Palestine Polytechnic University
Faculty of Engineering
Department of Civil Engineering and Architecture

Project Name

Structural Design of Palestine Polytechnic University College of Medicine

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This project was submitted to complement the requirements for obtaining a Bachelor's degree in the Faculty of Engineering

Palestine Polytechnic University

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The undersigned here by certify that they have read, examined and recommended to the Department of Civil Engineering and Architecture in the College of Engineering and Technology at Palestine Polytechnic University the approval of a project entitled: **Structural Design of Palestine Polytechnic University College of Medicine,** submitted by **Deya' Sayed Ahmad, Dua Al Taqatqa, Hasan Al Atrash, Mo'taz Abu-Awad, Wisam Amro** for partial fulfillment of the requirements for the bachelor's degree circle.

Dr. Maher Amro. (Supervisor), Palestine Polytechnic University.

Signature:__________________________ Date:__________________

Project Approved

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Signature:__________________________ Date:__________________

DEDICATION

To those who have always believed in me and given me wings to fly and told me that there are no limits in the sky.

To those who have helped me throughout my learning years without every grumbling about my curiosity and appetite to knowledge.

To those who have always showered me with unwavering support and care.

To those who know themselves and know what they mean to me without the need of articulation.

Those are my family, friends and teachers and for them I dedicate this research, hoping that -by doing so- I am repaying them a little amount of what they owe me.

ACKNOWLEDGEMENT

Thanks be to Allah for this guidance and providence!

We would like to take the opportunity to wholeheartedly thank to everyone who supported the project team.

We especially thank:

- *Palestine Polytechnic University, Engineering Collage, Civil and Architectural Engineering Department, including all members of the helpful and reverend staff.*
- *All lecturers in the university. We particularly like to thank* **Dr. Maher Amro** *who extended a great effort in the project.*
- *The library of the university including its entire staff for providing us with the needed books and resources.*
- *Everyone who extended a hand in the project and was of great help.*

Abstract

Structural Design of PPU College of Medicine

Supervision: D. Maher Amro

Team:

Deya Sayed Ahmad, Dua Al Taqatqa, Hasan Al Atrash, Mo'taz Abu-Awad, Wisam Amro

Structural design is the most important design of the building after the necessary of architectural design, the distribution of columns, loads, offer durability, the best prices and the highest degree of safety are the responsibility of the structural designer. In this project we will do the structural design of the " Palestine Polytechnic University College of Medicine ". The college contain five floors, the basement floor, contains scientific labs, store services and cafeteria. The ground floor contains labs, offices, class rooms, pray room and theater. The first and second floors are the same as ground floor contains, and the third floor is a library, with a total area of 9770 m^2.

This project was selected because of the importance to know how to design these buildings, which have a design requirements higher than other projects with long spans and big theaters and diversity in the form of the building by the architectural design, also it has been chosen for the importance of having this college because of the lack of this kind of colleges in this area.

It is important mentioning that we will use the Jordanian Code to determine the live loads, and to determine the loads of earthquakes, for the analysis of the structural and design sections we will use the US Code (ACI_318_14), it must be noted that we will be relying on some computer programs such as: AutoCAD, Robot, Staad pro, Safe, Office, Attir, and Etabs.

After completion of the project we expect to be able to provide structural design of all the structural elements of the project accordance to the requirements of the code.

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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
b	width of compression face of member
Cc	compression resultant of concrete section.
Dl	dead loads.
d	distance from extreme compression fiber to centroid of tension reinforcement.
Fc	compression strength of concrete.
Fy	specified yield strength of non-prestressed reinforcement.
h	overall thickness member.
LL	live loads.
M	bending moment.
Mu	factored moment at section.
Mn	nominal moment.
Pn	nominal axial load.
Pu	factored axial load.
S	spacing of shear in direction parallel to longitudinal reinforcement.
Vc	nominal shear strength provided by concrete.
Vn	nominal shear stress.

Vs	nominal shear strength provided by shear reinforcement.
Vu	factored shear force at section.
Wc	weight of concrete.(Kg/m^3)
W	width of beam or rib.
Wu	factored load per unit area.
φ	strength reduction factor.
S_c	compression strain of concrete.
S_s	strain of compression steel.
ρ	ratio of steel area.
ε_c	compression strain of concrete=0.003mm /mm
Fsd,r	total additional tension force above the support.
Ved,0	shear force at critical section.
Ned,0	normal tension force at support.
α	angel of stirrup.

Chapter 1

Introduction

The last century has witnessed a starting of a period of revolution and improvement in all the life aspects, and with the increasing demand of the people in the cities, it was very essential to cope up with this improvement in all of the fields, in such a way that suits and controls the environment.

Every one of us knows the importance of the medicine college, the building society for culture, especially here in Palestine under occupation. So, it was necessary to think about the college of medicine that includes many of the functions that support science in the city, and that contribute to the development of the education aspect in Palestine.

1.1 General Identification

The project is a medicine college in Hebron, it provides all requirements needed for suitable work-place like theory and offices, theater, classrooms, laboratories, waiting area, reception, library, mechanical and electrical rooms, Central Administration and all services needed.

1.2 Reasons of Choosing Project

After more than one month of searching on a good project, we decide to choose the college of medicine in Hebron from a lot of other projects because of the large size of the project and including of various structural members, the most important thing from this project is to have.

1.3 The Project Objectives

The objectives of this project are divided into architectural and structural objectives.

1.3.1 Architectural Objectives

The main architectural aim is to create a design that is unique in views, representative and break the lack of architectural that Palestine suffers. So, the college of medicine is designed upon the latest architectural views.

1.3.2 Structural Objectives

The structural objectives of this project are:

- Increasing the ability to choose a structural system that suits the objectives of the building.
- To correlate what we have taken in the design courses with the practical thinking.
- To get a new skills and experiences while facing problems and obstacles rising while working in the project, which has not mentioned in the theoretical studying.

1.4 The Problem of Project

The problem of the project is to find the most appropriate structural system that satisfies the strength and serviceability requirements, and to design and analyze the structural components that consists the project which is the college of medicine, so we will analyses and design these components like slabs, beams, columns, foundation, etc. After determining the loads on each of the structural member so we can select the required dimensions and reinforcement, after that all of the design outputs will be presented in the structural drawing that used to transfer the project from being a drawing to the practical field.

1.5 The Postulate of the Project

Our study aims to prepare the required structural drawings of the various structural members existing in the building in such a way that takes the architectural design as the main outlet. The design will be based on the requirements of the American Code (ACI-318-14), and the Jordanian Code of Loads.

1.6 Chapters of Project

Chapter One: General introduction of the project.

Chapter Two: The architectural description of the project.

Chapter Three: The structural studying of the project including: the structural members, the loads, and the function description.

Chapter Four: The structural analysis and the design of some structural members like: beams, slabs, stairs, columns, frames, and foundations.

Chapter Five: Results and recommendations.

1.7 The Time Table of the Project Stages

The Table below shows the time line table of the project stages.

Table 1.1: The 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

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. A good architect does more than just designing buildings, yet he or she understands how people's environment affects their feelings in order to create an atmosphere that meets their needs and desires.

Architecture requires a strong technical knowledge in the fields of engineering, logistics, geometry, building techniques, functional design and ergonomics. It also requires a certain sensibility to arts and aesthetics. Finally, it also requires taking in consideration human questions and society's problems. Architecture is a very broad humanistic field that, at the same time, is technical, artistic and social.

2.1 Basic Identification of Project

The idea of the project is the structural design of Palestine Polytechnic University college of medicine. The college consists of one building, the college contains five floors, the basement floor, it contains scientific labs, store services and cafeteria. The ground floor contains labs, offices, classrooms, pray room and theater. The first and second floors are the same as ground floor contains, and the third floor is a library, with a total area of 9770 m^2. The project is featured by many declines which adds special architecture beauty to the structure, also by its integration with nature in general.

Figure 2.1: General Picture of Project.

2.2 Project Site

Its recommended that you pursue land that has already been approved by the local authorities as an “approved building lot”. That means all surveys; soil testing, wetlands conservation, and site engineering work have been completed and approved. While raw land costs less, you will have to spend money to complete the required tests, surveys and engineering work before you can get the land approved for building.

2.2.1 Project Land Location

The project is located in Namerh north of Hebron.

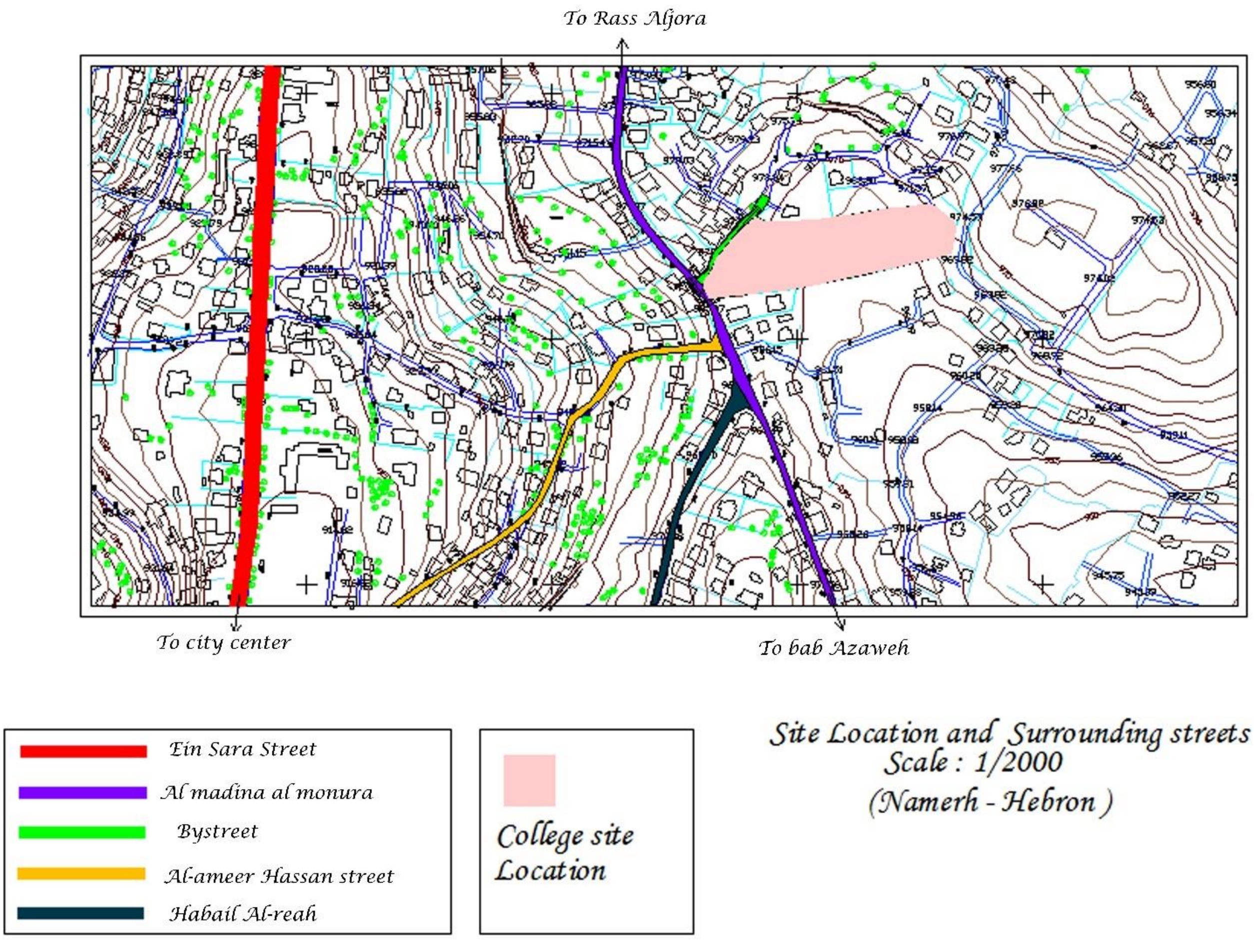


Figure 2.2: The location of the Project.

2.2.2 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 south western winds dominate, the northern winds are light and the eastern winds still blow on occasion.

2.2.3 Contour Lines of the Project Land

- The project land is semi flat area (slope of 3 degree).
- The project land is 970 m above sea level.

2.3 Project Components Description

The designer used many declines which add special architecture beauty to the structure.

2.3.1 Project Plans Description

The collage has one building with total area of 9770 m^2.

1. Basement Floor Plan

The area of this floor is 1932 m^2, and it contains scientific labs, store services and cafeteria.

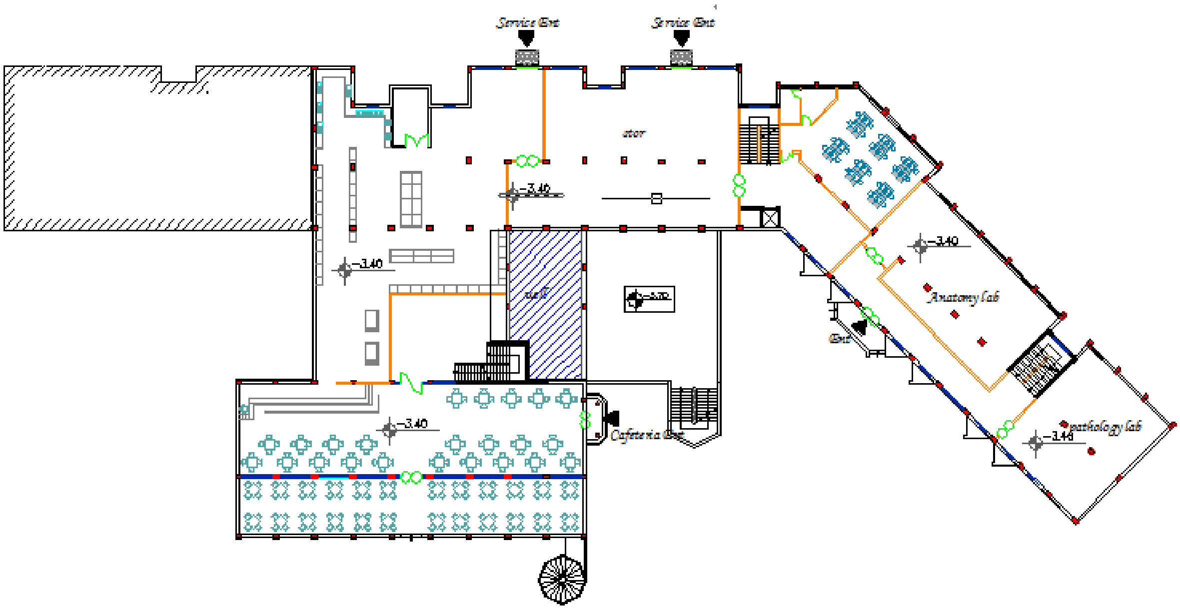


Figure 2.3: Basement Floor.

2. Ground Floor Plan

The area of this floor is 2406 m^2, and it consists of labs, offices, classrooms, pray room and theater.

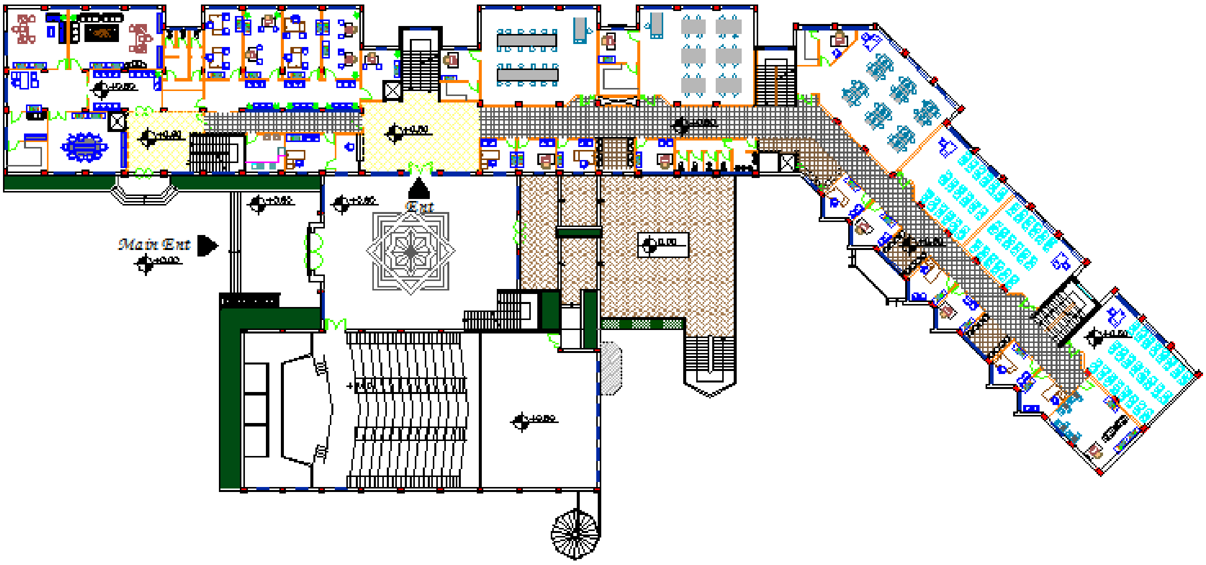


Figure 2.4: Ground Floor.

3. First Floor Plan

The area of this floor is 2357 m^2, and is the same as ground floor contains.

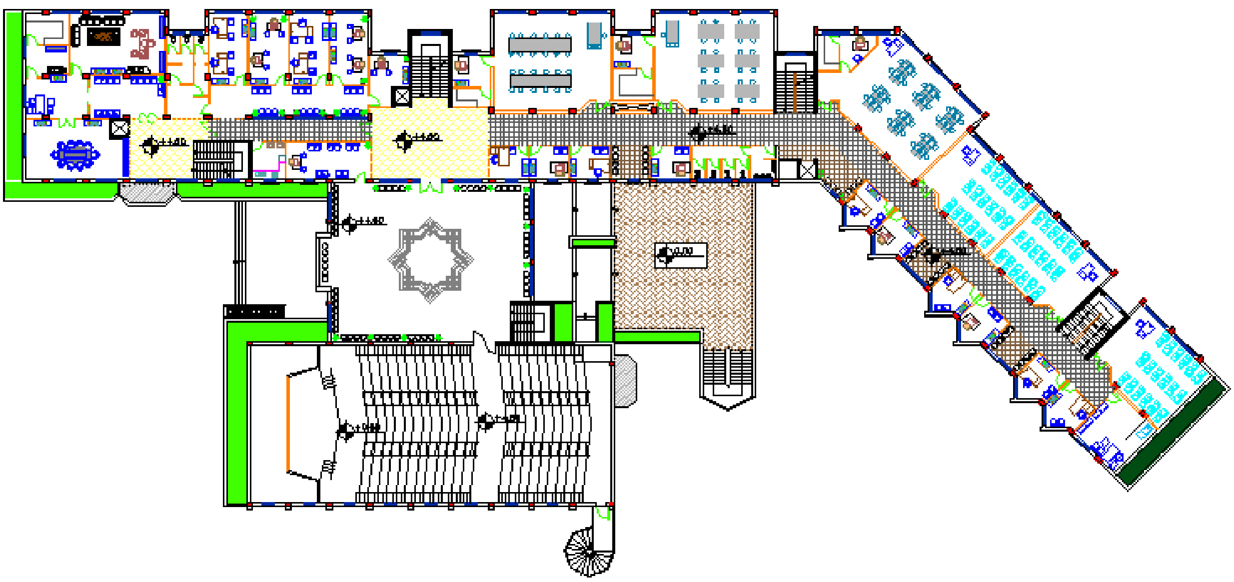


Figure 2.5 First Floor.

4. Second Floor Plan

The area of this floor is 2065 m^2, and is the same as ground and first floor contains.

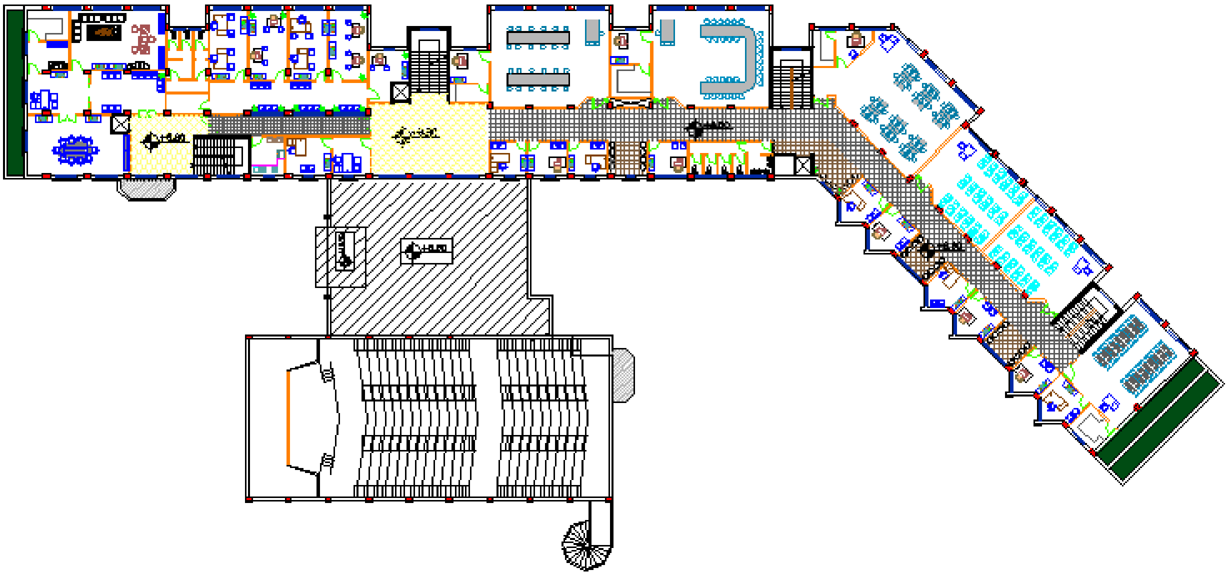


Figure 2.6 second Floor.

5. Third floor plan

The area of this floor is 1010 m^2, and it contains a library.

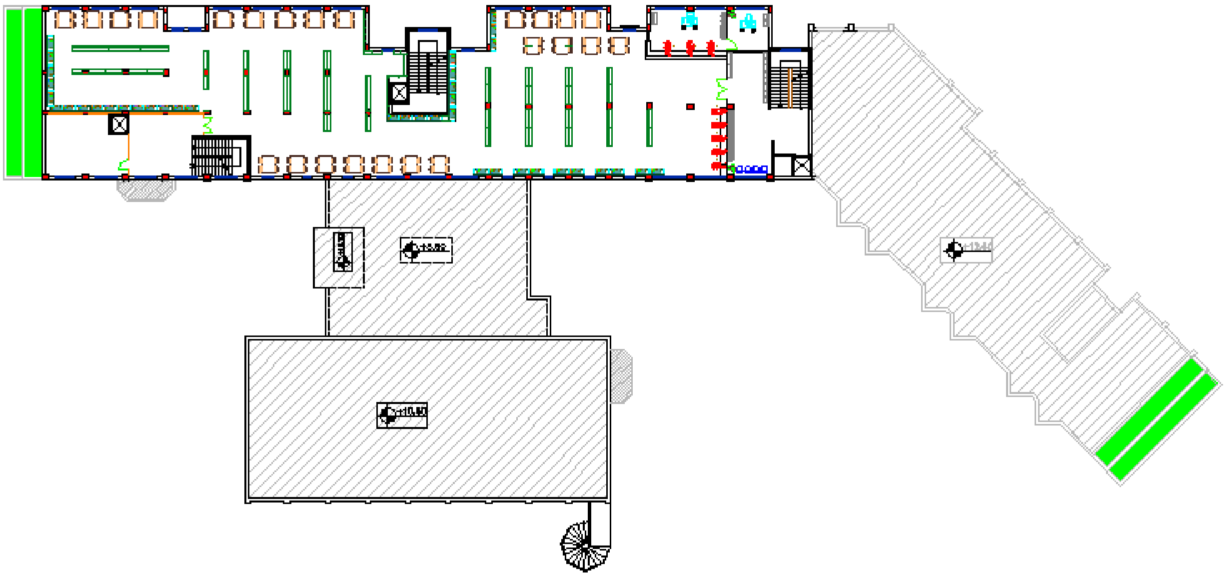


Figure 2.7 third Floor

2.3.2 Project Elevations Description

The interest of elevations for any architect is great as the elevations appearance should be suitable with the kind of the building and its uses, so it's a duty of the engineer to consider every detail of the elevations in terms of materials used, the distribution of the openings, and other factors that highlight the beauty of elevations design.

West Elevation

The main elevation and the main entrance of the building, we can observe the beauty of this elevation that contain glass integrated with stone.

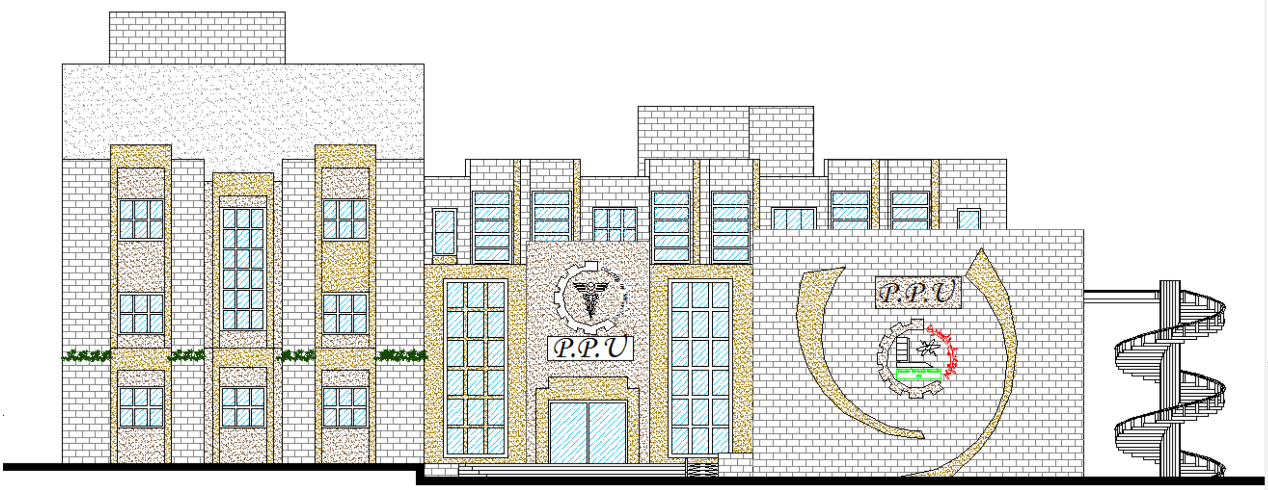


Figure 2.8 West Elevation.

East Elevation

This elevation shows the inclination of the road, and we can observe the integration between glass and stone in this elevation, and we can observe the setbacks in the building.

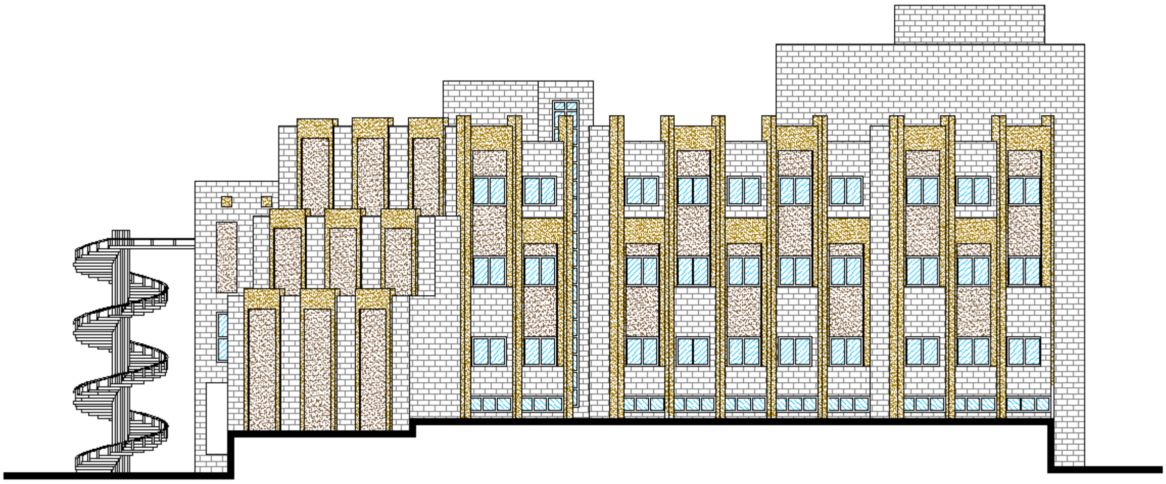


Figure 2.9 East Elevation

South Elevation

The back-side elevation, in this elevation we can observe some part of basement floor, and this elevation show some of columns.

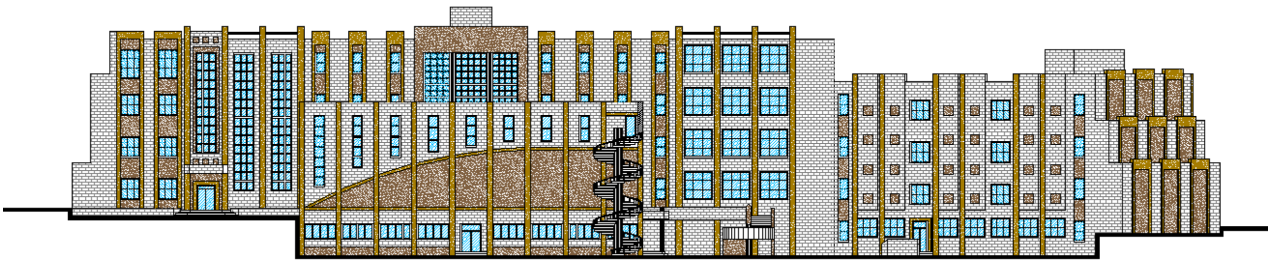


Figure 2.10 South Elevation.

North Elevation.

This elevation shows the entrance to the basement floor, here we can observe two entrance.

Figure 2.11 North Elevation.

2.3.3 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 2.12 Section A-A.

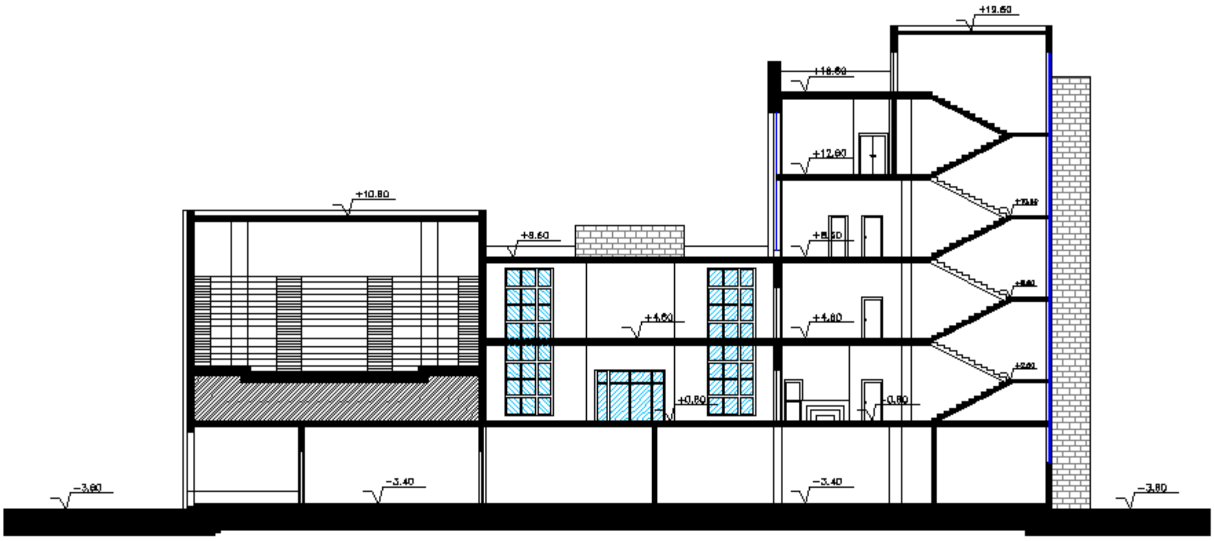


Figure 2.13 Section B-B.

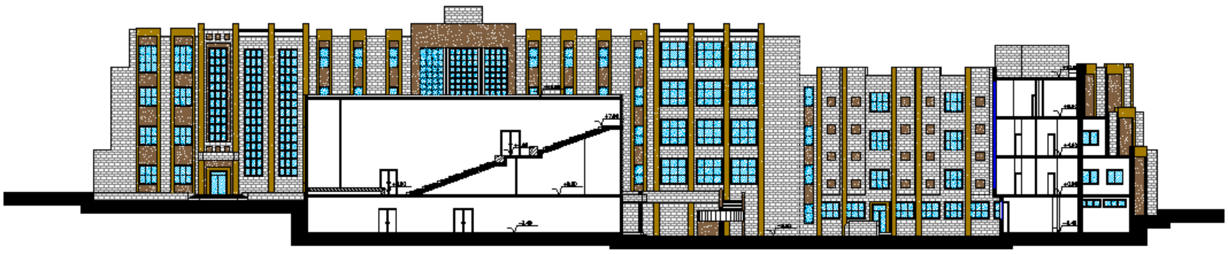


Figure 2.14 Section C-C

Figure 2.15 Section D-D

Chapter 3

Structural Description

After completing the process of the architectural project explanation of all the details, we must move to the construction phase of the study for the project, in order to choose the appropriate structural system for each element in the building, in order to provide all requirement and design all elements necessary for the system. So that it is taking into account the loads affecting the types of elements, showing how to deal with them and work to resist them, so we must know these structural elements in detail, in order to be customized and analyzed accurately.

3.1 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 loads of dead and live or external forces such as earthquakes, wind and landing in the soil. When designing any element of these it should be taken in consideration the following standers:

1. Safety: is the essential element that must be provided in the design, so choosing the

appropriate element of each region to resist loads that affecting them.

2. Economy: must be supplied when working on the selection of appropriate materials, and sufficient for its desired purpose and appropriate quantity, with lowest cost and highest quantity.

3. Serviceability: work to avoid any external failures, such as the decline in soil or 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.

3.2 Theoretical studies of the structural elements of the building

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

3.3 Types of Loads

Loads are the base of design process, so they must have great consideration is specialty, identifying and study.

Accurately, so differing building from 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 which must be taken into account in the structural design of the building in all cases, it includes: Dead load, Live load and Environmental loads.

2.Secondary loads:

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

3.3.1 Dead Load

Dead load includes loads that are relatively constant over time, including the weight of the structure itself, and immovable fixtures such as walls, plasterboard or carpet. Roof is also a dead load. Dead loads are also known as permanent loads.

Designer can also be relatively sure of the magnitude of dead loads as they are closely linked to density and quantity of the construction materials. These have a low variance, and the designer is normally responsible for specifying these components.

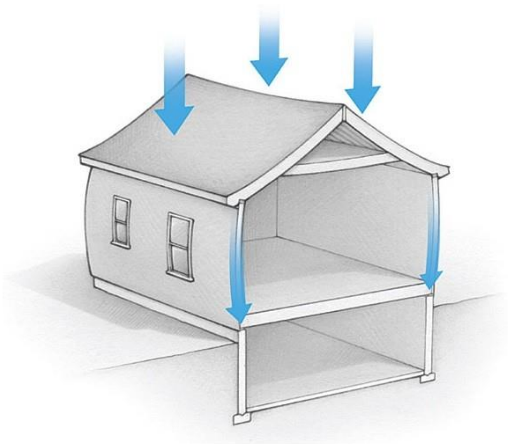


Figure 3.1 Dead Load.

Table 3.1: Specific Density of the Materials Used

Num.	Density (KN/m³)	Material
1	23	Tiles
2	22	Mortar
3	16	sand
4	22	plaster
5	15	block
6	25	Reinforcement concrete

3.3.2 Live load

Live load is imposed loads which are temporary, of short duration, or moving. These dynamic loads may involve consideration such as impact, momentum, vibration, slosh dynamic of fluids, fatigue, etc. Live loads, sometimes also referred to as probabilistic loads include all the forces that are variable within the object's normal operation cycle not including construction or environmental loads.

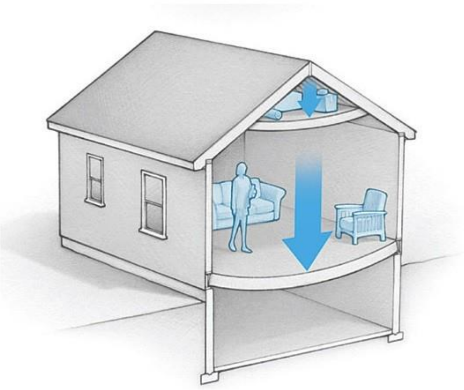


Figure 3.2 Live Load.

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

Num.	Live load (KN/m^2)	Use
1	5.0	Store
2	5.0	Parking
3	5.0	Theaters and terraces
4	4.0	Stairs
5	3.0	Offices

3.3.3 Environmental loads

The loads arising from the changes in the environmental such as seismic, wind and snow.

3.3.3.1 Seismic load:

Loads caused by earthquakes. Buildings should be designed to withstand minor earthquakes because they can occur almost anywhere. During an earthquakes the ground can move both horizontal and vertically in any direction. This exerts tremendous horizontal loads on members.

Figure 3.3 Seismic Load.

3.3.3.2 Wind load:

The forces that affect horizontally on the building appear especially in high-rise buildings, and its de- signed on the basis of wind speed and height of the building, and the amount of buildings surrounding the building.

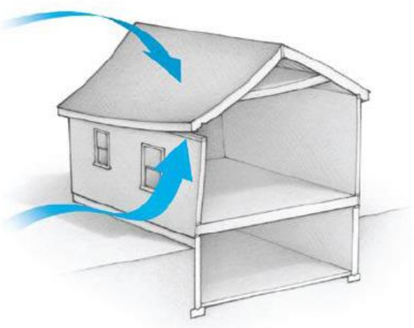


Figure 3.4 Wind Load.

3.3.3. 3 Snow load:

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

Figure 3.5 Snow loads.

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

Table 3.3: Loads of Snow by Sea Level (Ref.: Jordan Code)

Building height above sea level	The value of load in surface (KN/m^2)
250 > h	0
500 > h > 250	(h-250)/800
1500 > h > 500	(h-400)/320

3.4 Practical Tests

Before you begin the process of design and construction, should work some of necessary tests at the site, especially on the soil, and work to see the quality of the rocks in the region, and work to deviate place waterfalls groundwater and its impact on the building, and work to resolve the problems if available of these problems, as soil test.

3.5 Structural Elements

There are many structural elements used in the buildings as the slab, beam, column, stairs, the shear wall and foundations.

3.5.1 The Slabs

Is an element which transfers the loads that are exposed to other structural elements such as column, beam, wall. They many factor to select type of slabs:

1. The distance between the spaces and columns.
2. The desired function of the space.
3. Cost.
4. Ease of implementation and duration available forbuilding.

And In our project, we will use different types including:

3.5.1.1 Rib Slab:

In general, this type is most commonly used in our project, this contains the steel bars use to transfer the loads, and block and the concrete between this block and the topping of all, and we have two types of this:

- One way ribbed slab.
- Two way ribbed slab.

One way ribbed slab are used when it is intended to cover areas without bridges falling , was the use of these tiles in all floors of this project , to lightweight and effectiveness.

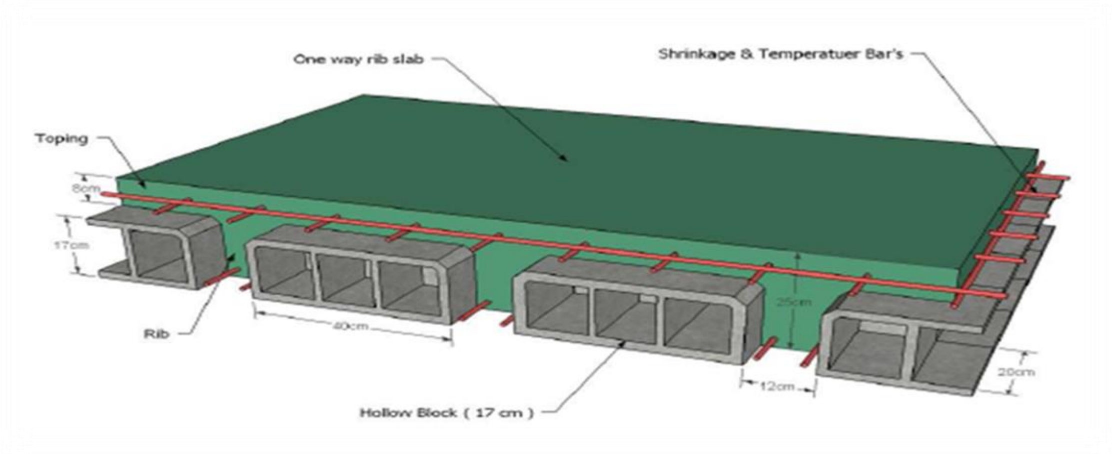


Figure 3.6 One Way Rib Slab.

Two way ribbed slab is the type use when the length of the two direction in the space approximately is equals, and we used in this type bar of steel in two direction to transfer the load.

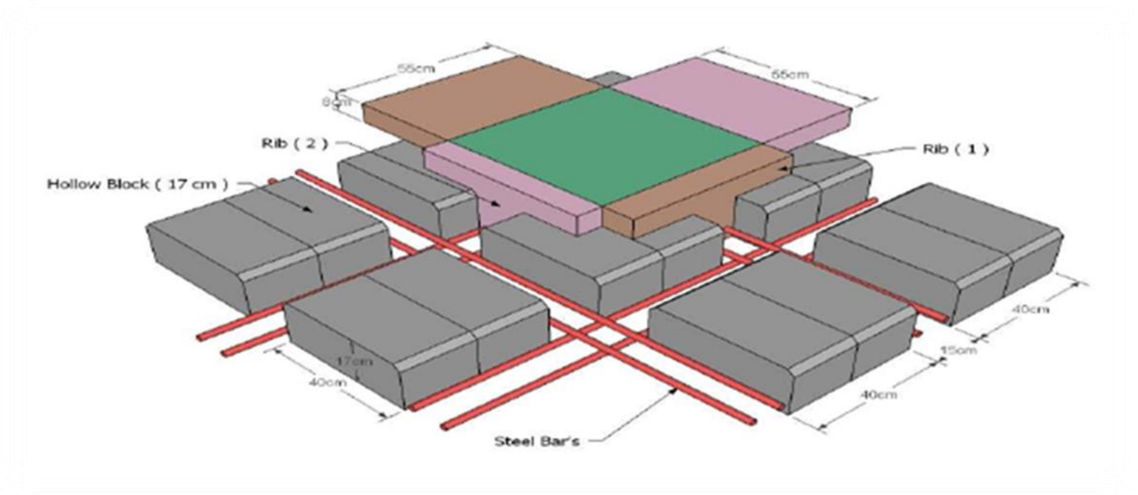


Figure 3.7 Two Way Rib Slab.

3.5.1.2 Solid Slab:

We use this method when the height of the spaces is important, and we don't have problem when show the drop beam and this transfer the load to the beam to the column, and we have two types: one way and two way, and the difference between two types is the direction of transfer load.

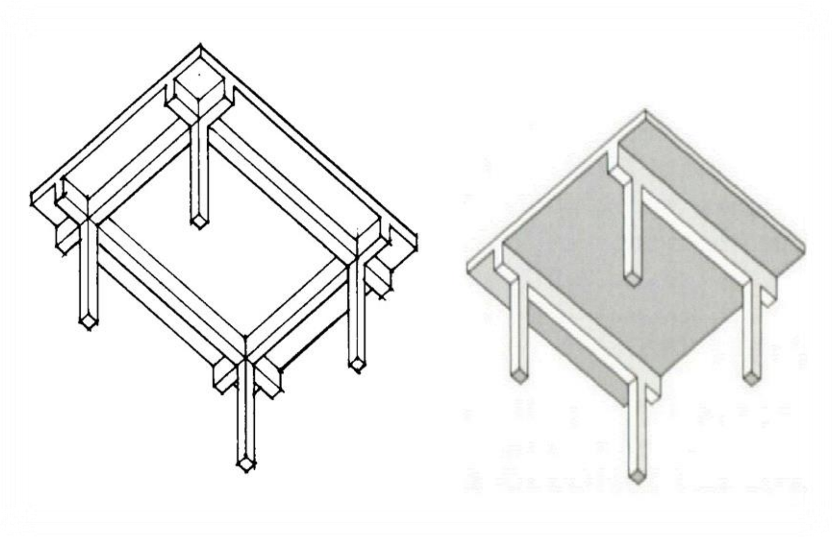
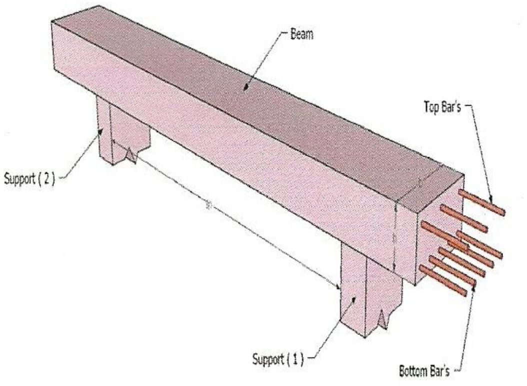


Figure 3.8 Solid Slabs

3.5.2 Beams

Use this element to transfer the load from the slab to the column, and have the type as hidden beam when have the same thickness of slab and drop beam when have different thickness.



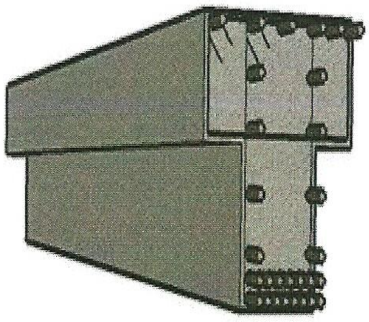


Figure 3.9 Hidden Beam. Figure 3.10 Drop Beam.

3.5.3 Columns

This element is uses to transfer the load from the slab to the foundation, and it helps in the stability of the building, and when design we will know the type design if short or slender column.

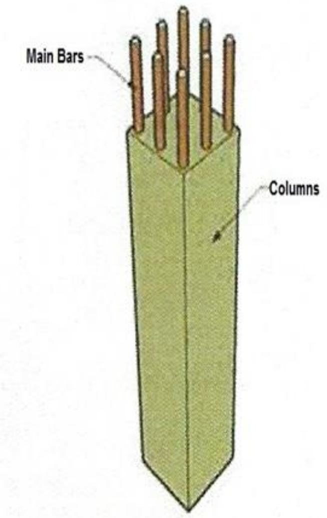


Figure 3.11 Square Column. Figure 3.12 Circular Column.

3.5.4 Shear Wall

Shear wall is the important element structure because it is uses 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 resist loads as the wind and earthquake. When design this wall, we use two layer steel to give it more strength.

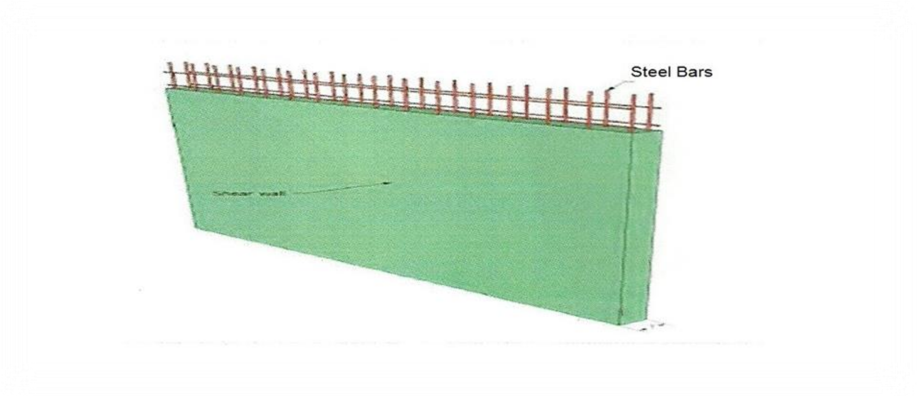


Figure 3.13 Shear wall.

3.5.5 The Foundations

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 as dead or live load or secondary load. So is the basic element, which receives all the loads and distributed it to the soil.

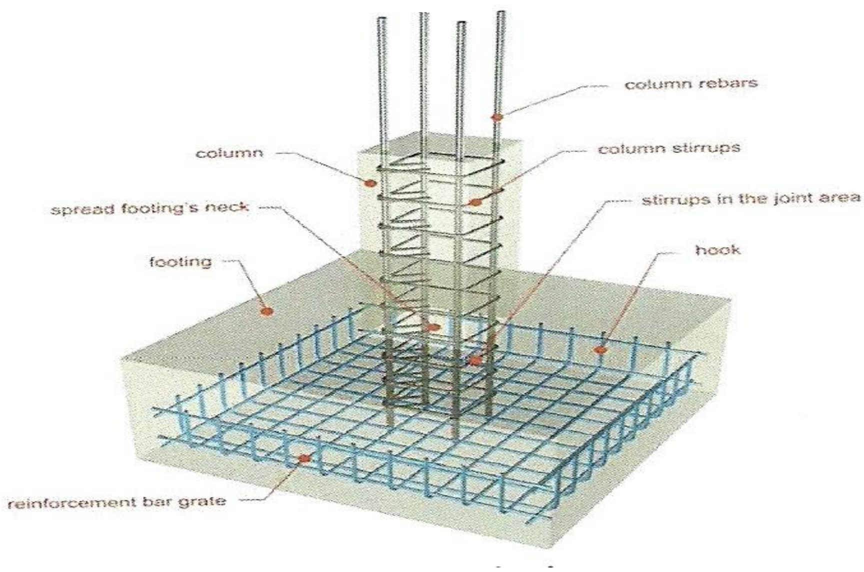


Figure 3. 14 Isolated Footing.

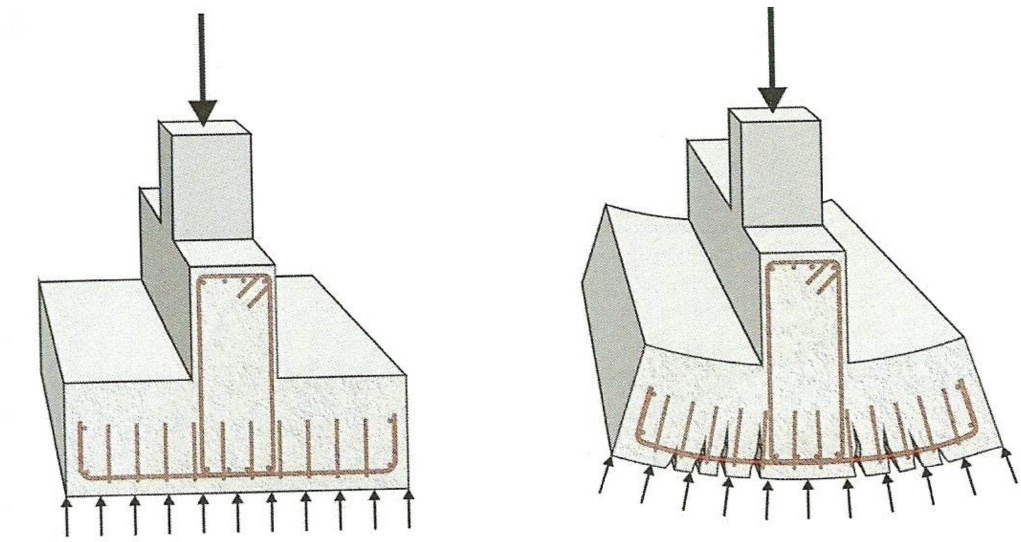


Figure 3.15 Strip Footing.

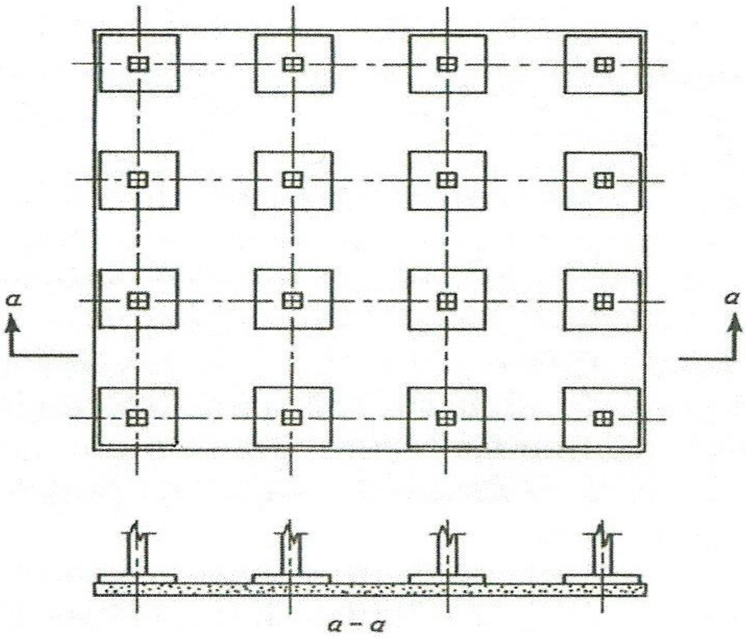


Figure 3.16 Mat Footing.

3.5.6 Stairs

The stairs is a vertical transmission element between the levels, and we used the one way solid slab in the landing structural design.

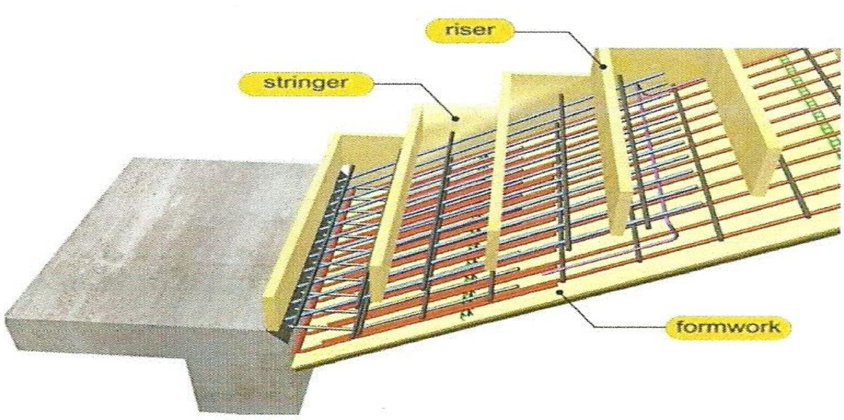


Figure 3.17 Stairs.

3.5.7 Expansion joints

Is a spacer which are used in order to avoid getting any expansion or other effects that may impair the building, where the building is separated entirely, and the building is separated after increasing distanced (35-45) m.

When you use joints must take into account the vast spaces of the building:

1. 40m areas with high humidity.
2. 36m areas with normal humidity.
3. 32m areas with medium humidity.
4. 28m with dry areas.

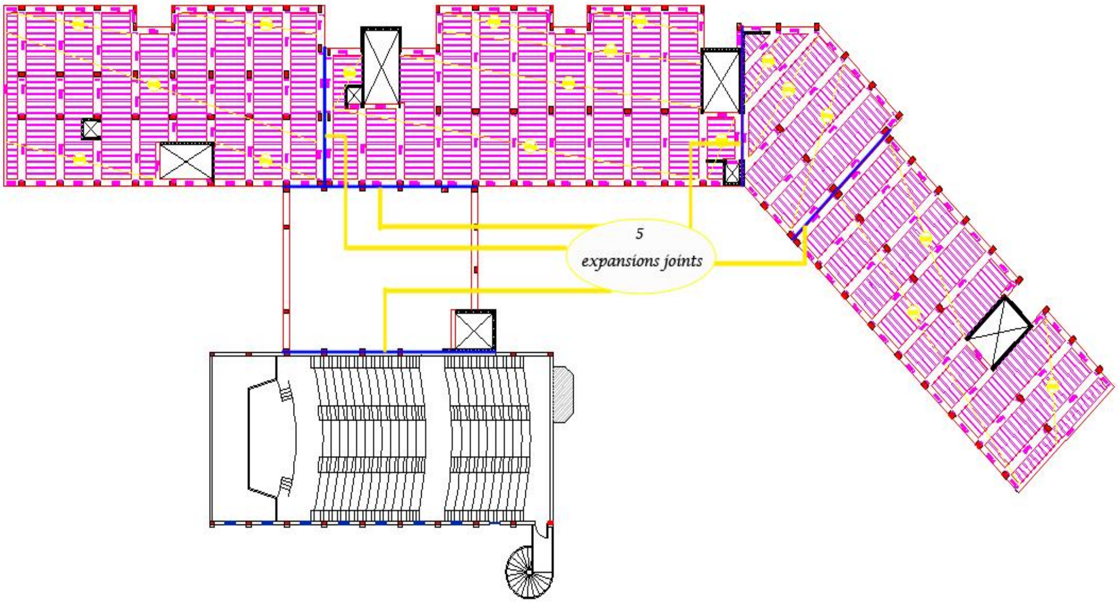


Figure 3.18 Expansion Joints in the Project.

- Will have the thickness 5 cm.
- We use five expansion joints with 5cm.

Chapter 4

Structural Analysis and Design

4.1 Introduction.

4.2 Factored Load

4.3 Determination of Slab Thickness.

4.4 Design of topping.

4.5 Determination of Loads of Ribs.

4.6 Design of Rib R1 (05).

4.7 Design of Beam " B1(14) " .

4.8 Design of two way ribbed slab.

4.9 Design of stair .

4.10 Design of long column.

4.11 Design of basement wall.

4.12 Design of basement footing.

4.13 Design of isolated foundation.

4.14 Design of shear wall.

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 virtually any form or shape.

Concrete used in most construction work is reinforced with steel. When concrete structure members must resist extreme tensile stresses, steel supplies the necessary strength. Steel is embedded in the concrete in the form of a mesh, or roughened or twisted bars. A bond forms between the steel and the concrete, and stresses can be transferred between both components.

In This Project, there are two types of slabs: solid slabs and one-way ribbe. They would be analyzed and designed by using finite element method of design, with aid of a computer Program called " ATTIR- Software" 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 {fy = 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 our project members, is determined as follows:

$$q_u = 1.2DL + 1.6L \qquad \textit{ACI – 318 - 14 (9.2.1)}$$

4.3 Determination of Slabs Thickness.

4.3.1 Determination of one way ribbed Slab Thickness:

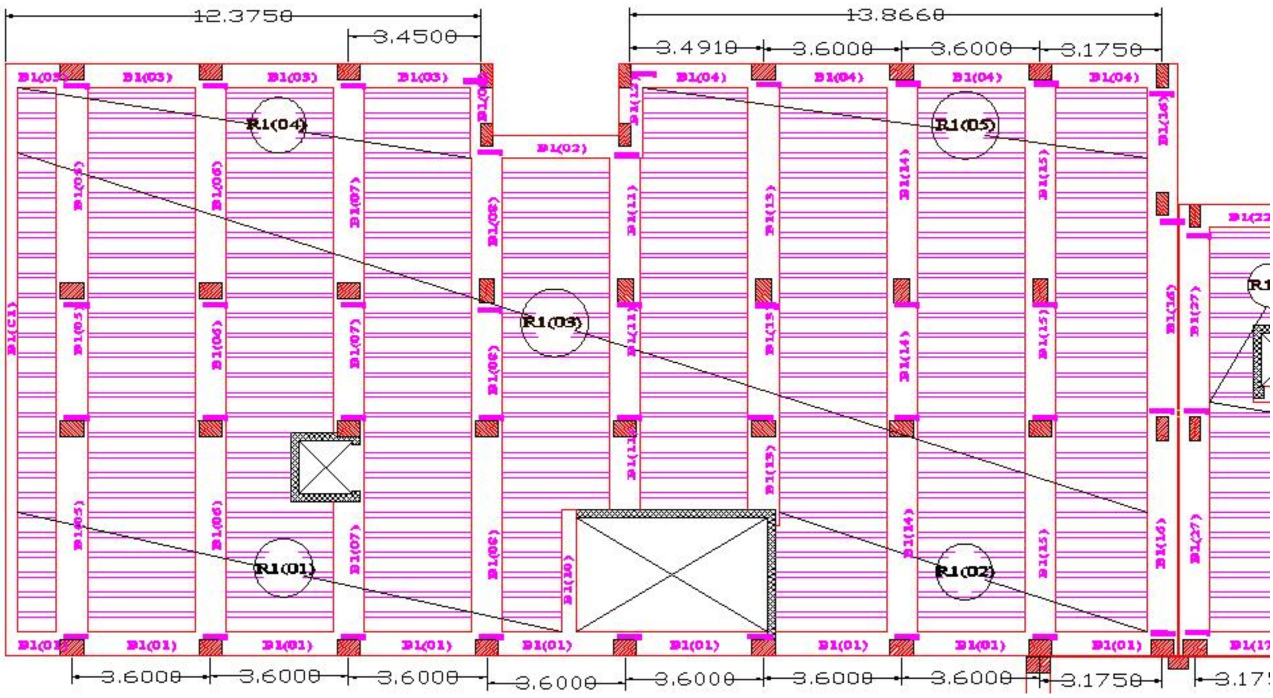


Figure 4.1: Part of First Floor Slab.

According to ACI Code 318-14, the minimum thickness of non-prestressed beams or one way slabs unless deflections are computed as follow:

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

$h_{min} = \frac{L}{18.5} = \frac{360}{18.5} = 19.5cm$

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

$h_{min} = \frac{L}{21} = \frac{360}{21} = 17.2cm$

-The maximum span length for simply suported (for ribs):

$h_{min} = \frac{L}{16} = \frac{360}{16} = 22.5cm$

-The maximum span length for cantilever (for ribs):

$h_{min} = \frac{L}{8} = \frac{160}{8} = 20cm$

Take slab thickness h=25 cm. (deflection will be checked)

h =25cm (17cm Hollow block + 8cm Topping).

4.3.2 Determination of one way solid Slab Thickness :

h_{min} for one-end continuous = L1/24

= 3.7/ 24 = 15.42 cm control

hmin for both-end continuous = L1/28

= 3.6/ 28 = 12.9 cm

We selected h = 20 cm

4.4 Design of Topping:

Table (4 – 1) Calculation of the total dead load on topping

No.	Material	Calculation
1	Tile	0.03*23*1= 0.69 KN/m
2	mortar	0.03*22*1= 0.66 KN/m
3	Coarse sand	0.07*17*1= 1.19 KN/m
4	topping	0.08*25*1 = 2 .0 KN/m
5	Interior partitions	2.3 *1 =2.3 KN/m
Sum		6.84 KN/m

Live load = 4 *1 KN/m

$W_u = 1.2DL + 1.6L$ = (1.2 * 6.84) + (1.6 * 4) = 14.608 KN/m.

(Total Factored load)

Assume slab fixed at supported points (ribs):

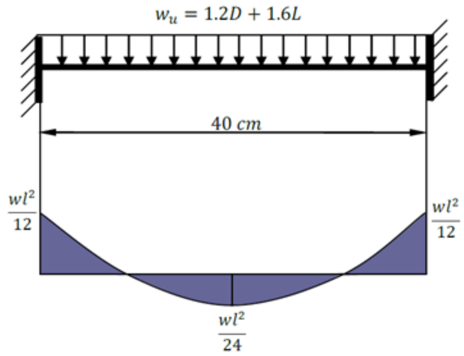


Figure 4.2 Topping System

$$M_u = \frac{Wu * l^2}{12}$$

$$= \frac{14.608 * 0.4^2}{12} = 0.195 \text{ KN.m /m of strip width .}$$

$(\Phi M)_n > M_u$ [Strength Condition, where Φ = 0.55] for plane concrete

$$Mn = 0.42 \times \sqrt{fc'} Sm \qquad \textit{ACI-318-14} \quad (22\text{-}5.1)$$

$$Sm = \frac{b * h^2}{6} = \frac{1000 * 80^2}{6} = 1066666.67 \text{ mm}^3$$

$$Mn = 0.42 \times \sqrt{24} * 106666667 = 2.194 \text{ KN.m}$$

Φ Mn = 0.55 * 2.194= 1.2 KN.m

Φ Mn = 1.2 KN.m > Mu = 0.195 KN.m

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

According to ACI 7.12.2.1, **ρ** shrinkage = 0.0018

As_{min} = ρ * b * h = 0.0018 * 1000 * 80 = 144mm^2 /1m

Try bars Φ 8 with As = 50.27mm^2

No. of Φ8 = $\frac{As_{req}}{A_{bar}} = \frac{144}{50.26}$ = 2.86 → Spacing(S) = $\frac{1}{2.86}$ = 0.348m = 348 mm

$$\leq 380\left(\frac{280}{fs}\right) - 2.5 * Cc \quad \leq 300\left(\frac{280}{fs}\right)$$

$$S = 380 * \left(\frac{280}{\frac{2}{3} * 420}\right) - 2.5 * 20 = 330mm$$

$$S = 300 * \left(\frac{280}{\frac{2}{3} * 420}\right) = 300mm$$

Not more than: S_{max} = 450 mm

Use Φ 8 / 20 cm, with As $_{provided}$ = 251mm^2/1m both directions.

4.5 Determination of Loads of Ribs:

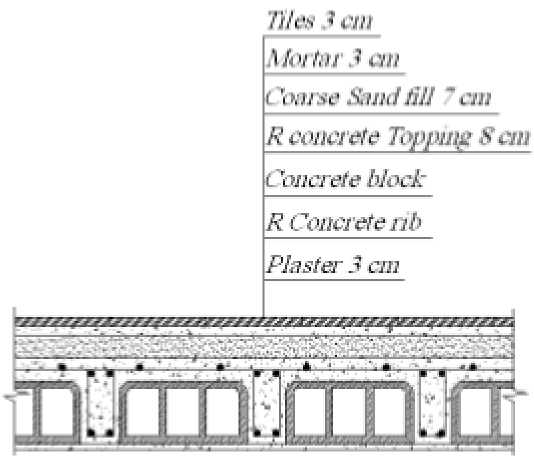


Figure 4.3: Typical Section in Ribbed slab.

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

Table (4 – 2) Calculation of the total dead load for one way rib slab.

No.	Parts of Rib	Calculation
1	**Tile**	**0.03*23*0.52 = 0.359 KN/m**
2	**mortar**	**0.03*22*0.52 = 0.343 KN/m**
3	**Coarse sand**	**0.07*17*0.52 = 0.619 KN/m**
4	**topping**	**0.08*25*0.52= 1.04 KN/m**
5	**RC rib**	**0.17*25*0.12 = 0.51 KN/m**
6	**Hollow block**	**0.17*10*0.4=0.68 KN/m**
7	**plaster**	**0.03*22*0.52=0.343 KN/m**
8	**Interior partitions**	**2.3*0.52= 1.196 KN/m**
Sum		**5.09 KN/m**

Nominal Total Live Load:

Live load = 4 * 0.52 = 2.08 KN/m of rib

Factored dead Load = 1.2* 5.09 = 6.108 KN/m

Factored live Load = 1.6 * 2.08 = 3.328 KN/m

4.6 Design of Rib R1 (05):

By using **ATTIR** program we get the envelope moment and shear diagram as the follows: -

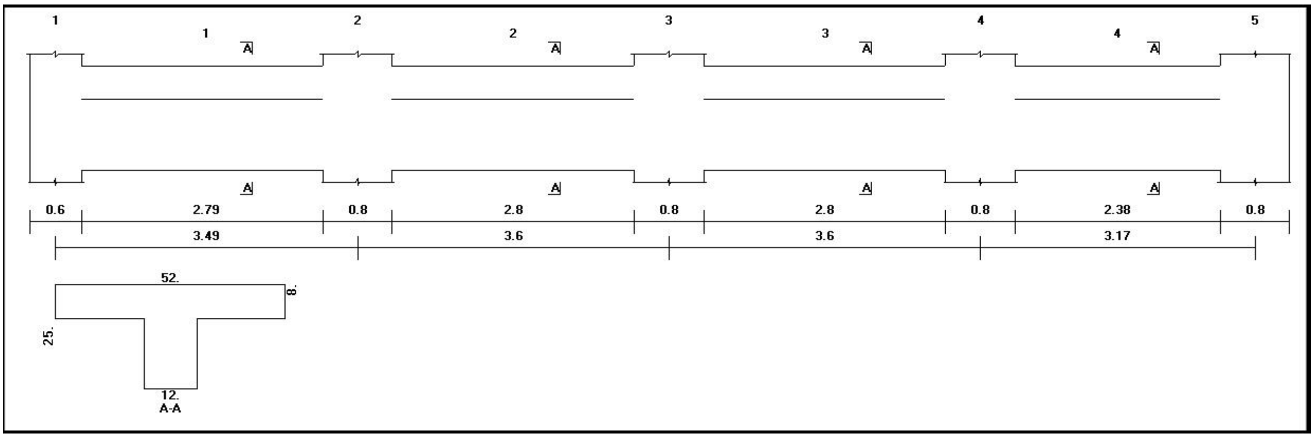


Figure 4.4: Rib (1-05) Geometry.

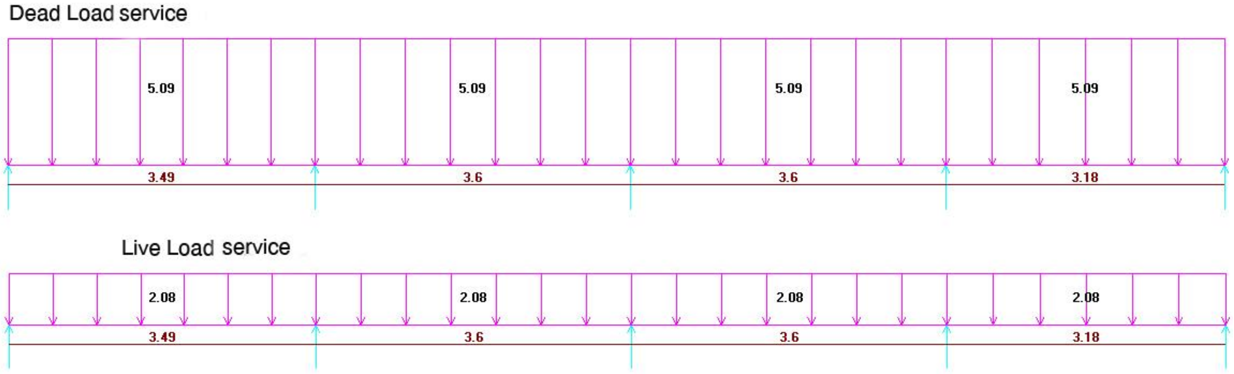


Figure 4.5: Loading of Rib 1 (05)

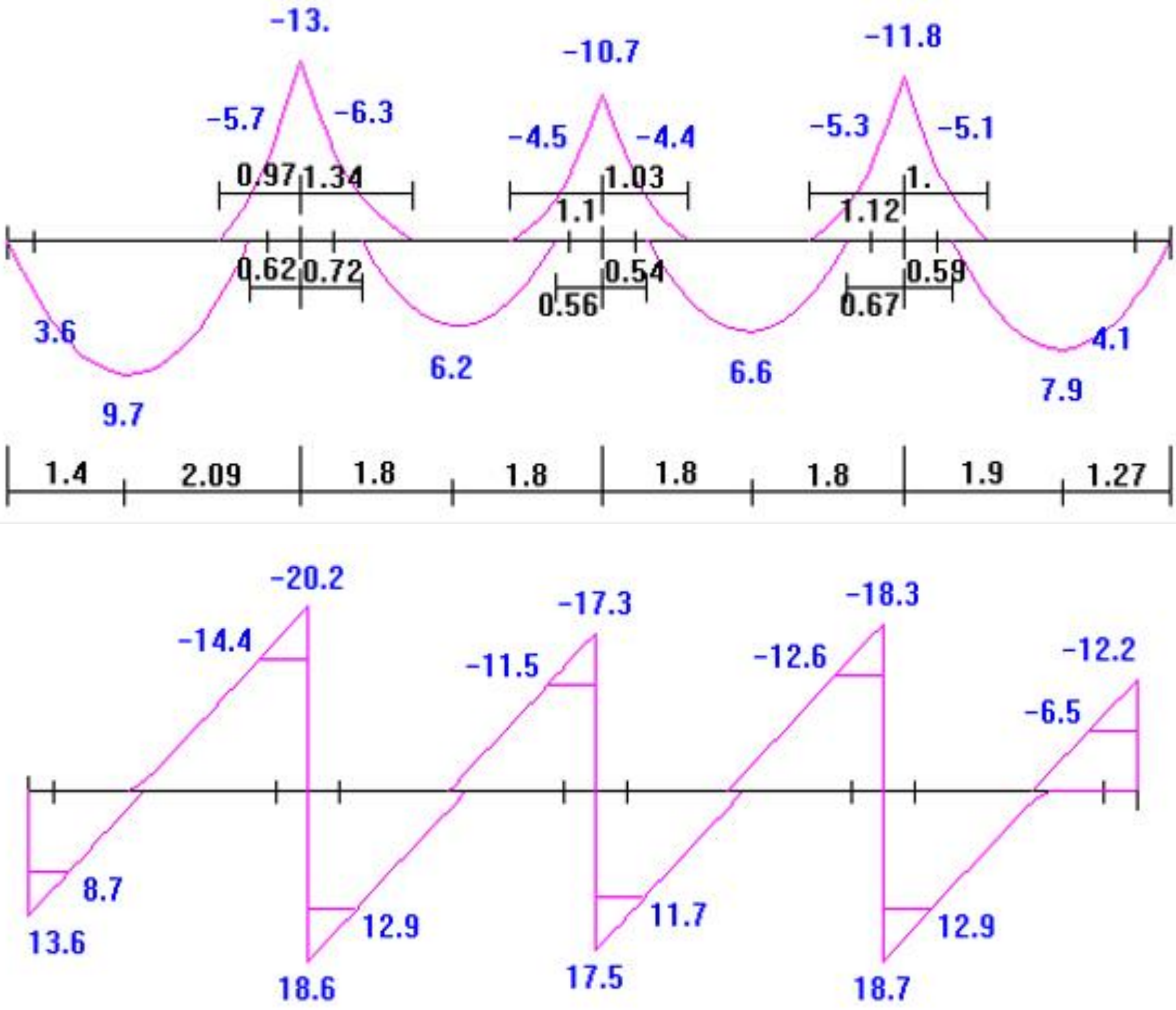


Figure 4.6: Moment and Shear Envelope of Rib 1 (05)

4.6.1 Design of rib"R1 (05)" for max positive moment: Mu =9.7 KN.m

Effective Flange width (b_E) : ACI-318-14 (8.12.2)

b_E For T- section is the smallest of the following:

$b_E \leq \frac{1}{2} * \text{clearspase} + b_w$ = 400 +120 = 520 mm.

$\leq$ Span/4 =4200/4 = 1050 mm.

$\leq$ $(16\times t_f) + b_w$ =(16× 80) +120 =1400 mm.

b_E= 520 mm.__________ controlled.

»Determine whether the rib will act as rectangular or T – section:

For $a = h_f = 8$ cm assume bar diameter 14 mm

d = h – cover –ds-db/2 = 250 – 20 – 10 - 14/2 = 213 mm

M_{nf} =0.85 *24*80*520(213- 80/2) 10^{-6} = 146.81 KN.m

$M_{n\ available}$ = 146.81 KN.m >> $M_{n\ required}$ = 9.7/0.9 =10.78 KN.m

$a<h_f$.

Design as a <u>rectangular with</u> b_E = 52 cm

This design for 3.49m span.

$$Rn=\frac{Mn}{bd^2}=\frac{9.7*(10)^6}{0.9*520(213)^2}=0.457 \text{ Mpa}$$

$$m=\frac{fy}{0.85fc'}=\frac{420}{0.85(24)}=20.58$$

$$\rho=\frac{1}{m}\left(1-\sqrt{1-\frac{2mRn}{fy}}\right)=\frac{1}{20.58}\left(1-\sqrt{1-\frac{2*20.58*0.457}{420}}\right)=0.0011$$

A_s = 0.0011 *(520) (213) = 121.89mm^2

$$A_s \min=\frac{\sqrt{fc'}}{4(fy)}(bw)(d) \qquad \text{ACI-318 (10.5.1)}$$

$$A_s \min=\frac{\sqrt{24}}{4(420)}(120)(213)=74.53\text{mm}^2$$

<u>Not less than</u>

$$A_s \min=\frac{1.4}{(fy)}(bw)(d)$$

$$A_s \min=\frac{1.4}{420}(120)(213)=85.2\text{ mm}^2\text{\_\_ control}$$

A_s = 121.89mm^2 $\geq$ As min = 85.2 mm^2. OK

Use 2Φ12with As =226.2 mm^2 for span 1

Check for strain:

$$a = \frac{As * fy}{0.85 fcb}$$

$$a = \frac{226.2*420}{0.85*24*520} = 8.96mm$$

C= 8.96/0.85 =10.54 mm.

* Note: $f_c' = 24$ MPa< 28 MPa→ $\beta_1 = 0.85$

d = 250 – 20 – 10 - 12/2=214 mm.

$$\varepsilon_s = 0.003(\frac{d-c}{c})$$

$$\varepsilon_s = 0.003(\frac{214-10.54}{10.54}) = 0.05791 > 0.005 \_\_ OK$$

4.6.2 Design of rib for positive moment: Mu =6.2 KN.m

Assume bar diameter 12 mm. d= 250-20- 10 - 10/2 = 214 mm.

$$Rn = \frac{Mn}{bd^2} = \frac{6.2*(10)^6}{0.9*520(214)^2} = 0.289 \text{MPa}$$

$$m = \frac{fy}{0.85 fc'} = \frac{420}{0.85(24)} = 20.58$$

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2mRn}{fy}}\right) = \frac{1}{20.58}\left(1-\sqrt{1-\frac{2*20.58*0.289}{420}}\right) = 0.000694$$

A_s =0.000694*(520) (214) = 77.23 mm^2

$$As\ \min = \frac{\sqrt{fc'}}{4(fy)}(bw)(d)$$ ACI-318 (10.5.1)

$$= \frac{\sqrt{24}}{4(420)}(120)(214) = 74.88\,\text{mm}^2$$

Not less than

$$As\ \min = \frac{1.4}{(fy)}(bw)(d)$$

$$As\ \min = \frac{1.4}{420}(120)(214) = 85.6\,\text{mm}^2 \_\_ \text{ control}$$

$As\ \min$ =85.6 mm^2 ≥ As = 77.23 mm^2. OK

Use 2Φ12with As = 226.19mm^2 for span 2

Check for strain:

$$a = \frac{As * fy}{0.85 fcb}$$

$$a = \frac{226.19 * 420}{0.85 * 24 * 520} = 8.955 mm$$

C= 8.955/0.85 =10.53 mm .

* Note: $f_c' = 24$ MPa< 28 MPa→ $\beta_1 = 0.85$

$$\varepsilon_s = 0.003\left(\frac{d-c}{c}\right)$$

$$\varepsilon_s = 0.003\left(\frac{214-10.53}{10.53}\right) = 0.058 > 0.005 \_\_ OK$$

4.6.3 Design of rib for positive moment: Mu =6.6 KN.m

Assume bar diameter 12 mm. d= 250-20- 10 - 10/2 = 214 mm.

$$Rn = \frac{Mn}{bd^2} = \frac{6.6*(10)^6}{0.9*520(214)^2} = 0.31\text{MPa}$$

$$m = \frac{fy}{0.85 fc'} = \frac{420}{0.85(24)} = 20.58$$

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2mRn}{fy}}\right) = \frac{1}{20.58}\left(1-\sqrt{1-\frac{2*20.58*0.31}{420}}\right) = 0.000744$$

A_s =0.000744*(520) (214) = 82.77 mm^2

$$A_s \min = \frac{\sqrt{fc'}}{4(fy)}(bw)(d)$$ ACI-318 (10.5.1)

$$= \frac{\sqrt{24}}{4(420)}(120)(214) = 74.88\,\text{mm}^2$$

Not less than

$$A_s \min = \frac{1.4}{(fy)}(bw)(d)$$

$$A_s \min = \frac{1.4}{420}(120)(214) = 85.6\,\text{mm}^2$$ __ control

A_s min =85.6 mm^2 $\geq$ As = 82.77 mm^2. OK

Use 2Φ12with As = 226.19mm^2 for span 3

Check for strain:

$$a = \frac{As * fy}{0.85 fcb}$$

$$a = \frac{226.19*420}{0.85*24*520} = 8.955mm$$

C= 8.955/0.85 =10.53 mm .

* Note: $f_c' = 24$ MPa< 28 MPa→ $\beta_1 = 0.85$

$$\varepsilon_s = 0.003(\frac{d-c}{c})$$

$$\varepsilon_s = 0.003(\frac{214-10.53}{10.53}) = 0.058 > 0.005 \_\_ OK$$

4.6.4 Design of rib for positive moment: Mu =7.9 KN.m

Assume bar diameter 12 mm.   d= 250-20- 10 - 10/2 = 214 mm.

$$Rn = \frac{Mn}{bd^2} = \frac{7.9*(10)^6}{0.9*520(214)^2} = 0.37 \text{ MPa}$$

$$m = \frac{fy}{0.85fc'} = \frac{420}{0.85(24)} = 20.58$$

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2mRn}{fy}}\right) = \frac{1}{20.58}\left(1-\sqrt{1-\frac{2*20.58*0.37}{420}}\right) = 0.00089$$

A s =0.00089*(520) (214) = 98.94 mm^2

$$A_s \min = \frac{\sqrt{fc'}}{4(fy)}(bw)(d)$$ ACI-318 (10.5.1)

$$= \frac{\sqrt{24}}{4(420)}(120)(214) = 74.88 \text{ mm}^2$$

Not less than

$$A_s \min = \frac{1.4}{(fy)}(bw)(d)$$

$$A_s \min = \frac{1.4}{420}(120)(214) = 85.6 \text{ mm}^2 \_\_ \text{control}$$

A s = 98.94 mm^2 $\geq$ As min = 85.6 mm^2. OK

Use 2Φ12 with As = 226.19 mm^2 for span 4

Check for strain:

$$a = \frac{As * fy}{0.85 fcb}$$

$$a = \frac{226.19 * 420}{0.85 * 24 * 520} = 8.955 mm$$

C= 8.955/0.85 =10.53 mm.

* Note: f'_c = 24 MPa < 28 MPa→ β_1 = 0.85

$$\varepsilon_s = 0.003(\frac{d-c}{c})$$

$$\varepsilon_s = 0.003(\frac{214-10.53}{10.53}) = 0.058 > 0.005 \_\_ OK$$

4.6.5 Design of rib for negative moment: **Mu = -6.3**

Assume bar diameter 12 mm . d= 250-20- 10-12/2 = 214 mm .

$$Rn = \frac{Mn}{bd^2} = \frac{6.3*(10)^6}{0.9*120(214)^2} = 1.274 \text{MPa}$$

$$m = \frac{fy}{0.85 fc'} = \frac{420}{0.85(24)} = 20.58$$

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2mRn}{fy}}\right) = \frac{1}{20.58}\left(1-\sqrt{1-\frac{2*20.58*1.274}{420}}\right) = 0.003134$$

A s = 0.003134*(120)*(214) = 80.46 mm^2

$$As\ \min = \frac{\sqrt{fc'}}{4(fy)}(bw)(d)$$ ACI-318 (10.5.1)

$$As\ \min = \frac{\sqrt{24}}{4(420)}(120)(214) = 74.9 \text{mm}^2$$

$$As\ \min = \frac{1.4}{(fy)}(bw)(d)$$

$$As\ \min = \frac{1.4}{420}(120)(214) = 85.6\ \text{mm}^2 \_\_ \ \text{control}$$

$As\ \min = 85.6\ \text{mm}^2 \geq As = 80.46\ \text{mm}^2$. OK

Use 2Φ12 with As = 226.2 mm² At support 2

Check for strain:

$$a = \frac{As * fy}{0.85 fcb}$$

$$a = \frac{226.2 * 420}{0.85 * 24 * 120} = 38.81 mm$$

C=38.81/0.85 =45.7mm

$$\varepsilon_s = 0.003(\frac{d-c}{c})$$

$$\varepsilon_s = 0.003(\frac{214-45.7}{45.7}) = 0.0111 > 0.005 \_\_ OK$$

∴ ∅ = 0.9 .... OK.

∅Mu = 0.9*226.2*420*(214 – 38.81 /2) $* 10^{-6}$ = 16.64 KN.m > $M_{u\ max}$ = -6.3 KN.m.

4.6.6 Design of rib for negative moment: Mu = -4.5

Assume bar diameter 12 mm . d= 250-20- 10-12/2 = 214 mm .

$$Rn = \frac{Mn}{bd^2} = \frac{4.5 * (10)^6}{0.9 * 120(214)^2} = 0.91 \text{MPa}$$

$$m = \frac{fy}{0.85 fc'} = \frac{420}{0.85(24)} = 20.58$$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mRn}{fy}}\right) = \frac{1}{20.58}\left(1 - \sqrt{1 - \frac{2 * 20.58 * 0.91}{420}}\right) = 0.00222$$

As = 0.00222*(120)*(214) = 56.6 mm²

$$As\ \min = \frac{\sqrt{fc'}}{4(fy)}(bw)(d)$$ ACI-318 (10.5.1)

$$As\ \min = \frac{\sqrt{24}}{4(420)}(120)(214) = 74.9\,mm^2$$

$$As\ \min = \frac{1.4}{(fy)}(bw)(d)$$

$$As\ \min = \frac{1.4}{420}(120)(214) = 85.6\ mm^2 \_\_ \text{ control}$$

$As\ \min$ =85.6 mm^2 $\geq$ As = 56.6 mm^2 . OK

Use 2Φ12 with As = 226.2 mm^2 At support 3

Check for strain:

$$a = \frac{As * fy}{0.85 fcb}$$

$$a = \frac{226.2 * 420}{0.85 * 24 * 120} = 38.81 mm$$

C=38.81/0.85 =45.7mm

$$\varepsilon_s = 0.003(\frac{d-c}{c})$$

$$\varepsilon_s = 0.003(\frac{214-45.7}{45.7}) = 0.0111 > 0.005 \_\_ OK$$

∴ ∅ = 0.9 .... OK.
∅Mu = 0.9*226.2*420*(214 – 38.81 /2) $* 10^{-6}$ = 16.64 KN.m > $M_{u\ max}$ = -4.5 KN.m.

4.6.7 Design of rib for negative moment: Mu = -5.3

Assume bar diameter 12 mm . d= 250-20- 10-12/2 = 214 mm .

$$Rn = \frac{Mn}{bd^2} = \frac{5.3*(10)^6}{0.9*120(214)^2} = 1.07\,\text{MPa}$$

$$m=\frac{fy}{0.85fc'}=\frac{420}{0.85(24)}=20.58$$

$$\rho=\frac{1}{m}\left(1-\sqrt{1-\frac{2mRn}{fy}}\right)=\frac{1}{20.58}\left(1-\sqrt{1-\frac{2*20.58*1.07}{420}}\right)=0.00262$$

A_s = 0.00262*(120)*(214) = 67.34mm^2

$$A_s\ \min=\frac{\sqrt{fc'}}{4(fy)}(bw)(d)$$ ACI-318 (10.5.1)

$$A_s\ \min=\frac{\sqrt{24}}{4(420)}(120)(214)=74.9\,mm^2$$

$$A_s\ \min=\frac{1.4}{(fy)}(bw)(d)$$

$$A_s\ \min=\frac{1.4}{420}(120)(214)=85.6\ mm^2$$ __ control

A_s min =85.6 mm^2 $\geq$ As = 67.34 mm^2 . OK

Use 2Φ12 with As = 226.2 mm^2 At support 4

Check for strain:

$$a=\frac{As*fy}{0.85fcb}$$

$$a=\frac{226.2*420}{0.85*24*120}=38.81mm$$

C=38.81/0.85 =45.7mm

$$\varepsilon_s=0.003\left(\frac{d-c}{c}\right)$$

$$\varepsilon_s=0.003\left(\frac{214-45.7}{45.7}\right)=0.0111>0.005\_\_OK$$

∴ ∅ = 0.9 .... OK.

∅Mu = 0.9*226.2*420*(214 – 38.81 /2) $*10^{-6}$ = 16.64 KN.m > $M_{u\,max}$ = -6.3 KN.m.

Select 2Ø12 For all negative moment.

4.6.8 Check for shear :

Vc : provided by concrete for the ribs shall be permitted to be taken as 1.1 times than that for beams . ACI-318-14 (11.2.1)

Vu at distance d from the face of the support:

d=214mm

Vu_{max}=12.9 KN

$Vc = 1.1 * \frac{1}{6}\sqrt{fc}\ bw\ d$

$Vc = 1.1 * \frac{1}{6}\sqrt{24} * 120 * 214 * 10^{-3} = 23.1$ KN

$\Phi\ Vc = 0.75 * 1.1 * \frac{1}{6}\sqrt{24} * 120 * 214 * 10^{-3} = 17.3$ KN

Check for Cases:

Case 1 :

$\frac{\phi V_c}{2} \leq Vu.$

$\frac{17.3}{2} = 8.65 \leq 12.9$

Minimum shear reinforcement is required except for concrete joist construction. So, No shear reinforcement is provided.

4.7 Design of Beam " B1(14) ":

Material :-

concrete B300 Fc' = 24 N/mm^2

Reinforcement Steel fy = 420 N/mm^2

$\frac{L1}{18.5} = \frac{5.7}{18.5} = 0.31m$ …. for span 1 and span 3

$\frac{L2}{18.5} = \frac{3.6}{18.5} = 0.20m$ …. for span 2

➔ Selected h = 35 cm (25 cm slab thickness ,10 drop below slab) .

By using **BEMED** program we get the envelope moment and shear force diagram as the follows: -

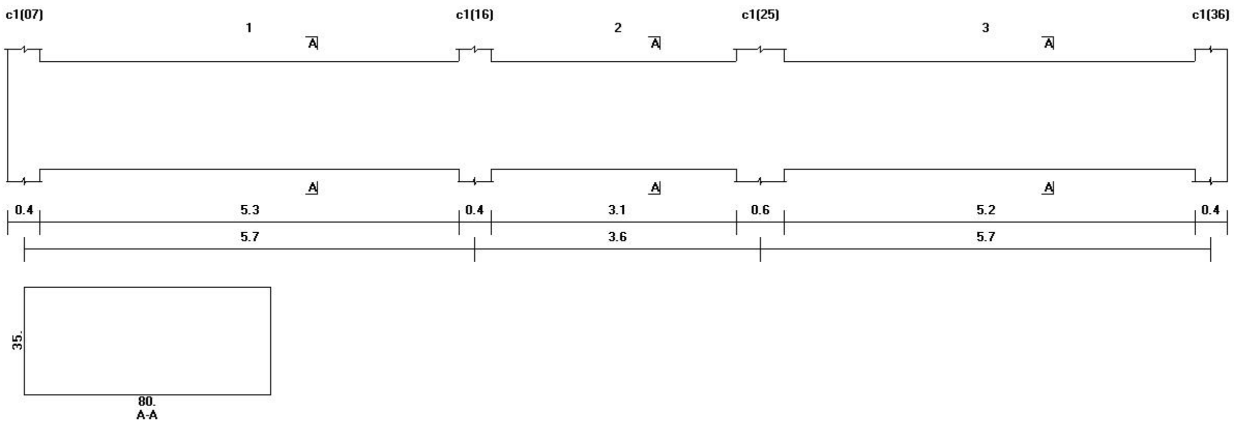


Figure 4.7: Beam 1 (14) Geometry.

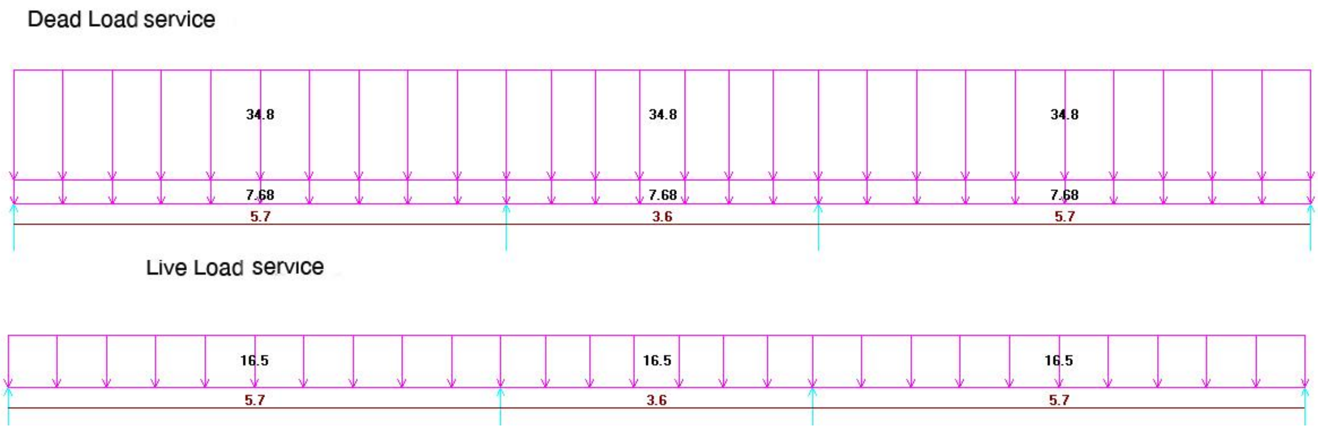
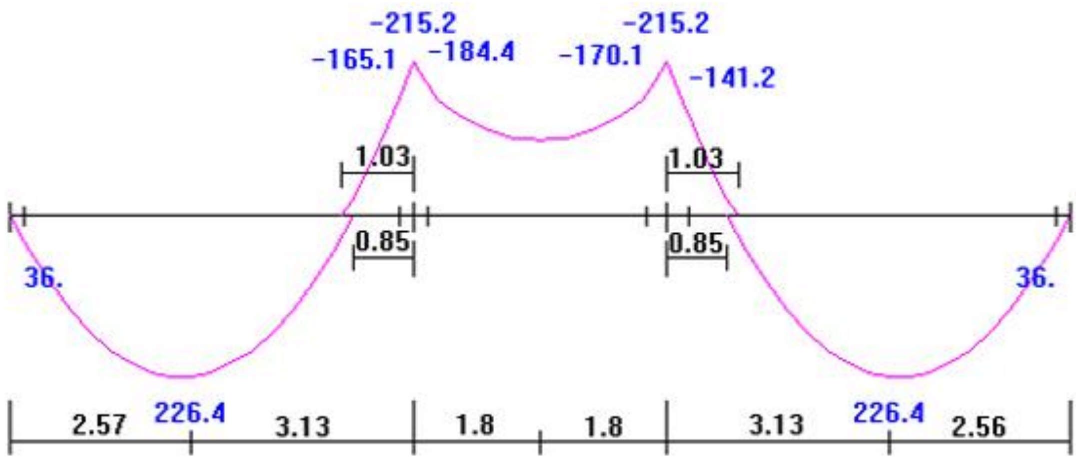


Figure 4.8: Loading of Beam 1 (14)



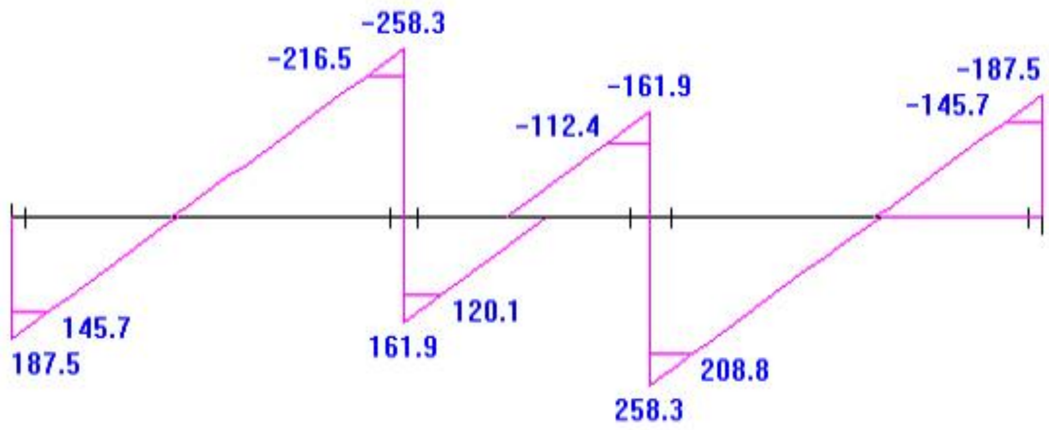


Figure 4.9: Moment and Shear Envelope of Beam 1 (14)

» Self-weight of beam = 0.8*0.35*25 = 7 KN/m

4.7.1 Design of positive moment:- ($M_{u\ max}$ = 226.4 KN.m **)**

b = 80 cm. , h = 35cm.

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

= 350 – 40 – 8 – $\frac{14}{2}$ = 295 mm.

Mu=226.4 KN.m

$C_{max} = \frac{3}{7} * d = \frac{3}{7} *295 = 126.43$ mm.

$a_{max} = \beta_1 * C_{max} = 0.85 * 126.43 = 107.46$ mm . *Note: $f_c' = 24$ MPa < 28 MPa→$\beta_1 = 0.85$

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

$= 0.85 * 24* 800* 107.46* (295 – \frac{107.46}{2}) * 10^{-6}$

= 423.12 KN.m .

* Note: $\epsilon_s = 0.004 \rightarrow \phi = 0.82$

→ϕMn_{max} = 0.82*423.12 = 346.96KN.m .

→Mu = 226.4 < ϕMn_{max} = 346.96 KN.m .

∴ Design section as singly reinforced concrete section.

Maximum positive moment $Mu^{(+)}$ = 226.4 KN.m .

Mn = Mu /ϕ= 226.4/ 0.9 = 251.56 KN.m .

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

$R_n = \frac{M_n}{b*d^2} = \frac{251.56*10^6}{800*(295)^2} = 3.61$ MPa.

$\rho = \frac{1}{m}(1 - \sqrt{1 - \frac{2*R_n*m}{f_y}})$

$= \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2*3.61*20.6}{420}}\right) = 0.00954$.

$\rightarrow As_{req} = \rho$ * b *d = 0.00954 * 800 *295 = 2251.62 mm^2.

$As_{min} = \frac{\sqrt{f_c'}}{4\ (f_y)} * b * d \ \le \frac{1.4}{f_y} * b_w * d$

$= \frac{\sqrt{24}}{4*420} * 800 * 295 \ \le \frac{1.4}{420} * 800 * 295$

= 688.19 mm^2< 786.67 mm^2 ………… Larger value is control.

→ As_{req} = 2251.62 mm^2 > As_{min} = 786.67 mm^2.

∴ As provided = As_{req} =2251.62 mm^2.

As Φ14 =153.94 mm^2

Φ14 = $\frac{As_{req}}{A_{bar}} = \frac{2251.62}{153.94}$ = 14.6 → # of bars = 15 bars.

∴ Use 15Φ 14 → As = 15*153.94 =2309.1 mm^2>As_{req} = 2251.62 mm^2 .

→ Check for strain:-($\varepsilon_s \ge 0.005$)

Tension = Compression

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

2309.1 * 420 = 0.85 * 24 * 800 * a

a = 59.42 mm.

$c = \frac{a}{\beta_1} = \frac{59.42}{0.85}$ = 70 mm. * Note: f_c' = 24MPa< 28 MPa→ β_1 = 0.85

$\varepsilon_s = 0.003 * (\frac{d-c}{c})$

=0.003*($\frac{295-70}{70}$) = 0.0096> 0.005 ∴ϕ =0.9 OK=

Check for bar placement

$$S_b = \frac{800 - (40 * 2) - (8 * 2) - (15 * 14)}{3} = 164.67mm > 25mm\ ok$$

∴ Use 15Φ14

(4.7.2) Design of negative moment:

***Max. Negative moment $Mu^{(-)}$ = 184.4KN**

ϕMn_{max} = 346.96KN.m> Mu = 184.4 KN.m → Singly reinforced concrete section.

Mn = 184.4 /ϕ = 184.4 / 0.9 = 204.89 KN.m .

$m = \frac{f_y}{0.85\, f_c'} = \frac{420}{0.85*24}$ = 20.6 .

$R_n = \frac{M_n}{b*d^2} = \frac{204.89*10^6}{800*(295)^2}$ = 2.94MPa.

$\rho = \frac{1}{m}(1 - \sqrt{1 - \frac{2*R_n*m}{f_y}})$

$= \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2*20.6*2.94}{420}}\right)$= 0.0076

$A_s = \rho$ * b *d = 0.0076 * 800 * 295 = 1794.15 mm^2.

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

$= \frac{\sqrt{24}}{4*420} * 800 * 295 \;\geq\; \frac{1.4}{420} * 800 * 295$

= 688.19 mm^2< 786.67 mm^2 ………… Larger value is control.

As_{req} = 1794.15 mm^2 > As_{min} = 786.67 mm^2.

∴ As provided = As_{req} =1794.15 mm^2.

0f Φ14 = $\frac{As_{req}}{A_{bar}} = \frac{1794.15}{153.94}$ = 11.65→ # of bars = 12 bars.

∴ Use 12Φ14 → As =12 * 153.94 = 1847.28 mm^2>As_{req} = 1794.15 mm^2 .

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

Tension = Compression

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

1847.28 * 420 = 0.85 * 24 * 800 * a

a = 47.54 mm.

$c = \frac{a}{\beta_1} = \frac{47.54}{0.85}$ = 55.92 mm. * Note: f_c' = 24MPa< 28 MPa→ β_1 = 0.85

$\varepsilon_s = 0.003 * (\frac{d-C}{c})$

=0.003*($\frac{295-55.92}{55.92}$) = 0.0128> 0.005 ∴ϕ =0.9 OK

4.7.3 Design of shear:-

$\phi Vc = \phi \times \frac{\sqrt{f_c'}}{6} \times b_w \times d$

$= 0.75 \times \frac{\sqrt{24}}{6} \times 800 \times 295 = 144.52$ KN.

» Check For dimensions :-

$\phi Vc + (\frac{2}{3} \times \phi \times \sqrt{f_c'} \times b_w \times d) = 144.52 + (\frac{2}{3} \times 0.75 \times \sqrt{24} \times 800 \times 295)$

$= 144.52 + 578.08 = 722.6$ KN > Vu max = **216.5** KN.

∴ Dimension is adequate enough.

$$\emptyset * Vs_{min} = \frac{0.75}{16} * \sqrt{24} * 800 * 295 = 54.09\ KN$$

or

$$\emptyset * Vs_{min} = \frac{0.75}{3} * 800 * 295 = 78.63\ KN \ \ ... control\ .$$

$$\emptyset\ V`s = \frac{0.75}{3} * \sqrt{24} * 800 * 295 * 10^{-3} = 289.03KN.$$

$$\emptyset\ Vs\ max = 0.75 * \frac{2}{3} * \sqrt{24} * 800 * 295 = 578.08\ KN$$

$\emptyset(Vc + Vs\ min) = 198.61\ KN.$ …... 1

$\emptyset(Vc + Vs`) = 433.55\ KN.$ …... 2

$\emptyset(Vc + Vs\ max) = 722.6\ KN.$ ….. 3

<u>Case 1</u>

Vu $\leq \frac{1}{2} \emptyset$ Vc

$216.5 \leq 0.5 * 144.52 = 72.26$ …………. Case 1 failed

Case 2

$\frac{1}{2}$ Ø Vc < Vu ≤ Ø Vc

$72.26 < 216.5 \ \leq 144.52$ ………… Case 2 failed

Case 3

Ø Vc < Vu ≤ $\emptyset(Vc + Vs\ min)$

$144.52 < 216.5 \ \leq 198.61$ ………… Case 3 failed

Case 4

$V_u = 216.5\ KN.$

Ø (Vc+Vs min) < Vu ≤ Ø(Vc+Vs`)

Vs = (Vu – Vc) / 0.75 = (216.5 – 192.7) / 0.75 = 31.74 KN.

$select\ 4\ leg\ .\emptyset 10\ \ ,,,,, Av = 4 * 78.5 = 314\ mm^2$

$$\frac{Av}{S_{req}} = \frac{Vs}{f_y * d}\ ,,,,, S_{req} = \frac{314 * 420 * 295}{31.74 * 10^3} = \ 1225.73\ mm$$

$$S_{max} \ \leq \frac{d}{2} \ = \frac{295}{2} = 147.5 \leq \ 600\ mm$$

So $S_{max} = 147.6$ mm

Select Ø10 − 10 cm (4 − legs). For 1m from face of support.

4.8 Design of two way ribbed slab (R025)

4.8.1 Minimum thickness for ribbed slab h= 35 cm

Check for the minimum thickness of the slab:

-All Exterior and interior beams have a rectangular section of 60 cm width and 60 cm depth:

$$I_b = \frac{b * h^3}{12} = \frac{0.60 * 0.60^3}{12} = 108 * 10^{-4}\, m^4$$

-The moment of inertia for the ribbed slab:

$$y_c = \frac{48 * 8 * 4 + 35 * 14 * 17.5}{48 * 8 + 35 * 14} = 11.57\ cm$$

$$I_{rib} = 0.62 * \frac{0.1157^3}{3} + 0.48 * \frac{0.0357^3}{3} + 0.14\ \frac{0.3025^3}{3} = 16.05 * 10^{-4} m^4$$

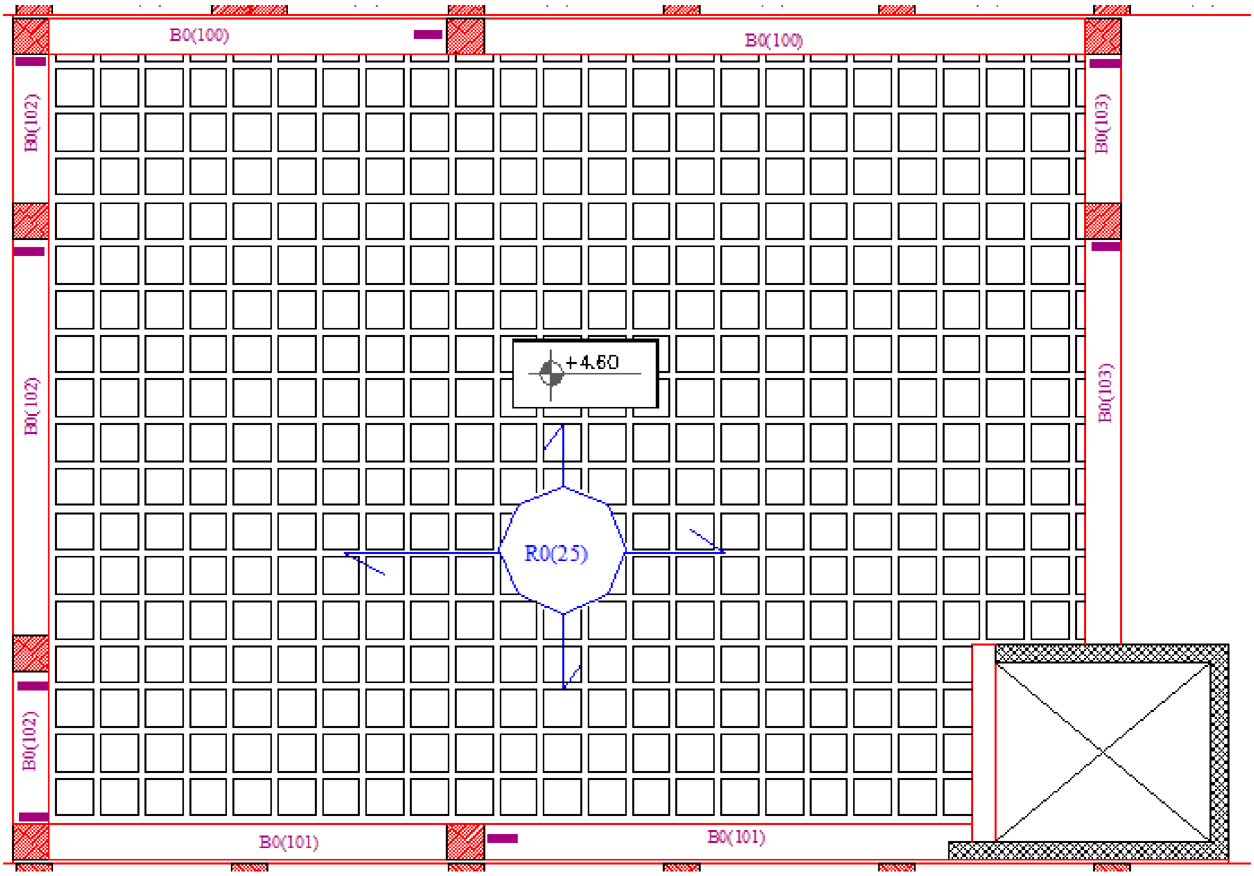


fig.(4.10): Two way Ribbed slab.

$Short\ direction\ l = 9.85\ m = 985\ cm$

$Long\ direction\ l = 12.30\ m = 1230\ cm$

$$I_{s1} = \frac{I_{rib} * (\frac{l}{2} + b_w)}{b_f} = \frac{16.05 * 10^{-4} * \left(\frac{9.85}{2} + 0.6\right)}{0.62} = 143.03 * 10^{-4}$$

$$\alpha_{f1} = \frac{I_b}{I_s} = \frac{108}{143.03} = 0.76$$

$$I_{s2} = \frac{I_{rib} * (\frac{l}{2} + b_w)}{b_f} = \frac{16.05 * 10^{-4} * \left(\frac{12.30}{2} + 0.6\right)}{0.62} = 174.74 * 10^{-4}$$

$$\alpha_{f2} = \frac{I_b}{I_s} = \frac{108}{174.74} = 0.62$$

$$I_{s3} = \frac{I_{rib} * (l + b_w)}{b_f} = \frac{16.05 * 10^{-4} * (9.85 + 0.6)}{0.62} = 270.52 * 10^{-4}$$

$$\alpha_{f3} = \frac{I_b}{I_s} = \frac{108}{270.52} = 0.4$$

$$I_{s4} = \frac{I_{rib} * (l + b_w)}{b_f} = \frac{16.05 * 10^{-4} * (12.30 + 0.6)}{0.62} = 333.94 * 10^{-4}$$

$$\alpha_{f4} = \frac{I_b}{I_s} = \frac{108}{333.94} = 0.32$$

$$\alpha_m = \frac{(0.76 + 0.62 + 0.4 + 0.32)}{4} = 0.525 < 2.0$$

The minimum slab thickness will be:

$$h = \frac{L_n(0.8 + \frac{f_y}{1400})}{36 + 5\beta(\alpha_m - 0.2)} = \frac{12.30 * (0.8 + \frac{420}{1400})}{36 + 5 * \frac{12.30}{9.85} * (0.525 - 0.2)} = 0.3457\ m$$

$h = 35\ cm > 34.57\ cm\ - OK$

Take slab thickness 35 cm

$b_{eff.}$= 620 mm b_w = 140 mm h_f= 80 mm

h = 350 mm h etolit block = 210 mm h cement block = 60 mm

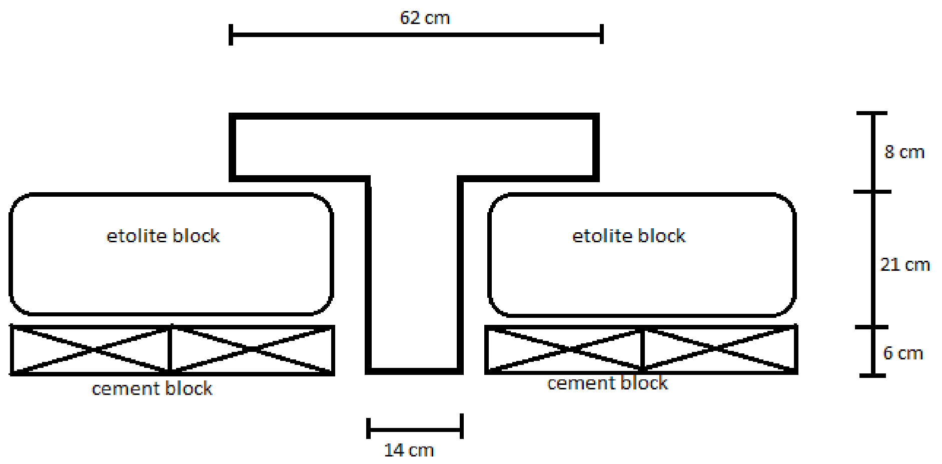


Fig.(4.11): Typical section in ribbed slab.

4.8.2 Load calculation:

For the two-way ribbed slabs, the total dead load to be used in the analysis and design is calculated as follows:

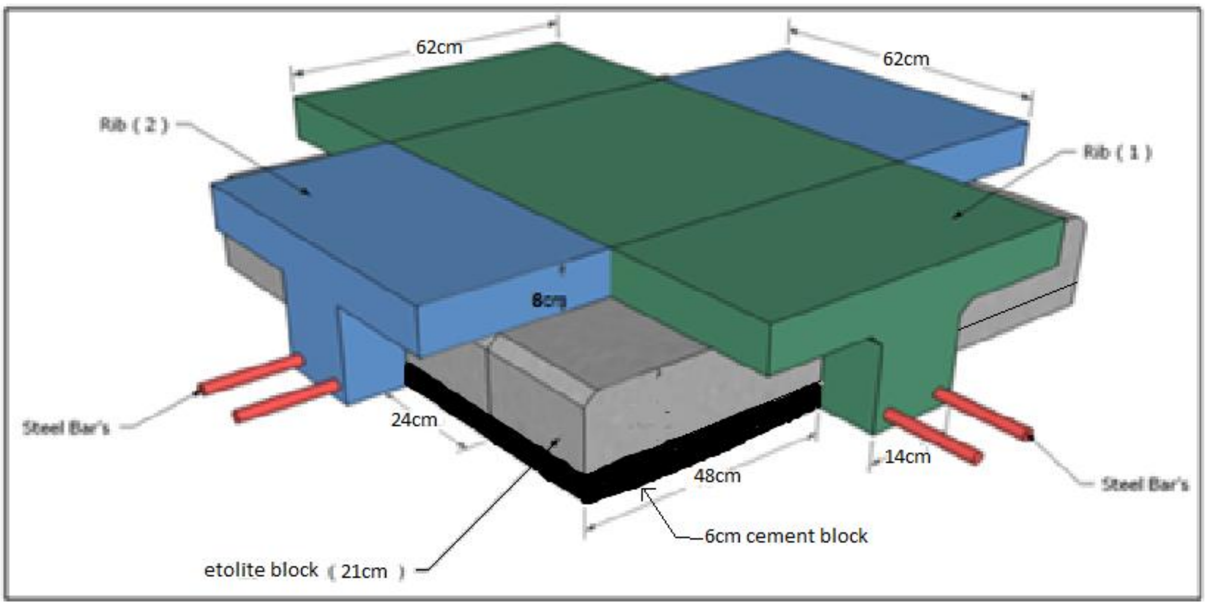


Fig.(4.12): Two way ribbed slab

Table (4-3) Calculation of the total dead load for two way rib slab (25).

Material	Quality Density (KN/m^3)	$W = \gamma * V$ (KN)
Tiles	23	23 × 0.03 × 0.62 × 0.62 = 0.265
Mortar	22	22 × 0.02 × 0.62 × 0.62 = 0.169
Sand	16	16 × 0.07 × 0.62 × 0.62 = 0.431
Topping	25	25 × 0.08 × 0.62 × 0.62 = 0.769
Concrete Rib	25	25 × 0.27 × 0.14 × (0.62+0.48) = 1.04
Concrete Block	15	15 × 0.06 × 0.48 × 0.48 = 0.207
Plaster	22	22 × 0.02 × 0.62 × 0.62 = 0.169
Partition = 1.5 KN/m^2		1.5 × 0.62 × 0.62 = 0.577
Total Dead load, KN		3.627

Dead Load of slab:

$$DL = \frac{3.627}{0.62 * 0.62} = 9.44\ KN/m^2$$

$$w_D = 1.2 * 9.44 = 11.328\ KN/m^2$$

$$LL = 4\ KN/m^2$$

$$w_L = 1.6 * 4 = 6.4\ KN/m^2$$

$$w = 11.328 + 6.4 = 17.728\ KN/m^2$$

4.8.3 Moments calculations:

$$Ma = Ca\, wla^2 bf \quad and \quad Mb = Cb\, wlb^2 bf$$

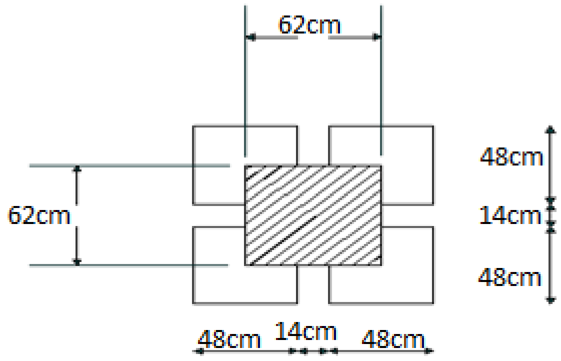


Fig.(4.13): Two way ribbed slab

-Negative moment

$C_{a,neg} = 0.075$

$C_{b,neg} = 0.00$

$\boldsymbol{M_{a,neg} = (0.075 * 17.728 * 9.45^2) * 0.62 = 71.76\ KN.m}$

$\boldsymbol{M_{b,neg} = 0}$

-Positive moment

$C_{aD,pos} = 0.027$

$C_{bD,pos} = 0.018$

$C_{aL,pos} = 0.032$

$C_{bL,pos} = 0.027$

$\boldsymbol{M_{a,pos,(dl+ll)} = (0.027 * 11.328 * 9.45^2 + 0.032 * 6.4 * 9.45^2) * 0.62 = 28.27\ KN.m}$

$\boldsymbol{M_{b,pos,(dl+ll)} = (0.018 * 11.328 * 12.85^2 + 0.027 * 6.4 * 12.85^2) * 0.62 = 38.6\ KN.m}$

Design of positive moment

- **Short direction ($\boldsymbol{Mu = 28.27\ KN.m}$)**

  $\boldsymbol{bf = 620\ mm}$

Assume bar diameter $\phi 14$ for main positive reinforcement.

$$d = h - cover - dstirrups - \frac{d_b}{2} = 350 - 20 - 10 - \frac{14}{2} = 313\ mm.$$

$$R_n = \frac{M_u}{\emptyset b d^2} = \frac{28.27 \times 10^6}{0.9 \times 140 \times 313^2} = 2.29\ MPa$$

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

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 2.29}{420}}\right) = 0.0058$$

$$As = \rho.b.d = 0.0058 \times 140 \times 313 = 254.16\ mm^2$$

- $Check\ for\ As,min..$

$$As,min = 0.25 \frac{\sqrt{f'_c}}{f_y} b_w * d \geq \frac{1.4}{f_y} b_w * d$$

$$As,min = 0.25 * \frac{\sqrt{24}}{420}\ 140 \times 313 = 127.78\ mm^2$$

$$As,min = \frac{1.4}{420} * 140 \times 313 = 146.07\ mm^2 \ldots..\boldsymbol{Control}.$$

- $As,required = 254.16\ mm^2 > As,min = 146.07\ mm^2 \quad (OK)$

Use 2Ø14, with As = 308 mm^2 > $As,required = 254.16\ mm^2$

Check for strain: ($\boldsymbol{\varepsilon_s \geq 0.005}$)

Tension = Compression

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

$308 * 420 = 0.85 * 24 * 140 * a$

$a = 45.3\ mm$

$$x = \frac{a}{\beta_1} == \frac{45.3}{0.85} = 53.3\ mm$$

$$\varepsilon_s = 0.003 * (\frac{d - x}{x})$$

$$= 0.003 * \left(\frac{313 - 53.3}{53.3}\right) = 0.0146 > 0.005 \quad \therefore \phi = 0.9 \ \ldots\ OK.$$

Design for Discontinuous edge

$A_s = \frac{1}{3} A_{s,pos} = \frac{1}{3} * \ 308\, mm^2 = 102.67\, mm^2 < As,min = 146.07\, mm^2$

Provide $As,min = 146.07\, mm^2$

$n = \frac{As}{As\phi 12} = \ \frac{146.07}{113.1} = 1.3$

Use $2\emptyset\ 12$, Top . . with $\mathrm{As} = 226.2\ \mathrm{mm}^2$

- **Long direction ($\boldsymbol{Mu = 38.6\ KN.m}$)**

  $\boldsymbol{bf = 620\, mm}$

Assume bar diameter $\phi 20$ for main positive reinforcement.

$d\ = h -\ cover\ -\ dstirrups\ - \frac{d_b}{2} = 350 - 20 - 10 - \frac{20}{2} = 310\, mm.$

$R_n = \frac{M_u}{\emptyset b d^2} = \frac{38.6{\times}10^6}{0.9{\times}140{\times}310^2} = 3.19\, MPa$

$m = \frac{fy}{0.85\, fc'} = \frac{420}{0.85 * 24} = 20.6$

$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2{\times}20.6{\times}3.19}{420}}\right) = 0.00831$

$As\ =\ \rho.b.d\ = 0.00831{\times}140{\times}310 = 360.47\, mm^2$

- $Check\ for\ As,min..$

$As,min\ = 0.25 \frac{\sqrt{f'_c}}{f_y} b_w * d \geq \ \frac{1.4}{f_y} b_w * d$

$$As,min\ = 0.25 * \frac{\sqrt{24}}{420}\ 140{\times}310 = 126.56\, mm^2$$

$$As,min\ =\ \frac{1.4}{420} * 140{\times}310 = 144.67\, mm^2 \ldots\ldots \boldsymbol{Control.}$$

- $As,required\ = 360.47\, mm^2 >\ As,min = 144.67\, mm^2 \quad (OK)$

Use $2\emptyset 16$, with As = $402.12\, mm^2 > As,required\ = 360.478\, mm^2$

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

Tension = Compression

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

$402.12 * 420 = 0.85 * 24 * 140 * a$

$a = 59.13\,mm$

$$x = \frac{a}{\beta_1} == \frac{59.13}{0.85} = 69.56\,mm$$

$$\varepsilon_s = 0.003 * (\frac{d-x}{x})$$

$$= 0.003 * \left(\frac{310-69.56}{69.56}\right) = 0.0104 > 0.005 \quad \therefore \phi = 0.9 \ \ldots\ OK.$$

Design for Discontinuous edge

$$A_s = \frac{1}{3}\,A_{s,pos} = \frac{1}{3} * 402.12\,mm^2 = 134.04\,mm^2 < As,min = 144.67\,mm^2$$

Provide $As,min = 144.67\,mm^2$

$$n = \frac{As}{As\phi 10} = \frac{144.67}{78.53} = 1.84$$

Use $2\text{Ø}\,10$, Top .. with $\mathrm{As} = 158\ \mathrm{mm}^2$

Design of negative moment ($Mu = 71.76\,KN.m$)

$$bf = 620\,mm$$

Assume bar diameter $\phi 20$ for main positive reinforcement.

$$d = h - cover - dstirrups - \frac{d_b}{2} = 350 - 20 - 10 - \frac{20}{2} = 310\,mm.$$

$$R_n = \frac{M_u}{\text{Ø} b d^2} = \frac{71.76\times 10^6}{0.9\times 140\times 310^2} = 5.93\,MPa$$

$$m = \frac{fy}{0.85\,fc'} = \frac{420}{0.85 * 24} = 20.6$$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2\times 20.6\times 5.93}{420}}\right) = 0.0171$$

$$As = \rho.b.d = 0.0171\times 140\times 310 = 742.14\,mm^2$$

- $Check\ for\ As,min..$

$$As,min\ = 0.25\frac{\sqrt{f'_c}}{f_y}b_w * d \geq \frac{1.4}{f_y}b_w * d$$

$$As,min\ = 0.25 * \frac{\sqrt{24}}{420}\ 140\times310 = 126.56\ mm^2$$

$$As,min\ = \frac{1.4}{420} * 140\times310 = 144.67\ mm^2 \ldots..\boldsymbol{Control.}$$

- $As,required\ = 742.14\ mm^2 >\ As,min = 144.67\ mm^2 \quad (OK)$

Use 3Ø20, with As =942.5 mm^2 > $As,required\ = 742.14\ mm^2$

Check for strain: ($\boldsymbol{\varepsilon_s \geq 0.005}$)

Tension = Compression

$As\ *\ fy\ =\ 0.85\ *\ f_c'\ *\ b\ *\ a$

$942.5 *\ 420\ =\ 0.85\ *\ 24\ *\ 140 *\ a$

$a\ = 138.6\ mm$

$x = \frac{a}{\beta_1} = \frac{138.6}{0.85} = 163.06\ mm$

$\varepsilon_s = 0.003 * (\frac{d-x}{x})$

$= 0.003 * \left(\frac{310-163.06}{163.06}\right) = 0.0072\ > 0.005\ \ \therefore \phi\ = 0.9\ \ldots\ OK.$

4.8.4 Check shear strength:

$W_a = 0.83$

$W_b = 0.17$

Short direction

$Au_a =\ 17.728 * 9.45 * 12.85 * 0.83 * 0.5 * \frac{0.52}{12.85} =\ 36.15\ KN$

$Vu =\ Au_a - W * 0.52 * d =\ 36.15 - 17.728 * 0.52 * 310 = 33.29\ KN$

$\emptyset * V_c =\ 1.1 * \frac{0.75}{6} * \sqrt{fc'} * bw * d = 1.1 *\ \frac{0.75}{6} * \sqrt{24} * 140 * 310 = 29.23\ KN$

$$Case\ 1$$

$V_u < \frac{1}{2} * \ \phi * V_c$

$V_u = 33.29KN > \frac{1}{2} * \ \phi * V_c = 14.615\ KN$ ... $\boldsymbol{Not\ OK}$

$$Case\ 2$$

$$\frac{1}{2} * \phi * V_c < V_u < \phi * V_c$$

$$\frac{1}{2} * \phi * V_c = 14.615\ KN < V_u = 33.29\ KN < \phi * V_c = 29.23\ KN - \boldsymbol{Not\ OK}$$

$$Case\ 3$$

$$\phi Vc < Vu \le \phi(Vc + V_{Smin})$$

Provide minimum shear reinforcement

$Vs_{min} \ \ \ge \frac{1}{16} * \sqrt{f_c'} * bw*d = \frac{1}{16} * \sqrt{24} *140*310*10^{-3} = 13.3$ KN.

$\phi Vs\ min = 9.97$

$\le \frac{1}{3} * b_w * d = \frac{1}{3} * 0.14 * 0.310*10^3 = 14.47$ KN

$\phi Vs,min = 10.85$ ………….. control

$\phi Vc = 29.23$ KN < $Vu=33.29$ KN $\le \phi(Vc+Vs_{min}) =40.08$ KN …… satisfy

∴Case (3) is satisfy shear reinforcement is required.

Use 2 Legϕ8 for stirrups with Av = 100.53mm2

$$\text{Vsmin} = \frac{\phi\text{Vsmin}}{\phi} = \frac{10.85}{0.75} = 14.47$$

$$\text{s} = \frac{\text{Av} * \text{fy} * \text{d}}{\text{Vsmin}} = \frac{100.53 * 420 * 310}{14.47} * 10^{-3} = 904.56\text{mm}$$

$S_{max} \le \frac{d}{2} = \frac{310}{2} = 155$ mm.

$\le$ 600 mm.

Select 2 leg ϕ8 @ 15cm

No shear reinforcement is required

4.9 Design of Stair:

- Limitation of deflection:

h_{min}= 3.6 / 20 = 18 cm

select h = 20 cm

tan ϕ = 17 /30

ϕ = 29.5

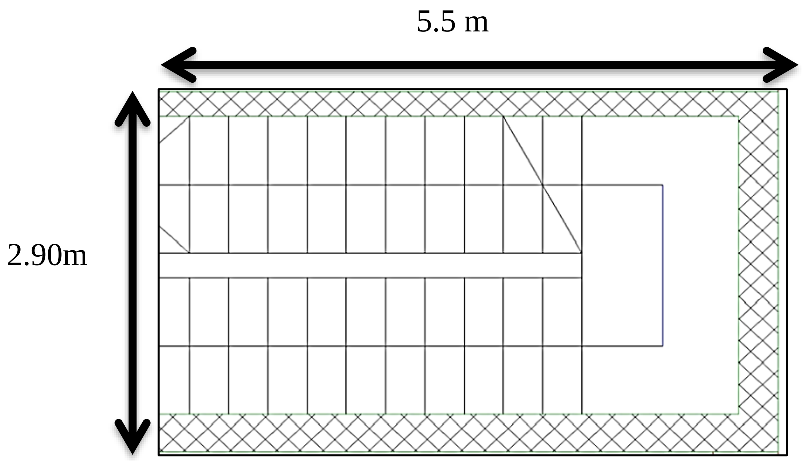


Figure (4.14): stair plan

- **Design of flight :**

Table (4-4) Calculation of the total dead load for Flight.

Plastering	(0.03*22*1)/(cos 29.5) = 0.76 KN/m
Concrete slab	(0.2*25*1)/(cos 29.5) = 5.75 KN/m
Horizontal mortar	0.03*22*1= 0.66 KN/m
Horizontal tiles	0.04*23*1*0.33/0.3 = 1.01 KN/m
vertical mortar	0.03*22*0.17/ 0.3= 0.385 KN/m
vertical tiles	0.03*23*0.17/0.3= 0.4 KN/m
triangle concrete	0.17 *0.25 /2 = 2.13 KN/m
$\sum$ =	11.1 KN/m

- Flight live Load computation:

Live = 5 KN/m^2 * 1 = 5 KN/m

- Factored load :

$$Qu = 1.2 * DL + 1.6 * LL = 1.2 * 11.1 + 1.6 * 5 = 21.32 \text{ KN/m}$$

- Design of shear force :

Max Vu = 33.4 KN/m

- d=200 -20 - 6 = 174 mm

$$\Phi * Vc = 0.75 * \frac{\sqrt{fc'}}{6} bw * d = 0.75 * \frac{\sqrt{24}}{6} * 174 * 1000 = 106.5 \text{ KN} >> Vu$$

- h is correct

- Design of moment diagram :

Max Mu = (38.4 *2) –(21.32 *1.8*1.8*0.5) = 42.3 KN.m

$$Rn = \frac{Mn}{b * d^2}$$

$$Rn = \frac{42.3 * 10^6 / 0.9}{1000 * (174)^2} = 1.5 \text{ MPa}$$

$$\rho = \frac{1}{m} (1 - \sqrt{1 - \frac{2mRn}{fy}})$$

$$\rho = \frac{1}{20.6} (1 - \sqrt{1 - \frac{2(20.6)(1.5)}{420}}) = 0.003843$$

As req = ρ * b * d = 0.003843* 100 *17.4 = 6.7 cm²/m.

As min = 0.0018 * b * h = 0.0018*100 * 20 = 3.6 cm²/m

As req > As min

select Φ12@ 15 cm $A_s\, provided = 7.54 cm^2 / m$

Tension = compression

As * fy = 0.85 * f_c * b * a

$$754 * 420 = 0.85 * 24 * 1000 * a$$
$$a = 15.5 mm$$
$$x = \frac{a}{\beta_1} = \frac{15.5}{0.85} = 18.3 mm$$
$$\varepsilon_S = \frac{174 - 18.3}{18.3} \times 0.003$$
$$\varepsilon_S = 0.0255 > 0.005 \longrightarrow$$ **Ok** **(Φ = 0.9)**

- # Design of Landing:

Table (4-5) Calculation of the total dead load for Landing.

Plastering	(0.02*23*1) = 0.46 KN/m
Concrete slab	(0.2*25*1)= 5 KN/m
mortar	0.02*23*1= 0.64 KN/m
tiles	0.03*22*1= 0.66 KN/m
Sand	0.07*17*1= 1.19 KN/m
$\sum$ =	7.95 KN/m

- Design of shear force :

Max Vu = 20.2 KN/m

- d=200 -20 - 6 = 174 mm

$$\Phi^* \ Vc = 0.75^* \ \frac{\sqrt{fc'}}{6} bw * d \ = 0.75 * \frac{\sqrt{24}}{6} * 174 * 1000 = 106.5 \text{ KN} >> Vu$$

- h is correct

- Design of moment diagram :

- Design of landing 1 :

Max Mu = $17.54*2.65^2/8$= 15.4 KN.m

$$Rn = \frac{Mn}{b*d^2}$$

$$Rn = \frac{15.4*10^6/0.9}{1000*(174)^2} = 0.565 \text{ MPa}$$

$$\rho = \frac{1}{m}(1 - \sqrt{1-\frac{2mRn}{fy}})$$

$$\rho = \frac{1}{20.6}(1 - \sqrt{1-\frac{2(20.6)(0.565)}{420}}) = 0.0013$$

As req = ρ * b * d = 0.0013* 100 *17.4 = 2.4 cm²/m.

As min = 0.0018 * b * h = 0.0018*100 * 20 = 3.6 cm^2/m

As req< As min

select Φ12@ 20 cm $A_s\, provided = 5.65 cm^2/m$

- Design of landing 2 :

- Qu= 17.54 +38.4 = 56 KN/m

Max Mu = 56*2.65^2/8= 49.16 KN.m

$$Rn = \frac{Mn}{b * d^2}$$

$$Rn = \frac{49.16 * 10^6 / 0.9}{1000 * (174)^2} = 1.8 \text{ MPa}$$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mRn}{fy}}\right)$$

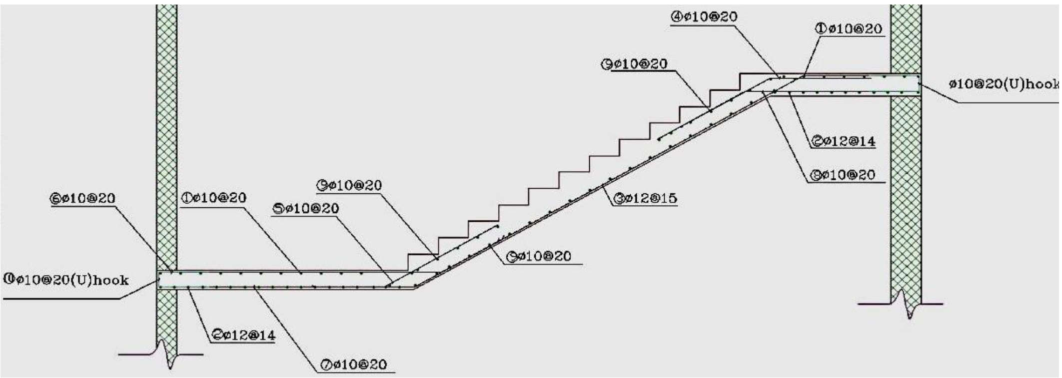
$$\rho = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2(20.6)(1.8)}{420}}\right) = 0.00449$$

As req = ρ * b * d = 0.00449* 100 *17.4 = 7.83 cm²/m.

As min = 0.0018 * b * h = 0.0018*100 * 20 = 3.6 cm^2/m

As req > As min

select Φ12@ 14 cm $A_s\, provided = 8.04 cm^2/m$



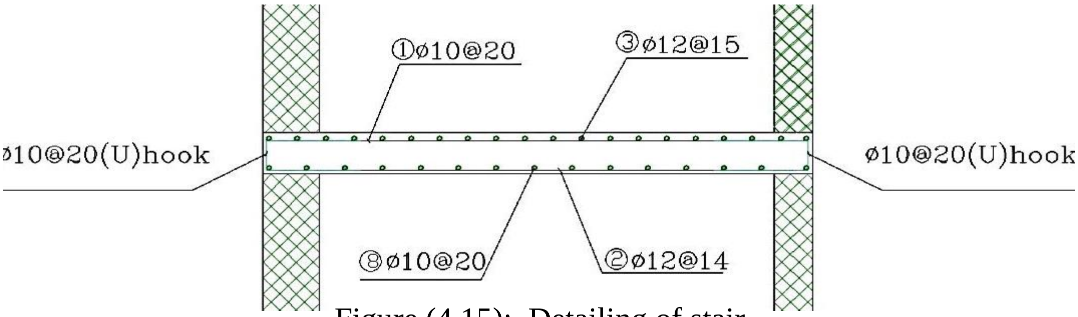


Figure (4.15): Detailing of stair

4.10 Design of Long Column :

Design of Longitudinal Reinforcement:

Select column (C113) for design

Pu = 2400 KN

Pn = 2400/(0.65) = 3692.31 KN

Assume $\rho g = 1.5\ \%$

$$Pn = 0.8 * Ag\{0.85 * fc' + \rho g(fy - 0.85 fc')\}$$
$$3692.31 = 0.8 * Ag[0.85 * 24 + 0.015 * (420 - 0.85 * 24)]$$
$$Ag = 1748.65 cm^2$$

Assume column dimension 40*60 cm

Use 40*60cm with Ag = 2400cm² > Ag_{req} = 1748.65 cm²

- **Check Slenderness Effect :**

$$\frac{klu}{r} < 34 - 12\frac{M1}{M2} \quad ....ACI - (10.12.2)$$

Lu: Actual unsupported (unbraced) length.

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

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

Lu = 3.75 m

M1&M2 =1

K=1 , According to ACI 318-14 (**10.10.6.3)** The effective length factor, ***k***, shall be permitted to be taken as 1.0.

$$\frac{klu}{r} < 34 - 12\frac{M1}{M2} \qquad ....ACI - (10.12.2)$$

$$\frac{1*3.75}{0.3*0.4} = 31.25 > 22$$

$$\frac{1*3.75}{0.3*0.6} = 20.8 > 22$$

$$\therefore long\ Coloumn$$

Slenderness is consider

$$EI = 0.4\frac{E_c I_g}{1+\beta_d} \qquad ....[ACI\,318-14\ \ (Eq.\ 10-15)]$$

$$E_c = 4750\sqrt{fc'} = 4750*\sqrt{24} = 23270.15 Mpa$$

$$\beta_d = \frac{1.2DL}{Pu} = \frac{1700}{2400} = 0.71$$

$$I_g = \frac{b*h^3}{12} = \frac{0.4*0.6^3}{12} = 0.0072 m^4$$

$$EI = \frac{0.4*23270.15*10^6*0.0072}{1+0.71} = 39.192 MN.m^2$$

$$P_{cr} = \frac{\pi^2 EI}{(KLu)^2} \qquad ....ACI\,318-14(Eq.\ 10-13)$$

$$P_c = \frac{3.14^2*39.192}{(1.0*3.75)^2} = 27.5 MN.$$

$$Cm = 0.6 + 0.4\left(\frac{M1}{M2}\right) \text{ ....}ACI\,318-2002(Eq.10-16)$$

$$Cm = 1 \text{ ....} According\ to\ ACI\,318-2002(10.10.6.4)$$

$$\delta_{ns} = \frac{Cm}{1-(Pu/0.75P_{c})} \geq 1.0 \quad \text{..........}.....ACI\,318-14(Eq.\ 10-12)$$

$$\delta_{ns} = \frac{1}{1-(2400/0.75*27.5*10^{3})} = 1.13 > 1$$

$$e_{\min} = 15 + 0.03*h = 15 + 0.03*600 = 33mm = 0.033m$$

$$e = e_{\min} \times \delta_{ns} = 0.033*1.13 = 0.0373$$

$$\frac{e}{h} = \frac{0.0373}{0.6} = 0.0622$$

From Interaction Diagram

$$\frac{\phi P_n}{A_g} = \frac{3374}{0.4*0.6} * \frac{145}{1000} = 2038.46Psi$$

$$\rho_g = 0.01$$

A_s= ρ * Ag = 0.01*400*600 = 2400mm^2

Use Φ 16 >> $\#\ of\ bar\ = \frac{2400}{201} = 12$

Use 12Φ 16 with As = 2412.7mm² >Asreq = 2400mm²

Design of the Tie Reinforcement :

For Φ 10 mm ties :

$S \leq$16 db (longitudonal bar diameter)......................ACI - 7.10.5.2

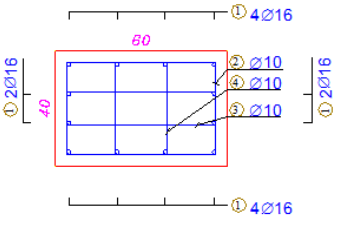
$S \leq$ 48dt (tie bar diameter).

$S \leq$ Least dimension.

$S \leq 16 \times 1.6$ = 25.6 cm

$S \leq 48 \times 1$ = 48 cm

$S \leq 40$ Use Φ10 @25



Section A-A

SCALE 1:20

Figure (4.16): Detailing of column

4.11 Design of Basement wall:

- Loads on basement wall :

q1 = Earth pressure soil

q1= γ * h * k0

K_0 = 1 – sin 30 = 0.5

q1= 18 * 4.025 * 0.5 = 36.225 KN/m2

factored load (q_u) =1.6 * q1 = 1.6 * 36.225 = 57.96

h wall = 30 cm

- Design of shear force :

From Attir Vu = 75.9 KN

d=300 -20 – 14/2 = 274 mm

$$\Phi * Vc = 0.75 * \frac{\sqrt{fc'}}{6} bw * d = 0.75 * \frac{\sqrt{24}}{6} * 274 * 1000 = 167.8 \text{ KN} > Vu$$

(h =30 is correct)

- **Design of the Vertical reinforcement** :

- In tension side:

Max Mu from Attir = 72.1 KN.m

$$Rn = \frac{Mn}{b * d^2}$$

$$Rn = \frac{72.1 * 10^6 / 0.9}{1000 * (274)^2} = 1.07 \text{ MPa}$$

$$\rho = \frac{1}{m}(1 - \sqrt{1 - \frac{2mRn}{fy}})$$

$$\rho = \frac{1}{20.6}(1 - \sqrt{1 - \frac{2(20.6)(1.07)}{420}}) = 0.0026$$

As req = ρ * b * d = 0.0026* 100 *27.4 = 7.12 cm²/m.

As min = 0.0012 * b * h = 0.0012*100 * 30 = 3.6 cm²/m

As req > As min

select Φ14@ 20 cm $A_s\, provided = 7.7cm^2 / m$

- In compression side :

As min = 0.0012 * b * h = 0.0012*100 * 30 = 3.6 cm²/m

select Φ10@ 20 cm $A_s\, provided = 3.95cm^2 / m$

Design of the Horizontal reinforcement :

For One layer :

As min = 0.001 * b * h = 0.001*100 * 30 = 3 cm²/m

select Φ10@ 25 cm $A_s\, provided = 3.16cm^2 / m$

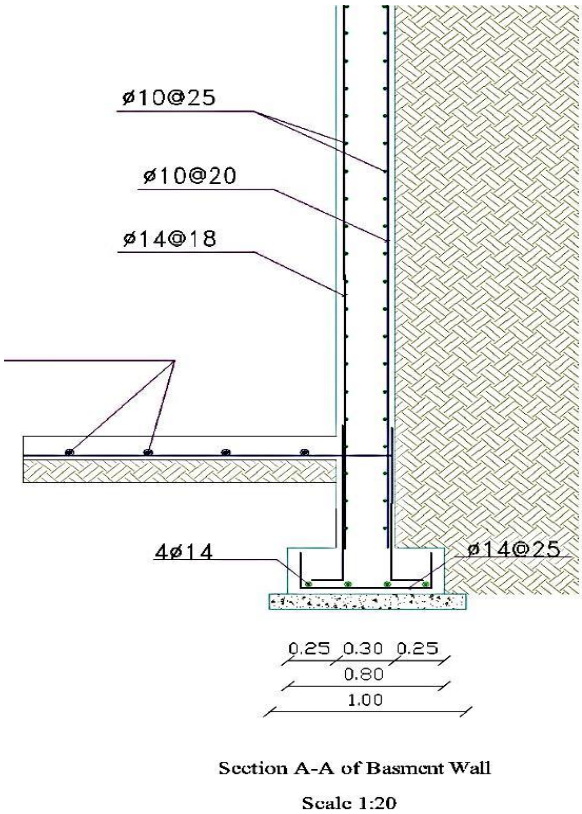


Figure (4.17): Detailing of basement wall

4.12 Design of Basement footing:

Total factored load in basement = 1.2* 4*25*0.3 = 36 KN/m
Soil density = 18 KN/m3
Allowable soil Pressure = 400 KN/m2
Assume footing to be about (30 cm) thick.
Footing weight =1.2 *25 *0.3 =9 KN/m^2
Soil weight above the footing = 1.6 *3.65* 18 = 105.12 KN/m^2
$q_{allow,net}$ = 400 - 105.12- 9=285.9KN/m2
assume b = 0.8 m , h =0.3 m

d= 300 – 75 – 14 = 211 mm

- **Check of One Way Shear :**

q_{ult} = 36 / (1* 0.8)= 45 KN/m ^{2}

Vu = 1* (0.25 – 0.211) *45 = 1.755 KN

$$\Phi * Vc = 0.75* \frac{\sqrt{fc'}}{6} bw * d = 0.75 * \frac{\sqrt{24}}{6} * 211 * 1000 = 129.2 \text{ KN}$$

Φ* Vc >> Vu ..... (No Shear Reinforcement is Required.)

- **Design of Bending Moment:**

Mu = 45 * (0.25) ^{2} *0.5 = 1.41 KN.m

$$Rn = \frac{Mn}{b * d^2}$$

$$Rn = \frac{1.41*10^6 / 0.9}{1000*(211)^2} = 0.0351 \text{ MPa}$$

$$\rho = \frac{1}{m}(1 - \sqrt{1 - \frac{2mRn}{fy}})$$

$$\rho = \frac{1}{20.6}(1 - \sqrt{1 - \frac{2(20.6)(0.0351)}{420}}) = 0.0000836$$

As req = ρ * b * d = 0.0000836* 100 *21.1 = 0.177cm²/m.

As min = 0.0018 * b * h = 0.0018*100 * 30 = 5.4 cm^2/m

As min > As req

select Φ14@ 25 cm $A_s\ provided = 6.2 cm^2 / m$

in lateral direction:

As min = 0.0018 * b * h = 0.0018*100 * 30 = 5.4 cm^2/m

select Φ14@ 25 cm $A_s\ provided = 6.2 cm^2 / m$

4.13 Design of Isolated foundation:

factored load = 2200 KN

Soil density = 18 KN/m3

Allowable soil Pressure = 400 KN/m2

assume h =0.55 m

Footing weight =(24*0.55) =13.2 KN/m^2

Allowable soil Pressure net = 400 – 13.2 = 386.8 KN/m^2

$\sigma \leq \sigma_{allow.\ net}$

$\leq 1.4 * \sigma net = 1.4 * 386.8 = 541.52$ KN/m^2

- assume square footing

$541.52 = \frac{2200}{a * b}$

a= 2.1 b= 1.9 with As = 3.99 m^2

$\frac{2200}{2.1 * 1.9} = 551.4$

541.52 $\leq$ 551.4 …. (ok)

- **Design against sliding**:

  Hor. Force = 0.0 (not required to check)

Design of reinforcement concrete:

- **Check for one way shear :**

Cover = 75 mm , Φ =14 mm , thickness = 550 mm

d= 550 – 75 – 14 = 461 mm

Vu = 0.389 * 551.34 * 2.1 = 450.4 KN

$$\Phi * Vc = 0.75* \frac{\sqrt{fc'}}{6} bw * d = \mathbf{0.75} * \frac{\sqrt{24}}{6} * 2100 * 461 = 1355.06 >> Vu$$

So h is correct.

- **Check for two way shear action (punching):**

d= 461 mm

Vu = 2200 –(551.52* 0.861^2) = 1791.15 KN

The punching shear strength is the smallest value of the following equations:

$$\phi.V_c = \phi.\frac{1}{6}\left(1+\frac{2}{\beta_c}\right)\sqrt{f_c'}\,b_o d$$

$$\phi.V_c = \phi.\frac{1}{12}\left(\frac{\alpha_s}{b_o/d}+2\right)\sqrt{f_c'}\,b_o d$$

$$\phi.V_c = \phi.\frac{1}{3}\sqrt{f_c'}\,b_o d$$

Where:

$$\beta_C = \frac{Column\ Length\ (a)}{Column\ Width\ (b)} = \frac{60}{40} = 1.5$$

b_o = Perimeter of critical section taken at (d/2) from the loaded area

$$b_o = 2(d+a1)+2(d+a2) = 2(400+461)+2(600+461) = 3844mm$$

α_s = 40 for interior column

$$\phi.V_C = \phi.\frac{1}{6}\left(1+\frac{2}{\beta_c}\right)\sqrt{f_c'}\,b_o d = \frac{0.75}{6}*\left(1+\frac{2}{1.5}\right)*\sqrt{24}*3844*461 = 2532.075KN$$

$$\phi.V_C = \phi.\frac{1}{12}\left(\frac{\alpha_s * d}{b_o}+2\right)\sqrt{f_c'}\,b_o d = \frac{0.75}{12}*\left(\frac{40*461}{3844}+2\right)*\sqrt{24}*3844*461 = 3688.015KN$$

$$\phi.V_C = \phi.\frac{1}{3}\sqrt{f_c{}'}\,b_o d = \frac{0.75}{3} * \sqrt{24} * 3844 * 461 = 2170.35KN$$

$$\phi.V_C = 2170.35KN \text{ .... } Control$$

$$Vu = 2200 * \{551.52 - (0.861 * 0.861)\} = 1211.71kN$$

$$\phi.Vc = 2170.35KN > Vu = 1211.71KN \text{........ } satisfied$$

- **Design of Bending Moment:**

$$Mu = 551.52 * 2.1 * 0.85^2 / 2 = 418.4kN.m$$

$$d = 550 - 75 - 14 = 461mm$$

$$Rn = \frac{Mn}{b * d^2} = \frac{(418.4/0.9) \times 10^6}{2100 \times 461^2} = 1.04Mpa$$

$$m = \frac{Fy}{0.85fc'} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m}(1 - \sqrt{1 - \frac{2mRn}{fy}})$$

$$\rho = \frac{1}{20.6}(1 - \sqrt{1 - \frac{2 \times 20.6 \times 1.04}{420}}) = 2.543 \times 10^{-3}$$

$$As_{req} = 2.543 \times 10^{-3} \times 2100 \times 461 = 2461.67mm^2$$

$$As_{\min} = 0.0018 * 2100 * 550 = 2079mm^2$$

$$As_{req} = 2461.67mm^2 > As_{\min} = 2079mm^2$$

$$\#of\,bar = \frac{2461.67}{153.94} = 16$$

Select 16 Φ14 $A_s\,provided = 2463.008mm^2$

Check for strain :

As * fy = 0.85 * f_c * b * a

$$2463.008 * 420 = 0.85 * 24 * 2100 * a$$

$$a = 24.15mm$$

$$x = \frac{a}{\beta_1} = \frac{24.15}{0.85} = 28.41mm$$

$$\varepsilon_s = \frac{461 - 28.41}{28.41} \times 0.003$$

$$\varepsilon_s = 0.0457 > 0.005$$ **Ok** **(Φ = 0.9)**

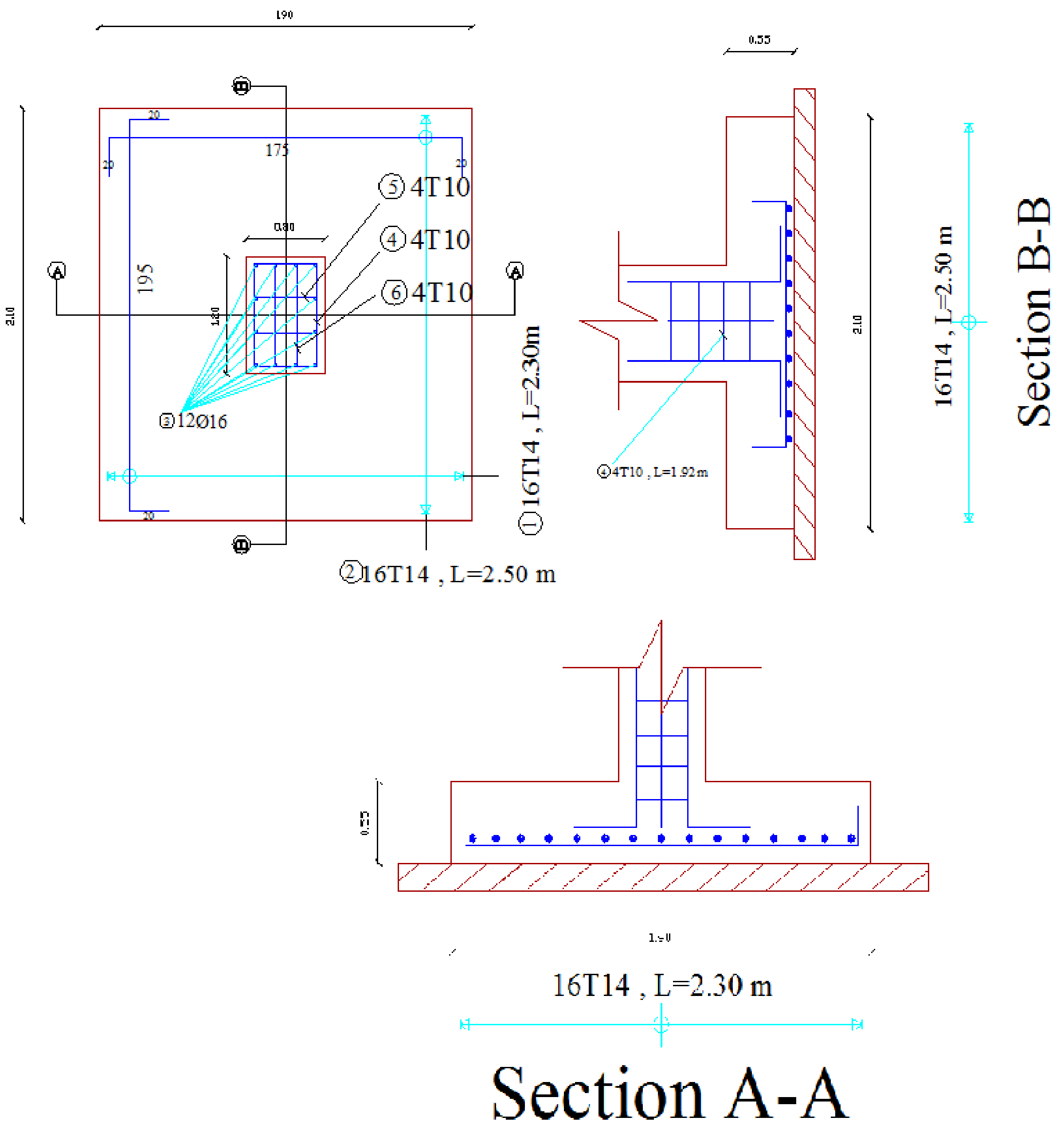


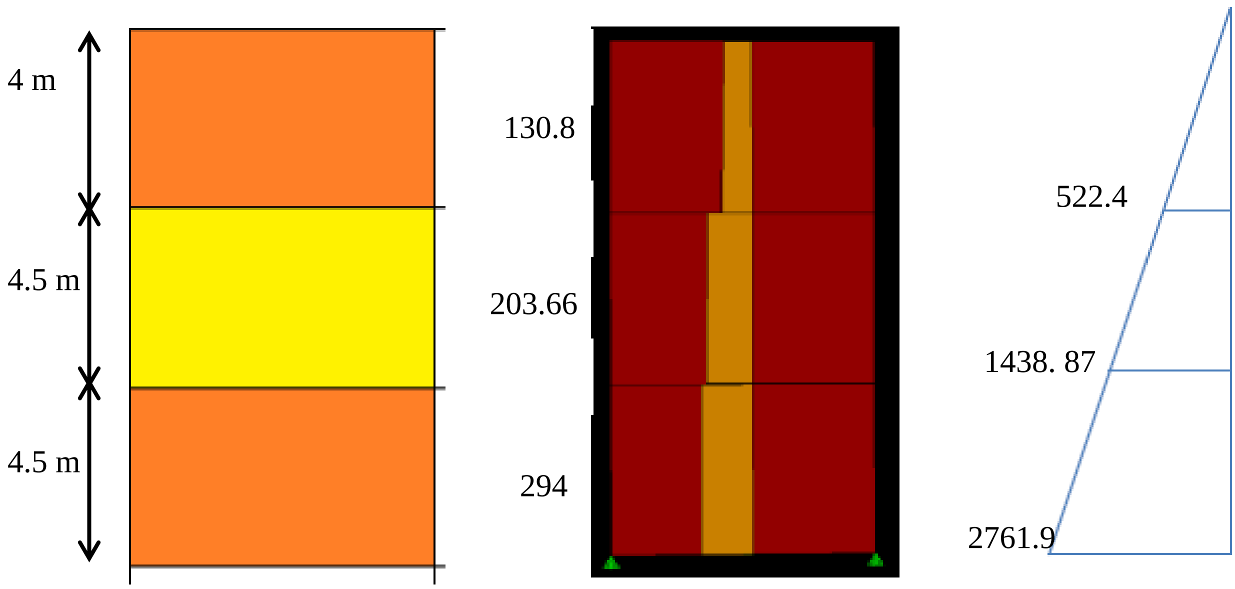
Figure (4.18): Detailing of isolated foundation

4.14 Design of shear wall:

$h_w = 13$ m , $L_w = 6.9$ m

$d \leq 0.8 * L_w = 0.8 * 6.9 = 5.52$ m … control

$d \leq 0.8 * h_w = 0.8 * 13 = 10.4$ m



4.19 Shear force and moment on the wall from ETABS

$L_w / 2 = 3.45$ m …… control

$h_w / 2 = 6.5$ m

Design horizontal reinforcement :

$$V_{C1} = \frac{\sqrt{fc'}}{6} \times b \times d$$

$$V_{c1} = \frac{\sqrt{24}}{6} \times 200 \times 5520 = 901.4KN(control)$$

$$V_{c2} = \frac{\sqrt{fc'} \times b \times d}{4} + \frac{N_u \times d}{4 \times L_w}$$

$$N_u = 0.0KN$$

$$V_{c2} = \frac{\sqrt{24} \times 200 \times 5520}{4} + 0.0 = 1352.12KN$$

$$Mu(1) = 1438.87 + 294 * (4.5 - 3.45) = 1747.4kN.m$$

$$V_{c3} = \left[\frac{\sqrt{fc'}}{2} + \frac{l_w\left(\sqrt{fc'} + \frac{2\times N_u}{l_w \times h}\right)}{\left\langle \frac{M_u(1)}{V_u} - \frac{l_w}{2} \right\rangle} \right] \times \frac{h\times d}{10}$$

$$V_{c3} = \left[\frac{\sqrt{24}}{2} + \frac{3.45\left(\sqrt{24}+0.0\right)}{\left\langle 294 - \frac{6.9}{2} \right\rangle} \right] \times \frac{200\times 5520}{10} = 1767.03KN$$

So thickness of wall is safe.

Design for horizontal reinforcement :

$A_{vh}\ \text{min.} = 0.0025 * s * h$

A_{vh} = 2 Φ 10 = 158 mm^2

$$\left(\frac{2*79}{s}\right) = 0.5$$

S = 316 mm

Smax ≤ L_w/5 =6900 /5 = 1380mm

≤ 450 mm

≤ 3 * h = 3*200= 600 mm

Take s = 300 mm < s max

Select Φ10 -30 cm

Design for Vertical reinforcement:-

$$Avv = \left\{0.0025 + 0.5\left(2.5 - \frac{h_w}{l_w}\right) * \left(\frac{A_{vh}}{S_2 * h} - 0.0025\right)\right\} * s * h$$

Avh = 2 Φ 10 = 158 mm^2

$$Avv = \left\{0.0025 + 0.5\left(2.5 - \frac{13}{6.9}\right) * \left(\frac{2*79}{300*200} - 0.0025\right)\right\} * s * 200$$

$$Avv = 0.0025 * s * h$$

$$\left(\frac{Avv}{s}\right) = 0.53$$

Avv = 2 Φ 10 = 158 mm^2

S=298mm

Smax ≤ L_w/3 =6900 /3 = 2300 mm

≤ 450mm

≤ 3 * h = 3*200= 600 mm

Take s = 250 mm < s max

Select Φ10 -25 cm

Design of bending moment:

$$C > \left(\frac{Lw}{0.007*600}\right) = \frac{6900}{4.2} = 1642.36mm$$

$$length \quad of \quad boundary \quad element = C - 0.1 \times L_w$$
$$length \quad of \quad boundary \quad element = 1642.36 - 0.1 \times 6900 = 952.86mm$$

$$C_w = \frac{C}{2.0} = \frac{1642.86}{2.0} = 821.43mm$$

Select the boundary element = 960mm

Avs= $\frac{Lw}{s1} \times As_v \longrightarrow = \frac{2*79}{250} \times 6900 = 4360mm^2$

$$\frac{Z}{Lw} = \frac{1}{2 + 0.85 * \beta * fc * Lw * h/(As * Fy)}$$
$$\frac{Z}{Lw} = \frac{1}{2 + 0.85 \times 0.85 \times 24 \times 6900 \times 200/(4360.8 \times 420)} = 0.0664$$

$$Muv = 0.9 \times Fy \times 0.5 \times As \times Lw \times \left(1 - \left(\frac{Z}{Lw}\right)\right)$$

$$Muv = 0.9 * 420 * 0.5 * 4360.8 \times 6900 * (1 - (0.0664/2)) = 5498.2\, KN.m$$

Muv > *Mu*

<u>So, Boundary is not required.</u>

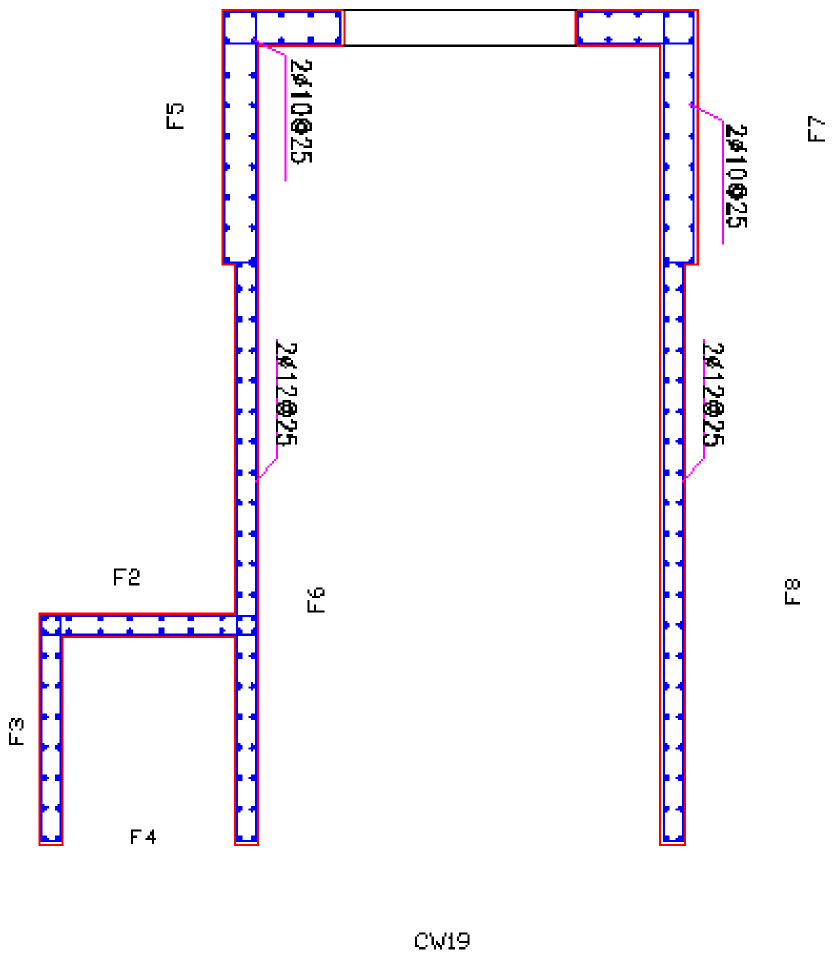


Figure (4.20): Detailing of shear wall

Chapter 5

Results and Recommendations

The Architectural and Structural Drawings shown in Appendix A and B, respectively.

5.1 The Result

1. Each student or structural designer should be able to design manually so he can get the experience and knowledge in using the computer software.
2. One of the factors that must be taken in consideration is the environment factors surrounding the building, the site terrains, and the forces effects on the site.
3. One of the important steps of the structural design is how to connect the structural members to work together, then to divide these members and design them individually, and should take the surrounding condition in the consideration.
4. Various types of slabs have been used: two way and one way ribbed slabs, in

some slabs that have a regular or nearly regular distribution of columns and beams. One way solid slabs mainly in the stairs, because it has high resistance to the concentrated forces.

5. The used software programs:
   - AutoCAD 2007, to draw the detail of drawings for structural drawings.
   - ATIR, Etabs, Safe, Sp column, Straap1, Staad pro and Autodesk Robot structure and analysis 2017 to analysis and design the structural members.

6. We have used the live loads using the Jordanian code of loads.

5.2 The Recommendations

This project has an important role in widening and enhancing our understanding to the nature of the structural project including all the details, analysis, and designs.

We want here through this experience- to introduce a group of recommendations, we hope it to be useful for planning to select a structural project.

At the beginning, the architectural drawings have to be prepared and ordered and the construction material and the structural system have to be choose alongside. And it’s essential at this stage to have information about the project site, the soil, the soil strength capacity at the site from the geotechnical report, after that the bearing walls and the columns is going to be set up alongside the architectural team in a compatible manner. The civil engineer tries at this stage to plant as much as possible the reinforced concrete walls, which should be use after that in resisting the earthquake loads and other lateral loads.

Appendices

Appendix A

Architectural Drawings

Appendix B

Structural Drawings

Appendix (C)

TABLE 9.5(a)—MINIMUM THICKNESS OF NONPRESTRESSED BEAMS 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	$\ell/20$	$\ell/24$	$\ell/28$	$\ell/10$
Beams or ribbed one-way slabs	$\ell/16$	$\ell/18.5$	$\ell/21$	$\ell/8$

Notes:
Values given shall be used directly for members with normalweight concrete (density w_c = 2320 kg/m^3) and Grade 420 reinforcement. For other conditions, the values shall be modified as follows:
a) For structural lightweight concrete having unit density, w_c, in the range 1440-1920 kg/m^3, the values shall be multiplied by $(1.65 - 0.003w_c)$ but not less than 1.09.
b) For f_y other than 420 MPa, the values shall be multiplied by $(0.4 + f_y/700)$.

MINIMUM THICKNESS OF NONPRESTRESSED BEAMS OR ONE-WAY SLABS UNLESS DEFLECTIONS ARE CALCULATED)

الأحمال الحية

تابع الأحمال الحية للأرضيات والعقدات

نوع المبنى		الاستعمال	الحمـ ـل المـ ـوزع	الحمل المركز البديل
عـ ـام	خاص	الاشـ ـغال	كن/م²	كن
تابع المبانـ ـي التعليمية وماشابهها.	تابع السجون والمستشفيات والمدارس والكليات.	أماكن التكديس الكثيف للكتب علـ ـى عربـ ـات متحركة.	4.8 لكل متر من ارتفاع التخـ ـزين على أن لا يقل عن (10).	7.0
		غرف تكديس الكتب.	2.4 لكل متر من ارتفاع التخزين على أن لا يقل عن (6.5).	7.0
		مستودعات القرطاسية.	4 لكل متر من ارتفاع التخزين.	9.0
		الممرات والمداخل المعرضة لحركـ ـة المركبـ ـات والعربات المتحركة.	5.0	4.5
		غرف وقاعات التدريب.	5.0	9.0
		قاعات التجمع والمسارح والجمنازيوم دون مقاعد ثابتة.	5.0	3.6
		المختبرات بما فيها مـ ـن أجهزة، والمطابخ وغرف الغسيل.	3.0	4.5
		الممـ ـرات والمـ ـداخل والأدراج و بـ ـسطات الأدراج الثانويـ ـة.	3.0	2.7

Bibliography

[1] American Concrete Institute (A.C.I). Building code requirement for structural concrete.

[2] National Jordanian Construction loads. The National Jordanian Construction council.