Palestine Polytechnic University

College of Engineering

Department of Civil Engineering

Construction Engineering

Hebron – Palestine

Graduation Project

Structural Design of Plant Biodiversity Research Center

Team of Work

Wafaa AbuSaif **Al-Mutasem Masharqa**

Supervisor

Dr. Maher Amro

May, 2022

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On the instructions of the project supervisor and with the consent of all members of the examiner's committee, this project has been submitted to the College of Engineering in partial fulfillment of the requirements for the Bachelor degree in Civil Engineering.

Project supervisor signature
Dr. Maher Amro

Signature of the Head of Department
Dr. Bilal Al-Masri

Dedication

To those whom Allah has entrusted with honor and dignity, to those who have taught us to give without expectation, to those whose names we most proudly bear, may Allah extend your life to see fruit whose harvest has come, after a long wait. Your words will remain stars to guide us today, tomorrow and forever, our dear Fathers.

To the meaning of love and the meaning of tenderness and devotion, to the smile of life and the secret of existence, to those whose prayers were the secret of our success and tenderness in the peace of our wounds, our mothers.

To those who are closer to us than to our own spirit, to those who shared our mother's lap with us, with whom we derive our strength and determination, our brothers and sisters.

To those who have humanized us in our study and shared our worries with us as a reminder and a tribute, our friends.

Acknowledgement

Praise be to Allah, what has been completed along the way, and has not been pursued except through His grace. O God, not through my hard work and effort, but through Your success and blessing on me. Praise be to Allah in the beginning and at the conclusion. We extend our thanks and gratitude to our University, Polytechnic University of Palestine, which hosted us throughout our study at the Faculty of Engineering.

We extend our highest thanks, gratitude and appreciation to our supervisor, Dr. Maher Amr, who was better able to supervise this project. May God reward him with all the best.

As we take our final steps in university life, we must go back to the years that we spent at university with our honorable professors, who have given us so much, thus making great efforts to build the generation of tomorrow so that the nation may be revived again. We thank you very much.

In the end, we give thanks to everyone who extended a hand in the project and was of great help.

Abstract

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 "Plant Biodiversity Research Center. The Center contain four floors, the basement floor, it contains store, Generator and Heating and air conditioning. The ground floor contains Video conference, Kitchen, Cafeteria, Gallery and theater. The first floor contains plant receipt, plant sorting, plant desiccation, plant Packaging, herbarium, seeds store, seeds desiccation, seeds sorting and sifting, seeds Packaging, seeds receipt, plant microbiology lab, Molecular biology lab and Molecular biology lab. The second floors it contains publication store, printing hall, raw material store, and office, and the third floor it contains finance manager, secretary, manager assistant, personnel officer and Archive. With a total area of 4000 m2.

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

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.

ملخَّص المشروع :

التصميم الإنشائي هو أهم تصميم للمبنى بعد التصميم المعماري، توزيع الأعمدة، الأحمال؛ توفر المتانة، أفضل الأسعار وأعلى درجة من السلامة هي مسؤولية المصمم الإنشائي. في هذا المشروع، سوف نقوم بالتصميم الإنشائي لـ "مركز أبحاث التنوع البيولوجي النباتي". يحتوي المركز على أربعة طوابق، أرضية الطابق السفلي، والذي يحتوي على مخازن ومولدات وتدفئة وتكييف للهواء. أما الطابق الأرضي فيحتوي على مؤتمرات فيديو ومطبخ وكافتيريا ومعرض ومسرح. يحتوي الطابق الأول على إيصالات نباتية، وفرز نباتي، وجفاف نباتي، وتغليف نباتي، ومخزن للبذور، وجفاف للبذور، وفرز وغربلة للبذور، وتعبئة للبذور، ومختبر علم الأحياء الدقيقة للنبات، ومختبر البيولوجيا الجزيئية ومختبر البيولوجيا الجزيئية. أما الطابق الثاني فيحتوي على مخزن مطبوعات وقاعة طباعة ومخزن مواد خام ومكتب، أما الطابق الثالث فيحتوي على مدير الشؤون المالية والأمين ومساعد المدير وموظف شؤون الموظفين والمحفوظات. بمساحة إجمالية تبلغ 4000 متر مربع.

تم إختيار هذا المشروع نظرًا لأهمية معرفة كيفية تصميم هذه المباني، التي لها متطلبات تصميم أعلى من غيرها من المشاريع مع الأبراج الطويلة والمسارح الكبيرة والتنوع في شكل المبنى، من خلال التصميم المعماري. كما تم إختيارها لأهمية هذا المركز لعدم وجود مثل هذه المراكز في هذا المجال.

وبعد إنجاز المشروع، نتوقع أن نكون قادرين على توفير تصميم هيكلي لجميع العناصر الهيكلية للمشروع وفقًا لمتطلبات الكود.

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List of Abbreviations:

- **Ac** = area of concrete section resisting shear transfer.
- **As** = area of non-pre-stressed tension reinforcement.
- **Ag** = gross area of section.
- **Av** = area of shear reinforcement within a distance (S).
- **At** = area of one leg of a closed stirrup resisting tension within a (S).
- **b** = width of compression face of member.
- **bw** = web width, or diameter of circular section.
- **DL** = dead load.
- **d** = distance from extreme compression fiber to cancroids of tension reinforcement.
- **Ec** = modulus of elasticity of concrete.
- **Fy** = specified yield strength of non-pre-stressed reinforcement.
- **I** = moment of inertia of section resisting externally applied factored loads.
- **Ln** = length of clear span in long direction of tow-way construction, measured face- to-face of supports in slabs without beams and face to face of beam or other supportsin other cases.
- **LL** = live load.
- **Ld** = development length.
- **M** = bending moment.
- **Mu** = factored moment at section.
- **Mn** = nominal moment.
- **Pn** = nominal axial load.
- **S** = spacing of shear or in direction parallel to longitudinal reinforcement.
- **Vc** = nominal shear strength provided by concrete.
- **Vn** = nominal shear stress.
- **Vs** = nominal shear strength provided by shear reinforcement.
- **Vu** = factored shear force at section.
- **Wc** = weight of concrete. (Kg/m^3)

CHAPTER

1

INTRODUCTION

1.1 INTRODUCTION.

1.2 RESEARCH PROBLEM.

1.3 AN OVERVIEW OF THE PROJECT.

1.4 THE OBJECTIVE OF THE PROJECT.

1.5 PROJECT METHODOLOGY.

1.6 REASONS TO CHOOSE PROJECT.

1.7 THE SCOPE OF THE PROJECT.

1.8 SCHEDULE.

1.1 Introduction

Palestine is an agricultural country that needs facilities such as a Plant Biodiversity Research Center so we adopted this project as a graduation project where we take into account the importance of the project and its requirements that have designed to meet these considerations. Generally, design process requires the introduction of all aspects of the building to create in the architectural appearance of the building and how to distribute the spaces and areas, or structural terms deal with structural system capable of carrying the loads affecting the building taking into account the most possible economical construction system as is compatible with the architectural design.

The project includes the architectural and structural design of Stage, Library, Management rooms, Galleries, Oratory, Cafeteria, Video Conference Hall, Lecture halls, Stores and Computer halls. Distributing columns and bridges in line with architectural and design elements from components to bases and foundations and structural schemes and processing in order to produce an integrated project and enforcement.

1.2 Research Problem:

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 analyzed and designed in the project. Then the dimensions and the reinforcement of various structural elements will be determined.

1.3 An Overview of the Project:

This project includes the structural design of Stage, Library, Management rooms, Galleries, Oratory, Cafeteria, Video Conference Hall, Lecture halls, Stores and Computer halls that fulfilled all the requirements of comfort and safety according to usage requirements.

The stage is located in the ground floor and it can accommodate about195persons with an area of nearly 313 square meters.

The library has an area of 240m2 and it can accommodate up to 60 persons.

The management rooms have an area of 134m^2.

The gallery has an area of 295m^2.

The capable has an area of 35m^2 and it can almost accommodate 27 persons.

The cafeteria has an area of252m^2 and it can accommodate nearly 100 persons.

The educational section has an area of 120m^2.

1.4 The Objective of the Project:

The objectives of the project divided into two parts:

1. Architectural Goals:

In this project architectural design is not the main goal as civil, building engineers, however this building where necessary to achieve beauty and utility requirements, cost, and durability in these facilities, which are the basic architectural design requirement.

2. Structural Goals:

Structural design of the units will be done in this project with preparation of all structural drawings for beams, slabs, columns, footings and shear walls to be ready for execution on the location of the project.

1.5 Project Methodology:

Architecture design (construction drawings, elevations, sections, public location).

1. Study the units structurally to identify structural elements, loads on the buildings and the selection of appropriate structural system.
2. Distribute columns to the chosen structural system.
3. Structural analysis of all structural elements of the units.
4. Structural design of all structural elements.
5. Writing project in accordance with the requirements of the construction engineering.

1.6 Reasons to Choose the Project:

The reason of selecting the project is to improve our skill in design for structural elements in buildings. In addition, to increase the knowledge of machine construction systems in our country and other countries, as well as to acquire scientific knowledge and the process followed in the design and implementation of construction projects and the structural engineer after graduation in the work market in the future.

This research submitted to the department of civil engineering and architecture at the College of engineering and technology at Palestine Polytechnic University to meet graduation requirements for a Bachelor's degree in civil engineering and building engineering.

1.7 The scope of the Project:

This project contains several chapters detailed as follows:

- Chapter One: a general introduction to the project.
- Chapter Two: includes description of 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 reached and recommendations.

1.8 Schedule:

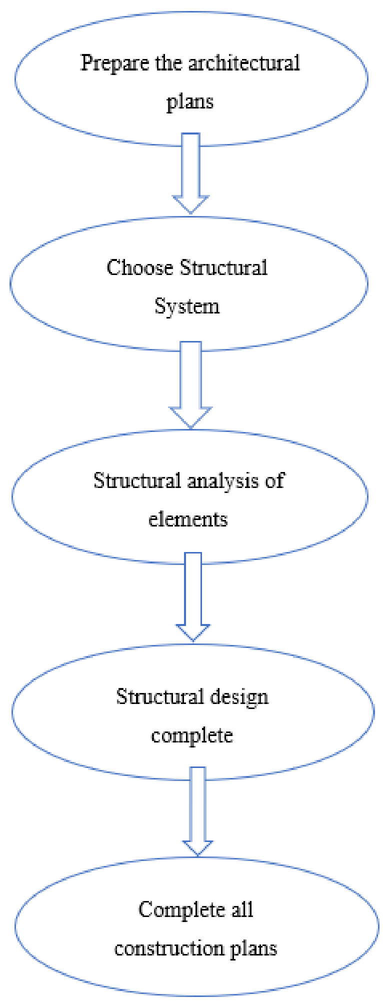

Figure 1-1: The Stage of the project

Table 1.1: Project Schedule

Task \ Week NO.	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:

Architectural description is the most important thing. That defining and understanding the nature of the project and its sections.

Architectural design requirements must meet the required job and human needs in this time. These terms are in the functional beauty and economy, it is important in these conditions that they can connect between each other and in conformity to achieve our vision of optimal design and get an integrated and overall architectural design, and this is achieved by understanding the functional demands of the building and space as well as taking into account the natural movement of each part of the project.

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

2.2 The Main Elements in the Plant Biodiversity Research Center:

The project areas are divided into internal and external spaces tied together to reach the goals that we need it.

2.2.1 Interior Spaces:

The interior area of the project is 4000 m^2.

- Interior spaces divided to:

1- Basement.
2- Stage.
3- Cafeteria.

4- Gallery.
5- Video conference.
6- Labs.
7- Library.
8- Office rooms.
9- Internal stores.
10- Educational section.

- **<u>1-Basement:</u>**

It is less than the level in the building, an area equivalent to $132m^2$ divided into quarters services as follows: -

- Heating and air conditioning room: has an area of $28m^2$.
- Generator room: has an area of $22m^2$.
- Elevator Room: has an area of $7m^2$.
- Store: has an area of $28m^2$.
- Passage: has an area $47m^2$.

- **<u>2-stage:</u>**

It is located on ground floor and it accommodates 195 persons with an area of nearly 313 m2 divided into**:**

- Backstage1: has an area of 16 m^2.
- Control room: has an area of 9 m^2.
- Backstage2: has an area of 10 m^2.
- Platform: has an area of 30 m^2.

- **<u>3-Cafeteria:</u>**

It has an area of 252 m2 and can accommodate about 100 persons.

- **<u>4-Gallery:</u>**

It located on ground floor with an area of nearly 295 m^2.

- **<u>5-Video conference:</u>**

It is located on ground floor and it accommodates 32 persons with an area of nearly 90 m^2.

- **6-Labs:**

They are located on first floor and it accommodates about32 persons with an area of nearly 103 m^2 divided into:

- Plant physiology lab has an area of60 m^2.
- Molecular physiology lab: has an area of 43 m^2.

- **7-Library:**

It is located on second floor and it accommodates about60 persons with an area of nearly 240 m2 divided into: -

- Office: has an area of 40 m2.
- Entrance: has an area of 36 m2.
- Reading hall: has an area of 105 m2.
- Bookshelves: has an area of 59 m2.

- **8-Office rooms: -**

They have an area of 90$m^{2.}$

- **9-Foreign stores:**

They have an area of 71m^2.

- **10-Educational section:**

It has an area of 120 m^2.

2.2.2 External Spaces:

Consisting of:

- Green spaces.
- Cars parking: It consists of 41-car parking with an area 915 m^2.

2.3 Project Plans:

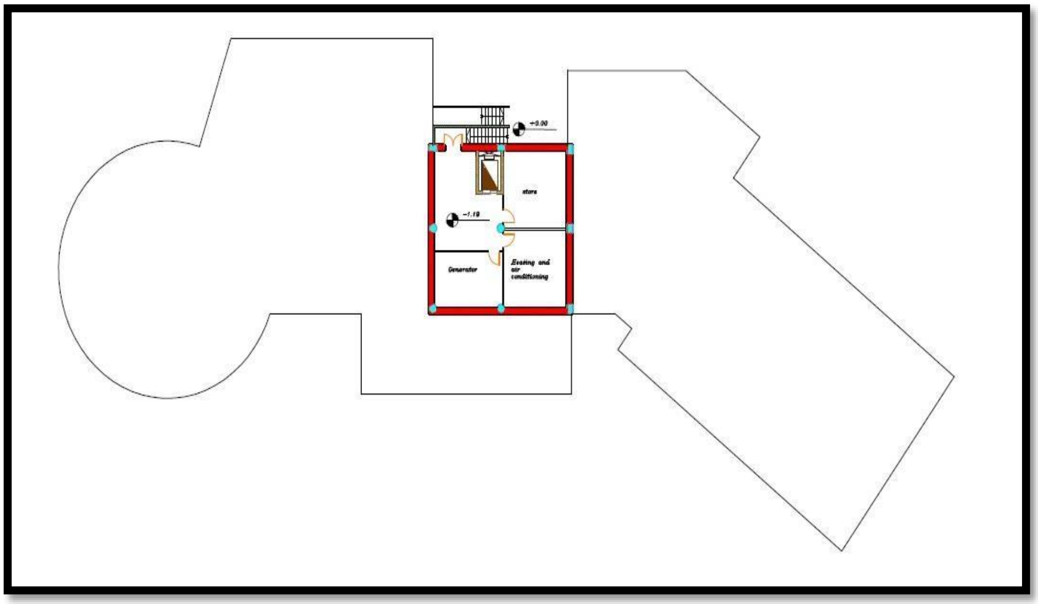

Figure 2-1: Basement floor Plan

Figure 2-2: Ground Floor Plan

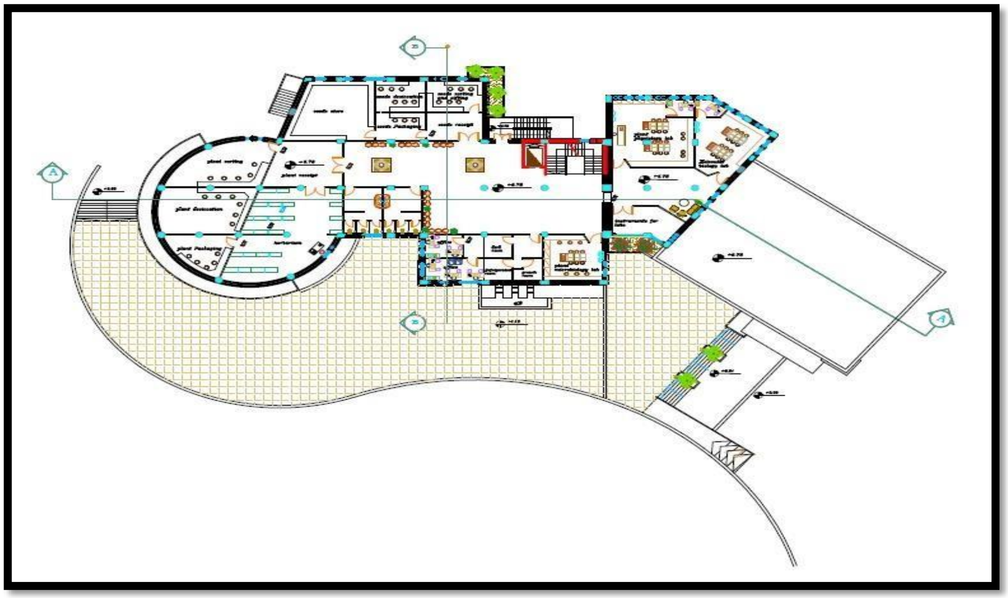

Figure (2-3): First floor plan

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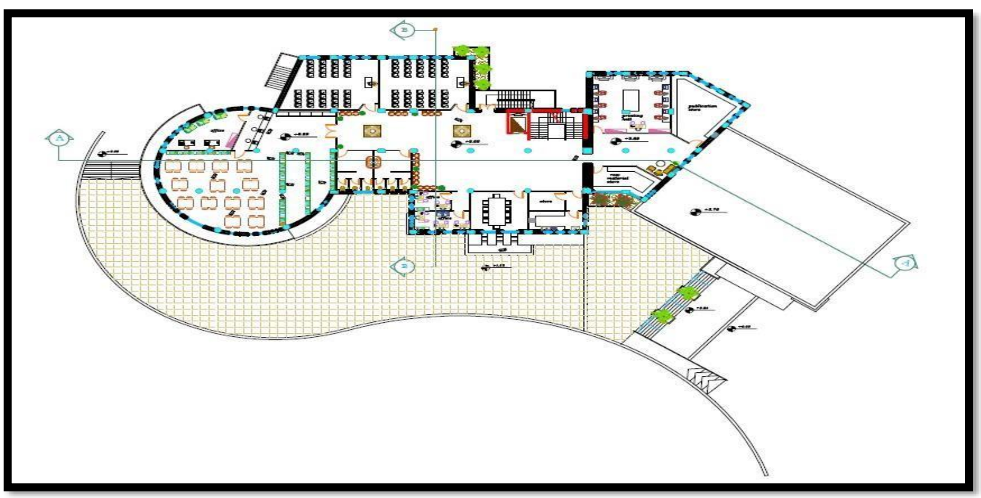

Figure (2-4): Second floor plan

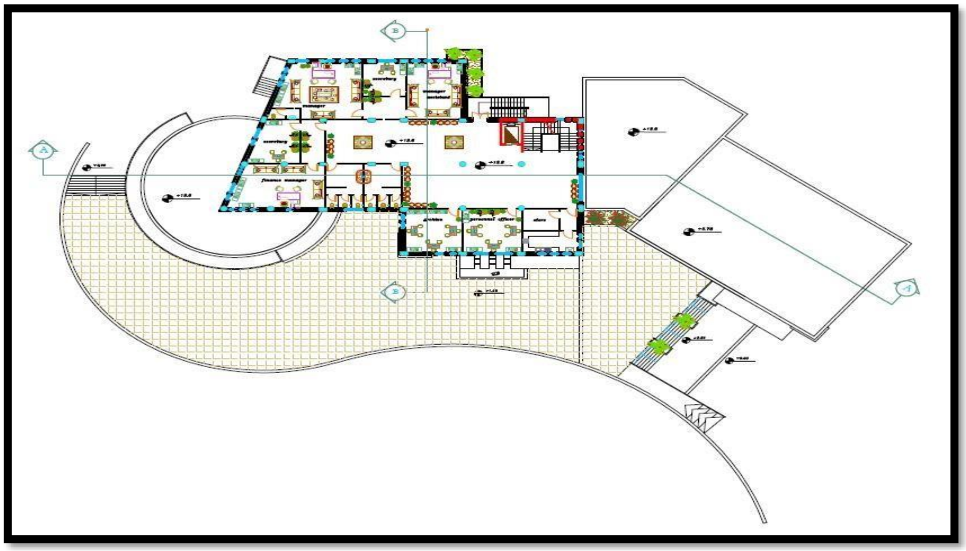

Figure (2-5): Third floor plan 1

2.4 Project Elevations:

Figure (2-6): South East Elevation (Main Elevation)

Figure (2-7): North West Elevation

Figure (2-8): South West Elevation

Figure (2-9): North East Elevation

2.5 Project Sections:

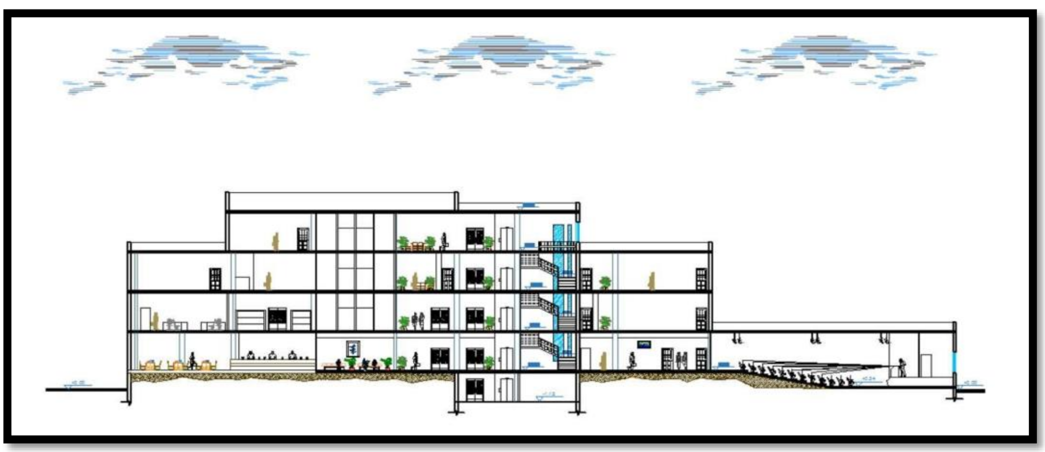

Figure (2-10): Section A-A

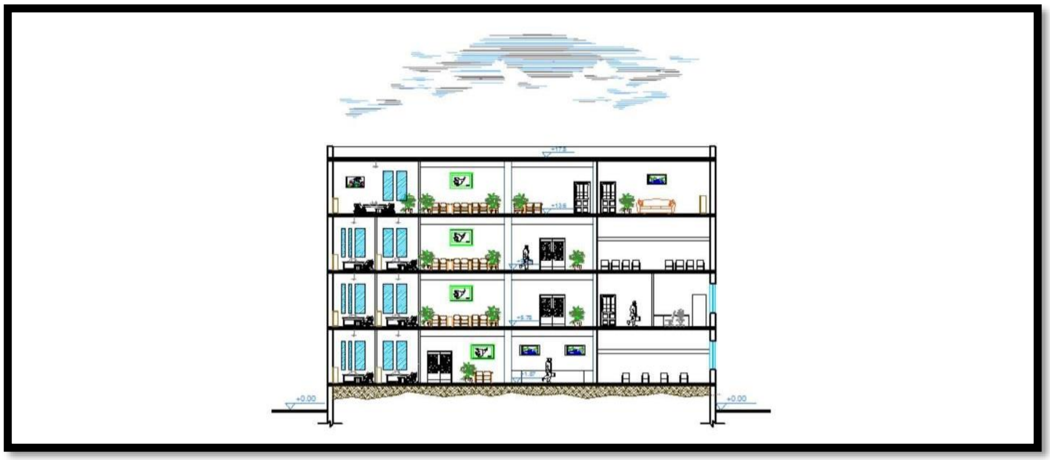

Figure (2-11): Section B-B

2.6 Some Perspective Shots for the Biological Research Centre:

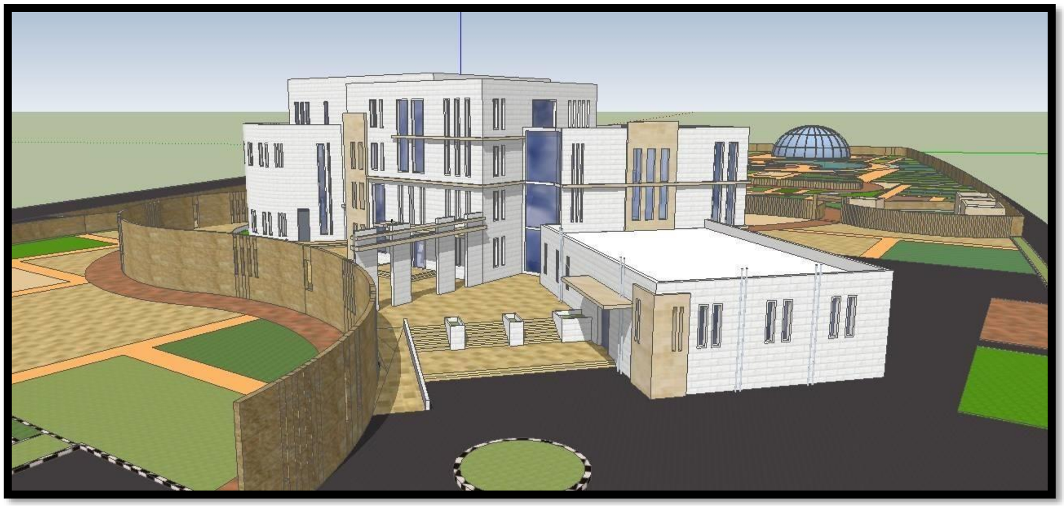

Figure (2-12) Shot for the Building

Figure (2-13) Shot for the Building

Figure (2-14) Shot for the Building

CHAPTER

3

Structural Description

3.1 Introduction:

The main objective of the process design is to ensure the existence of necessary operating advantages with structural elements on the most suitable dimensions in terms of security and economic terms.

The knowledge of structural elements of any project is essential in the design of reinforced concrete structures to make comparisons between different types of these elements for the construction of safer system. So, the structural elements that go into the design of this project will described.

3.2 The Goal of the Structural Design:

The structural design is an integrated and balanced structural system capable of carrying it meet the established requirements and desires of users, and thus determines the structural elements from the following:

1- Factor of Safety: Is achieve by selecting sections for structural elements capable of withstanding the forces and resulting stresses.
2- Economy: Checked by choosing the appropriate building materials and by selecting the perfect low-cost section.
3- Serviceability: To avoid excessive landing (deflection), fissures (cracks).
4- Preservation of architectural design.
5- Preserving the environment.

3.3 Scientific Tests:

Before the design of any construction project some test must done. For example, tests of the soil to know bearing capacity of the soil, specifications, type, the underground water level and depth of the foundation layer.

3.4 Steps for Structural Design:

We will divide the structural design of the project in two phases: -

1. The first step: -
   In this step, the appropriate structural system of project construction and analysis for this system will be determined.

2. The second step: -

The structural design of each element detailed and examined according to the chosen construction system and executive structural plans.

3.5 Loads Acting on the Building:

Is a group of forces that is designed to bear, and that any building is subjected to several types of loads must be calculated and selected carefully because any error in identifying and calculating loads reflect negatively on structural design of various structural elements.

The permanent forces and resulting from gravity and location and do not change during the age of the building, and the loads on the weight of structural elements and the weights of the items based upon permanently as cutters and walls, as well as the weight of the body adjacent to the building. Beside the calculation and estimate of the loads by knowing the dimensions of the structural elements and specific gravity of the material used in the manufacture of structural elements. These elements include concrete, steel reinforcement, plaster, bricks, tiles, finishes, and the stone used in building coverage abroad.

نوع المبنى		الاستعمال	الحمل الموزع	الحمل المركز البديل
عام	خاص	الاشغال	كن/م٢	كن
تابع مباني التجمعات العامة.	تابع القاعات، قاعات الاجتماعات، المطاعم، المتاحف، المكتبات،	الممرات والمداخل والأدراج وبسطات الأدراج والممرات المرتفعة الموصلة بين المباني.	4.0	4.5
	النوادي، المسارح، ستوديوهات الاذاعة.	المنصات.	7.5	4.5
		أرضيات المتاحف وصالات عرض الفنون.	4.0	4.5
		أماكن العبادة (المساجد والكنائس).	3.0	2.7

Figure (3-1) Determination of live load

3.5.1 Snow Loads:

Snow loads can calculate by knowing the altitude using the table below by Jordanian code.

Figure (3-2): snow loads

Based on the scale of previous snow loads and after selecting the high building surface and that equals (860 m) according to item III snow load calculated as follows:

$$So = \frac{h - 400}{320} = \frac{860 - 400}{320} = 1.44\ KN/m^2.$$

$$Sd = Mi * So = 0.8 * 1.44 = 1.152\ KN/m^2.$$

3.5.2 Earthquake Load:

Produce earthquakes of horizontal and vertical vibrations due to the relative motion of the earth rock layers, resulting in strong cut affect the origin, and these loads must take into account during the design to ensure resistance of earthquakes. This will be resisted by shear walls in the building.

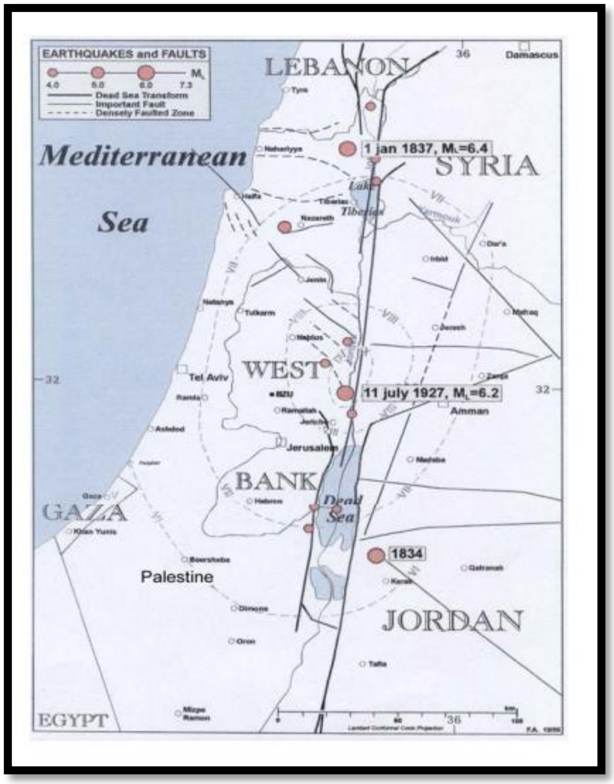

Figure (3-3): Earthquake Map of Palestine

3.5.3 Wind Loads:

Wind loads affect the horizontal forces on the building. The wind load determination process depends on the wind speed and the change height from the surface of the earth and the building location, whether it is built in a high or a low place taking into account many other variables.

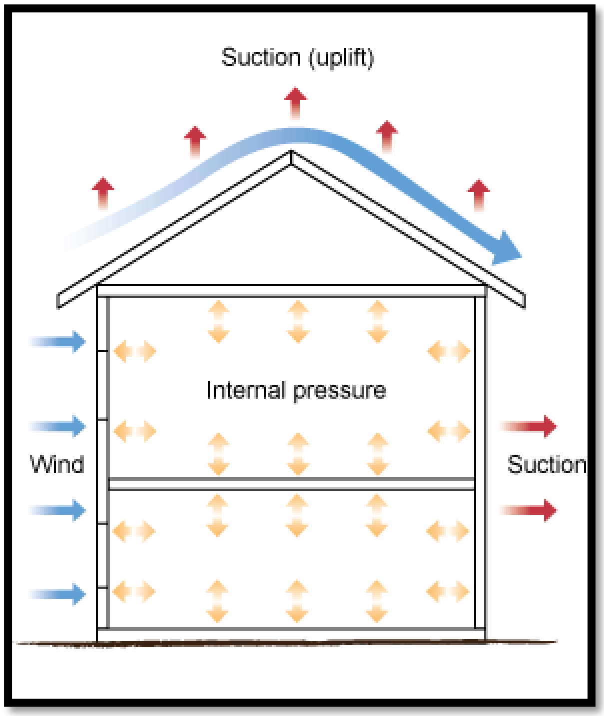

Figure (3-4): Wind Pressure on buildings.

3.6 Structural Elements of the Building:

All buildings are usually consisting of a set of structural elements that work together to satisfy the continuity of the building and its suitability for human use. The most important of these slabs, beams, columns and load-bearing walls, it must define.

- **Slabs:**

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

In this project, two types of components each in its appropriate place, and will clarify the structural design in the subsequent chapter, and these types are:

1- One Way Ribbed Slab.
2- Flat Slab.

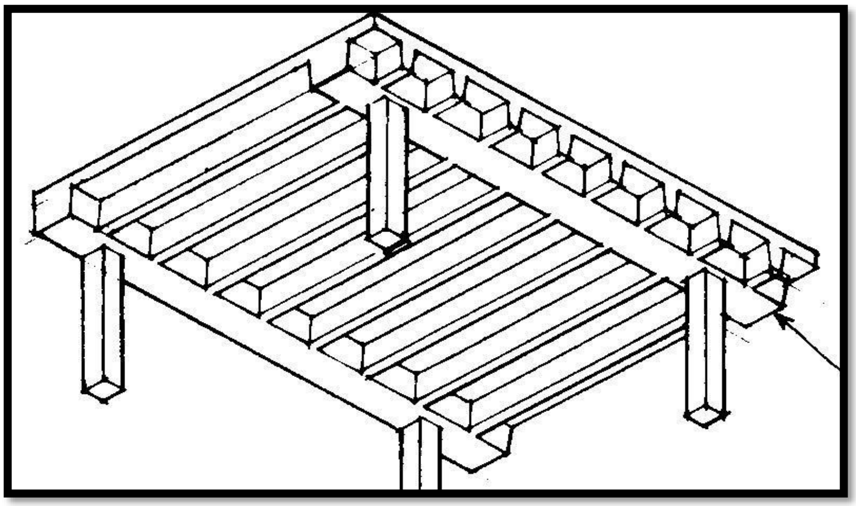

Figure (3-5): One Way Ribbed Slab

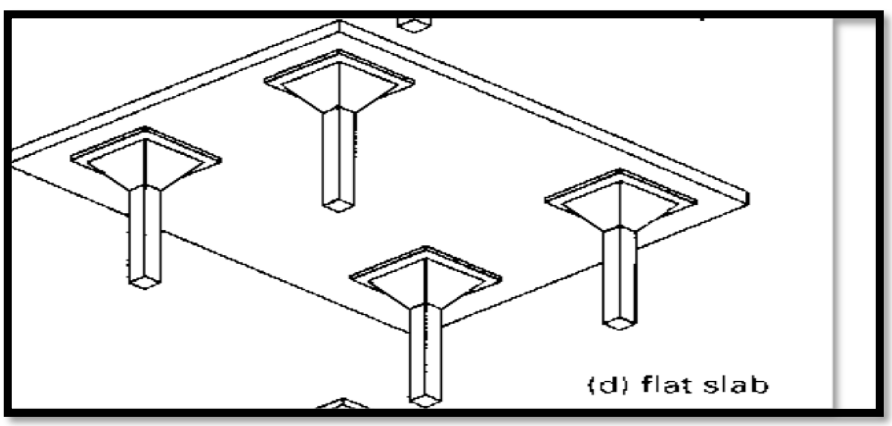

Figure (3-6): flat Slab.

- **Beams**:

The basic structural elements in moving load of tiles into columns, and are of two types:

1- Hidden Beam: Hidden inside Slabs.

2- Dropped Beam: (Paneled Beam).

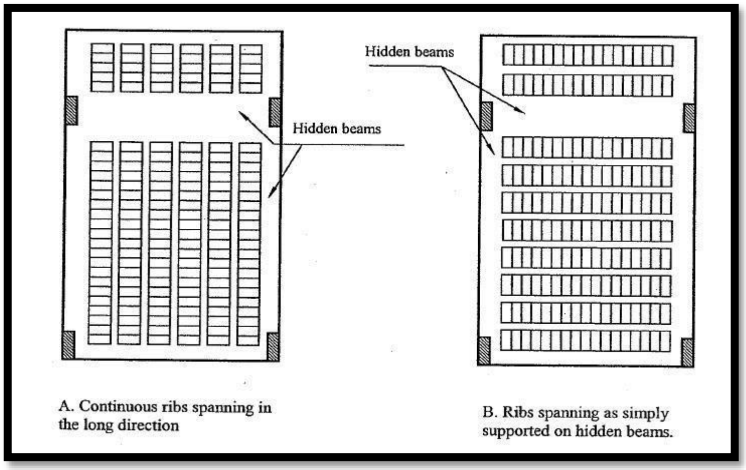

Figure (3-7): Hidden Beam

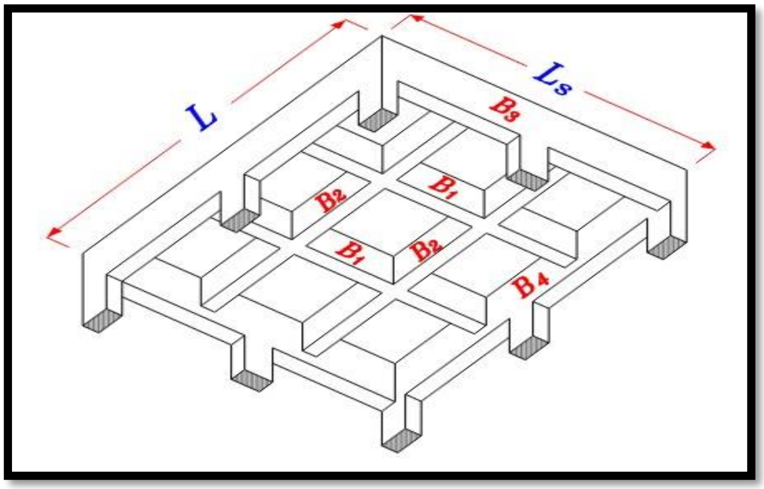

Figure (3-8): Paneled Beam

- **Column:**

The column is an important element in moving loads of bridges to the foundations, it is essential to transfer the loads and the building, and therefore must designed to be able to load them, and two types were used rectangular and circular concrete columns.

Figure (3-9): Column

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- **Frames:**

The frame construction is a method of building and designing structures, primarily using steel or steel-reinforced precast concrete. The connections between the columns and the rafters designed to be moment-resistant.

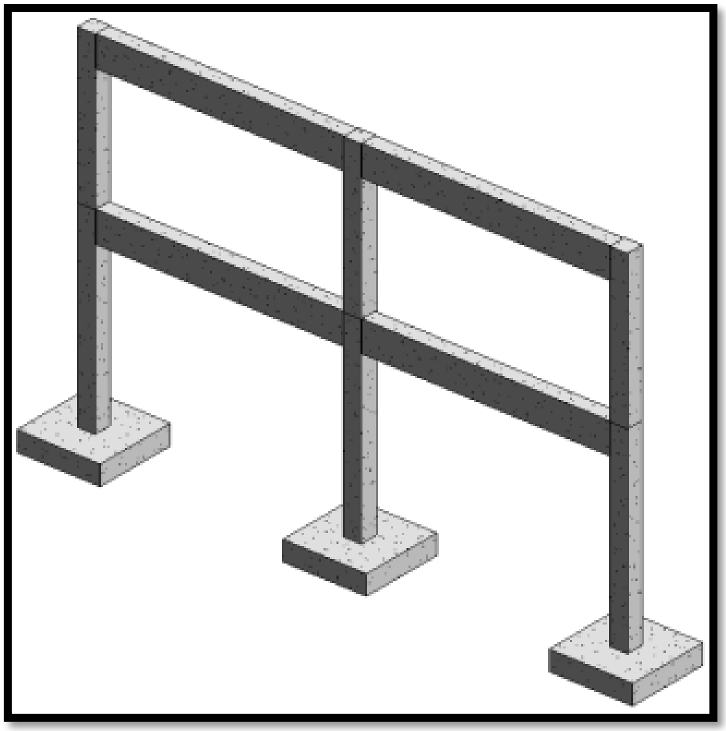

Figure (3-10): Frame Structure

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- **Shear wall:**

Is a structural system composed of braced panels (also known as shear panels) to counter the effects of lateral load acting on the building, the building contains a number of shear wall continued from Foundation to the end minaret.

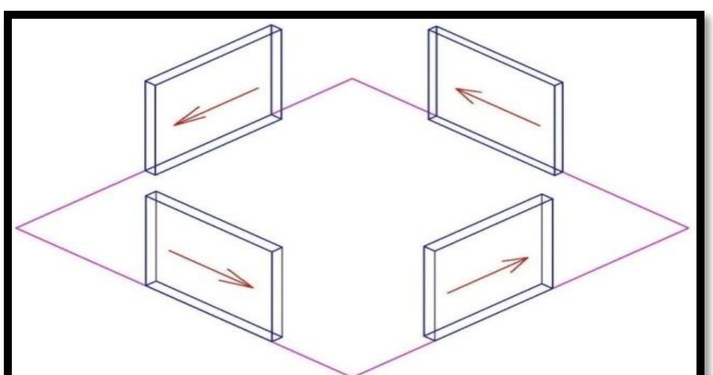

Figure (3-11): Shear Wall

- **Stairs:**

The architectural elements used for vertical transmission between the different levels of the lever through the building, and will be one of inclusion type design development.

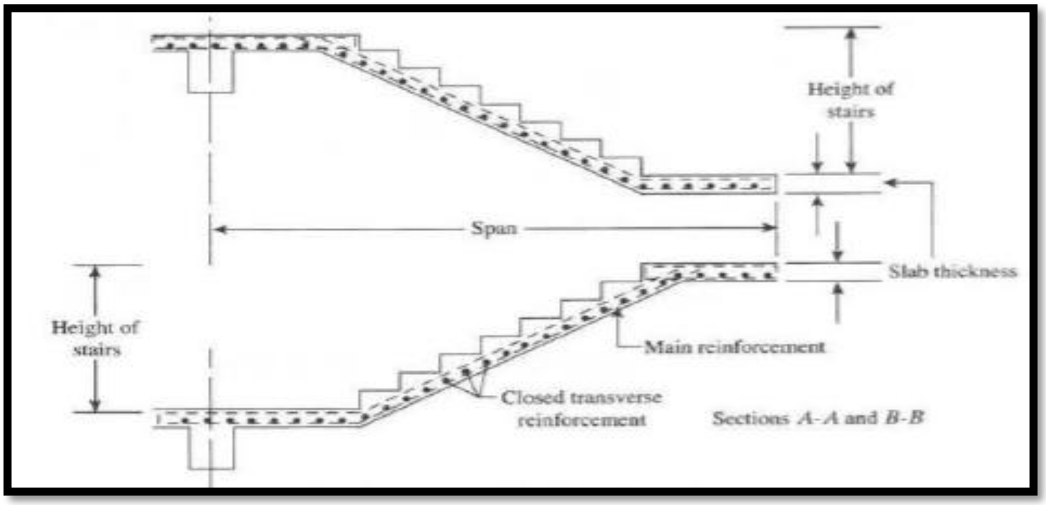

Figure (3-12): The shape of Stairs

CHAPTER

4

DESIGN OF STRUCTURAL MEMBERS

4.1 Introduction:

Concrete is the only major building material that can 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 info any form or shape.

Concrete used in most construction work. It can reinforce with steel, when concrete structure members must resist extreme tensile stresses; steel will supply the necessary strength. Steel embedded in the concrete in the form of a mesh, or roughened or twisted bars. A bond forms between the steel and the concrete, are exist stresses can be transferred between both components.

In this project, all of the design calculation for all structural members will done upon the structural system chosen in the previous chapter.

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

The design strength provided by a member is connections to other members, and its cross – sections in terms of flexure, load, shear, and torsion taken as the nominal strength calculated in accordance with the requirements and assumptions of ACI-318-11 code.

Materials properties: -

- **Compressive strength of concrete = 24 MPa.**
- **Yield strength of steel Fy = 420 MPa.**

4.2 Factored Loads:

The factored loads on which the structural analysis and design based for our project members, is determined as follows:

$W_u = 1.2Dl + 1.6LL$ ACI-318-11 (9.2)

DL: Dead Load.

LL: Live Load.

4.3 Determination of Thickness:

4.3.1 Determination of Thickness for One-Way Ribbed Slab:

According to ACI-Code-318-11, Table (7.3.1.1), the minimum thickness computed as follow of non-re-stressed beams or one-way slabs (unless deflections are calculated): - h_{min} for one-end continuous = L/18.5

= 560 /18.5 = 30cm.

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

= 560/21 = 26 cm.

The controller slab thickness is 30 cm.

Select Slab thickness h= 32cm with block 24 cm & Topping 8cm.

4.4 DESIGN OF ONE-WAY RIBBED SLAB:

4.4.1 Design of Topping:

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

Dead Load from:	Density (KN/m^3)	Calculation
Tiles	23	23*0.03*1 = 0.69 KN/m
Mortar	22	22*0.03*1 = 0.66 KN/m
Coarse Sand	17	17*0.07*1 = 1.19 KN/m
Topping	25	25*0.08*1 = 2 KN/m
Interior Partitions	2.3	2.3 *1 = 2.3 KN/m
∴ Dead Load for 1m strip of topping = 6.84 KN/m		

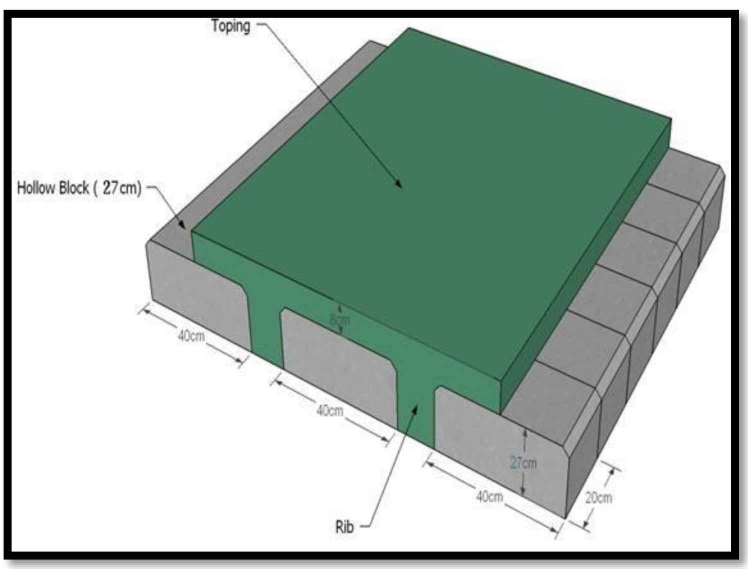

Figure (4-1): Topping of Slab

(Assume a stripe 1 m long with 0.4 m width).

From Jordanian code LL = 5 KN/m^2.

$$Wu = 1.2 * DL + 1.6 * LL$$

$$= 1.2 * 6.84 + 1.6 * 5 = 16.208\ KN/m.$$

(Total Factored Load). Assume slab fixed at supported points (ribs):

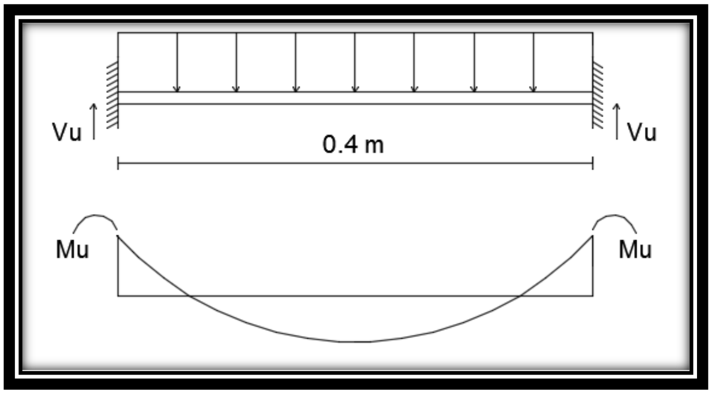

Figure (4-2): System and analysis Topping

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

$$= \frac{16.208*0.4^2}{12} = 0.216 \text{ KN.m}$$

$$\Phi.\ Mn = 0.55 * 0.42 * \sqrt{Fc'} * \frac{b\,h^2}{6}$$

$$= 0.55 * 0.42 * \sqrt{24} * \frac{1000*80^2}{6} * 10^{-6} = 1.207 \text{ KN.m}$$

Φ. Mn for (plane concrete) =1.207 KN.m > Mu max = 0.216 KN.m.

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

According to ACI 7.12.2.1, $\rho_{shrinkage}$ = 0.0018

$$As_{min} = \rho\ shrinkage * Ag$$

$$= 0.0018 * b * h$$
$$= 0.0118 * 1000 * 80$$
$$= 144\ \ mm^2/m\ strip$$

Try bars Ø 8 with As = 50.27 mm²

Bar number n = $\frac{As}{As\emptyset 8} = \frac{144}{50.27} = 2.87$

Step* (S) *is the smallest of:

1. 3h = 3*80 = 240 mm - ***control***

2. 450 mm.

3. S = 380 ($\frac{280}{fs}$) - 2.5Cc

= 380 ($\frac{280}{\frac{2}{3}*420}$) – 2.5*20

= 330 mm

But S ≤ $300(280/fs)$ = 300 (280 / $(2/3 * 420)$) = 300mm

Take S = 200mm < Smax = 240mm

4.4.2 Design of Ribs (Rib 2):

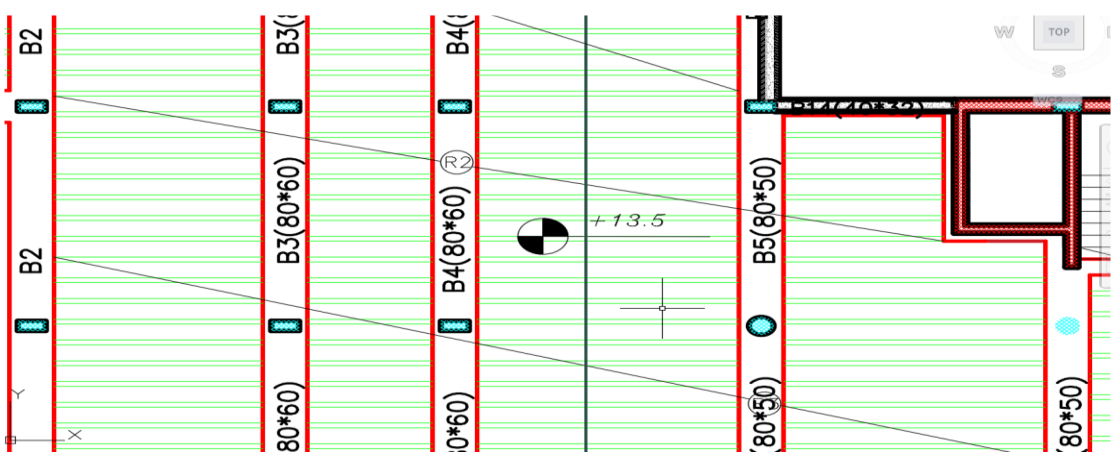

Figure (4-3): Rib 2 location

Table (4 – 2): Calculation of the total dead load for rib2.

Material	Quality Density (KN/m^3)	Calculation	Dead Load (KN/m/Rib)
Tiles	23	0.03×23×0.54	0.3726
Mortar	22	0.03×22×0.54	0.3564
Sand	17	0.07×17×0.54	0.6426
RC. Topping	25	0.08×25×0.54	1.0800
Block	12	0.24×12×0.40	1.1520
RC. Rib	25	0.24 ×25×0.14	0.8400
Plaster	22	0.03×22×0.54	0.3564
Partitions	2.3	2.3×0.54	1.242
∴ Dead Load = 6.042 KN/m/Rib			

- Dead load / rib = 6.042 KN/m

- Live load / rib = 5.0 × 0.54 = 2.7 KN/m

- Factored Load (W_u) = 1.2D.L + 1.6L.L

WuD = 1.2× 6.042
= 7.2504 KN/m/rib

WuL = 1.6×2.7
= 4.32 KN/m/rib

Wu = 11.5704

The Effective flange width (be) According to ACI8.12.2:

be is the smallest of

1. $be \leq \frac{L}{4} = \frac{2250}{4} = 562.5$ mm

2. $be \leq bw + 16\ hf$ = 140 + 16*80 = 1420mm

3. $be \leq$ Center to Center spacing between adjacent beam = $\frac{400}{2} + \frac{400}{2} + 140 = 540$mm

⇒ Take be = 520 mm

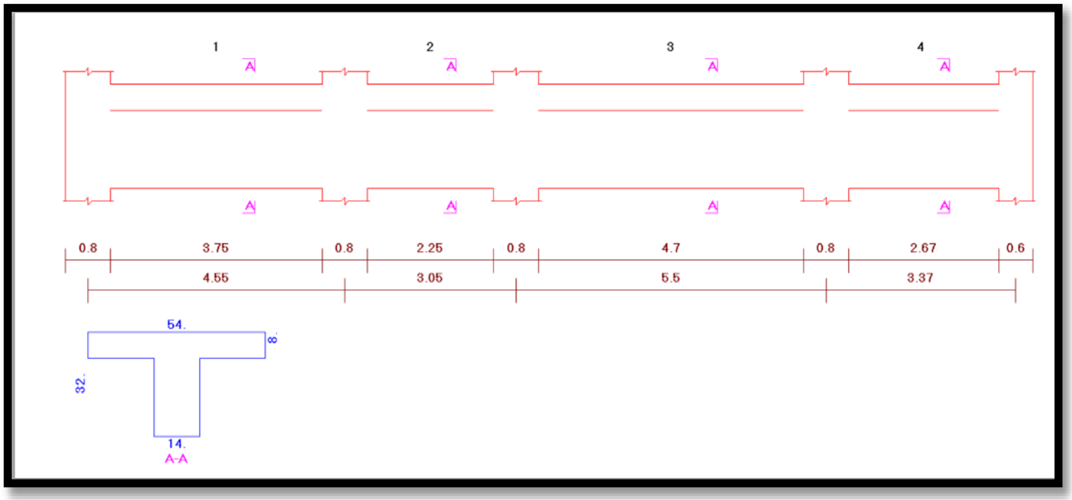

Figure (4-4): Rib 2 Geometry

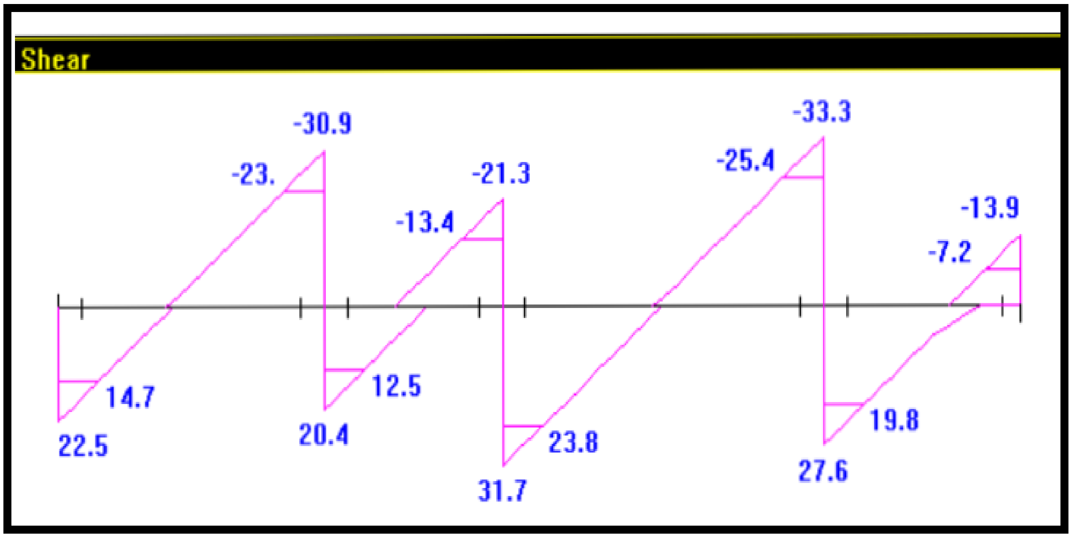

Figure (4-5): Shear Envelop for Rib 2

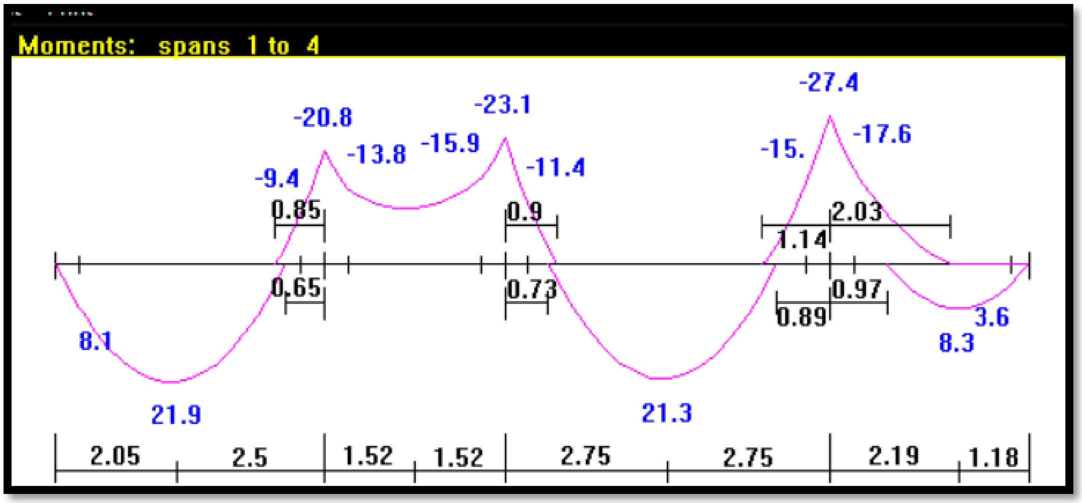

Figure (4-6): Moment Envelop for rib 2

4.4.2.1 Design Negative Moment of Rib 2:

Assume bar diameter Ø 14 for main negative reinforcement.

d = h - cover – $d_{stirrups}$ – $\frac{db}{2}$ = 320 – 20 – 10 – $\frac{14}{2}$ = 283mm

The Maximum negative moment at the face of support Mu = -17.6 KN.m

$$Rn = \frac{Mu}{\emptyset bwd^2}$$

$$= \frac{17.6*10^6}{0.9*140*283^2} = 1.74 \text{ Mpa}$$

$$m = \frac{f_y}{0.85f'_c}$$

$$= \frac{420}{0.85*24} = 20.59$$

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

$$= \frac{1}{20.59}\left(1 - \sqrt{1 - \frac{2*1.74*20.59}{420}}\right) = 4.34*10^{-3}$$

$$\boldsymbol{As_{req} = \rho bwd}$$

$= 4.34*10^{-3}$ (140) (283) = 171.81 mm^2

Check for $A_{s,\ min}$

$A_{s,\ min}$ is the maximum of: -

$$\boldsymbol{As_{min} = 0.25\frac{\sqrt{f'_c}}{f_y} b_w d \geq \frac{1.4}{f_y} b_w d}$$

1. $\boldsymbol{As_{min}}=0.25\frac{\sqrt{24}}{420}\,140 * 283 = 115.5mm^2$
2. $\boldsymbol{As_{min}} = \frac{1.4}{420} 140 * 283 = 132.1\ mm^2$. ***Control***

$$\boldsymbol{As_{req} = 171.81\ \text{mm2}\ >= \ 132.1mm^2}$$

Of bars $\frac{As}{Asbar} = \frac{171.81}{113.097}$ = 2bars * Note $A_{\Phi12}$ = 113.097 mm^2

Select 2 Φ 12mm.

As provided= 226.19 mm^2

Check for strain: -

According to AC -318-11 (10.3.5), ($\varepsilon_s \geq 0.005$)

$$\boldsymbol{a = \frac{A_{s f_y}}{0.85 b\ f'_c}}$$

$$= \frac{226.19*420}{0.85*140*24} = 33.26\ mm$$

$$c = \frac{a}{\mathcal{B}_1}$$

$= \frac{33.26}{0.85} = 39.13\ mm$ * Note $f_c' = 24\ MPa < 28$ Mpa → $\mathcal{B}_1 = 0.85$

d = 320 – 20 – 10 - 6 = 284 mm

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

$= 0.003\left(\frac{284 - 39.13}{39.13}\right) = 0.0188 > 0.005$ **0k**

∴ ∅ = 0.9 .... *OK.*

$$\emptyset Mn = \emptyset A_{sf_y}(d - \frac{c}{2})$$

$= 0.9*226.19*420*(284 - (\frac{39.13}{2})) *10^{-6}$
= 22.61 KN.m > Mu max = 17.6 KN.m.

4.4.2.2 Design of Positive Moment of Rib 2:

For main positive reinforcement Assume Φ 12 bar diameter, stirrups Φ 10

$d = h - cover - d_{stirrups} - d_b/2 = 320 - 20 - 10 - 6 = 284$ mm.

The Maximum positive moment is M_u= 21.9 KN.m

Check if $a > h_f$ to determine whether the section will act as rectangular or T- section,

$$M_{nf} = 0.85\ f_c' b_e h_f (d - \frac{h_f}{2})$$

$$= 0.85 * 24 * 540 * 80 * \left(284 - \frac{80}{2}\right) * 10^{-6} = 215.03\ KN.m$$

$M_{nf} \gg \frac{M_u}{\varphi} = \frac{21.9}{0.9}$ = 2.4 KN.m, the section will be designed as rectangular section with be =540 mm.

$$Rn = \frac{Mu}{\emptyset bwd^2}$$

$$= \frac{21.9*10^6}{0.9*540*284^2} = 0.56 \text{ Mpa}$$

$$m = \frac{f_y}{0.85f_c'}$$

$$= \frac{420}{0.85*24} = 20.59$$

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

$$= \frac{1}{20.59}\left(1 - \sqrt{1 - \frac{2*0.56*20.59}{420}}\right) = 1.35*10^{-3}$$

$$As_{req} = \rho bwd$$

$= 1.35*10^{-3}$ (540) (284) = 206.87 mm^2

Check for As_{min}:

As_{min} is the maximum of: -

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

1. $As_{min} = 0.25\frac{\sqrt{24}}{420}140 * 284 = 115.94mm^2$
2. $As_{min} = \frac{1.4}{420}140 * 284 = 132.53\ mm^2$. $Control$

As_{req} = 206.87 mm2 $>$ As_{min} = $132.53\ mm^2$

Of bars $\frac{As}{Asbar}$ = $\frac{206.87}{153.93}$ = 2 bars * Note $A_{\Phi 14}$ = 153.93 mm²

Select 2 Φ 14 mm.

As provided= 307.87 mm²

Check for strain: -

According to AC -318-11 (10.3.5), ($\varepsilon_s \geq 0.005$)

$$a = \frac{A_{s}f_{y}}{0.85b\,f'_c}$$

$$= \frac{307.87 * 420}{0.85 * 540 * 24} = 11.73\ mm$$

$$c = \frac{a}{\mathcal{B}_1}$$

$$= \frac{11.73}{0.85} = 13.81\ mm$$

* Note $f'_c = 24\ MPa < 28$ Mpa → $\mathcal{B}_1$ = 0.85

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

$$= 0.003\left(\frac{284 - 13.81}{13.81}\right) = 0.0587 > 0.005 \qquad \mathbf{0}\boldsymbol{k}$$

4.4.2.3 Design for shear:

The maximum shear force at the distance d from the face of support V_u= 25.4 KN

Shear strength V_c, provided by concrete for the rib may be taken 10% greater that for beams. This is mainly due to the interaction between the slab and closely spaced ribs.

(ACI, 8.13.8).

$$\mathbf{Vc = \frac{1.1}{6}\ \lambda \sqrt{f'_c} b_w d}$$

$$= \frac{1.1}{6}\sqrt{24} * 140 * 283 * 10^{-3} = 35.58KN$$

$\emptyset V_c$ = 0.75*35.58 =26.7 KN

0.5 $\emptyset V_c$ = 0.5*26.7 =13.34 KN

0.5 $\emptyset V_c < V_u < \emptyset V_c$ **OK.**

Minimum shear reinforcement is required except for concrete joist construction. so,

No shear reinforcement is provided.

4.5 Design of Beam 3:

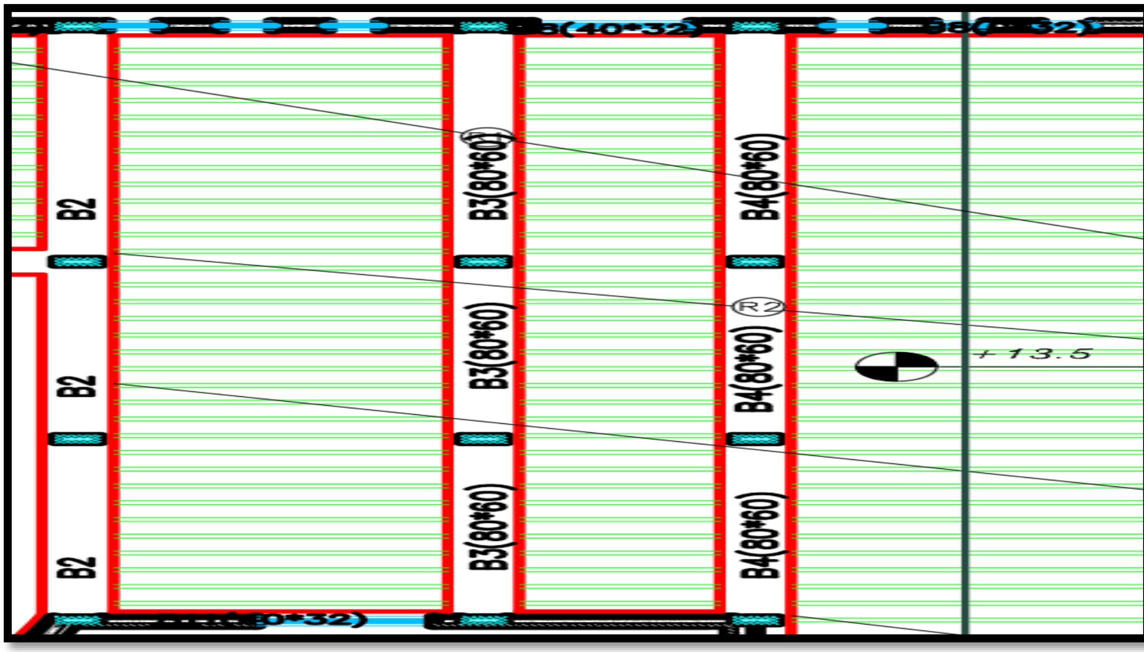

Figure (4-7): Beam 3 Location

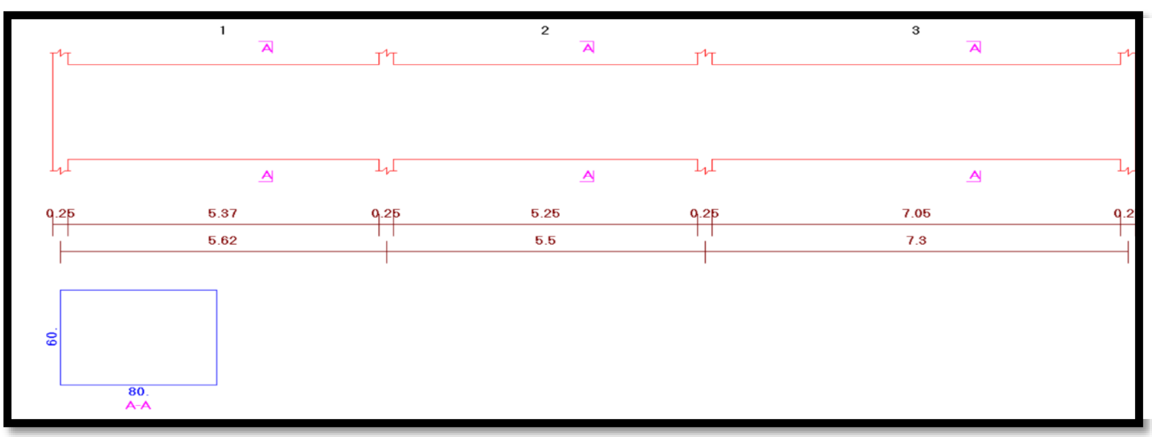

Figure (4-8): Beam 3 Geometry

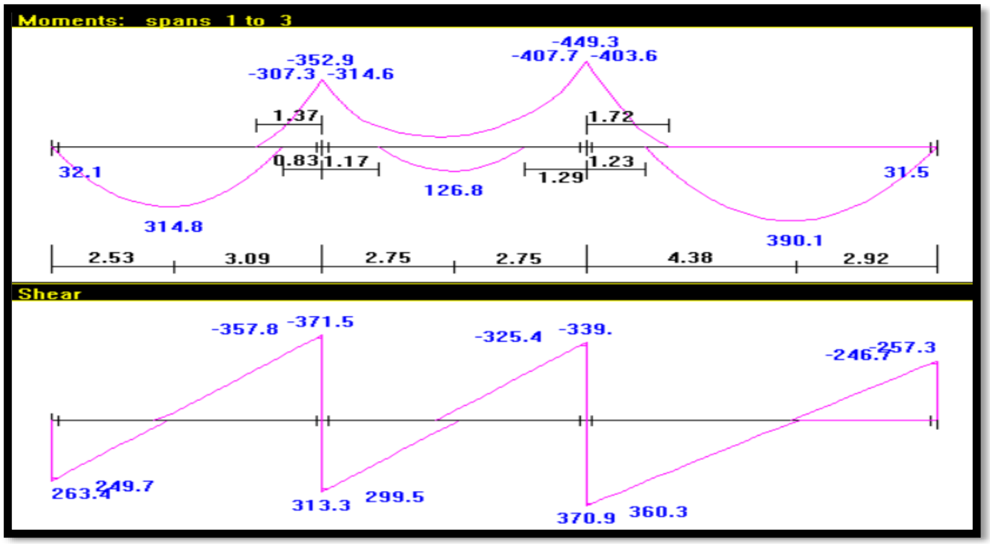

Figure (4-9): Moment and shear envelop for Beam 3

L/18.5 = 5.63/18.5 = 0.304 m for span 1 and span 3

L/18.5 = 5.5/18.5 = 0.297 m for span 2

Take h = 32 cm

Self-Wight of beam (3) = 0.8*0.6*25 = 12 KN/m

4.5.1 Design of Positive Moment:

Assume bar diameter Φ16 for main positive reinforcement, stirrups Φ10

$$\boldsymbol{d = 600 - 40 - 10 - (16/2) = 542mm}$$

Mu $^{(+)}$ 1 = 314.8 KN.m

$$c = \frac{3}{7} d$$

$$= \frac{3}{7} * 542 = 232.3\ mm$$

$a = \mathcal{B}_1 c$

$= 0.85 * 232.3 = 197.44\ mm$ * Note: $fc' = 24$ MPa < 28 Mpa → $\beta 1 = 0.85$

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

$= 0.85*24*197.44*800*(542 - \frac{197.44}{2}) *10^{-6} = 1428.3$ KN.m

$\emptyset\ Mn_{max} = 0.82* 1428.3 = 1171.24$ KN.m * Note: $\epsilon s = 0.004 \rightarrow \phi = 0.82$

Mu < $\emptyset\ Mn_{max}$

∴ Design section as singly reinforced concrete section.

Design of positive moment Mu1 $^{(+)}$ = 314.8 KN.m

$$Rn = \frac{M_u}{\emptyset bd^2}$$

$$= \frac{314.8 * 10^6}{0.9 * 800 * 542^2} = 1.5\ Mpa.$$

$$m = \frac{f_y}{0.85 f_c'}$$

$$= \frac{420}{0.85*24} = 20.59$$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mR_n}{420}}\right)$$

$$= \frac{1}{20.59}\left(1 - \sqrt{1 - \frac{2*20.59*1.5}{420}}\right) = 3.68 * 10^{-3}$$

$A_s = \rho bd$

$= 3.68 * 10^{-3}*800*542 = 1597.1\ mm^2$.

Check for As_{min}:

As_{min} is the maximum of: -

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

1. $As_{min} = 0.25\frac{\sqrt{24}}{420}\,800 * 542 = 1264.4\ mm^2$
2. $As_{min} = \frac{1.4}{420}800 * 542 = 1445.33\ mm^2.\ Control$

As_{req} = 1597.1 mm^2 > $As_{min} = 1445.33\ mm^2$

Of bars $\frac{As}{Asbar} = \frac{1597.1}{201.06}$ = 8bars * Note $A_{\Phi 16}$ = 201.06 mm^2

Select 8 Φ 16 mm.

As provided= 1608.5 mm^2

Check for strain: -

According to AC -318-11 (10.3.5), ($\varepsilon_s \geq 0.005$)

$$a = \frac{A_s f_y}{0.85 b\, f'_c}$$

$$= \frac{1608.5 * 420}{0.85 * 800 * 24} = 41.4\ mm$$

$$c = \frac{a}{\mathcal{B}_1}$$

$$= \frac{41.4}{0.85} = 48.7\ mm$$

* Note $f'_c = 24\ MPa < 28$ Mpa → $\mathcal{B}_1$ = 0.85

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

$$= 0.003\left(\frac{542 - 48.7}{48.7}\right) = 0.03 > 0.005 \qquad \mathbf{0}\boldsymbol{k}$$

$$\therefore \emptyset = 0.9$$

4.5.2 Design of Negative Moment:

Assume bar diameter Φ14 for main negative reinforcement, stirrups Φ10

d =600 – 40 -10 - (14/2) = 543 mm

Design of negative moment Mu $^{(-)}$ = 407.7 KN.m

$$\boldsymbol{Rn} = \frac{\boldsymbol{M_u}}{\boldsymbol{\emptyset b d^2}}$$

$$= \frac{407.7 * 10^6}{0.9 * 800 * 543^2} = 1.9\ Mpa.$$

$$\boldsymbol{m} = \frac{\boldsymbol{f_y}}{\mathbf{0.85}\boldsymbol{f'_c}}$$

$$= \frac{420}{0.85*24} = 20.59$$

$$\boldsymbol{\rho} = \frac{\mathbf{1}}{\boldsymbol{m}}\left(\mathbf{1} - \sqrt{\mathbf{1} - \frac{\mathbf{2}.\boldsymbol{m}.\boldsymbol{R_n}}{\mathbf{420}}}\right)$$

$$= \frac{\mathbf{1}}{\mathbf{20.59}}\left(\mathbf{1} - \sqrt{\mathbf{1} - \frac{\mathbf{2*20.59*1.9}}{\mathbf{420}}}\right) = 4.81 * 10^{-3}$$

$A_s = \rho bd$

= $4.81 * 10^{-3}$*800*543 = 2089.82mm^2.

Check for As_{min}:

As_{min} is the maximum of: -

$$As_{min} = \mathbf{0.25}\frac{\sqrt{f'_c}}{f_y} b_w d \geq \frac{1.4}{f_y} b_w d$$

1. $As_{min} = 0.25\frac{\sqrt{24}}{420}\, 800 * 543 = 1266.74\ mm^2$
2. $As_{min} = \frac{1.4}{420} 800 * 543 = 1448\ mm^2.\ Control$

$As_{req} = 2089.82\ mm^2 > As_{min} = 1448\ mm^2$

\# Of bars $\frac{As}{Asbar} = \frac{2089.82}{254.47} = 9$bars * Note $A_{\Phi 18} = 254.47\ mm^2$

Select 9 Φ 18 mm.

As provided= 2290.22 mm^2

Check for strain: -

According to AC -318-11 (10.3.5), ($\varepsilon_s \geq 0.005$)

$$a = \frac{A_s f_y}{0.85 b\, f'_c}$$

$$= \frac{2290.22 * 420}{0.85 * 800 * 24} = 58.94\ mm$$

$$c = \frac{a}{\mathcal{B}_1}$$

$$= \frac{58.94}{0.85} = 69.34\ mm$$ * Note $f'_c = 24\ MPa < 28$ Mpa $\rightarrow \mathcal{B}_1 = 0.85$

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

$$= 0.003\left(\frac{541 - 69.34}{69.34}\right) = 0.02 > 0.005 \qquad \mathbf{0k}$$

$\therefore \emptyset = 0.9$

4.5.3 Design of shear:

Vu = 360.3 KN

$$V_c = \frac{1}{6}\sqrt{fc'}\, b_w\, d$$

$$= \frac{1}{6}\sqrt{24} * 800 * 541 * 10^{-3} = 353.38 \text{ KN}$$

$\Phi\, V_c$ = 0.75*353.38 = 265.03 KN

Check For dimensions: -

$\Phi\, V_c + (\frac{2}{3} \times \Phi \times \sqrt{f_{c'}} \times b_w \times d) >$ Vu max

= 265.03 + (2/3 * 0.75 * √24 * 800 * 541) *10^{-3} = 1325.2 KN

1325.2 > Vu max = 369.3 KN

∴ Dimension is adequate enough.

$$v_{s,min} = \frac{1}{3} b_w\, d$$

$$= \frac{1}{3}\, 800 * 541 * 10^{-3} = 144.27\, KN \qquad Control$$

$$v_{s,min} = \frac{1}{16}\sqrt{fc'}\, b_w\, d$$

$$= \frac{1}{16} * \sqrt{24} * 800 * 541 * 10^{-3} = 132.52\, KN$$

$$\emptyset v_c < v_u \leq \emptyset(v_c + v_{s,\min})$$

265.03 < 360.3 ≤ 0.75(353.38 + 144.27)

265.03 < 360.3 < 373.24.

Minimum shear reinforcement is provided $\boldsymbol{A_v}$ with,

$$s_{max} \leq \frac{d}{2} \quad \textbf{or} \quad s_{max} \leq 600\ mm$$

Use 4 leg Φ 10 for stirrups

$$A_v = 4 * \frac{\pi * 10^2}{4} = 314.2\ \text{mm}^2$$

$$S = \frac{A_v f_{yt}\ d}{v_s}$$

$$v_s = \frac{v_u}{\emptyset} - v_c$$

$$S = \frac{314.2 * 420 * 541}{127.02 * 1000} = 562.1\ \text{mm}$$

$$s_{max} \leq \frac{d}{2} = \frac{541}{2} = 270.5\ \text{mm}$$

Select S = 150 mm.

4.6 DESIGN OF COLUMN (C3):

4.6.1 Dimension of column:

Pu = 2804 KN

$$Pn = \frac{2804}{0.65} = 4313.84\ KN$$

Assume $\rho g = 1.1\%$ → $Ast = 0.011Ag$

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

$$4313.84 * 10^3 = 0.8 * \{0.85 * 24(Ag - 0.011Ag) + 0.011Ag * 420\}$$
$$\rightarrow \quad Ag = 2156.92\ cm^2$$

Assume rectangular column.

Use* 50*60 *cm with Ag = 3000cm² > Agreq = 2156.92 cm².

4.6.2 Check Slenderness Effect:

$\frac{Klu}{r} \leq 34 - 12\left(\frac{M1}{M2}\right) \leq 40 \rightarrow ACI - 10.12.2$

Where:

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 = 3.6 m

M1&M2 =1

K=1, *According to ACI 318-2002* (**10.10.6.3)** *the effective length factor,* ***k****, shall be permitted to be taken as 1.0.*

$\frac{Klu}{r} \leq 34 - 12\left(\frac{M1}{M2}\right) \leq 40 \rightarrow ACI - 10.12.2$

$\frac{Klu}{rx} = \frac{1*3.6}{0.3*0.5} = 24 > 22$ $\therefore$ *Long column for bending about x-axis.*

$\frac{Klu}{ry} = \frac{1*3.6}{0.3*0.6} = 20 < 22$ $\therefore$ *short column for bending about y-axis.*

$$EI = \frac{0.4E_cI_g}{1+\beta dns} \rightarrow [\ ACI\ 318 - \ 2002\ (Eq. 10 - 15)]$$

$$Ec = 4700\sqrt{fc'} = 4700\sqrt{24} = 23270.15\ Mpa$$

$$\beta dns = \frac{1.2DL}{Pu} = \frac{1716}{2804} = 0.61$$

$$Ig = \frac{bh^3}{12} = \frac{0.6 * 0.5^3}{12} = 0.00625\ m^4$$

$$EI = \frac{0.4 * 23270.15 * 0.00625}{1 + 0.61} = 36.13\ MN.m^2$$

$$P_{cr} = \frac{\pi^2 EI}{(KLu)^2} \rightarrow ACI318 - 2002(Eq.10 - 13)$$

$$P_{cr} = \frac{3.14^2 * 36.13}{(1.0 * 3.6)^2} = 27.4\ MN$$

$$Cm = 0.6 + 0.4\left(\frac{M1}{M2}\right) \rightarrow ACI318 - 2002(Eq.10 - 16)$$

$$Cm = 1$$

$$\delta_{ns} = \frac{Cm}{1 - \left(\frac{Pu}{0.75Pc}\right)} \geq 1.0 \rightarrow ACI318 - 2002(Eq.10 - 12)$$

$$\delta_{ns} = \frac{1}{1 - \left(\frac{2804}{0.75 * 27.4 * 10^3}\right)} = 1.15 > 1$$

$$e_{min} = 15 + 0.03 * h$$
$$= 15 + 0.03 * 500 = 30mm = 0.03m$$

$$e = e_{min} * \delta_{ns}$$

= 0.03*1.15 = 0.034

$$\frac{e}{h} = \frac{0.034}{0.5} = 0.068$$

$From\ Interaction\ Diagram:$

$$\frac{\varphi P_n}{A_g} = \frac{2804}{0.5 * 0.6} * \frac{145}{1000} = 1355.26\ Psi$$

$$\rho g = 0.01$$

A_s= ρ * Ag = 0.0107*500*600 = 3210mm^2

Use 16 ∅ 16 with As = 3216mm² > As_{req} = 3210mm².

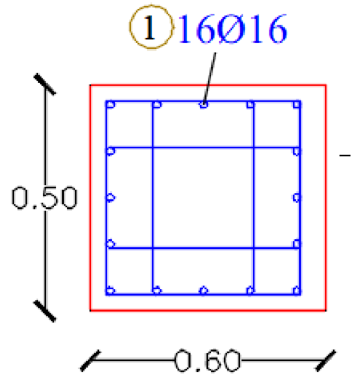

Figure (4-10): Column Section

4.6.3 Design of the Tie Reinforcement:

For ∅ 10 mm ties

$S \leq db\ (\ longitudonal\ bar\ diameter\ ) \rightarrow ACI - 7.10.5.2$
$S \leq dt\ (\ tie\ bar\ diameter)$
$S \leq Least\ dimension$
$S = 16 * 1.6 = 25.6\ cm$
$S = 48 * 1 = 48\ cm$
$S = 50$

Use ∅10 /20, and ∅10 / 20 for end.

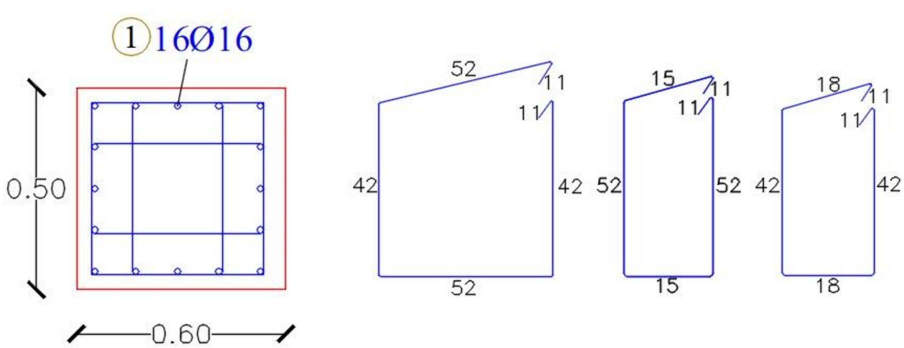

Figure (4 - 11): C3 Reinforcement Details

4.7 DESIGN OF ISOLATED FOOTINGS (F3)

4.7.1 DETERMINATION OF FOOTING DIMENTIONS:

The following parameters are used in design:

- $\gamma_{\ concrete}$ = 25 KN/m^3
- $\gamma_{\ soil}$ = 18 KN/m^3
- σ_{allow} = 400 KN/m^2
- $Service\ Surcharge$ = 5 KN/m^2

Loads acting on footing:

DL =1430 KN, LL = 680 KN

Calculating the weight of footing, soil, and the surcharge floor load:

Weight of footing, assume h *footing = 60cm*

$$Wfooting = 0.6 * 25 = 15\ \mathrm{KN/m2}$$

Weight of soil:

$$WSoil = 1 * 18 = 18\ \mathrm{KN/m2}$$

Total surcharge load on foundation:

$$W = 15 + 18 + 5 = 38\,\frac{\mathrm{KN}}{\mathrm{m2}}$$

Net soil pressure, $q_{\text{a, net:}}$

$$q_{\text{a, net}} = 400 - 38 = 362\,\frac{\mathrm{KN}}{\mathrm{m2}}$$

Required sizes of footings:

$$A = \frac{Pn}{qa,\mathrm{net}} = \frac{1430 + 680}{362} = 5.83\ \mathrm{m2}$$

$$L = \sqrt{A} = 2.5\ m$$

ONE WAY SHEAR:

$$Pu = 1.2 * 1430 + 1.6 * 680 = 2804\ KN$$

$$qu = \frac{2804}{2.5 * 2.5} = 448.64\ KN/m2$$

Vu at distance d from the face of support:

$$Vu = qub\left(\frac{l}{2}-\frac{a}{2}-d\right) = 448.8 * 2.5\left(\frac{2.5}{2}-\frac{0.6}{2}-d\right)$$

$let\ Vu = \emptyset Vc$

$$Vc = \frac{1}{6}\sqrt{fc'}bwd = \frac{1}{6} * \sqrt{24} * 2500 * d$$

$$\frac{448.8*2.5}{0.75}\left(\frac{2.5}{2}-\frac{0.6}{2}-d\right) = \frac{1}{6} * \sqrt{24} * 2500 * d \quad \rightarrow \quad d = 0.4\,m$$

Assume cover 75 mm, and steel bars of Ø 20

$h = 400 + 75 + 20 = 495mm\ , take\ h = 500\ mm$

$d = 500 - 75 - 20 = 405\ mm$

TWO WAY SHEAR (PUNCHING SHEAR):

$let\ Vu = \emptyset Vc$

$Vu = 448.8\,(2.5 * 2.5 - (0.6 + 0.405)(0.5 + 0.405)) = 2396.81$ KN

$\beta = \frac{600}{500} = 1.2,$ $\qquad$ $b_\circ = 2(0.6 + 0.405) + 2(0.5 + 0.405) = 3.82\ m$

$Vc = \frac{1}{6}\left(1+\frac{2}{\beta}\right)\sqrt{fc'}b_\circ d$ $\qquad$ $where\ \frac{1}{6}\left(1+\frac{2}{1.2}\right) = 0.444$

$Vc = \frac{1}{12}\left(\frac{\alpha sd}{b_\circ}+2\right)\sqrt{fc'}b_\circ d$ $\qquad$ $where\ \frac{1}{12}\left(\frac{40 * 0.405}{1.2}+2\right) = 1.292$

$Vc = \frac{1}{3}\sqrt{fc'}b_\circ d$ $\qquad$ $where\ \frac{1}{3} = 0.333 - Control$

$Take\ Vc = 0.333\sqrt{fc'}b_\circ d = 0.333\sqrt{24} * 3820 * 405 * 10^{-3} = 2526.4\ KN$

$\emptyset Vc = 0.75 * 2526.4 = 1894.8\ KN < Vu = 2396.81$ KN $\qquad - Not\ OK$

$try\ h = 600mm,$ $\qquad$ $d = 600 - 75 - 20 = 505\ mm$

$b_\circ = 2(0.6 + 0.505) + 2(0.5 + 0.505) = 4.22\ m$

$Vu = 448.8\,(2.5 * 2.5 - (0.6 + 0.505)(0.5 + 0.505)) = 2306.6$ KN

$Vc = 0.333\sqrt{fc'}b_\circ d = 0.333\sqrt{24} * 4220 * 505 * 10^{-3} = 3480.07\ KN$

$\emptyset Vc = 0.75 * 3480.07 = 2610.1\ KN > Vu = 2396.81$ KN $\qquad - OK$

4.7.2 Design of flexure in long direction:

Take steel bars of Ø 20

$d = 600 - 75 - \frac{20}{2} = 515\ mm$

$Mu = 448.8 * 2.5 * 1 * \frac{1}{2} = 561\ KN.m$

$Mn = \frac{Mu}{\emptyset} = \frac{561}{0.9} = 623.33\ KN.m$

$$\boldsymbol{Rn = \frac{M_n}{bd^2}} = \frac{623.33 * 10^6}{2500 * 515^2} = 0.94\ Mpa.$$

$$\mathbf{m} = \frac{\boldsymbol{f_y}}{\boldsymbol{0.85 f'_c}} = \frac{420}{0.85*24} = 20.59$$

$$\boldsymbol{\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right)} = \frac{1}{20.59}\left(1 - \sqrt{1 - \frac{2 * 20.59 * 0.94}{420}}\right) = 2.29 * 10^{-3}$$

$$\boldsymbol{As = \rho bd} = 2.29 * 10^{-3} * 2500 * 515 = 2948.375\ mm^2$$

$$\boldsymbol{As, min = 0.0018bh} = 0.0018 * 2500 * 600 = 2700\ mm^2$$

$$\boldsymbol{As, req} = 2948.375\ mm^2 > \boldsymbol{As, min} = 2700 mm^2$$

Use Ø16 then, # Of bars $\frac{\boldsymbol{As,req}}{\boldsymbol{As\emptyset 16}} = \frac{2948.375}{201.06} = 14.66$

Take 15Ø16 with, $As = 3015.93\ mm^2 > \boldsymbol{As, req}$

$$\boldsymbol{S} = \frac{2500 - 75 * 2 - 15 * 16}{14} = 150.71\ mm$$

Step (s) is the smallest of:

1. $3h = 3 * 600 = 1800\ mm$
2. $450\ mm\ - Control$

$S = 150.71\ mm < Smax = 450\ mm$

4.7.3 Design of flexure in short direction:

$$d = 600 - 75 - 16 - \frac{16}{2} = 501\ mm$$

$$Mu = 448.8 * 2.5 * 0.95 * \frac{0.95}{2} = 506.3\ KN.m$$

$$Mn = \frac{Mu}{\emptyset} = \frac{506.3}{0.9} = 562.56\ KN.m$$

$$\boldsymbol{Rn = \frac{M_n}{bd^2}} = \frac{562.56 * 10^6}{2500 * 501^2} = 0.897\ Mpa.$$

$$\mathbf{m} = \frac{\boldsymbol{f_y}}{\boldsymbol{0.85f'_c}} = \frac{420}{0.85 * 24} = 20.59$$

$$\boldsymbol{\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right)} = \frac{1}{20.59}\left(1 - \sqrt{1 - \frac{2 * 20.59 * 0.897}{420}}\right) = 2.18 * 10^{-3}$$

$$\boldsymbol{As = \rho bd} = 2.18 * 10^{-3} * 2500 * 501 = 2734.99\ mm^2$$

$$\boldsymbol{As, min = 0.0018bh} = 0.0018 * 2500 * 600 = 2700\ mm^2$$

$$\boldsymbol{As, req} = 2734.99\ mm^2 > \boldsymbol{As, min} = 2700 mm^2$$

Use Ø16 then, # Of bars $\frac{\boldsymbol{As,req}}{\boldsymbol{As\emptyset16}} = \frac{2734.99}{201.06} = 13.6$

Take 14Ø16 with, $As = 2814.87\ mm^2 > \boldsymbol{As, req}$

$$\boldsymbol{S} = \frac{2500 - 75 * 2 - 14 * 16}{13} = 163.54\ mm$$

Step (s) is the smallest of:

1. $3h = 3 * 600 = 1800\ mm$
2. $450\ mm\ - Control$

$S = 163.54\ mm < Smax = 450\ mm$

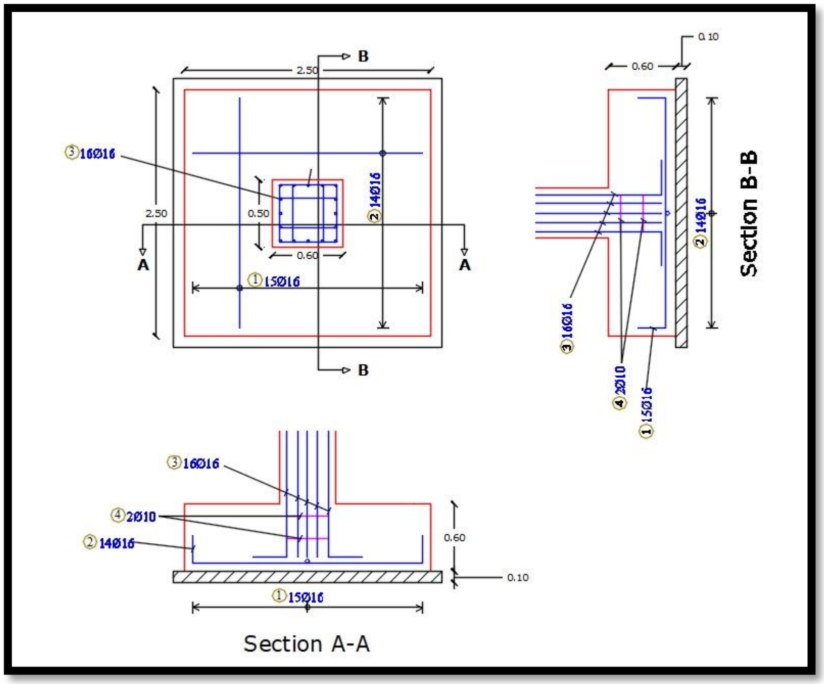

Figure (4 - 12): Isolated Footing Reinforcement Details

4.8 DESIGN OF SHEAR WALL (SW10):

$hw = 11.73\ m$
$Lw = 3.8\ m$
$Thickness = 0.3\ m$

$d \leq 0.8 * hw = 0.8 * 11.73 = 9.38\ m$
$d \leq 0.8 * Lw = 0.8 * 3.8 = 3.04\ \ Control$

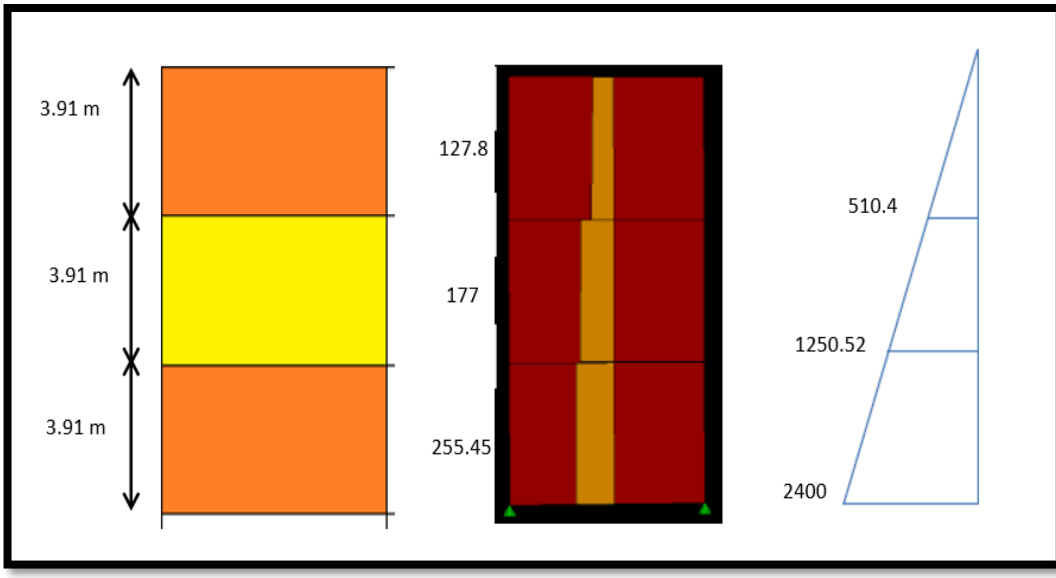

Figure (4–13) Shear force and moment on the wall from ETABS

$$\frac{hw}{2} = 5.865\ m$$

$$\frac{Lw}{2} = 1.9\ m\ \rightarrow Control$$

$$V_{c1} = \frac{\sqrt{fc'}}{6} bd$$

$$= \frac{\sqrt{24}}{6} * 300 * 3040 = 744.644\ KN\ \ Control$$

$$V_{c1} = \frac{\sqrt{fc'} * b * d}{4} + \frac{Nu * d}{4Lw}$$

$$= \frac{\sqrt{24} * 300 * 3040}{4} + 0 = 1116.96\ KN$$

4.8.1 Design for Horizontal reinforcement:

$$A_{vh}\ min. = 0.0025 * s * h$$
$$A_{vh} = 2\ \emptyset\ 10 = 158\ mm^2$$
$$\frac{2*79}{s} = 0.75 \rightarrow s = 210\ mm$$
$$Smax \leq \frac{Lw}{5} = \frac{3800}{5} = 760\ mm$$
$$\leq 450\ mm$$
$$\leq 3*h = 3*300 = 900\ mm$$
$$Take\ s = 200\ mm < Smax = 450\ mm$$

Select Ø10/20 *cm*

4.8.2 Design for Vertical reinforcement:

$$A_{vv}\ min. = 0.0015 * s * h$$
$$A_{vv} = 2\ \emptyset\ 10 = 158\ mm^2$$
$$\frac{2*79}{s} = 0.45 \rightarrow s = 350\ mm$$
$$Smax \leq \frac{Lw}{5} = \frac{3800}{5} = 760\ mm$$
$$\leq 450\ mm$$
$$\leq 3*h = 3*300 = 900\ mm$$
$$Take\ s = 200\ mm < Smax = 450\ mm$$

Select* Ø10/20 *cm

4.8.3 Design of bending moment:

$$Mu = 1250.52 + 255.45 * (3.91 - 1.9) = 1764\ KN.m$$
$$C > \frac{Lw}{(0.007*600)} = \frac{3800}{4.2} = 904.76\ mm$$

$$Length\ of\ boundary\ element = C - 0.1 * Lw$$
$$= 904.76 - 0.1 * 3800 = 524.76\ mm$$

$$C_w = \frac{C}{2} = \frac{904.76}{2} = 452.38\ mm$$

$Select\ the\ boundary\ element\ =\ 600\ mm$

$$A_{vs} = \frac{Lw}{s1} * As_v = \frac{2*79}{200} * 3800 = 3002\ mm^2$$

$$\frac{Z}{Lw} = \frac{1}{2 + \frac{0.85 * \beta * fc' * Lw * h}{As * Fy}}$$

$$\frac{Z}{Lw} = \frac{1}{2 + \frac{0.85 * 0.85 * 24 * 3800 * 300}{3002 * 420}} = 0.0566$$

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

$$= 09 * 420 * 0.5 * 3002 * 3800 * \left(1 - \left(\frac{0.0566}{2}\right)\right) = 2095\ KN.m$$

$$\boldsymbol{Muv = 2095\ KN.m\ > Mu = 1764\ KN.m}$$

<u>So, Boundary Element isn't required.</u>

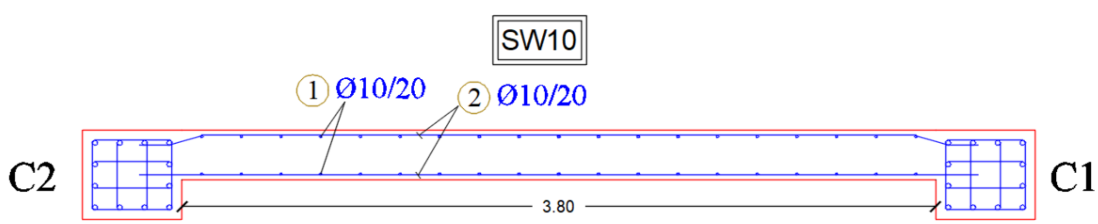

Figure (4–14): Detailing of shear wall

4.9 DESIGN OF BASEMENT WALL:

4.9.1 Loads on basement wall:

$q1 = Earth\ pressure\ soil$

$$q1 = \gamma * h * k0$$

$$k0 = 1 - \sin 30 = 0.5$$

$$q1 = 18 * 3.06 * 0.5 = 27.54 Kn/m2$$

$$qu\ (Factored\ Load) = 1.6 * q1 = 1.6 * 27.54 = 44 \frac{KN}{m2}$$

$$hwall = 30\ cm$$

4.9.2 Design of shear force:

From atir Vu = 45 KN

$$d = 300 - 20 - \frac{14}{2} = 274\ mm$$

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

$$\therefore h = 30\ cm \rightarrow\ coorect$$

4.9.3 Design of the reinforcement concrete:

4.9.3.1 Design of the Vertical reinforcement in tension side:

Max Mu from Atir = 28.2 KN.m.

$$Rn = \frac{M_n}{\emptyset bd^2} = \frac{28.2 * 10^6}{0.9 * 1000 * 274^2} = 0.42\ Mpa.$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 * 24} = 20.59$$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right) = \frac{1}{20.59}\left(1 - \sqrt{1 - \frac{2 * 20.59 * 0.42}{420}}\right) = 0.001$$

$$As = \rho bd = 0.001 * 1000 * 27.4 = 2.74\ cm^2/m$$

$As, min = 0.0012bh = 0.0012 * 1000 * 30 = 3.6\ cm^2/m$

$As, min = 3.6\ cm^2/m > As, req = 2.74\ cm^2/m$

Select $\emptyset 10$ */ 20 cm, with As provided = 3.95* cm^2/m

4.9.3.2 Design of the horizontal reinforcement in tension side:

For One layer:

$As, min = 0.0012bh = 0.0012 * 1000 * 30 = 3.6\ cm^2/m$

Select $\emptyset 10$ */ 20 cm, with As provided = 3.95* cm^2/m

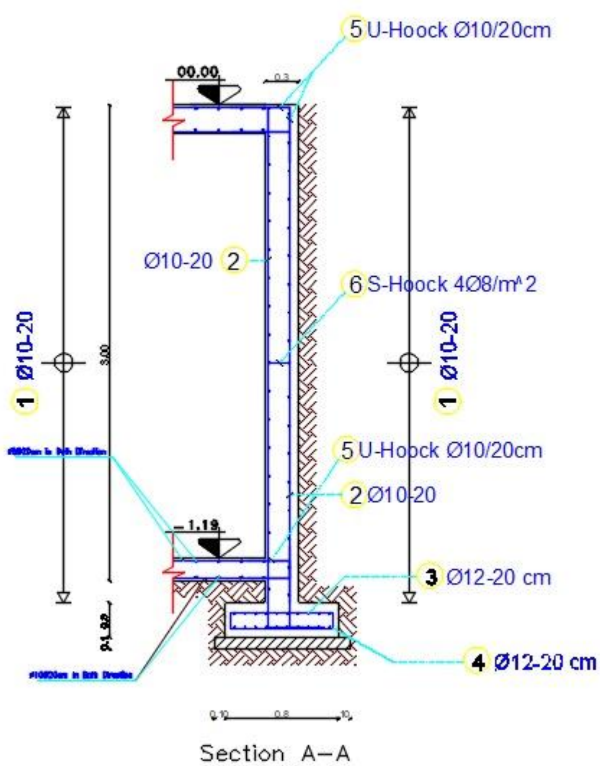

Figure (4-15): Basement Wall Reinforcement details.

4.10 Design of Stair:

The following figure shows a top view of the stairs:

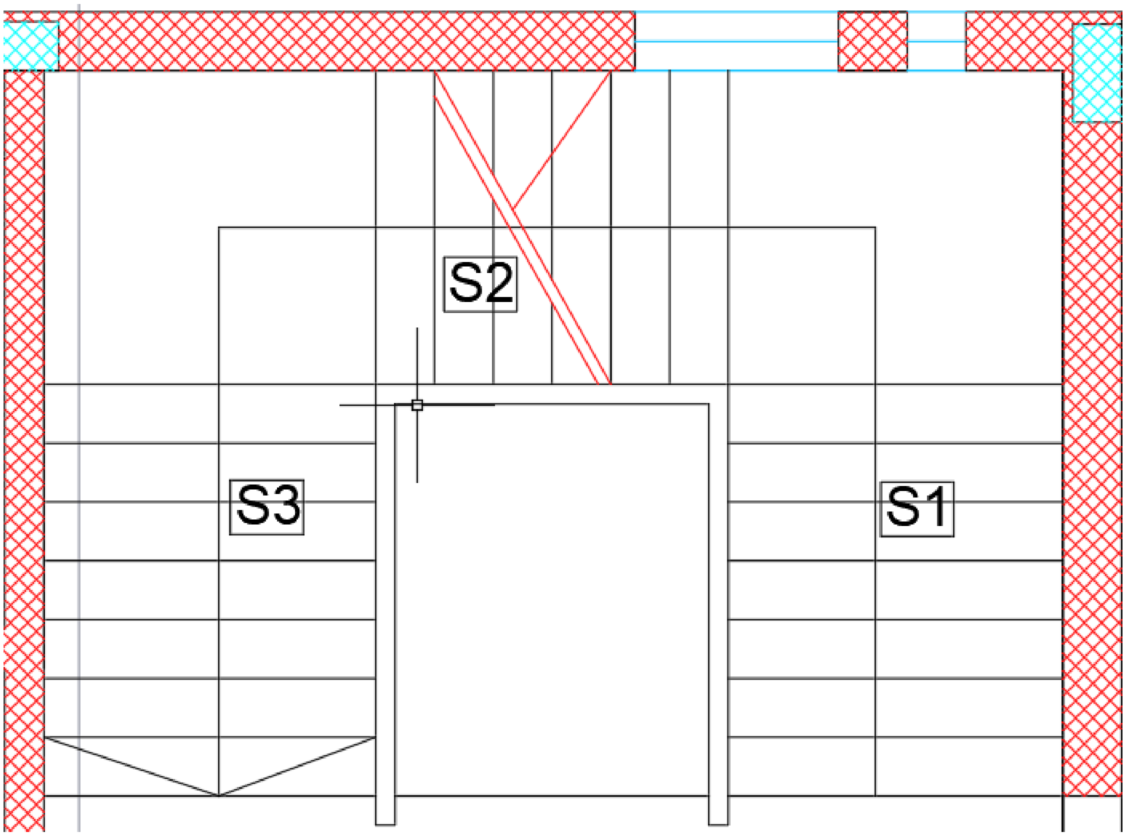

Figure (4-16): The shape of Stair

4.10.1 Limitation of deflection:

Minimum slab thickness for deflection is (for a simply supported one-way solid slab):

$$hmin = \frac{L}{20} = \frac{351.25}{20} = 17.5625\ cm$$

∴ Select h = 20 cm

2. Loads calculation:

1.Flight Dead Load computation:

$tan\emptyset = \frac{17}{30}$,

$\emptyset = 29.54°$

Table (4 – 3): Calculation flight dead load

Material	Quality Density (KN/m^3)	W (KN/m)
Tiles	23	$23\ (\frac{0.17+0.35}{0.3})0.03 * 1 = 1.196$
Mortar	22	$22\ (\frac{0.17+0.3}{0.3})0.02 * 1 = 0.689$
Stair steps	25	$\frac{25}{0.3}\ (\frac{0.17*0.3}{2}) * 1 = 2.125$
R.C Solid Slab	25	$\frac{25*0.2*1}{\cos 29.54°} = 5.747$
Plaster	22	$\frac{22 * 0.03 * 1}{\cos 29.54°} = 0.759$
∴ Total Dead Load = 10.516 KN/m		

2. Landing Dead Load computation:

Table (4 – 4): Calculation landing dead load

Material	Quality Density (KN/m^3)	$\gamma . h . 1$ (KN/m)
Tiles	23	$23 * 0.03 * 1 = 0.69$
Mortar	22	$22 * 0.02 * 1 = 0.44$
R.C Solid Slab	25	$25 * 0.2 * 1 = 5$
Plaster	22	$22 * 0.03 * 1 = 0.66$
∴ Total Dead Load = 6.79 KN/m		

L.L= 5 KN/m2

Total factored load: $\boldsymbol{w = 1.2D + 1.6L}$

For flight, $\boldsymbol{w = 1.2 * 10.516 + 1.6 * 5 = 20.6192\ KN/m}$
For landing, $\boldsymbol{w = 1.2 * 6.79 + 1.6 * 5 = 16.148\ KN/m}$

Design of slab (1):

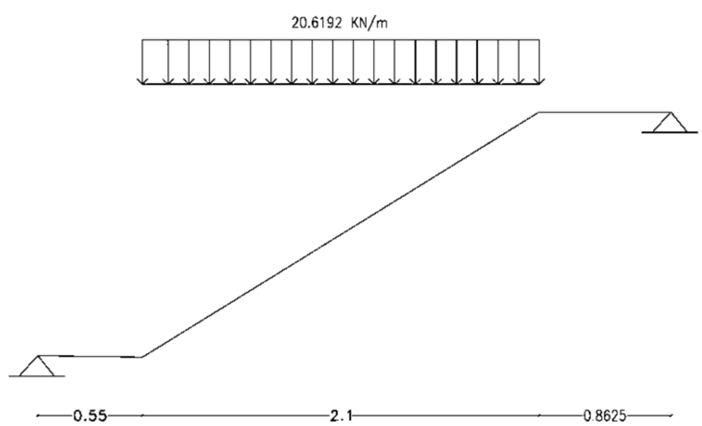

Figure (4-17): System of stair slab 1

The reaction at each end:

$$R = \frac{wl}{2} = \frac{20.6192 * 2.1}{2} = 21.65\ KN$$

4.10.2 Check for shear strength:

Assume bar diameter Ø 12 for main reinforcement.

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

Take the maximum shear as the support reaction $Vu = 21.65\ KN$

$$\boldsymbol{Vc = \frac{1}{6}\sqrt{fc'}bwd} = \frac{1}{6} * \sqrt{24} * 1000 * 174 * 10^{-3} = 142.07\ KN/1\ m\ strip.$$

$\emptyset = 0.75 - for\ shear$

$\emptyset Vc = 0.75 * 142.07 = 106.55KN\ /\ 1m\ strip$

$Vumax = 21.65\ KN < \frac{1}{2}\ \emptyset\ Vc = 53.28\ KN$

The thickness is adequate enough.

4.10.3 Design of bending moment:

$$Mu = \ 21.65 * (0.55 + 1.05) - 20.6192 * \frac{1.05^2}{2} = 23.27\ KN.m$$

$$Mn = \frac{Mu}{\emptyset} = \frac{23.27}{0.9} = 25.86\ KN.m$$

$$\boldsymbol{Rn = \frac{M_n}{bd^2}} = \frac{25.86 * 10^6}{1000 * 174^2} = 0.85\ Mpa.$$

$$\mathbf{m} = \boldsymbol{\frac{f_y}{0.85f'_c}} = \frac{420}{0.85 * 24} = 20.59$$

$$\boldsymbol{\rho\ = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right)} = \frac{1}{20.59}\left(1 - \sqrt{1 - \frac{2 * 20.59 * 0.85}{420}}\right) = \ 2.1 * 10^{-3}$$

$$\boldsymbol{As = \ \rho bd} = \ 2.1 * 10^{-3} * 1000 * 174 = 365.4\ mm^2$$

$$\boldsymbol{As, min = 0.0018bh} = 0.0018 * 1000 * 200 = 360\ mm^2$$

$$\boldsymbol{As,req} = 365.4\ mm^2 > \boldsymbol{As,min} = 360\ mm^2$$

Use Ø12 then, # Of bars $\frac{\boldsymbol{As,req}}{\boldsymbol{As\text{Ø}12}} = \frac{365.4}{113.1} = 3.23$

$s = \frac{1}{n} = \frac{1}{3.23} = 0.31\ m$

Take 4Ø12 with $As = 452.4mm^2/\ m\ strip, or\ Ø12\ @\ 250$

Step (s) is the smallest of:

$1.\ 3h = 3 * 200 = 600mm$ $\quad$ $2.\ 450mm$

$$3.\ s = 380\left(\frac{280}{fs}\right) - 2.5Cc = 380\left(\frac{280}{\frac{2}{3} * 420}\right) - 2.5 * 20 = 330mm, but$$

$$s \leq 300\left(\frac{280}{\frac{2}{3} * 420}\right) = 300mm. \quad - \boldsymbol{control}$$

$s = 250mm < Smax = 300mm \quad - OK533333$

4.10.3.1 Temperature and shrinkage reinforcement:

$$\boldsymbol{As, Temperature\ \&\ shrinkage = 0.0018bh} = 0.0018 * 1000 * 200 = 360\ mm2$$

Use Ø12 then, # Of bars $\frac{\boldsymbol{As,req}}{\boldsymbol{As\text{Ø}12}} = \frac{360}{113.1} = 3.18$

$s = \frac{1}{n} = \frac{1}{3.18} = 0.314\ m$

Take 4Ø12 with $As = 452.4mm^2/\ m\ strip, or\ Ø12\ @\ 300$

Step (s for $temperature\ \&\ shrinkage$) is the smallest of:

$1.\ 5h = 5 * 200 = 1000mm$ $\quad$ $2.\ 450mm \quad - contorl$

$s = 300\ mm < Smax = 450\ mm \quad - OK$

Design of slab (2):

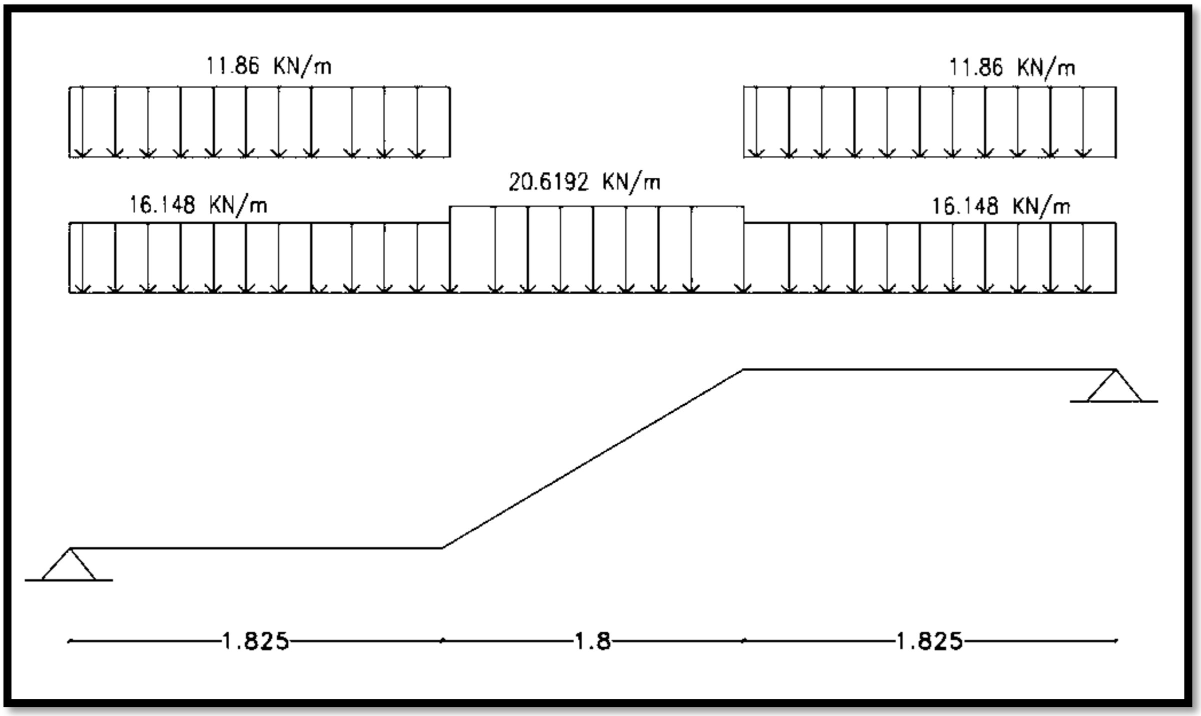

Figure (4-18): System of stair slab 2

The reaction at each end:

$R = (2(16.148 * 0.9125) + 20.1692 * 1.8)/2 + 11.86 * 0.9125 = 43.71\ KN$

4.10.4 Check for shear strength:

Assume bar diameter Ø 12 for main reinforcement.

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

Take the maximum shear as the support reaction $Vu = 43.71\ KN$

$\boldsymbol{Vc = \frac{1}{6}\sqrt{fc'}bwd} = \frac{1}{6} * \sqrt{24} * 1000 * 174 * 10^{-3} = 142.07\ KN/1\ m\ strip.$

$\emptyset = 0.75 - for\ shear$

$\emptyset Vc = 0.75 * 142.07 = 106.55 KN\ /\ 1m\ strip$

$Vumax = 43.71\ KN < \frac{1}{2}\ \emptyset\ Vc = 53.28\ KN$

The thickness is adequate enough.

4.10.5 Design of bending moment:

Calculate the maximum bending moment at midspan and the steel reinforcement:

$Mu = 43.71 * 1.8125 - 16.148 * 0.9125 * 1.35625 - 20.6192 * 0.9 * 0.45 - 11.86 *$

$0.9125 * 1.35625 = 36.21\ KN.m$

$$Mn = \frac{Mu}{\emptyset} = \frac{36.21}{0.9} = 40.23\ KN.m$$

$$\boldsymbol{Rn = \frac{M_n}{bd^2}} = \frac{40.23 * 10^6}{1000 * 174^2} = 1.33\ Mpa.$$

$$\mathbf{m} = \boldsymbol{\frac{f_y}{0.85 f'_c}} = \frac{420}{0.85 * 24} = 20.59$$

$$\boldsymbol{\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right)} = \frac{1}{20.59}\left(1 - \sqrt{1 - \frac{2 * 20.59 * 1.33}{420}}\right) = 3.28 * 10^{-3}$$

$$\boldsymbol{As = \rho bd} = 2.28 * 10^{-3} * 1000 * 174 = 570.24\ mm^2$$

$$\boldsymbol{As, min = 0.0018bh} = 0.0018 * 1000 * 200 = 360\ mm^2$$

$$\boldsymbol{As, req} = 570.24\ mm^2 > \boldsymbol{As, min} = 360\ mm^2$$

Use Ø12 then, # Of bars $\frac{\boldsymbol{As,req}}{\boldsymbol{As\emptyset 12}} = \frac{570.24}{113.1} = 5.04$

$s = \frac{1}{n} = \frac{1}{5.04} = 0.198\ m$

Take 6Ø12 with $As = 678.58mm^2 / m\ strip, or\ \emptyset 12\ @\ 150$

Step (s) is the smallest of:

1. $3h = 3 * 200 = 600mm$ 2. $450mm$

3. $s = 380\left(\frac{280}{fs}\right) - 2.5Cc = 380\left(\frac{280}{\frac{2}{3} * 420}\right) - 2.5 * 20 = 330mm, but$

$$s \leq 300\left(\frac{280}{\frac{2}{3} * 420}\right) = 300mm. \quad -\ \boldsymbol{control}$$

$$s = 150mm\ < Smax = 300mm \quad -OK$$

4.10.5.1 Temperature and shrinkage reinforcement:

$$\boldsymbol{As, Temperature\ \&\ shrinkage = 0.0018bh} = 0.0018 * 1000 * 200 = 360\ mm^2$$

Use Ø12 then, # Of bars $\frac{\boldsymbol{As,req}}{\boldsymbol{As\text{Ø}12}} = \frac{360}{113.1} = 3.18$

$$s = \frac{1}{n} = \frac{1}{3.18} = 0.314\ m$$

Take 4Ø12 with $As =\ 452.4mm^2/\ m\ strip, or$ Ø12 @ 300

Step (s for $temperature\ \&\ shrinkage$) is the smallest of:

1. $5h = 5 * 200 = 1000mm$ 2. $450mm\ \ -contorl$

$$s = 300\ mm\ < Smax = 450\ mm \quad -OK$$

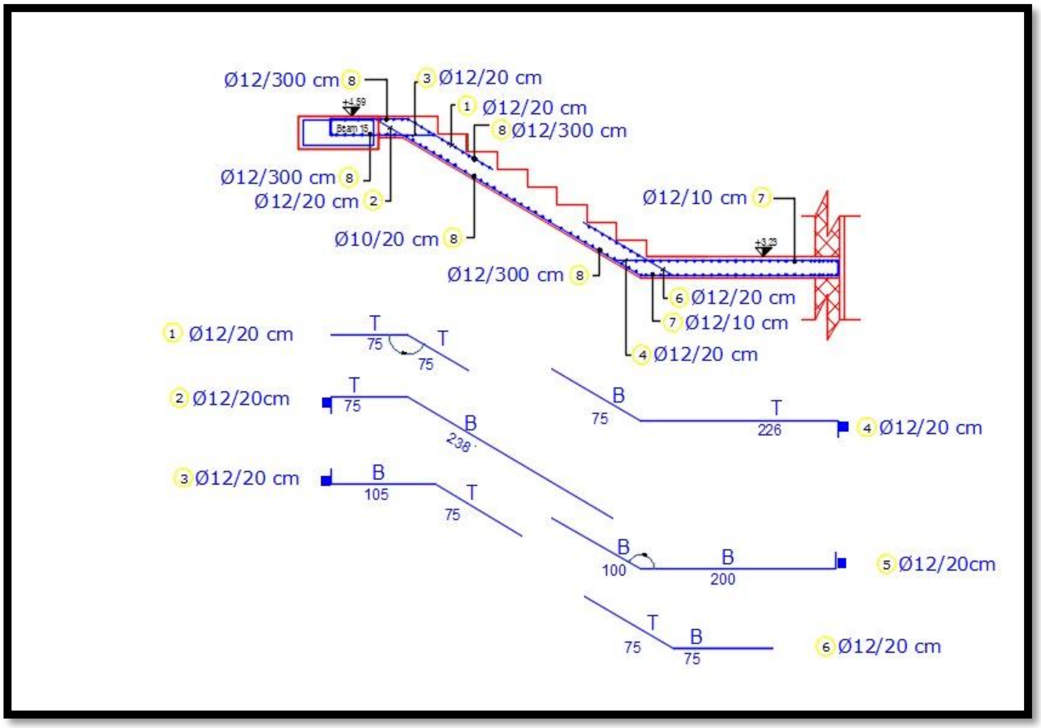

Figure (4-19): Reinforcement details of stair slab 1

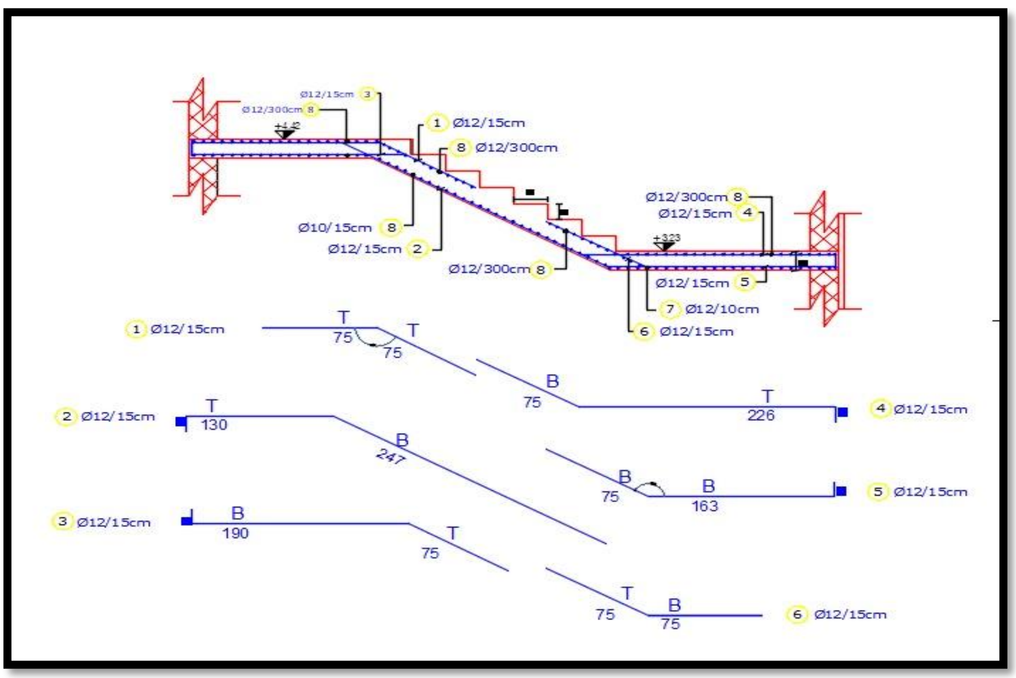

Figure (4-20): Reinforcement details of stair slab 2

CHAPTER

5

Results and Recommendations

5.1 The Results

1. The most important step before you start designing is to carefully stud y architectural plans for proper column distribution.
2. Each student or structural designer should be able to design manually so he can get the experience and knowledge in using the computer software.
3. Experience in the use of construction programs cannot be reached with out understanding the basic concepts of structural design.
4. 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 .
5. When choosing the construction system, it is best to distribute nerves i n the long direction and bridges in the short direction to reduce the loa ds on bridges resulting in less armament which means less costs.
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 chosen 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.

5.3 Reference

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[2] Building code requirements for structural concrete (ACI-318-14), USA: American Concrete Institute, 2014.

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