Palestine Polytechnic University

Faculty of Engineering

Department of Civil Engineering and Architecture

Project Name

Structural Design of Plant Biodiversity Research Center

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

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- *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 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 contain store, Generator and Heating and air conditioning. The ground floor contain Video conference, Kitchen, Cafeteria, Gallery and theater. The first floor contain 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 contain publication store, printing hall, raw material store, and office, and the third floor it contain 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.

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_11), it must be noted that we will be relying on some computer programs such as Autocad2007, Safe, Office2007, Atir, and others.

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.

DEDICATION

To those who have always believed in me, 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 cu- riosity 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.

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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-stressedreinforcement.
- **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 supports in 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

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1.1 Introduction

Palestine is an agricultural country that needs facilities such asa Plant BiodiversityResearch 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 has 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 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:

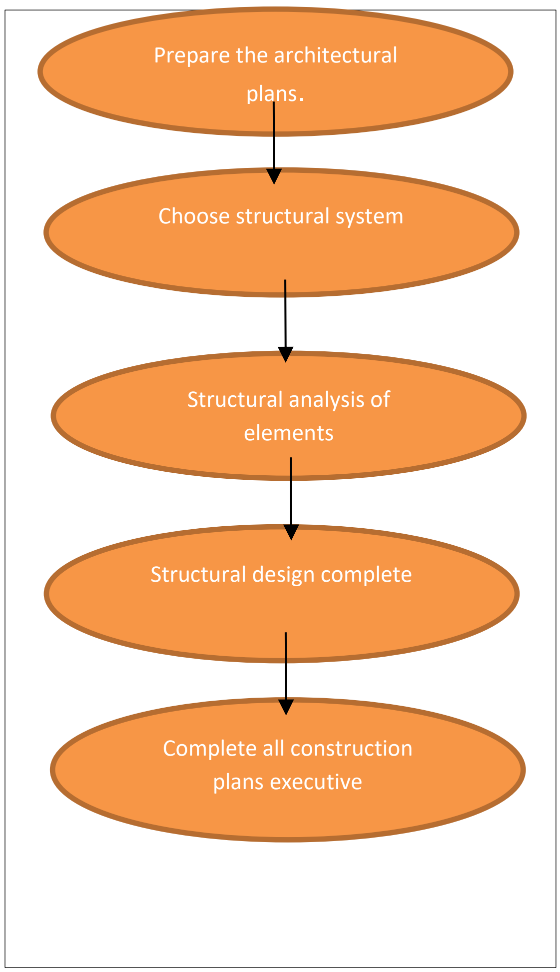

Figure (1-1): The Stages of the Project.

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.

2.2 THE MAIN ELEMENTS IN THE PLANT BIODIVERSITY RESEARCH CENTER.

2.2.1 INTERIOR SPACES.

2.2.2 EXTERNAL SPACES

2.3 PROJECT PLANS.

2.4 PROJECT ELEVATIONS.

2.5 PROJECT SECTIONS.

2.6 SOME PERSPECTIVE SHOTS FOR THE PLANT BIODIVERSITY RESEARCH CENTER.

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.

2.2The Main Elements in the Plant Biodiversity Research Center:

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

2.2.1Interior 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.

- **4-Gallery:**

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

- **5-Video conference:**

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 m^2.
  - Entrance: has an area of 36 m^2.
  - Reading hall: has an area of 105 m^2.
  - Bookshelves: has an area of 59 m^2.

- **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:

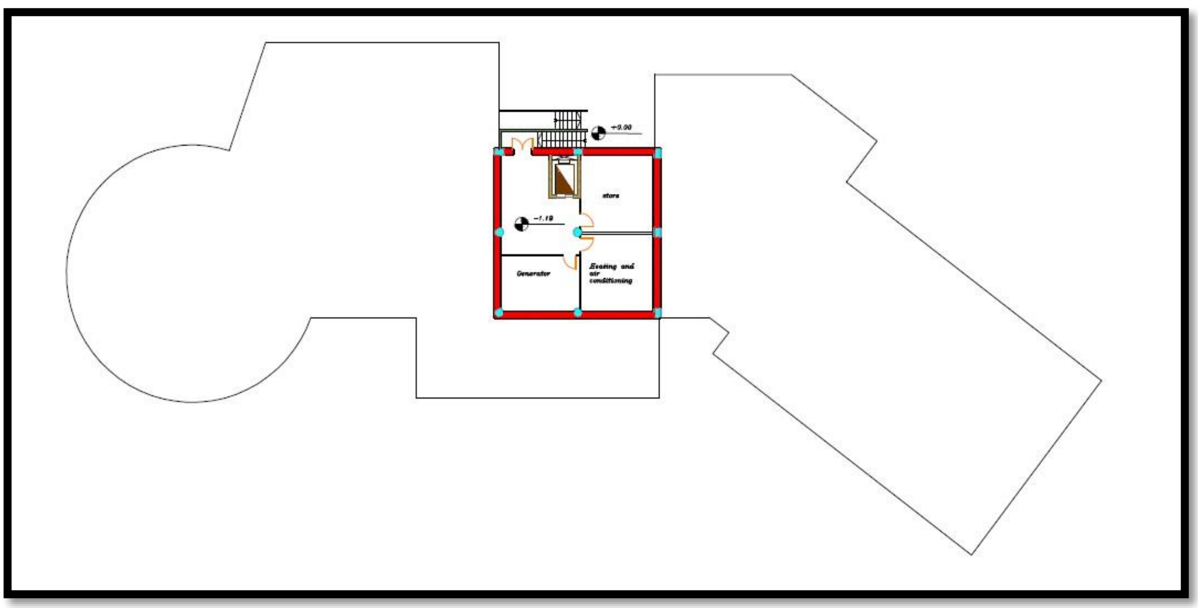

Figure (2-1): Basement floor plan.

Figure (2-2): Ground floor plan.

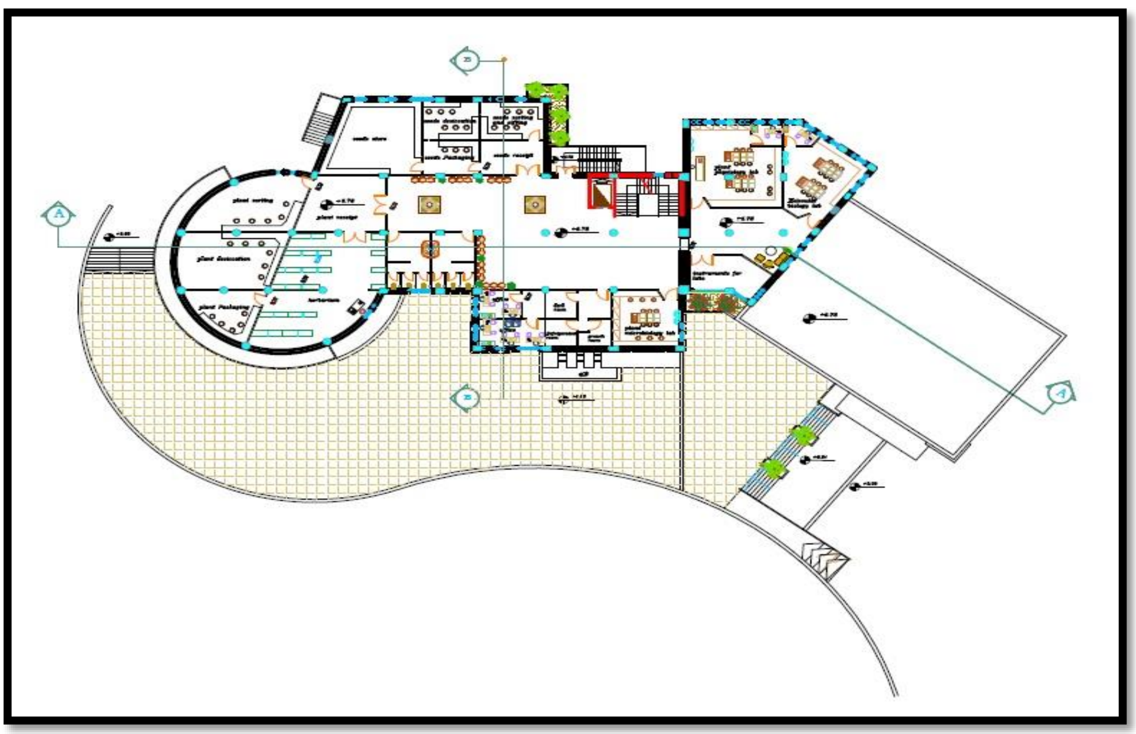

Figure (2-3): First floor plan.

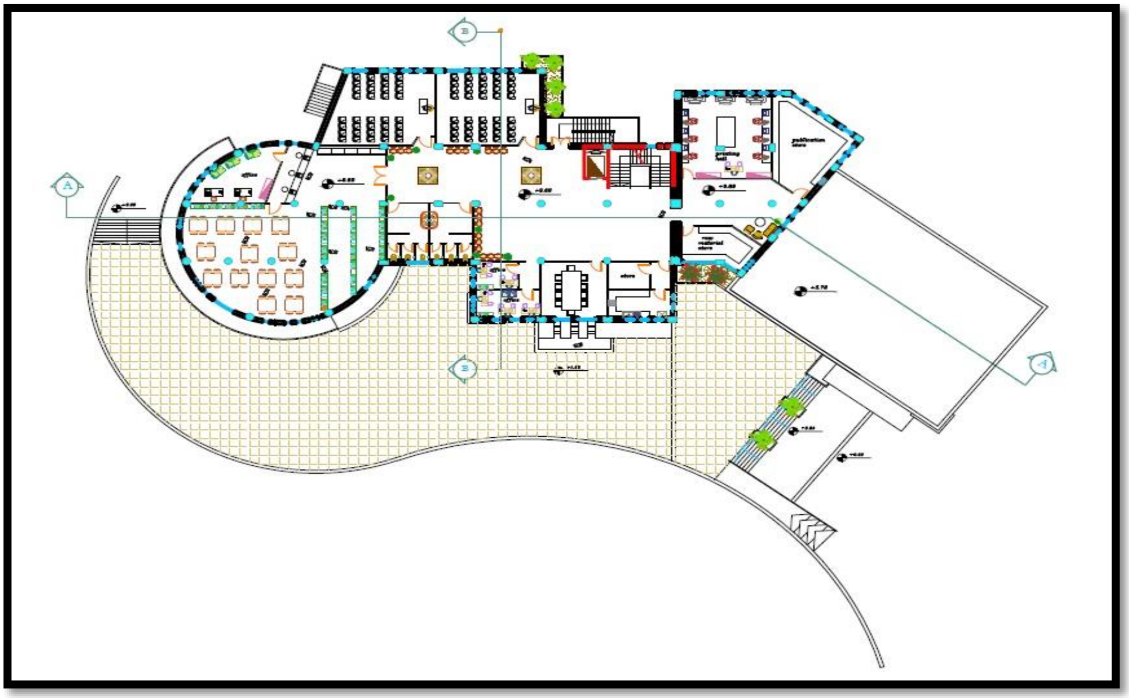

Figure (2-4): Second floor plan.

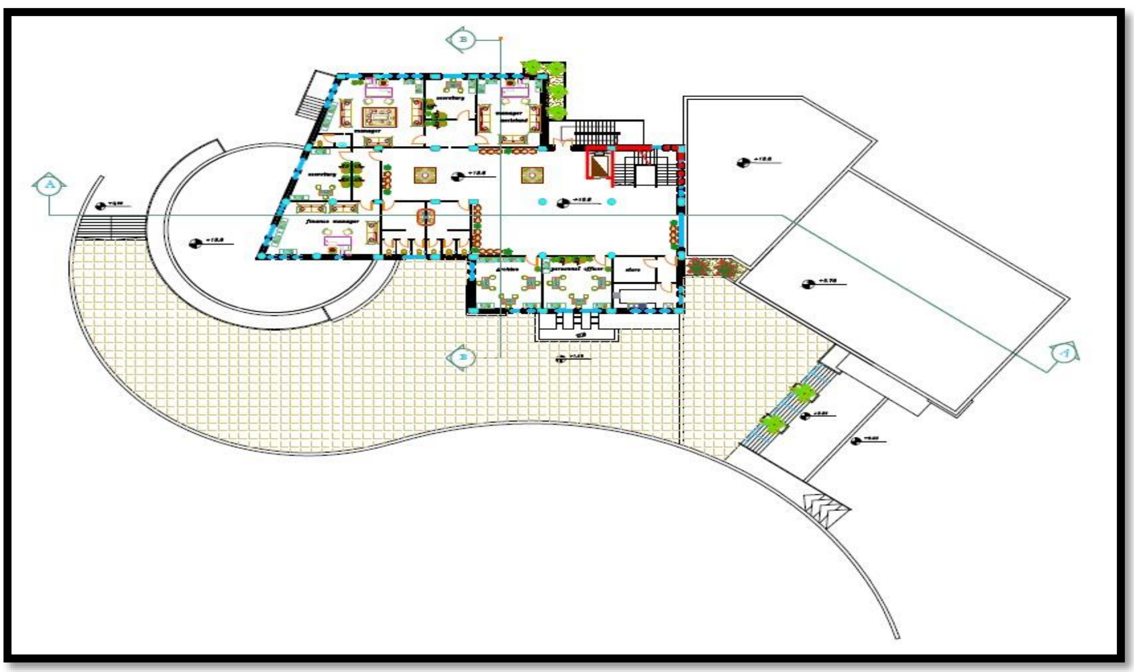

Figure (2-5): Third floor plan.

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:

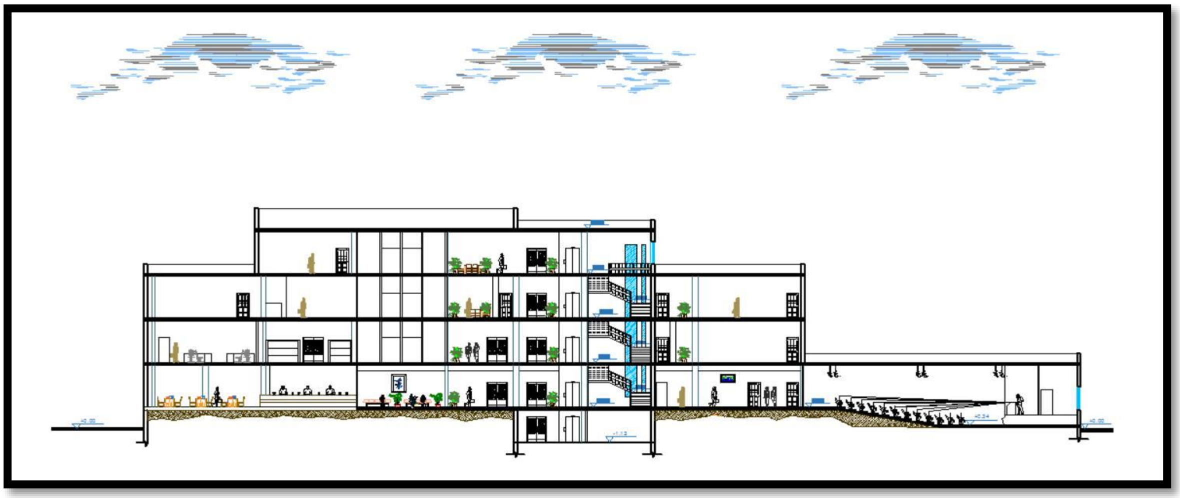

Figure (2-10): section A-A

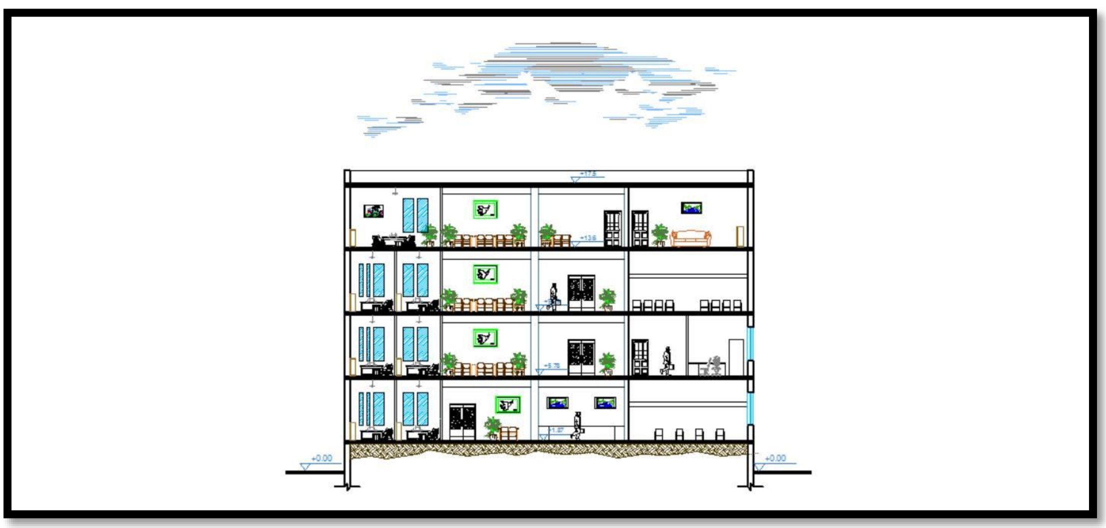

Figure (2-11): Section B-B

2.6 Some Perspective Shots for the Biological Research Centre:

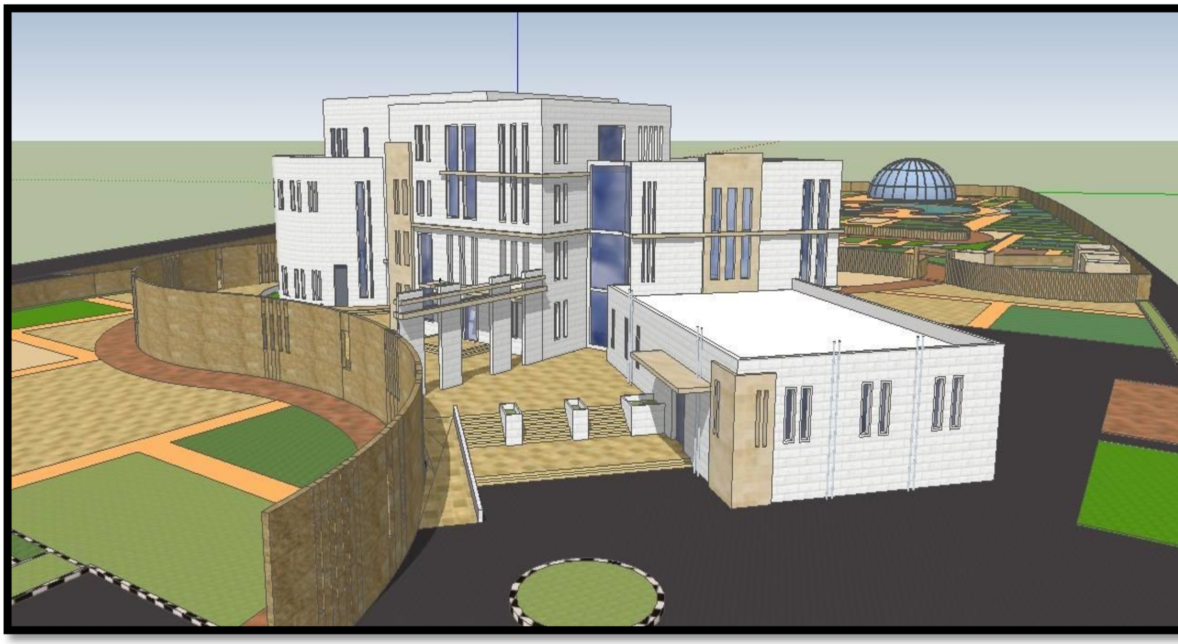

Figure (2-12): Shot For The Building.

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 building exposed to loads of live and dead loads, wind loads, snow loads and loads of earthquakes.

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/م²	كن
تابع مباني التجمعات العامة.	تابع القاعات، قاعات الاجتماعات، المطاعم، المتاحف، المكتبات، النوادي، المسارح، ستوديوهات الاذاعة.	الممرات والمداخل والأدراج و... سطحات الأدراج والممرات المرتفعة الموصلة بين المباني.	4.0	4.5
		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 code (page 25)

3.5.1 Snow Loads:

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

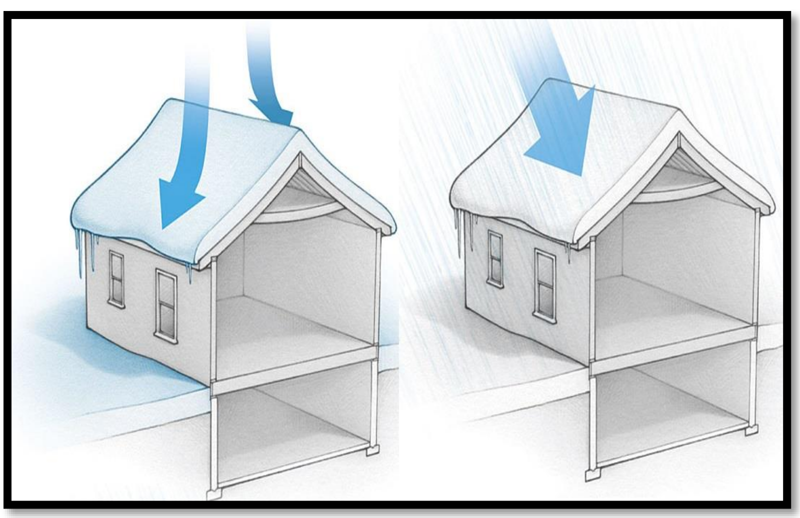

Figure (3-2): snow loads.

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:

S_o= (h-400)/320 = (860-400)/320 = 1.44 KN/m^2.

S_d= M_i* S_o= 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 resisted by shear walls in the building.

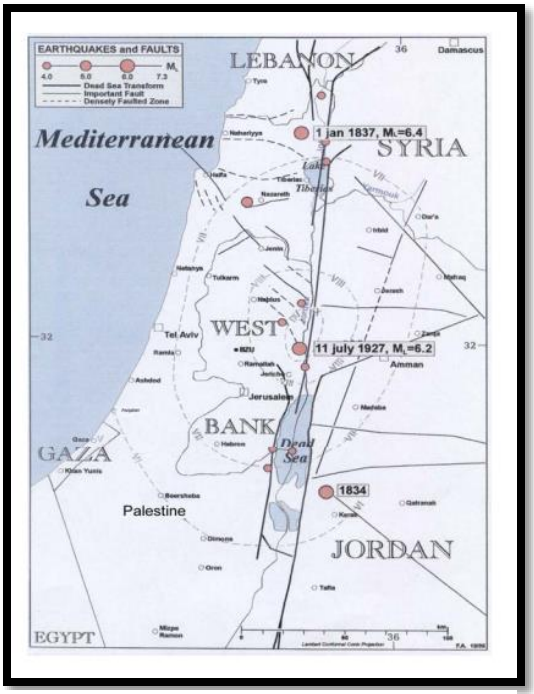

Figure (3-3): Earthquake Map of Palestine

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.

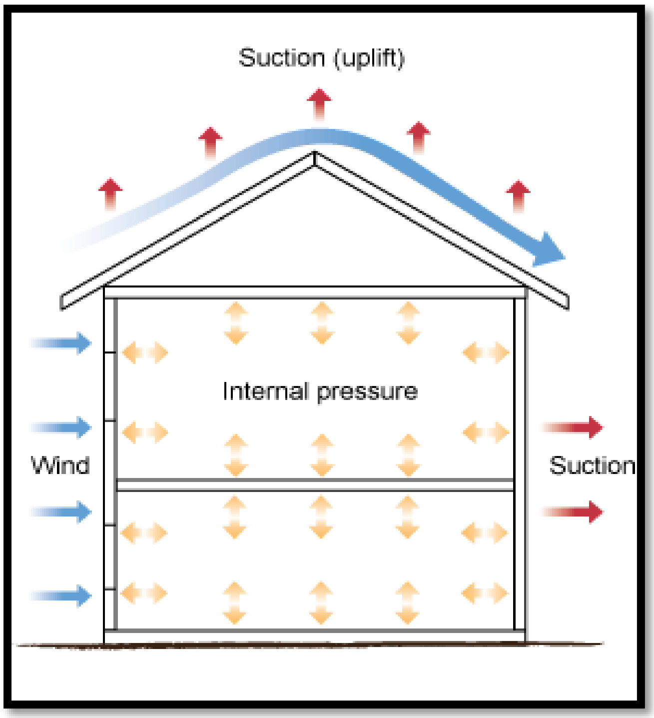

Figure (3-4): Wind Pressure on buildings.

3.6 Structural Elements of the Building:

All buildings are usually consists 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 defined.

- **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, three 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- Tow Way Ribbed Slab.

3- Flat slab

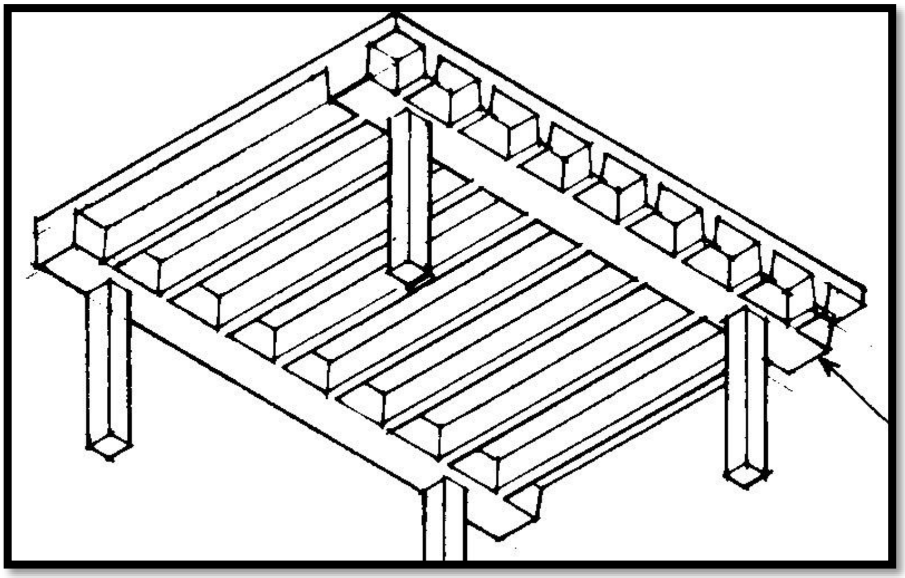

Figure (3-5): One Way Ribbed Slab.

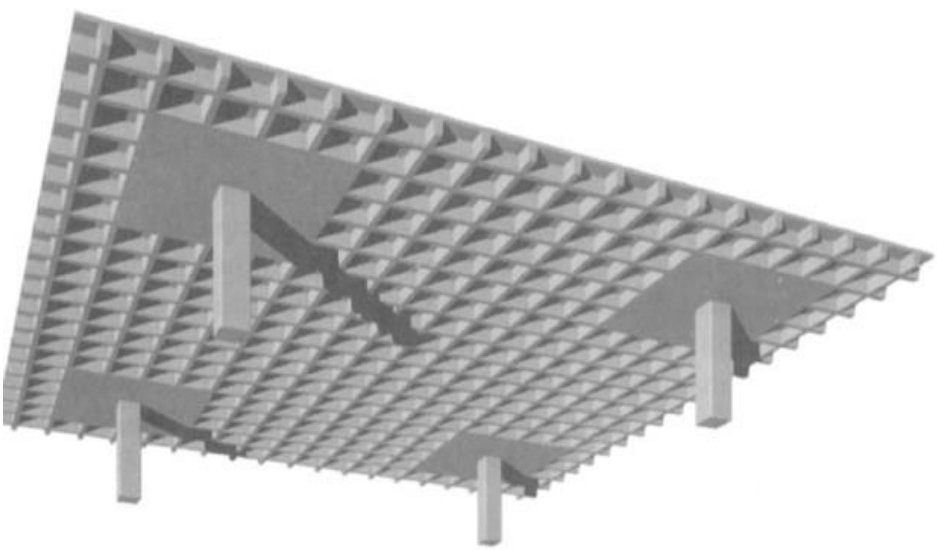

Figure (3-6): Two Way Ribbed Slab.

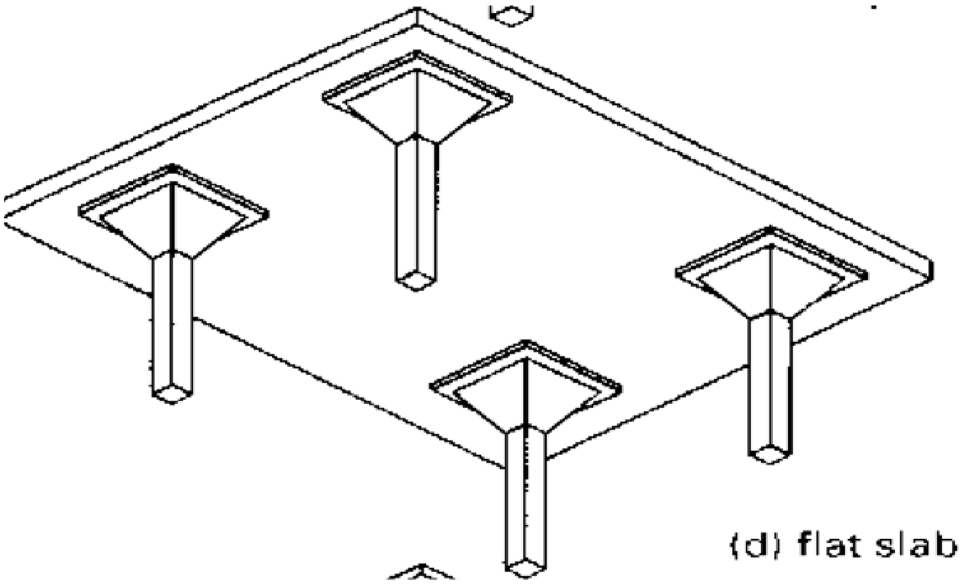

Figure (3-7): flat Slab.

- **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.

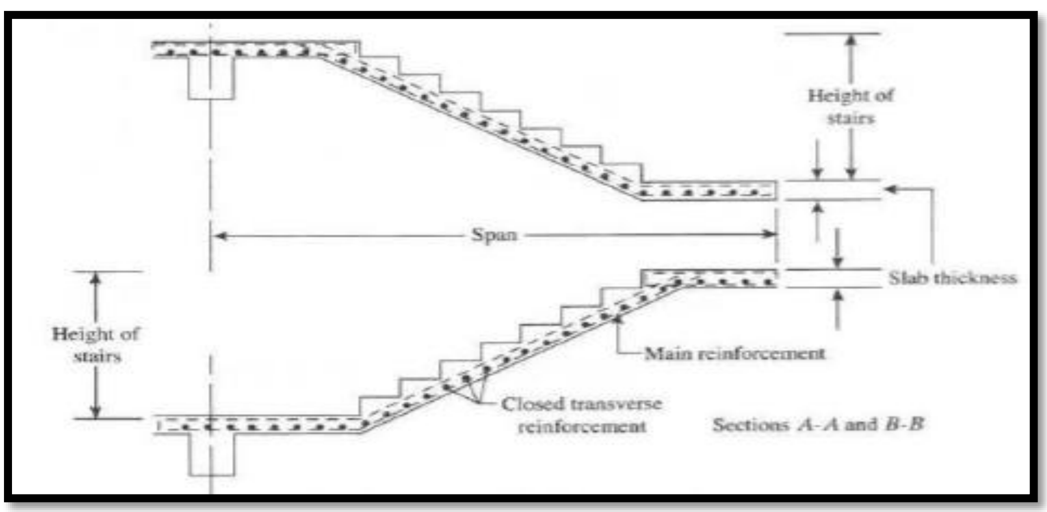

Figure (3-8): The shape of stairs.

- **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).

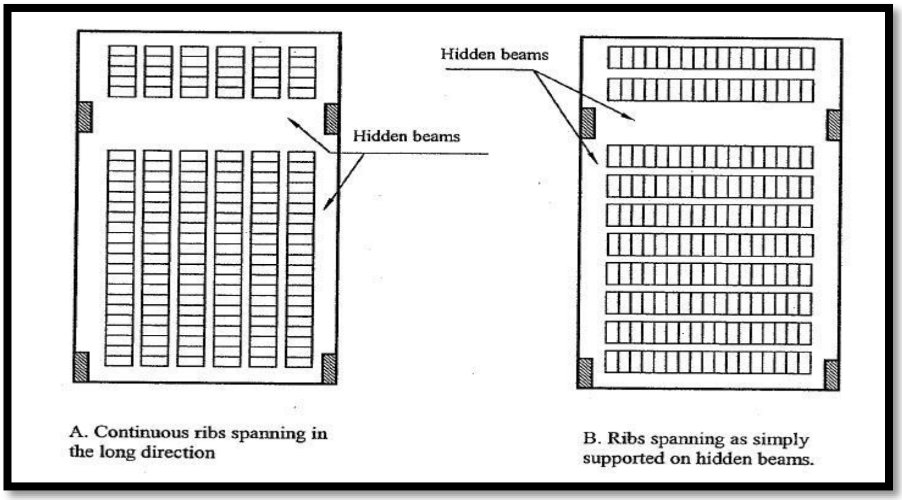

Figure (3-9): Hidden Beam.

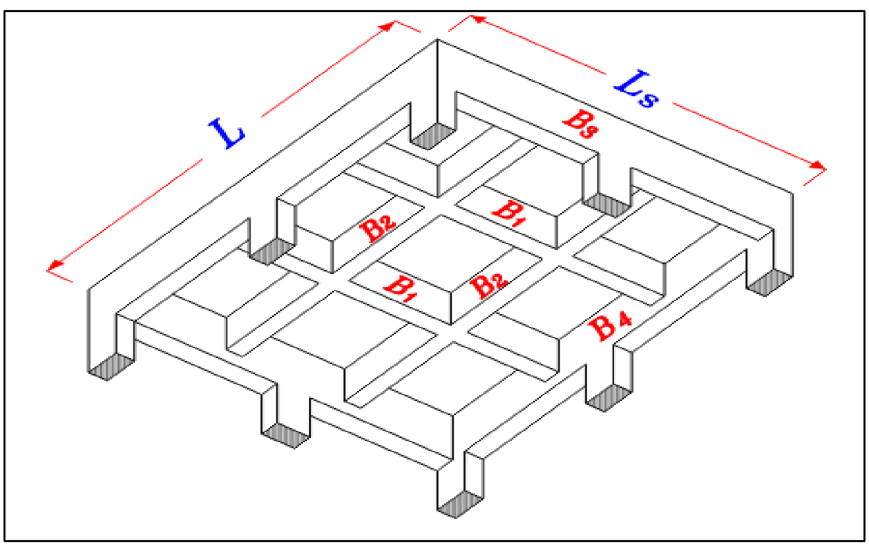

Figure (3-10): Paneled Beam.

- ## 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.

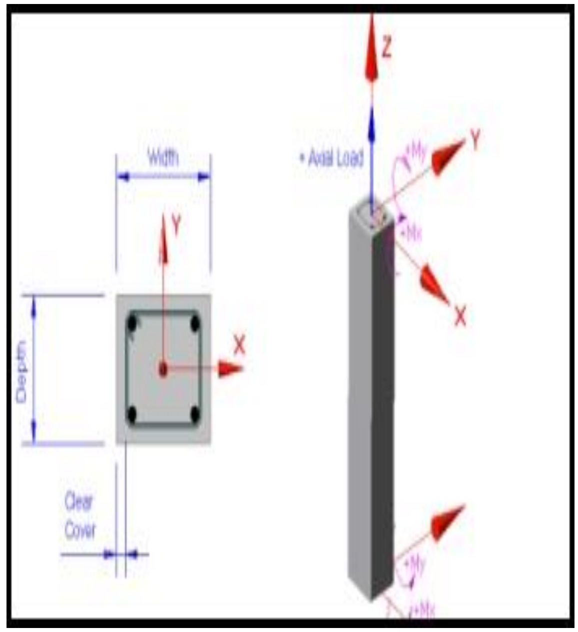

Figure (3-11): Column.

- ## 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.

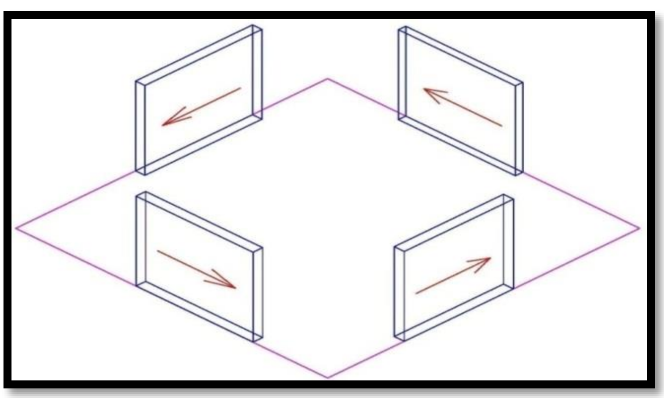

Figure (3-12): Shear Wall.

- **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.

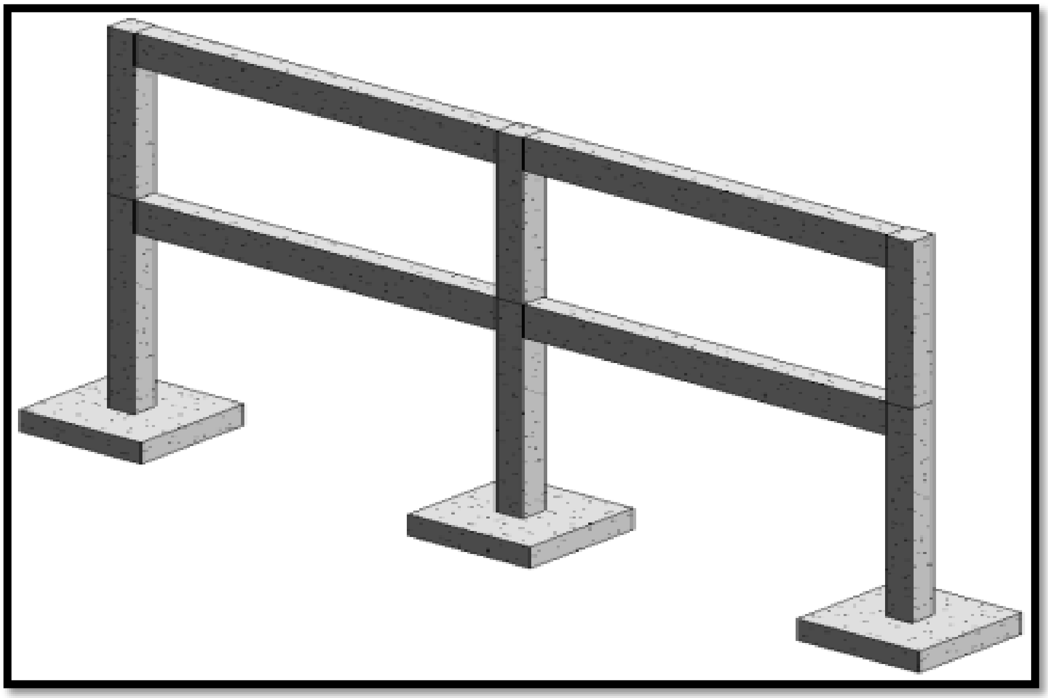

Figure (3-13): Frame Structure.

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 reinforced with steel, when concrete structure members must resist extreme tensile stresses; steel will supplies 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 type of slabs such as “one way ribbed slab”, they will 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:

$Q_u = 1.2DL + 1.6LL$ 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.

4.3.2 Determination of Thickness for Two-Way Ribbed Slab:

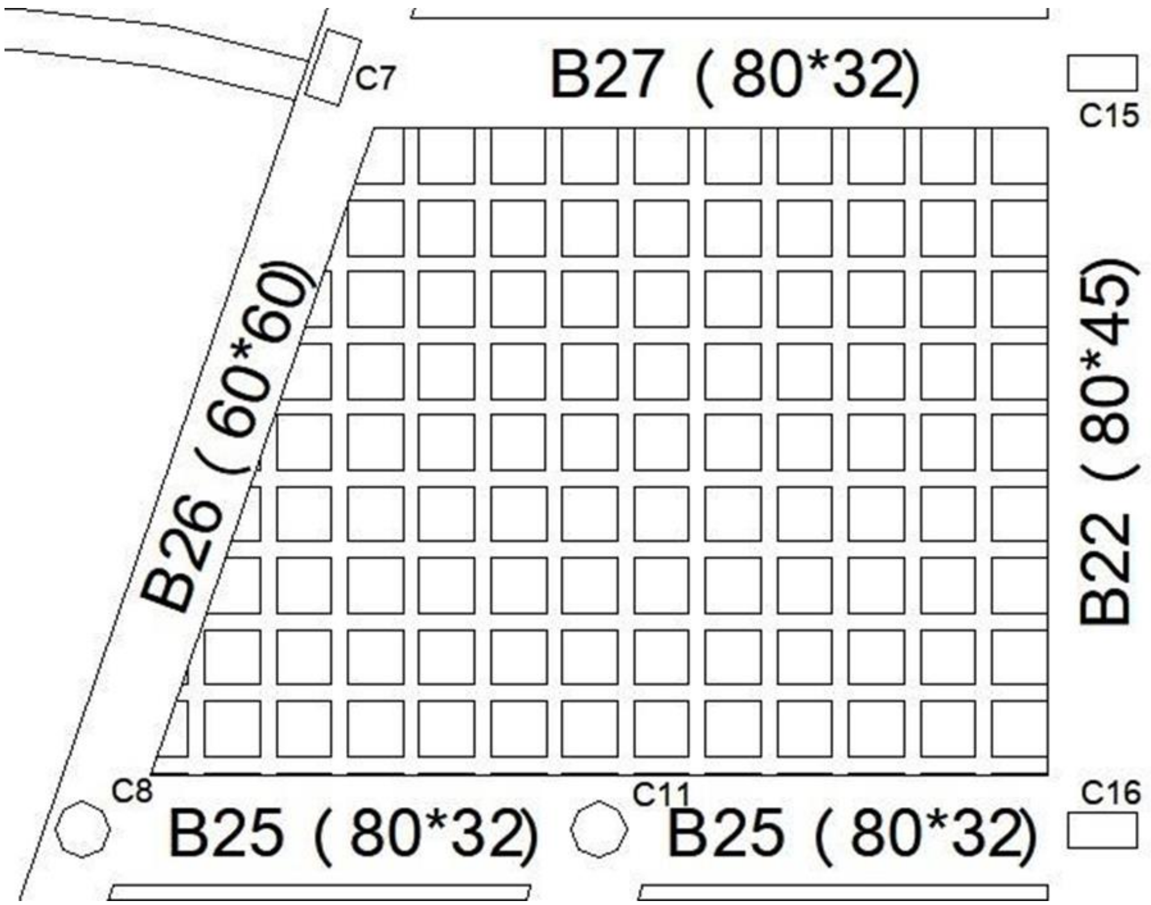

Fig. (4–1): Two way ribbed slab.

- Exterior beam have a rectangular section of 60 cm width and 60 cm depth:

$$I_b = \frac{b * h^3}{12} = \frac{60 * 60^3}{12} = 1080000 \; cm^4$$

-The moment of inertia for the ribbed slab:

$$y_c = \frac{40*8*4+32*12*16}{40*8+32*12} = 10.55\ cm$$

$$I_{rib} = 52*\frac{10.55^3}{3} - 40*\frac{2.55^3}{3} + 12\ \frac{21.45^3}{3} = 59609\ cm^4$$

L= 5.0 m

$$I_s = \frac{I_{rib}*(\frac{l}{2}+b_w)}{b_f} = \frac{59609*\left(\frac{500}{2}+60\right)}{52} = 355361.34\ cm^4$$

$$\alpha_f = \frac{I_b}{I_s} = \frac{1080000}{355361.34} = 3.04$$

- Interior beams have a rectangular section of 80 cm width and 32 cm and 45 depth

$$I_{b1} = \frac{b*h^3}{12} = \frac{60*32^3}{12} = 163840\ cm^4$$

$$I_{b2} = \frac{b*h^3}{12} = \frac{60*45^3}{12} = 455625\ cm^4$$

-The moment of inertia for the ribbed slab:

$$y_c = \frac{40*8*4+32*12*16}{40*8+32*12} = 10.55\ cm$$

$$I_{rib} = 52*\frac{10.55^3}{3} - 40*\frac{2.55^3}{3} + 12\ \frac{21.45^3}{3} = 59609\ cm^4$$

$$I_{s1} = \frac{I_{rib} * (\frac{l}{2} + b_w)}{b_f} = \frac{59609 * \left(\frac{490}{2} + 60\right)}{52} = 349629.7\ cm^4$$

$$I_{s2} = \frac{I_{rib} * (\frac{l}{2} + b_w)}{b_f} = \frac{59609 * \left(\frac{470}{2} + 60\right)}{52} = 338166.44\ cm^4$$

$$\alpha_{f1} = \alpha_{f3} = \frac{I_b}{I_s} = \frac{163840}{338166.44} = 0.4845$$

$$\alpha_{f2} = \frac{I_b}{I_s} = \frac{455625}{349629.7} = 1.3$$

$$\alpha_m = \frac{(3.04 + 0.4845 + 0.4845 + 1.3)}{4} = 1.327 < 2.0$$

The minimum slab thickness will be:

$$h = \frac{L_n(0.8 + \frac{f_y}{1400})}{36 + 5\beta(\alpha_m - 0.2)} = \frac{5.0 * (0.8 + \frac{420}{1400})}{36 + 5 * \frac{5.0}{4.7} * (1.327 - 0.2)} = 0.23\ m$$

$$h = 32\ cm > 23\ cm\ - OK$$

Take slab thickness 32 cm.

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.

No.	Parts	Density	Calculation
1	Tiles	23	**23×0.03=0.69 KN/m**
2	Mortar	22	**22×0.03=0.66 KN/m**
3	Coarse Sand	17	**17×0.07=1.19 KN/m**
4	Topping	25	**25×0.08=2 KN/m**
5	Partition	1.5 KN/m^2	**1.5×1=1.5 KN/m**
			6.04 KN/m

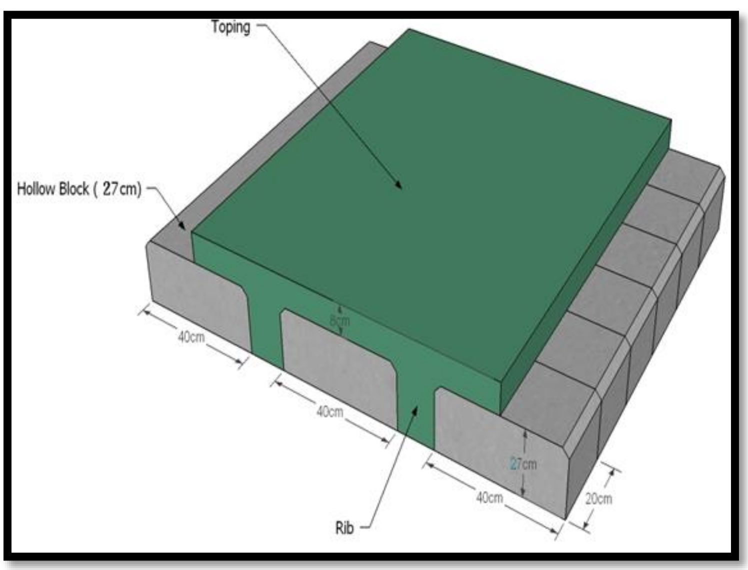

Figure (4-2): Toping of slab

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

From Jordanian code LL = 4.5 KN/m^2.

Q u = 1.2×DL+1.6×LL

= 1.2×6.04+1.6×4.5 = 14.448 KN/m.

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

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

$$\text{Mu} = \frac{14.448 * 0.4^2}{12} = 0.192 \text{ KN.m}$$

Ø*Mn=0.55*0.42*√24*1000*80^2/6=1.207 KN.m

Ø*Mn (plane concrete) =1.207 KN.m> Mu max=0.192 KN.m.

No structural reinforcement needed. Therefore, shrinkage and temperature reinforcement must provide.

For the shrinkage and temperature reinforcement:-

ρ min=0.0018

As= ρ*b*h=0.0018*1000*80=144 mm².

Number 0f Ø8 = As_{req}/A_{bar} = 144/50.3 = 2.87 → Spacing(S) = 1/2.87 = 35cm = 350 mm.

S ≤ 380 (280/f_s) – 2.5 × C_c≤ 300 (280/fs)

= 380 × (280/(2/3 f_y)) – 2.5× 20 ≤ 300 × (280/(2/3 f_y))

= 380 × (280/ (2/3* 420)) – 2.5 × 20 = 330 mm ≤ 300 × (280/ (2/3* 420))

= S ≤ 300 mm.

≤ 3 × h = 3× 80 = 240 mm…...controlled.

≤ 450 mm.

4.4.2 Design of Ribs (Rib 6):

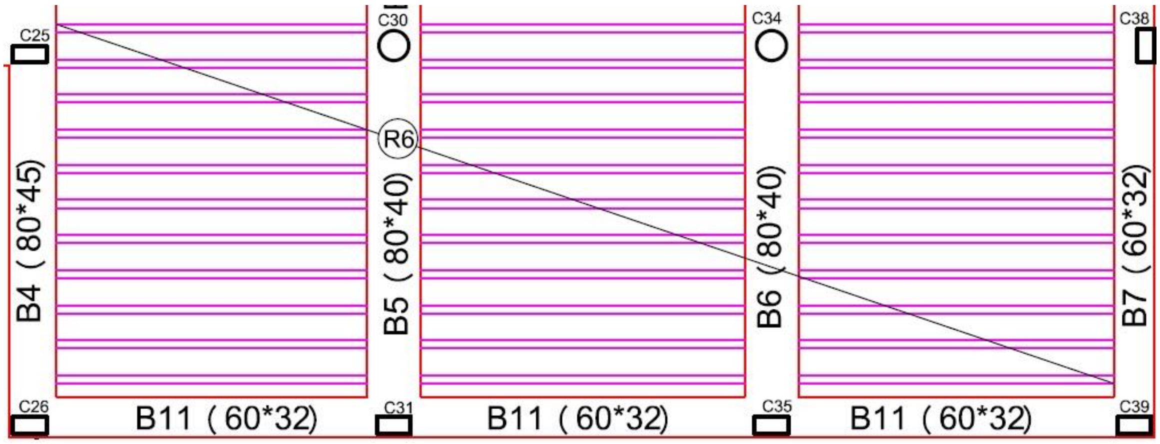

Figure (4-3): Rib location

Table (4 – 2): Calculation of the total dead load for rib 6.

No.	Parts of Rib	Density	Calculation
1	Tiles	23	0.03*23*0.52 = 0.359 KN/m
2	Mortar	22	0.03*22*0.52 = 0.343 KN/m
3	Sand	17	0.07*17*0.52 = 0.619 KN/m
4	Topping	25	0.08*25*0.52 = 1.04 KN/m
5	Rib	25	0.24*25*0.12 = 0.72 KN/m
6	Block	10	0.24*10*0.4 = 0.96 KN/m
7	Plaster	22	0.03*22*0.52 = 0.343KN/m
8	Partitions	1.5 KN/m^2	1.5*0.52 = 0.78 KN/m
			5.164 KN/m

Concrete B300 Fc' = 24 Mpa

Reinforcement Steel FY = 420 Mpa

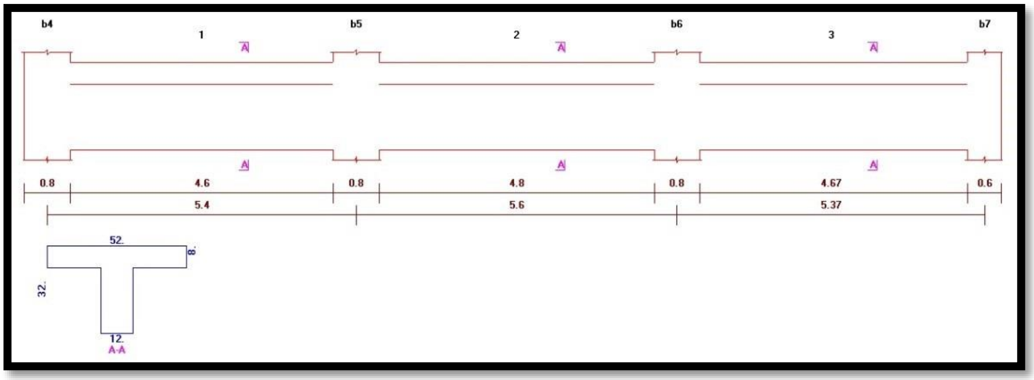

Figure (4-4): Rib 6 geometry.

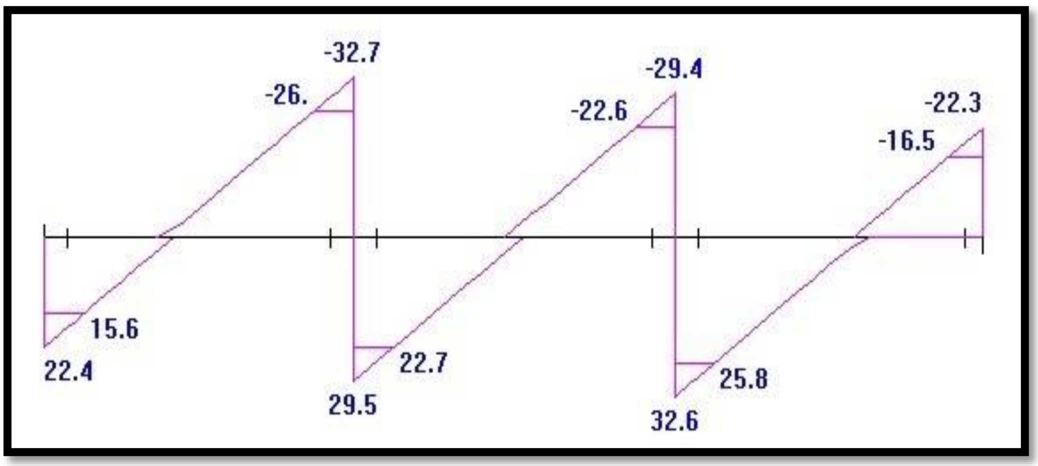

Figure (4-5): Shear Envelop of rib 6.

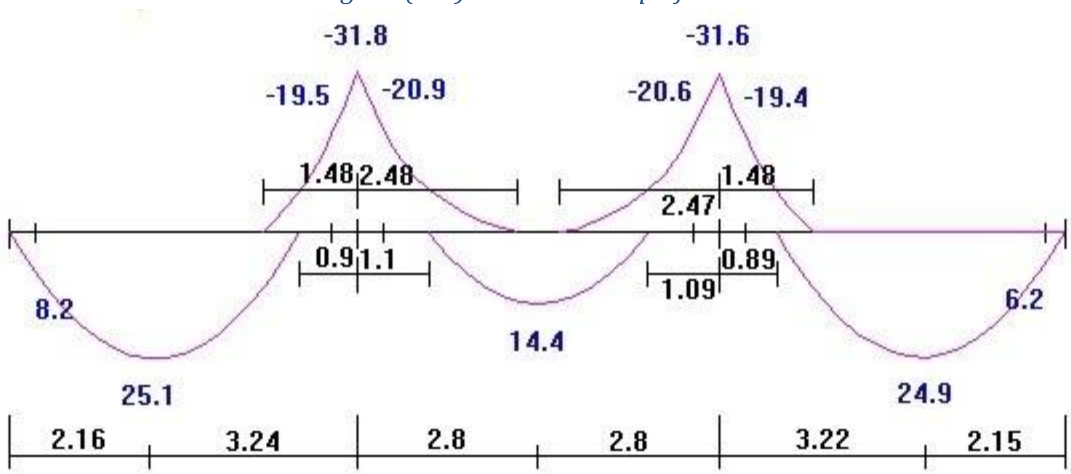

Figure (4-6): Moment Envelop of rib 6.

4.4.2.1 Design Negative Moment of Rib 6:

d= h- cover – d $_{stirrups}$ –d_b/2 = 320 – 20 – 10 – 7 = 283mm

Maximum negative moment M_u= -20.9 KN.m

M_n = 20.9/ 0.9 = 23.22kN.m

$$m = \frac{f_y}{0.85\, f_c'} = \frac{420}{0.85*24} = 20.59$$

$$Rn = \frac{23.22*10^6}{120*283^2} = 2.416 \text{ MPa.}$$

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

$$\rho = \frac{1}{20.59}\left(1 - \sqrt{1 - \frac{2(20.59)(2.416)}{420}}\right) = 0.00614$$

As = 0.00614 (120) (283) = 208.54 mm^2

$$As_{min} = \frac{\sqrt{f_c'}}{4\,(f_y)} * b_w * d \;\geq\; \frac{1.4}{f_y} * b_w * d$$
$$= \frac{\sqrt{24}}{4*420} * 120 * 282 \;\geq\; \frac{1.4}{420} * 120 * 282$$

$As_{min} = 98.68 < 112.8$…………the larger is control

$A_{s\,min}$ = 112.8 mm^2

A_s= 208.54 mm^2 >As_{min} = 112.8 mm^2

Of bars = As/ As $_{bar}$ = 208.54/113.097 =2bars * Note $A_{\Phi12}$ = 113.097 mm^2

Select 2 Φ 12mm.

As provided= 226.19 mm^2

- **Check for strain:-($\varepsilon_s \geq 0.005$)**   **ACI-318-11 (10.3.5)**

$As \times f_y = 0.85 \times f_c' \times b \times a$

$226.19 \times 420 = 0.85 \times 24 \times 120 \times a$

a=38.8mm.

$$c = \frac{a}{\beta_1}$$

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

c= 38.8/0.85 = 45.656

d = 320 – 20 – 10 – 6 = 284 mm

ε_s = 0.003*((d-c)/c) = 0.003*((284 - 45.656)/45.656) = 0.01566> 0.005

∴Ø = 0.9.... OK.

ØMn =0.9*226.19*420*(284– (38.8 /2))*10^{-6} = 22.6 KN.m>Mu max = 20.9 KN.m.

4.4.2.2 Design of Positive Moment of Rib 6:

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

∴ Assume rectangular & tension control section.

Maximum positive moment is M_u= 25.1 kN.m.

Mn = 25.1 / 0.9 = 27.89kN.m

$$m = \frac{f_y}{0.85\, f_c'} = \frac{420}{0.85*24} = 20.59$$

Rn = $\frac{27.89 * 10^6}{520 * 284^2}$ = 0.665 MPa

ρ = $\frac{1}{20.59}$ (1 - $\sqrt{1 - \frac{2(0.665)(20.59)}{420}}$) = 0.00161

As = 0.00161 (520) (284) = 237.76 mm^2

$$As_{\min} = \frac{\sqrt{fc'}}{4(fy)}(bw)(d) \geq \frac{1.4}{fy}(bw)(d) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (ACI - 10.5.1)$$

$$As_{\min} = \frac{\sqrt{24}}{4(420)}(120)(284) \geq \frac{1.4}{420}(120)(284))$$

$$As_{\min} = 99.38 < 113.6$$

$$As_{\min} = 113.6 mm^2$$

237.76 mm^2> $As_{\min} = 113.6 mm^2$

# of bars = As/ As $_{bar}$ = 237.76/153.93 = 2 bars * Note $A_{\Phi 14}$ = 153.93 mm²

As providing = 307.87 mm^2

Select 2 Φ 14mm.

- **Check for strain:-($\varepsilon_s \geq 0.005$) ACI-318-11 (10.3.5)**

As × f_y = 0.85 × f_c' × b × a

307.87 × 420 = 0.85 × 24 × 120 × a

a=52.82 mm

$$c = \frac{a}{\beta_1} = \frac{52.82}{0.85} = 44.897 mm$$

$$\varepsilon_s = \frac{283 - 44.897}{44.897} X0.003$$

$$\varepsilon_s = 0.0159 > 0.005 OK$$

4.4.2.3 Design for shear:

V_u= 26 KN

Φ Vc= Φ * $\frac{\sqrt{fc'}}{6}$ *bw * d

= 0.75 * $\frac{\sqrt{24}}{6}$ * 0.12 * 0.283*1000

= 20.796 KN

1.1 * Φ Vc = 1.1*20.796 = 22.875 KN.

Check for Vu:-

1) Vu $\leq \Phi$ Vc/2

26 $\leq$ 10.398 (X)

2) Φ Vc/2 $\leq$ Vu $\leq \Phi$ Vc

10.398$\leq$26 $\leq$ 20.796 (X)

3) Φ Vc $\leq$ Vu $\leq \Phi$ Vc + Φ Vsmin

Vsmin = $\frac{\sqrt{fc'}}{16}$ *bw * d OR Vsmin = 1/3 *bw * d

Vsmin = 10.398 KNORVsmin = 11.32 KN

Φ Vsmin = 0.75*11.32 = 8.49 KN

20.796$\leq$ 27.4 $\leq$ 20.796+8.49

20.796$\leq$ 27.4 $\leq$ 29.286…. (OK)

So Case (3) satisfy

Vs = (Vu-(ΦVc))/Φ = 20.8KN.

Take Av = 2 Φ 8 = 2 * 50.265=100.53 mm^2.

$Av/s = 1/3\ (b_w/f_y)$

$100.53/s = 1/3\ (120/420) \rightarrow s = 1055.56$ mm

$S \leq d/2 = 141.5$ mm

$S \leq 600$ m.

Use Φ 8 @ 14 cm c/c.

4.5 Design of Beam 6:

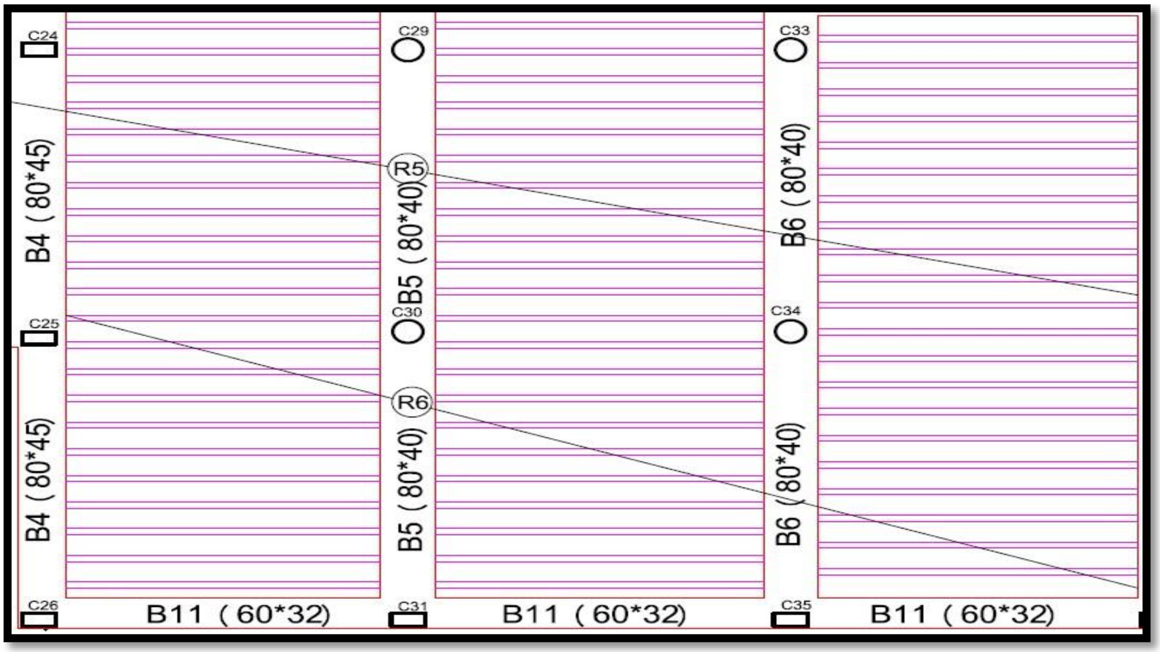

Figure (4-7): Beam 6 location.

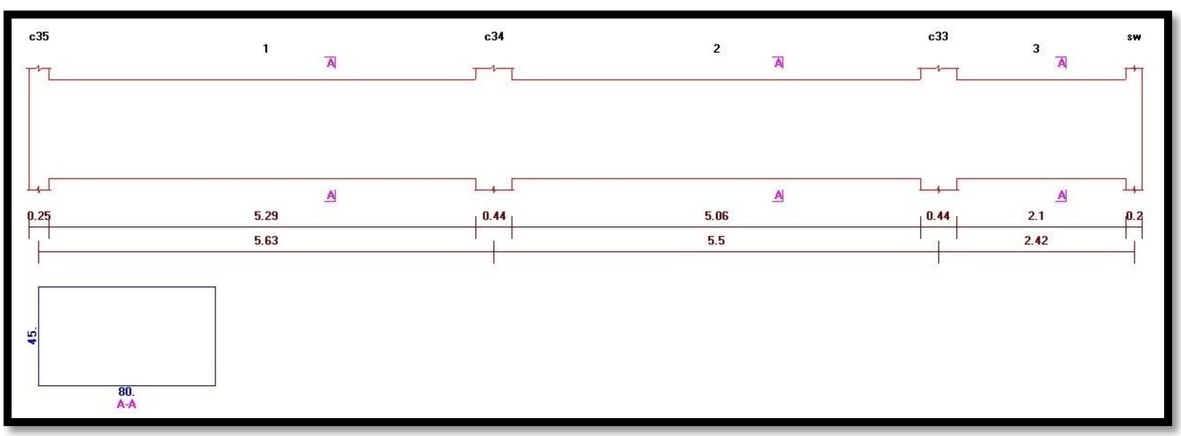

Figure (4-8): Beam 6 geometry.

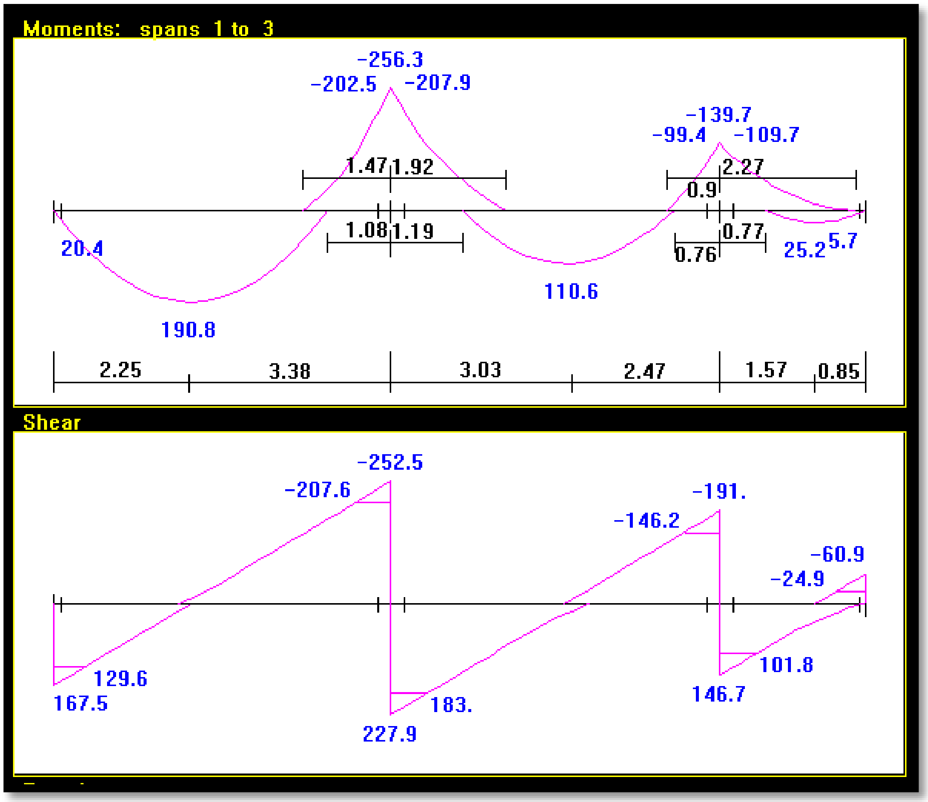

Figure (4-9): Moment and shear envelop of beam 6.

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 6 = 0.8*0.32*25 = 6.4 KN/m

4.5.1 Design of Positive Moment:

For main positive reinforcement Φ16 Assume bar diameter, stirrups Φ10

$b_w = 80cm, h = 32cm$

$d = 320 - 40 - 10 - (16/2) = 262mm$

Mu (+) 1 = 190.8 KN.m

∴ Assume rectangular & tension control section.

C_{max} = 3/7 * d = 3/7 * 262 = 112.28

a_{max} = $\beta1$*C_{max}= 0.85 * 112.28 = 95.438 mm *Note: fc' = 24 MPa < 28 MPa→$\beta1$ = 0.85

Mn_{max}= 0.85 * fc' * b * a * (d –a/2)

Mn_{max}= 0.85 * 24 * 800 * 95.438 * (262-(95.438/2)) * 10^{-6}= 333.753 KN.m

* Note: ϵs = 0.004 → ϕ = 0.82

ΦMn_{max} = 0.82 * 333.753 = 273.677 KN.m

Mu<ΦMnmax

∴ Design section as singly reinforced concrete section.

Design of positive moment Mu (+) = 190.8 KN.m

Mn= Mu/ϕ = 190.8/0.9 = 212 KN.m

$$m = \frac{f_y}{0.85\, f_c'} = \frac{420}{0.85*24} = 20.59$$

$$Rn = \frac{212*10^6}{800*262^2} = 3.86 \text{ MPa}$$

$$\rho = \frac{1}{20.59}\left(1 - \sqrt{1-\frac{2*(3.86)(20.59)}{420}}\right) = 0.01028$$

As_{req} = ρ × b ×d = 0.01028 × 800 × 262 = 2154.688 mm2.

$$As_{\min} \geq \frac{\sqrt{fc'}}{4(fy)}(bw)(d) \geq \frac{1.4}{fy}(bw)(d)$$

$$As_{\min} \geq \frac{\sqrt{24}}{4(420)}(800)(262) \geq \frac{1.4}{420}(800)(262)$$

=611.2 mm^2< 698.66 mm^2 …………. Larger value is control.

As_{min}= 698.66mm^2< As_{req} = 2154.688 mm^2.

∴As = 2154.688 mm^2.

11∅16 = 2211.68 mm^2>As_{req} = 2154.688 mm^2 … OK.

∴ Use 11∅16

- **Check for strain ($\varepsilon_s \geq 0.005$) ACI-318-11 (10.3.5)**

As × fy = 0.85 × fc' × b × a

2211.68 × 420 = 0.85 × 24 × 800 × a

a =56.918mm

$$c = \frac{a}{\beta_1} = \frac{56.918}{0.85} = 66.96mm$$

$$\varepsilon_s = \frac{262 - 66.96}{66.96} \times 0.003$$ **=0.0087 > 0.005 (tension control section).**

∴∅ = 0.9 …. OK.

4.5.2 Design of Negative Moment:

For main negative reinforcement Assume bar diameterΦ14, stirrups Φ10

$b_w = 80cm, h = 32cm$
$d = 320 - 40 - 10 - (14/2) = 263mm$

$Mu^{(-)} = 256.3$ KN.m

Mn = 256.3 / 0.9 = 284.77 KN.m

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

$$Rn = \frac{284.77 * 10\text{^}6}{800 * (263)^2} = 5.146 \text{ MPa}$$

$$\rho = \frac{1}{20.59}\left(1 - \sqrt{1 - \frac{2(5.146)(20.59)}{420}}\right) = 0.01438$$

As = 0.01438 (800) (263) = 3026.11 mm^2.

$$As_{\min} = \frac{\sqrt{fc'}}{4(fy)}(bw)(d) \geq \frac{1.4}{fy}(bw)(d) \text{...................}(ACI - 10.5.1)$$

$$As_{\min} = \frac{\sqrt{24}}{4(420)}(800)(263) \geq \frac{1.4}{420}(800)(263)$$

$$As_{\min} = 613.5 < 701.33$$

$$As_{\min} = 701.33 mm^2$$

3026.11 mm^2>As_{min} = 701.33 mm^2

#Of bars = As/ As_{bar} = 3026.11/254.469 = 12 bars * Note $A_{\Phi 18}$ = 254.469 mm²

As providing = 3053.628 mm^2

Select 12 Φ 18 mm.

- **Check for strain (εs ≥0.005)** **ACI-318-11 (10.3.5)**

Tension = Compression

As * fy = 0.85 * b * a

$$3053.628*420 = 0.85*800*24*a$$

$$a = 78.586 mm$$

$$c = \frac{a}{\beta_1} = \frac{78.586}{0.85} = 92.454 mm$$

$$\varepsilon_s = \frac{263-92.454}{92.454} X0.003$$

$$\varepsilon_s = 0.00553 > 0.005$$

∴Ø = 0.9 …. OK.

4.5.3 Design of shear:

Vu = 207.6 KN

$$Vc = \frac{\sqrt{fc'}}{6} bw * d = \frac{\sqrt{24}}{6} *800 *263*10^{-3} = 171.79 \text{ KN}$$

ΦVc= 0.75 * 171.79 = 128.84 KN

Check For dimensions:-

$\phi Vc + (2/3 \times \phi \times \sqrt{f_{c'}} \times b_w \times d) = 128.84 + (2/3 * 0.75 * \sqrt{24} * 800 * 263)*10^{-3} = 515.37$ KN

515.37 > Vu max = 207.6 KN

∴ Dimension is adequate enough.

ΦVs min = (0.75*√24*800*263)/16 = 48.316 KN

ΦVs min = (0.75 * 800 * 263)/3 = 52.6 KN ….. (Control)

$\emptyset\ V`s = \frac{0.75}{3} * \sqrt{24} * 800 * 263 * 10^{-3} = 257.686\ KN.$

$\emptyset\ Vs\ max = 0.75 * \frac{2}{3} * \sqrt{24} * 800 * 263 = 515.372\ KN$

1- $\emptyset(Vc + Vs\ min) = 181.44\ KN.$
2- $\emptyset(Vc + Vs`) = 386.526\ KN.$
3- $\emptyset(Vc + Vs\ max) = 644.212\ KN.$

Vs = $\frac{Vu}{\emptyset} - vc$ = = $\frac{207.6}{0.75} - 171.79 = 105.01\ KN$

1.

0.5 * Φ Vc≤ Vu ≤ Φ Vc

64.42 ≤ 207.6 ≤ 128.84 …. Failed

2.

Φ Vc≤ Vu ≤ Φ Vc + Φ* Vs min

128.84≤207.6≤ 181.44 …. Failed

3.

∅(Vc+Vs min) < Vu ≤ ∅ (Vc+Vs`)

181.44 < 207.6 < 386.526 …. Control

Use 4 leg Φ 10 for stirrups … Av = 314.16 mm²

S= $\frac{Av*fy*d}{vs}$ = $\frac{314.16*420*263}{105.2*1000}$ = 329.868 mm

Select s = 15cm≤$\frac{d}{2}$ = $\frac{263}{2} = 131.5\ mm$

≤ 300 mm ok.

4.6 DESIGN OF TWO-WAY RIBBED SLAB:

4.6.1 Load calculation:

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

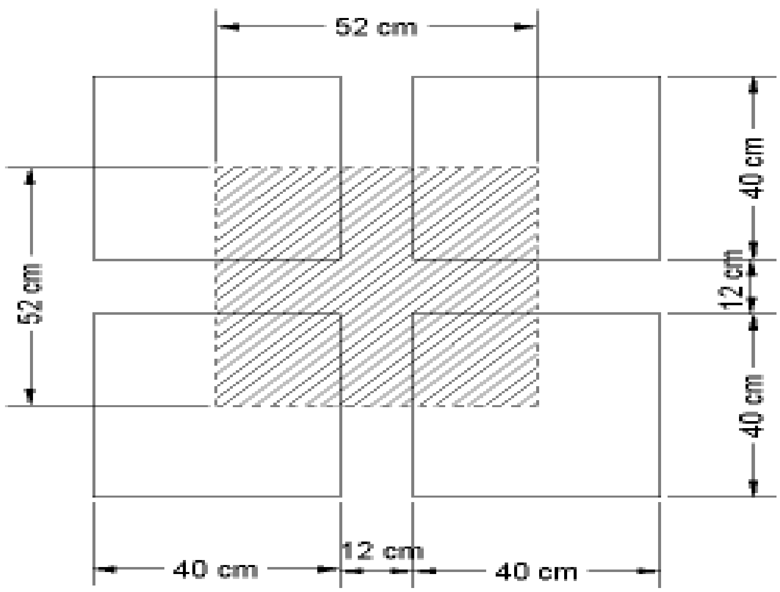

Fig. (4–10): Two way ribbed slab

Table (4 – 3): Load calculation of 2-wayribbed slab.

No.	Parts of Beam	Density	Calculation
1	Tiles	23	23*0.03*0.52*0.52=0.186 KN
2	Mortar	22	22*0.02*0.52*0.52=0.119 KN
3	Sand	17	17*0.07*0.52*0.52=0.321 KN
4	Topping	25	25*0.08*0.52*0.52=0.541 KN
5	Rib	25	25*0.24*0.12*(0.52+0.4)=0.662 KN
6	Block	10	10*0.24*0.4*0.4=0.384 KN
7	Plaster	22	22*0.02*0.52*0.52=0.119 KN
8	Partitions	1.5 KN/m^2	1.5*0.52*0.52 = 0.405 KN/m
			2.737 KN/m

Dead Load of slab = 2.737/ (0.52*0.52) = 10.12 KN/m^2.

W_D = 1.2*10.12 = 12.144 KN/m^2.

Live Load of slab = 5 KN/m^2.

W_L = 1.6*5 = 8 KN/m^2.

W= 8 + 12.144 = 20.144 KN/m^2.

4.6.2 Moments calculations:

$M_a = C_a * W L_a^2$

$M_b = C_b * W L_b^2$

All negative and positive coefficients from tables.

L_a/L_b= 5.0/4.7 = 1.0638

- **Negative Moment:**

$$C_{a,neg} = 0.033$$
$$C_{b,neg} = 0.061$$

$$\boldsymbol{M_{a,neg} = (0.033 * 20.144 * 5.0^2) = 16.615\ KN.m}$$
$$\boldsymbol{M_{b,neg} = (0.061 * 20.144 * 4.7^2) = 27.221\ KN.m}$$

- **Positive Moment:**

$$C_{aD,pos} = 0.02$$
$$C_{bD,pos} = 0.023$$
$$C_{aL,pos} = 0.028$$
$$C_{bL,pos} = 0.03$$

$$M_{a,pos,(dl+ll)} = (0.02 * 12.144 * 5^2 + 0.028 * 8 * 5^2) = 11.67\ KN.m$$

$$M_{b,pos,(dl+ll)} = (0.023 * 12.144 * 4.7^2 + 0.03 * 8 * 4.7^2) = 11.5\ KN.m$$

4.6.3 Slab reinforcement:

- **Design of negative moment , M_u = 27.221 KN.m**

M_n = 27.221/0.9 = 30.24 KN.m

Assume bar diameter D=14 mm for main reinforcement.

$$d = 320 - 20 - 8 - 7 = 285\,mm$$

$$Rn = \frac{Mn}{b*d^2} = \frac{30.24\times10^6}{120\times285^2} = 3.1 Mpa$$

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

$$\rho = \frac{1}{20.6}(1 - \sqrt{1 - \frac{2\times20.6\times3.1}{420}}) = 8.04\times10^{-3}$$

$$As_{req} = 8.04\times10^{-3}\times120\times285 = 275 mm^2$$

$$As_{\min} = \frac{\sqrt{24}}{4(420)}(120)(285) \geq \frac{1.4}{420}(120)(285)$$

$A_{s,min}$ = 114 mm^2 < $A_{s,req}$= 275 mm^2.

Use 2Ø 14 in both direction with A_s= 307.9 mm^2> 275 mm^2

- **Check for strain :**

As * fy = 0.85 * f_c * b * a

307.9*420=0.85*24*120*a

a=52.83 mm.

$$x = \frac{a}{\beta_1} = \frac{52.83}{0.85} = 62.15 mm.$$

$$\varepsilon_s = \frac{285 - 62.15}{62.15} \times 0.003$$

$$\varepsilon_s = 0.0108 > 0.005$$

∴∅ = 0.9 …. OK

❖ Design of positive moment = M_u^- = 11.67 KN.m.

M_n = 11.67/0.9 = 13 KN.m

Assume bar diameter D=12 mm for main reinforcement.

$$d = 320 - 20 - 8 - 6 = 286 mm$$

$$Rn = \frac{Mn}{b * d^2} = \frac{13 \times 10^6}{120 \times 286^2} = 1.32 Mpa$$

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

$$\rho = \frac{1}{20.6}(1 - \sqrt{1 - \frac{2 \times 20.6 \times 1.32}{420}}) = 3.26 \times 10^{-3}$$

$$As_{req} = 3.26 \times 10^{-3} \times 120 \times 286 = 111.88 mm^2$$

$$As_{\min} = \frac{\sqrt{24}}{4(420)}(120)(285) \geq \frac{1.4}{420}(120)(285)$$

$A_{s,min}$ = 114 mm^2 > $A_{s,req}$ = 111.88 mm^2

Use 2∅ 12 in both direction with A_s= 226.2 mm^2> 114 mm^2

❖ Check for strain :-

As * fy = 0.85 * f_c * b * a

226.2*420=0.85*24*120*a

a=38.8 mm.

$$x = \frac{a}{\beta_1} = \frac{38.8}{0.85} = 45.65mm.$$

$$\varepsilon_s = \frac{286-45.65}{45.65} \times 0.003$$

$$\varepsilon_s = 0.0158 > 0.005$$

∴∅ = 0.9 …. OK

4.7 DESIGN OF LONG COLUMN:

4.7.1 Dimension of column:

Pu = 2435.6 KN

Pn = 2435.6/ (0.65) = 3747 KN

Assume $\rho g = 1.35$ %

$$Pn = 0.8 * Ag\{0.85 * fc' + \rho g(fy - 0.85 fc')\}$$
$$3747 = 0.8 * Ag[0.85 * 24 + 0.01 * (420 - 0.85 * 24)]$$
$$Ag = 1919.8 cm^2$$

Assume rectangular column

Use 50*45cm with Ag = 2250cm^2 >Ag req = 1919 cm^2.

4.7.2 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 = 3.6 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.

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

$$\frac{1*3.6}{0.3*0.5} = 24 > 22$$

$$\therefore long\ Coloumn$$

Slenderness is consider

$$EI = 0.4\frac{E_c I_g}{1+\beta_d} \quad ....[ACI318-2002\ (Eq.\ 10-15)]$$

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

$$\beta_d = \frac{1.2DL}{Pu} = \frac{1717.2}{2435.6} = 0.70$$

$$I_g = \frac{b*h^3}{12} = \frac{0.5*0.45^3}{12} = 0.00379m^4$$

$$EI = \frac{0.4*23270.15*10^6*0.00379}{1+0.70} = 20.75MN.m^2$$

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

$$P_c = \frac{3.14^2*20.75}{(1.0*3.6)^2} = 15.78MN.$$

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

$$Cm = 1\ ....According\ to\ ACI318-2002(10.10.6.4)$$

$$\delta_{ns} = \frac{Cm}{1-(Pu/0.75P_c)} \geq 1.0 \quad ....ACI318-2002(Eq.\ 10-12)$$

$$\delta_{ns} = \frac{1}{1-(2435.6/0.75*15.78*10^3)} = 1.26 > 1$$

$$e_{\min} = 15 + 0.03*h = 15 + 0.03*450 = 28.5mm = 0.0285m$$

$$e = e_{\min}\times\delta_{ns} = 0.0285*1.21 = 0.034$$

$$\frac{e}{h} = \frac{0.034}{0.45} = 0.075$$

$$From \quad Interaction \quad Diagram$$

$$\frac{\phi P_n}{A_g} = \frac{2435.6}{0.45*0.5} * \frac{145}{1000} = 1569.6 Psi$$

$$\rho_g = 0.015$$

$A_s = \rho * Ag = 0.0135*500*450 = 3038mm^2$

Use 10 Φ 20 with As = 3140mm² >As req = 3038mm².

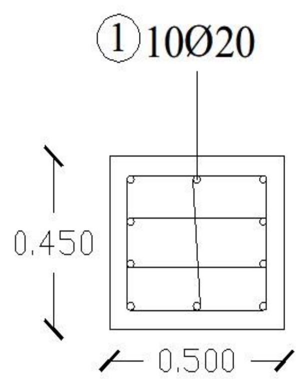

Figure (4–11): Column Section

4.7.3 Design of the Tie Reinforcement:

For Φ 10 mm ties:

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

$S \leq 48$ dt (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 @20

And use Φ10 @10 for end.

4.8 Design of Stair:

4.8.1 Limitation of deflection:

h min= 3.91 / 20 = 19.5 cm

Select h = 20 cm

Tanϕ = 17 /30

ϕ = 29.5

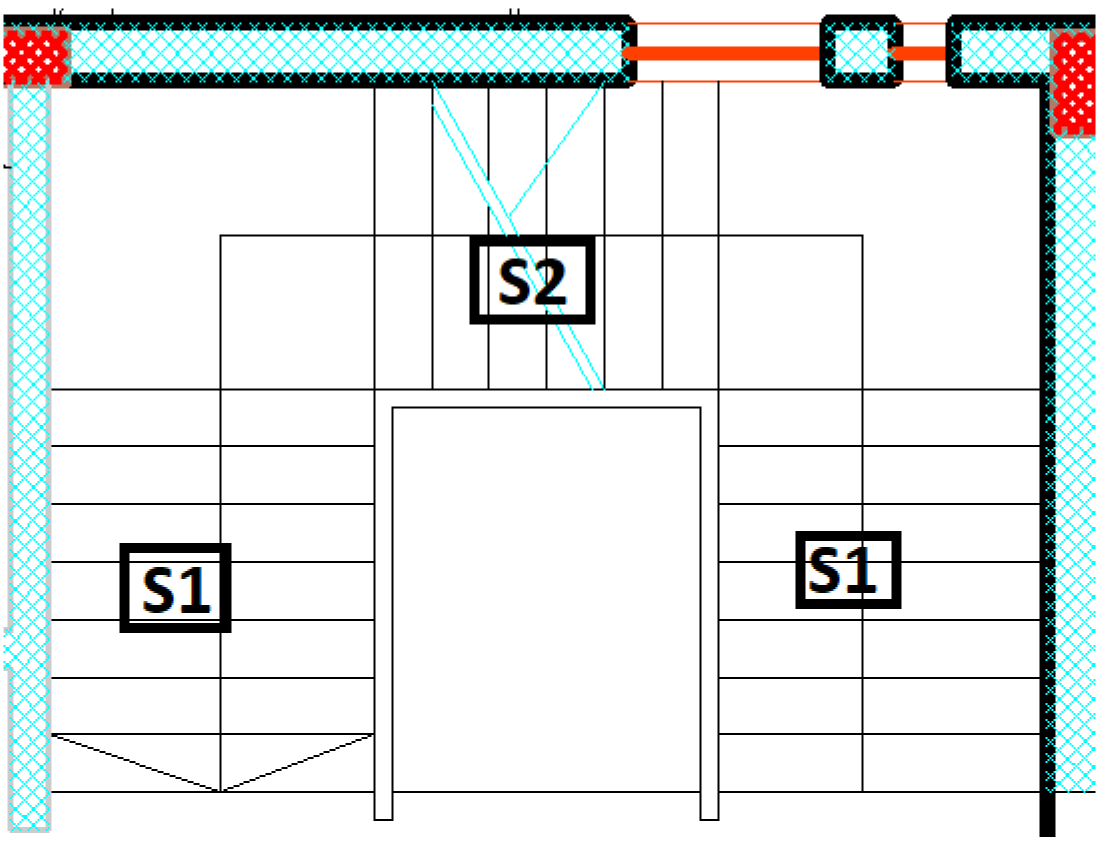

Figure (4-12): The shape of Stair

4.8.2 Calculation of load:

(Note: calculation for 1 meter strip)

Table (4 – 4): Calculation flight dead load.

No.	Parts of Beam	Density	Calculation
1	Tiles	23	**23*((0.17+0.35)/0.3)*0.03*1=1.196 KN/m**
2	Mortar	22	**22*((0.15+0.3)/0.3)*0.02*1=0.69 KN/m**
3	Stair steps	25	**(25/0.3)*(0.17*0.3/2)*1= 2.125 KN/m**
4	R.C solid slab	25	**(25*0.20*1)/cos29.5=5.75 KN/m**
5	Plaster	22	**(22*0.03*1)/cos29.5 = 0.76 KN/m**
			10.521 KN/m

Table (4 – 5): Calculation landing dead load.

No.	Parts of Beam	Density	Calculation
1	Tiles	23	**23*0.03*1=0.69 KN/m**
2	Mortar	22	**22*0.02*1=0.44 KN/m**
3	R.C solid slab	25	**25*0.2*1=5 KN/m**
4	Plaster	22	**(22*0.03*1)/cos29.5 = 0.76 KN/m**
			6.89 KN/m

L.L= 5 KN/m^2.

Total factored load:

For flight w = 1.2D +1.6L = 1.2*10.521+1.6*5= 20.625 KN/m.

For landing w = 1.2*6.89+1.6*5=16.268 KN/m.

4.8.3 Design of slab (1):

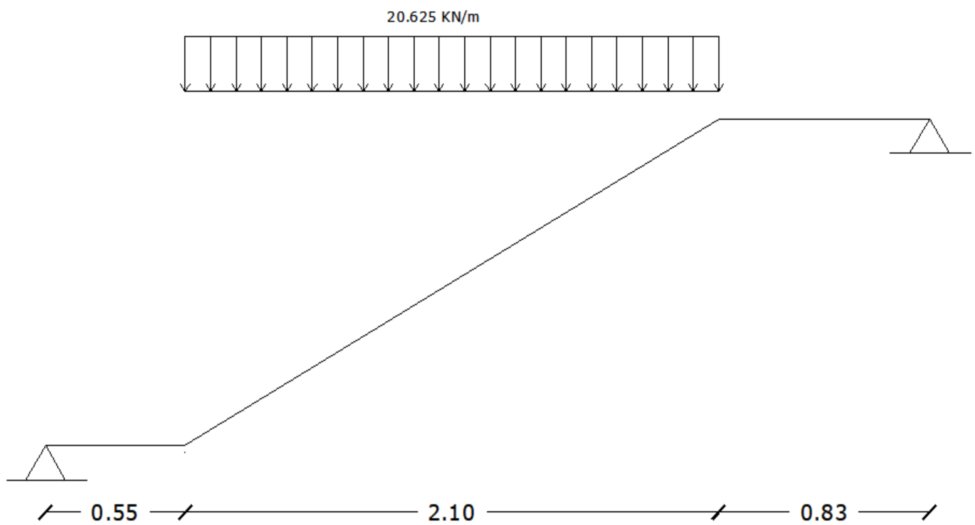

Figure (4-13): System of stair slab 1.

4.8.3.1 Design of shear forces:

The reaction at each end:

R= W*L/2 = (20.625*2.1)/2 = 21.656 KN.

Assume bar diameter 12 mm.

Max Vu = 22 KN/m.

d=200 -20 - 6 = 174 mm

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

h is correct.

4.8.3.2 Design of bending moment:

Max Mu = (22 *1.9) – (20.96 *1.05^2*0.5) = 30.43 KN.m

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

Rn = $\frac{30.43*10^6/0.9}{1000*(174)^2}$ = 1.11 MPa

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

ρ = $\frac{1}{20.59}$ (1 - $\sqrt{1-\frac{2(20.59)(1.11)}{420}}$) = 0.00271

As req = ρ * b * d = 0.00271* 100 *17.4 = 4.71 cm^2/m.

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

As req>As min

Select Φ12@ 10 cm with A_s = 11.3 cm^2/m.

4.8.3.3 Check of strain:

Tension = compression

As * fy = 0.85 * f_c * b * a

113*420=0.85*24*1000*a

a=2.326 mm.

$$x=\frac{a}{\beta_1}=\frac{2.326}{0.85}=2.737\,mm\,.$$

$$\varepsilon_S = \frac{174-2.737}{2.737} \times 0.003$$

$$\varepsilon_S = 0.1877 > 0.005$$

∴∅ = 0.9 …. OK.

4.8.4 Design of slab (2):

W_R= R_{s1}/B = 22/1.65 = 13.3 KN/m.

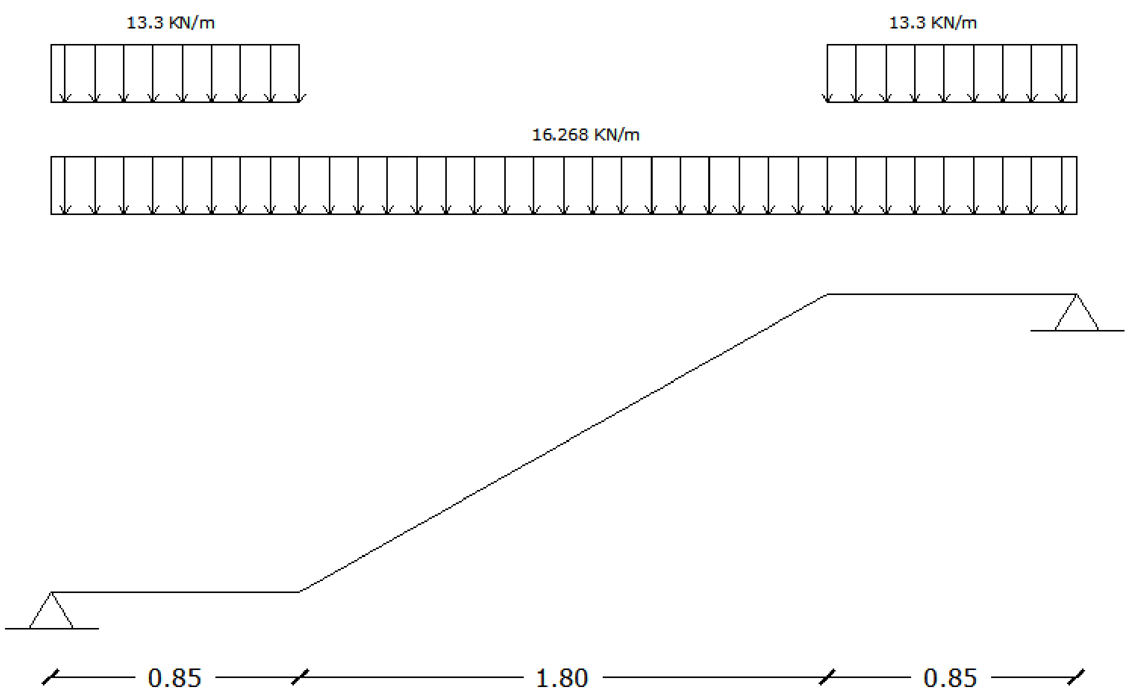

Figure (4-14): System of stair slab 2.

4.8.4.1 Design of shear forces:

R= ((16.268*3.5)/2) + (13.3*0.85) = 39.77 KN.

d=200 -20 - 6 = 174 mm

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

h is correct.

4.8.4.2 Design of bending moment:

Max Mu = (39.77*1.75) – (16.268*1.75^2*0.5) – 13.3*0.85*((0.85/2) +0.9) = 29.7 KN.m

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

Rn = $\frac{29.7*10^6/0.9}{1000*(174)^2}$ = 1.08 MPa

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

ρ = $\frac{1}{20.59}$ (1 - $\sqrt{1-\frac{2(20.59)(1.08)}{420}}$) = 0.00264

As req = ρ * b * d = 0.00264* 100 *17.4 = 4.6 cm^2/m.

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

As req>As min

Select Φ12@ 10 cm with A_s = 11.3 cm^2/m.

4.8.4.3 Check of strain:

Tension = compression

As * fy = 0.85 * f_c * b * a

113*420=0.85*24*1000*a

a=2.326 mm.

$$x = \frac{a}{\beta_1} = \frac{2.326}{0.85} = 2.737\,mm\,.$$

$$\varepsilon_s = \frac{174 - 2.737}{2.737} \times 0.003$$

$$\varepsilon_s = 0.1877 > 0.005$$

∴∅ = 0.9 …. OK.

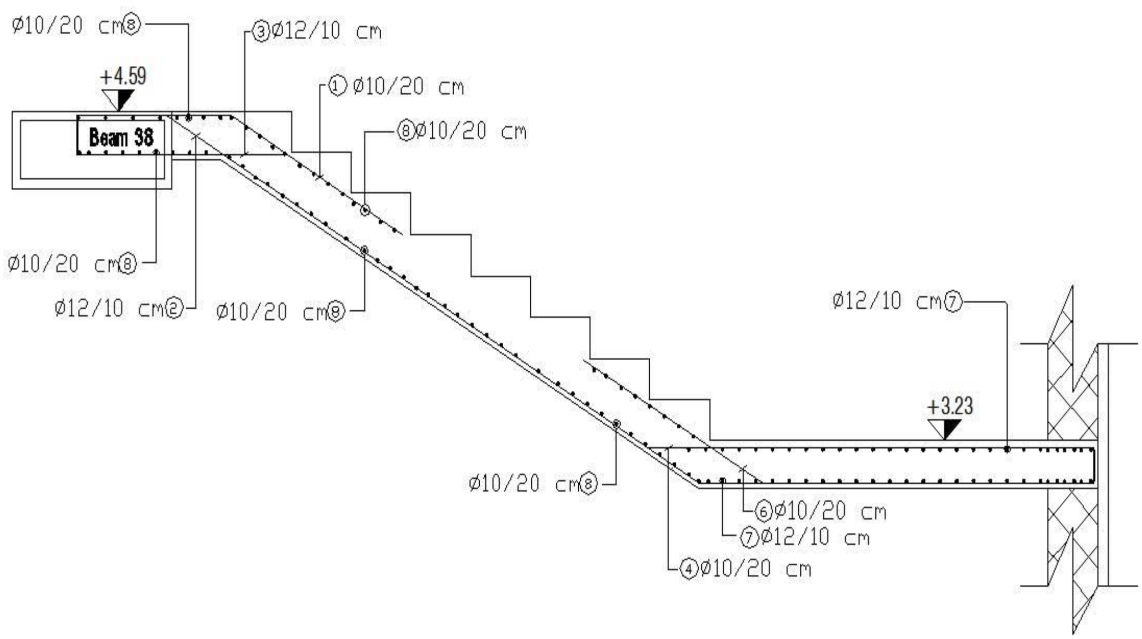

Figure (4-15): Detailing of stair slab 1.

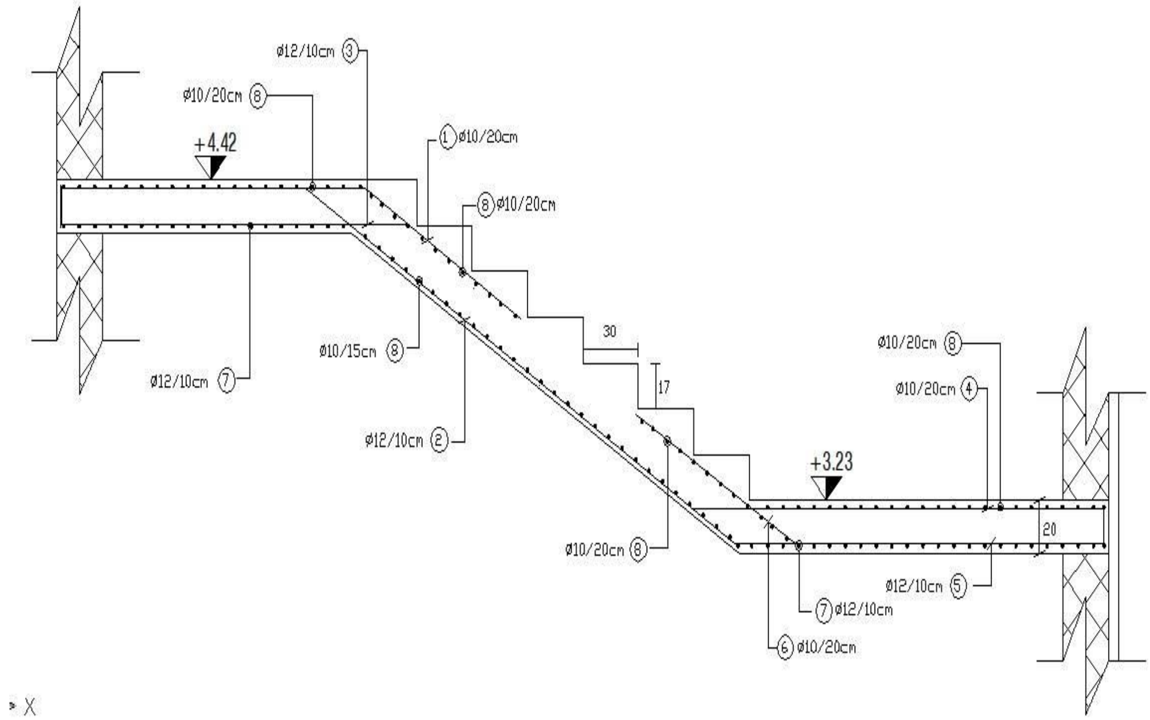

Figure (4-16): Detailing of stair slab 2.

4.9 DESIGN OF BASEMENT WALL:

4.9.1 Loads on basement wall:

q1 = Earth pressure soil

q1= γ * h * k0

K0 = 1 – sin 30 = 0.5

q1= 18 * 3.06* 0.5 = 27.54 KN/m^2

Factored load (qu) =1.6 * q1 = 1.6 * 27.54 = 44 KN/m^2

h wall = 30 cm.

4.9.2 Design of shear force:

From atir Vu = 45 KN

d=300 -20 – 14/2 = 274 mm.

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

(h =30 is correct).

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

Rn = $\frac{28.2*10^6/0.9}{1000*(274)^2}$ = 0.42 MPa

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

ρ = $\frac{1}{20.59}$ (1 - $\sqrt{1-\frac{2(20.59)(0.42)}{420}}$) = 0.001

As req = ρ * b * d = 0.001* 100 *27.4 = 2.74 cm²/m.

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

As min >As req

Select Φ10@ 20 cm .As provided =3.95 cm²/m

4.9.3.2 Design of the horizontal reinforcement in tension side:

For One layer:

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

Select Φ10@ 20 cm. As provided =3.9 cm²/m

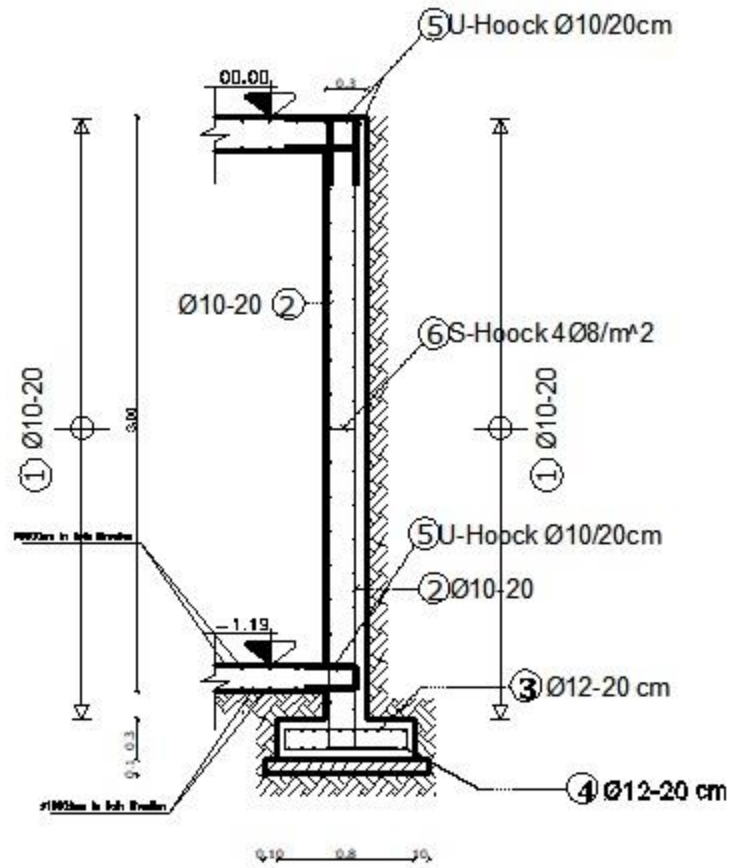

Figure (4-17): Detailing of Basement Wall.

4.10 Design of Basement footing:

Total factored load in basement = 1.2*(11.42*25*0.3) = 102.78 KN/m

Soil density = 18 KN/m3

Allowable soil Pressure = 450 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* 18 = 86.4 KN/m^2

$q_{allow,net}$ = 450 – 86.4- 12=351.6KN/m2

Assume b =0.8 m, h =0.3 m

d= 300 – 75 – 12 = 213 mm.

4.10.1 Design of One Way Shear:

q_{ult} = 30 / (1* 0.8)= 37.5 KN/m^2

Vu = 1* (0.25–0.213) *37.5 = 1.388 KN

$$\Phi * Vc = 0.75 * \frac{\sqrt{fc'}}{6} bw * d = 0.75 * \frac{\sqrt{24}}{6} * 213 * 1000 = 130.44 \text{ KN}$$

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

4.10.2 Design of Bending Moment:

Mu = 37.5 * $(0.25)^2$ *0.5 = 1.172 KN.m

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

Rn = $\frac{1.172*10^6/0.9}{1000*(213)^2}$ = 0.0287 MPa

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

ρ = $\frac{1}{20.59}$ (1 - $\sqrt{1-\frac{2(20.59)(0.0287)}{420}}$) = 0.000068

As req = ρ * b * d = 0.000068* 100 *21.3 = 0.14566 cm²/m.

As min = 0.0018 * b * h = 0.0018*100 * 30 = 5.4 cm²/m

As min >Asreq

Select Φ12@ 20. As provided = 5.652 cm²/m

<u>In lateral direction:</u> As min = 0.0018 * b * h = 0.0018*100 * 30 = 5.4 cm²/m

Select Φ12@ 20. As provided =5.652 cm²/m.

4.11 DESIGN OF ISOLATED FOUNDATION (F7):

4.11.1 DETERMINATION OF FOOTING DIMENTIONS:

Factored load = 4257 KN

Soil density = 18 KN/m3

Allowable soil Pressure = 450 KN/m2

Assume h =0.75 m

Footing weight = (25*0.75) =18.75 KN/m^2

Allowable soil Pressure net = 450 – 18.75 = 431.25 KN/m^2

$q \leq q_{allow.\ net}$

$\leq 1.4 * q_{net}$ = 1.4 * 431.25 = 603.75 KN/m^2

Assume square footing

603.75 = 4257/a*a

a= 2.655 m, area = 7.05 m^2

4352/7.05 = 617.3

603.75 ≤617.3 …. (Ok)

Take Square Footing with b=2.7m.

4.11.2 Design against sliding:

Horizontal Force = 0.0 (not required to check)

4.11.3 Design of reinforcement concrete:

❖ **Check for one way shear:**

Cover = 75 mm, Φ =20 mm, thickness = 750 mm

d= 750 – 75 – 20 = 655 mm

Vu = 0.287 *617.3*2.7 = 478.345 KN

$\Phi * V_c = 0.75 * \frac{\sqrt{fc'}}{6} bw * d = 0.75 * \frac{\sqrt{24}}{6} * 2700 * 655 = 1082.98 > Vu$

So h is correct.

❖ **Check for two way shear (punching):**

d= 655 mm

Vu = 4257 - (617.3 * 0.863[2)] = 3797.25 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: $\beta_C = \frac{Column\ Length\ (a)}{Column\ Width\ (b)} = \frac{50}{45} = 1.11$

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

$b_o = 2(d + a1) + 2(d + a2) = 2(655 + 500) + 2(655 + 450) = 4520mm$

α_s = 40 for interior column

$$\phi.V_C = \phi.\frac{1}{6}\left(1+\frac{2}{\beta_c}\right)\sqrt{f_c'}\,b_o d = \frac{0.75}{6}*\left(1+\frac{2}{1.11}\right)*\sqrt{24}*4520*655 = 5079.638KN$$

$$\phi.V_C = \phi.\frac{1}{12}\left(\frac{\alpha_s * d}{b_o}+2\right)\sqrt{f_c'}\,b_o d = \frac{0.75}{12}*\left(\frac{40*655}{4520}+2\right)*\sqrt{24}*4520*655 = 7067.451KN$$

$$\phi.V_C = \phi.\frac{1}{3}\sqrt{f_c'}\,b_o d = \frac{0.75}{3}*\sqrt{24}*4520*655 = 3825.979KN$$

$\phi.V_C = 3825.979KN$ .... *Control*

$Vu = 3797.25KN$

$\phi.Vc = 3696.25KN > Vu = 3797.25KN$........ *satisfied*

❖ Design of Bending Moment:-

$$Mu = 603.75*2.7*1.1*1.1/2 = 986.22kN.m$$

Mu = 986.22 KN.m

$d = 750-75-20 = 655\,mm$

$$Rn = \frac{Mn}{b*d^2} = \frac{(986.22/0.9)\times 10^6}{2700\times 655^2} = 0.946Mpa$$

$$m = \frac{Fy}{0.85fc'} = \frac{420}{0.85\times 24} = 20.59$$

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

$$\rho = \frac{1}{20.59}(1-\sqrt{1-\frac{2\times 20.59\times 0.323}{420}}) = 2.31\times 10^{-3}$$

$$As_{req} = 2.31\times 10^{-3}\times 2700\times 655 = 4080.2mm^2$$

$$As_{\min} = 0.0018*2700*750 = 3645mm^2$$

$$As_{req} = 4080.2mm^2 > As_{\min} = 3645mm^2$$

$$\#of\,bar = \frac{4080.2}{314.16} = 13bars$$

Select 13 Φ20 $A_{s,prov}$ = 4084.07mm²

❖ **Check for strain :-**

As * fy = 0.85 * f_c * b * a

4084.07*420=0.85*24*2700*a

a= 31.142 mm.

$$x = \frac{a}{\beta_1} = \frac{31.142}{0.85} = 36.6mm.$$

$$\varepsilon_s = \frac{655 - 36.6}{36.6} \times 0.003$$

$$\varepsilon_s = 0.05068 > 0.005$$

∴∅ = 0.9 …. OK.

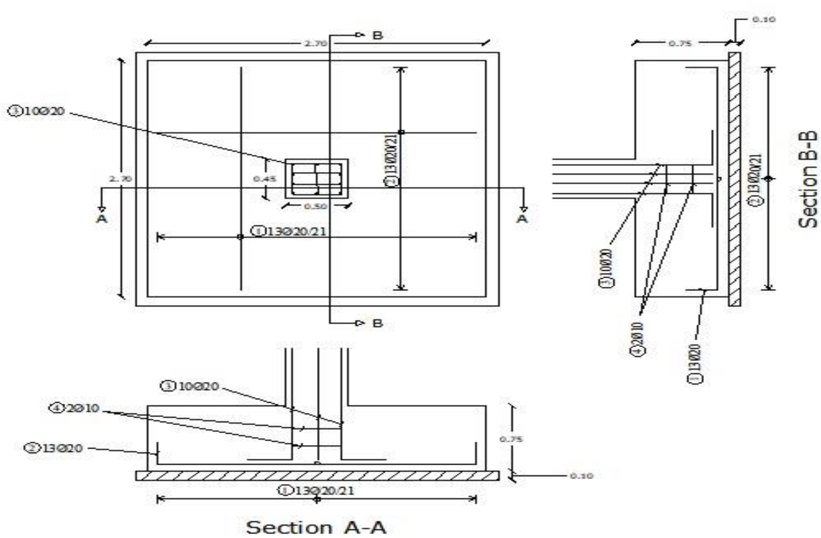

Figure (4-18): Detailing of isolated foundation.

4.12 DESIGN OF SHEAR WALL (SW10):

h_w = 11.73 m

L_w = 3.8 m

Thickness = 0.3 m

d≤ 0.8* L_w = 0.8 *3.8= 3.04 m … control

d≤ 0.8*h_w = 0.8 * 11.73 = 9.38 m

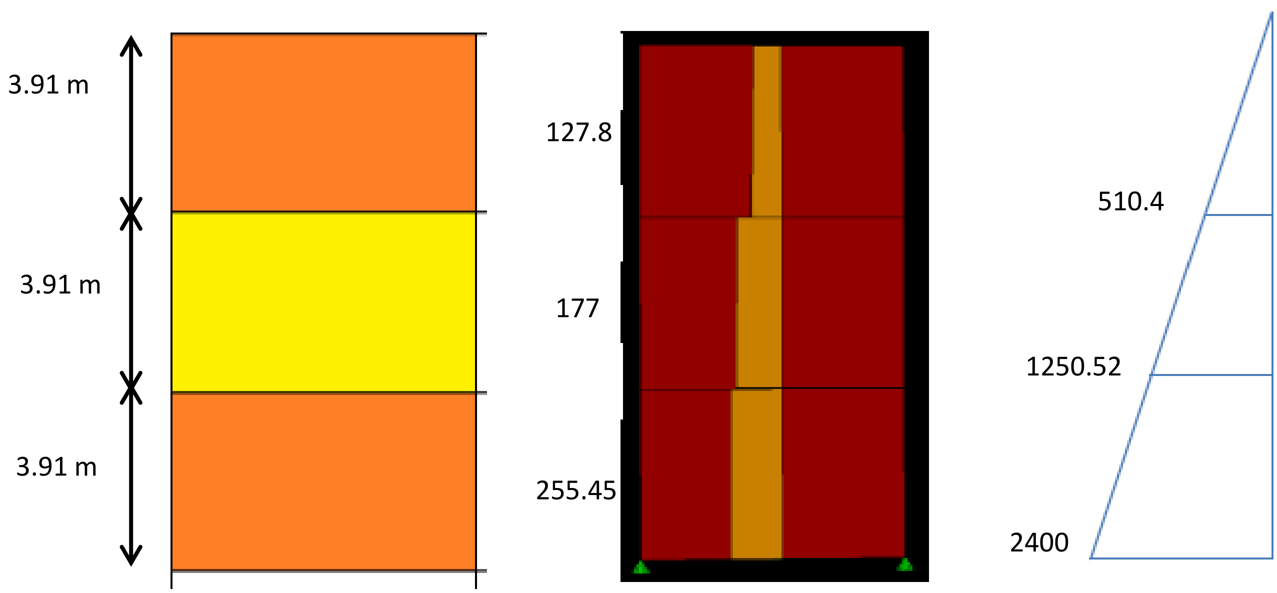

Figure (4–19) Shear force and moment on the wall from ETABS

L_w / 2 = 1.9 m …… control

h_w / 2 = 5.865 m

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

$$V_{c1} = \frac{\sqrt{24}}{6} \times 300 \times 3040 = 744.644 KN (control)$$

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

$$N_u = 0.0 KN$$

$$V_{c2} = \frac{\sqrt{24} \times 300 \times 3040}{4} + 0.0 = 1116.96 KN$$

So thickness of wall is safe.

- **Design for horizontal reinforcement :**

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

A_{vh} = 2 Φ 10 = 158 mm^2

$$\left(\frac{2*79}{s}\right) = 0.75$$

S = 210 mm

Smax ≤ L_w/5 = 3800 /5 = 760 mm

≤ 450 mm

≤ 3 * h = 3*300= 900 mm

Take s = 200 mm < s max

Select Φ10/20 cm

- **Design for Vertical reinforcement:**

$A_{vh}\ \min. = 0.0015 * s * h$

A_{vh} = 2 Φ 10 =158 mm^2

$$\left(\frac{2*79}{s}\right) = 0.45$$

S = 350 mm

Smax ≤ L_w/5 = 3800 /5 = 760 mm

≤ 450 mm

≤ 3 * h = 3*300= 900 mm

Take s = 200 mm < s max

Select Φ10/20 cm

- **Design of bending moment:**

$$Mu = 1250.52 + 255.45 * (3.91 - 1.9) = 1764 KN.m$$

$$C > \left(\frac{Lw}{0.007*600}\right) = \frac{3800}{4.2} = 904.76mm$$

$$length\ \ of\ \ boundary\ \ element = C - 0.1 \times L_w$$
$$length\ \ of\ \ boundary\ \ element = 904.76 - 0.1 \times 3800 = 524.76mm$$

$$C_w = \frac{C}{2.0} = \frac{904.76}{2.0} = 452.38mm$$

Select the boundary element = 600mm

Avs= $\frac{Lw}{s1} \times As_v \longrightarrow = \frac{2*79}{200} \times 3800 = 3002mm^2$

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

$$\frac{Z}{Lw} = \frac{1}{2 + 0.85 \times 0.85 \times 24 \times 3800 \times 300/(3002 \times 420)} = 0.0566$$

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

$$Muv = 0.9 * 420 * 0.5 * 3002 \times 3800 * (1 - (0.0566/2)) = 2095 KN.m$$

$$Muv \quad > Mu$$

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

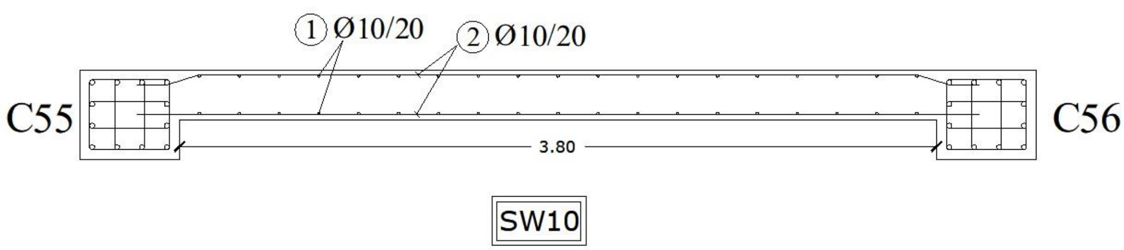

Figure (4–20): Detailing of shear wall

CHAPTER

5

Results and Recommendations

5.1 The Results

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	الحم ل الم وزع	الحمل المركز البديل
ع ام	خاص	الاشغ ال	كن/م٢	كن
تابع المباذ ي التعليمية وماشابهها.	تابع السجون والمستشفيات والمدارس والكليات.	أماكن التكديس الكثيف للكتب عل ى عرب ات متحركة.	4.8 لكل متر من ارتفا ع التخ زين على أن لا يقل عن (10).	7.0
		غرف تكديس الكتب.	2.4 لكل متر من ارتفا ع التخزين على أن لا يقل عن (6.5).	7.0
		مستودعات القرطاسية.	4 لكل متر من ارتفا ع التخزين.	9.0
		الممرات والمداخل المعرضة لحرك ـ ة المركب ـ ات 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 م ن أجهزة، والمطابخ وغرف الغسيل.	3.0	4.5
		المم ـ رات والم ـ داخل والأدراج و ب ـ سطات الأدراج الثانوي 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.