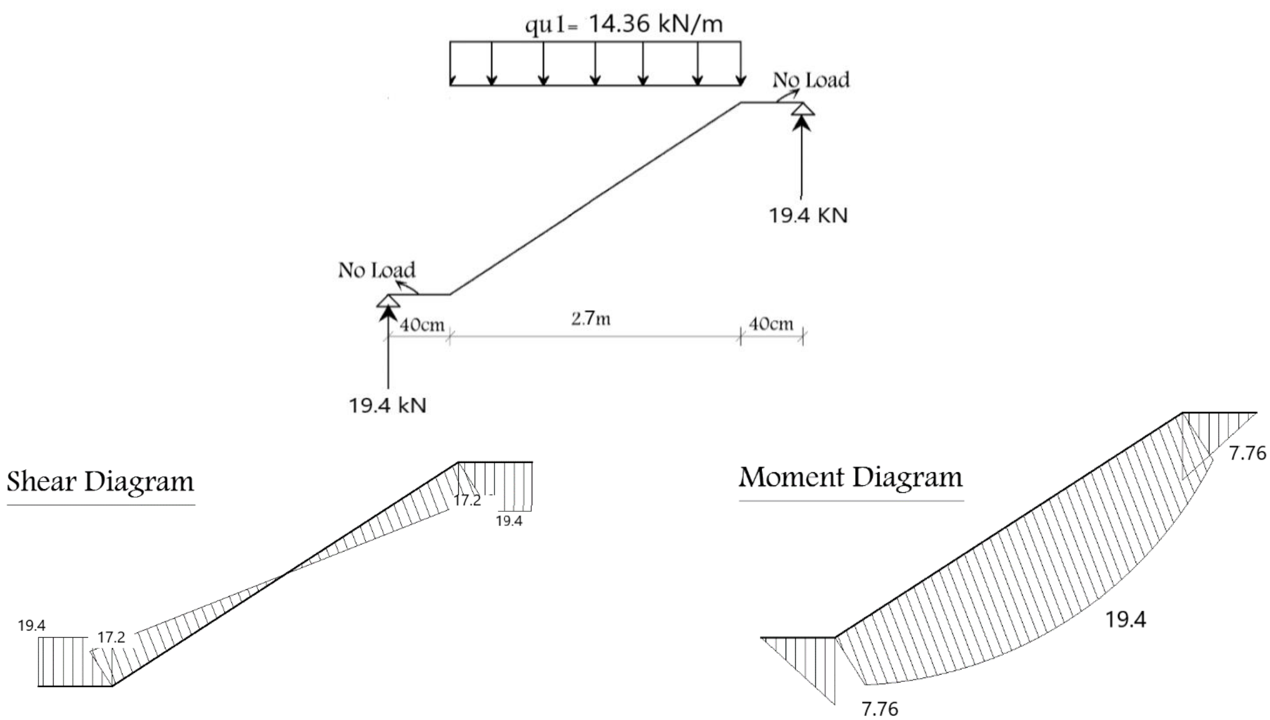


Figure (4- 24) :Analysis of the flight

4. Design :

- **Design of Shear Force :**

d=200-20-(12/2) = 174 mm

$Ø \times Vc = 0.75 * \frac{1}{6} * \sqrt{Fc'} * bw * d$

$= 0.75 * \frac{1}{6} * \sqrt{24} * 1000 * 174$

= 106.55 kN > Vu max = 17.2 kN

∴ No Shear Reinforcement is Required#

- **Design of Bending Moment :**

→ $m = \frac{Fy}{0.85 * Fc'} = \frac{420}{0.85*24} = 20.6$

→ $Rn = \frac{Mu/Ø}{b*d^2} = \frac{19.4 * 10^6/0.9}{1000*174^2} = 0.71$ MPa

→ $\rho = \frac{1}{m} * (1 - \sqrt{1 - \frac{2*Rn*m}{Fy}}) = \frac{1}{20.6} * (1 - \sqrt{1 - \frac{2*0.71*20.6}{400}}) = 0.0018$

→ $Asreq = \rho * b * d = 0.0018 * 1000 * 174 = 315.16\ mm^2$

→ As min = 0.0018 *1000*200 = 360 mm^2 << control .

∴ Select **Ø12/20 with As = 565 mm^2** > As min …. For Main Reinforcement

For secondary Reinforcement select **Ø10 /20 with As=395 mm^2** > As min

→ Check Spacing :

20cm > **S min** = 2.5 + 1.0 = **3.5 cm** or 2*(1.0)= **2.0 cm … ok**

20cm < **S max** = 3 * 20 = **60 cm … ok**

→ Check Strain:

C = T

0.85*fc'*a*b = As*fy

0.85*24*a*1000 = 565 *420

a = 11.6 mm → X = a/β = 11.6/0.85 = 13.68 mm

$\varepsilon_s = \frac{0.003*d}{x} - 0.003 = \frac{0.003*174}{13.68} - 0.003$

∴ **ε_s = 0.035 > 0.005 …. Ø = 0.9 (OK)**

4.10.2. Design of Landing

The structural system of the landing is shown in figure (4-25) and the following steps explain the design procedure of it :

- **Determination of Landing thickness :**

  Limitation of deflection:

  h ≥ minimum h

  h (min) = L/20 = 260/20 = 13 cm

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

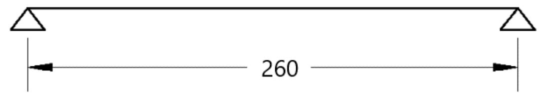


Figure (4- 25):Structural system of landing

- **Loads calculation :**

  Figure (4-26) shows a section in the landing in which the layers carried by the landing appear.

Table(4- 7):Calculation of Dead Loads that act on Landing

Landing Dead Loads
Tiles = 0.03*23*1=0.7 kN/m
Mortar = 0.03*22*1=0.4 kN/m
Sand = 0.07*16*1=1.1 kN/m
Slab = 0.15*25*1=3.75 kN/m
Plaster = 0.02*22*1=0.4 kN/m
Sum = 6.35 kN/m

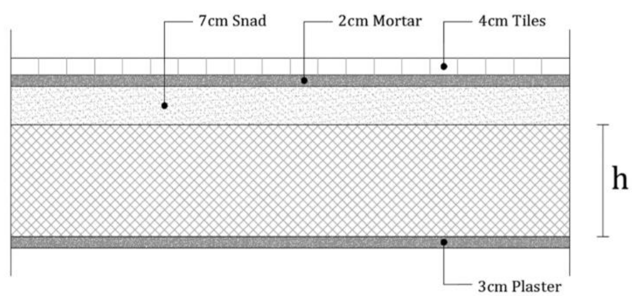


Figure (4- 26):Section of The Landing

Factored Loads :

qu = 1.2*6.35+1.6*2 = 10.82 kN/m

The landing carries (dead load & live load of landing + support reaction resulted from the flight)

qu = 10.82 + Support reaction of flight = 10.82 + 19.4 = **30.22 kN/m**

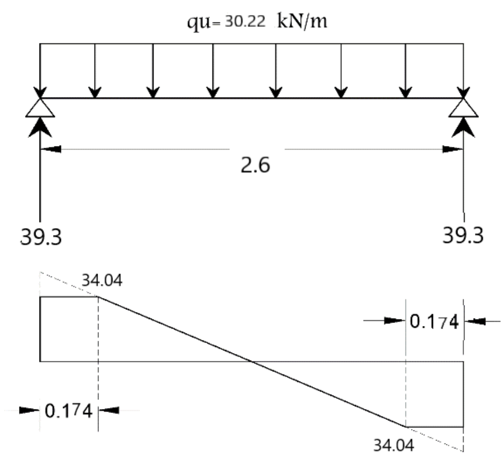


Figure (4- 27):Analysis of Landing

→ **Analysis :**

d= 200-20-(12/2) = 174mm

Vumax= 39.3 – (30.22*0.174) = **34.04 kN**

Mu max = $\frac{30.22*2.6^2}{8}$ = **25.5 kN.m**

→ **Shear Force Design :**

d=174mm & Vu max=34.04 kN

$Ø\times Vc = 0.75 * \frac{1}{6} * \sqrt{24} * 1000 * 174 = 106.5$ kN > Vu max = 34.04 kN

∴No Shear Reinforcement is Required#

→ **Bending Moment Design : (Mu max = 25.5 kN.m)**

- m = 20.6
- Rn = $\frac{25.5 *10^6/0.9}{1000*174^2}$ = 0.935 MPa
- $\rho = \frac{1}{20.6} * (1- \sqrt{1 - \frac{2*0.935*20.6}{420}}) = 0.0023$
- Asreq = $0.0023 * 1000 * 174 = 400.2$ mm^2
- As min = 0.0018 *1000*200 = 360 mm^2

∴ Select **Ø12 /20cm with As = $\frac{\pi*12^2}{4} * \frac{100}{20}$ = 565 mm^2** > As req …. For Main Reinforcement

- Check Spacing :

  20cm > **S min** = 2.5 + 1.0 = **3.5 cm** or 2*(1.0)= **2.0 cm … ok**

  20cm < **S max** = 3 * 20 = **60 cm … ok**

- Check Strain:

$$C = T$$

$$0.85*fc'*a*b = As*fy$$

$$0.85*24*a*1000 = 565*420$$

$$a = 11.63 \text{ mm} \rightarrow \quad X = a/\beta = 11.63/0.85 = 13.68 \text{ mm}$$

$$\varepsilon_s = \frac{0.003*174}{13.68} - 0.003$$

$$\therefore\ \boldsymbol{\varepsilon_s = 0.035 > 0.005 \ \ldots.\ \emptyset = 0.9 \ \ (OK)}$$

The following figure shows section A-A of the stairs in which reinforcement detailing appears .

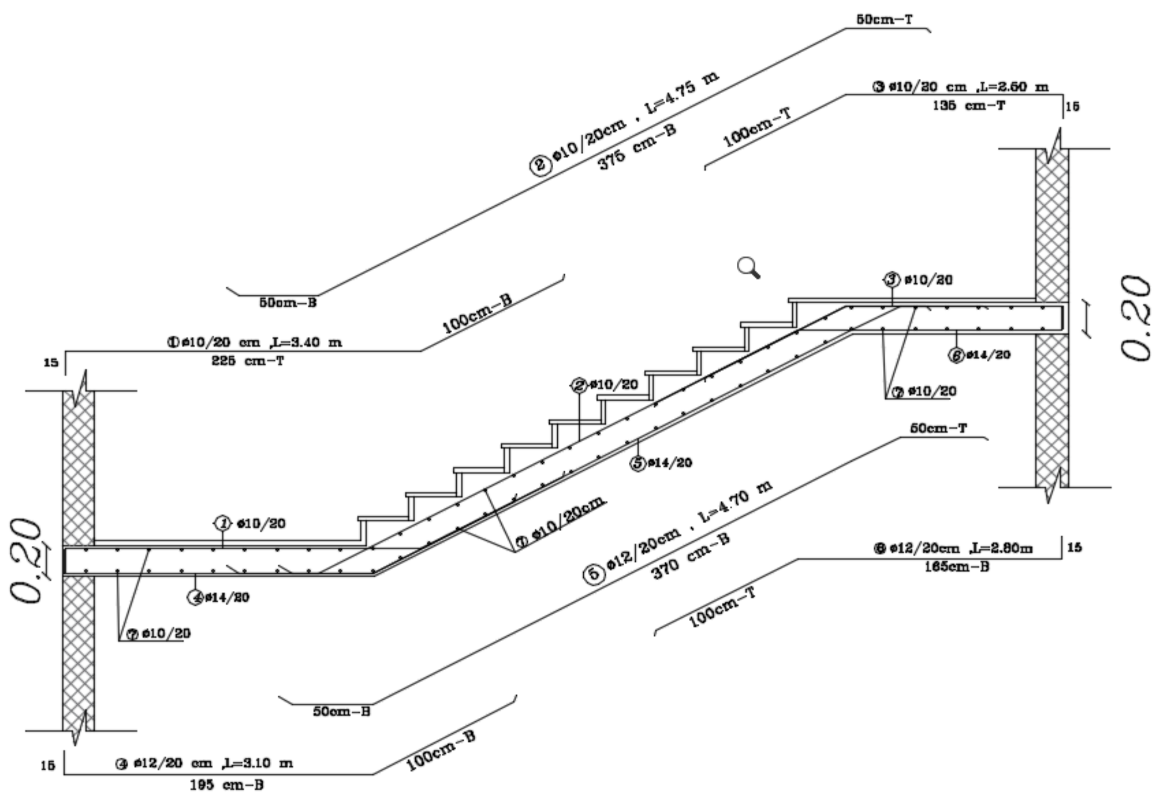


Figure (4- 28):Reinforcement Details of Stairs

CHAPTER 5

RESULTS AND RECOMMENDATIONS

5.1 Introduction

5.2 Results

5.3 Recommendations

5.1 INTRODUCTION

After completing the project and dealing with problems that had been faced during the work on it, it is necessary to summarize the results that were reached and to give some recommendations that will be helpful for students who will work on such projects.

The most prominent of these problems was deflection in beams that could have been solved by using drop beams which are not preferred in a residential building. So that another solution had been found, and that was through changing the structural system by changing the bearing direction of ribs and beams. After dealing with that problem a complete design for all structural members were done and the results of the design is presented in a form of drawings in appendix B.

5.2 RESULTS

The following are results that had been reached during the work on this project :

1. The most important step before starting a design is to study the architectural plans carefully to distribute the columns correctly.
2. The theoretical background is important but not enough, experience that reached by practicing the design is more important.it helps the engineer to be able to solve any problem that may appear in a project.
3. Gaining experience in using structural programs cannot be reached without an understanding of basic concepts of the structural design.
4. When choosing the structural system it is better to distribute ribs in the long direction and beams in the short one that will reduce loads that act on beams which leads to reducing of reinforcement which meant reducing costs.
5. We used solid slab & ribbed slab system , rectangular & circular column , isolated &combined & mat footing , For this model to be ready for implementation

5.3 RECOMMENDATIONS

This project has an important role in expanding the understanding of construction projects. So after completing this project, some recommendations should be mentioned that may help students who will work on such projects after us.

First of all, the architectural drawings had to be prepared and studied carefully to choose the most appropriate structural system. Collecting data about the project is an important step as the study of the site and the type of soil are important in choosing the construction materials to be used.

Before starting the design of the building a good structural planning must be done to determine the location of columns, beams, and shear walls to fit with architectural plans.

Before implementation, the electrical and mechanical plans of the project must be completed to introduce any possible modifications to the structural or architectural plans.It is recommended that a supervising engineer is present during the implementation of the project, and he admitted to the plans and conditions to complete the project in the best way.

3-D SHOTS

1ST & 2ND SHOTS

3RD & 4TH SHOTS

5TH & 6TH SHOTS