Structural Design of Al-Salam Hospital

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Abstract

Dura is a Town in Hebron which is located 6 km to the west of Hebron city. the town had a population of over 28,268. The total area of Dura town is estimated to be 17,600 dunums, of which 7,100 are built-up areas 8,220 are agricultural lands, and 1,270 are forests, uncultivated areas, or public lands. Patient suffer due to lack of hospital in Dura, they need to go to hebron for treatment, so from this point we decide to design hospital. Our project aims to have the ability and knowledge of the design of some components of a hospital locates in Dura, consist of 5 stories (basement, ground, first, second and third floor). ACI-318-11 will be used in the design while the Jordanian code will be adopted in the calculation of loads. The design will be done both manually and using available software. In this semester we were studied the architecture design, the units structurally to identify structural elements, loads on the buildings, and selected the appropriate structural system, we designed one beam and one rib and we will design all of structural members in the graduation project course.

الإهداء

نُهدي هذا العَمل المُتواضِع..

لِمَن عَمِلنا لِأجلِها ..لِتُرابها وَ سَمائِها وَ مِياهِها..

لِلأقصى، لِلقُدس،للأسرى والشهداء، لِفِلسطين، وَلِلأُمة الإسلامِيَّة.

لِكُل مَن دَعمَنا وَ وَقفَ بِجانِبنا...

إلى مَن جَرَع الكَأس فارغاً لِيُسقيني قطرةَ حُب...

إلى مَن كلّت أنامِلُهُ لِيُقدِم لِي لَحظة سَعادة..

إلى مَن حَصَدَ الأشواك عَن دَربي لِيُمَهدَ لِي طَريق العِلم

إلى القَلبِ الكَبير (وَالدي العَزيز).

إلى مَن تَتَسابَق الكَلمات لِتَخرج مُعبرة عَن مَكنون ذاتِها...
مَن عَلَمَتني وَعانَت الصِّعاب لِأصِل إلى ما أنا فيه

أنتِ يا أُمي حَياتي كُلها، لكِ مِني فُؤادي فاقبَلِيهِ ....

إلى مَن وَقفَ على المَنابِر وَ أعطى مِن حَصيلة فِكره لِيُنير دُربنا ...

إلى الأساتِذَةِ الكِرام ...

لِزَميلاتِنا وَ زُمَلائِنا مُهَندِسي وَ مُهَندِسات المُستَقبَل ....

إليكُم جَميعاً نُهدي فاتِحَة العَطاء ....**على أَمل اللِقاء بِإذن الله تَعالى.**

الشكر

للشُكر أولاً وآخراً □ِ سُبحانَه وَتَعالى، الذي مَنّ□ عَلينا مِن فَضلِه،

وَ أتمّ□ عَلينا نِعَمِه وَ أعطانا مِن كَرَمِه، وَ عَلّمَنا مِن عِلمِه

وَ كُل الشُكر لدائرة الهَندَسة المدنية والمعمارية مُمَثلة بكَوادِرِها إداريين وَ أكاديميين،

وَ نَخُص بِالذكر المهندس فهد صلاحات....

أمُعَلِمي مَا ليسَ تكفيك حُروف أو جُمل فلقد تَعِبتَ مِثلنا وا□ يَجزي بِالعمل

وَ إلى زَميلاتنا رَفيقات الروح وَ مُهَندِسات المُستَقبَل كُل الشُكر...

إن لَم نقُل شُكراً لكُم سَيَقُولها قلبي لِمَن ؟

وختام القول مسك، فكل الشكر لآبائنا وأمهاتنا أصحاب الدور الأبرز في الوصول إلى ما وصلنا إليه....

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List of Abbreviation

- **Ac** = area of concrete section resisting shear transfer.
- **As** = area of non-prestressed 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-prestressed 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 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).

- **k** = is a factor that depends on end condition of column and whether it is braced or unbraced
- **ln =** unsupported length of column
- **r** = radius of gyration
- $\frac{\mathbf{k\,ln}}{\mathbf{r}}$= slenderness ratio
- **M1& M2** = factored end moments of the column
- $\mathbf{e_{min}}$ = minimum eccentricity
- $\mathbf{M_{min}}$ = minimum moment
- $\mathbf{I_g}$ = gross moment of inertia of the section
- $\mathbf{I_{se}}$ =moment of inertia of the reinforcement steel
- $\boldsymbol{\beta_{dns}}$ =ratio of maximum factored sustained shear within a story to the total factored shear in that story
- **EI**= member stiffness
- **Pc** = Euler buckling load
- $\boldsymbol{\delta_{ns}}$= moment magnifier factor
- **C m** = factor
- $\boldsymbol{\gamma}$ =the ratio of the distance between the centers of the outside layers of bars to the overall depth of the column
- **h min**= Minimum thickness of slab
- **αf**= The ratio of flexural stiffness of a beams on the beam section to the flexural stiffness of the slab.
- **Afm**= The average value of αf for all beams on the sides panel.
- **Lnc**= Clear span in the long direction measured face to face of the columns or (face to face of beams for slabs with beams.
- **B**= the ratio of the load to the short clear spans.
- $\boldsymbol{Cad_{pos}}$= Coefficients for dead load positive moment in short clear length of slabs.
- $\boldsymbol{Call_{pos}}$=Coefficients for live load positive moment in short clear length of slabs.
- **S** = Spacing of shear or in direction parallel to longitudinal reinforcement
- **Vc** = Nominal shear strength provided by concrete

- **Vs** = Nominal shear strength provided by shear reinforcement

Chapter One

Proposal

1.1 INTRODUCTION.

1.2 RESEARCH PROBLEM

1.3 AN OVERVIEW OF THE PROJECT

1.4 THE OBJECTIVE OF THE PROJECT

1.5 PROJECT STEPS

1.6 REASONS TO CHOOSE PROJECT

1.7 THE SCOPE OF THE PROJECT

1.8 ACTION PLAN

1.1 Introduction

Human nature needs to have places of curing in place of residence, and these places must have all the means to ensure comfort and safety. General design process requires the introduction of all aspects of the building to be created both in the architectural appearance of the building and how to distribute the spaces and areas within various service sections linked to each other, or structural terms dealing with structural system capable of carrying the loads affecting the building taking into account the minimum possible economical system construction as is compatible with the architectural design choice.

The project includes the architectural and structural design of Emergency department, Pharmacy, Department of Radiology, operation department, CCU, Bones department, Ear nose and throat department, Obstetrics and Gynecology department, laboratory and blood bank, Internal Medicine Department, gases room, boilers room, laundry, maintenance, stores and shops. 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 implementation.

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

1.3 An Overview of the Project

This project includes the structural design of Emergency department, Pharmacy, Department of Radiology, operation department, CCU, Bones department, Ear nose and throat department, Obstetrics and Gynecology department, Children department, laboratory and blood bank, Internal Medicine Department, gases room, boilers room, laundry, maintenance, stores shops and Patient rooms that fulfilled all the requirements for comfort and safety according to usage requirements.

<u>Basement Floor:</u>

Gases room, Boilers room, Laundry, Maintenance and Stores.

Ground Floor:

Clinics departments have an area of 625 m^2.

Emergency department has an area of568m^2.

Department of Radiology has an area of 264 m^2.

Blood bank and laboratory have an area of 124 m^2.

Administration department has an area of 380.1 m^2

Shops have an area of 79.1 $m^{2.}$.

Cafeteria has an area of 103.6 m^2.

First Floor:

Operation department has an area of 1733m^2.

Bones department has an area of 625 m^2.

Second Floor:

Ear nose and throat department has an area of 675 m^2.

Obstetrics and Gynecology department has an area of 1066 m^2.

Third Floor:

Internal Medicine Department has an area of 1066 m^2.

Children department has an area of 675 m^2.

1.4 The Objective of the Project

The objectives of the project are divided into two parts:

- Architectural Goals:

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

- Structural Goals:

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

1.5 Project Steps

1. Architecture design (construction drawings, elevations, sections, public location).
2. Study the units structurally to identify structural elements, loads on the buildings, and the selection of appropriate structural system.
3. Distribute columns to the chosen structural system.
4. Structural analysis of all structural elements of the units.
5. Structural design of all structural elements.
6. Preparation of construction drawings of the building to remove the executable image.
7. Writing project in accordance with the requirements of the construction engineering.

1.6 Reasons to Choose the Project

The reason of selecting the project back to several things, including the conquest of skill in design for structural elements in buildings, in addition to increase the knowledge of construction systems in our country and other countries, as well as the conquest of 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.

1.7 The scope of the Project

Project contains several chapters are 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 have been reached and recommendations.

1.8 Action Plan

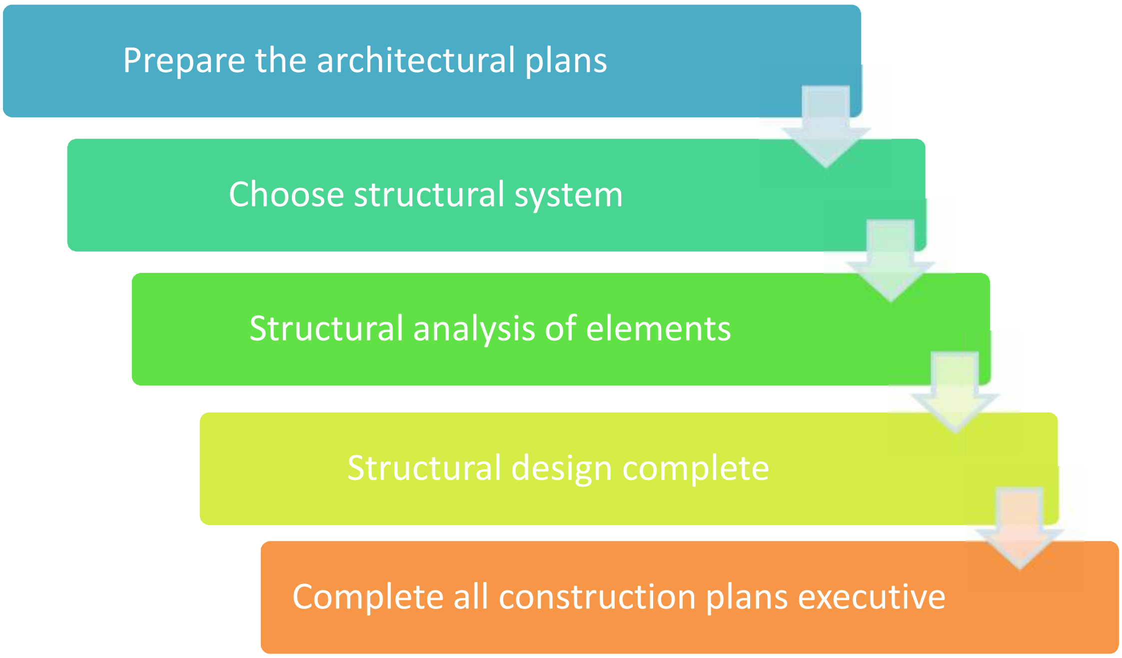


Figure (1.1): The Stages of The Project.

Table (1.1): Time Table

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							■	■																								
Architectural study									■	■	■																					
Structural study											■	■	■																			
Prepare the introduction														■	■																	
Display the introduction																■																
Structural analysis																	■	■	■	■	■											
Structural design																				■	■	■	■	■	■							
Prepare the project plans																										■	■	■				
Write the project																													■	■	■	
Project presentation																																■

Chapter Two
Architectural Description

2.1 INTRODUCTION.

2.2 THE MAIN ELEMENTS IN THE Al-SALAM HOSPITAL

2.2.1 INTERIOR SPACES.

2.2.2 EXTERNAL SPACES

2.3 PROJECT PLANS.

2.4 PROJECT ELEVATIONS.

2.5 PROJECT SECTIONS.

2.1 Introduction

Architectural description is the most important things that should be consider when preparing for any project because of its importance in defining and understanding the nature of the project and its sections.

Architectural design requirements task must meet the desired job and human needs in the present time, these terms are in the functional, lasting beauty and economy, it is important in these conditions can interact between each other and in harmony to achieve our vision of optimal design and get an integrated and comprehensive architectural design, and this is achieved by understanding the functional demands of the building and space as well as taking into account nature movement of each part of the project.

Architectural study that 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 picture 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 Al-Salam Hospital

The project areas is divided into internal and external spaces tied together to achieve the goals that were found for it.

2.2.1 Interior Spaces:

The interior area of the project is 4230.2m^2 and 1271.76 m^2 for movement spaces, thus the total interior spaces is 5501.9 m^2.

- Interior spaces are divided into:
- Basement Floor:
- This floor has an area of 990.8 m^2

  Gases room: 40 m^2

  Boilers room: 93 m^2

Laundry: 129.5 m^2

Maintenance: 40 m^2

Stores: 88 m

- <u>Ground Floor:</u>

- Clinics departments have an area of 625 m^2 divided into:

  Pharmacy: 42m^2

  Examination room: 232.2m^2

  Bathroom: 54.8 m^2

  Stores: 54.8 m^2

  Medicine room: 8.5m^2

- Emergency department: has an area of 54.8 m^2

  Offices: 54.8 m^2

  Files room: 4.4 m^2

  Operation rooms: 26 m^2

  Examination room: 129.5 m^2

  Bathrooms: 36.7m^2

  Security: has an area of20 m^2

  Waiting area: 33.6m^2

- Department of Radiology: has an area of 264 m^2

  Offices: 27.5m^2

  Bathrooms: 8m^2

Dark rooms: 16.6m^2

Radiology room: 100.3m^2

Files room: 7.5m^2

- Blood bank and laboratory: have an area of 124 m^2

Lab rooms: 47.4 m^2

Files room: 7 m^2

Waiting area: 12.3 m^2

Blood sampling room: 10.4 m^2

- Administration department: has an area of 380.1 m^2

Offices: 105 m^2

Meeting halls: 120.1 m^2

Archive: 23 m^2

Accounting: 24.4 m^2

Bathrooms: 22.3m^2

Shops: 79.1 m^2

Cafeteria: 103.6 m^2

➢ <u>First Floor</u>:

- Operation department: has an area of 1733 m^2

Operation rooms: 197 m^2

Sterile rooms: 32.7 m2

Anesthesia rooms: 34.1 m^2

ICU rooms: 100.6 m^2

Examination rooms: 14.2 m^2

Bathrooms: 16 m^2

Offices: 11.3 m^2

Waiting areas: 64.8 m^2

Files rooms: 14.37 m^2

Patient's rooms: 573.6 m^2

Stores: 15 m^2

- Bones department: has an area of 625 m^2

Patient's rooms: 261 m^2

Medicine room: 4.5 m^2

Linen room: 4.5 m^2

Orthopedic chamber: 43.7 m^2

Operation room: 67.8 m^2

Doctors offices: 67.8 m^2

Bathrooms: 10.2 m^2

Waiting area: 30.2 m^2

➢ <u>Second Floor:</u>

- Ear nose and throat department: has an area of 675 m^2

Stuff rest: 9.2 m^2

Bathrooms: 9.7 m^2

Room: 311.8 m^2

Doctor office: 52.9 m^2

Operation room: 53.3 m^2

- Obstetrics and Gynecology department: has an area of 1066 m^2

Stuff rest: 23.8 m^2

Archive: 8.5 m^2

Doctor office: 81 m^2

Operation room: 115.5 m^2

Babies' room: 59.5 m^2

Bathrooms: 9.7 m^2

Rooms: 327.5m^2

Nurse room: 11.9 m^2

Waiting hall: 30 m^2

- <u>Third Floor:</u>

- Internal Medicine Department has an area of 1066 m^2

Patient's rooms: 499.4 m^2

Stores: 43.4 m^2

Doctors offices: 43.7 m^2

Waiting hall: 23.2 m^2

Stuff rest room: 25.5 m^2

Archive room: 7.7 m^2

Files room: 11.8 m^2

Bathrooms: 9.6 m^2

- Children department: has an area of 675 m^2

Patient's rooms: 356.8 m^2

Toys room: 34.1 m^2

Stores: 16.3 m^2

Stuff rest room: 15.2 m^2

Doctors offices: 16.4 m^2

Bathrooms: of 5.8

2.2.2 External Spaces

Consist of:

- Green spaces.
- Parking: enough for 138 cars with an area 3036 m2.
- External Theater.
- External display spaces.

2.3 Project Plans

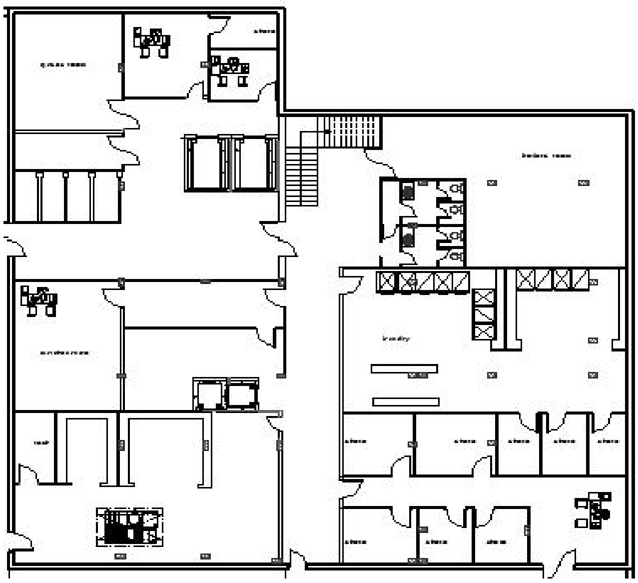


Figure (2.1): Basement Floor Plan.

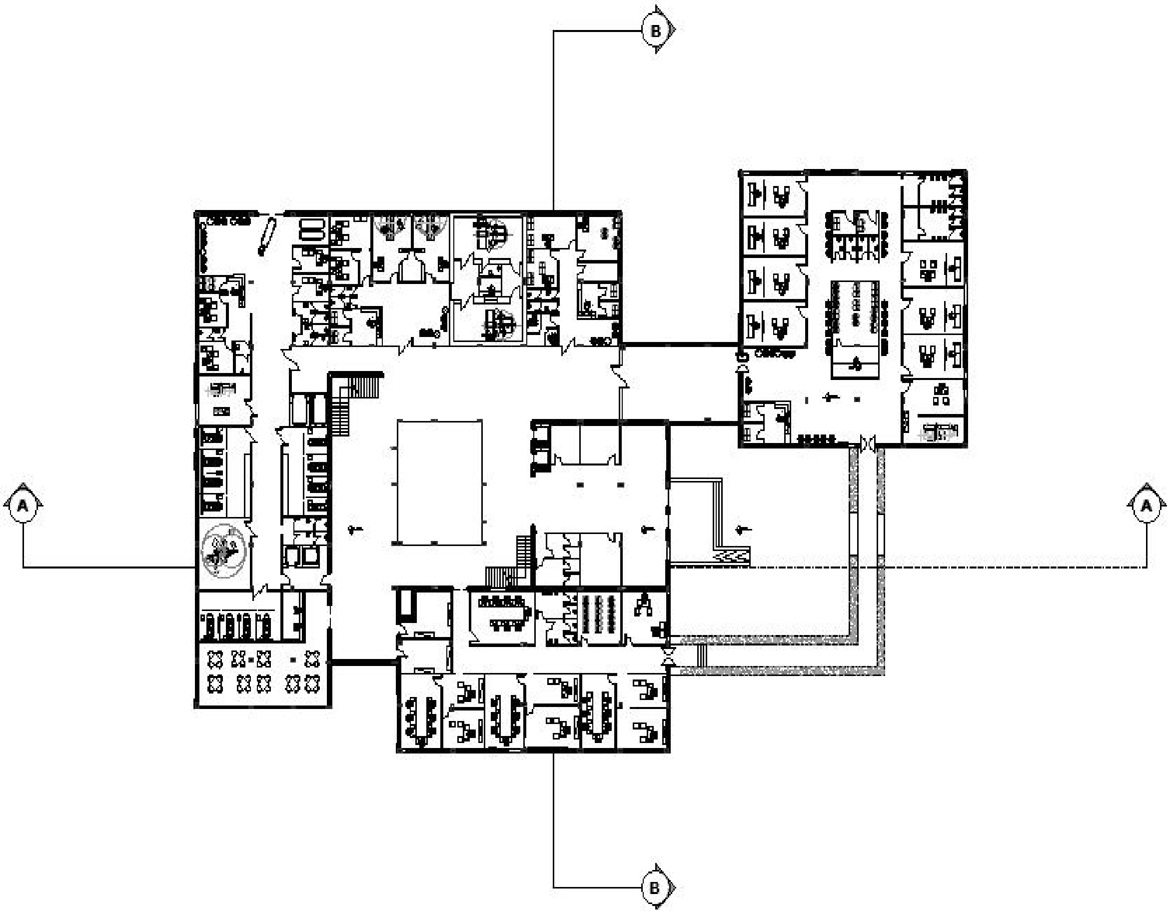


Figure (2.2): Ground Floor Plan

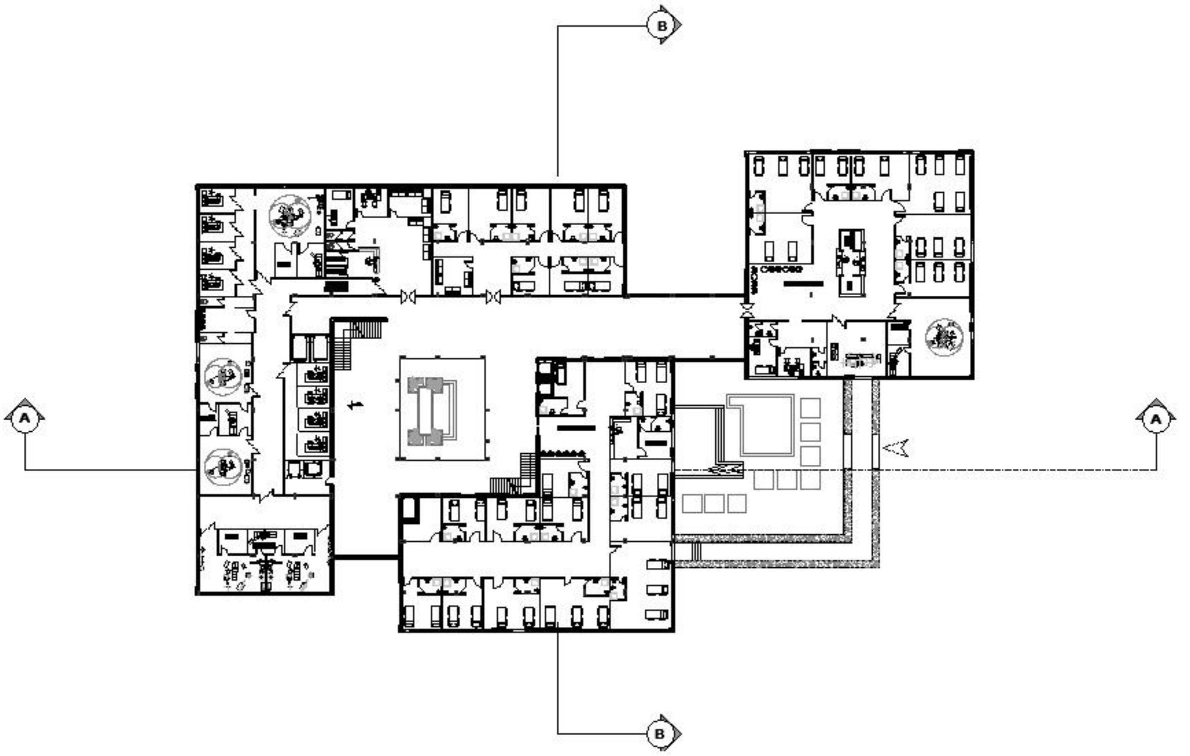


Figure (2.3): First Floor Plan.

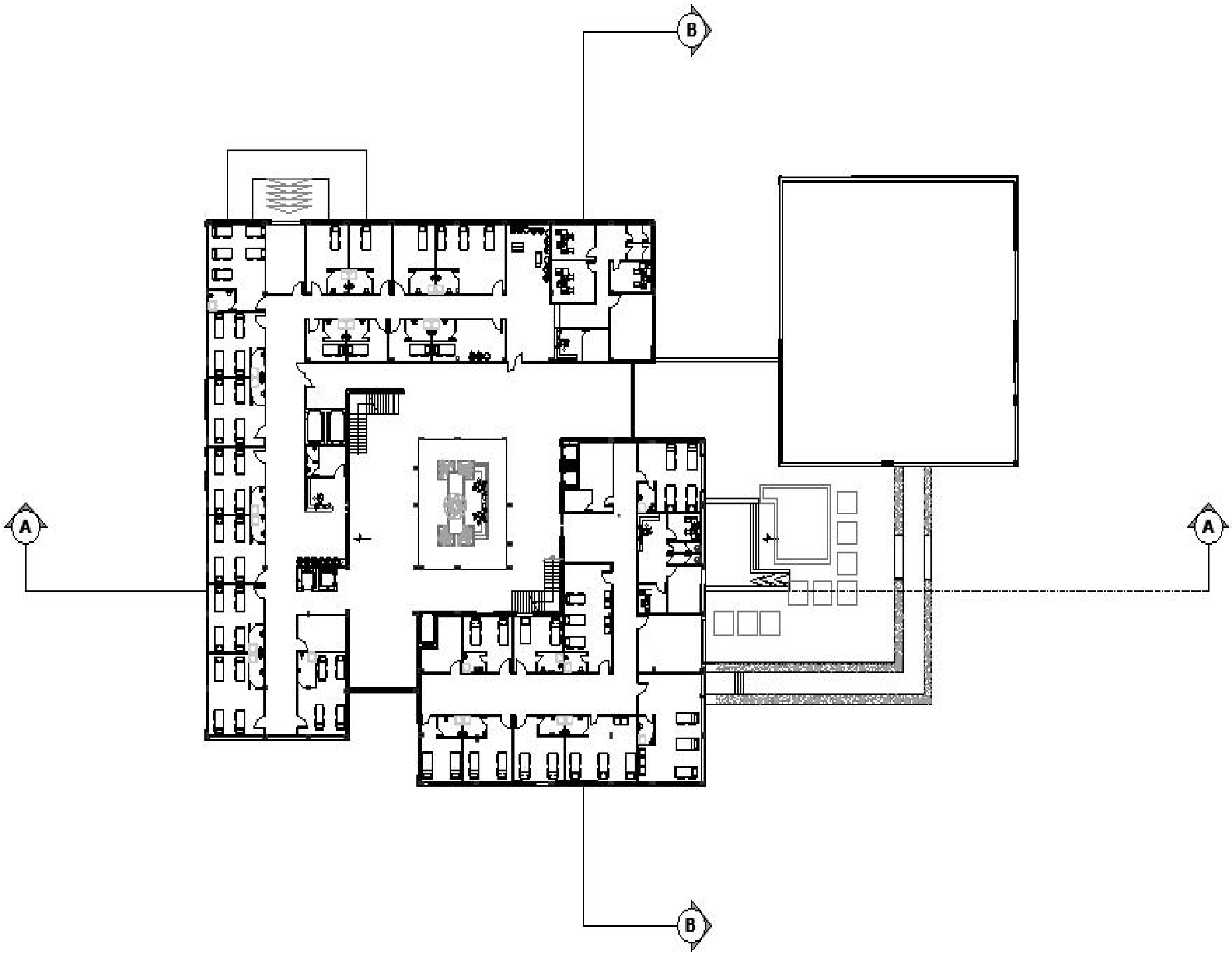


Figure (2.4): Third Floor Plan.

2.4 Project Elevations

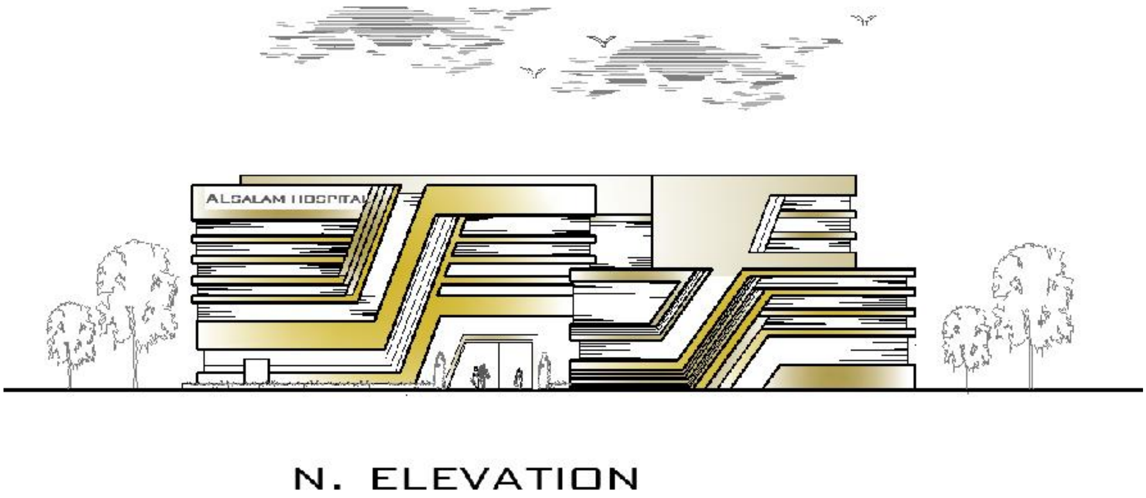


Figure (2.5): North Elevation.

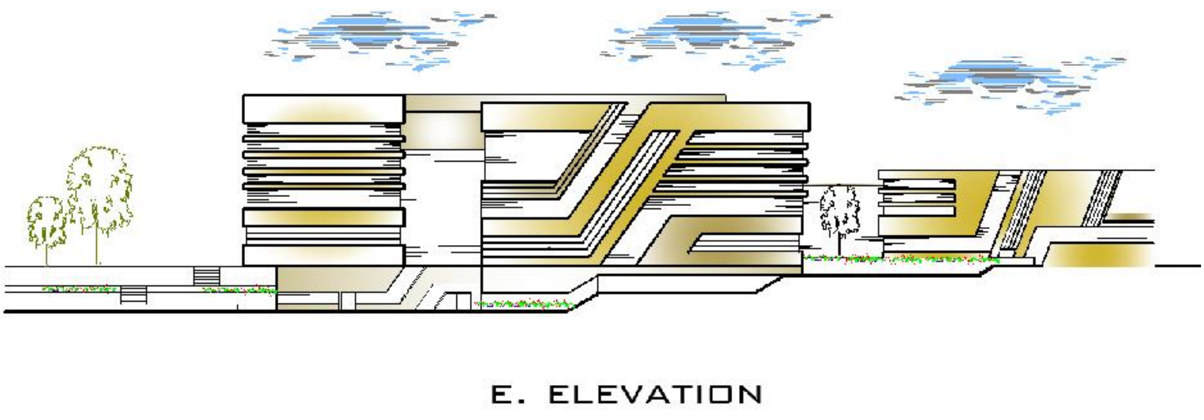


Figure (2.6): East Elevation.

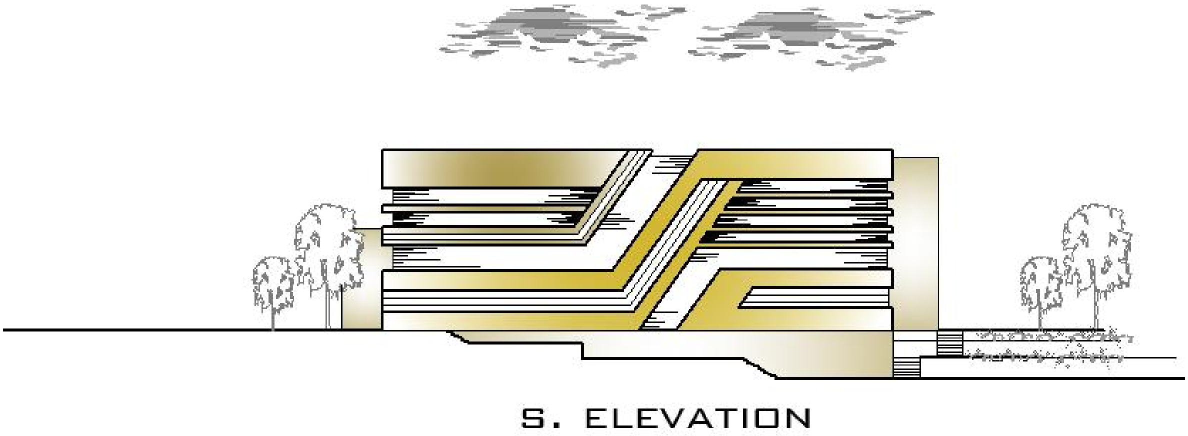


Figure (2.7): South Elevation.

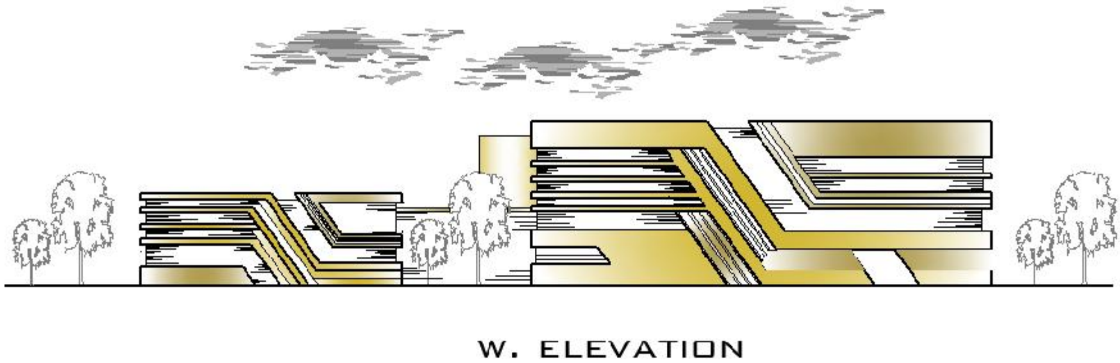


Figure (2.8): West Elevation.

2.5 Project Sections

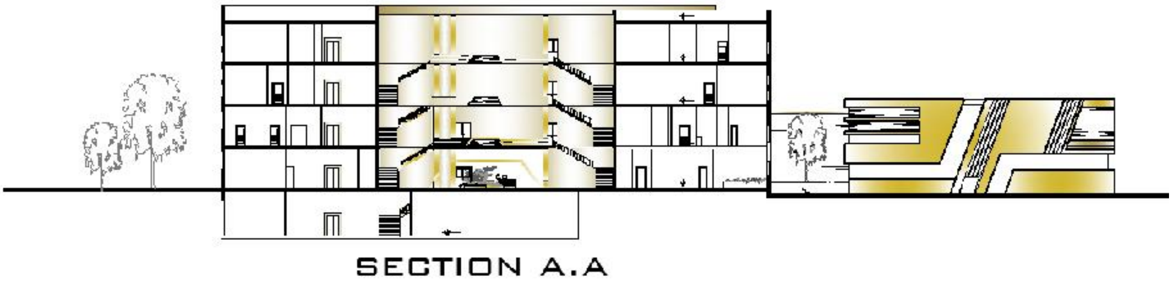


Figure (2.9): Section A-A.

Figure (2.10): Section B-B.

Chapter Three

Structural Description

3.1 INTRODUCTION.

3.2 THE GOAL OF THE STRUCTURAL DESIGN.

3.3 SCIENTIFIC TESTS.

3.4 STAGES OF STRUCTURAL DESIGN.

3.5 LOADS ACTING ON THE BUILDING.

- 3.5.1 DEAD LOADS
- 3.5.2 LIVE LOADS
- 3.5.3 SNOW LOADS
- 3.5.4 EARTHQUAKE LOADS
- 3.5.5 WIND LOADS

3.6 STRUCTURAL ELEMENTS OF THE BUILDING.

- 3.6.1 SLABS
- 3.6.2 STAIRS
- 3.6.3 BEAMS
- 3.6.4 COLUMNS

3.6.5 SHEAR WALL

3.6.6 EXPANSION JOINT

3.6.7 FOUNDATION

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 be 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 achieved by selecting sections for structural elements capable of withstanding the forces and resulting stresses.
2- Economy: Check by choosing the appropriate building materials and by choosing 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 must be doing some tests, tests of the soil to see breaking strength, specifications, type, the underground water level and depth of the foundation layer, and through holes up and depths measured by the appropriate International Center for Geotechnical Engineering Studies (ICGES) in Bethlehem, and took samples of the soil, has been getting the value soil durability of Earth-based project.

3.4 Stages for Structural Design:

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

1. The first stage:-
   In this stage, the appropriate structural system of project construction and analysis for this system will be determined.
2. The second stage: - The structural design of each element of the set is detailed and accurate according to the chosen construction system and structural blueprints for executable.

3.5 Loads Acting on the Building:

Is a group of forces that is designed to endure, 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 is exposed to loads of live and dead loads, wind loads, snow loads, loads of earthquakes.

The permanent forces and resulting from strong gravity which are fixed in terms of amount and location and does 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 sustainably as cutters and walls, as well as the weight of the body adjacent to the building permanently, and the calculation and estimate the loads by knowing the dimensions of the structural elements and specific gravity of the material used in the manufacture of structural elements, And are most often include: concrete, and Rebar, and plaster, and bricks, tiles and finishes, and the stone used in building coverage abroad, there is also a tube extensions, as well as suspended ceilings and decorations for the building.

3.5.1 Dead Loads

Table (3-1) Dead load

Material	Density(KN/m^3)	Thickness(m)
Tiles	22	**0.03**
Mortar	22	**0.02**
Sand	16	**0.07**
Concrete	25	**0.08**
Plaster	22	**0.02**
Partition=1.5 KN/m^2		

3.5.2 Live Loads

Which are the loads that are subjected to buildings and constructions depending on various uses, including distributed and concentrated loads, which include the following:

1. The weights of the hospital's users.
2. Dynamic loads, such as devices that produce vibration.
3. Static loads, which can be changed from time to time, such as furniture, machines, static unstable machines, stored materials, furniture, equipment.

Table 3-2 shows the value of live loads depending on type of building according to the Jordanian code.

We take live load for hospital =5KN.

Table (3-2) Determination of live load

NO.	Building Type	Live Load
1	**School**	**5**
2	**Hospital**	**5**
3	**Hotel**	**2.5**
4	**Restaurant**	**5**
5	**Residential building**	**2.5**
6	**Barking**	**5**
7	**Sport Center**	**5**

3.5.3 Snow Loads

Figure (3.1): snow loads.

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

حمل الثلج (S_o) (كن/م²)	ارتفاع المنشأ عن سطح البحر (h) (بالمتر)
0	250 > h
(h-250)/800	500 > h > 250
(h-400)/320	1500 > h > 500

Figure (3.2): Determination of snow load, Jordanian loads code

Based on the scale of previous snow loads and after selecting the high building surface and that equals (900m) according to item III snow load is calculated as follows:

SL= (h-400)/320

SL= (900-400)/320= 1.56 KN/m²

3.5.4 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 be taken into account in the design to ensure resistance to earthquakes. This will be resisted by shear walls designed with sufficient thickness and reinforcement to ensure the safety of the building when subjected to earthquakes loads that must be considered in the design process to reduce the risk and maintain the performance of the building, and determine the loads of earthquakes and shear forces depending on the American code (UBC).

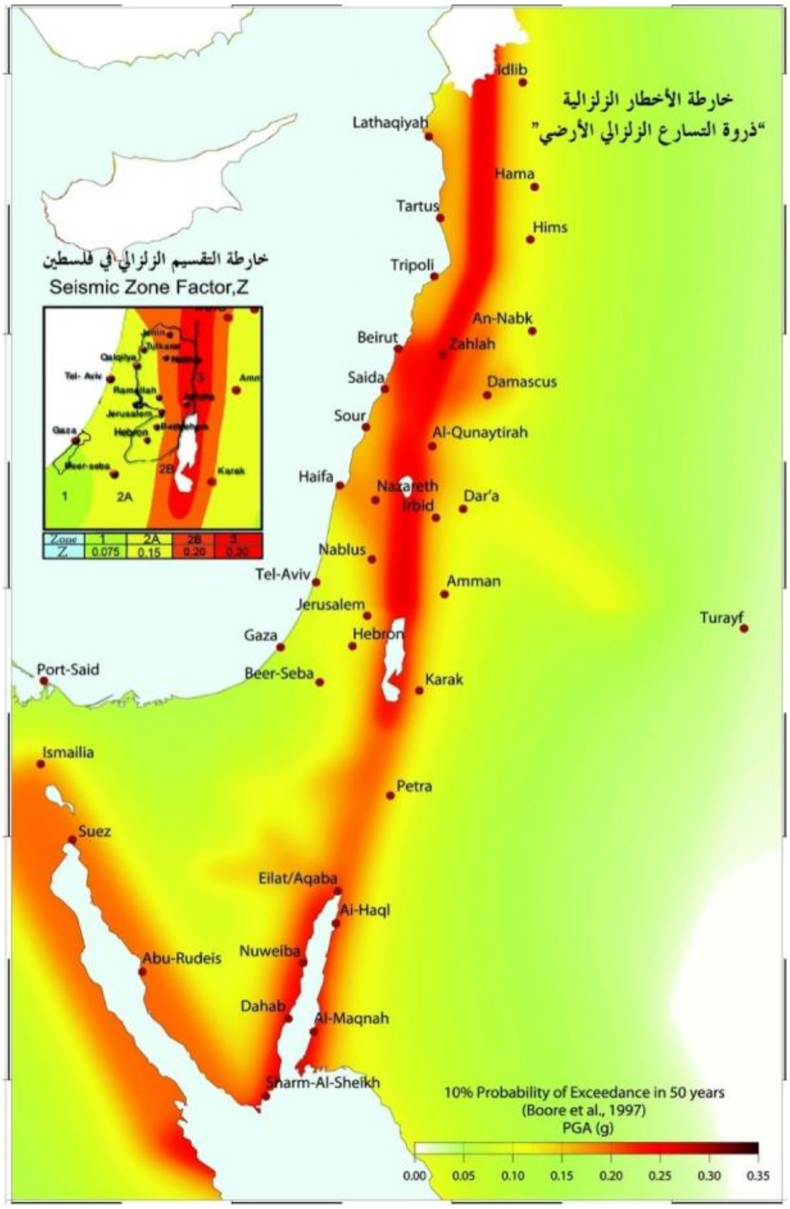


Figure (3.3): Earthquake map for palestine

3.5.5Wind Loads:

Wind loads affect the horizontal forces on the building, and the wind load determination process is depending on wind speed and change height from the surface of the Earth and the location of where his high buildings or having established himself in the high or low position and many other variables.

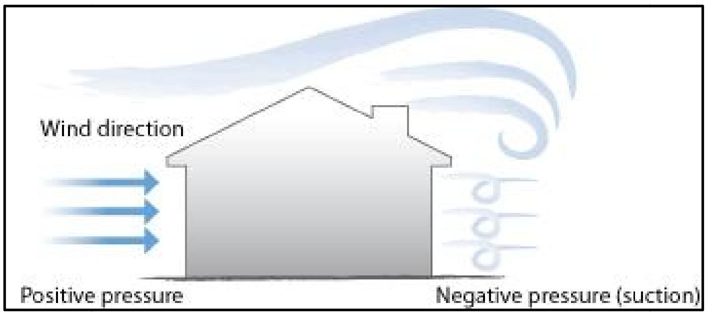


Figure (3.4): Wind Pressure on buildings.

3.6 Structural Elements of the Building:

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

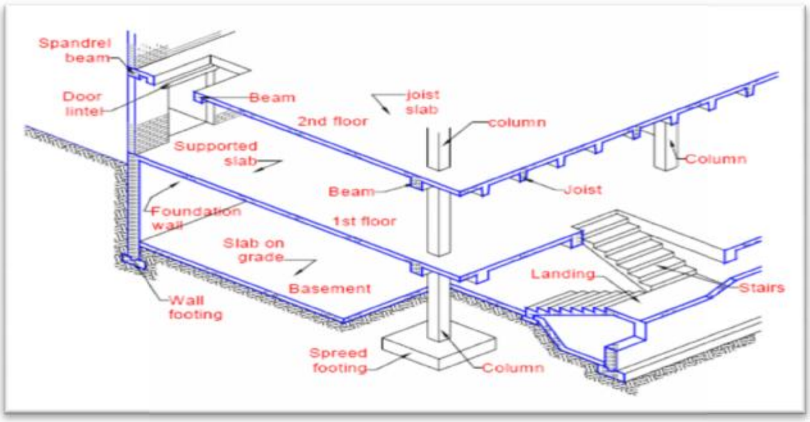


Figure (3.5): Structural Elements of the Building.

3.6.1 Slabs

Structural elements are capable of delivering vertical forces due to the loads affecting the building's load-bearing structural elements such as beams, columns and walls, In this project, two types of components both in its appropriate place, and which will clarify the structural design in the subsequent chapter, and below these types:

1- One Way Ribbed Slab.
2- Tow Way Solid Slab.
3- Flat slab

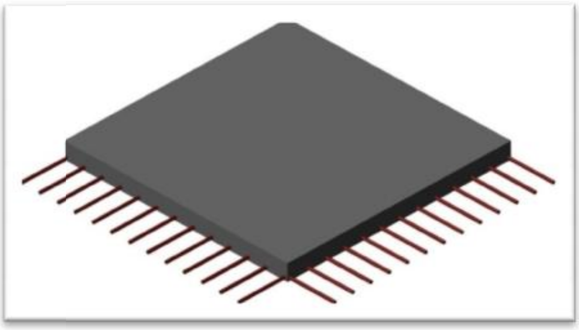


Figure (3.6) Solid Slab.

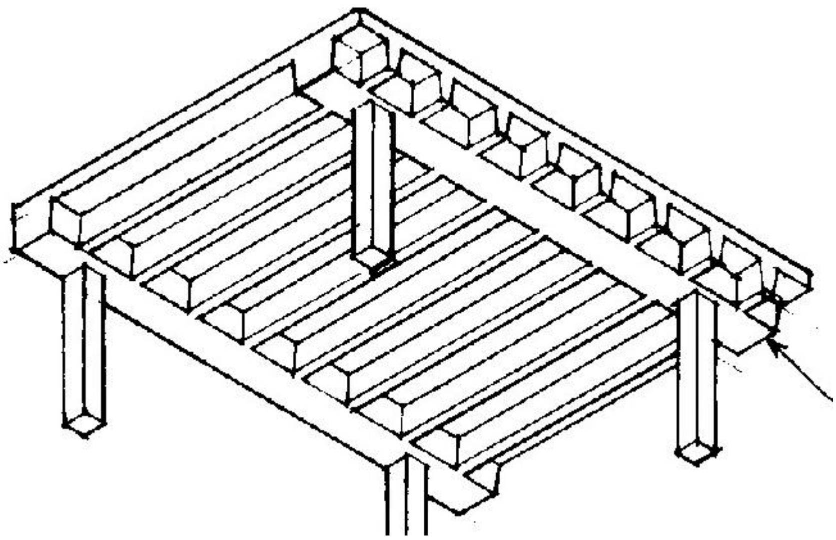


Figure (3.7) One Way Ribbed Slab.

3.6.2 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.

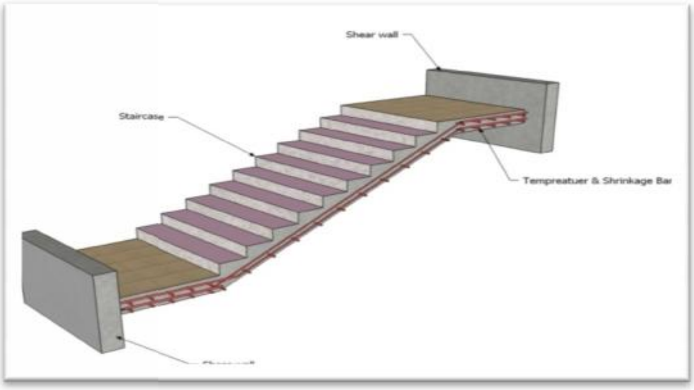


Figure (3.8) The shape of stairs.

3.6.3 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).

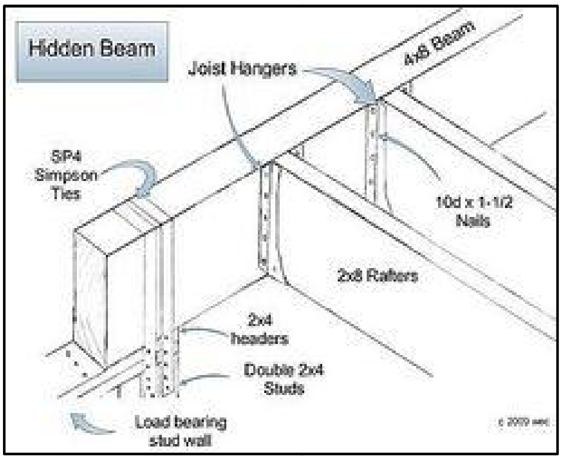


Figure (3.9) Hidden Beam.

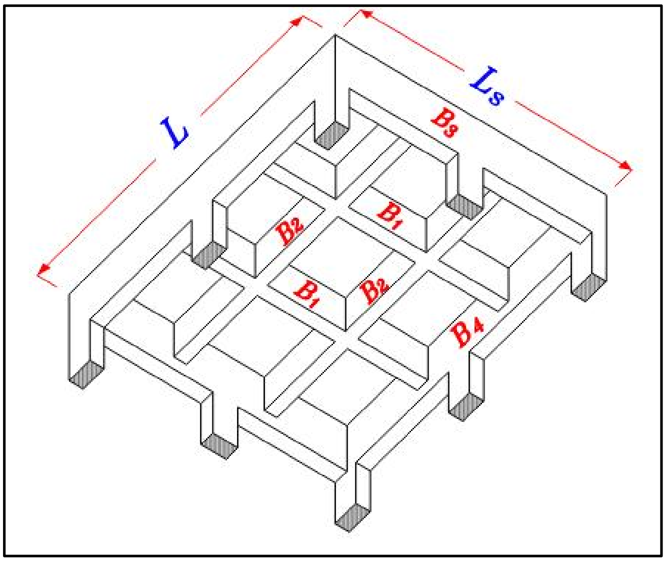


Figure (3.10) Paneled Beam.

3.6.4 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 be designed so as to be able to download and load them, and two rectangular and square concrete columns.

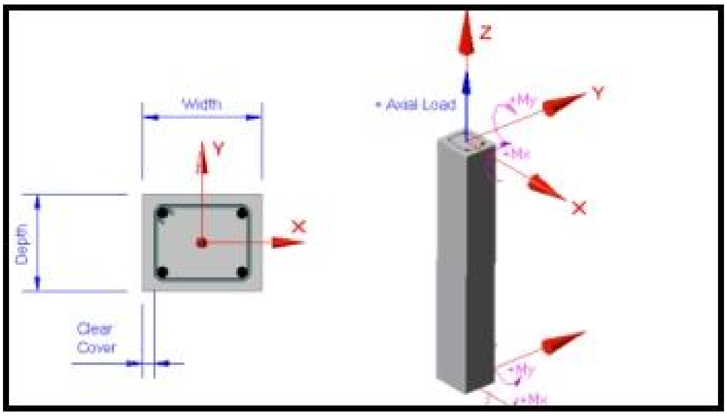


Figure (3.11) Column.

3.6.5 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.

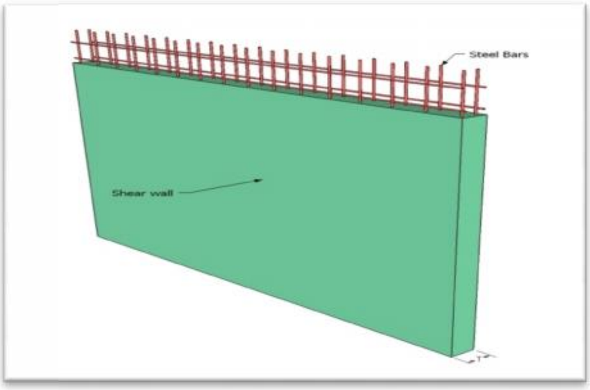


Figure (3.12) Shear Wall.

3.6.6 Expansion joint

We can determine the maximum distance between the expansion joints for buildings as follow:

- From 40 to 45 m in normal regions like Palestine.
- From 30 to 35 m in warm regions like Palestine.
- We can increase these distances by consider the effect of creep and shrinkage.
- In retaining walls we must decrease distances between expansion joints, and

Figure (3.13): Expansion join

3.6.7 Foundation

Although the foundations are the first element constructs, but we did the design after the completion design all the structural elements in the building.

The foundations are the link between the structural elements in the building and the earth. The loads on the slab move to the beams and then to the columns and finally to the foundations to the soil. The foundation is responsible for carrying the dead loads of the building and also the dynamic loads resulting from wind, snow and earthquakes. Also Live loads inside the building.

We determined the type of foundations depending on the strength of the soil and the loads on each footing.

3.6.7.1 Shallow Foundation

The foundation is close to the surface of the earth, and this type has several forms, such as strip (wall) footings, isolated footing or mat footings.

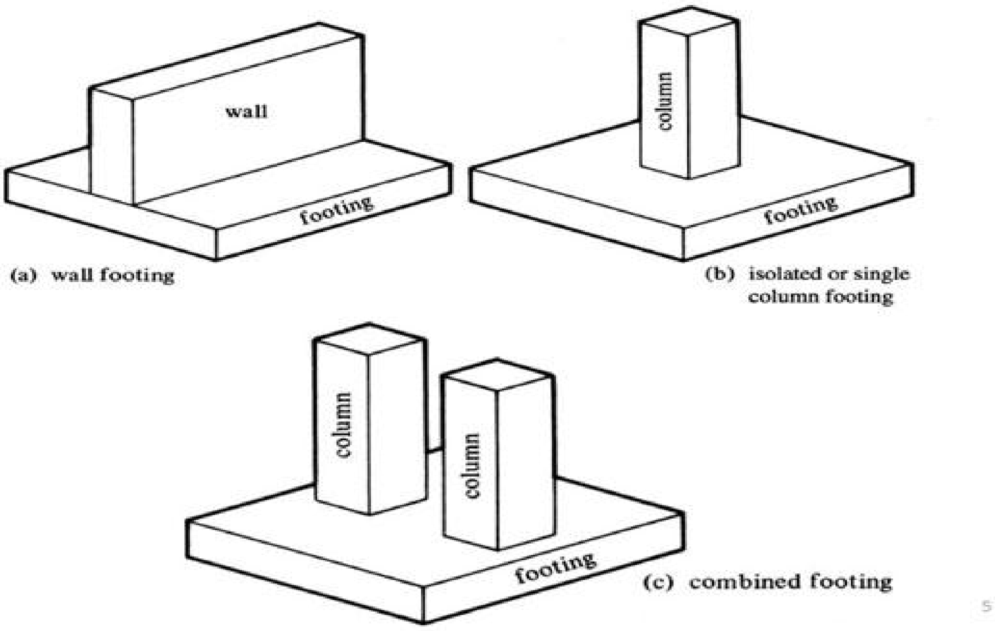


Figure (3.14): Shallow Foundation

3.7 Structural programs

1. AutoCAD (2007/2014) for Structural and Architectural Drawings.
2. Microsoft Office word (2010) For Text Edition.
3. Microsoft Office Excel (2010).
4. Atir 11.5 (BEAMD/FOUND).
5. SpColumn.
6. ETABS 2016.
7. SAFE 2016.

Chapter Four

Structural Analysis and Design

4.1 Introduction:

This chapter contains the structural analysis and design of some elements of Al-Salam Hospital.

The structural design of the project is the most important thing to be done, through design we determine the amount of reinforcement in each part of the project to be realized all the conditions of construction and safety.

As we mentioned before, ACI 318m-11, and some engineering program were used in the design of the structures like: Atir, spColumn, Etabs and Safe to find the internal forces, deflection and moments, and then hand calculation were done to find the required reinforcement for the structures.

4 .2 Factored Loads

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

qu = 1.2DL + 1.6L.L , ACI – 318 - 11

4.3 Determination of thickness.

4.3.1 Determination of Thickness for One Way Rib Slab:

The structure may be exposed to different loads such as dead and live loads. The value of the load depends on the structure type and the intended use.

The overall depth must satisfy ACI Table (9.5.a):

The maximum span for one –end continuous is L= 6.41m

$$\frac{L}{18.5} = \frac{6.71}{18.5} = 0.36m$$ *ACI-318-11*

The maximum span for two - end continuous is L= 6.47 m

$$\frac{L}{21} = \frac{6.9}{21} = 0.33\ m$$

Deflection is ok because one –end continuous span give deflection value less than L/240, So

Selected h = 35 cm

Select 27 cm block + 8 cm topping = 35 cm

4.3.2 Load Calculation.

One - way ribbed slab.

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

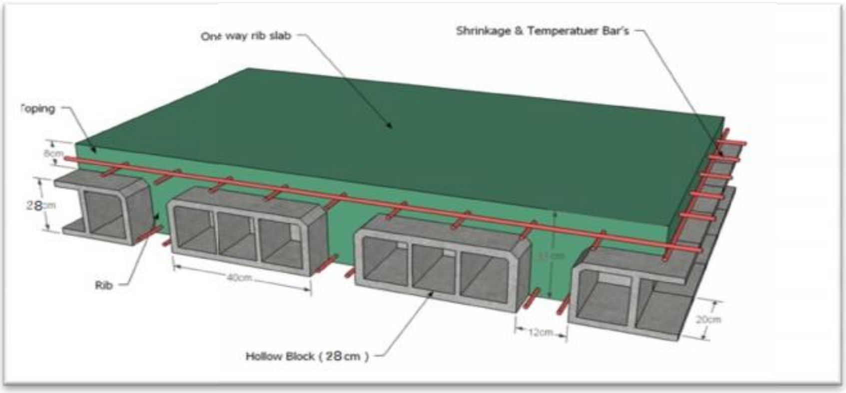


Figure (4.1) One way rib slab

Calculation of the total dead load for one way rib slab is shown in the following table:

Table (4.1) Calculation of the total dead load for one way rib slab.

No.	Parts of Rib	Density KN/m^3	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*0.25 = 1.04 KN/m
5	Rib	25	0.20*25*0.12 = 0.6 KN/m
6	Block	10	0.2*10*0.4 = 0.8 KN/m
7	Plaster	22	0.03*22*0. 52 = 0.343 KN/m
8	Partition		1.5*.52 = 0.78 KN/m
			4.884 KN/m

Nominal Total Dead Load:

D.L. $_{total}$ = 0.359+0.343+ 0.619 + 1.04 + 0.6 + 0.8+ 0.343 + 0.78 = 4.884 KN/m of rib

L.L. $_{total}$= 5 * 0.52= 2.6KN/m of rib

4.4 Design of One Way Ribbed Slab:

4.4.1 Design of Topping:

Table (4.2) 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		1.5×1=1.5 KN/m
			6.04 KN/m

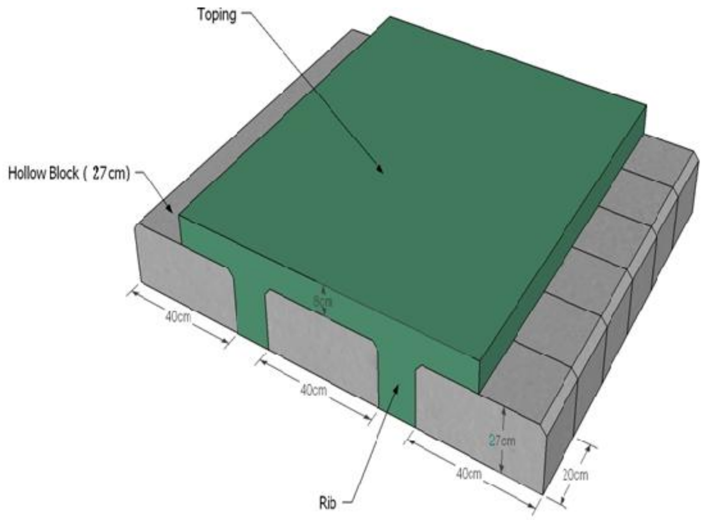


Figure (4.2): Toping of slab

Design of Topping for Ribbed Slab as a Plain Concrete Section:-

qu= (1.2 * 6.04) + (1.6 * 5*1)
= 15.248 KN/m

→ For a one meter strip qu = 15.248 KN/m

Assume slab fixed at supported points (ribs):

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

Mu = $\frac{15.248 * 0.4^2}{12}$ = 0.2KN.m /m

$$Vu = \frac{q_u \times l}{2} = \frac{15.248 \times 0.4}{2} = 3.05kN$$

Design of shear:

Used fy = 420 MPa & fc' = 24MPa

Φ* V_c = $0.75 \times \sqrt{24} \times \frac{1}{6} \times 1000 \times 80 = 49KN$ >> 3.05kN

No shear reinforcement is required.

Design of Moment:

$$Mn = 0.42 \times \sqrt{24} \times \frac{1000 * 80^2}{6} \times 10^{-6} = 2.19kN.m$$

$$¤ \times Mn = 0.55 * 2.19 = 1.207kN.m.$$

$$¤ \times Mn = 1.207kN.m > Mu = 0.16kN.m.$$

No structural reinforcement is required.

The strength of plain concrete section > loaded section.

The plain concrete section is safe; however, minimum reinforcement for shrinkage and temperature to control the cracks should be used.

ρ =0.0018 , *ACI-318-11*

As = ρ * b * h = 0.0018 * 1000 * 80 = 144 mm^2/ m

- Use Φ 8 @15 cm

$$As = 335.1mm^2 / m > As_{min} = 144mm^2 / m$$

- ✓ Ok

4.4.2 Design of Rib R-2:

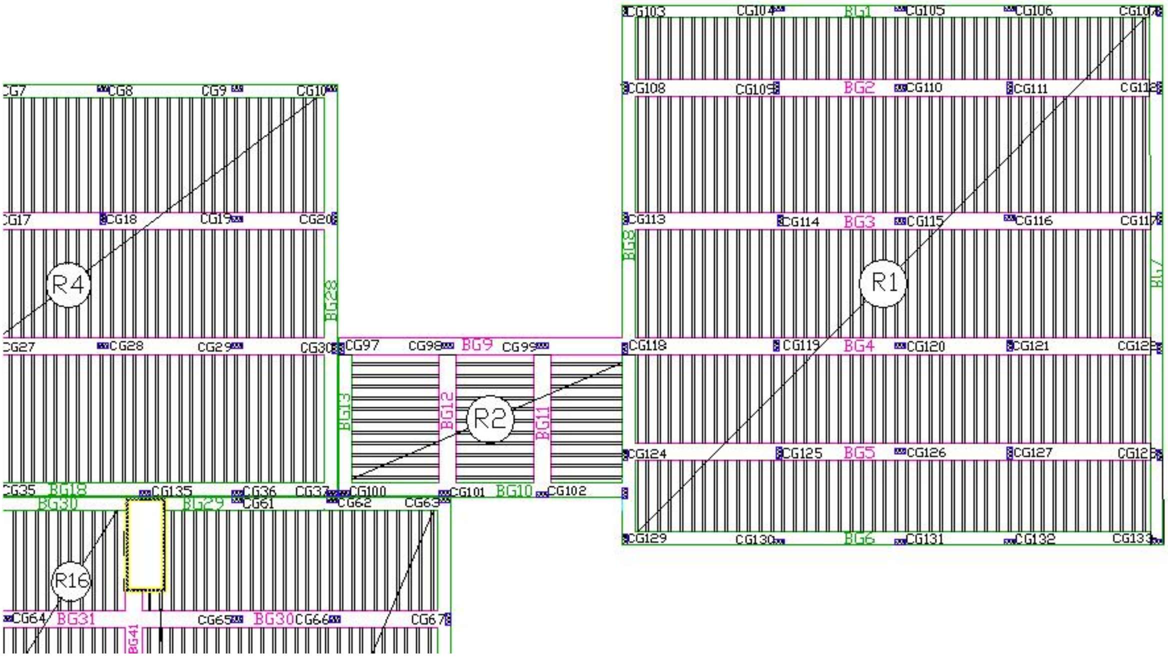


Figure (4.3) Rib location

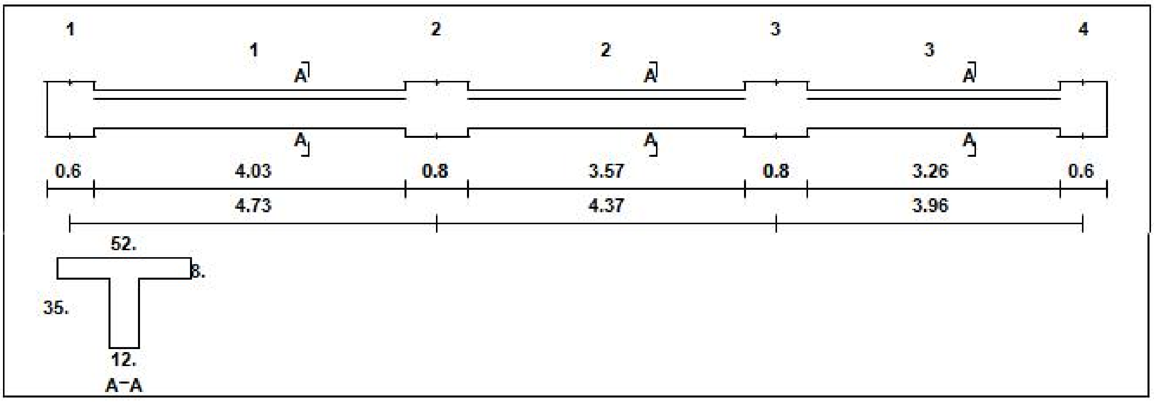


Figure (4.4) Geometry of rib R-2

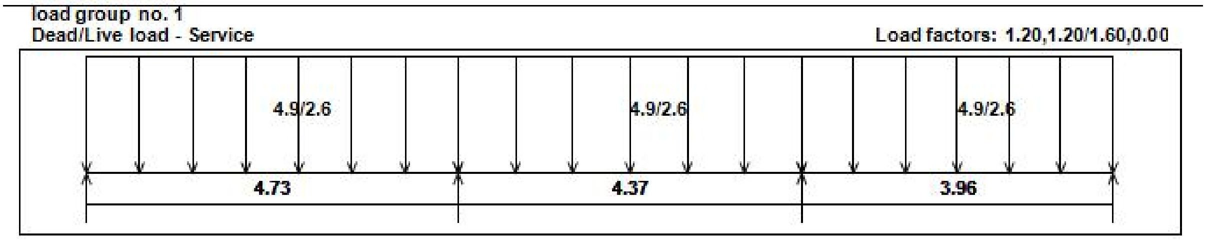
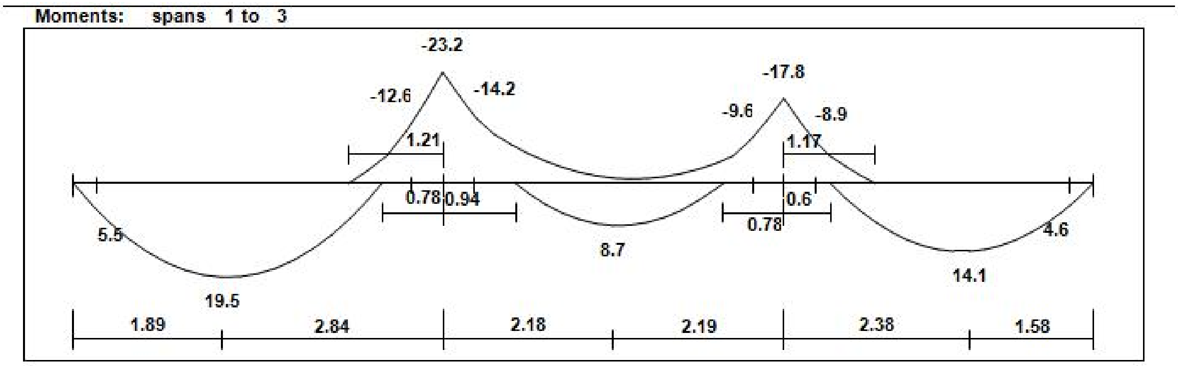


Figure (4.5) Loading of rib R-2(KN/m)



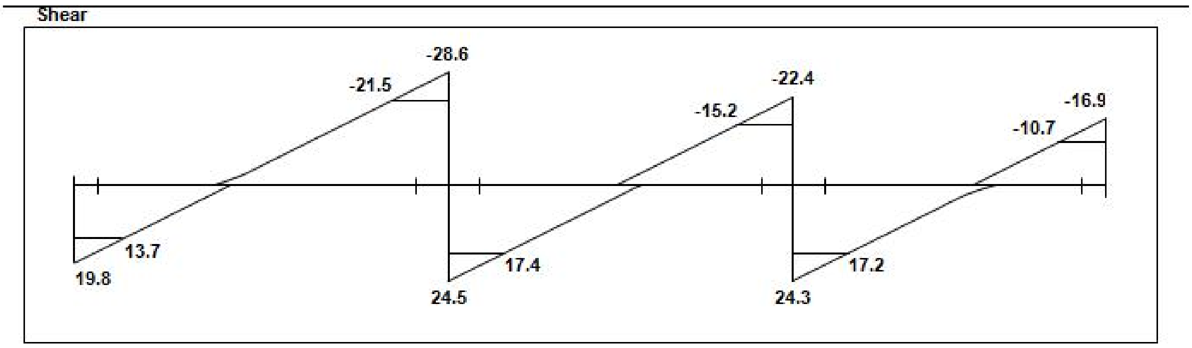


Figure (4.6) Moment and Shear Envelop for rib R-2

4.4.2.1 Design of shear for rib R-2:

Categories for shear design:

Vu = 21.5KN

Use Φ8 with two legs

d=350-20-8-4=318

Region II

$1.1\Phi Vc \geq Vu$

$$1.1\Phi\ \mathrm{Vc} = 1.1\Phi \frac{\sqrt{fc'}}{6} \times b_w \times d$$

$$1.1\Phi\ \mathrm{Vc} = 1.1 \times 0.75 \times \frac{\sqrt{24}}{6} \times 120 \times 318 = 25.7\ \mathrm{KN}$$

25.7 KN > Vu = 21.7KN

$0.5 * 1.1\emptyset\ \mathrm{Vc} = 12.58\mathrm{KN} < v_u = 21.5 \leq 1.1\ \emptyset * v_c = 25.7\mathrm{KN}$

No need for shear reinforcement (exception for joist constructions).

4.4.2.2 Design of Max Negative Moment for (Rib):

Mu = - 14.2 KN.m

The section will be designed as a rectangular section with b_w= 120 mm

Assume bar diameter Φ14 for main negative reinforcement.

d = 350 – 20 – 8–7= 315mm

$$As\ min = \frac{\sqrt{fc'}}{4(fy)}(bw)(d) >= As\ min = \frac{1.4}{(fy)}(bw)(d) \quad ACI\text{-}318\text{-}05$$

$$As\ min = \frac{\sqrt{24}}{4(420)}(120)(315) = 110.22mm^2$$

$$As\ min = \frac{1.4}{420}(120)(315) = 126mm^2 \quad \boxed{\text{control}}$$

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

$$Kn = \frac{Mu}{\Phi bd^2} = \frac{14.2*10^6}{(0.9)(120)(315)^2} = 1.33\ Mpa$$

$$° = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2*m*kn}{fy}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2*20.6*1.33}{420}}\right) = 0.00328$$

A_s = 0.00328(120) (315) = 123.98mm^2< $As\ min$ = 126 mm^2

$As\ min$ = 126 mm^2 control

# of bars = A_s / $A_{s\ bar}$ = 126/78.5= 1.6 * Note $A_{\Phi 10}$= 78.5mm^2

- Select bottom bars 2 Φ10

Total As $_{(provide)}$=157 mm^2>126mm^2

* Check Strain for the magnitude of under strength factor Φ:

Tension = Compression

$$157 \times 420 = 0.85 \times 24 \times 120 \times a$$

$$a = 26.9m$$

$$x = \frac{a}{0.85} = \frac{26.9}{0.85} = 31.6mm$$

$$£_s = \frac{315 - 31.6}{31.6} \times 0.003 = 0.026$$

$£_s = 0.026 > 0.005$

- ✓ Ok

Mu = - 9.6KN.m

The maximum negative moment from spans with support (3).

Assume bar diameter Φ14for main negative reinforcement.

d = 350 – 20 – 8–7= 315mm

The section will be designed as a rectangular section with bw=120mm

$$A_{s\ min} = \frac{\sqrt{fc'}}{4(fy)}(bw)(d) >= A_{s\ min} = \frac{1.4}{(fy)}(bw)(d)\ ACI\text{-}318\text{-}05$$

$$A_{s\ min} = \frac{\sqrt{24}}{4(420)}(120)(315) = 110.22mm^2$$

$$A_{s\ min} = \frac{1.4}{420}(120)(315) = 126mm^2 \quad \underline{\text{control}}$$

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

$$Kn = \frac{Mu}{\Phi bd^2} = \frac{9.6 * 10^6}{(0.9)(120)(315)^2} = 0.89\ Mpa$$

$$° = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2 * m * kn}{fy}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2 * 20.6 * 0.89}{420}}\right) = 0.00217$$

A_s = 0.00217(120) (315) = 82 mm^2< $A_{s\ min}$ = 126 mm^2

$A_{s\ min}$ = 126 mm^2 control

# of bars = A_s / $A_{s\ bar}$ = 126/78.5= 1.6 * Note $A_{\Phi10}$= 78.5mm^2

- Select bottom bars 2 Φ10

Total As $_{(provide)}$ =157 mm^2>126mm^2

* Check Strain for the magnitude of under strength factor Φ:

Tension = Compression

$157 \times 420 = 0.85 \times 24 \times 120 \times a$

$a = 26.9m$

$$x = \frac{a}{0.85} = \frac{26.9}{0.85} = 31.6mm$$

$$£_s = \frac{315 - 31.6}{31.6} \times 0.003 = 0.026$$

$£_s = 0.026 > 0.005$

- ✓ Ok

4.4.2.3 Design of Positive Moment for (Rib):

Effective Flange width (b_E) , *ACI-318-11*

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

b_E = (4950) / 4 = 1237.5 mm

b_E = 120 + 16 (80) = 1400mm

b_E = 520 mm................. control

Use M_u max positive for span 1 = 19.5 KN.m

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

For hf = 0.08 m

Assume bar diameter main positive reinforcement.

d = 350 – 20 – 10–7= 313mm

Φ*Mn= 210 KN.m>> M_u = 19.5 KN.m

The section will be designed as a rectangular section with b_E = 520mm

$$As\ min = \frac{\sqrt{fc'}}{4(fy)}(bw)(d) >= As\ min = \frac{1.4}{(fy)}(bw)(d)\ ACI\text{-}318\text{-}05$$

$$As\ min = \frac{\sqrt{24}}{4(420)}(120)(315) = 110.22mm^2$$

$$As\ min = \frac{1.4}{420}(120)(315) = 126mm^2$$ <u>control</u>

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

$$Kn = \frac{Mu}{\Phi bd^2} = \frac{19.5*10^6}{(0.9)(520)(315)^2} = 0.0418\ Mpa$$

$$\circ = \frac{1}{m}\left(1-\sqrt{1-\frac{2*m*kn}{fy}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2*20.6*0.0418}{420}}\right) = 0.000099$$

A_S = 0.000099(520) (315) = 16.22mm^2 < $As\ min$ = 126 mm^2

$As\ min$ = 126 mm^2 control

# of bars = A_s / $A_{s\ bar}$ = 126/78.5= 1.6 * Note $A_{\Phi 10}$= 78.5mm^2

- Select bottom bars 2 Φ10

Total As $_{(provide)}$=157 mm^2>126mm^2

* Check Strain for the magnitude of under strength factor Φ:

Tension = Compression

$A_s \times fy = 0.85 \times f_c' \times b \times a$

$157 \times 420 = 0.85 \times 24 \times 520 \times a$

$a = 6.2mm$

$$x = \frac{a}{0.85} = \frac{6.2}{0.85} = 7.3\ mm$$

$$£_s = \frac{0.315 - 0.0073}{0.0073} \times 0.003 = 0.126$$

$£_s = 0.126 > 0.005$

$£_s = 0.126 > 0.005$

- ✓ Ok

Use M_u max positive for span 2 = 8.7 kN.m

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

For hf = 0.08 m

~ Assume bar diameter Φ14 for main positive reinforcement.

d = 350 – 20 – 8 – 7 = 315mm

ΦMn =0.9*0.85* ƒc'*b*hf* (d- hf/2)

= 0.9*0.85*24*0.52*0.08*(0.315-0.08/2)=210KN.m

ΦMn = 210KN.m >> M_u = 8.7 KN.m

The section will be designed as a rectangular section with b_E = 520mm

$$As\ min = \frac{\sqrt{fc'}}{4(fy)}(bw)(d) >= As\ min = \frac{1.4}{(fy)}(bw)(d)\ ACI\text{-}318\text{-}05$$

$$As\ min = \frac{\sqrt{24}}{4(420)}(120)(315) = 110.22mm^2$$

$$As\ min = \frac{1.4}{420}(120)(315) = 126mm^2$$ control

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

$$Kn = \frac{Mu}{\Phi bd^{2}} = \frac{8.7 * 10^{6}}{(0.9)(520)(315)^{2}} = 0.187 \ Mpa$$

$$\circ = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2\,mkn}{fy}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2 * 20.6 * 0.187}{420}}\right) = 0.00044$$

A_S = 0.00044 (520) (315) = 72.07 mm^2<$A_{s\ min}$ = 126mm^2

# of bars = A_s / $A_{s\ bar}$ = 126 / 78.5 = 1.6 * Note $A_{\Phi 10}$ = 78.5 mm^2

- Select bottom bars 2 Φ10

Total $As_{(provide)}$ =157 mm^2>126mm^2

* Check Strain for the magnitude of under strength factor Φ:

Tension = Compression

$$A_s \times fy = 0.85 \times f_c' \times b \times a$$

$$157 \times 420 = 0.85 \times 24 \times 520 \times a$$

$$a = 6.2mm$$

$$x = \frac{a}{0.85} = \frac{6.2}{0.85} = 7.3\ mm$$

$$£_s = \frac{0.315 - 0.0073}{0.0073} \times 0.003 = 0.126$$

$$£_s = 0.126 > 0.005$$

- ✓ Ok

Use M_u max positive for span 3 = 14.1 KN.m

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

For hf = 0.08 m

Assume bar diameter Φ10 for main positive reinforcement.

d = 350 – 20 – 8 – 7 = 315mm

ΦMn =0.9*0.85* fc'*b*hf* (d- hf/2)

= 0.9*0.85*24*0.52*0.08*(0.315-0.08/2)=210 KN.m

ΦMn = 210KN.m >> M_u = 14.1 KN.m

The section will be designed as a rectangular section with b_E = 520mm

$$As_{min} = \frac{\sqrt{fc'}}{4(fy)}(bw)(d) >= As_{min} = \frac{1.4}{(fy)}(bw)(d) \quad ACI\text{-}318\text{-}05$$

$$As_{min} = \frac{\sqrt{24}}{4(420)}(120)(315) = 110.22mm^2$$

$$As_{min} = \frac{1.4}{420}(120)(315) = 126mm^2 \ \underline{\text{control}}$$

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

$$Kn = \frac{Mu}{\Phi bd^2} = \frac{14.1*10^6}{(0.9)(520)(315)^2} = 0.3Mpa$$

$$\circ = \frac{1}{m}\left(1-\sqrt{1-\frac{2mkn}{fy}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2*20.6*0.3}{420}}\right) = 0.00072$$

A_s = 0.00072 (520) (315) = 117.9 mm^2<As_{min} = 126mm^2

As_{min} = 126 mm^2 control

# of bars = A_s / $A_{s\ bar}$ = 126/78.5= 1.6 * Note $A_{\Phi 10}$= 78.5mm^2

- Select bottom bars 2 Φ10

Total As$_{(provide)}$ =157 mm^2>126mm^2

* Check Strain for the magnitude of under strength factor Φ:

Tension = Compression

$A_s \times fy = 0.85 \times f_c' \times b \times a$

$157 \times 420 = 0.85 \times 24 \times 520 \times a$

$a = 6.2m$

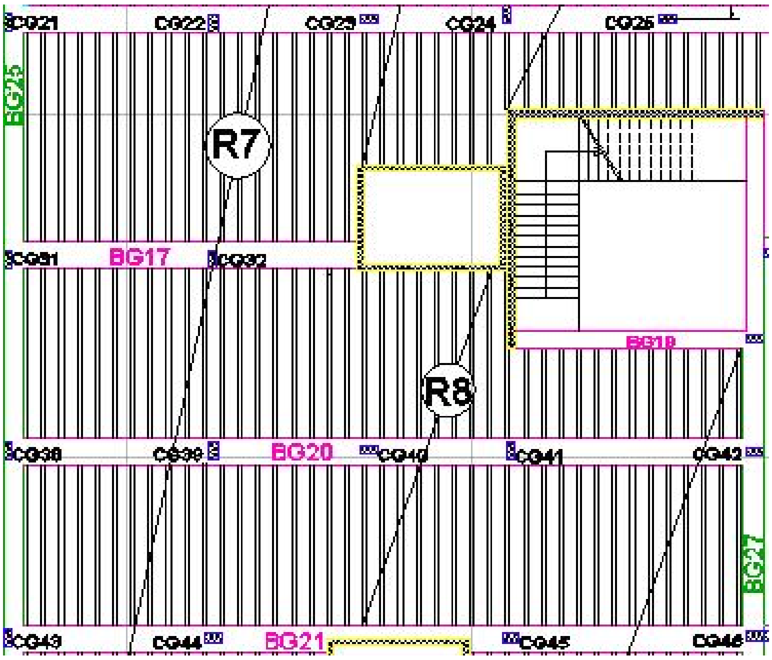
$x = \frac{a}{0.85} = \frac{6.2}{0.85} = 7.3mm$

$£_s = \frac{315 - 7.3}{7.3} \times 0.003 = 0.126$

$£_s = 0.126 > 0.005$

- ✓ Ok

4.5 Design of Beam B-20



Figure(4.7)Beam location in ground floor slab

4.5.1 Load calculations for Beam:

The distributed Dead and Live loads acting upon the Beam **B-20**can be defined from the support reactions of the rib **R-7, R-8, R-9 .**

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

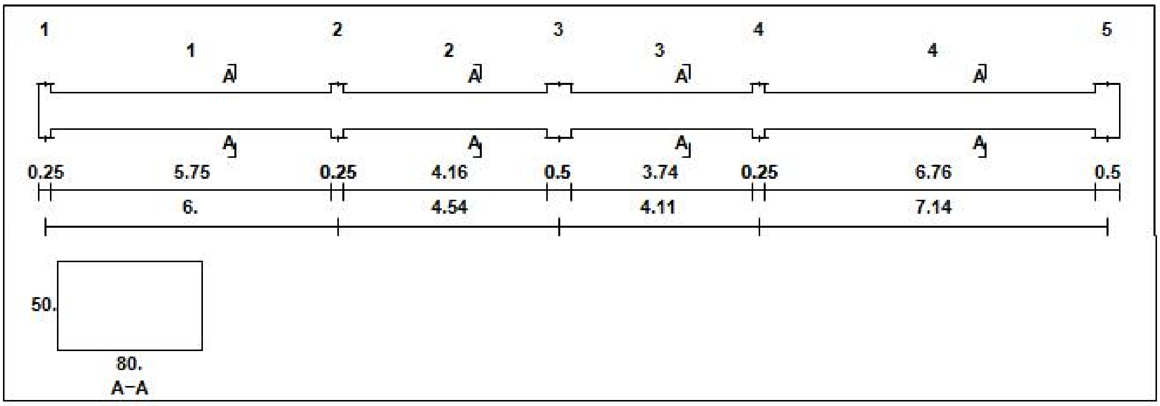


Figure (4.8) Geometry of Beam B-20

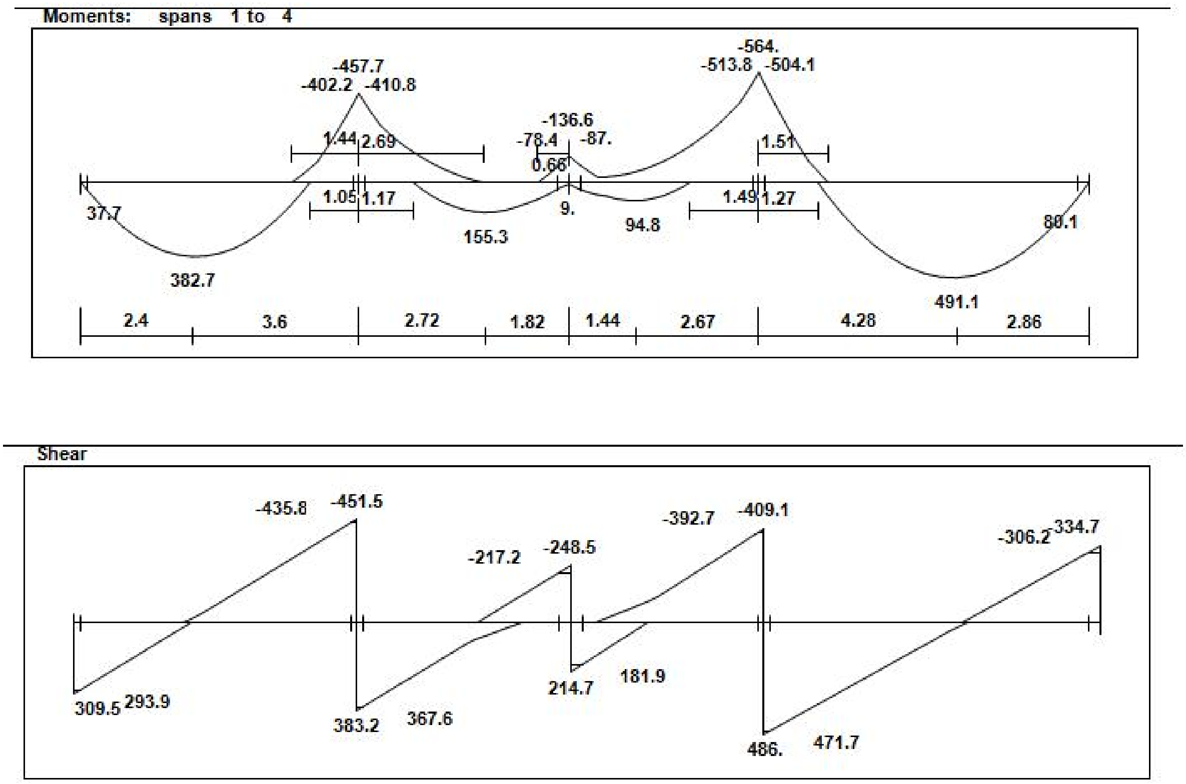


Figure (4.9) Moment and Shear envelop for Beam B-20

Assume bar diameter Φ20 for main reinforcement.

Selected dropped beam

$b_w = 80cm, h = 50cm$

$d = 500 - 40 - 8 - \frac{16}{2} = 444mm$

4.5.2 Design of shear for Beam

ACI – 318 – Categories for shear design:

Vu critical =471.7 KN

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

Vc = $\frac{1}{6}\sqrt{24} * 800 * 444$

Vc= 290KN.

Φ Vc= 0.75*290=217.5 KN

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

$v_{s,min} = \frac{1}{16}\sqrt{24} * 800 * 444$

$v_{s,min} = 108.76KN$

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

$v_{s,min} = \frac{1}{3} * 800 * 444 = 118.4$ KN ... control..

$\emptyset(v_c + v_{s,min}) < v_u \leq 3\emptyset * v_c$

0.75(290.05+118.4) <471.7 <3* 0.75*217.5

306.3<471.7<652.5

So, shear reinforcement are required.

Use 2 leg Φ 10.

Av =157 mm2.

Vs = Vn – VC = $\frac{471.7}{0.75}$ – 290= 339KN

$$S = \frac{A_v f_{yt} d}{v_s} = \frac{157 * 420 * 444}{339 * 1000} = 86.4mm$$

$s_{max} \le \frac{d}{2}$ or $s_{max} \le 600$ mm

$S\ max = \frac{d}{2} = \frac{442}{2} = 222$ mm ... control

- Select Φ10 @ 8 cm (2 Legs) or Φ10 @ 16 cm (4 Legs).

Let S2=2S1=160mm < S max =222mm

$$Vs = \frac{A_v f_{yt}\, d}{s} = \frac{157 * 420 * 444}{160} = 183\ KN$$

Vn =Vs + Vc

=183+290

=473KN

Vu=$\emptyset Vn = 0.75(473)$

=354.75KN < V critical=471.7KN

From the similarities of triangles:

$$\frac{486}{4.22} = \frac{354.7}{X}$$

X=3.1 m.

After x= 3.1 m use Φ10 @ 16 cm (2 legs).

4.5.3 Design of Beam of negative moment :

Mu =-410.8KN.m at support (2).

Mn= Mu/0.9

= 410.8/0.9 =456.4 KN.m

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

$$Kn = \frac{Mn}{bd^2} = \frac{456.4 * 10^6}{(800)(442)^2} = 2.92\ Mpa$$

$$As\ min = \frac{\sqrt{24}}{4(420)}(800)(442) = 1031.118 mm^2$$

$A_{s\ min} = \frac{1.4}{420}(800)(442) = 1178.67 mm^2$ ~ control

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2\,mkn}{fy}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2 * 20.6 * 2.92}{420}}\right) = 0.00754$$

A_s = 0.00754 (800) (442) =2666.144mm^2> $A_{s\ min}$ = 1178.67mm^2

# of bars = A_s / $A_{s\ bar}$ = 2666.144 /491 = 5.43 * Note $A_{\Phi 25}$ = 491 mm^2

- Select bar 6 Φ 25

Total As $_{(provide)}$ =2945.24 mm^2> 4632mm^2

* Check strain for the magnitude of under strength factor Φ:

Tension = Compression

$$A_s \times fy = 0.85 \times f_c' \times b \times a$$

$$2945.24 \times 420 = 0.85 \times 24 \times 800 \times a$$
$$a = 75.8 mm$$

$$X = \frac{a}{0.85} = \frac{75.8}{0.85} = 89.176 mm$$

$$\pounds_s = \frac{442 - 89.176}{89.176} \times 0.003 = 0.011$$
$$\pounds_s = 0.011 > 0.005$$

- ✓ Ok

Check for bar distance:

$$S = \frac{800 - 2\times 40 - 2\times 8 - 6\times 25}{5} = 110.8 mm > 25 mm.$$

- ✓ Ok

Mu =-87KN.m at support (3).

Mn= Mu/0.9

= 87/0.9 =96.7 KN.m

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

$$Kn = \frac{Mn}{bd^2} = \frac{96.7 * 10^6}{(800)(442)^2} = 0.62\ Mpa$$

$$As\ \min = \frac{\sqrt{24}}{4(420)}(800)(442) = 1031.118 mm^2$$

$$As\ \min = \frac{1.4}{420}(800)(442) = 1178.67 mm^2 \sim \text{control}$$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2\,mkn}{fy}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2 * 20.6 * 0.67}{420}}\right) = 0.0015$$

As = 0.0015 (800) (442) =530.4mm^2<$As\ \min$ = 1178.67mm^2

Use As=1178.67mm

# of bars = A_s / $A_{s\ bar}$ = 1178.67/252.46 = 4.67 * Note $A_{\Phi 18}$ = 254.46 mm^2

- Select bar 5 Φ 18

Total As $_{(provide)}$ = 1272.3 mm^2.

* Check strain for the magnitude of under strength factor Φ:

Tension = Compression

$$A_s \times fy = 0.85 \times f_c' \times b \times a$$

$$1272.3 \times 420 = 0.85 \times 24 \times 800 \times a$$

$$a = 32.74 mm$$

$$X = \frac{a}{0.85} = \frac{32.74}{0.85} = 38.52 mm$$

$$£_s = \frac{442-38.52}{38.52}\times 0.003 = 0.0314$$

$$£_s = 0.0314 > 0.005$$

- ✓ Ok

Check for bar distance:

$$S = \frac{800-2\times 40-2\times 8-5\times 18}{4} = 153.5mm > 25mm$$

- ✓ Ok

Mu =-513.8KN.m at support (4).

Mn= Mu/0.9

= 513.8/0.9 =570.88 KN.m

Kn = $\frac{Mn}{b\times d^2}$ = $\frac{570.88\times 10^6}{800\times(442)^2}$ = 3.65 Mpa

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

$$As\ \min = \frac{\sqrt{24}}{4(420)}(800)(442) = 1031.116mm^2$$

$$As\ \min = \frac{1.4}{420}(800)(442) = 1178.67mm^2 \sim \text{control}$$

ρ = $\frac{1}{20.6}$ (1 - $\sqrt{1-\frac{2(20.6)(3.65)}{420}}$) = .00965

As =ρ* b*d= 0.0965(800) (442) = 3412.24 mm^2 >As min =1178.67mm^2

# of bars = $\frac{As_{req}}{As_{bar}} = \frac{3412.24}{491} = 6.94$ *Note $A_{\Phi 25}$= 491 mm^2

- Select 7Φ25in one layer

Total As (provide) = 3436.116mm^2

* Check strain for the magnitude of under strength factor Φ:

Tension = Compression

$$A_s \times fy = 0.85 \times f_c' \times b \times a$$

$$3436.116 \times 420 = 0.85 \times 24 \times 800 \times a$$

$$a = 88.43mm$$

$$X = \frac{a}{0.85} = \frac{88.43}{0.85} = 103.88\ mm$$

$$£_s = \frac{442 - 103.88}{103.88} \times 0.003 = 0.0097$$

$$£_s = 0..0097 > 0.005$$

- ✓ Ok

Check for bar distance:

$$S = \frac{800 - 2\times 40 - 2\times 8 - 7\times 25}{6} = 88.167mm > 25mm$$

- ✓ Ok

4.5.4 Design of positive moment

Take Mu = 382.7 KN.m at span (1).

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

$$Kn = \frac{Mn}{bd^2} = \frac{382.7 * 10^6}{(0.9)(800)(442)^2} = 2.72\ Mpa$$

$$As\ \min = \frac{\sqrt{24}}{4(420)}(800)(442) = 1031.1mm^2$$

$A_s\ min = \frac{1.4}{420}(800)(442) = 1178.6mm^2$ ~ control

$$° = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2\,mkn}{fy}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2 * 20.6 * 2.72}{420}}\right) = 0.0069$$

A_s = 0.0069 (800) (442) =2467.3 mm^2> $A_s\ min$ = 1178.6mm^2

# of bars = A_s / $A_{s\ bar}$ = 2467.3/314 = 7.8 * Note $A_{Φ20}$ = 314 mm^2

- Select bar 8 Φ 20

Total $As_{(provide)}$ = 2512 mm^2> 2467.3 mm^2

* Check strain for the magnitude of under strength factor Φ:

Tension = Compression

$$A_s \times fy = 0.85 \times f_c' \times b \times a$$

$$2512 \times 420 = 0.85 \times 24 \times 800 \times a$$

$$a = 64.6mm$$

$$X = \frac{a}{0.85} = \frac{64.6}{0.85} = 76mm$$

$$£_s = \frac{442 - 76}{76} \times 0.003 = 0.0144$$

$$£_s = 0.0144 > 0.005$$

- ✓ Ok

Check for bar distance:

$$S = \frac{800 - 2\times 40 - 2\times 8 - 8\times 20}{3} = 181.3mm > 25mm$$

- ✓ Ok

Take Mu = 155.3 KN.m at span (2).

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

$$Kn = \frac{Mn}{bd^2} = \frac{155.3 * 10^6}{(0.9)(800)(442)^2} = 1.104\ Mpa$$

$$As\ \min = \frac{\sqrt{24}}{4(420)}(800)(442) = 1031.1 mm^2$$

$$As\ \min = \frac{1.4}{420}(800)(442) = 1178.6 mm^2 \sim \text{control}$$

$$° = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mkn}{fy}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2 * 20.6 * 1.104}{420}}\right) = 0.0027$$

As = 0.0027 (800) (442) =956.14 mm^2< $As\ \min$ = 1178.6mm^2

\# of bars = A_s / $A_{s\ bar}$ = 1178.6/314 = 3.7 * Note $A_{\Phi 20}$ = 314 mm^2

- Select bar 4 Φ 20

Total $As_{(provide)}$ = 1256 mm^2> 1178.6 mm^2

* Check strain for the magnitude of under strength factor Φ:

Tension = Compression

$$A_s \times fy = 0.85 \times f_c' \times b \times a$$

$$1256 \times 420 = 0.85 \times 24 \times 800 \times a$$
$$a = 32.32 mm$$

$$X = \frac{a}{0.85} = \frac{32.32}{0.85} = 38 mm$$

$$£_s = \frac{442 - 38}{38} \times 0.003 = 0.0318$$
$$£_s = 0.0318 > 0.005$$

- ✓ Ok

Check for bar distance:

$$S = \frac{800-2\times40-2\times8-4\times20}{3} = 208mm > 25mm.$$

- ✓ Ok

Take Mu = 94.8KN.m at span (3).

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

$$Kn = \frac{Mn}{bd^2} = \frac{94.8*10^6}{(0.9)(800)(442)^2} = 0.673\ Mpa$$

$$As\ min = \frac{\sqrt{24}}{4(420)}(800)(442) = 1031.1mm^2$$

$$As\ min = \frac{1.4}{420}(800)(442) = 1178.6mm^2 \sim \text{control}$$

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2mkn}{fy}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2*20.6*0.673}{420}}\right) = 0.0016$$

A_s = 0.0016 (800) (442) =577.1 mm^2< A_s min = 1178.6mm^2

# of bars = A_s / $A_{s\ bar}$ = 1178.6/314 = 3.7 * Note $A_{\Phi20}$ = 314 mm^2

- Select bar 4 Φ 20

Total $As_{(provide)}$ = 1256 mm^2> 1178.6 mm^2

* Check strain for the magnitude of under strength factor Φ:

Tension = Compression

$$A_s \times fy = 0.85 \times f_c' \times b \times a$$

$$1256\times420 = 0.85\times24\times800\times a$$

$$a = 32.32mm$$

$$X = \frac{a}{0.85} = \frac{32.32}{0.85} = 38mm$$

$$£_s = \frac{442-38}{38} \times 0.003 = 0.0318$$

$$£_s = 0.0318 > 0.005$$

- ✓ Ok

Check for bar distance:

$$S = \frac{800-2\times40-2\times8-4\times20}{3} = 208mm > 25mm.$$

- ✓ Ok

Take Mu = 491.1KN.m at span (4).

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

$$Kn = \frac{Mn}{bd^2} = \frac{491.1*10^6}{(0.9)(800)(442)^2} = 3.49\ Mpa$$

$$As\ min = \frac{\sqrt{24}}{4(420)}(800)(442) = 1031.1mm^2$$

$$As\ min = \frac{1.4}{420}(800)(442) = 1178.6mm^2 \sim \text{control}$$

$$\circ = \frac{1}{m}\left(1-\sqrt{1-\frac{2mkn}{fy}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2*20.6*3.49}{420}}\right) = 0.0091$$

A_s = 0.0091 (800) (442) =3246.3 mm^2 > A_s min = 1178.6mm^2

\# of bars = A_s / $A_{s\ bar}$ = 3246.3/314 = 10.3 * Note $A_{\Phi20}$ = 314 mm^2

- Select bar 11 Φ 20

Total $As_{(provide)}$ = 3454 mm^2> 3246.3 mm^2

* Check strain for the magnitude of under strength factor Φ:

Tension = Compression

$$A_s \times fy = 0.85 \times f_c' \times b \times a$$

$$3454 \times 420 = 0.85 \times 24 \times 800 \times a$$

$$a = 88.8mm$$

$$X = \frac{a}{0.85} = \frac{88.8}{0.85} = 104.5mm$$

$$£_s = \frac{442 - 104.5}{104.5} \times 0.003 = 0.0096$$

$$£_s = 0.0096 > 0.005$$

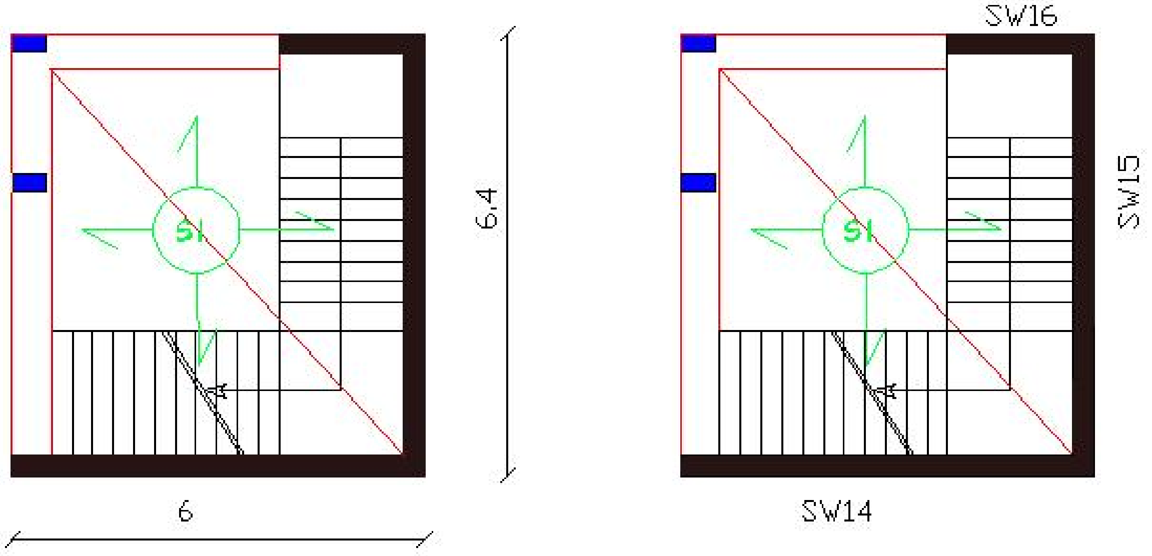
- ✓ Ok

Check for bar distance:

$$S = \frac{800 - 2\times40 - 2\times8 - 11\times20}{3} = 161mm > 25mm.$$

- ✓ Ok

4.6 Design of Two way solid slab (ST-1)



Figure(4.10) ST-1 location in third floor slab

Material

Concrete B300 fc' = 24 N/mm^2

Reinforcement Steel Fy = 420 N/mm^2

4.6.1 Limitation of deflection

h min = clear span\180

= 2*(5.1+5.6)/180

=0. 11m

Select h = 20 cm.

Solid slab is supported on shear walls.

Stiffness of shear wall is very great.

αfm> 2.0

h min = Lnc (0.8 + fy /1400) \ (36 + 9B)

Lnc = 5.6 m.

B= 5.6/5.1 = 1.098

h min =5.6(0.8+420\1400)\(36+9*1.098)= 0.134m

select h = 20 cm.

4.6.2 Load calculation

For 1 m^2:

20 cm concrete = 25*0.2= 5 KN\m^2

D= 5 KN\m2

L= 10 KN\m2

- Factored loads:

qu= 1.2D+1.6L

= 1.2*5+1.6*10

=22 KN/m2

4.6.3 Analysis for shear force:

Approximate method for determination of max Vu

- Assumption

Slab is one way with short direction.

Wa (La/Lb =0.91) =0.59

The total load on the panel =22*5.1*5.6 = 628.32KN.

The load per meter on the long beam is:

Vu = 0.59*628.32/2*5.6

= 33.1KN.

d= 200 – 20 – 10/2 = 175 mm

$\emptyset Vc = \emptyset \times \frac{\overline{f'_c}}{6} \times bw \times d$

$= 0.75 \times \frac{\sqrt{24}}{6} \times 1000 \times 175 = 107.16$ KN.

$0.5\emptyset Vc$ = 53.58 KN > Vu =33.4 KN

The thickness of the slab is enough.

No shear reinforcement is required.

h = 20 cm is safe.

4.6.4 Analysis and design of bending moment

- Positive Moments calculations

Cad_{pos} $\frac{l_a}{l_b} = 0.91$ = 0.044 from table by interpolation

$Mu.a_{pos} = Cad * wd * La^2$

$Mu.a_{pos} = 0.044 * 6 * 5.1^2 = 6.86\ KN.m$

$Cb.D_{pos}(\frac{l_a}{l_b} = 0.91)$= 0.0298 from table by interpolation

Mu.b.pos = $0.0298*6*5.6^2$=5.6 KN.m

$Call_{pos}$ $\frac{l_a}{l_b} = 0.91$ = 0.044 from table by interpolation

$Mu.a_{pos} = 0.044 * 16 * 5.1^2 = 18.311$ KN. m

$Cb.D_{pos}(\frac{l_a}{l_b} = 0.91)$= 0.0298 from table by interpolation

$Mu.b_{pos} = 0.044 * 16 * 5.6^2 = 15\ KN.m$

Mu a= 6.86+18.31 =25.17 KN .m

Mu b= 5.6+15 =20.6 KN.m

- Design of Positive moment

Mu= 25.17 KN .m

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

$$Kn = \frac{Mu}{\Phi bd^2} = \frac{22.17 * 10^6}{(0.9)(1000)(175)^2} = 0.91\ Mpa$$

$$\circ = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2 * m * kn}{fy}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2 * 20.58 * 0.91}{420}}\right) = 0.00221$$

A_s = 0.0022(1000) (175) = 385 mm^2

$A_{s\ min}$ =0.0018*1000*200=350 mm^2

Use Φ10

#Of bars = A_s / $A_{s\ bar}$ = 385/78.5= 5 * Note $A_{\Phi 10}$= 78.5mm^2

- Select bars 6 Φ10 /m or Φ10 /15 cm

Total $As_{(provide)}$ =471 mm^2 > 385 mm^2

S= 15 cm < 2h =2*200 =400 mm < 450 mm.

4.7 Design of column C111

Material

Concrete B350 fc' = 28 N/mm^2

Reinforcement Steel Fy = 420 N/mm^2

The Column is an interior one.

DL =1362.82 KN

LL = 668.18KN

qu = 1.2DL+1.6LL

= 1.2(1362.82) +1.6(668.18)

= 2704.5KN

- Check for slenderness

$$\frac{k\ ln}{r} \leq 34 - 12(\frac{M_1}{M_2}) \leq 40$$

$\frac{M_1}{M_2} = 1$ Braced frame with M_{min}

K=1 for column in non-sway frames.

$$\frac{k\ ln}{r} \leq 34 - 12 = 22 \leq 40$$

$\frac{k\ ln}{r_x} = \frac{1*4}{0.3*0.6} = 22.22 > 22$ Column is long about x-axis

$\frac{k\ ln}{r_y} = \frac{1*4}{0.3*0.6} = 22.22 > 22$ Column is long about y-axis

- Calculate the minimum eccentricity e_{min} and the minimum moment M_{min}

e_{min}= (15+0.03h) = 15+0.03*600 = 33 mm

$Pu_{factored}$ = 2704.5KN.

M_{min}= Pu*e_{min}= 2704.5* $\frac{33}{1000}$ =89.25KN.

- Compute EI

$$I_g = \frac{bh^3}{12} = \frac{600 * 600^3}{12} = 10.8 * 10^9 mm^4$$

$$\beta_{dns} = \frac{1.2\,D\,(sustaind)}{1.2D + 1.6L} = \frac{1.2 * ١٣٦٢.٨٢}{2704.5} = 0.61$$

$$EI = \frac{0.4*4700\sqrt{fc'}\,Ig}{1+\beta_{dns}} = \frac{0.4*4700\sqrt{28'}*10.8*10^9}{1+0.61} = 66732.09 KN.m^2$$

- Determine the Euler buckling load, P_c

$$P_c = \frac{\pi^2 EI}{(kl_n)^2} = \frac{\pi^2 * 66732.09}{(1*4)^2} = 41163.71 KN$$

- Calculate the moment magnifier factor δ_{ns}

$$C_m = 0.6 + 0.4\frac{M_1}{M_2} = 0.6 + 0.4 * 1 = 1 > 0.4$$

$$\delta_{ns} = \frac{C_m}{1 - \frac{Pu}{0.75P_C}} = \frac{1}{1 - \frac{2704.5}{0.75*41163.71}} = 1.1$$

1.4> 1.1 > 1

✓ Ok

- The magnified eccentricity and moment

e =$e_{min} * \delta_{ns} = 33 * 1.1 = 36.3\,mm$

$$M_u = \delta_{ns} * M_u = 1.1 * 89.25 = 98.17\,KN.m$$

- Select column reinforcement

We will use the tide column interaction diagrams

$$\frac{e}{h} = \frac{36.3}{600} = 0.06$$

- ✓ Compute ratio γ

$$\gamma = \frac{d - d'}{h} = \frac{600 - 2*40 - 2*10 - 16}{600} = 0.81$$

$$\frac{\emptyset P_n}{A_g} = \frac{P_u}{A_g} = \frac{2704.5*10^{-3}}{0.6*0.6} = 7.52 Kn/m\text{^}2$$

$$\rho_g = 0.01$$

- Select column reinforcement

$$A_{st} = \rho_g A_g = 0.01*600*600 = 3600mm^2$$

$$A_s \emptyset 16 = 201.1\ mm^2$$

$$\frac{A_s}{A_s \emptyset 16} = 17.9$$

Use 18Ø16 $with\ A_s = 3619.8mm^2 > 3600mm^2$

- ✓ Ok

- Select 18Ø16

Figure (4.11): cross section in column (C111)

- Design of ties

Use ties Ø10 with spacing of ties shall not exceed:

1) 48 times the tie diameter , $48d_s = 48 * 10 = 480mm$

2) 16 times the longitudinal bar diameter $16d_b = 16 * 16 = 256mm$ ……….. control

3) The lest dimension of column =40 mm

Use ties Ø10@ 200 mm

- Check for clear spacing between longitudinal bars

Clear spacing $= \frac{600-40*2-10*2-6*16}{5} = 80.8 > 40\ mm$

$80.8 > 1.5 * 16 = 24$

4.8 Design of Stair

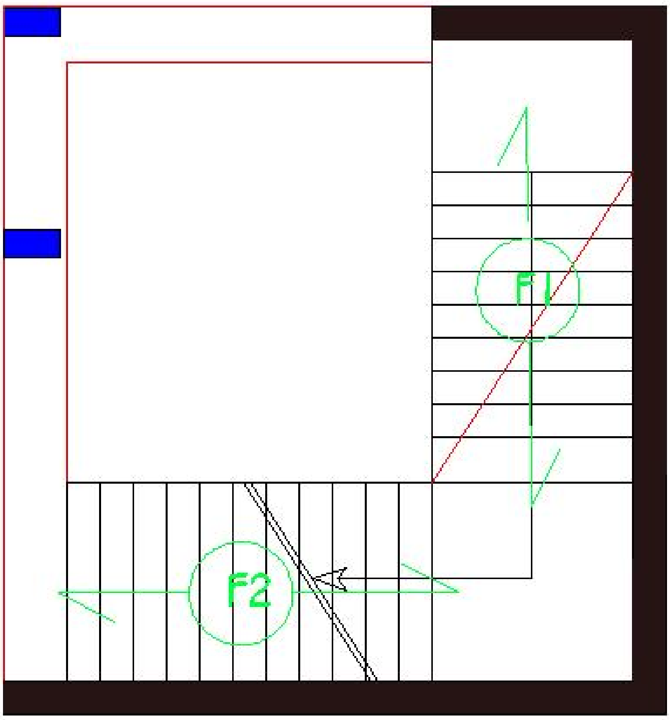


Figure (4.12): Stair plan

Material

Concrete B300 fc' = 24 N/mm^2

Reinforcement Steel Fy = 420 N/mm^2

Height = 4 m

Rise = 4 / 22=0.18m

Run = 30 cm

Live Load on Stair (Landing & Flight) =5 KN /m^2 (Horizontal projection)

4.8.1 Structural system and minimum thickness

- The structural system of this stair was taken as a simply supported (one-way solid slab) since that the flight of stair will be supported at the ends of upper and lower landings.
- Minimum Slab thickness for deflection is (for simply supported one-way solid slab) according Jordanian code is:

$h_{min} = \frac{L}{20} = \frac{658}{20} = 32.9$ cm , but in this case presented here where the slab ends are cast white the supporting beams and additional negative reinforcement is provided , minimum thickness can be assumed to be $h_{min} = \frac{L}{28} = \frac{658}{28} = 23.5$ cm.

- Take $h_{min} = 25$ cm
- The Stair Slope by $\theta = \tan^{-1} \frac{rise}{run} = \tan^{-1} \frac{180}{300} = 31.10^{\circ}$

4.8.2 Design of Flight

- Load Calculations

➢ Flight Dead Load computation

Dead load:

25cm flight: 25*0.25*1/cos31.10= 7.3KN/m

3cm plaster: 22*0.03*1/cos31.10=0.771 KN/m

Horizontal mortar: 22*0.03*1=0.66KN/m

Vertical mortar: 22*0.03*1*(18/30) = 0.396KN/m

Horizontal tiles: 23*0.03*1*(35/30) =0.805KN/m

Vertical tiles: 23*0.03*1*(18/30) =0.414KN/m

Vertical mortar: 22*0.03*1*(18/30) = 0.396KN/m

Triangle: 25*0.18*1/2=2.25 KN/m

∑D=13 KN/m

L=5*1=5 KN/m

Factored load:

qu=1.2*D +1.6*L

qu=1.2*13 + 1.6*5

=23.6 KN/m

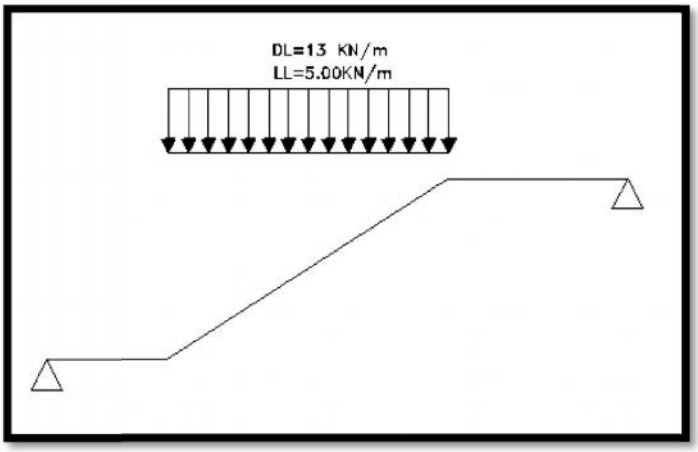


Figure (4.13) structural system of flight 1

4.8.3 Design of Landing

- Load Calculations

➢ Landing Dead Load computation

Dead load:

25cm concrete   25*0.25*1=6.25 KN/m

7cm sand   16*0.07*1= 1.1 KN/m

2cm mortar   22*0.03*1 = 0.66 KN/m

3cm tiles   23*0.03*1 = 0.69 KN/m

3cm plaster   22*0.03*1 = 0.66 KN/m

∑D = 9.36 KN/m

L = 5 KN/m

Factored load:

qu=1.2*D +1.6*L

qu=1.2*9.36 + 1.6*5

=19.23 KN/m

Because the load on the landing is carried into two directions, only half the load will be considered in each direction $\frac{19.23}{2} = 9.616 \quad \frac{kN}{m}$.

System (I) of Landing:

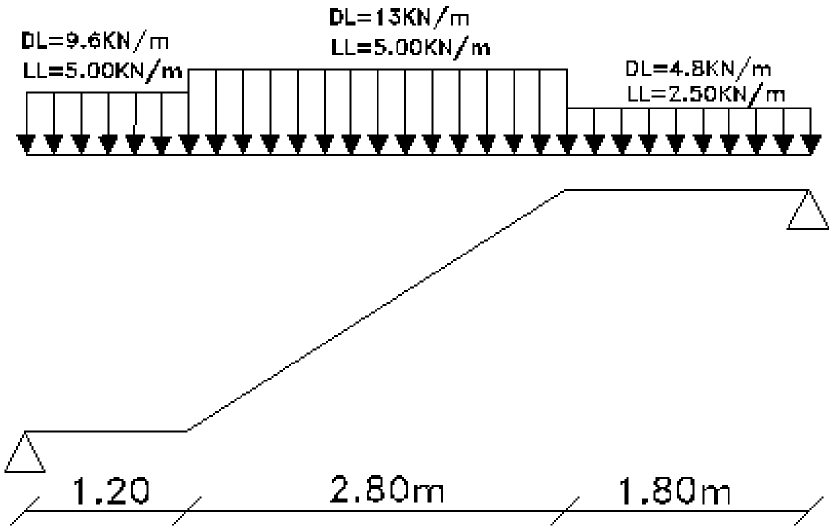
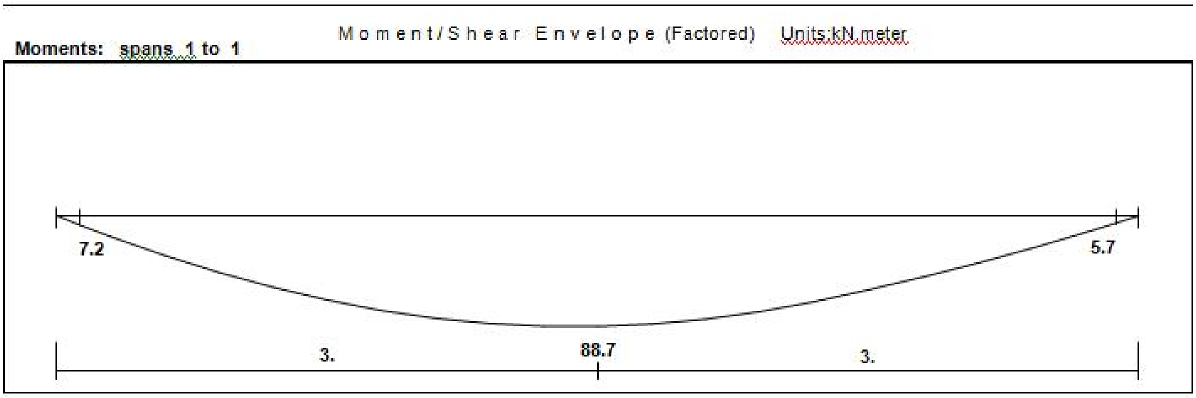


Figure (4.14) structural system of landing system (I)



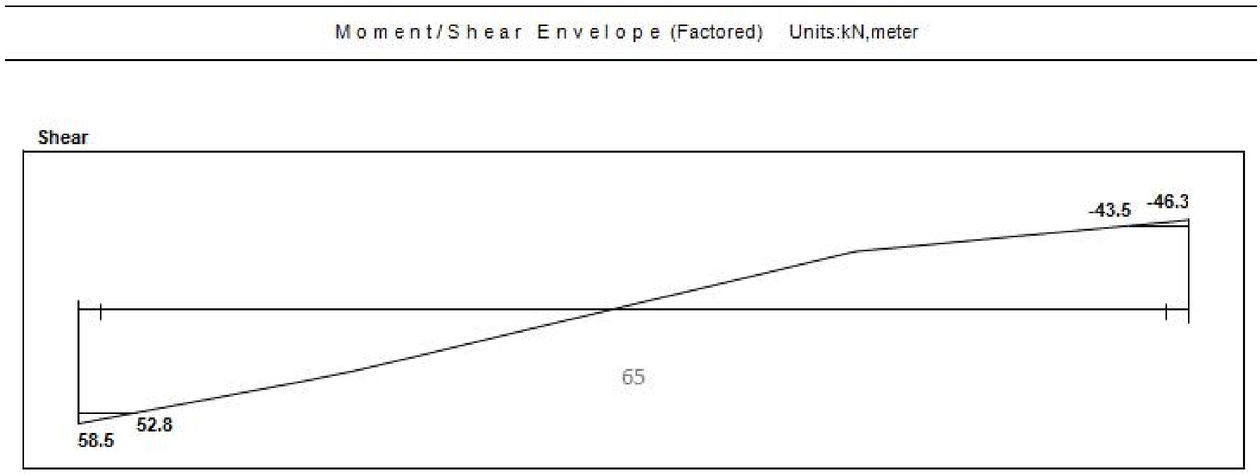


Figure (4.15) Moment & shear Envelope of system (I)

- Shear and moment calculations:

Check for shear strength:

Assume bar diameter Ø14 for main reinforcement.

$$d = h - cover - \frac{d_b}{2} = 250 - 20 - \frac{14}{2} = 223 \text{ mm}$$

Assume beam width 25 cm

$$V_c = \frac{1}{6}\sqrt{f_c'}\, b_w d = \frac{1}{6} \times \sqrt{24} \times 1000 \times 223 = 182 \text{ kN} \text{ .. fot 1 m strip}$$

$\phi = 0.75 - \text{for shear}$

$\phi V_c = 0.75 \times 182 = 136.5 \text{ kN .. for 1m strip}$

$V_{u,max} = 52.8 \text{ kN} < \frac{1}{2}\phi V_c = 68.3\text{kN}$ …… No shear reinforcement is required.

The thickness of the slab is enough

- Calculation of maximum moment and steel reinforcement

$M_{u,max} = 88.7 \text{ kN.m / m.}$

assume bar diameter Ø14for main rinforcemnt with , $d = 223$ mm

$$R_n = \frac{M_u}{\emptyset b d} = \frac{88.7 \times 10^6}{0.9 \times 1000 \times 223^2} = 1.9\text{Mpa} \text{ , } m = \frac{f_y}{0.85 f_c'} = \frac{420}{0.85 \times (24)} = 20.58$$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2R_n m}{f_y}}\right) = \frac{1}{20.58}\left(1 - \sqrt{1 - \frac{2 \cdot 1.9 \cdot 20.58}{420}}\right) = 0.0047$$

$A_s = \rho bd = 0.0047 \times 1000 \times 223 = 1048.1\ mm^2$

$A_{s,min} = 0.0018bh = 0.0018 \times 1000 \times 250 = 450mm^2$

$A_s = 1048.1mm^2 > A_{s,min} = 450\ mm^2$, use Ø12

Use Ø12@10cm with $A_{s,prov} = 1130\ mm^2 > A_s = 1048.1\ mm^2$ for 1m strip

Check maximum step for main reinforcement (the smallest of):

$3h = 3 \times 250 = 750$ mm.

450mm.

$$S = 38\left(\frac{280}{f_s}\right) - 2.5C_c = 380\left(\frac{280}{\frac{2}{3}\times 420}\right) - 2.5 \times 20 = 330mm.$$

$$S_{max} = 300\left(\frac{280}{f_s}\right) = 300\left(\frac{280}{\frac{2}{3}\times 420}\right) = 300mm$$ ………Control

$S = 15cm < S_{max} = 30$ cm

- ✓ Ok

- ➢ Temperature and shrinkage reinforcement

$A_s = 0.0018bh = 0.0018 (1000)(300) = 540\ mm^2$

Use 5Ø12@20 cm with $A_{s,prov} = 565.48\ mm^2 > A_s = 450\ mm^2$ for 1m strip

Check maximum step for temperature and shrinkage (the smallest of):

$5h = 5 \times 300 = 1500$ mm

450mm. – controled

$S = 20\ cm < S_{max} = 45$ cm

- ✓ Ok

- ➢ Check for strain

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{1077.5\times 420}{0.85\times 1000\times 24} = 22.18\ mm$$

$$c = \frac{a}{\beta_1} = \frac{22.18}{0.85} = 26\ mm$$

$\varepsilon_s = 0.003\ \frac{d-c}{c} = 0.003\ \frac{223-26}{26} = 0.022 > 0.005$

System (II) of Flight:-

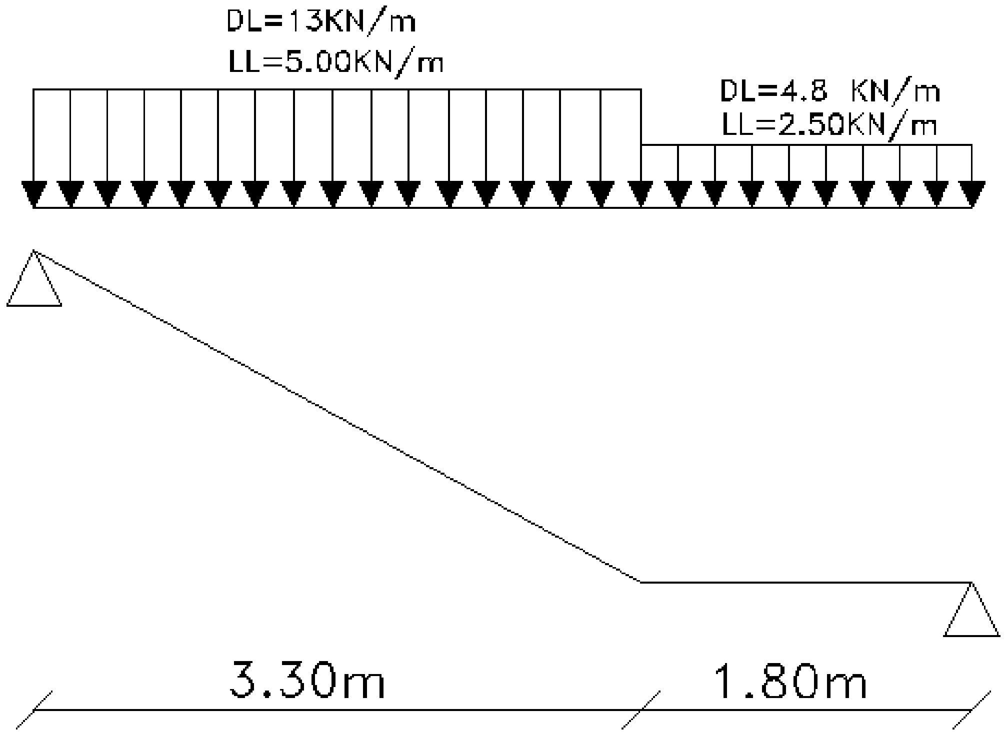
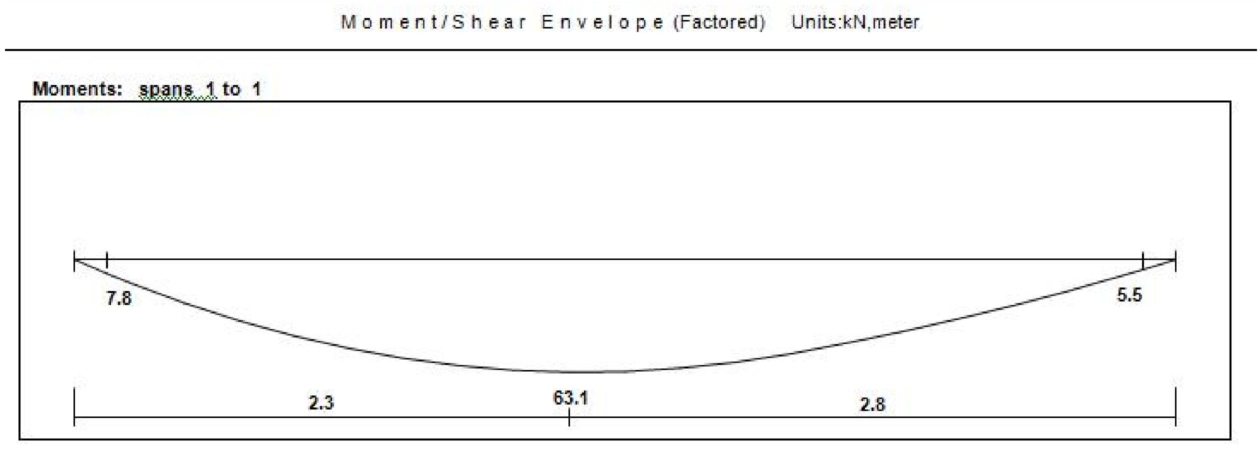


Figure (4.16) structural system of flight System (II)



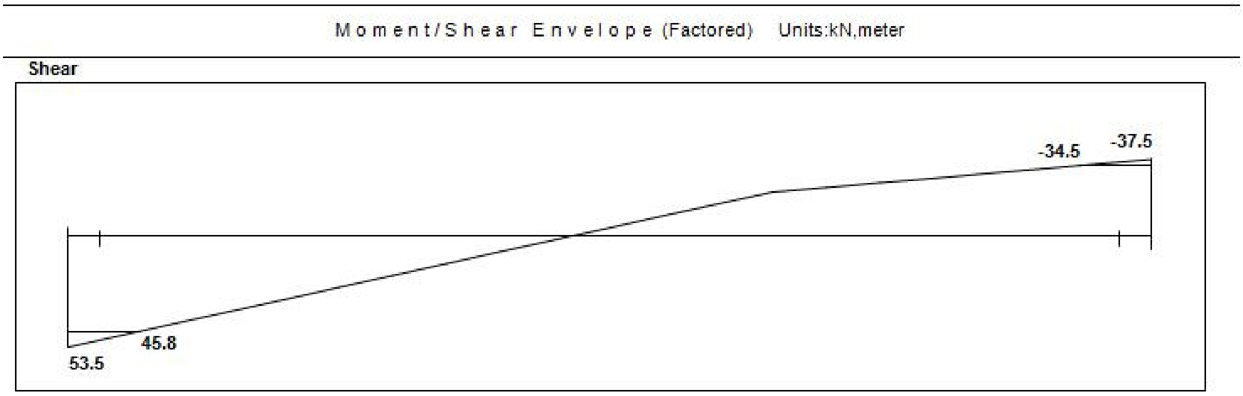


Figure (4.17) Moment & shear Envelope of system (II)

- Shear and moment calculations:

Check for shear strength

Assume bar diameter Ø14 for main riforemnt.

$d = h - cover - \frac{d_b}{2} = 250 - 20 - \frac{14}{2} = 223\ mm$

Assume beam width 25 cm

$V_c = \frac{1}{6}\sqrt{f_c'}b_w d = \frac{1}{6} \times \sqrt{24} \times 1000 \times 223 = 182\ kN$ ..fot 1 m strip

$\phi = 0.75 - $ for shear

$\phi V_c = 0.75 \times 182 = 136.5\ kN$ .. for 1m strip

$V_{u,max} = 45.8kN < \frac{1}{2}\phi V_c = 68.3kN$ …… No shear reinforcement is required

The thickness of the slab is enough

- Calculation of maximum moment and steel reinforcement:

$M_{u,max} = 63.1\ \ kN.m$ / m.

assume bar diameter Ø14for main rinforcemnt with , $d = 223\ mm$

$R_n = \frac{M_u}{\emptyset bd} = \frac{63.1 \times 10^6}{0.9 \times 1000 \times 223^2} = 1.4Mpa$, $m = \frac{f_y}{0.85\ f_c'} = \frac{420}{0.85 \times (24)} = 20.58$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2R_n m}{f_y}}\right) = \frac{1}{20.58}\left(1 - \sqrt{1 - \frac{2 \cdot 1.4 \cdot 20.58}{420}}\right) = 0.0034$$

$A_s = \rho bd = 0.0034 \times 1000 \times 223 = 752.2 \ mm^2$

$A_{s,min} = 0.0018bh = 0.0018 \times 1000 \times 250 = 450 mm^2$

$A_s = 758.2 mm^2 > A_{s,min} = 450 \ mm^2$, use Ø12

UseØ12@15cm with $A_{s,prov} = 753.3 \ mm^2 > A_s = 752.2 \ mm^2$ for 1m strip

Check maximum step for main reinforcement (the smallest of):

$3h = 3 \times 250 = 750 \ mm$

450mm.

$S = 38\left(\frac{280}{f_s}\right) - 2.5C_c = 380\left(\frac{280}{\frac{2}{3}\times 420}\right) - 2.5 \times 20 = 330mm$

$S_{max} = 300\left(\frac{280}{f_s}\right) = 300\left(\frac{280}{\frac{2}{3}\times 420}\right) = 300mm$ ………. Control

$S = 20cm < S_{max} = 30 \ cm$

- ✓ Ok

- ➢ Temperature and shrinkage reinforcement

$A_s = 0.0018bh = 0.0018 \ (1000) \ (300) = 540 \ mm^2$

Use 5Ø12@20 cm with $A_{s,prov} = 565.48 \ mm^2 > A_s = 450 \ mm^2$ for 1m strip

Check maximum step for temperature and shrinkage (the smallest of):

$5h = 5 \times 300 = 1500 \ mm$

450mm. Control

$S = 20 \ cm < S_{max} = 45 \ cm$

- ✓ Ok

- ➢ Check for strain

$a = \frac{A_s . f_y}{0.85 b \, f'_c} = \frac{1077.5 \times 420}{0.85 \times 1000 \times 24} = 22.18 \ mm$

$c = \frac{a}{\beta_1} = \frac{22.18}{0.85} = 26 \ mm$

$\varepsilon_s = 0.003\left(\frac{d-c}{c}\right) = 0.003\left(\frac{223-26}{26}\right) = 0.022 > 0.005$

- ✓ Ok

4.9 Design of Basement wall

Material

Concrete B300 fc' = 24 N/mm^2

Reinforcement Steel Fy = 420 N/mm^2

Allowable Bearing Capacity qall=400KN/m^2

Φ=30 s=20KN/m^3

4.9.1 Load calculation

$K_O = 1 - \sin\varphi = 1 - \sin 30 = 0.5$

$q_o = K_O * h * \gamma = 0.5 * 4.175 * 20 = 41.75\ KN/m$

Q_O = 0.5 * 41.75 * 4.175 = 87.15 KN

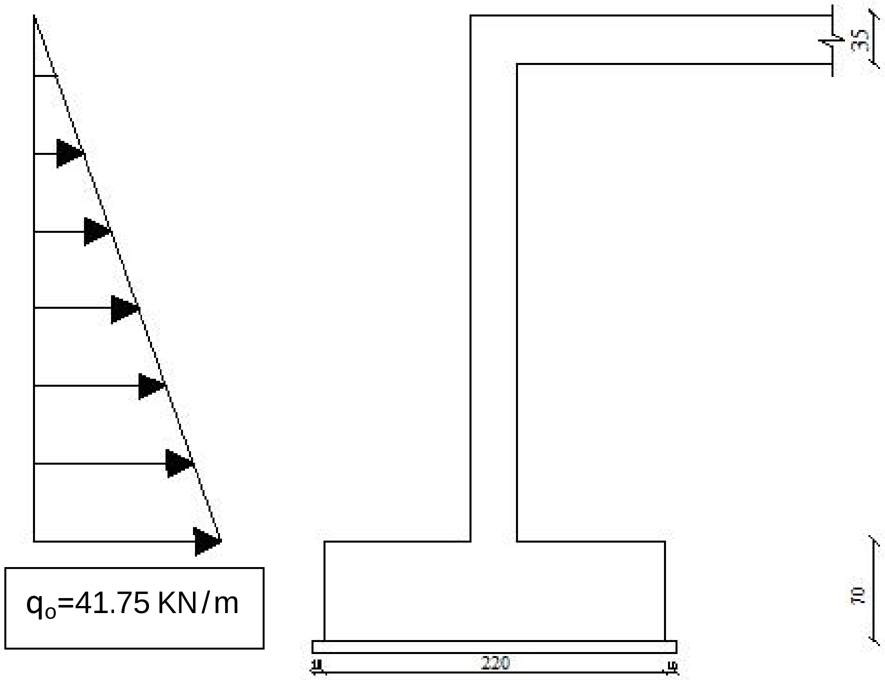


Figure (4.18): Loads on Basement wall.

4.9.2 Support reaction

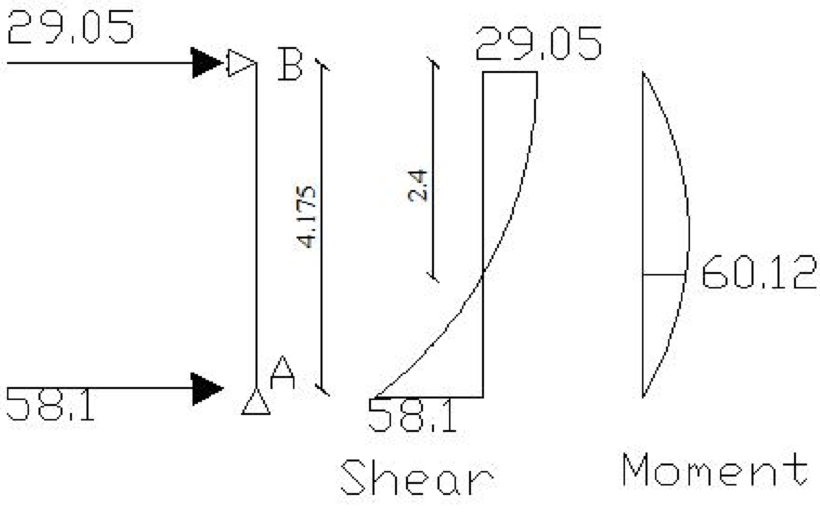


Figure (4.19): Envelope diagram of Basement Wall.

MRA= 0

87.15 * 4.175 /3 – B*4.175 = 0

B= 29.05 KN

MRB= 0

87.15 * 4.175*2 /3 – A*4.175 = 0

A= 58.1 KN

Max V = 58.1 KN

Max M at V=0

V=0 at Y=?

41.75/4.175 = P(Y) /Y

P(Y) = 10 Y

V=0

29.05 -10*Y*(Y/2) =0

Y=2.4m

Max M = 29.05 * 2.4 – 0.5 * 10*2.4 * 2.4/3 = 60.12 KN.m

pu is relative low

Design as a slab with b=1m

Vu =1.6*58.1=92.96 KN

Mu= 1.6*60.12=96.19 KN.m

4.9.3 Design of Shear

h=30 cm

d= 300-20-14 =266 mm

Vu max =92.96 KN

$$\Phi\ Vc = 0.75 \times \frac{\sqrt{24}}{6} \times 1000 \times 266 = 162.8\ KN > Vu\ max = 92.96KN$$

- NOTE: No shear reinforcement is required.

4.9.4 Design of Bending Moment:

Tension face:

$M_u = 96.19$ KN. m/m

$k_n = \frac{Mn}{b \cdot d^2}$

$k_n = \frac{96.19*10^6}{0.9*1000*266^2} = 1.51 MPa$.

$m = \frac{f_y}{0.85 * f'_c} = \frac{420}{0.85 * 24} = 20.58$

$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mk_n}{f_y}}\right) = \frac{1}{20.58}\left(1 - \sqrt{1 - \frac{2 * 20.58 * 1.51}{420}}\right) = 0.00374$

As req = 0.00374 *100*26.6= 9.95 cm^2/m

As min = 0.0012 *100*30=3.6 cm^2/m

Use Φ14 @15cm, with $A_{s,provided}$ =10.3 cm^2/m

- Vertical reinforcement of compression face:

As min = As req /3 =9.95/3= 3.32 cm2/m

Use Φ10 @15cm, with $A_{s,provided}$ = 5.2cm2/m

- horizontal reinforcement

for two layers ... $As\ min = 0.002bh = 0.002 * 300 * 1000 = 600\ mm^2/m$.

for one layer ... $As\ req = 600/2 = 300\ mm^2/m$.

Use Φ10 @20cm, with $A_{s,provided} = 395mm^2/m$ … In both sides.

- NOTE: the structural system for this basement wall assumes as pin and roller supports, so must be connected with slab before put a backfill.

4.10 Design of Flat slab:

The design done by using SAFE program.

4.10.1 Load calculation

Assume slab thickness 35cm.

Table (4–3) Calculation of the total dead load for flat slab.

No.	Material	Thickness cm	Quality Density KN/m^3	Calculation
1	Slab	35	25	0.35×25 = 8.75
2	Sand	7	17	0.07×17 = 1.19
3	Mortar	3	22	0.03×22 =0.66
4	Tile	3	23	0.03×23 =0.69
5	Plaster	2	22	0.02×22 =0.44
6	Partitions			1.5
				∑ =13.25 KN/m2

4.10.2 Check for punching shear

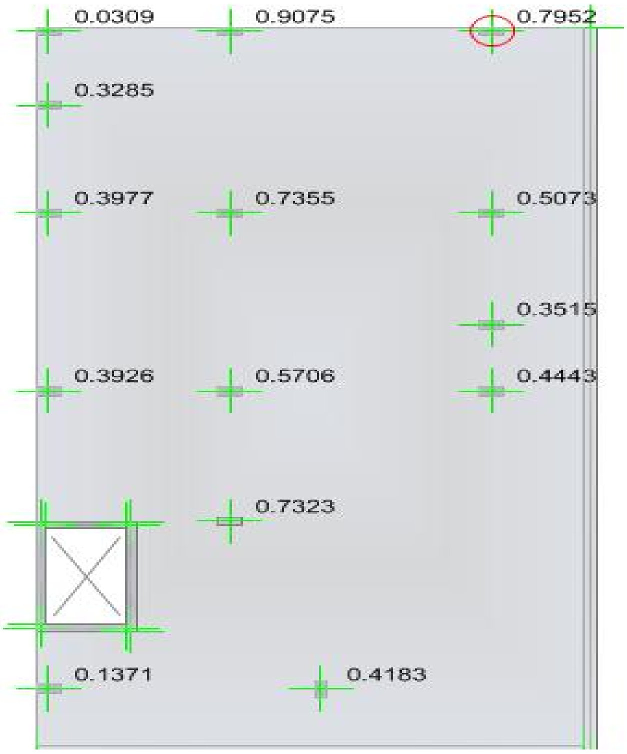


Figure (4.20): Punching Shear Capacity Ratios / Shear Reinforcement for flat slab

As shown all ratios less than 1, so we don't have punching reinforcement.

4.10.3 Design for bending moment

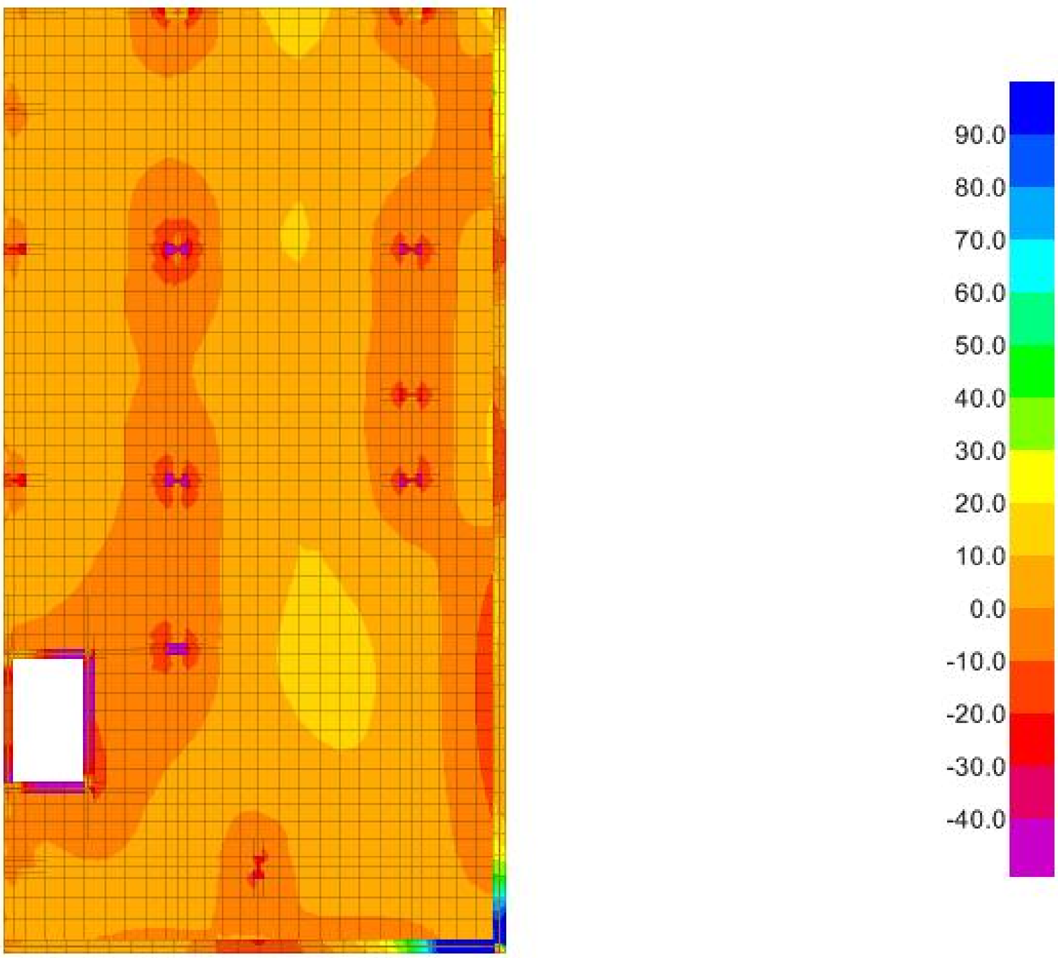


Figure (4.21): moment distribution in x-direction

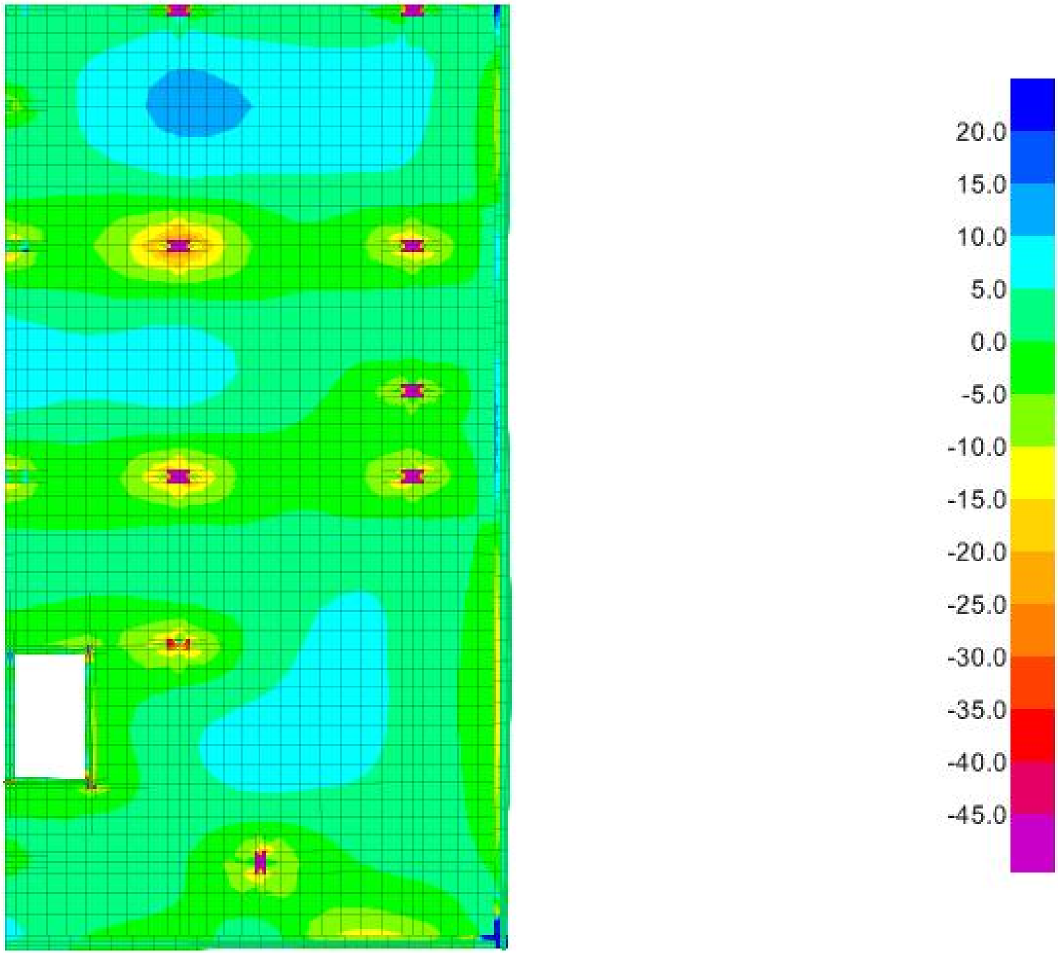


Figure (4.22): moment distribution in y-direction

The design of flat slab done by using Finite Element method.

Selected □14/15cm in both direction for top reinforcement.

Selected □14/15cm in both direction for bottom reinforcement.

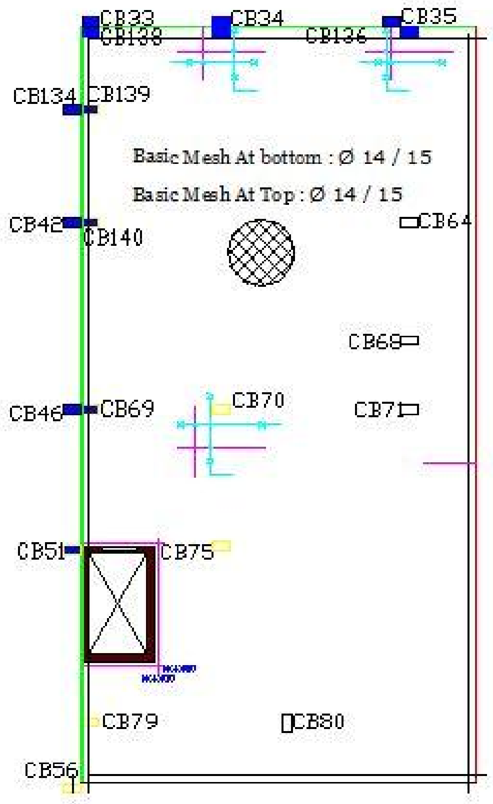


Figure (4.23): Reinforcement for flat.

Chapter Five

Results and Recommendations

5.1 INTRODUCTION

5.2 RESULT

5.3 RECOMMENDATIONS

5.1 Introduction

In this project, architectural plans lacked for a lot of things. After studying all the requirements, the architectural plans and the structural plans were prepared.

This report provides an explanation of all architectural and structural design steps of the building.

5.2 Results

1 Each student or designer must be able to design manually, so he or she can use design programs.

2 The natural factors surrounding the building, the nature of the site and the impact of natural forces on the site are factors that must be considered.

3 The most important steps of structural design, how to connect the various structural elements through the overall view of the building, and then divide all of these elements to design individually.

4 One-Way Ribbed Slab has been used in most slabs due to the shape of building. Solid Slab and flat slab system was also used.

5 Software programs Used:

There are several computer programs used in this project:

a) AUTOCAD 2010/2007: for detailing drawings of structural elements.
b) ATIR: Structural design and analysis of structural elements.
c) Microsoft Office : It was used in various parts of the project such as text writing, formatting and project output.
d) Etabs for the design and reinforced Shear Walls).
e) Safe design of solid and flat slabs and foundations.

6 The live loads used in this project were from the Jordanian Code.

5.3 Recommendations

This project has a major role in expanding and deepening our understanding of construction projects with all the details, analyzes and designs. Here we would like to offer recommendations, which we hope that will benefit those who are planning to choose projects of a structural nature.

Initially, all architectural plans must be coordinated and prepared, so that the building materials are selected and the structural system of the building is determined. At this stage, the overall information about the site, soil and the soil strength of the site must be provided through a geotechnical report. Then the locations of the basement and shear walls and columns will be determined with architectural engineering team.

At this stage, the structural engineer tries to obtain as many shear walls as possible, and distributed them regularly throughout the building; that will be used to resist earthquakes and other horizontal forces.

Reference

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