

**Palestine Polytechnic University**  
**College of Engineering**  
**Department of Civil Engineering**



**The structural design of apartment building in Hebron city**

By  
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Submitted to the College of Engineering  
In partial fulfillment of the requirements for the  
Bachelor degree in Building Engineering

**Hebron**  
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**Palestine Polytechnic University**

**Hebron-Palestine**

**The structural design of apartment building in Hebron city**

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By the guidance of our supervisor, and the approval of member of the testing Committee, this project Submitted to the Department of Civil Engineering, in the College of Engineering and Technology to be as partial fulfillment of the requirements for the Bachelor degree in Civil Engineering

Supervisor Signature:

.....

Head of Dep. Signature:

.....

Committee members signature:

Name:.....

Name:.....

Name:.....

## **Dedication**

To my family

## **Acknowledgment**

I would like to thank Palestine Polytechnic University, College of Civil Engineering and wish to it more progress and successes. I would also like to show my deep appreciation to my primary supervisor, Enas Shweiki who guided our throughout this project.

I wish to acknowledge the help provided by Dr.Ghassan Dweik in the Architecture department of the Palestine Polytechnic University who helped me, for choose the project.

# Table of Contents

List of Table.....	8
List of Figure.....	9
List of Abbreviations.....	11
Abstract.....	12
ملخص المشروع.....	13
1 Chapter 1: Introduction .....	14
1.1 Background.....	خطأ! الإشارة المرجعية غير معرفة.
1.2 Aims and objectives.....	خطأ! الإشارة المرجعية غير معرفة.
1.3 Problem statement.....	خطأ! الإشارة المرجعية غير معرفة.
1.4 Literature review.....	خطأ! الإشارة المرجعية غير معرفة.
1.5 Methodology.....	خطأ! الإشارة المرجعية غير معرفة.
1.6 Project scope.....	خطأ! الإشارة المرجعية غير معرفة.
1.7 Time plan.....	خطأ! الإشارة المرجعية غير معرفة.
2 Chapter 2: Architectural description.....	خطأ! الإشارة المرجعية غير معرفة.
2.1 Introduction .....	خطأ! الإشارة المرجعية غير معرفة.
2.2 Basic Identification of Project.....	خطأ! الإشارة المرجعية غير معرفة.
2.3 Project site.....	خطأ! الإشارة المرجعية غير معرفة.
2.3.1 Project Land Location.....	خطأ! الإشارة المرجعية غير معرفة.
2.3.2 General climate of the city.....	20
2.3.3 Contour lines of the project land.....	20
2.3.4 Roads and Transport.....	20
2.4 Project components description.....	21
2.4.1 Project plans description.....	21
2.4.2 Project elevations description.....	24
2.4.3 Description of vertical section.....	28
3 Chapter 3: Structural description.....	29
3.1 Introduction.....	30
3.2 The purpose of structural design.....	30
3.3 Theoretical studies of the structural elements of the building.....	30
3.4 Types of loads.....	31

3.4.1	Dead Load. ....	31
3.4.2	Live Load.....	31
3.4.3	Environmental loads.....	32
3.4.3.1	Seismic load.....	32
3.4.3.2	Snow load.....	32
3.4.3.3	Wind load.....	33
3.5	Practical Tests.....	34
3.6	Structural elements.....	خطأ! الإشارة المرجعية غير معرّفة.
3.6.1	Slabs.....	خطأ! الإشارة المرجعية غير معرّفة.
3.6.1.1	One-way ribbed Slab and sold slab.....	خطأ! الإشارة المرجعية غير معرّفة.
3.6.2	Beams.....	خطأ! الإشارة المرجعية غير معرّفة.
3.6.3	Columns.....	خطأ! الإشارة المرجعية غير معرّفة.
3.6.4	Shear wall.....	خطأ! الإشارة المرجعية غير معرّفة.
3.6.5	Foundation.....	خطأ! الإشارة المرجعية غير معرّفة.
3.6.6	Stairs.....	خطأ! الإشارة المرجعية غير معرّفة.
3.7	Structural programs used.....	40
4	Chapter 4: Structural analysis and design.....	42
4.1	Introduction.....	43
4.2	Factored loads.....	43
4.3	Determination of thickness.....	43
4.3.1	Determination of one-way ribbed slab thickness.....	43
4.4	Design of Topping.....	خطأ! الإشارة المرجعية غير معرّفة.
4.5	Determination loads of ribs.....	خطأ! الإشارة المرجعية غير معرّفة.
4.6	Design of rib (06).....	خطأ! الإشارة المرجعية غير معرّفة.
4.6.1	Design of rib (06) for a max positive moment. ( $M_u = +15.1 \text{ KN.m}$ ) ..	خطأ! الإشارة المرجعية غير معرّفة.
4.6.2	Design of rib (06) for a max negative moment at the face of support. ( $M_u = -11.8 \text{ KN.m}$ ).....	50
4.2.3	Design of rib (06) for shear.....	51
4.7	Design of Beam (03).....	51
4.7.1	Determination Loads of beam (03).....	51
4.7.2	Design of beam (B03) for a maximum positive moment .....	54
4.7.3	The maximum shear force at the distance $d$ from the face of support for beam (03).....	خطأ!
	الإشارة المرجعية غير معرّفة.	

4.8.	Design of column (C8).....	56
4.8.1.	Check the Slenderness effect.....	56
4.8.2.	Calculation of Required Reinforcement Ratio.....	57
4.8.3.	Check spacing between the bars.....	57
4.8.4.	Determination of Stirrups Spacing.....	
4.9.	Design of Shear Wall.....	59
4.9.1.	Design of Horizontal Reinforcement.....	59
4.9.2.	Design of Vertical Reinforcement.....	60
4.9.3.	Design of Bending Moment.....	61
4.10.	Design of Basement Wall.....	62
4.10.1.	System and Loads.....	62
4.10.2.	Design of Shear Force.....	63
4.10.3.	Design of Wall Reinforcement.....	63
4.11.	Design of Basement Footing.....	64
4.11.1.	Check if footing width is correct.....	64
4.11.2.	Design of one way shear.....	65
4.11.3.	Design of Bending Moment.....	65
4.12.	Design of Isolated Footing (F4).....	66
4.12.1.	Determination of footing dimension (a).....	67
4.12.2.	Determination of footing depth (h).....	68
4.12.3.	Design of Punching (two way shear).....	68
4.12.4.	Design for flexure in long direction.....	69
4.12.5.	Design for flexure in short direction.....	69
4.12.6.	Design the Connection between Column & Footing.....	70
4.13.	Design of cantilever stair.....	72
4.13.1.	Calculation for each strip.....	72
4.13.2.	The calculation for Landing.....	74
5.	Chapter 5: Results and Recommendations.....	76
5.1.	Introduction.....	77
5.2.	Results.....	77
5.3.	Recommendations.....	77
	References.....	78

## List of Table

Table name	Page
Table (1.1): Time line table of the project stages.	17
Table (3.1): specific density of the materials used.	31
Table (3.2): Live Loads (Ref.: Jordan Code).	32
Table (3.3): Snow Loads (Ref.: Jordan Code).	33
Table (4.1):Table 9.5(a) - minimum thickness of nonprestressed beam or one-way slabs Unless deflections are calculated.	44
Table (4.2): Dead Load calculations for topping.	45
Table (4.3): Dead Load calculations for ribs.	46
Table (4.4): Dead Load calculations for beam (03).	51

## List of Figure

Figure name	Page
Figure 2.1: The location of project.	20
Figure 2.2: Basement floor	21
Figure 2.3: Ground floor	23
Figure 2.4: west elevation	24
Figure2.5: South elevation	25
Figure2.6: East elevation	26
Figure 2.7: North elevation	27
Figure 2.8: Sec A-A	28
Figure 3.0: inclination factor	33
Figure 3.1: Loads on the building	34
Figure 3.2: Load distribution	35
Figure 3.3: One-way ribbed slab	36
Figure 3.4: Solid slab	36
Figure 3.5: Hidden beam	37
Figure 3.6: Columns forms	37
Figure 3.7: Shear wall	38
Figure 3.8: load on footing	39
Figure 3.9: Shallow foundation	39
Figure 3.10: Stairs	39
Figure 4.1: moment diagram for topping	45
Figure 4.2: Rib (06) Geometry	47
Figure 4.3: Loading on Rib (06)	48

Figure 4.4: Moment and Shear Envelope of Rib (06)	48
Figure 4.5: Beam (03) Geometry	52
Figure 4.6: Loading on beam (03)	52
Figure 4.7: Moment and Shear Envelope of beam (03)	53
Figure 4.8 column (C8)	58
Figure 4.9 :Basement wall	62
Figure 4.10: Shear and moment diagram	63
Figure 4.11: Critical Section of Shear force	65
Figure 4.12: section in the basement wall and its footing	66
Figure 4.13: Critical Section of Shear Force	67
Figure 4.14: Punching Shear Critical Section	68
Figure 4.15: Reinforcement Details of footing	71
Figure 4.16: Dimension of stair	72
Figure 4.17: Load analysis on strip	72

## List of Abbreviations

<b>As</b>	Area Of Non-Prestressed Tension Reinforcement.
<b>As'</b>	Area Of Non-Prestressed Compression Reinforcement.
<b>Ag</b>	Gross Area Of Section.
<b>Av</b>	Area Of Shear Reinforcement Within A Distance (S).
<b>At</b>	Area Of One Leg Of A Closed Stirrup Resisting Tension Within A (S).
<b>b</b>	Width Of Compression Face Of Member.
<b>bw</b>	Web Width, Or Diameter Of Circular Section.
<b>d</b>	Distance From Extreme Compression Fiber To Centroid Of Tension Reinforcement.
<b>Ec</b>	Modulus Of Elasticity Of Concrete.
<b>fy</b>	Specified Yield Strength Of Non-Prestressed Reinforcement.
<b>h</b>	Overall Thickness Of Member.
<b>I</b>	Moment Of Inertia Of Section Resisting Externally Applied Factored Loads.
<b>ln</b>	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.
<b>M</b>	Bending Moment.
<b>Mu</b>	Factored Moment At Section.
<b>Mn</b>	Nominal Moment.
<b>S</b>	Spacing Of Shear Or In Direction Parallel To Longitudinal Reinforcement.
<b>Vc</b>	Nominal Shear Strength Provided By Concrete.
<b>Vn</b>	Nominal Shear Stress.
<b>Vs</b>	Nominal Shear Strength Provided By Shear Reinforcement.
<b>ρ</b>	Ratio Of Steel Area.
<b>εc</b>	Compression Strain Of Concrete=0.003mm /Mm
<b>Fsd,r</b>	Total Additional Tension Force Above The Support.
<b>Ved,0</b>	Shear Force At Critical Section.
<b>Vu</b>	Factored Shear Force At Section.
<b>Wu</b>	Factored Load Per Unit Length.
<b>Φ</b>	Strength Reduction Factor.

## **Abstract**

### **The structural design of apartment building in Hebron city**

**Palestine Polytechnic University**

**Supervisor: Enas Shweiki**

This project aims to design all structural elements that make up the building, such as slabs, beams, columns, walls, and foundations. The building consists of seven floors and a basement floor, this building contains facilities that fit the needs of the apartment building according to the appropriate requirements. This apartment building is characterized by includes several structural elements as a ribbed slab, beams, several columns, wall, and foundation.

The structural design of the building consists of many stages, starting with the studying and analyzing of architectural plans to select fit structural elements for the building that does not contradict the architectural design. Then determination of the live loads on the building according to the building use, and studying the earthquake loads according to the nature of the region in which the building is located. Finally, the design structure according to the calculated loads to occur the stability of the building also prepares the structural working drawing.

At end of the project, we have a completed design for all structural elements. Moreover, after finishing the structural design for this project we get a structural working drawing to start building.

## التصميم الإنشائي لمبنى سكني في مدينة الخليل

جامعة بوليتكنك فلسطين

إشراف: م. إيناس شويكي

يهدف هذا المشروع الى عمل التصميم الإنشائي المناسب لجميع العناصر الإنشائية المكونة للمبنى وتشمل العقدات، الجسور، الأعمدة، الجدران، والأساسات. يتشكل المبنى من سبعة طوابق وطابق تسوية، تحتوي داخلها على مرافق تتلاءم مع احتياجات المبنى السكني وفق المتطلبات الملائمة. يتميز هذا المبنى السكني بتنوع عناصره الإنشائية حيث يحتوي على عقدات مفرغة، جسور، العديد من الأعمدة، جدران، وأساسات.

عملية التصميم الإنشائي للمبنى تمر في عدة مراحل، بدءاً من دراسة وتحليل المخططات المعمارية، من ثم اختيار العناصر الإنشائية المناسبة لأجزاء للمبنى بشكل لا يتناقض مع التصميم المعماري. ويتبع ذلك دراسة وتحديد الأحمال الحية الواقعة على المبنى حسب طبيعة استخدامه. بالإضافة الى دراسة أحمال الزلازل وفقاً لطبيعة المنطقة المقام فيها المبنى ومن ثم التصميم الإنشائي المناسب لجميع العناصر وفقاً للأحمال المحسوبة بما يضمن ثبات المبنى، واعداد المخططات التنفيذية.

بعد الانتهاء من التصميم الإنشائي لعناصر هذا المبنى سيتم تصميم جميع العناصر الإنشائية للمبنى، والحصول على مخططات تنفيذية جاهزة للبدء بالعمل الميداني.

## **Chapter 1: Introduction**

- 1.1. Background.**
- 1.2. Aims and objectives.**
- 1.3. Problem statement.**
- 1.4. Literature review.**
- 1.5. Methodology.**
- 1.6. Project scope.**
- 1.7. Time plan.**

## **1.1. Background.**

Civil engineering 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, etc. The development of life requires mental development in design to achieve human requirements while ensuring all means of comfort and safety in these designs. In addition, the civil engineer is the one who designs and supervises the implementation of various projects, where his work is connected with human lives.

The project includes distributing columns, bridges in line with the architectural plan. And designing elements from the components to foundations for preparing a structural drawing in order to produce an integrated project.

## **1.2. Aims and objectives.**

1. The ability to choose the appropriate structural system that achieves the architectural goals in its implementation on the ground.
2. The ability to design various structural elements.
3. Conducting a process of application and setting the information that is taken in theory to the design on the ground.
4. Mastering the use of different design programs such as Ateer, Safe, and AutoCAD, and comparing them with the manual solution.
5. Recognizing new models and structural methods that we did not gain it during our studies, and knowing how to deal with them according to the need.

## **1.3. Problem statement.**

The problem centralized in the project analysis, architectural design and structural system of all sections of the buildings. Forces and loads of structural components, such as beams and columns, ribs, etc. will be analyzed in the project. Then the dimensions and the reinforcement of various structural elements will be determined.

## **1.4. Literature review.**

We considered some Previous graduation projects to take some knowledge that help preparing project, such as, “Structural Design of Al-Salam Hospital”,for students: Bara'a Tamimi, Lamia Melhem, Raghad Alhoor, Raghad Qabajah and the supervisor Eng. Fahed Salahat. In addition “Structural Design of Industrial Building”, for students: Ishaq Mah. Jweiles and Ma'moun Abu Rayyan and the supervisor Dr. Maher Amro where they are similar with our project that they contains multiple structural elements and different construction ideas. Also in the design methods.

Our project differs from these projects in the architectural design and in the distribution of loads on the building so it is different in the result.

### **1.5. Methodology.**

1. Studying and reviewing the architectural plans in order to ensure that they are completely correct in terms of architecture and ensure that it aligns with the project objectives, also modify the architectural plans if it needs.
2. Study the structural elements that make up the building to distribute these elements such as columns, beams, and ribs.
3. Select the appropriate structural system and then analyze the structural elements and the loads affecting them, in a way that is consistent with the architectural design and achieves the economic aspect and the safety factor.
4. Designing the structural elements based on the results of the analysis.
5. Use of design software such as Ateer, Safe, etc.
6. Preparing the structural working drawing for the structural elements that have been designed to finish the project.

### **1.6. Project scope.**

This project contains several chapters that are detailed as follows:

Chapter One: a general introduction to the project.

- Chapter Two: includes a description of the architectural project.
- Chapter Three: contains a description of the structural elements of the project.
- Chapter Four: Analysis and structural design of all structural elements.
- Chapter Five: The results that have been reached and recommendations.

### **1.7. Time plan.**

This project is limited to the construction aspect, as the work will be implemented during the first and second semesters of the 2021-2022 academic year through the introduction of the graduation project in the first semester and the graduation project in the second semester.

Table 1.1 below shows the timeline table of the project stages.

**Table1.1: Time line table of the project stages.**

Week NO. Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	
Select project	■	■	■	■																													
Inception report					■	■	■	■																									
Collect information about the project								■	■																								
Architectural study of the building										■	■	■	■																				
Structural study of the building												■	■	■																			
Prepare the introduction															■	■																	
Display the introduction																■																	
Structural analysis																	■	■	■	■	■	■											
Structural design																		■	■	■	■	■	■										
Prepare the project plans																										■	■	■	■	■			
Write the project																														■	■	■	■
Project presentation																																	■

## **Chapter 2: Architectural description**

- 2.1. Introduction.**
- 2.2. Basic identification of project.**
- 2.3. Project site.**
  - 2.3.1. Project land location.**
  - 2.3.2. General climate of the city.**
  - 2.3.3. Contour lines of the project land.**
  - 2.3.4. Roads and transport.**
- 2.4. Project components description.**
  - 2.4.1. Project plans description.**
  - 2.4.2. Project elevations description.**
  - 2.4.3. Description of vertical section.**

## **2.1. Introduction**

The soul of architecture is to design a structure that is suitable for humans to live in, work in, play in, etc. It is also to give comfort to its residents in order to make them feel comforted, uplifted, and feel that the structure is designed to appeal their requirements of leisure and enjoyment.

Architectural description is the most important things that should be consider when preparing for any project because of its importance in defining and understanding the nature of the project and its sections. Architectural design requirements must meet the desired job and human needs at the same time, it is important in these conditions are interact between each other with a harmony to achieve the vision of optimal design and get an integrated and comprehensive architectural design. This is achieved by understanding the functional demands of the building and space as well as taking into account nature movement of each part of the project.

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

## **2.2. Basic Identification of Project.**

The idea of the project is the structural design of an apartment building. This building consists of recurrent seven floors and a barking in basement floor. With a total area of 3719 m<sup>2</sup>. This building contains rooms that meet the needs of the residents.

## **2.3. Project site.**

It is recommended that you pursue land that has already been approved by the local authorities as an “approved building lot”. That means all of the surveys, soil testing, wetlands conservation, and site-engineering work have been completed and approved.

For the design of any project, it is necessary to study the site in which the building is to be constructed very carefully, whether it is related to the geographical location or the impact of climatic forces in the area. In order to achieve the optimal design, a general idea of the site elements must be given, such as explaining the dimensions and the coordinates points of the proposed land for construction, the site’s relationship with the surrounding streets and services, the height of the nearest buildings, the direction of the prevailing winds, the path of the sun and noise.

The area land of this project is about 1250m<sup>2</sup>.

### **2.3.1. Project Land Location.**

The project is located in Namerh in north of Hebron. The figure2.1 show the location of project.

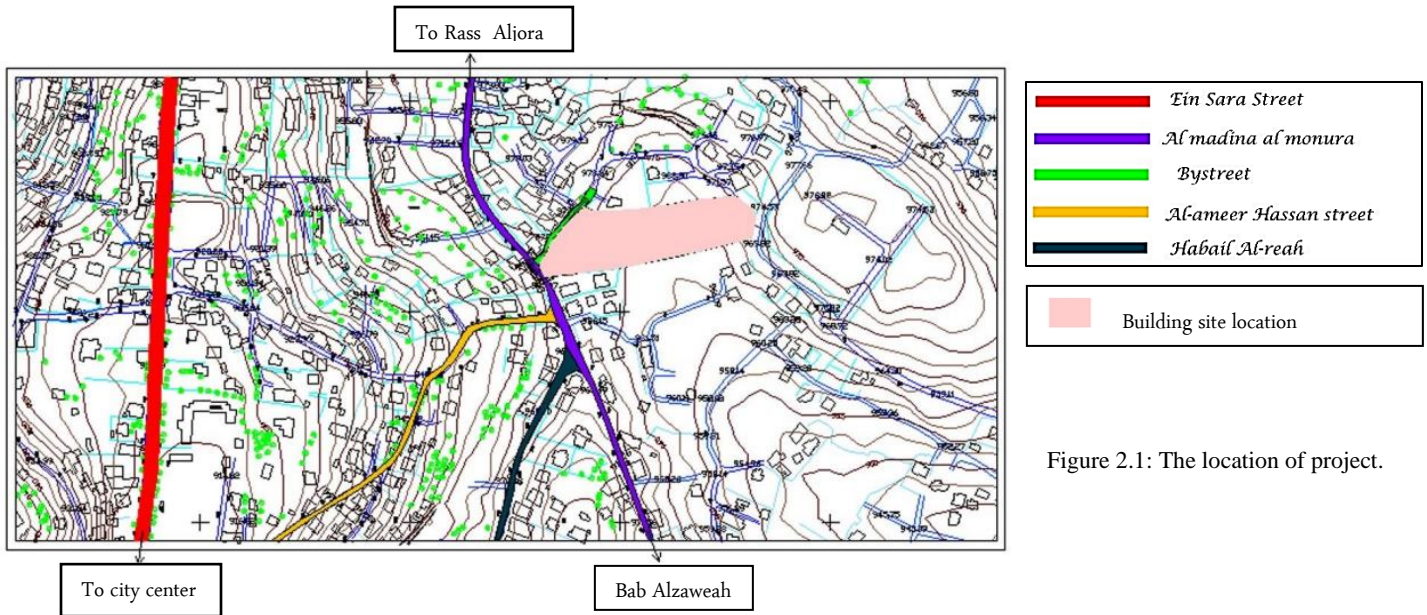


Figure 2.1: The location of project.

### 2.3.2. General climate of the city.

This area generally enjoys a Mediterranean Climate of a dry summer and mild, rainy winter with occasional snowfall. The recorded average of Hebron's rainfall is about 750 mm (26 in). While the western and southwestern winds dominate, the northern winds are light and the eastern winds still blow on occasion. In addition, the average humidity in the city is up to 60%.

### 2.3.3. Contour lines of the project land.

- The project land is semi flat area.
- The project land is 970 m above sea level.

### 2.3.4. Roads and Transport.

The project site of the active sites in Hebron and the advantage is easily accessible by public transport. Where are accessing the site through several streets.

## 2.4. Project components description.

The project consists of eight floors with residential usage, and contains multiple facilities. The architectural distribution of the building is clear and consistent between the floors, which facilitated the structural design process of the project.

### 2.4.1. Project plans description.

The total area of the building is 3719 m<sup>2</sup>.

#### a) Basement Floor Plan.

The area of this floor is 471 m<sup>2</sup>, and it contains a car parking as shown in the figure( 2.2). Also, the level of the plan is (-2.42m) under the ground level.

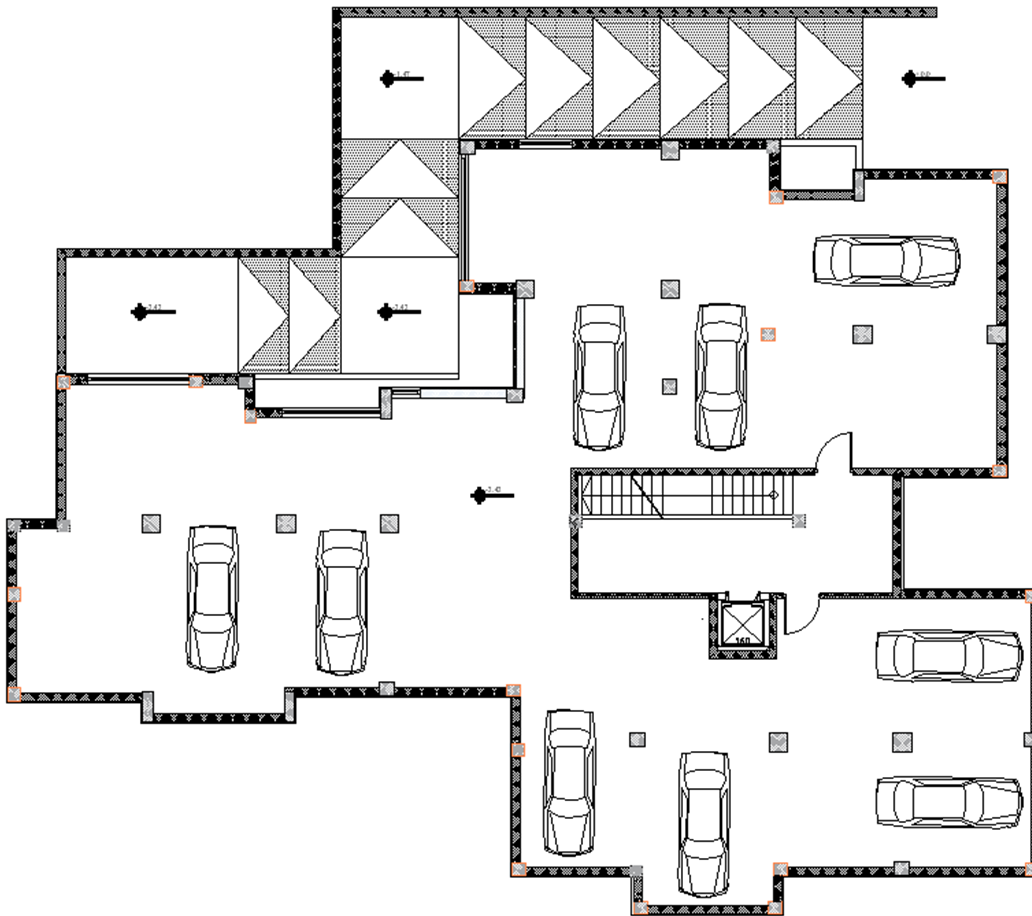


Figure 2.2: Basement floor

b) Ground floor.

This floor is recurrent in the other six floors.

The area of the floor is  $464\text{m}^2$ , it has three apartments. Every one of them has an area  $140\text{m}^2$ .and each one contains three bedrooms, kitchen, hall, guest room, Dining room, two bathroom, and one WC as shown in figure2.3.

Levels of floor:

- Ground floor +3.76 m
- First floor +7.04m
- Second floor +10.32m
- Third floor +13.60m
- Fourth floor +16.88m
- Fifth floor +20.16m
- Sixth floor +23.44m

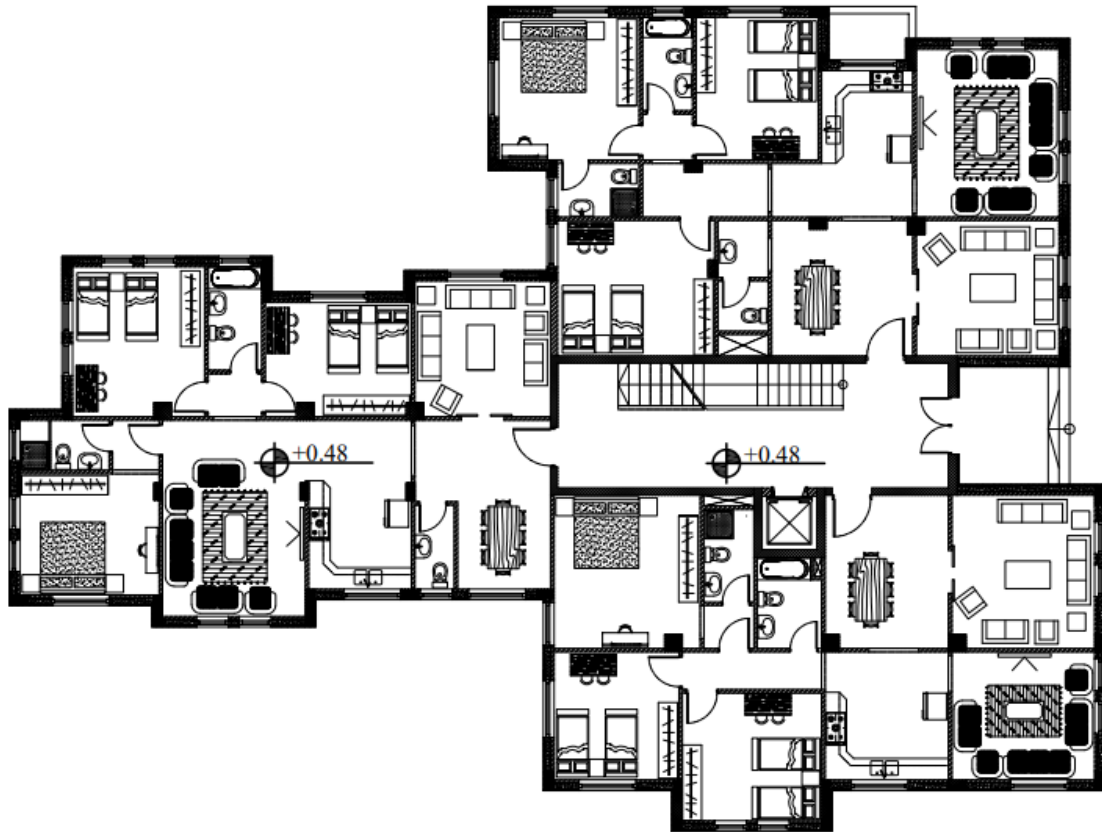


Figure 2.3: Ground floor

## 2.4.2. Project elevations description.

### a. West elevation.

The main elevation and the main entrance of the building, we can observe the beauty of this elevation that contains a variety of materials, as shown in figure2.4

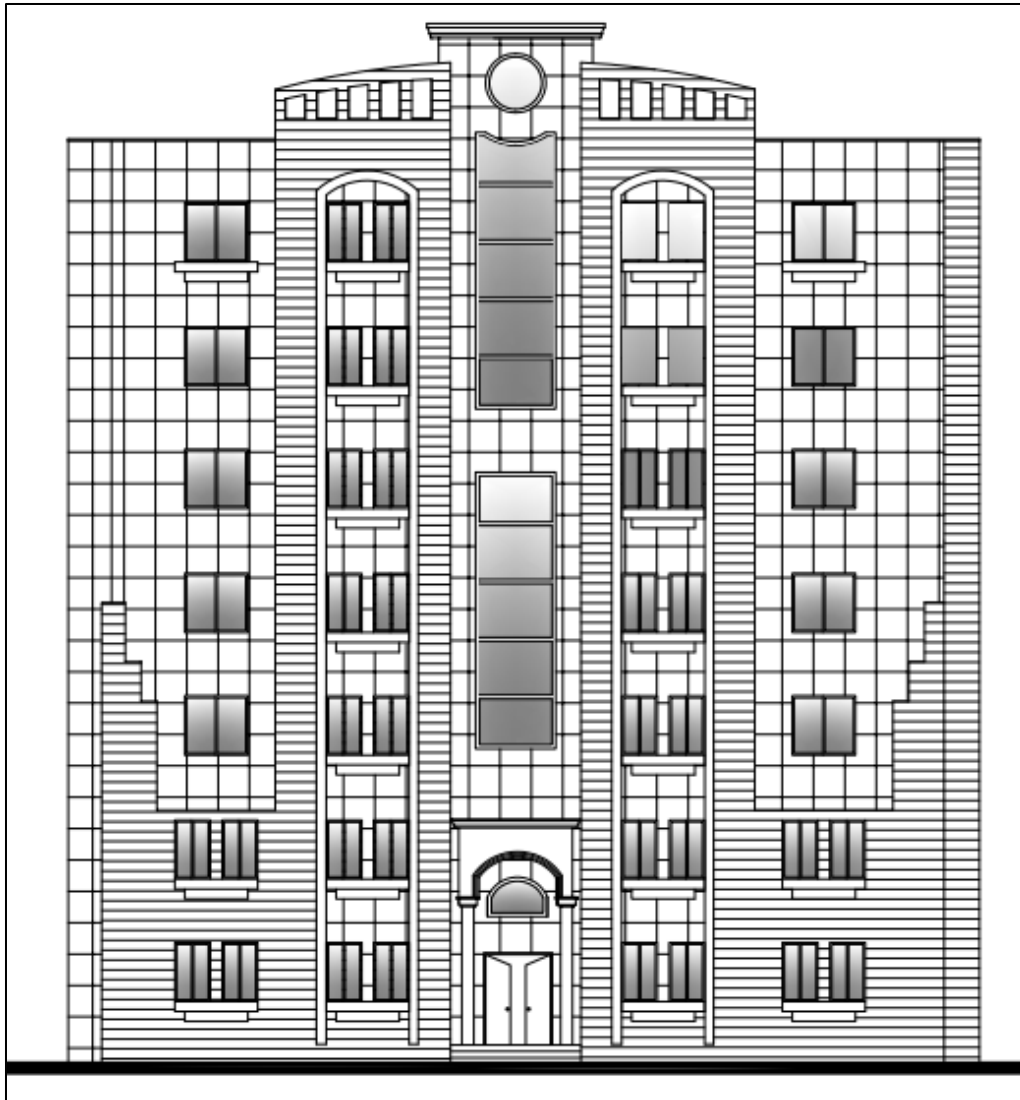


Figure 2.4: west elevation

b. South elevation.

This elevation shows the entrance to the basement floor, as shown in figure2.5



Figure2.5: South elevation

c. East elevation.

This elevation shows the inclination of the road, and we can observe some part of the basement floor, and this elevation shows some of the columns, as shown in figure2.6.



Figure2.6: East elevation

d. North elevation.

The back-side elevation, in this elevation we can note in this interface using glass in abundance, which gave it a nice look and use a variety of materials as shown in figure 2.7.



Figure 2.7: North elevation

### 2.4.3. Description of vertical section.

The designer distributed the movement through the horizontal and vertical axes through stairs and corridors, according to the number of users and the allowable distance between each vertical axis for easy movements between the floors and to facilitate exiting in case of emergency. Figure(2.8 )shows that.



Figure 2.8: Sec A-A

## **Chapter 3: Structural description.**

### **3.1. Introduction.**

### **3.2. The purpose of structural design.**

### **3.3. Theoretical studies of the structural elements of the building.**

### **3.4. Types of loads.**

#### **3.4.1. Dead load.**

#### **3.4.2. Live load.**

#### **3.4.3. Environmental loads.**

##### **3.4.3.1. Seismic load.**

##### **3.4.3.2. Snow load.**

##### **3.4.3.3. Wind load.**

### **3.5. Practical Tests.**

### **3.6. Structural elements.**

#### **3.6.1. Slabs.**

##### **3.6.1.1. One-way ribbed and Solid Slab.**

#### **3.6.2. Beams.**

#### **3.6.3. Columns.**

#### **3.6.4. Shear wall.**

#### **3.6.5. Foundation.**

#### **3.6.6. Stairs.**

### **3.7. Structural programs used.**

### **3.1. Introduction.**

After completing the process of the architectural project explanation of all the details, we must move to the construction phase of the project to choose the appropriate structural system for each element in the building. In order to provide all requirements and design all elements that are necessary for the system.

As structural design mainly depends on the design of all structural elements, so that resist all loads that affect them. Therefore must all these elements describe an accurate description, meet the engineering calculations for the project requirements, as well as to maintain the architectural design without changes.

### **3.2. The purpose of structural design.**

The purpose of structural design is to find the building is available where all safety requirements, in order to resist all the forces that affect the building in different forms, such as dead loads and live load, also the external forces such as earthquakes, wind, and landing in the soil.

When designing any element of these it should be taken into consideration the following standers:

1. **Safety:** is the essential element that must be provided in the design. It is achieved by selecting structural sections able to withstand the forces and stresses resulting therefrom.
2. **Economy:** when working start it must be a selection of appropriate materials that sufficient for its desired purpose and appropriate quantity with the lowest cost and highest quantity.
3. **Serviceability:** in terms of avoiding any external failures, such as the soil settlement, also any cracks in the external shape or anything that works to increase this failure.
4. **Architectural side:** work to take into account the architectural elements in the building and try to keep it as much as possible.

### **3.3. Theoretical studies of the structural elements of the building.**

The most important step that should be done before starting the structural design, is working on a comprehensive study of the project in terms of its size the nature of its work. In addition, how to estimate the loads that affect the building then choose items that are exposed to these loads and identify a system construction which is used to resist these loads.

### 3.4. Types of loads.

Loads are the base of the design process, so they must have great consideration, identifying and studying accurately. All structural elements must be designed to be able to carry loads without incident by a collapse of these facilities the load difference from one building to another depends on the architectural design, project site, materials used in construction, and other influences.

Therefore, loads can be classified as follow:

#### 1. Basic loads:

The loads that must be taken into account in the structural design of the building in all cases include Dead load, Live load, and Environmental loads.

#### 2. Secondary loads:

The loads that should be taken into account in the design in some buildings, depending on the nature of the building and other influences, include Shrinkage load, Thermal load, Snows load, Dynamic load, Seismic load.

#### 3.4.1. Dead Load.

Also known as permanent loads. The dead load includes loads that are relatively constant over time in the building, a fixed amount and direction. . Its loads are caused by the weight of the building, which consists of weights of building materials used. Which include all the structural elements and fixtures.

As regard to the specific gravity of the materials used is as follows in the table (3.1).

**Table (3.1): specific density of the materials used.**

<b>No#</b>	<b>Materials</b>	<b>Density KN\m<sup>3</sup></b>
<b>1</b>	Tiles	23
<b>2</b>	Mortar	22
<b>3</b>	Sand	17
<b>4</b>	Plaster	22
<b>5</b>	Hollow block	10
<b>6</b>	Reinforcement concrete	25
<b>7</b>	Partitions	2.3 KN/m <sup>2</sup>

#### 3.4.2. Live Load.

Live load is imposed temporary loads, of short duration, or moving. It loads affecting the buildings and construction because of their different uses. Which include:

- Weights of people users,
- Dynamic loads, such as devices, which give rise to vibrations, affect the building.
- Static loads, which can change their place from time to time, such as houses furniture and appliances and the stored material, furniture, appliances, and equipment.

Table (3.2) shows the value of live loads depending on the quality of use of the building for an apartment building by the Jordanian code.

**Table (3.2): Live Loads (Ref.: Jordan Code).**

<b>No#</b>	<b>Use</b>	<b>Density KN\m<sup>3</sup></b>
<b>1</b>	Bedrooms	2
<b>2</b>	Bathrooms	2
<b>3</b>	Sitting room and dining room	2
<b>4</b>	Kitchen	3
<b>5</b>	Stairs	3

### **3.4.3. Environmental loads.**

The loads arise from the changes in the environment and from natural sources, such as seismic, snow, and wind.

#### **3.4.3.1. Seismic load.**

Loads are caused by earthquakes. Buildings should be designed to withstand minor earthquakes because they can occur almost anywhere. During earthquakes, the ground can move both horizontally and vertically in any direction. This exerts tremendous horizontal loads on members. We use the UBC code to determine the earthquake load.

#### **3.4.3.2. Snow load.**

The building must be designed to resist snow loads and to be taken into account design and it depends on the height of the building and the area of this building.

The following table shows the relationship between the height of the building and the carry snow that we take him in the case of design.

**Table (3.3): Snow Loads (Ref.: Jordan Code).**

<b>Building height above sea level</b>	<b>The value of load in surface (KN/m<sup>2</sup>)</b>
$250 > h$	0
$500 > h > 250$	$(h-250)/800$
$1500 > h > 500$	$(h-400)/320$
$2500 > h > 1500$	$(h-812.5)/250$

According to the previous table (3.3), the snow load is calculated as:

The project land is 970 m above sea level so use:

$$(h-400)/320 = (970-400)/320 = 1.78 \text{ KN/m}^2$$

The inclination factor for building equals zero.

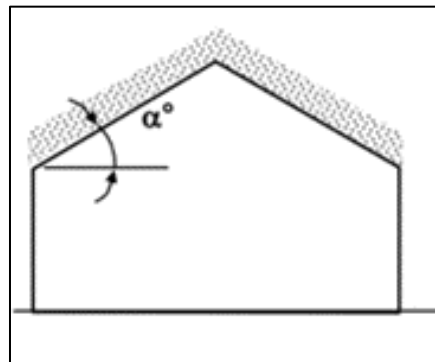


Figure 3.0: inclination factor

### **3.4.3.3. Wind load.**

The forces that affect horizontally on the building appear especially in high-rise buildings, and it is designed based on wind speed and height of the building, and the number of buildings surrounding the building.

Figure 3.1 shows the load component's effect on the building.

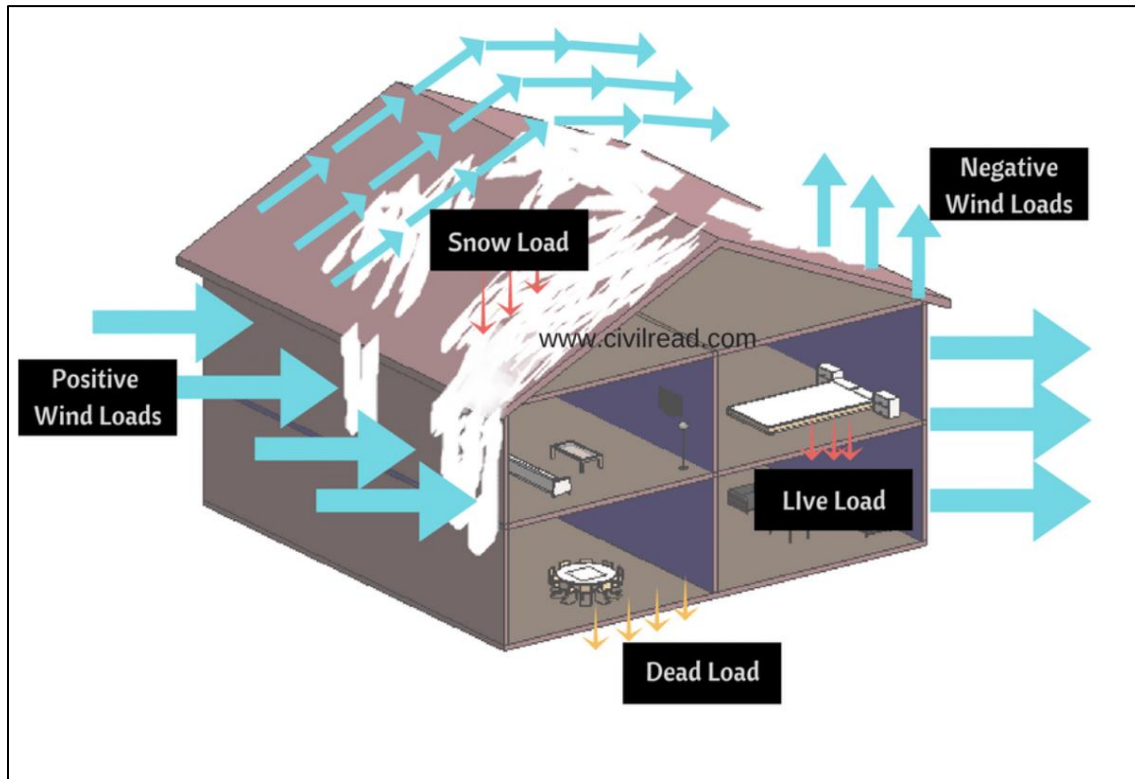


Figure 3.1: Loads on the building

### 3.5. Practical Tests.

Before you begin the process of design and construction, should work on some of the necessary tests at the site

Geotechnical studies for the site means by all businesses that have a relationship to explore the site and study the soil, rock, and groundwater, and analysis of information and translate it to predict the way the soil behavior when built upon. In addition, more what concerns structural engineer is to get the durability of the soil (Bearing Capacity) by the soil tests necessary for the design of the foundations of the building.

### 3.6. Structural elements.

All buildings usually consist of a set of structural elements that work together to maintain the continuity of a building and its suitability for human use. Moreover, the most important elements of these are slabs, beams, columns, stairs, shear walls, and foundation, etc.

All the structural elements operate as a single unit, where loads are passed from slab to the beam and then to the bearing walls or columns to finally end to the foundation, the following figure3.2 describes how the load distributions between structural elements.

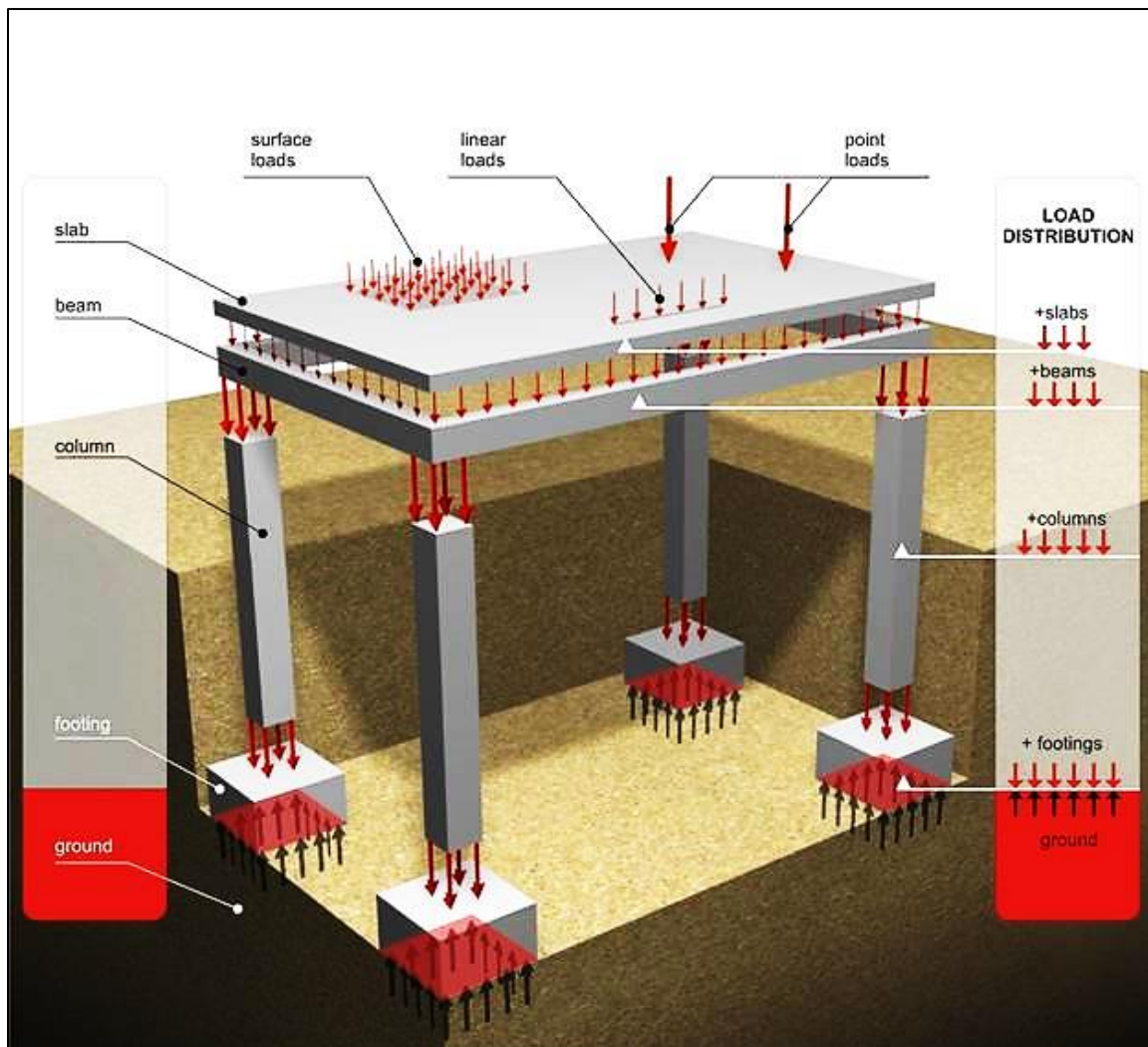


Figure 3.2: Load distribution

### 3.6.1. Slabs.

Slabs are structural members forming floors and roofs in buildings. Also, the slabs are elements that transfer the loads that are exposed to other structural elements such as columns, beams, walls. They may be solid of uniform thickness or ribbed with ribs running in one direction or two directions.

Many factors affect to select of the type of slabs such as:

- The distance between the spaces and columns.
- The desired function of the space.
- Cost.
- Ease of implementation and duration available for building.
- 

#### 3.6.1.1. One-way ribbed Slab and sold slab.

##### Ribbed Slab:

It consists of a row of brick, followed by rib, and a reinforcement in one direction as showmen in figure 3.3. Also introducing voids to the soffit of a slab reduces dead weight and increases the efficiency of the concrete section. A slightly deeper section is required, but these stiffer floors facilitate longer spans and provision of holes.

##### Soled Slab:

We use this method when the height of the spaces is important, and we do not have a problem when showing the drop beam and this transfers the load from the beam to the column. See figure3.4

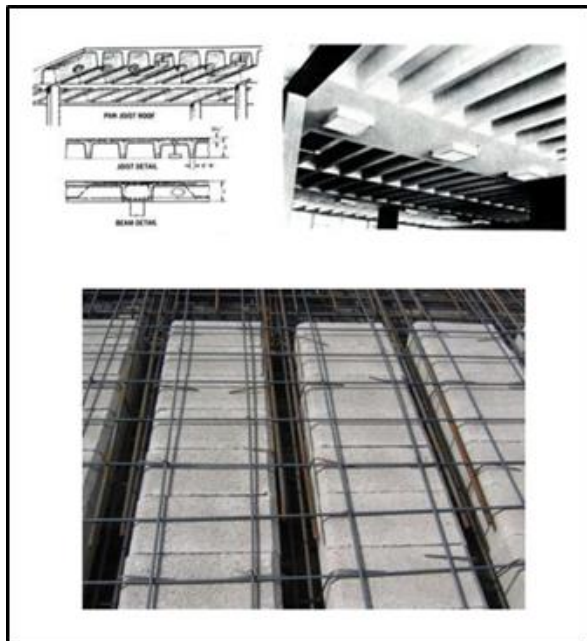


Figure 3.3: One-way ribbed slab

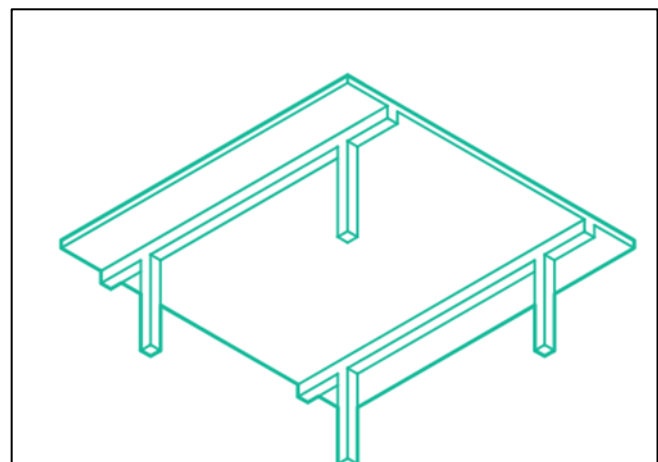


Figure 3.4: Sold slab

### 3.6.2. Beams.

The primary purposes of beam structure include resisting and uniformly distributing loads, uniting the structure together. Also, it is the element that uses to transfer the load from the slab to the column. There are two types of beams:

- Hidden Beam: hidden inside slabs with the same thickness of the slab. As in figure 3.5
- Dropped Beam: with different thicknesses of the slab.

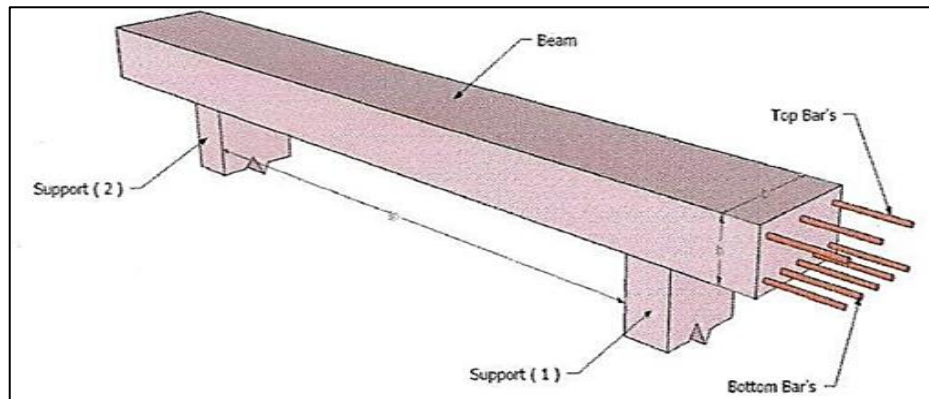


Figure 3.5: Hidden beam

### 3.6.3. Columns.

Columns are considered key members of the transport loads from slabs and beams to foundations, and so it is a structural element necessary for the transfer of loads and the stability of the building. Therefore, it must be designed to be capable of carrying and distributing loads located on them. The columns have many forms, including rectangular and circular and polygon and square, as shown in figure 3.6. Also, there are two types of columns design: short and long (slender) columns.

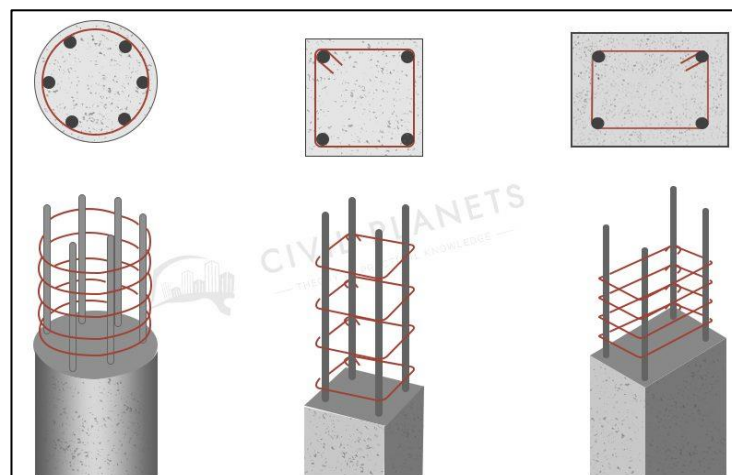


Figure 3.6: Columns forms

### 3.6.4. Shear wall.

Shear wall is an important element of structure because it is used to resist the vertical and horizontal load; Shear wall is a type of structural system that provides lateral resistance to the building or structure. It resists loads as the wind and earthquake. When designing this wall, we use two-layer steel to give it more strength. Figure 3.7 shows a shear wall.

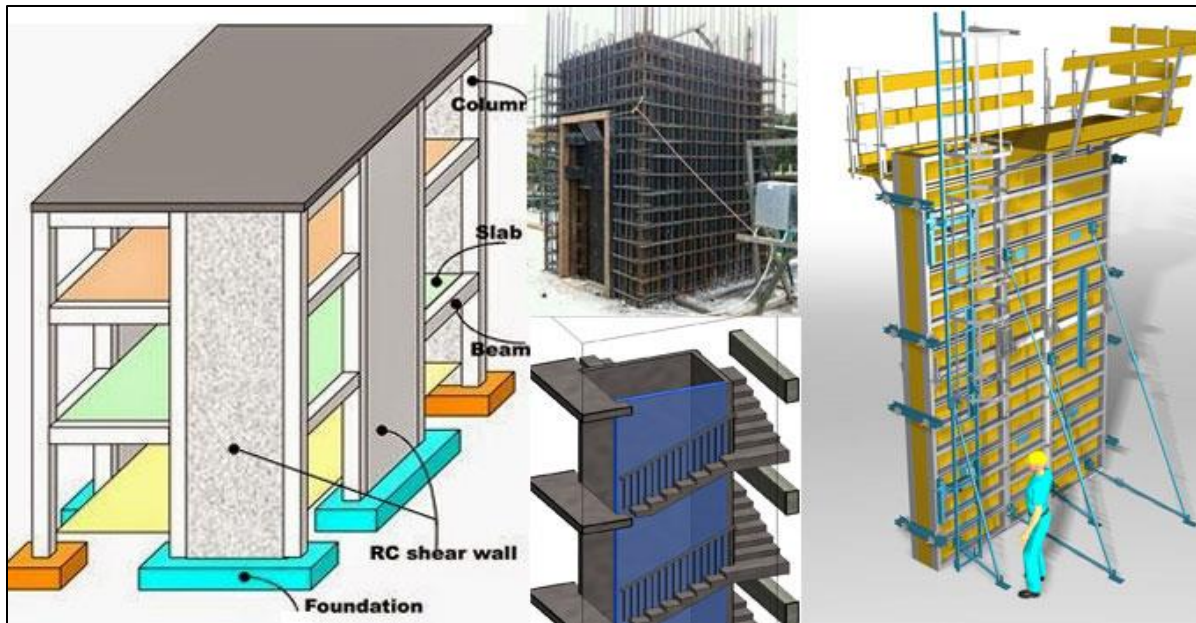


Figure 3.7: Shear wall

### 3.6.5. Foundation.

The foundations are the link between the structural elements in the building and the earth. It is the first element we implemented on the ground but is the last element we design because all loads are transmitted to it whether the basic load is dead or live load or secondary load. Therefore, it is the basic element, which receives all the loads and distributed them to the soil. Figure 3.8 shows that.

In general, all foundations are divided into two categories, shallow and deep foundations. As the shallow foundation depth is low and it is economical, it is the most popular type of foundation for lightweight structures. Some of the types the shallow foundations are isolated footing, strip footing, and combined footing, Figure 3.9 shows this types.

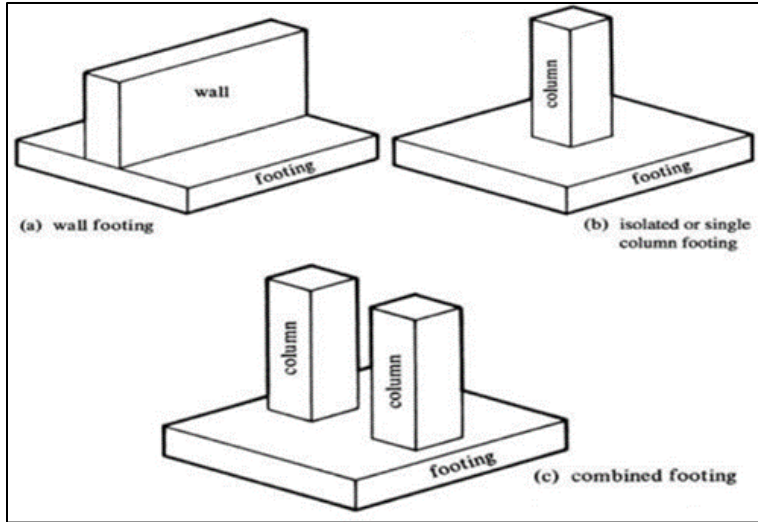


Figure 3.9: Shallow foundation

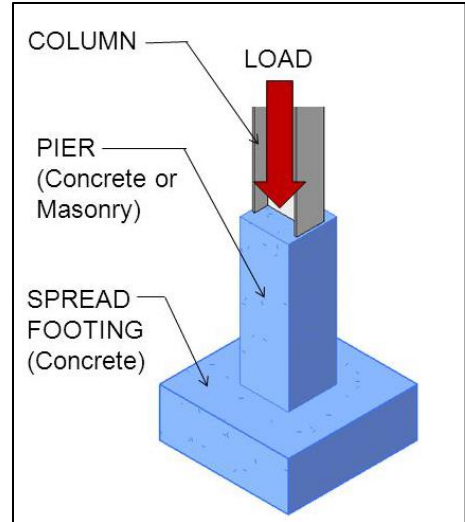


Figure 3.8: load on footing

### 3.6.6. Stairs.

Is responsible for vertical transmission between the classes in the building element, where the floor is divided into small high-altitude representing the height of steps. The stairs design usually as one-way solid slabs. The figure 3.10 shows a stairs.

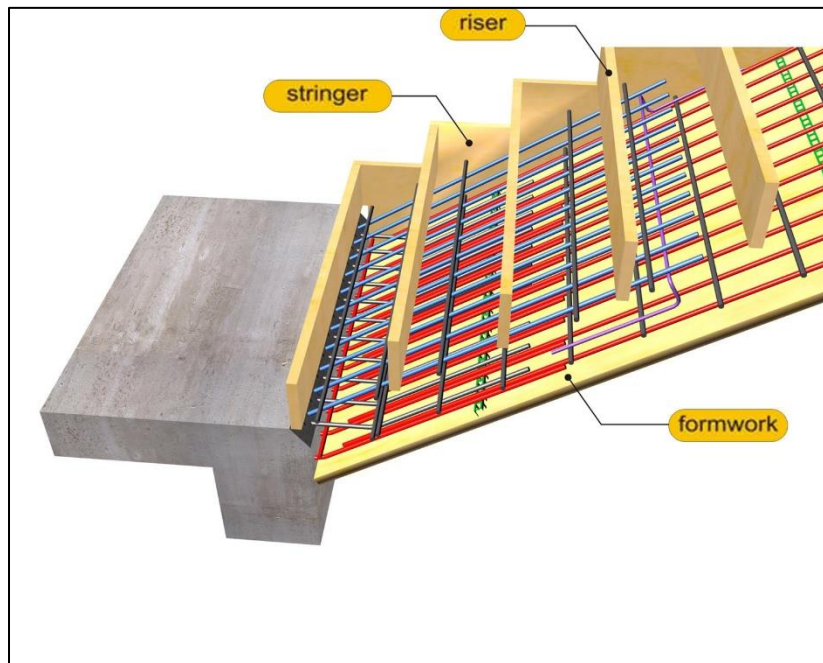


Figure 3.10: Stairs

### **3.7. Structural programs used.**

- AutoCAD 2018 for Structural and Architectural Drawings.
- Microsoft Office word 2010 For Text.
- Microsoft Office Excel (2010).
- Atir18.

## **Chapter 4: Structural analysis and design.**

- 4.1. Introduction.**
- 4.2. Factored loads.**
- 4.3. Determination of thickness.**
  - 4.3.1. Determination of one-way ribbed slab thickness.**
- 4.4. Design of Topping.**
- 4.5. Determination loads of ribs.**
- 4.6. Design of rib (06).**
  - 4.6.1. Design of rib (06) for a max positive moment.**
  - 4.6.2. Design of rib (06) for a max negative moment.**
  - 4.6.3. Design of rib (06) for shear.**
- 4.7. Design of Beam (03).**
  - 4.7.1. Determination Loads of beam (03).**
  - 4.7.2. Design of beam (03) for a maximum positive moment.**
  - 4.7.3. The maximum shear force at the distance  $d$  from the face of support for beam (03).**
- 4.8. Design of column (C8).**
  - 4.8.1. Check the Slenderness effect.**
  - 4.8.2. Calculation of Required Reinforcement Ratio.**
  - 4.8.3. Check spacing between the bars.**
  - 4.8.4. Determination of Stirrups Spacing.**
- 4.9. Design of Shear Wall.**
  - 4.9.1. Design of Horizontal Reinforcement**
  - 4.9.2. Design of Vertical Reinforcement**
  - 4.9.3. Design of Bending Moment**
- 4.10. Design of Basement Wall.**
  - 4.10.1. System and Loads**
  - 4.10.2. Design of Shear Force**
  - 4.10.3. Design of Wall Reinforcement**
- 4.11. Design of Basement Footing.**
  - 4.11.1. Check if footing width is correct**
  - 4.11.2. Design of one way shear**
  - 4.11.3. Design of Bending Moment**

**4.12. Design of Isolated Footing (F4).**

**4.12.1. Determination of footing dimension (a)**

**4.12.2. Determination of footing depth (h)**

**4.12.3. Design of Punching (two way shear)**

**4.12.4. Design for flexure in long direction**

**4.12.5. Design for flexure in short direction**

**4.12.6. Design the Connection between Column & Footing**

**4.13. Design of cantilever stair.**

**4.13.1. Calculation for each strip**

**4.13.2. The calculation for Landing**

## 4.1. Introduction.

Concrete is the only major building material that can be delivered to the job site in a plastic state. This unique quality makes concrete desirable as a building material because it can be molded to varied shape.

Concrete used in most construction work is reinforced concrete that is a logical union of two materials: plain concrete, which possesses high compressive strength but little tensile strength, and steel bars embedded in the concrete, which can provide the needed strength in tension. Steel is embedded in the concrete in the form of a mesh or roughened or twisted bars. So a bond forms between the steel and the concrete, and stresses can be transferred between both components.

Understanding of reinforced concrete behavior is still far from complete, building codes and specifications that give design procedures are continually changing to reflect the latest knowledge.

In This Project, there is a one-way ribbed slab. It would be analyzed and designed by using the finite element method of design, with aid of a Software Program called “ATTIR” to find the internal forces, deflections, and moments for ribbed slabs. The design strength provided by a member, its connections to other members, and its cross-sections in terms of flexure, and load, and shear is taken as the nominal strength calculated in accordance with the requirements and assumptions of ACI-code.

Note:

- Concrete B300, ( $f_c = 24$  MPa for rectangular section).
- The specified yield strength of the reinforcement, ( $f_y = 420$  MPa).

## 4.2. Factored loads.

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 structural members, is determined as follows:

$$Q_u = 1.2DL + 1.6L \quad - \text{(ACI - 318 - 14(9.2.1))}$$

## 4.3. Determination of thickness.

### 4.3.1. Determination of one-way ribbed slab thickness.

The minimum thickness of one-way slabs using grade 420 steel can be defined according to the ACI Code, 9.5.2.1, Table 9.5a, for solid slabs and for beams or ribbed one-way slabs.

**Table 4.1: Table 9.5(a) - minimum thickness of nonprestressed beam or one-way slabs unless deflections are calculated.**

	Minimum thickness, $h$			
	Simply supported	One end continuous	Both ends continuous	Cantilever
Member	Members not supporting or attached to partitions or other construction likely to be damaged by large deflections			
Solid one-way slabs	$l/20$	$l/24$	$l/28$	$l/10$
Beams or ribbed one-way slabs	$l/16$	$l/18.5$	$l/21$	$l/8$

The minimum thickness of one way ribbed slab is computed as follow:

**For ribs:**

- The maximum span length for one- end continuous:

$$h_{\min} = L / 18.5 = 459 / 18.5 = 24.8 \text{ cm}$$

- The maximum span length for both -end continuous:

$$h_{\min} = L / 21 = 446 / 21 = 21.24 \text{ cm}$$

- The maximum span length for simply supported:

$$h_{\min} = L / 16 = 415 / 16 = 25.9 \text{ cm}$$

**For beams:**

- The maximum span length for one- end continuous:

$$h_{\min} = L / 18.5 = 538.7 / 18.5 = 29.1 \text{ cm}$$

- The maximum span length for both -end continuous:

$$h_{\min} = L / 21 = 410 / 21 = 19.5 \text{ cm}$$

The maximum span length for simply supported:

- $h_{\min} = L / 16 = 425 / 16 = 26.56 \text{ cm}$

- Take ribbed slab thickness  $h=28\text{cm}$ . (deflection will be checked)
- $h =28\text{cm}$  (2cm Hollow block + 8cm Topping).

#### 4.4. 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.

Dead Load calculations:

**Table 4.2: Dead Load calculations for topping**

Dead Load from	$\gamma * \delta * 1$	KN/m
Tiles	$0.03 * 23 * 1$	0.69
Mortar	$0.03 * 22 * 1$	0.66
Coarse Sand	$0.07 * 17 * 1$	1.19
Topping	$0.08 * 25 * 1$	2.0
Interior Partitions	$2.3 * 1$	2.3
sum		6.84

Live Load calculations:  $2 * 1 = 2 \text{ KN/m}$ .

Total Factored Load:

$$W_u = 1.2DL + 1.6LL = (1.2 * 6.84) + (1.6 * 2) = 11.41 \text{ KN/m}.$$

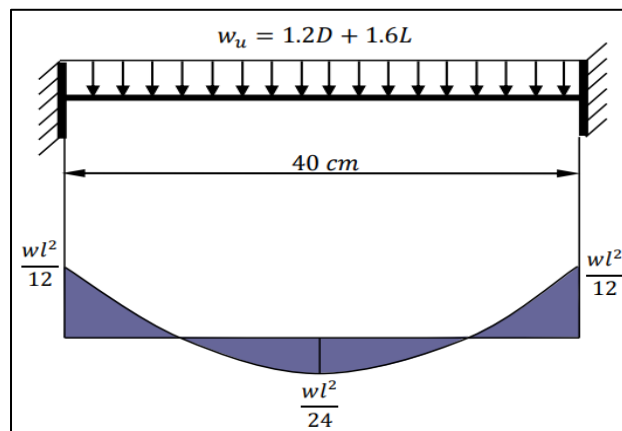


Figure 4.2: moment diagram for topping

$$M_u = \frac{W_u * l^2}{12} = \frac{11.41 * 0.4^2}{12} = 0.152 \text{ KN. m /m strip width.}$$

$\Phi M_n > M_u$  - [Strength Condition, where  $\Phi = 0.55$ ] for plane concrete.

$$\Rightarrow M_n = 0.42 \times \sqrt{f_c'} S_m \quad \text{ACI-318-14 (22-5.1)}$$

$$\Rightarrow S_m = \frac{b \cdot h^2}{6} = \frac{1000 \cdot 80^2}{6} = 1066666.67 \text{ mm}^2$$

$$\Rightarrow \Phi M_n = 0.55 \cdot 0.42 \cdot \sqrt{24} \cdot 1 \cdot 1066666.67 \cdot 10^{-6} = 1.207 \text{ KN.m}$$

$$\Phi M_n = 1.207 \text{ KN.m} > M_u = 0.152 \text{ KN.m}$$

No reinforcement required by analysis. According to ACI 10.5.4, provide  $A_{(s, \min)}$  for slabs as shrinkage and temperature reinforcement.

$$\rho = 0.0018$$

$$\Rightarrow A_s = \rho \cdot b \cdot h = 0.0018 \cdot 1000 \cdot 80 = 144 \text{ mm}^2 \text{ m /strip.}$$

Try  $\emptyset 8$  with  $A_s = 50.27 \text{ mm}^2$

$\Rightarrow$  Step (s) is the smallest of:

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

Take  $\emptyset 8 @ 200 \text{ mm}$  in both direction,  $S = 200 \text{ mm} < S_{\max} = 240 \text{ mm} \dots \text{OK}$

#### 4.5. Determination loads of ribs.

**Table 4.3: Dead Load calculations for ribs.**

Dead Load from	$\gamma \cdot \delta \cdot b$	KN/m
Tiles	$0.03 \cdot 23 \cdot 0.52$	0.359
Mortar	$0.03 \cdot 22 \cdot 0.52$	0.343
Coarse Sand	$0.07 \cdot 17 \cdot 0.52$	0.619
Topping	$0.08 \cdot 25 \cdot 0.52$	1.04
RC Rib	$0.17 \cdot 25 \cdot 0.12$	0.51
Hollow Block	$0.17 \cdot 10 \cdot 0.4$	0.68
Plaster	$0.03 \cdot 22 \cdot 0.52$	0.343
Interior Partitions	$2.3 \cdot 0.52$	1.196
sum		5.09

$$LL = 2 \cdot 0.52 = 1.04 \text{ KN/m.}$$

**So the load on rib:**

DL/rib= 5.09 KN/m.

LL/rib= 1.04 KN/m.

**The effective flange width ( $b_e$ ) According to ACI 8.12.2:**

$b_e$  is the smallest of:

a.  $b_e \leq L/4 = 3100/4 = 755 \text{ mm.}$

(L= the smallest clear span)

b.  $b_e \leq b_w + 16hf = 120 + (16 \cdot 80) = 1400 \text{ mm.}$

c.  $b_e \leq \text{Center to center spacing between adjacent beams} = 400 + 120 = 520 \text{ mm} \dots\dots\dots \mathbf{control}$

**4.6. Design of rib (06).**

By using BEAMD program, we get the envelope moment and shear diagram as the follows:

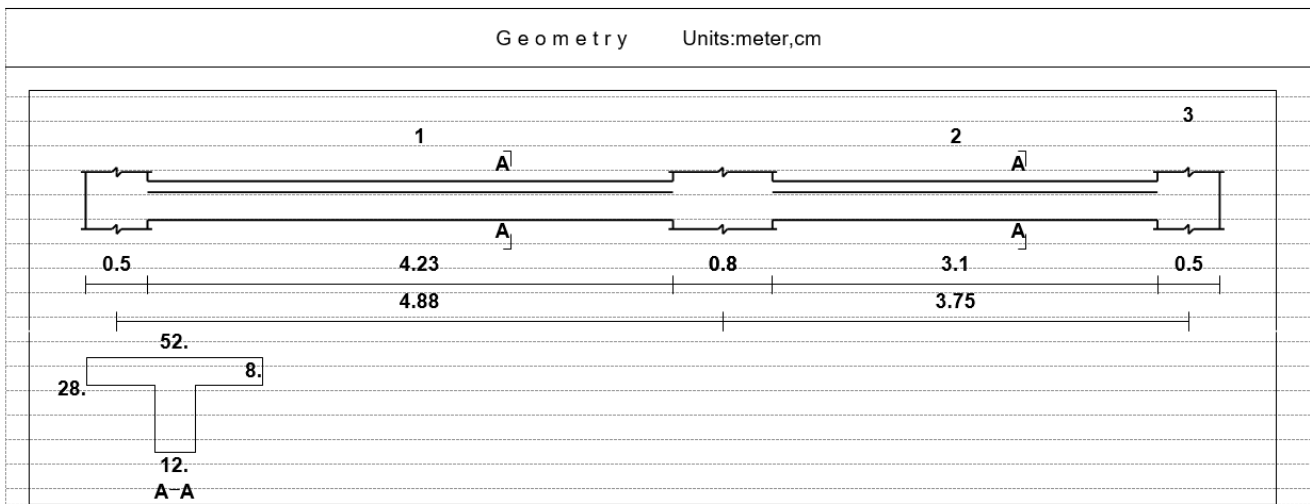


Figure 4.2: Rib (06) Geometry.

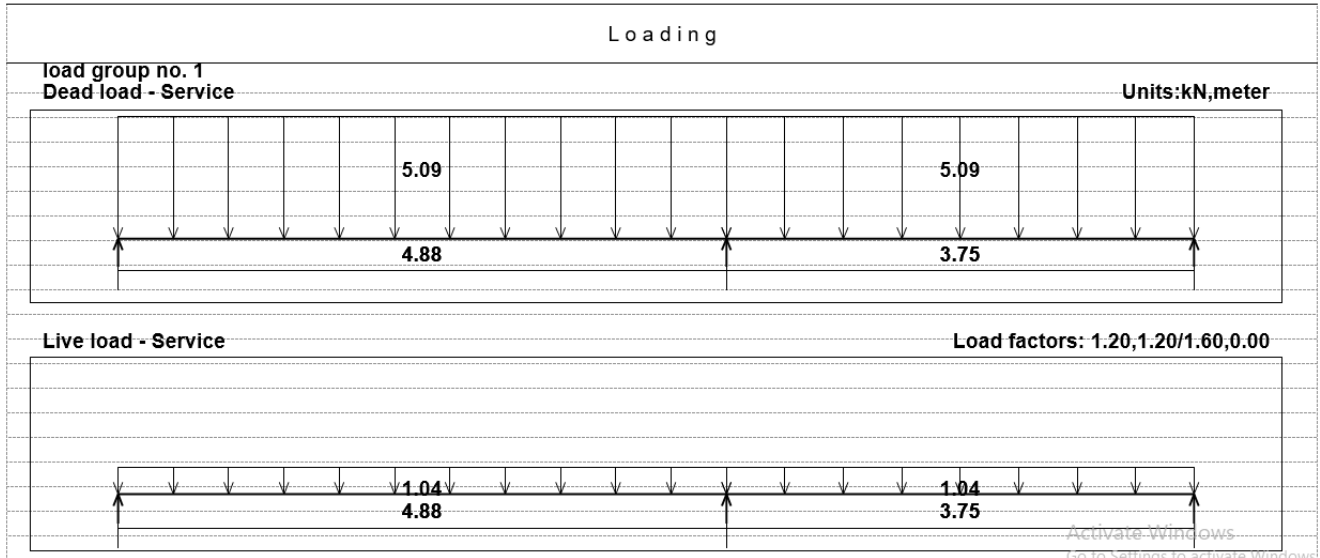


Figure 4.3: Loading on Rib (06)

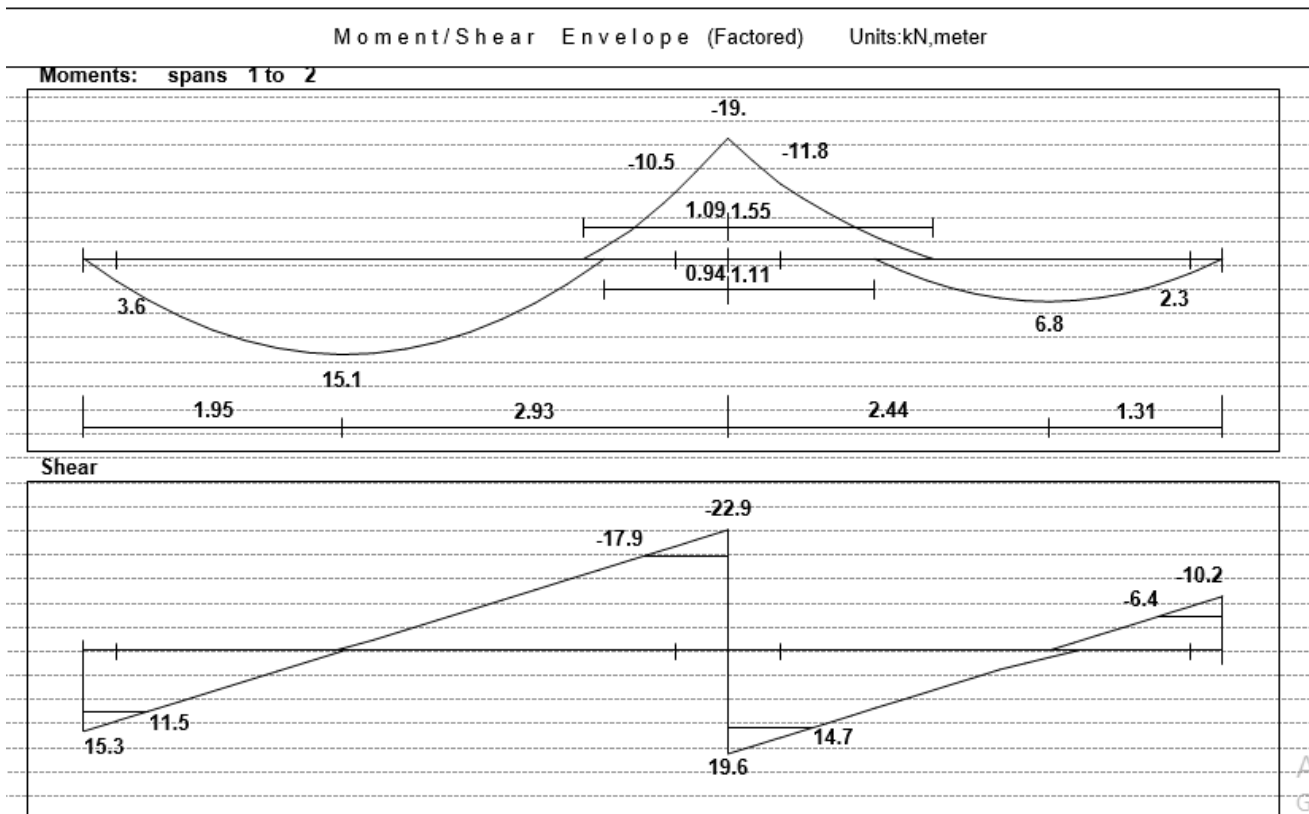


Figure 4.4: Moment and Shear Envelope of Rib (06)

#### 4.6.1. Design of rib (06) for a max positive moment. ( $M_u = +15.1 \text{ KN.m}$ )

⇒ Assume bar diameter  $\emptyset 12$  for main positive reinforcement.

$$d = (h - \text{cover} - d_s - d_b/2) = (280 - 20 - 10 - 12/2) = 244 \text{ mm.}$$

⇒ Check if ( $a > h_f$ ) to determine whether the section will act as rectangular or T- section.

$$M_{nf} = 0.85 \cdot f'_c \cdot b_e \cdot h_f \cdot \left(d - \frac{h_f}{2}\right) = 0.85 \cdot 24 \cdot 520 \cdot 80 \left(244 - \frac{80}{2}\right) \cdot 10^{-6} = 173.12 \text{ KN.m}$$

$$M_{nf} \gg \frac{M_u}{\phi} = \frac{15.1}{0.9} = 16.77 \text{ KN.m}$$

So ( $h_f > a$ ), the section will be designed as rectangular section with  $b_e = 520 \text{ mm}$ .

$$\Rightarrow R_n = \frac{M_u}{\phi b d^2} = \frac{15.1 \times 10^6}{0.9 \times 520 \times 244^2} = 0.54 \text{ Mpa}$$

$$\Rightarrow m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\Rightarrow \rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{420}}\right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 0.54}{420}}\right) = 0.0013$$

$$\Rightarrow A_{(s,req)} = \rho \cdot b \cdot d = 0.0013 \times 520 \times 244 = 171.28 \text{ mm}^2$$

⇒ Check for  $A_{s,min}$  :

$$A_{s,min} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = 0.25 \frac{\sqrt{24}}{(420)} (120)(244) = 85.38 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} (120)(244) = 97.6 \text{ mm}^2 \quad \text{-controls}$$

$$A_{(s,req)} = 171.28 \text{ mm}^2 > A_{s,min} = 85.38 \text{ mm}^2 \quad \text{-Ok}$$

⇒ Use  $2\emptyset 12$  with  $A_{(s,pro)} = 2.26 \text{ cm}^2 > A_{(s,req)} = 1.71 \text{ cm}^2$ .

⇒ Check for strain:

$$a = \frac{A_s \cdot f_y}{0.85 b f'_c} = \frac{226 \times 420}{0.85 \times 520 \times 24} = 8.95 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{8.95}{0.85} = 10.53 \text{ mm}$$

$$\varepsilon_s = 0.003 \left( \frac{d - c}{c} \right) = 0.003 \left( \frac{214 - 10.53}{10.53} \right) = 0.0579 > 0.005 \quad - \text{Ok}$$

#### 4.6.2. Design of rib (06) for a max negative moment at the face of support.

(Mu = -11.8 kN.m)

⇒ Assume bar diameter Ø 12 for main positive reinforcement.

$$d = (h - \text{cover} - d_s - d_b/2) = (280 - 20 - 10 - 12/2) = 244 \text{ mm.}$$

$$\Rightarrow R_n = \frac{M_u}{\phi b d^2} = \frac{11.8 \times 10^6}{0.9 \times 120 \times 244^2} = 1.84 \text{ Mpa}$$

$$\Rightarrow m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\Rightarrow \rho = \frac{1}{m} \left( 1 - \sqrt{1 - \frac{2mR_n}{420}} \right) = \frac{1}{20.6} \left( 1 - \sqrt{1 - \frac{2 \times 20.6 \times 1.84}{420}} \right) = 0.0005$$

$$\Rightarrow A_{(s, \text{req})} = \rho \cdot b \cdot d = 0.0005 \times 120 \times 244 = 134.28 \text{ mm}^2$$

⇒ Check for  $A_{s, \text{min}}$  :

$$A_{s, \text{min}} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = 0.25 \frac{\sqrt{24}}{(420)} (120)(244) = 85.38 \text{ mm}^2$$

$$A_{s, \text{min}} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} (120)(244) = 97.6 \text{ mm}^2 \quad - \text{controls}$$

$$A_{(s, \text{req})} = 134.28 \text{ mm}^2 > A_{s, \text{min}} = 97.6 \text{ mm}^2$$

$$\Rightarrow \text{Use } 2\text{Ø}12 \text{ with } A_{(s, \text{pro})} = 226.1 \text{ mm}^2 > A_{(\text{min})} = 97.6 \text{ mm}^2$$

⇒ Check for strain:

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{226.1 \times 420}{0.85 \times 120 \times 24} = 38.77 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{8.95}{0.85} = 45.61 \text{ mm}$$

$$\varepsilon_s = 0.003 \left( \frac{d - c}{c} \right) = 0.003 \left( \frac{244 - 45.61}{45.61} \right) = 0.013 > 0.005 \quad - \text{Ok}$$

#### 4.6.3. Design of rib (06) for shear.

The maximum shear force at the distance  $d$  from the face of support  $V_u = 17.9$  KN.

Shear strength  $V_c$ , provided by concrete for the joists may be taken 10% greater than for beams. This is mainly due to the interaction between the slab and closely spaced ribs (ACI code, section 8.13.8).

$$\Rightarrow V_c = \frac{1.1}{6} \lambda \sqrt{f'_c} b_w d = \frac{1.1}{6} \times 1 \times \sqrt{24} \times 120 \times 244 \times 10^{-3} = 26.30 \text{ KN}$$

$$\Rightarrow \phi V_c = 0.75 \times 26.30 = 19.72 \text{ KN}$$

$$\Rightarrow 0.5 \phi V_c = 9.86 \text{ KN} < V_u = 17.9 \text{ KN} \quad \text{-case II}$$

Minimum shear reinforcement is  $\phi 10 @ 10$ .

#### 4.7. Design of Beam (03).

Beam geometry:

- $B = 50$  cm
- $H = 25$  cm

##### 4.7.1. Determination Loads of beam (03).

The load calculate as:

**Table 4.4: Dead Load calculations for beam (03).**

Dead Load from	$\gamma * \delta * 1$	KN/m
Tiles	$0.03 * 23 * 0.5$	0.69
Mortar	$0.03 * 22 * 0.5$	0.66
Coarse Sand	$0.07 * 17 * 0.5$	1.19
Plaster	$0.03 * 22 * 0.5$	2.0
Interior Partitions	$2.3 * 0.5$	2.3
sum		6.84

Weight of RC wall =  $0.3 * 3 * 25 * (2/3) = 14.3$  KN/m.

Loads from support reaction #4 for rib (06) are:

- $DL = 7.87 / 0.52 = 15.13$  KN/m.
- $LL = 1.65 / 0.52 = 3.17$  KN/m.



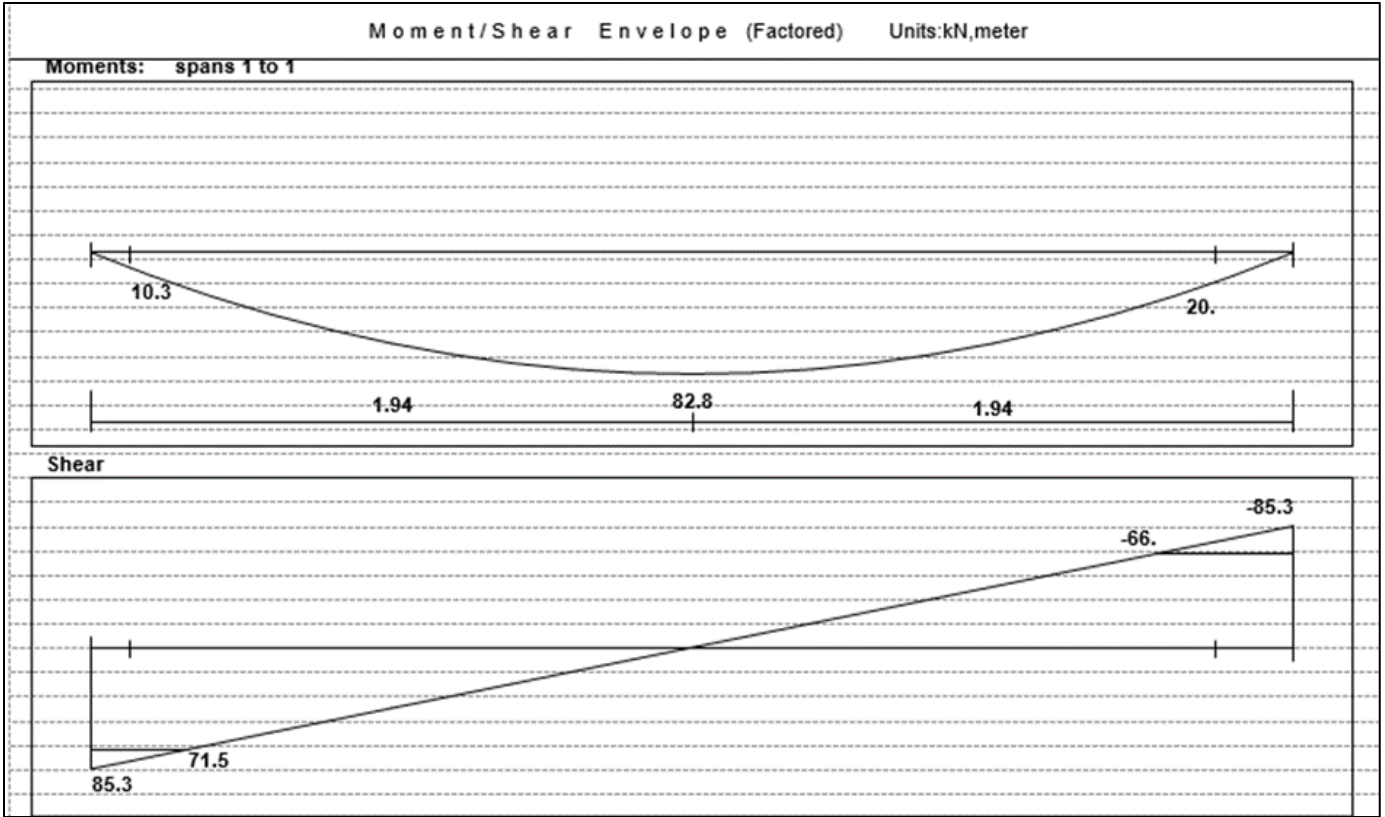


Figure 4.7: Moment and Shear Envelope of beam (03)

#### 4.7.2. Design of beam (B03) for a maximum positive moment. ( $M_u = +82.8 \text{ KN.m}$ )

⇒ Assume bar diameter  $\emptyset 18$  for main positive reinforcement.

$$d = (h - \text{cover} - d_s - d_b/2) = (280 - 40 - 10 - 18/2) = 221 \text{ mm.}$$

$$\Rightarrow R_n = \frac{M_u}{\emptyset b d^2} = \frac{82.8 \times 10^6}{0.9 \times 500 \times 191^2} = 3.77 \text{ Mpa}$$

$$\Rightarrow m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\Rightarrow \rho = \frac{1}{m} \left( 1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{420}} \right) = \frac{1}{20.6} \left( 1 - \sqrt{1 - \frac{2 \times 20.6 \times 3.77}{420}} \right) = 0.0100$$

$$\Rightarrow A_{(s, \text{req})} = \rho \cdot b \cdot d = 0.0100 \times 500 \times 221 = 1106 \text{ mm}^2$$

⇒ Check for  $A_{s, \text{min}}$  :

$$A_{s, \text{min}} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = 0.25 \frac{\sqrt{24}}{(420)} (500)(221) = 322.2 \text{ mm}^2$$

$$A_{s, \text{min}} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} (500)(221) = 368.33 \text{ mm}^2 \quad \text{-controls}$$

$$A_{(s, \text{req})} = 1106 \text{ mm}^2 > A_{s, \text{min}} = 368.33 \text{ mm}^2$$

$$\Rightarrow \text{Use } 6\emptyset 18 \text{ with } A_{(s, \text{pro})} = 1.527 \text{ cm}^2 > A_{(s, \text{req})} = 1.106 \text{ cm}^2$$

⇒ Check spacing :

$$S = \frac{500 - 40 \times 2 - 20 - (6 \times 18)}{5} = 59.2 \text{ mm} > d_b = 18 \text{ mm} > 25 \text{ mm} \quad \text{OK}$$

⇒ Check for strain:

$$a = \frac{A_s \cdot f_y}{0.85 b f'_c} = \frac{1527 \times 420}{0.85 \times 500 \times 24} = 55.05 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{105}{0.85} = 64.77 \text{ mm}$$

$$\varepsilon_s = 0.003 \left( \frac{d - c}{c} \right) = 0.003 \left( \frac{221 - 64.77}{64.77} \right) = 0.0073 > 0.005 \quad \text{OK}$$

**4.7.3. The maximum shear force at the distance d from the face of support for beam (03).**

**(Vu,max= 71.5 KN)**

$$\Rightarrow V_c = \frac{1}{6} \sqrt{f'c'} b_w d = \frac{1}{6} \sqrt{24} * 500 * 221 * 10^{-3} = 90.22 \text{ KN}$$

$$\Rightarrow \Phi V_c = 0.75 * 90.22 = 67.67 \text{ KN}$$

$$\Rightarrow V_u = 71.5 \text{ KN} > \Phi V_c = 67.67 \text{ KN}$$

$$\Rightarrow V_s = \left( \frac{71.5}{0.75} - 90.22 \right) = 5.11 \text{ KN}$$

$$\Rightarrow v_{s'} = \frac{1}{3} \sqrt{f'c'} b_w d = \frac{1}{3} \sqrt{24} * 500 * 221 * 10^{-3} = 180 \text{ KN}$$

$$v_s < v_{s'} = 5.11 \text{ KN} < 180.56 \text{ KN}$$

$$\Rightarrow \Phi V_c < V_u < \Phi(V_c + V_s) \quad \text{-case 3}$$

**Shear reinforcement is required.**

$\Rightarrow$  Use 2 leg  $\Phi 10$ :

$$A_v = 157.07 \text{ mm}^2$$

$$S = \frac{A_v f_{yt} d}{v_s} = \frac{100.53 * 420 * 221}{5.11 * 1000} = 1826 \text{ mm}$$

$$s_{max} \leq \frac{d}{2} = \frac{221}{2} = 110.5 \text{ mm} \quad \text{control}$$

$$\text{or } s_{max} \leq 600 \text{ mm}$$

Use 2 leg  $\Phi 10 @ 10 \text{ mm}$ .

#### 4.8. Design of column (C8).

- $P_u = 2076.44 \text{ KN}$
- $LL = 391.92 \text{ KN}$
- $f_c' = 24 \text{ MPa}$
- $f_y = 420 \text{ MPa}$

Assume  $\rho = 0.02$

$$\rho_g = A_{st} / A_g \implies A_{st} = 0.02 * A_g$$

$$\phi P_n = P_u = \phi * 0.8 * (.85 f_c' (A_g - A_{st}) + A_{st} f_y)$$

$$2076.44 * 10^3 = 0.65 * 0.8 * (0.85 * 24 * (A_g - 0.02 A_g) + 0.02 A_g * 420)$$

$$2076.44 * 10^3 = 0.52 * (20.4 A_g - 0.408 A_g + 8.4 A_g)$$

$$\rightarrow A_g = 140680.22 \text{ mm}^2$$

$\rightarrow$  Select column dimension (550\*550) mm, with  $A_g = 302500 \text{ mm}^2$

##### 4.8.1. Check the Slenderness effect:

$$\frac{KLu}{r} \leq 34 - 12 \left( \frac{M_1}{M_2} \right) \leq 40 \quad \text{ACI - (10.12.2)}$$

- $Lu$ : Actual unsupported (unbraced) length.
- $K$ : effective length factor ( $K = 1$  for braced frame).
- $r$ : radius of gyration =  $0.3 h$

For column (C8):

- $Lu = 3 \text{ m}$
- $K = 1$ , for braced frame
- $\frac{M_1}{M_2} = 1$ , for braced frame with  $M_{\min}$

$$\frac{KLu}{r} \leq 22 \leq 40$$

$$\frac{KLu}{rx} = \frac{1 * 3}{0.3 * 0.55} = 18.18 < 22 \quad (\text{long column for bending about x-direction.})$$

$$\frac{KLu}{ry} = \frac{1 \cdot 3}{0.3 \cdot 0.55} = 18.18 < 22 \quad (\text{Short column for bending about y-direction.})$$

→ Column is Short, so the Slenderness effect will not be considered.

#### 4.8.2. Calculation of Required Reinforcement Ratio

$$\phi P_n = 0.65 * 0.8 * A_g \{0.85 * f_c' + \rho_g (f_y - 0.85 f_c')\}$$

Where,  $P_u = 2076.44 \text{ KN}$

$$2076.44 * 10^3 = 0.65 * 0.8 * 550 * 550 \{0.85 * 24 + \rho_g (420 - 0.85 * 24)\}$$

$$\Rightarrow \rho_g = 0.011 > \rho_{min} = 0.01 \ \& \ < \ \rho_{max} = 0.08$$

$$A_{s \text{ req}} = 0.011 * 550 * 550 = 3206 \text{ mm}^2$$

$$\text{Use } \Phi 16, \text{ so the no of bar} = \frac{3206}{201.1} = 16$$

$$\text{Use } 16 \ \Phi 16 \text{ with } A_s = 3217.6 \text{ mm}^2 > A_{s \text{ req}} = 3206 \text{ mm}^2$$

#### 4.8.3. Check spacing between the bars :

$$S = \frac{550 - 2 \cdot 40 - 2 \cdot 10 - 5 \cdot 16}{4} = 92.5 \text{ mm}$$

$$S \geq 40 \text{ mm}$$

$$\geq 1.5 d_b = 24 \text{ mm}$$

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

#### 4.8.4. Determination of Stirrups Spacing

According to ACI:

$$\text{Spacing} \leq 16 \times d_b (\text{Longitudinal bar diameter}) = 16 \times 1.6 = 25.6 \text{ cm.}$$

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

$$\text{Spacing} \leq \text{Least dimension} = 55 \text{ cm}$$

→ **Select  $\Phi 10/20 \text{ cm}$**

Column (C8) Section is shown in figure (4.8) where bars arrangement and stirrups detailing appear:

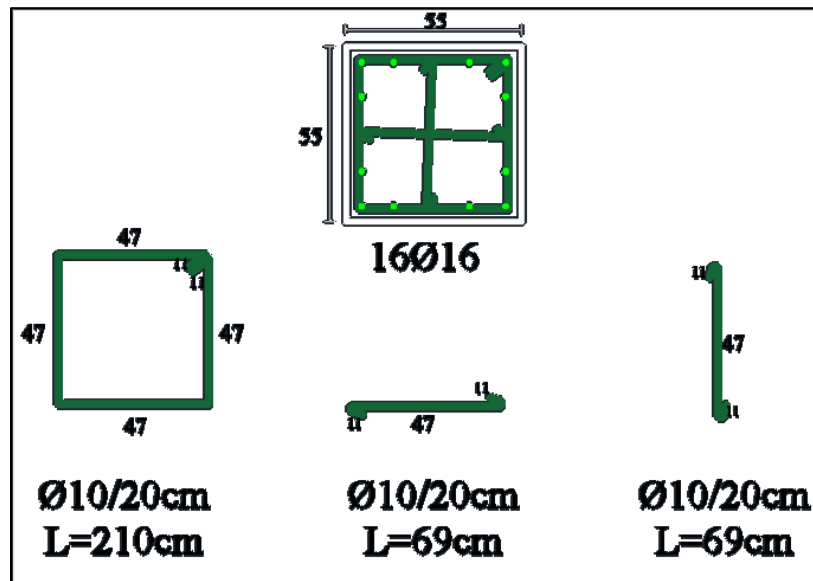


Figure 4.8 column (C8)

## 4.9. 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, SW5.

The following data that used in the design:

- Shear Wall thickness = h = 20 cm
- Shear Wall length  $L_w = 2.0$  m
- Building height  $H_w = 27.41$  m
- Critical section shear :  $L_w < h_w \rightarrow d = 0.8 * L_w = 1.6$  m

### 4.9.1. Design of Horizontal Reinforcement

Calculation of Shear Strength Provided by concrete  $V_c$ :

- Shear Strength of Concrete is the smallest of :

$$1- V_c = \frac{1}{6} \sqrt{f_c'} \times b \times d$$

$$= \frac{1}{6} \sqrt{24} \times 200 \times 1600 = \mathbf{261.27 \text{ KN}} \quad \dots \text{control}$$

$$2- V_c = \frac{\sqrt{f_c'} \times b \times d}{4} + \frac{N_u \times d}{4L_w}$$

$$= \frac{\sqrt{24} \times 200 \times 1600}{4} + 0 = 392.0 \text{ kN}$$

$$3- V_c = \left[ \frac{\sqrt{f_c'}}{2} + \frac{L_w \left( \sqrt{f_c'} + \frac{2N_u}{L_w \cdot h} \right)}{\frac{M_u1}{V_u} - \frac{L_w}{2}} \right] \times \frac{h \times d}{10}$$

Where:

$M_u1 = 254.62$  kN.m

$$\frac{M_u1}{V_u} - \frac{L_w}{2} = \frac{254.62}{440.52} - \frac{2.0}{2} = -0.422 < 0 \rightarrow \text{This equation is not applicable.}$$

$\therefore V_c = 261.27 \text{ kN} \rightarrow \phi V_c < V_{u \max} = 440.52 \text{ kN} \rightarrow \text{Horizontal Reinforcement is Required.}$

$$\rightarrow V_s = \frac{V_u}{\phi} - V_c = \frac{440.52}{0.75} - 261.27 = 326.09 \text{ kN}$$

$$\rightarrow \frac{A_v h}{s} = \frac{V_s}{f_y \cdot d} = \frac{326.09 \cdot 10^3}{420 \cdot 1600} = 0.47$$

$$\text{but } \left( \frac{A_v h}{s} \right)_{\min} = 0.0025 \cdot h = 0.0025 \cdot 200 = \mathbf{0.5} \dots \dots \text{Controlled.}$$

→ Avh : For 2 layers of Horizontal Reinforcement

Select Ø10 :

$$A_{vh} = 2 * 79 = 158 \text{ mm}^2$$

$$\frac{A_{vh}}{s} = 0.5 \rightarrow S, req = \frac{158}{0.5} = 316 \text{ mm}$$

$$S_{max} = Lw/5 = 1600/5 = 320 \text{ mm} \dots\dots\dots\text{Controlled.}$$

$$= 3h = 3*200 = 600\text{mm}$$

$$= 450 \text{ mm}$$

∴ Select Ø10 @ 250 mm at each side.

#### 4.9.2. Design of Vertical Reinforcement

$$\rightarrow A_{vv} = [0.0025 + 0.5 (2.5 - \frac{hw}{lw}) (\frac{A_{vh}}{S_{hor} * h} - 0.0025)] * h * S, ver$$

$$\frac{hw}{lw} = \frac{27.41}{2.0} = 12.21 > 2.50$$

$$\rightarrow \frac{A_{vv}}{S_{ver}} = [0.0025 + 0.5 (0) (\frac{2*79}{250*200} - 0.0025)] * 200$$

$$\therefore \frac{A_{vv}}{S, ver} = 0.5$$

$$S_{max} = Lw/3 = 1600/3 = 534 \text{ mm}$$

$$= 3h = 3*200 = 600\text{mm}$$

$$= 450 \text{ mm} \dots\dots\dots\text{Controlled.}$$

Select Ø12 :

$$A_{vv} = 2 * 113 = 226 \text{ mm}^2$$

$$\frac{A_{vv}}{s} = 0.5 \rightarrow S, req = \frac{226}{0.5} = 452 \text{ mm}$$

∴ Select Ø12 @ 150 mm at each side.

### 4.9.3. Design of Bending Moment

Moment diagram were obtained from ETABS

→ Max  $M_u = 983.65 \text{ kN.m}$

→ Part of Moment that resisted through  $A_{sv}$  :

$$M_{uv} = 0.9 \left[ 0.5 * A_{sv} * f_y * L_w \left( 1 - \frac{Z}{2 L_w} \right) \right]$$

Where :

$$- A_{sv} = 2 * 113 * \frac{1600}{200} = 1808 \text{ mm}^2$$

$$- \frac{Z}{L_w} = \frac{1}{2 + \frac{0.85 * \beta_1 * f_c' * L_w * h}{A_{sv} * f_y}} = \frac{1}{2 + \frac{0.85 * 0.85 * 24 * 1600 * 200}{4407 * 420}} = 0.20$$

$$\therefore M_{uv} = 0.9 \left[ 0.5 * 4407 * 420 * 1600 \left( 1 - \frac{0.20}{2} \right) \right] = 1199.35 \text{ kN.m}$$

$$M_{uv} = 1199.35 \text{ kN.m} > M_u = 983.65 \text{ kN.m}$$

So, Boundary Element is not required.

## 4.10. Design of Basement Wall.

### 4.10.1. System and Loads

The wall spans vertically and it is considered to be pinned at both ends as shown in figure (4.9) which also illustrates loads that act on the wall.

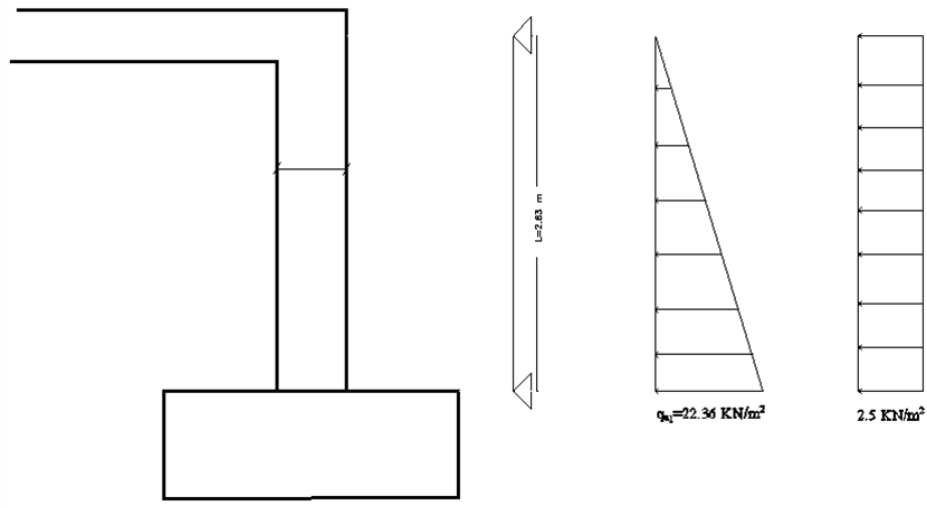


Figure 4.9 :Basement wall

The different lateral pressures on a 1m length of the wall are calculated as follows:

$$k_o = 1 - \sin 30 = 0.5$$

$$\text{Due to soil pressure at rest: } q_{u1} = k_o \cdot \gamma \cdot h = 0.5 \cdot 17 \cdot 2.63 = 22.36 \text{ kN/m}^2$$

$$\text{Due to surcharge: } q_{u2} = 5 \cdot 0.5 = 2.5 \text{ kN/m}^2$$

The following figure (4.10) is shear and moment diagrams that were obtained from Atir Software.

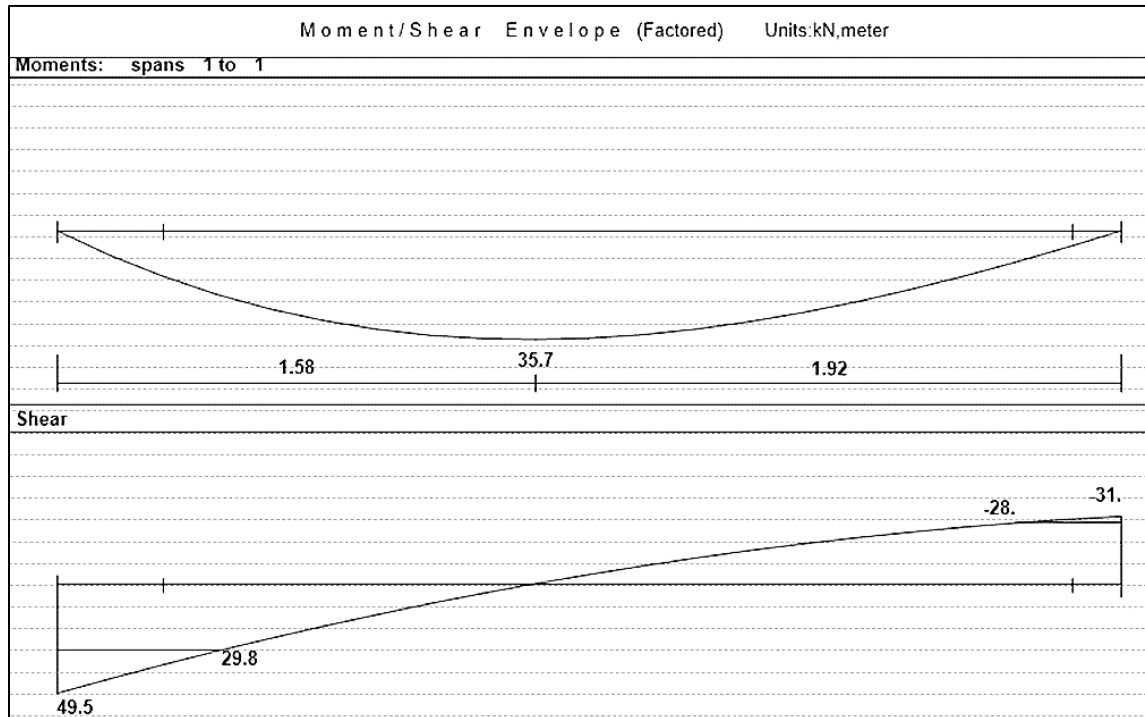


Figure 4.10: Shear and moment diagram

#### 4.10.2. Design of Shear Force

Max value shear force is obtained from figure(4.) ,  $V_u = 29.8$  kN

$$d = 25 - 2 - 2 = 21 \text{ cm}$$

$$\phi * V_c = 0.75 * \frac{1}{6} * \sqrt{24} * 1000 * 210 = 128.6 \text{ kN} > V_u$$

$\therefore h = 25 \text{ cm}$  is correct.

#### 4.10.3. Design of Wall Reinforcement

Design of Vertical Reinforcement at Tension Side:

Max value Moment is obtained from figure(4.) ,  $M_u = 35.7$  kN.m

$$m = \frac{420}{0.85 * 24} = 20.6$$

$$M_n = 35.7 / 0.9 = 39.67 \text{ kN.m}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{32.13 \cdot 10^6}{1000 \cdot 210^2} = 0.73 \text{ MPa}$$

$$\rho = \frac{1}{20.6} * \left( 1 - \sqrt{1 - \frac{2 * 0.73 * 20.6}{420}} \right) = 0.0018$$

$$A_{s, \text{req}} = \rho * b * d = 0.0018 * 1000 * 210 = 378 \text{ mm}^2 / \text{m}$$

$$A_s (\text{min}) = 0.0012 * b * h = 0.0012 * 1000 * 250 = 300 \text{ mm}^2 / \text{m}$$

→ Select Ø14/20cm with  $A_s = 770 \text{ mm}^2 / \text{m} > A_s \text{ min}$

➤ **Design of Vertical Reinforcement Compression Side:**

$$A_s = A_s (\text{min}) = 300 \text{ mm}^2$$

→ Select Ø10/25cm with  $A_s = 314 \text{ mm}^2 / \text{m}$

➤ **Design of Horizontal Reinforcement:**

$$A_s = A_s (\text{min}) = 0.001 * 1000 * 250 = 250 \text{ mm}^2 / \text{m} \text{ for one layer}$$

→ Select Ø10/25cm

## 4.11. Design of Basement Footing

- $q_D = 57 \text{ kN/m}$  &  $q_L = 6 \text{ kN/m}$
- Total Service Loads:  $q_{\text{tot}} = 57 + 6 = 63 \text{ KN/m}$
- Total Factored Loads :  $q_u = 1.4 * 59 = 88.2 \text{ kN/m}$

### 4.11.1. Check if footing width is correct

$$\sigma_b = \frac{q_{\text{tot}}}{A_{\text{req}}} \leq \sigma_{b(\text{allow. net})}$$

$$63 / (1.0 * 1.0) = 63 < \sigma_{b(\text{allow. net})} = 400 \text{ KN/m}^2$$

a=1.0m is correct

#### 4.11.2. Design of one way shear

Assume  $h = 30\text{cm}$

$$d = 300 - 50 - 20$$

$$= 230 \text{ mm}$$

$$V_u = 88.2 * 0.145 * 1\text{m} = 12.79 \text{ KN}$$

$$\phi * V_c = 0.75 * \frac{1}{6} * \sqrt{24} * 1000 * 230 = 140.8 \text{ KN} > V_u$$

→  $h = 30 \text{ cm}$  (SAFE) .

#### 4.11.3. Design of Bending Moment

##### ▪ Main Steel:

$$M_u = 88.2 * 0.375 * 1 * (0.375/2) = 6.2 \text{ KN.m}$$

$$M_n = 6.2 / 0.9 = 6.9 \text{ kN.m}$$

$$k_n = \frac{M_n}{b * d^2} = \frac{6.9 * 10^6}{1000 * 230^2} = 0.13 \text{ MPa}$$

$$\rho = \frac{1}{20.6} * \left( 1 - \sqrt{1 - \frac{2 * 0.13 * 20.6}{420}} \right) = 0.00031$$

$$A_{s, \text{req}} = 0.00031 * 1000 * 230 = 71.3 \text{ mm}^2/\text{m}$$

$$A_s (\text{min}) = 0.0018 * 1000 * 300 = 540 \text{ mm}^2/\text{m}$$

→ Select  $\text{Ø}12/20\text{cm}$  with  $A_s = 565 \text{ mm}^2 > A_{s, \text{min}}$

##### ▪ Secondary Steel:

$$A_s (\text{min}) = 0.0018 * b * h = 0.0018 * 1000 * 300 = 540 \text{ mm}^2$$

→ Select  $\text{Ø}12/20\text{cm}$  with  $A_s = 565 \text{ mm}^2 > A_{s, \text{min}}$

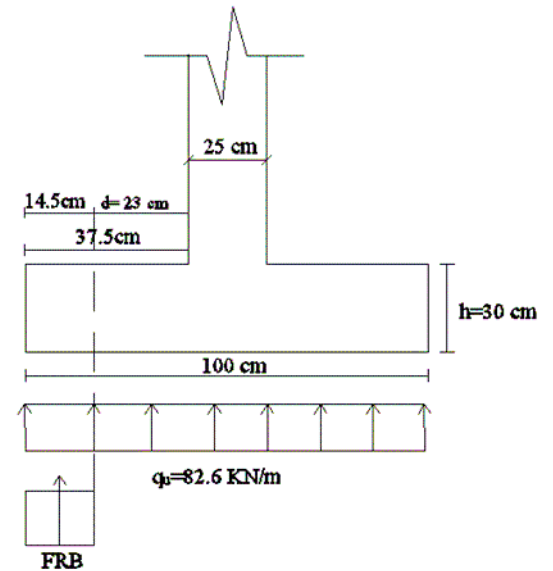


Figure 4.11: Critical Section of Shear force



#### 4.12.1. Determination of footing dimension (a)

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

- Assume  $h = 50 \text{ cm}$
- $\sigma_{b(\text{allow})_{\text{net}}} = 400 - 25 \cdot 0.50 = 387.5 \text{ kN/m}^2$
- $\sigma_{\text{bu}(\text{allow})_{\text{net}}} = 1.4 \cdot 387.5 = 542.5 \text{ kN/m}^2$
- $\sigma_{\text{bu}} = \frac{Pu}{A_{\text{req}}} \leq \sigma_{\text{bu}(\text{allow})_{\text{net}}}$

$$\therefore \frac{1895}{a^2} = 539 \rightarrow a = 1.87 \text{ m} \rightarrow \text{Select } a = 2.0 \text{ m}$$

- Bearing Pressure  $\sigma_{\text{bu}} = \frac{Pu}{A} = \frac{1895}{2 \cdot 2} = 473.8 \text{ kN/m}^2 \leq 542.5 \text{ kN/m}^2 \dots \text{ (SAFE)}$

#### 4.12.2. Determination of footing depth (h)

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

- $d = h - \text{cover} - \phi = 500 - 50 - 16 = 434 \text{ mm}$
- $V_u$  at a distance  $d$  from the face of the column :

$$V_u = FRB = \sigma_{\text{bu}} \times 0.366 \times b$$

$$= 473.8 \times 0.366 \times 2 = 346.8 \text{ kN}$$

$$\rightarrow \phi * V_c = 0.75 * \frac{1}{6} * \sqrt{F_c'} * b * d$$

$$= 0.75 * \frac{1}{6} * \sqrt{24} * 2000 * 434 * 10^{-3}$$

$$= 531.5 \text{ kN} > V_u$$

$\therefore h = 50 \text{ cm}$  is correct

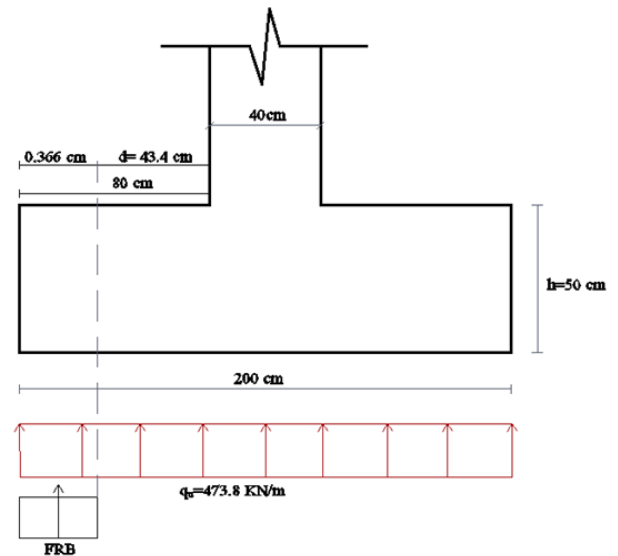


Figure 4.13: Critical Section of Shear Force

### 4.12.3. Design of Punching (two way shear)

$$\rightarrow d = 434 \text{ mm}$$

$$\rightarrow b_o = 2 \times (0.45 + 0.434) + 2 \times (0.40 + 0.434) = 3.44 \text{ m}$$

$$\rightarrow Bc = 1$$

$$\rightarrow \alpha_s = 40 \text{ (interior column)}$$

$$q_u = Pu/A = 1895 / (2 \times 2) = 473.75 \text{ KN/m}^2$$

$$V_u = 473.75 (2 \times 2 - (0.45 + 0.434)(0.4 + 0.434)) = 1545.7 \text{ KN}$$

**$\phi \times V_c$  is the smallest of:**

$$1. V_c = \left(2 + \frac{4}{Bc}\right) \times \frac{\sqrt{f_c'}}{12} \times b_o \times d = \left(2 + \frac{4}{1}\right) \times \frac{\sqrt{24}}{12} \times 3440 \times 434 = 3656.9 \text{ kN}$$

$$2. V_c = \left(\frac{\alpha_s \times d}{b_o} + 2\right) \times \frac{\sqrt{f_c'}}{12} \times b_o \times d = \left(\frac{40 \times 434}{3440} + 2\right) \times \frac{\sqrt{24}}{12} \times 3440 \times 434 = 4294.8 \text{ KN}$$

$$3. V_c = 4 \times \frac{\sqrt{f_c'}}{12} \times b_o \times d = 4 \times \frac{\sqrt{24}}{12} \times 3440 \times 434 = 2438 \text{ KN ....cont.}$$

$$\rightarrow \phi \times V_c = 0.75 \times 2438 = 1828.5 \text{ KN} > V_u = 1545.7 \text{ KN}$$

**$\therefore h = 50 \text{ cm}$  is correct**

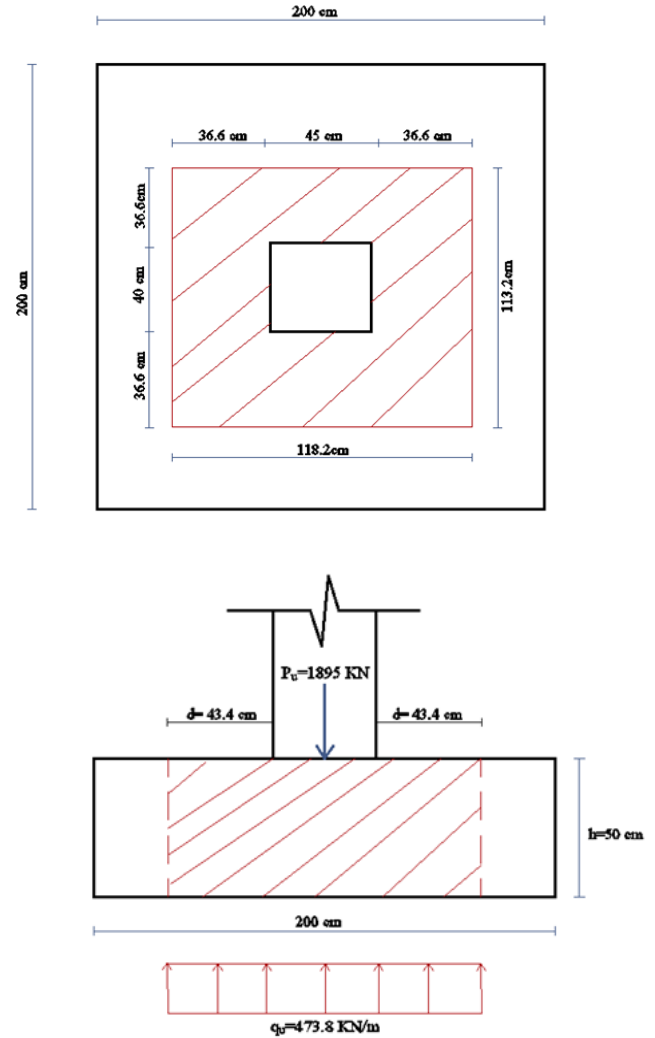


Figure 4.14: Punching Shear Critical Section

#### 4.12.4. Design for flexure in long direction

$$M_u = 473.75 * 2.0 * 0.775 * (0.775/2) = 284.5 \text{ kN.m}$$

$$m = \frac{F_y}{0.85 * F_c'} = \frac{420}{0.85 * 24} = 20.6$$

$$M_n = 284.5 / 0.9 = 316.2 \text{ kN.m}$$

$$R_n = \frac{M_n / \phi}{b * d^2} = \frac{316.2 * 10^6}{2000 * 434^2} = 0.84 \text{ MPa}$$

$$\begin{aligned} \rho &= \frac{1}{m} * \left( 1 - \sqrt{1 - \frac{2 * R_n * m}{F_y}} \right) \\ &= \frac{1}{20.6} * \left( 1 - \sqrt{1 - \frac{2 * 0.84 * 20.6}{420}} \right) = 0.0020 \end{aligned}$$

$$A_{sreq} = \rho * b * d = 0.0020 * 2000 * 434 = 1736 \text{ mm}^2$$

$$A_s (\text{min}) = 0.0018 * b * h = 0.0018 * 2000 * 500 = 1800 \text{ mm}^2$$

$$A_s (\text{min}) > A_{sreq}$$

∴ Select for both directions: 11Ø16 with  $A_s = 2211.7 \text{ mm}^2 > A_{sreq} \dots$  (ok)

#### 4.12.5. Design for flexure in short direction

$$M_u = 473.75 * 2.0 * 0.80 * (0.80/2) = 303.2 \text{ kN.m}$$

$$m = \frac{F_y}{0.85 * F_c'} = \frac{420}{0.85 * 24} = 20.6$$

$$M_n = 303.2 / 0.9 = 336.9 \text{ KN.m}$$

$$R_n = \frac{M_n / \phi}{b * d^2} = \frac{303.2 * 10^6}{2000 * 434^2} = 0.80 \text{ MPa}$$

$$\begin{aligned} \rho &= \frac{1}{m} * \left( 1 - \sqrt{1 - \frac{2 * R_n * m}{F_y}} \right) \\ &= \frac{1}{20.6} * \left( 1 - \sqrt{1 - \frac{2 * 0.80 * 20.6}{420}} \right) = 0.0019 \end{aligned}$$

$$A_{sreq} = \rho * b * d = 0.0019 * 2000 * 434 = 1649.2 \text{ mm}^2$$

$$A_s (\text{min}) = 0.0018 * b * h = 0.0018 * 2000 * 500 = 1800 \text{ mm}^2$$

$$A_s (\text{min}) > A_{sreq}$$

∴ Select for both directions: 11Ø16 with  $A_s = 2211.7 \text{ mm}^2 > A_{sreq} \dots$  (ok)

#### 4.12.6. Design the Connection between Column & Footing

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

$$\begin{aligned}\phi \times Pnb &= 0.65 \times 0.85 \times f_c' \times A1 \geq P_u \\ &= 0.65 \times 0.85 \times 24 \times 450 \times 400 = 2386.8 \text{ kN} > P_u = 1895 \text{ kN}\end{aligned}$$

∴ Dowels are not needed, so:

$$\begin{aligned}\text{The minimum area of dowels } (A_{s,\min}) &= 0.005A_g \\ &= 0.005 \times 450 \times 400 = 900 \text{ mm}^2\end{aligned}$$

→ Select 16Ø12, which is just like the reinforcement of the column.

- **Check Compression lap splice between steel of column and dowels (Lsc) :**

$$\begin{aligned}L_{sc \text{ req}} &= 0.071 \times f_y \times db = 0.071 \times 420 \times 12 = 357.84 \text{ mm} > 300 \text{ mm} \\ \rightarrow \text{Select } L_{sc} &= 40 \text{ cm} > L_{sc \text{ req}} = 35.784 \text{ cm}\end{aligned}$$

- **Design of compression development length (Ldc) :**

- $L_{dc} = 0.24 \times \frac{f_y}{\sqrt{f_c'}} \times db = 0.24 \times \frac{420}{\sqrt{24}} \times 12 = 246.9 \text{ mm} \dots \text{cont.}$

- $L_{dc} = 0.043 \times f_y \times db = 0.043 \times 420 \times 12 = 216.7 \text{ mm}$

$$\therefore L_{dc,\text{req}} = 246.9 \text{ mm}$$

- $\text{Available } L_{dc} = 500 - 50 - 12 - 12 = 426 \text{ mm} > L_{dc,\text{req}} = 246.9 \text{ mm} \dots \text{ok}$

- **Check tension development length using simplified method ( Ldt) :**

Since we have a footing, it must satisfy two conditions to be considered under category A , otherwise, it will be considered as category B :

- 1-  $\text{Clear lateral spacing} = \frac{2000 - (2 \times 50) - (16 \times 12)}{11} = 155.27 \text{ mm} > 2db = 12 \text{ mm}$

- 2-  $\text{Clear cover} = 50 \text{ mm} > db = 12 \text{ mm}$



### 4.13. Design of cantilever stair.

- $f_c = 24 \text{ Mpa}$
- $f_y = 420 \text{ Mpa}$
- $h_{\text{floor}} = 3\text{m}$
- rise = 15cm
- going = 30 cm
- LL = 3 KN
- Floor covering ( $F_c$ ) =  $1.5 \text{ KN/m}^2$

#### 4.13.1. Calculation for each strip

➤ **Dimension:**

- $h_s = \text{span}/10 = 1300/10 = 130\text{mm}$
- $\theta = \tan^{-1}(150/300) = 26.56^\circ$
- $h^* = h_s / \cos \theta$
- $h_{\text{avg}} = 134 + (150/2) = 209.16 \text{ mm}$

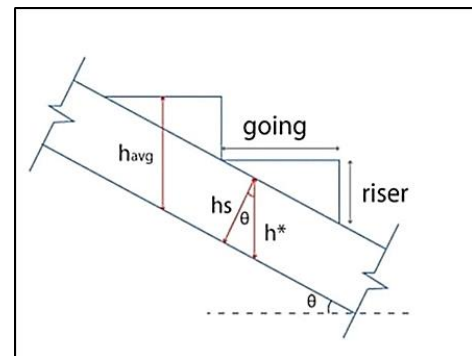


Figure 4.16: Dimension of stair

➤ **load:**

- $OW = \gamma_c * h_{\text{avg}} = 25 * 0.209 = 5.23 \text{ KN/m}^2$
- $DL = OW + FC = 5.23 + 1.5 = 6.73 \text{ KN/m}^2$
- $W_u = 1.2DL + 1.6LL = (1.2 * 6.27) + (1.6 * 3) = 12.88 \text{ KN/m}$ .
- Let point live load  $P = 2 \text{ KN/m}$ .

➤ **Analysis:**

Choose a strip 1m wide.

$$P_u = 2 * 1.6 = 3.2 \text{ KN/m}$$

$$R = (12.88 * 1.3) + 3.2 = 19.94 \text{ KN}$$

$$M_u = (1.6 * 1.3) + 12.88 * 1.3 * (1.3/2) = 12.96 \text{ KN.m}$$

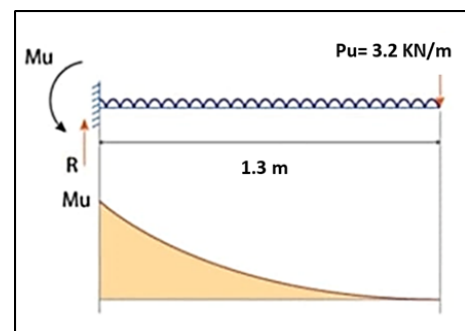


Figure 4.17: Load analysis on strip

➤ **Design:**

Assume:

- Bar diameter =  $\emptyset 14$  for main reinforcement at top.
- Stirrup =  $\emptyset 8$

$$d = (h_{avg} - \text{cover} - d_s - d_b/2) = (209.2 - 20 - 8 - 14/2) = 174.2 \text{ mm.}$$

$$\Rightarrow R_n = \frac{M_u}{\emptyset b d^2} = \frac{12.46 \times 10^6}{0.9 \times 1000 \times 174.2^2} = 0.47 \text{ Mpa}$$

$$\Rightarrow m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\Rightarrow \rho = \frac{1}{m} \left( 1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{420}} \right) = \frac{1}{20.6} \left( 1 - \sqrt{1 - \frac{2 \times 20.6 \times 0.47}{420}} \right) = 0.00113$$

$$\Rightarrow A_{(s,req)} = \rho \cdot b \cdot d = 0.00113 \times 1000 \times 174.2 = 196.68 \text{ mm}^2$$

$$\begin{aligned} \Rightarrow A_{(s,min)} &= \rho \cdot b \cdot d = 0.0018 \times b \times h_{avg} \\ &= 0.0018 \times 1000 \times 209.2 = 376.56 \text{ mm}^2 \end{aligned}$$

$$A_{(s,min)} = 376.65 \text{ mm}^2 > A_{(s,req)} = 196.68 \text{ mm}^2$$

$$\Rightarrow \text{Use } 4\emptyset 14 \text{ with } A_{(s,pro)} = 615.75 \text{ mm}^2 > A_{(min)} = 376.56 \text{ mm}^2$$

**Shrinkage and temperature:**

$$A_{(s,req)} = A_{(s,min)}$$

$$\Rightarrow \text{Use } 5\emptyset 10 \text{ with } A_{(s,pro)} = 392.70 \text{ mm}^2$$

### 4.13.2. The calculation for Landing

➤ **Dimension:**

-  $h_s = \text{span}/10 = 1300/10 = 130\text{mm}$

➤ **load:**

-  $OW = \gamma_c * h_s = 25 * 0.130 = 3.25 \text{ KN/m}^2$

-  $DL = OW + FC = 3.25 + 1.5 = 4.75 \text{ KN/m}^2$

-  $W_u = 1.2DL + 1.6LL = (1.2 * 4.75) + (1.6 * 3) = 10.5 \text{ KN/m}$ .

- Let point live load  $P = 2 \text{ KN/m}$

➤ **Analysis:**

Choose a strip 1m wide.

$$P_u = 2 * 1.6 = 3.2 \text{ KN/m}.$$

$$R = (10.5 * 1.3) + 3.2 = 16.85 \text{ KN}.$$

$$M_u = (3.2 * 1.3) + 10.5 * 1.3 * (1.3/2) = 13.03 \text{ KN.m}$$

➤ **Design:**

Assume:

- Bar diameter =  $\emptyset 14$  for main reinforcement at top.

- Stirrup =  $\emptyset 8$

$$d = (h_s - \text{cover} - d_s - d_b/2) = (130 - 20 - 8 - 14/2) = 95\text{mm}.$$

$$\Rightarrow R_n = \frac{M_u}{\emptyset b d^2} = \frac{13.03 \times 10^6}{0.9 \times 1000 \times 95^2} = 1.5 \text{ Mpa}$$

$$\Rightarrow m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\Rightarrow \rho = \frac{1}{m} \left( 1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{420}} \right) = \frac{1}{20.6} \left( 1 - \sqrt{1 - \frac{2 \times 20.6 \times 1.5}{420}} \right) = 0.0037$$

$$\Rightarrow A_{(s,req)} = \rho \cdot b \cdot d = 0.0037 \times 1000 \times 95 = 356.5 \text{ mm}^2$$

$$\begin{aligned} \Rightarrow A_{(s,min)} &= \rho \cdot b \cdot d = 0.0018 \times b \times h_s \\ &= 0.0018 \times 1000 \times 130 = 234 \text{ mm}^2 \end{aligned}$$

$$A_{(s,req)} = 356.5 \text{ mm}^2 > A_{(s,min)} = 234 \text{ mm}^2$$

$$\Rightarrow \text{Use } 4\emptyset 14 \text{ with } A_{(s,pro)} = 615.75 \text{ mm}^2 > A_{(s,req)} = 356.5 \text{ mm}^2$$

**Shrinkage and temperature:**

$$A_{(s,req)} = A_{(s,min)}$$

$$\Rightarrow \text{Use } 5\emptyset 10 \text{ with } A_{(s,pro)} = 392.70 \text{ mm}^2$$

## **Chapter 5: Results and Recommendations**

### **5.1. Introduction**

### **5.2. Results**

### **5.3. Recommendations**

## **5.1. Introduction**

In this project, the architectural plans for the building were obtained and all requirements were studied, and then the comprehensive construction plans for the residential building were prepared in a detailed, accurate and clear manner to facilitate the construction process, and the design steps described in this report were implemented.

After completing the project and dealing with the problems encountered while working on it, it is necessary to summarize the results obtained and give some recommendations that will be useful to students who are going to work on such projects.

## **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 is 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 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 that meant reducing costs.

## **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 might help students who will work on such projects after us.

First, 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 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.

## References

- [1] Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE7-16).
- [2] Building code requirements for structural concrete (ACI-318-14), USA: American Concrete Institute, 2014.
- [3] كود البناء الأردني, كود الأحمال والقوى, عمان, الأردن: مجلس البناء الوطني الأردني, 2006م