"The Structural Design of Al-Razi Specialized Hospital"

By:

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Submitted to the College of Engineering

In partial fulfilment of the requirements for the degree of

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According to the system of the College of Engineering, the supervision of our supervisor and the approval of the members of the examination committee, this project was submitted to the Department of Civil and Architectural Engineering in order to finish the requirements of a bachelor's degree in building engineering.

Supervisor signature

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Examination committee signature

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College head signature

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Dec 2017

Dedication

To our home land Palestine,,, land of heroes

To Palestine capital city,,, land of religions,,, Jerusalem

To our honoured prophet Mohammed (peace be upon him)

To the spring that never stops giving,,,to mother

To who taught us to promote our life stairs wisely and patiently,,,to father

To whose love flows in our veins,,,our brothers and sisters

To our home university,,,Palestine Polytechnic University

To our friend Neda Nemer who gave us the permission to analyse her project

To who make a light through knowledge and success path to guide us ,,,our teachers

To who teach and direct us friendly,,,our special supervisor Eng.Inas Shweiki

To everyone who helped us in our project

To everyone who loves us

Thanks and appreciation

The first thank is to Allah, who gave us the ability to start work and complete this task**.** Lots of thanks to our home university "Palestine Polytechnic University","Department of Civil and Architectural Engineering" wish it more progress and success.

Moreover, we express our big thanks to our supervisor Eng.Inas Shweiki, who directs and supports us every time we need it, in addition to her knowledge, time, encouragement, supervision and guidance which gave it to us.

Thanks for all teachers who gave us a little of their time and answered our questions. Finally, our deep sense and sincere thanks to our parents, brothers and sisters for their patience and their endless support. In addition to everyone who tried to help us during our work and gave us strength to complete this task.

Project abstract

In this project, we will study the structural design of Al-Razi specialized hospital, which is located in Ber Haram Alrama north of Hebron city. It consists of 7 floors, each floor area is approximately 2700m², and the total project area is about 17000m², this project is supposed to be built on a land with an area around 6 acres with 3 different levels.

Detailed structural study will be made by determining and analysing all the predicted structural elements and loads, then the structural design for the elements and the structural working drawing will be done according to the previous design for all project elements.

The Jordanian code will be used to determine the live loads, the British code (UBC) to determine earthquake loads, and the American code (ACI) to design all the structural elements . Moreover, we will use some structural design programs such as: Atir and Safe programs, drawing programs like AutoCAD program, in addition to Microsoft office programs.

At the end of this project, it is expected to be able to make complete detailed structural working drawings that ensure achieving all project goals and carrying it out in reality.

ملخص المشروع

سوف يتضمن المشروع التصميم الانشائي لمستشفى الرازي التخصصي والذي يقع في منطقة بئر حرم الرامة شمال الخليل ، حيث يتكون من 7 طوابق ، بمساحة طابقية تقدر ب 2700 متر مربع , ومساحة اجمالية تقدر ب 17000 متر مربع , على ارض مساحتها 6 دونم بثلاث مستويات.

بإذن الله سوف نقوم بعمل دراسة إنشائية تفصيلية من تحديد وتحليل للعناصر الإنشائية والأحمال المختلفة المتوقعة ومن ثم التصميم الإنشائي للعناصر وإعداد المخططات التنفيذية بناء على التصميم المعد لجميع العناصر الإنشائية التي تكوّن الهياكل الإنشائية للمستشفى.

سوف يتم استخدام الكود الاردني لتحديد الاحمال الحية , والكود البريطاني (UBC) لتحديد احمال الزلازل , والكود الامريكي(ACI) لتصميم العناصر الانشائية المختلفة, بالاضافة الى استخدام بعض البرامج التصميمية مثل برنامج العتير والسيف , وبرنامج الرسم الاوتوكاد , وبرامج ميكروسوفت اوفيس.

يتوقع في نهاية هذا المشروع ان نكون قادرين على اعداد مخططات انشائية تفصيلية كاملة تحقق الاهداف المرجوة من المشروع وتضمن تنفيذه على ارض الواقع.

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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).

Chapter I

Introduction

Contents:

1-1 Introduction

Civil engineering can design, build, and maintain the foundation for our modern society “our roads and bridges, drinking water and energy systems, seaports and airports, and the infrastructure for a cleaner environment", to name just a few.

Building engineering is considered as a branch of civil engineering, and it may be considered as a whole branch standing by itself, it can study all the analysis and designs for all constructions types with its variant applications taking into consideration all dynamic and static effects and its relation with the environment effects involving winds, earthquakes and weather.

In any construction project there are 3 main players:

- Owner: he decides the intended use and occupancy of the construction.
- Architect: he develops the architectural plans and layout.
- Building engineer: he decides a suitable structural framework, estimates the structural loads depending on the building use and occupancy, analyses of the structure to determine member and connection design forces, makes a good design for the structural members and connections, and finally verificates this design with ensuring the safety and serviceability of the structure.

So you can see the main role of the building engineer in the structural projects, involves the structural design, executing the work according to the previous design and supervision of the executed work.

1-2 Reasons for choosing the project:

1-2-1 General reasons

There are several reasons led us to the selection of this project; including reasons related to the nature of the project as a specialized hospital, and the other belonging to personal reasons can be summarized as follows:

1. Emphasis on health value because we live a state of population increasing in generally, and accidents and diseases particularly nowadays.

2. Providing building serves the surrounding environment and works to minimize damage as much as possible.
3. The need for achieving building works to provide healthy atmosphere for Patients taking into consideration their needs to have safe and comfortable environment inside the hospital.

1-2-2 Personal reasons

The need of a structural project as the project team desired, to acquire the structural design skills by linking theoretical aspects that have been gained from the courses studied, and apply it effectively in this project and the contents of various structural elements, the design of these elements to fit with loads located them, taking into consideration the provision of global and durability economy.

Moreover, we would like to submit this project to the architectural and civil engineering department in the Engineering College at Palestine Polytechnic University for completing graduation conditions and gaining a bachelor's degree in building engineering specialist.

1-3 Project objectives:

Objectives of this project are divided into two parts:

1-3-1 Architectural Goals

In this project architectural design is not the main goal as civil and building engineers; however; our role here as building engineers is to achieve this project with saving the beauty and utility requirements, cost and durability in its facilities, which are the basic of architectural design requirement.

1-3-2 Structural Goals

Structural design of the units will be done in this project by choosing the most appropriate structural components with its different types for our project to achieve best serviceability, factor of safety as well as the most appropriate economic cost and prepare all structural drawings for beams, slabs, columns, footings and shear walls to be ready for executing the project on reality.

1-4 Research problem

The problem of our project is designing the structural elements of Al-Razi specialized hospital, which is expected to be solved at the end of this project. Our structural design consists of different structural elements involves slabs, beams, columns and foundations taking into consideration its structural distribution without any conflict with the architectural design.

1-5 Methodology:

1. Preparation of architectural plans completed and evaluated in terms of architecture and its compatibility with the objectives of the project and its services.
2. Study of structural elements and choosing the most appropriate mechanism for the distribution of these elements as columns, beams, ribs which don't collide with architectural design topic and achieve the economic aspect and Security.
3. Analysis of the structural elements and loads affecting them.
4. Design of structural elements based on the results of the analysis.
5. Design by different design programs.
6. Completion plans of structural elements which have been designed to project the final and executable drawings.

1-6 scope of the Project

Project contains several chapters as follows:

7. Chapter One: general introduction to the project.
8. Chapter Two: architectural description of the project.
9. Chapter Three: description of the structural elements of the project.
10. Chapter Four: Analysis and structural design of all structural elements.
11. Chapter Five: The results that have been reached and recommendations.

1-7 Time schedule

The expected time table of the first and second semester of the year 2017\2018.

Suggested Time	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	33	34
Project Selection	■	■	■	■	■	■	■																											
Site Study							■	■	■																									
Collect information about the project									■	■																								
Architectural study of the building										■	■	■																						
Structural study of the building												■	■	■																				
Preparation of graduation project introduction															■																			
Make the presentation																■																		
Structural analysis																	■	■	■	■														
Structural design																				■	■	■	■											
Preparation of construction drawings of the project																							■	■	■	■	■	■						
Writing the document																												■	■	■				
Stand by time																															■	■	■	
Presentation of the project																																		■

Table 1-1: time schedule table.

Chapter II

Architectural description

Contents:

2-1 Introduction

Public Art is an example of media that has been planned and executed with the intention of being staged in the public realm. The public realm refers to publicly-owned streets, parks and rights-of-way, which is where buildings are situated. Architecture clearly meets this definition. All of us, as the public, interact with architecture. We are affected on a practical and emotional level by both the way a building appears in its context and by its interior environment.

The design for any structure or building should be processed in many stages; first stage is architectural design which starts with determining the shape of the building taking into consideration achieving the various functions and requirements for which this building will be constructed. So, the initial distribution of its facilities will be done, in order to achieve the required spaces, dimensions and the location of columns and axes. Moreover, in this stage a study of lighting, ventilation, movement and other functional requirements will be done.

After the completion of the architectural design stage and its final output, the structural design process begins, which aims to determine the dimensions of the structural elements and their characteristics, depending on the different loads that are transported through these elements to the foundations and then to the soil.

2-2 Overview of the project

There are good numbers of hospitals in Hebron city in general, but because of the continuous increase of population, diseases and pollution in the city, it is necessary to build a new hospital as a specialized hospital.

There is no doubt that the role of hospitals in our time is no longer limited to the provision of therapeutic service only, also it is no longer known as a place to accommodate patients and injured as in the past. However, the modern definition of hospital is an integrated medical organization aims to provide health services in its comprehensive concept of prevention, therapy and medical education in addition to conducting health researches in various branches.

2-3 Project location

For the design of any project, its location should be considered to create the building carefully whether relating to geographical location or the impacts of climatic prevailing in the region, so the existing elements and their relations with the proposed design should be studied to achieve the optimal design. Therefore, project location should give a general idea about the elements around the site, to know the relationship between project and surrounding streets, the height of surrounding buildings, the direction of the prevailing winds and the path of the sun

2-3-1 Proposed site

The project is suggested to be located in Ber Haram Alrama north of Hebron city. It is supposed to be built on a land with an area of 6acres with 3 different levels. The land is located at a height of 990m above sea level next to a main street.

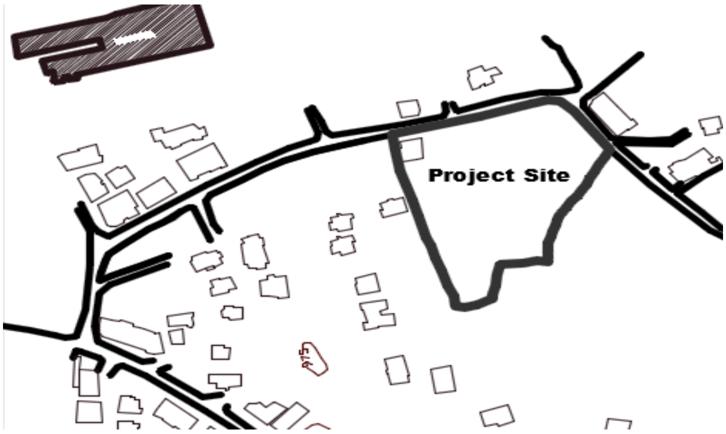


Figure 2-1: Project site.

2-3-2 Project land analysis:

2-3-2-1 Roads and Transport

Project site is one of the active sites in Hebron city, and the services there are easily accessible by public transport. Because the site can be accessed through main street.

2-3-2-2 Movement of the sun

The amount of solar radiation varies throughout the year and reaches its maximum rate in the city in June. The annual average number of hours that the sun radiate is 3300 hours / year.

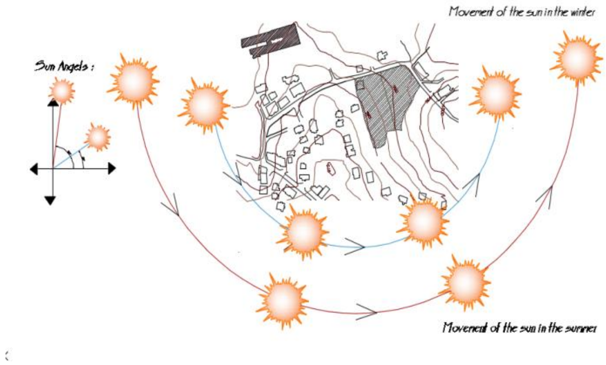


Figure 2-2: Movement of the sun.

2-3-2-3 Wind movement at the site

Wind affects the buildings either on the walls or the structure in addition to erosion processes, therefore, taking into account the wind direction when directing the building is essential in design process. Usually Wind direction and its speed are different from one region to another, but the usual known wind blowing on the city of Hebron and affect the proposed site is south-east wind blows in winter, North West wind blows in summer and winter, so it’s important to pay attention when directing the building to avoid the winds that have a negative impact on the building.

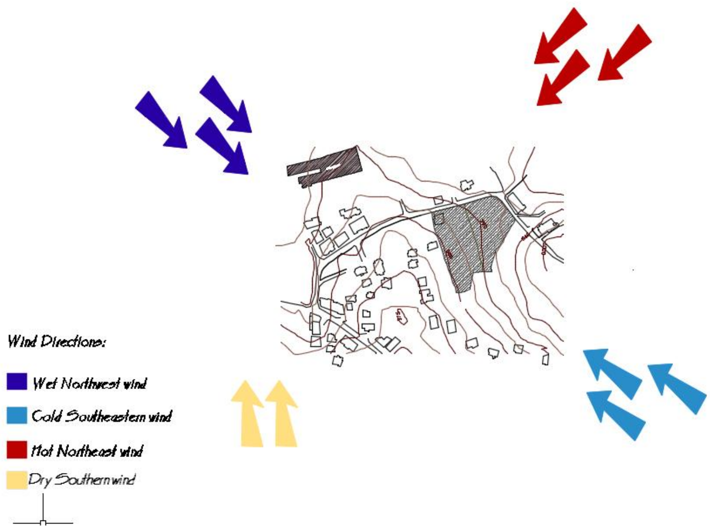


Figure 2-3: Wind movement at the site.

2-3-2-4 Contour lines

Figure 2-4: Contour lines of the land.

2-3-2-5 Project land

Figure 2-5: Project land.

2-4 Description of the project elements

The project total area is about 17000m², it consists of 7floors , two of them are below ground level as basement floors and the others are above ground level described as follows:

2-4-1 Basement (-2) floor

The area of this floor is 1654.2m², on a depth of 7.0m below ground level (0.0), it consists of a large entrance that allows ambulances to enter. It's also has cars park allows all vehicles to pass easily. In addition to gas heater room, generator room, equipment maintenance room, staircase and electric elevators.

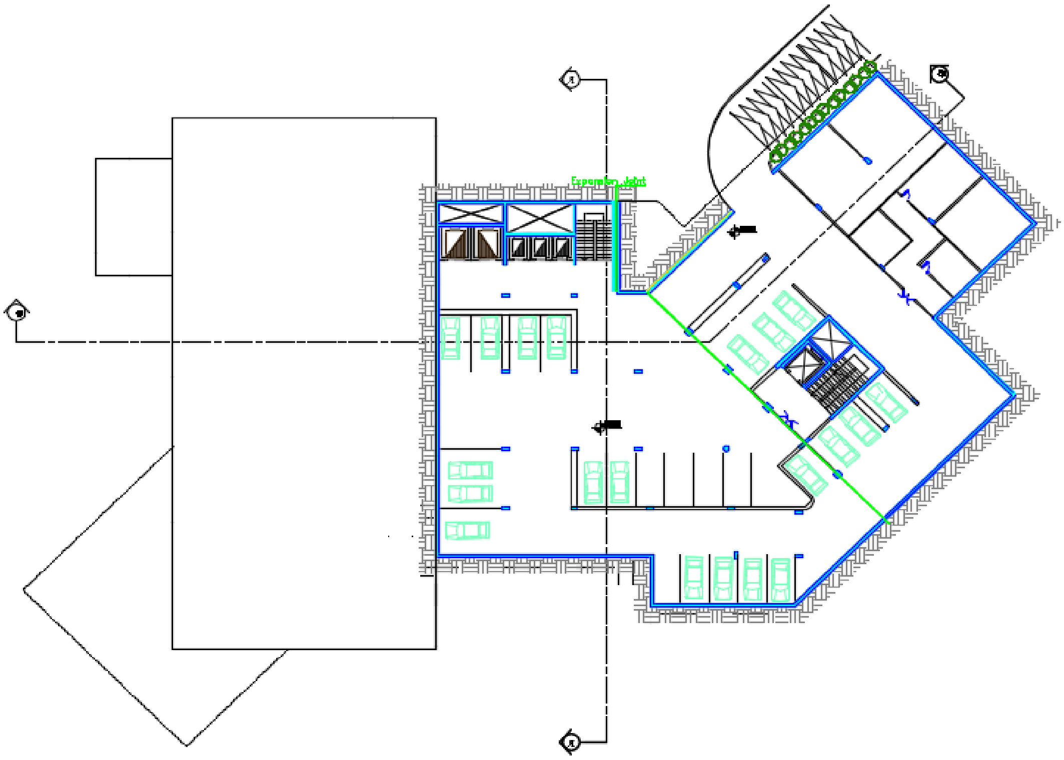


Figure 2-6: Basement (-2) floor.

2-4-2 Basement (-1) floor

The area of this floor is 1654.2m², on a depth of 3.20m below ground level (0.0), it consists of:

1. Dead Rooms: this floor contains a room for dead washing and a refrigerator room for the dead.
2. Guest rooms: on this floor there are rest rooms for staffs and guest lounge.
3. Drug stores.
4. Department of kitchens and food storage: the floor includes a large kitchen that includes all the necessary equipment to prepare food for all patients and employees, large storages and large refrigerators for food.

5. Laundry rooms: there is a full section on this floor with laundry and has three laundry and drying rooms, folding and ironing room, and registration and delivery area.

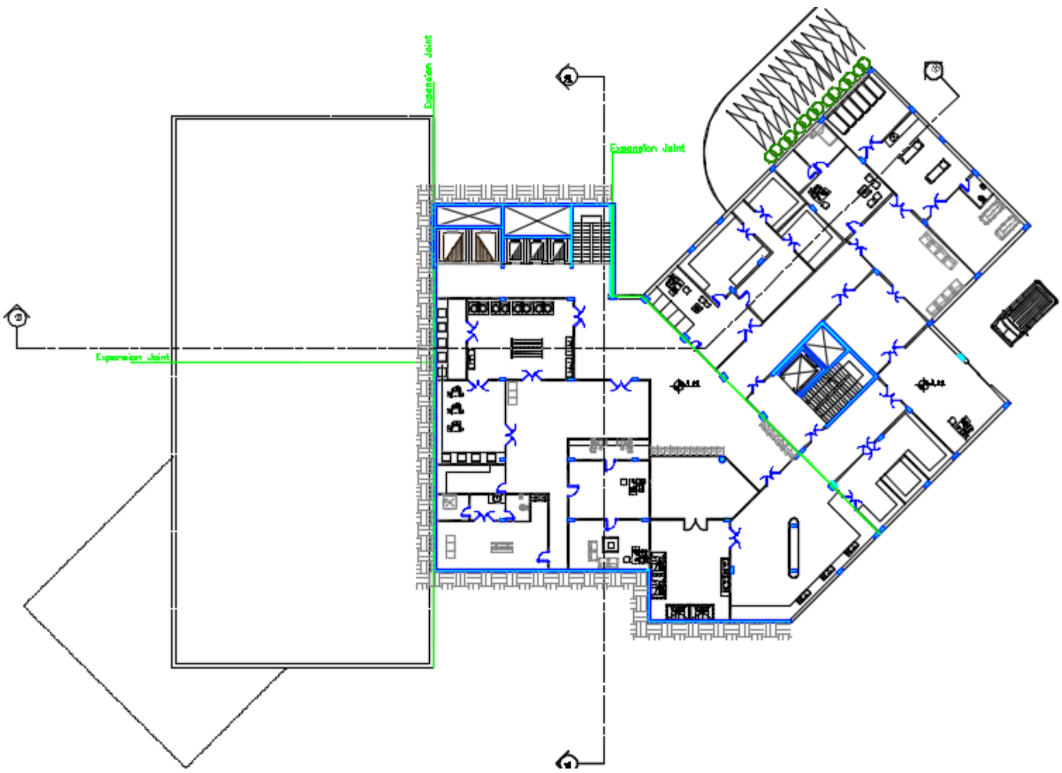


Figure 2-7: Basement (-1) floor.

2-4-3 Ground floor

The area of this floor is $1891m^2$, on a height of 0.6m above ground level (0.0), it consists of:

1. Entrance, consists of: entrance hall, reception, and elements of the movement (elevators, stairs).
2. External clinics.
3. Master cafeteria, kitchen, storage room and gifts shop.

This floor has two entrances, main entrance and sub entrance.

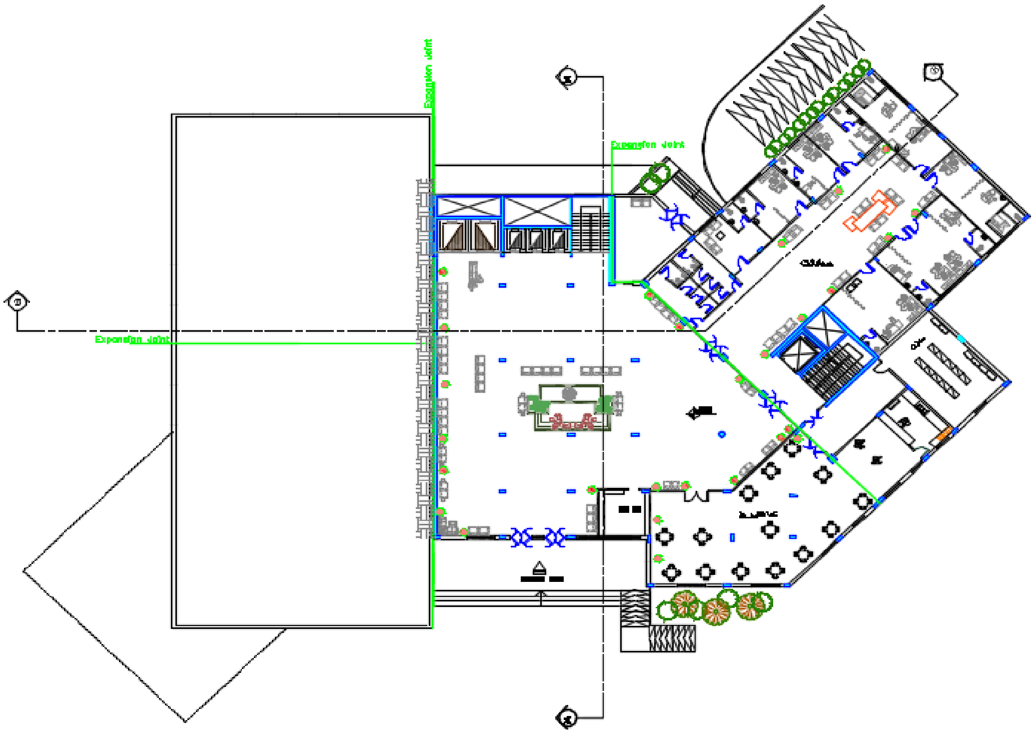


Figure 2-8: Ground floor.

2-4-4 First floor.

The area of this floor is 2687m², on a height of 4.39m above ground level (0.0), it consists of:

1. Department of Administration consists of: meeting hall, the office of the hospital director, the secretariat, archivist, public relations office and the accounting office.
2. It has a pharmacy, a drug store and a staff lounge.
3. There is a special ward consisting of two sections: the laboratory section and the radiology department, it also has a staff lounge.
4. Emergency department: It has a large entrance, next to the security department; there are also security, guest and staff lounges.
5. Reception :It has a guest lounge, reception and registration desks and staff lounge.
6. Department of examination: divided into two sections one for women and the other one for men. In addition to, rapid operations room.

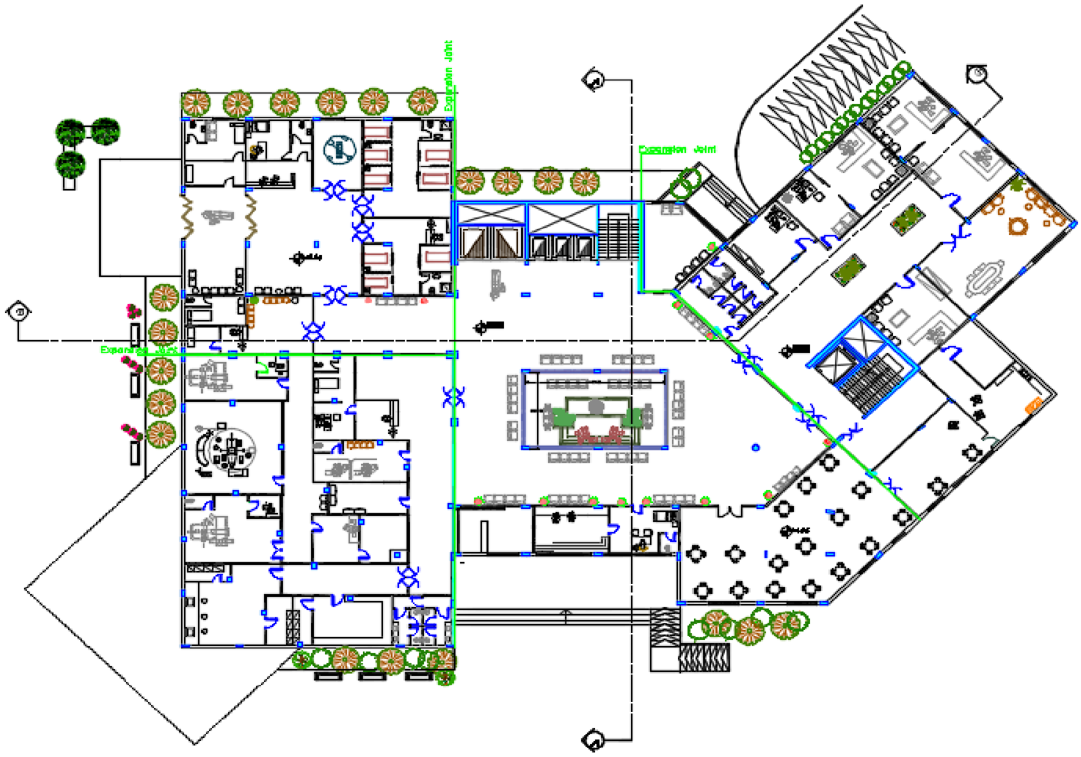


Figure 2-9: First floor.

2-4-5 Second floor

The area of this floor is 2815m², on a height of 8.2m above ground level (0.0), it consists of:

1. Special section for operations: It consists of a clean corridor along the section that reaches the sterilization chambers, also it consists of two operating rooms each one is containing an anesthesia room that has a special part for washing.
2. Department of intensive care: consists of ICO and CCU rooms ,in addition to two rooms for rapid operations with the necessary preparations of sterilization and anesthesia.

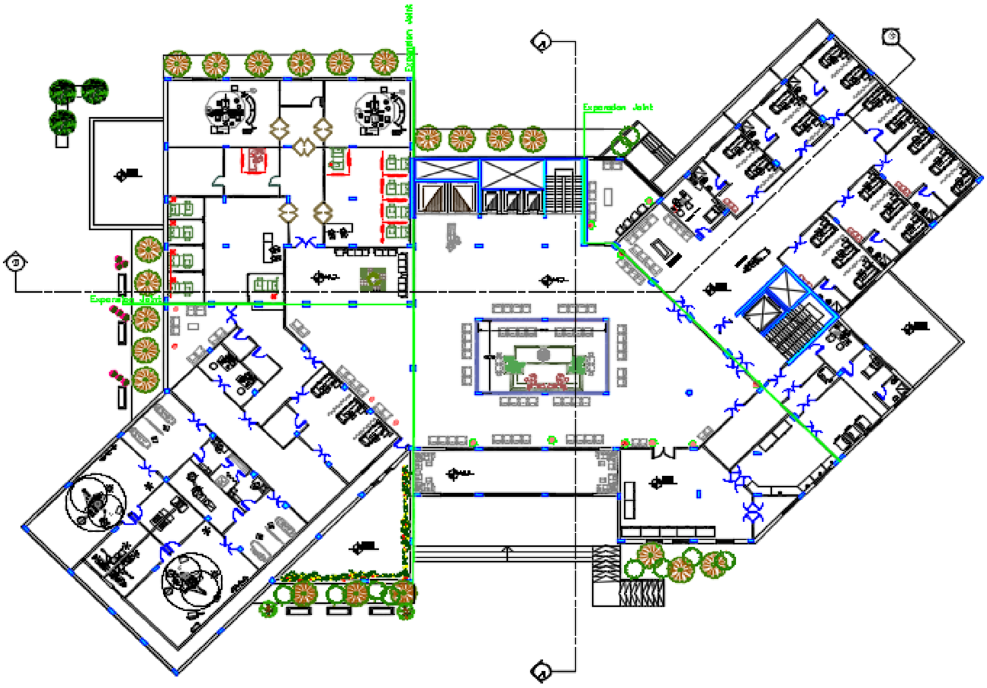


Figure 2-10: Second floor.

2-4-6 Third floor

The area of this floor is 2464m², on a height of 12.0m above ground level (0.0), it consists of:

1. The Department of Obstetrics: Patient’s rooms section has the largest part of it. The second part consists of the natural and caesarean delivery rooms, the examination and preparation rooms, the preterm section, and doctors’ rest rooms.
2. Children's section: consists of: patient’s rooms, playroom for children, queries and rest rooms for visitors and nurses.

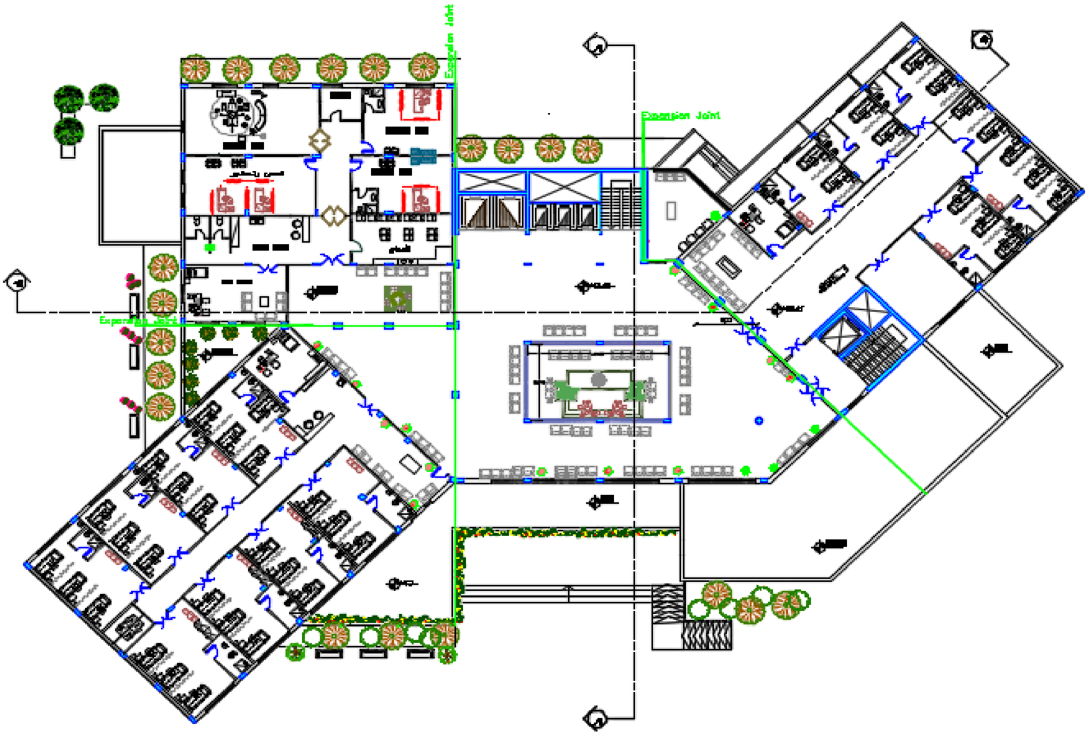


Figure 2-11: Third floor

2-4-7 Fourth floor

The area of this floor is 2000m², on a height of 15.8m above ground level (0.0), it consists of:

1. Department of Internal Medicine: it consists of patients rooms, rest section for staffs and visitors, and nurses' inquiries.
2. Ear, nose and throat Department.
3. Department of Surgery: it consists of several rooms for its patients. In addition to its sterilization section.

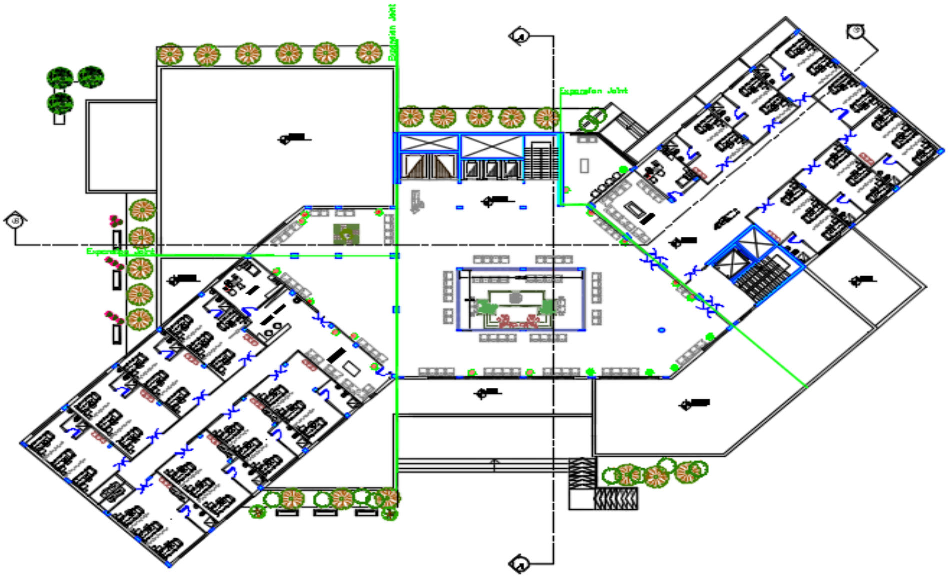


Figure 2-12: Fourth floor.

2-5 Description of elevations

Building elevations give the first impression of the idea of the building and its interconnection with the surrounding. Project elevations here are simple and having a traditional nature. Moreover, the difference in the levels of the building blocks helps in giving the idea and the aesthetic of the project elevations. In addition to the salience and retreating are clear in the elevations as follows:

2-5-1 North elevation (main elevation)

It is the main elevation with a clear difference in the levels, showing all the blocks of the building. It contains the main entrance of the hospital and several forms of windows. This elevation consists of various types of materials such as stone and glass.

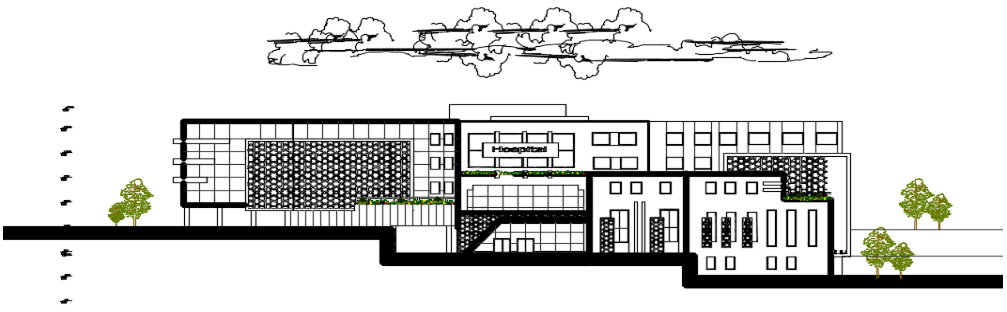


Figure 2-13: North elevation (main elevation).

2-5-2 South elevation

It shows the different levels of the land, in addition to the outer columns.

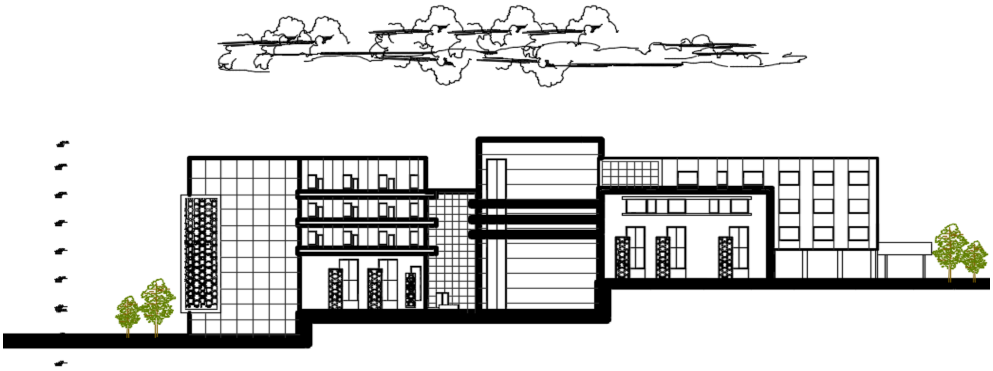


Figure 2-14: South elevation.

2-5-3 East elevation

It contains an emergency entrance surrounded by glass.

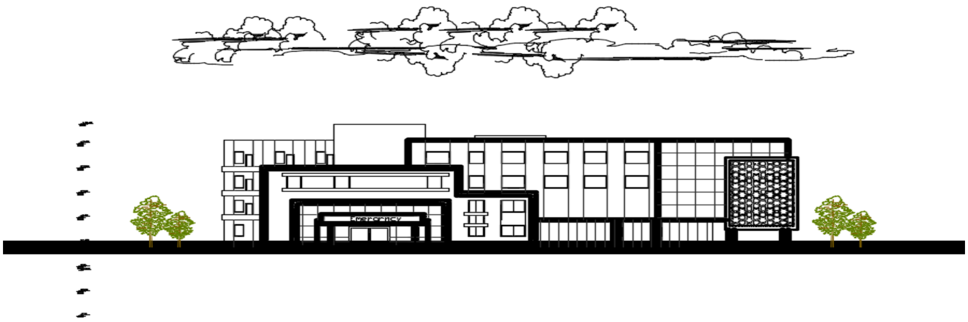


Figure 2-15: East elevation.

2-5-4 West elevation

Car parking entrance is appearing in this elevation. Moreover, levels difference and building blocks retreating are clear here.

Figure 2-16: West elevation.

2-6 Description of movement of the building:

2-6-1 Internal Movement

The vertical movement between the floors is based on its elevators and stairs. In each floor, there are elevators for patients and elevators for visitors, as well as a staircase and elevators for hospital services. Moreover, the horizontal movement is applied to transport freely in the hospital sections.

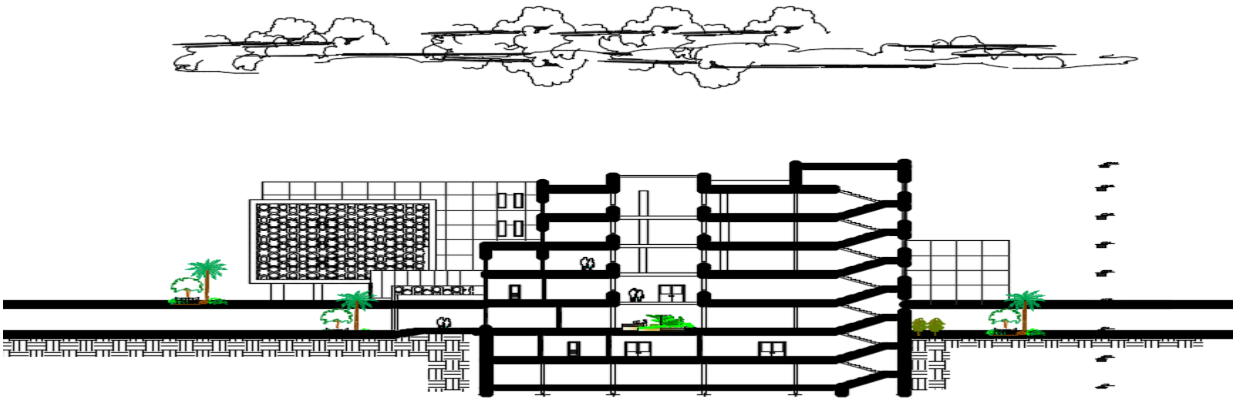


Figure 2-17: Section(A-A).

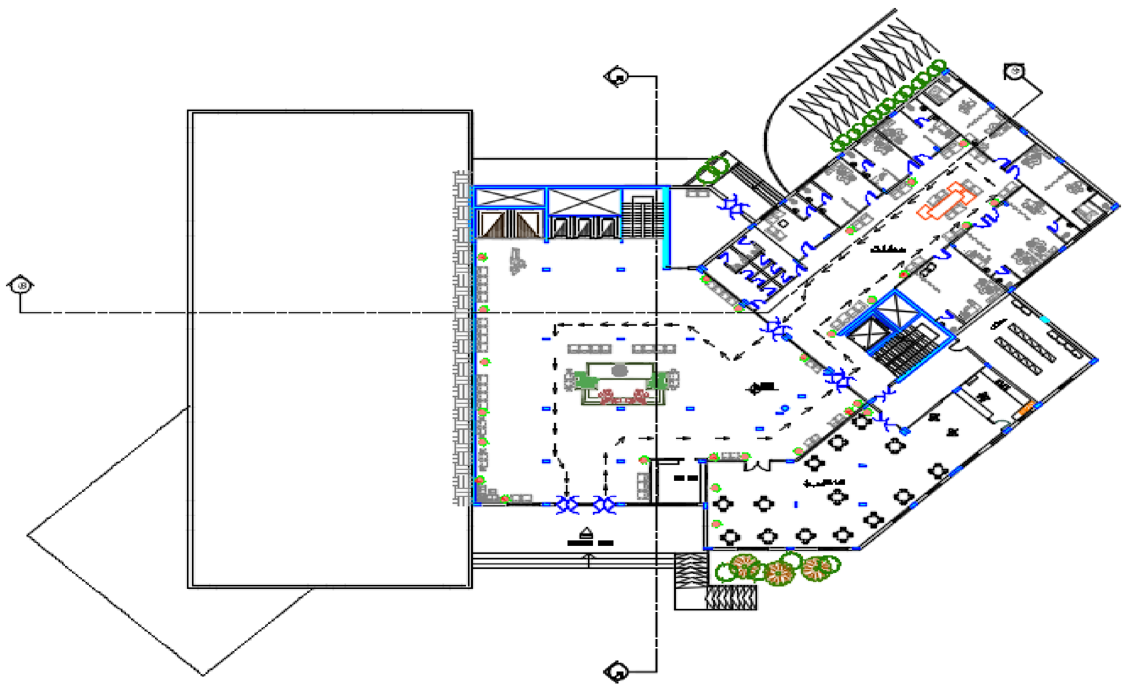


Figure 2-18: Horizontal movement.

2-6-2 External Movement

Project land is divided into 3 levels; the difference between each level is 4m, so the construction of the hospital will be built on 3 levels.

The lowest level contains the garage with a comfortable ramp and some external car parking. The middle level contains a free cars path to reach the entrance of the hospital with some external parkings. Finally, the highest level contains an emergency entrance with an excellent path for the ambulance to reach it, in addition to external parking for the visitors and the ambulance.

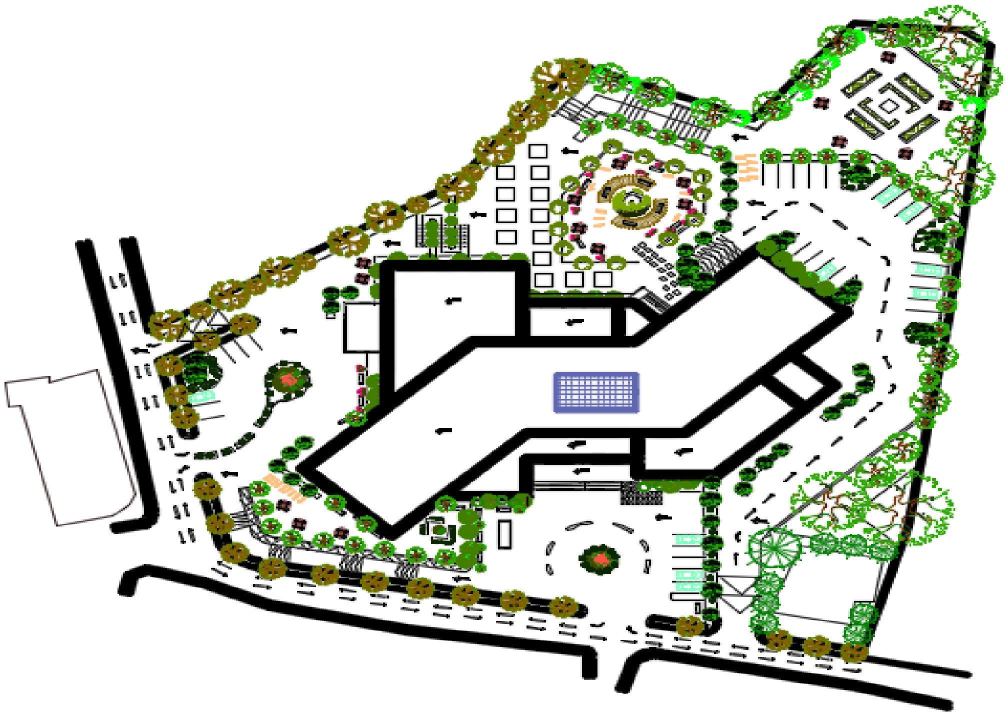


Figure 2-19: Site plan.

Chapter III

Structural description

Content :

3-1 Introduction

The process of structural analysis and design of any building is integrated and indivisible, so after study the description of the architectural elements in our project, we started to Study the existing structural elements in constructions so we can choose the accurate structural system for the building which we are planning to design.

In this chapter, different structural elements will be discussed such as columns, beams, foundations and other structural elements, in addition to determine the value of the loads affecting on these elements, such as dead and live loads and other loads which will be mentioned later.

3-2 The purpose of structural analysis and design

Structural design is a connected process which depends on the structural elements that is supposed to act as one unit, so it is important to make the best design of the building to achieve these wanted aims:

1. **Safety:** it is supposed to do the design taking into consideration the safety of the building in every condition.
2. **Economical Coast:** Achieving the best level of safety with the least coast.
3. **Serviceability:** avoiding deflection and cracks which can make the building weak.
4. Save the architectural design of the building.

3-3 Structural analysis steps:

3-3-1 Soil investigation

The purpose of soil investigation is to explore and evaluate the subsurface conditions at various locations in the project site in order to develop geotechnical engineering recommendations for foundation design and construction.

Before the construction analysis of any building, geotechnical studies for the site must be done, it means every process to explore the site and study the soil, rocks and groundwater must be done, then analysis the previous study information and translate it, in order to predict the soil .behaviour .The most important thing is to get the soil bearing capacity in order to know how to design and execute the building.

3-3-2 primary structural design

In this stage, the appropriate structural system of project will be determined, according to the site of the project, its size, and the nature of the project.

3-3-3 final structural design

Final structural design of each element will be done with high accuracy according to the chosen construction system, in addition to make structural details appears in the structural drawings.

3-4 Loads classification

Loads which are directly affects the building classified into:

1. **Main loads (direct):** which include dead and live loads and environmental loads.
2. **Secondary loads (indirect):** These include shrinkage of concrete drought, heat impact and crawl and consolidation.

So, in structural calculation, we must consider the accuracy in the process of representation of loads on structural elements as the previous classification. Concrete, for example, has an expansion and shrinkage factor different than its reinforcement steel factor.

The designed structural elements must be able to carry loads without the occurrence of any failure, and these loads are:

1. **Dead loads.**
2. **Live loads.**
3. **Environmental loads.**

3-4-1-1 Dead loads

Loads resulting from the self-weight of building, which consists of the weights of the materials used in the building which include all the structural elements and fixtures weight. There is some of the specific density of the materials used as follows:

	Material	Density (KN/m³)
1	Mortar	22
2	Tiles	23
3	Reinforced concrete	25
4	Coarse sand	17
5	Plaster	22

Table 3-1: specific density of the used materials.

3-4-1-2 Live loads

Loads act on buildings and construction because of their different uses, including distributed and concentrated loads, which include:

1. **Dynamic loads:** such as the equipments which create vibrations affecting the entity.
2. **Static loads:** such as weights of people, the stored material and furniture. The table below shows the values of the live loads depending on the use of our building according to the Jordanian code.

So, in our project as a hospital building, we will take the live load in our calculations as 5KN/m according to Jordanian code.

تابع الأحمال الحية للأرضيات والعقدات

الحمل المركز البديل	الحمـ ل الـ موزع	الاستعمال	نوع المبنى	
كن	كن/م²	الاشغـ ال	خاص	عـ ام
7.0	4.8 لكل متر من ارتفاع التخـ زين على أن لا يقل عن (10).	أماكن التكديس الكثيف للكتب عـ ى عـ ات متحركة.	تابع السجون والمستشفيات والمدارس والكليات.	تابع المبا ي التعليمية وماشابهها.
7.0	2.4 لكل متر من ارتفاع التخزين على أن لا يقل عن (6.5).	غرف تكديس الكتب.		
9.0	4 لكل متر من ارتفاع التخزين.	مستودعات القرطاسية.		
4.5	5.0	للممرات والمداخل المعرضة لحرك . ة المركب . ات والعربات المتحركة.		
9.0	5.0	غرف وقاعات التدريب.		
3.6	5.0	قاعات التجمع والمسارح والجمنازيوم دون مقاعد ثابتة.		
4.5	3.0	للمختبرات بما فيها مـ ن أجهزة، والمطابخ وغرف الغسيل.		
2.7	3.0	للمـ . رات والمـ . بداخل والأدراج و ـ . سطحات الأدراج الثانو ـ ة.		

Table 3-2: Live loads according to Jordanian code.

3-4-1-3 Environmental loads

loads caused by the environmental effects on the building.

3-4-1-4 Wind load

Horizontal forces affect the building which can clearly appears in the high ones, it has a positive value as a result of pressure and negative value as a result of tension, measured in kilo Newton per square meter (KN / m2). The determination of wind loads depending on the height of the building above ground level, and its location in compared with the surrounding buildings, whether higher or lower. Wind loads can be resisted through shear walls which are designed according to the loads acting over them.

3-4-1-5 Snow loads

loads affect the building due to snow accumulation, snow loads can be evaluated as the following:

1. The height of the building above sea level.
2. Slope of roof.

The following table shows the value of snow loads according to height above sea level by the Jordanian code.

Height of building above sea level (m)	Snow load (KN /m²)
1. h < 250	0
2. 500 > h > 250	(800) /h-250
3. 1500 > h > 500	(h-400) / 320

Table 3-3: snow loads according to Jordanian code.

The height of the project land=990m above sea level, so case (3) from the table above will be considered,and snow load will be equal to (990-400)/320=1.84KN/m²

3-4-1-6 Earthquakes

One of the most important environmental loads affecting the building, consist of horizontal and vertical forces which create moments, including overturning and torque moments. It can be resisted using shear walls with a good thicknesses and enough reinforcement to assure the safety of the building. Earthquakes must be considered in the structural design to reduce its risk and improve the performance of the building. Code (UBC

1997) will be used in order to define and determine the seismic loads and shear forces according to it.

3-5 Construction elements

The building is a set of construction elements related for each other and acting as one unit. There are some of the construction elements used in the buildings like slabs, columns, stair, beams, and foundations. Here are some of the construction elements used in our project:

3-5-1 Slabs

Slabs are structural elements that transfer the vertical forces due to the loads affecting the structural elements of the building such as beams, walls and columns, without any distortions.

There are different types of commonly used reinforced concrete slabs, including the following:

1. **Solid slabs.**
2. **Ribbed slabs.**

But in our project only two types of slabs are suggested to be used:

3-5-1-1 One Way Solid Slabs: which have been used in some stairwall slabs.

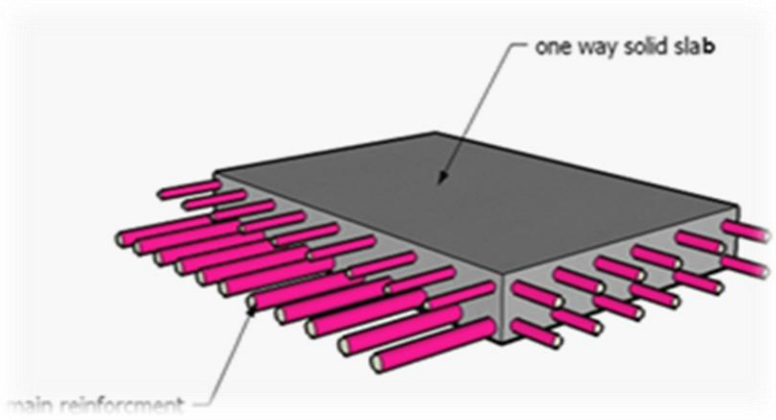


Figure 3-1: One way solid slab.

3-5-1-2 One way ribbed slabs: which consists of hollow slabs with total depth greater than solid slabs depth. This system is economical for buildings where superimposed loads are small and spans are relatively large, such as schools, hospitals, and hotels etc... .

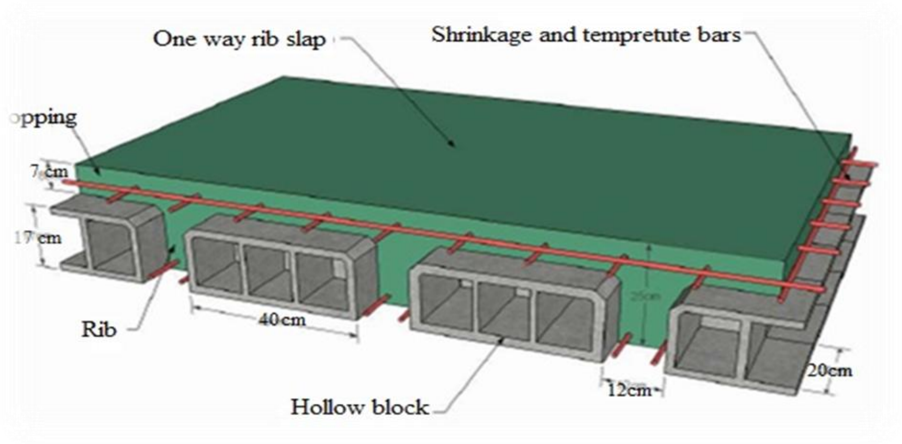


Figure 3-2: One way ribbed slab.

3-5-2 Columns

Columns are considered as the main component in the transfer of loads from slabs, beams and transferred it to the foundations, so it is an essential structural component of transfer the loads and the stability of the building. it must be designed to be able to carry and distribute all the loads act on it.

there are two types of columns, short and long columns. Columns sections have many forms, including rectangular, circular, polygon, box and the boat. Another classification of columns is according to the type of construction material used such as concrete, metal, and wood.

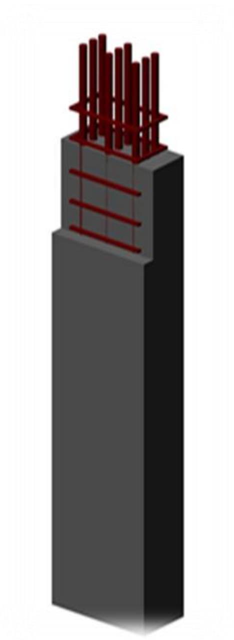


Figure 3-3: Rectangular column.

Figure 3-4: Circular column.

3-5-3 Beams

They are essential structural elements transport loads of ribs and solid slabs to columns. Concrete beams divided into two types:-

1. **Hidden beams:** beams hidden inside the slab so that its height equals to the height of the slab.
2. **Drop beams:** beams with height greater than the height of the slap, the excess part of the beam is in both directions, lower one (Down Stand Beam) or upper (Up stand Beam),so these parts are called L –section and T-section.

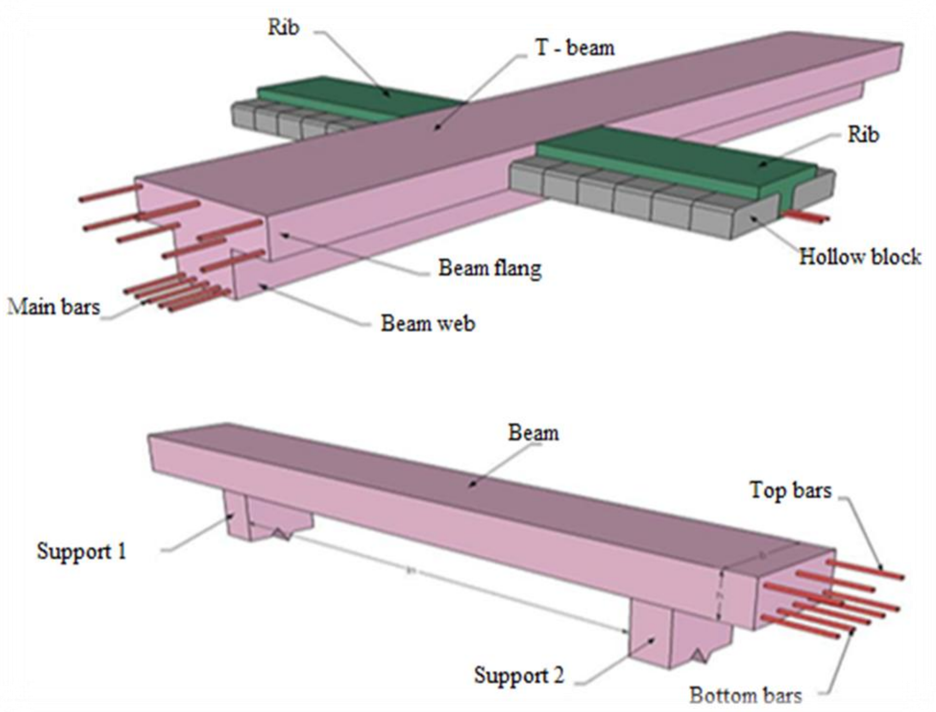


Figure 3-5: Beams.

3-5-4 Shear walls

Structural elements resist the vertical and horizontal forces which affecting the building, such as strong winds and earthquakes.

These walls resisting the vertical loads transferred to them, and resist the horizontal forces that affecting the building, so they must be available in both directions, taking into account that the distance between the centre of rigidity where the shear walls should be built and the centre of gravity of the building must be as less as it possible, and be enough to reduce the torques and their effects on the building walls that resist the horizontal forces.

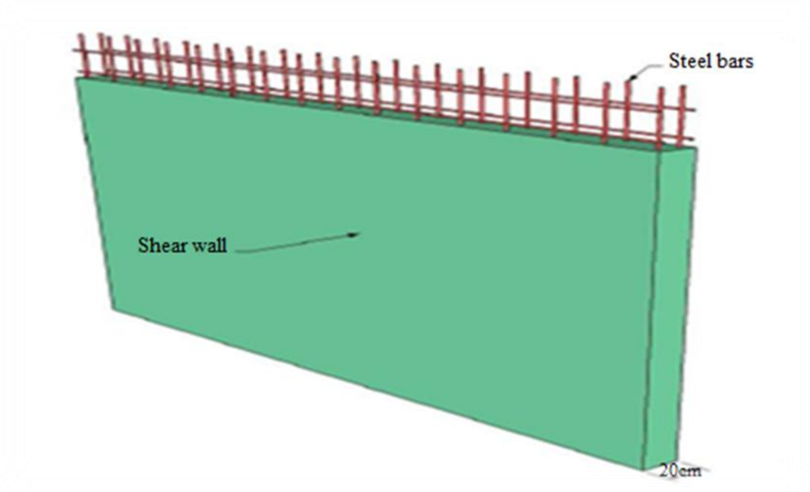


Figure 3-6: Shear wall.

3-5-5 Foundations

Foundations are the link between the structural elements of the building and the land, the weights and loads which have been carried by foundations come from the loads located on slabs moves into beams then to columns and finally to footings into the soil. The foundation must be responsible for carrying the dead loads of the building and also dynamic loads resulting from wind ,snow, earthquakes and also live loads within the building.

it is expected in our project to use different types of foundations depending on soil bearing capacity and loads along each foundation.

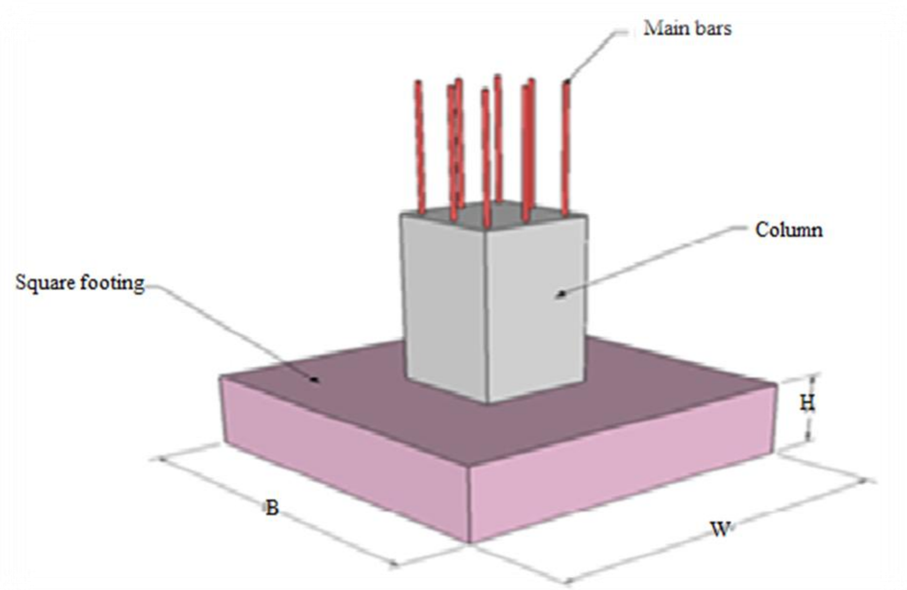
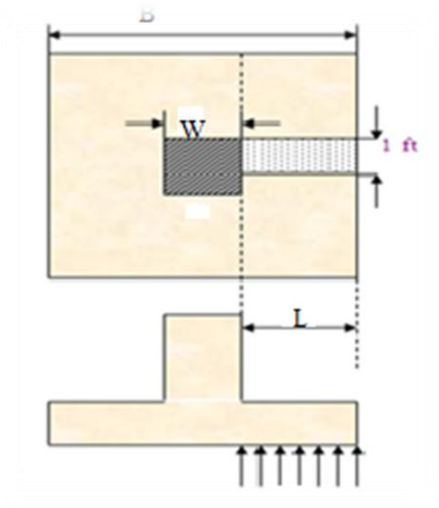


Figure 3-7: Isolated footing.



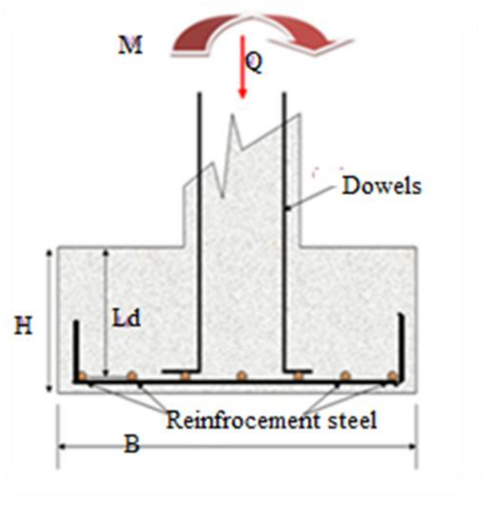


Figure 3-8: isolated footing plan. Figure 3-9: isolated footing section.

3-5-6 Stairs

Structural element responsible for vertical movement between floors in the building. Staircase design is structurally as a solid slab in one direction.

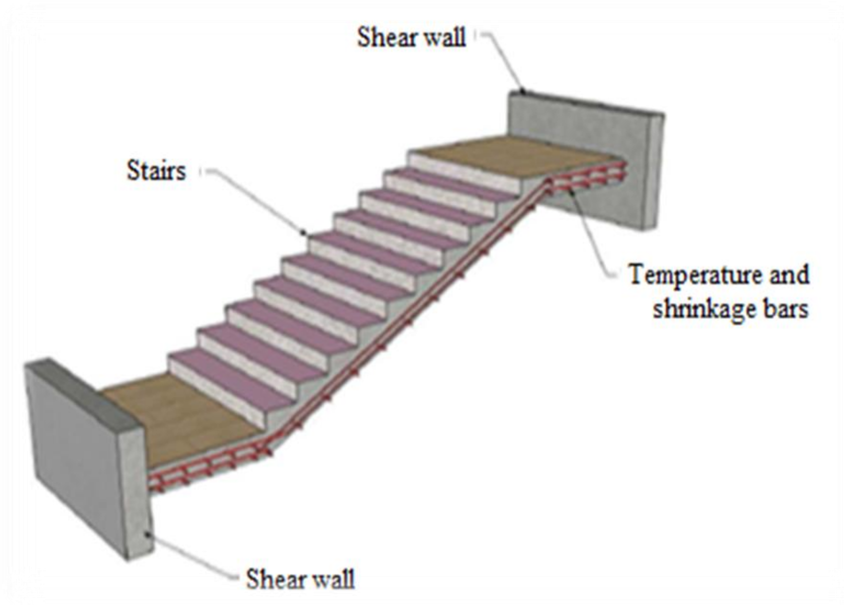


Figure 3-10: Stair diagram.

3-5-7 Expansion Joints

It can be used in buildings with large horizontal dimensions or special shapes and situations. Expansion joints have some requirements and recommendations as follows:

- From 40 to 45 m in normal regions like Palestine.
- From 30 to 35 m in warm regions.
- We can increase these distances by consider the effect of creep and shrinkage.
- In retaining walls we must decrease distances between expansion joints.
- Expansion joint width should not be less than (3cm).

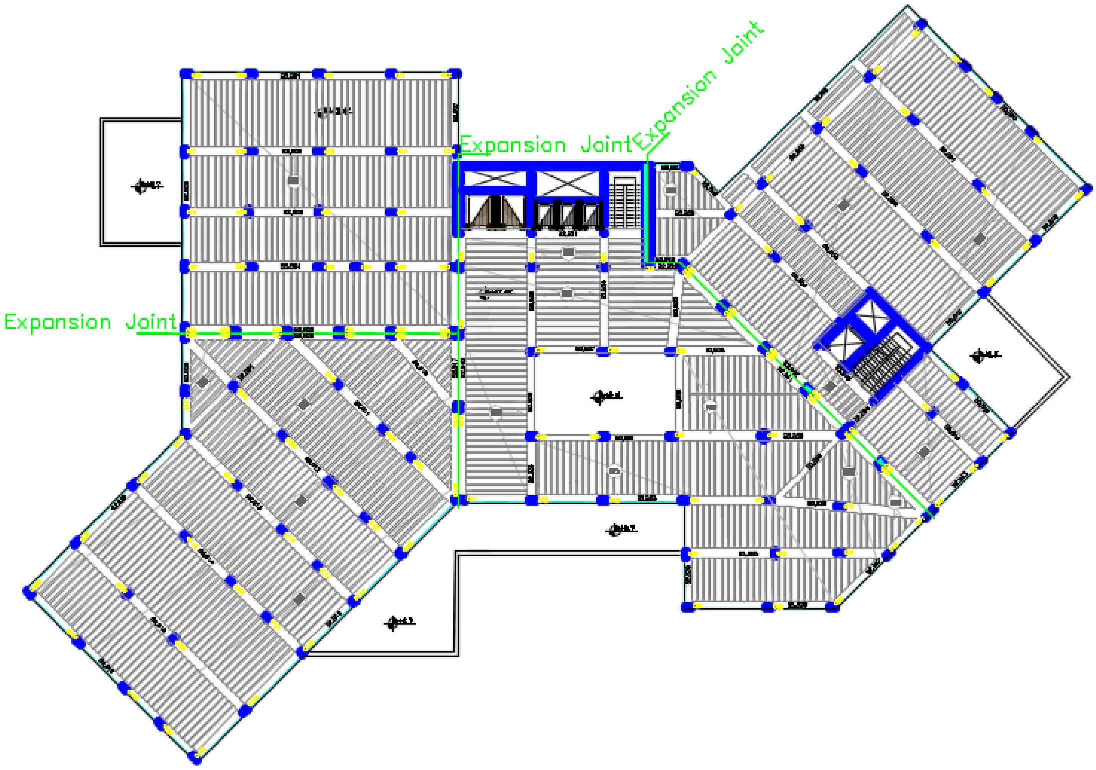


Figure 3-11: Expansion joint.

Chapter IV

Structural analysis and design

Contents:

4-1 Introduction

Many structures are built of reinforced concrete: bridges, buildings, retaining walls, tunnels and others. Reinforced concrete is logical union of two materials: plain concrete, which possesses high compressive strength but little tensile strength, and steel bars embedded in the concrete, which can provide the needed strength in tension.

Plain concrete is made by mixing cement, fine aggregate, coarse aggregate, water, and frequently admixtures. Understanding of reinforced concrete behavior is still far from complete, building codes and specifications that give design procedures are continually changing to reflect latest knowledge.

Structural concrete can be classified into:

- Lightweight concrete with unit weight from about 1350 to 1850 kg/m3.
- Normal weight concrete with unit weight from about 1800 to 2400 kg/m3.
- Heavyweight concrete with unit weight from about 3200 to 5600 kg/m3.

4-2 Design Method and Requirements

The design strength provided by a member is calculated in accordance with the requirements and assumptions of ACI_code (318_08).

Strength design method:

In ultimate strength design method, the service loads are increased by factors to obtain the load at which failure is considered to be occurring, this load called factored load or factored service load, the structure or structural element is then proportioned such that the strength is reached when factored load is acting, the computation of this strength takes into account the nonlinear stress-strain behavior of concrete.

The strength design method is expressed by the following, Strength provided ≥ strength required to carry factored loads.

NOTE:

The statically calculation and the key plans dependent on the architectural plans.

Code: ACI 2008 UBC

Material: Concrete B300

$Fcu = 30 N/mm^2 (MPa)$ For circular section.

But, for rectangular section ($fc' = 30 * 0.8 = 24MPa$).

Reinforcement steel:

The specified yield strength of the reinforcement {fy = 420 N/mm² (MPa)}.

Factored loads:

The factored loads for members in our project are determined by:

Wu = 1.2 DL + 1.6 LL ACI-code-318-08(9.2.1)

4-3 Check of Minimum Thickness of Structural Member

Minimum thickness (h)				
Member	Simply supported	One end continuous	Both end continuous	Cantilever
solid one way slabs	L/20	L/24	L/28	L/10
Beams or ribbed one way slabs	L/16	L/18.5	L/21	L/8

Table 4-1: Check of minimum thickness of structural member.

For Rib :

hmin for(one end continuous)=L/18.5=6.16/18.5=33.3cm.

hmin for(both end continuous)=L/21=5.9/21=28.1cm.

hmin for(simply supported)=L/16=4.97/16=31cm.

Take h = 35 cm.

27 cm block + 8 cm topping = 35cm.

For Beam:

hmin for(one end continuous)=L/18.5=5.85/18.5=31.6cm.

hmin for(both end continuous)=L/21=5.95/21=28.3cm.

hmin for(cantilever)=L/8=2/8=25cm.

Take h = 35 cm, but in some regions we have a drop beam.

4-4 Design of Topping

Statically System For Topping :

Consider the topping as strip of (1m) width, and span of mold length with both end fixed in the ribs.

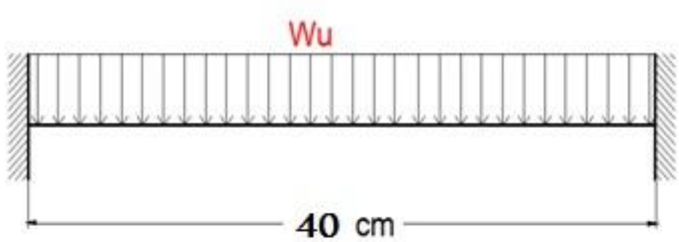


Figure 4-1: Topping load.

Load Calculations:

Dead Load:

No.	Parts of Rib	Calculation	
1	Tiles	0.03*23*1 = 0.69 KN/m	
2	Mortar	0.02*22*1 = 0.44 KN/m	
3	Coarse Sand	0.07*17*1 = 1.19 KN/m	
4	Topping	0.08*25*1 = 2.0 KN/m	
5	partions	KN/m1= 11*	
		Sum =	5.32KN/m

Table 4-2: Dead load calculation of topping.

Live Load:

LL =5 KN/m2.

LL =5 KN/m2×1m=5KN/m.

Factored Load :

WU = 1.2 ×5.32 + 1.6×5 =14.4 KN/m.

Check the strength condition for plain concrete, øMn ≥ Mu, where ø = 0.55.

Mn = 0.42 λ $\sqrt{f_c'}$ Sm (ACI 22.5.1, equation 22-2).

$S_m = \frac{b.h^2}{6} = \frac{1000.80^2}{6} = 1066666.67\ mm^2$.

øMn =0.55×0.42×1×$\sqrt{24}$ ×1066666.67 ×10^{-6} =1.21 KN.m

Mu = $\frac{W_u L^2}{12} = 0.192$ KN. m (negative moment)

Mu = $\frac{W_u L^2}{24} = 0.96\ \text{KN.m}$ (positive moment)

øMn>> Mu = $0.192\ \text{KN.m}$

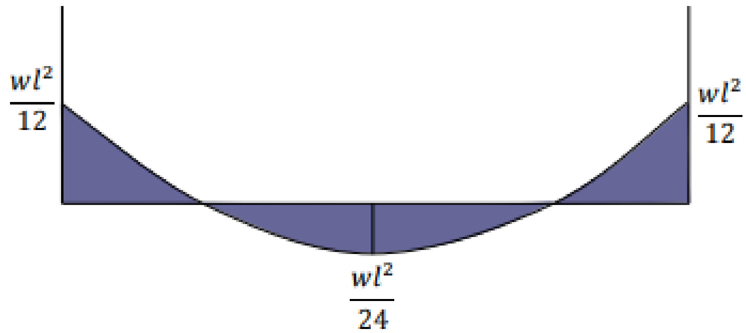


Figure 4-2: Moment diagram.

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

ρshrinkage= 0.0018. ACI 7.12.2.1

As = ρ×b×htopping =0.0018 ×1000×80 = 144 mm2/m

Step (s) is the smallest of:

3h = 3×80 =240 mm control ACI 10.5.4 450mm.

S =$380\left(\frac{280}{f_s}\right) - 2.5C_c = 380\left(\frac{280}{\frac{2}{3}420}\right) - 2.5\ .20 = 330\text{mm}$ACI 10.6.4.

Take ø 8 @ 200 mm in both direction , S = 200 mm < Smax = 240 mm … OK

4-5 Design of One Way Rib Slab

Requirements For Ribbed Slab Floor According to ACI- (318-08) .

bw ≥ 10cm……………………………………………ACI(8.13.2)

Select bw=12 cm

h ≤ 3.5*bw ……………………………….…ACI(8.13.2)

Select h=35cm<3.5*12= 49 cm

tf ≥ Ln/12=600/12 ≥50mm ………………………………..ACI(8.13.6.1)

Select tf=8cm

Material :concrete B300 Fc' = 24 N/mm2

Reinforcement Steel fy = 420 N/mm2

Section :

B = 520 mm ,Bw= 120 mm ,h= 350 mm ,t= 80 mm , d=350-20-10-12/2= 314 m.

Statically System and Dimensions:

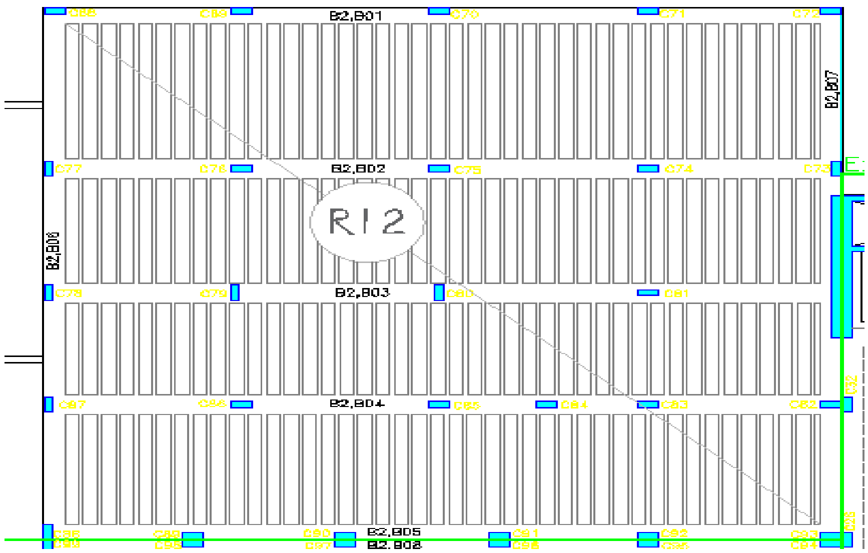


Figure 4-3: One way rib slab (R12).

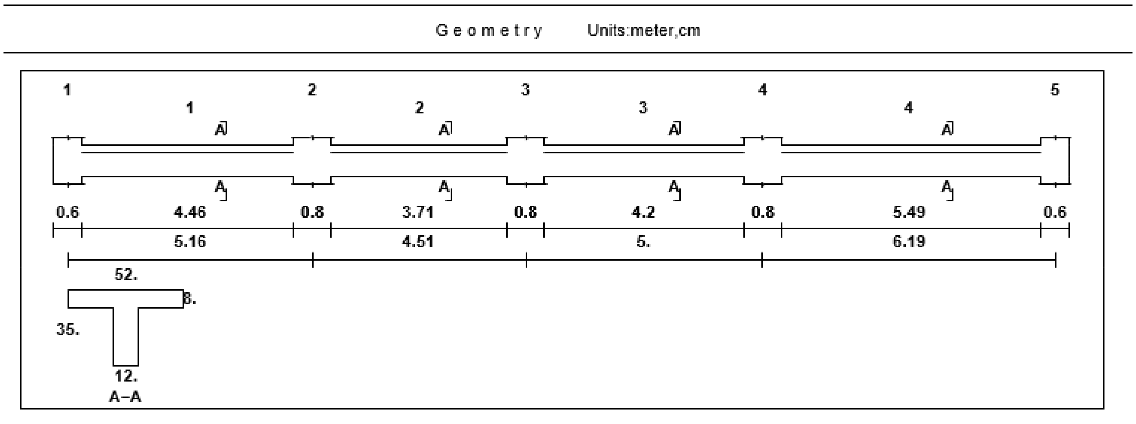


Figure 4-4: Geometry of rib slab (R12).

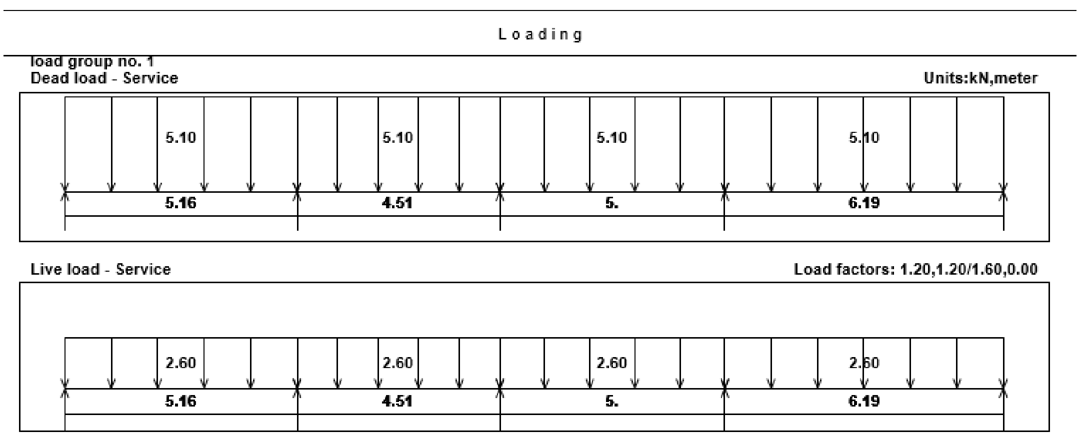


Figure 4-5: Statically system and loads distribution of rib (R12).

Load Calculation:

Dead Load:

No.	Parts of Rib	Calculation
1	Tiles	0.03*23*0.52 = 0.359 KN/m/rib
2	Mortar	0.03*22*0.52 = 0.229 KN/m/rib

3	Coarse Sand	0.07*17*0.52 = 0.620 KN/m/rib
4	Topping	0.08*25*0.52 = 1.04 KN/m/rib
5	RC. Rib	0.27*25*0.12 = 0.81 KN/m/rib
6	Hollow Block	0.27*10*0.4 = 1.08 KN/m/rib
7	plaster	0.02*22*.52= 0.229 KN/m/rib
8	partions	1*0.52= 0.52 KN/m/rib
		Sum = 5.1 KN/m/rib

Table 4-3: Dead Load Calculation of Rib(R12).

Dead Load /rib = 5.1 KN/m.

Live Load:

Live load = 5 KN/M2.

Live load /rib = 5 KN/m2 × 0.52m = 2.6 KN/m.

Effective Flange Width (b_E):-ACI-318-11 (8.10.2)

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

b_E = L / 4 = 619/ 4 =154.75cm

b_E = 12 + 16 t = 12 + 16 (8) = 140 cm

b_E = be ≤ center to center spacing between adjacent beams = 52 cm. Control

b_E For T-section = 52cm .

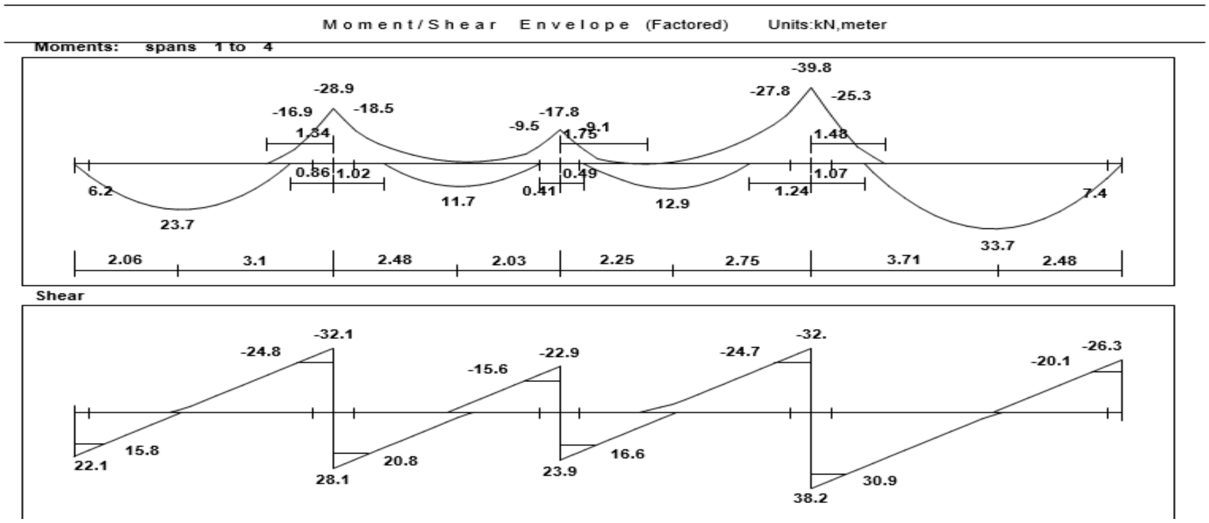


Figure 4-6: Shear and moment envelope diagram of rib (R12).

Moment Design for (R 12):

Design of Positive Moment for (Rib12):-(Mu=23.7 KN.m)

Assume bar diameter ø 12 for main positive reinforcement

d =h- cover - dstirrups$-\frac{d_b}{2} = 350 - 20 - 10 - \frac{12}{2} = 314$ mm

Check if a>hf to determine whether the section will act as rectangular or T- section.

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

$$= 0.85 \times 24 \times 520 \times 80 \times \left(314 - \frac{80}{2}\right) \times 10^{-6} = 232.5 \text{ KN.m}$$

Mn$\gg\frac{M_u}{\varphi} = \frac{23.7}{0.9}$= 26.33KN.m , the section will be designed as rectangular section withbe =520 mm.

Rn= $\frac{M_u}{\emptyset bd^2} = \frac{23.7\times10^6}{0.9\times520\times314^2} = 0.514$ Mpa

m= $\frac{f_y}{0.85f_c'} = \frac{420}{0.85\times24} = 20.6$

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times0.514}{420}}\right) = 0.00124$$

As,req = ρ.b.d = 0.00124 ×520×314 = 202.5 mm2

Check for As min:

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

$$A_s\ min = \frac{\sqrt{24}}{4(420)}(120)(314) = 110mm^2$$

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

$$A_s\ min = \frac{1.4}{420}(120)(314) = 125.6mm^2$$ controls

Asreq= 202.5mm2 >Asmin= 125.6 mm2 OK

Use 2 ø 12 ,As,provided= 226 mm2>As,required= 202.5mm2 …. Ok

$$S = \frac{120-40-20-(2\times12)}{1} = 36\ mm > d_b = 12 > 25\ mm \quad OK$$

Check for strain:

$$a = \frac{A_{s.}f_y}{0.85b\ f'_c} = \frac{226\times420}{0.85\times520\times24} = 8.94\ mm$$

$$x = \frac{a}{\mathcal{B}_1} = \frac{8.94}{0.85} = 10.53\ mm$$

$$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{314\ -10.53}{10.53}\right) = 0.0864 > 0.005 \quad 0k$$

Design of Positive Moment for(Rib12):- (Mu=11.7 KN.m) d =h- cover - dstirrups$-\frac{d_b}{2} = 350 - 20 - 10 - \frac{12}{2} = 314$ mm

Rn= $\frac{M_u}{\emptyset b d^2} = \frac{11.7\times10^6}{0.9\times520\times314^2} = 0.25$ Mpa

m= $\frac{f_y}{0.85 f'_c} = \frac{420}{0.85\times24} = 20.6$

ρ= $\frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times0.25}{420}}\right) = 0.000599$

As,req = ρ.b.d = 0.000599×520×314 = 97.8 mm2

Check for As min:-

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

$A_s \min = \frac{\sqrt{24}}{4(420)}(120)(314) = 110 mm^2$

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

$A_s \min = \frac{1.4}{420}(120)(314) = 125.6 mm^2$ controls

As,required= 125.6 mm2.

Use 2 ø 10 ,As,provided= 157.08 mm2>As,required= 125.6 mm2 … Ok

$S = \frac{120-40-20-(2\times10)}{1} = 40 \text{ mm} > d_b = 10 > 25$ mm OK

Check for strain:

a =$\frac{A_{s.}f_y}{0.85 b\, f'_c} = \frac{157\times420}{0.85\times520\times24} = 6.22$ mm

x= $\frac{a}{\mathcal{B}_1} = \frac{6.22}{0.85} = 7.31$mm

$$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{314-7.31}{7.31}\right) = 0.125 > 0.005 \qquad 0k$$

Design of Positive Moment for (Rib12):- (Mu=12.9 KN.m)

Assume bar diameter ø 12 for main positive reinforcement

d =h- cover - dstirrups $-\frac{d_b}{2} = 350 - 20 - 10 - \frac{12}{2} = 314$ mm

Rn= $\frac{M_u}{\emptyset bd^2} = \frac{12.9\times10^6}{0.9\times520\times314^2} = 0.28$ Mpa

m= $\frac{f_y}{0.85f'_c} = \frac{420}{0.85\times24} = 20.6$

ρ= $\frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times0.28}{420}}\right) = 0.000671$

As,req = ρ.b.d = 0.000671×520×314 = 109.56 mm2

Check for As min:

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

$A_s \min = \frac{\sqrt{24}}{4(420)}(120)(314) = 110mm^2$

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

$A_s \min = \frac{1.4}{420}(120)(314) = 125.6mm^2$ controls

Asreq = 125.6 mm2

Use 2 ø10 ,As,provided=157.08 mm2>As,required= 125.6 mm2… Ok

$S = \frac{120-40-20-(2\times10)}{1} = 40 \text{ mm} > d_b = 10 > 25 \text{ mm}$ OK

Check for strain:

$a = \frac{A_{s.}f_y}{0.85b\ f'_c} = \frac{157\times420}{0.85\times520\times24} = 6.22$ mm

$x = \frac{a}{\mathcal{B}_1} = \frac{6.22}{0.85} = 7.31$ mm

$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{314-7.31}{7.31}\right) = 0.125 > 0.005$ 0k

Design of Positive Moment for (Rib12):- (Mu=33.7 KN.m)

Assume bar diameter ø 12 for main positive reinforcement

d =h- cover - dstirrups$- \frac{d_b}{2} = 350 - 20 - 10 - \frac{12}{2} = 314$ mm

$Rn = \frac{M_u}{\emptyset bd^2} = \frac{33.7\times10^6}{0.9\times520\times314^2} = 0.73$ Mpa

$m = \frac{f_y}{0.85f'_c} = \frac{420}{0.85\times24} = 20.6$

$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times0.73}{420}}\right) = 0.00177$

As,req = ρ.b.d = 0.00177×520×314 = 289 mm2

Check for As min:

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

$A_s\ \min = \frac{\sqrt{24}}{4(420)}(120)(314) = 110mm^2$

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

$A_s\ \min = \frac{1.4}{420}(120)(314) = 125.6mm^2$ controls

Asreq= 289 mm2 >Asmin= 125.6 mm2 OK

Use 2 ø14 ,As,provided=308 mm2>As,required= 289 mm2… Ok

$S = \frac{120-40-20-(2\times14)}{1} = 32 \text{ mm} > d_b = 14 > 25 \text{ mm}$ OK

Check for strain:

$a = \frac{A_{s.}f_y}{0.85b\, f_c'} = \frac{308\times420}{0.85\times520\times24} = 12.2 \text{ mm}$

$x = \frac{a}{\mathcal{B}_1} = \frac{12.2}{0.85} = 14.35 \text{ mm}$

$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{314-14.35}{14.35}\right) = 0.0626 > 0.005$ 0k

Design of Negative Moment for (Rib12):- (Mu= -16.9 KN.m)

Assume bar diameter ø 12 for main positive reinforcement

d =h- cover - dstirrups$-\frac{d_b}{2} = 350 - 20 - 10 - \frac{12}{2} = 314 \text{ mm}$

$Rn = \frac{M_u}{\emptyset bd^2} = \frac{16.9\times10^6}{0.9\times120\times314^2} = 1.59 \text{ Mpa}$

$m = \frac{f_y}{0.85f_c'} = \frac{420}{0.85\times24} = 20.6$

$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times1.59}{420}}\right) = 0.00395$

As,req = ρ.b.d = 0.00395×120×314 = 148.8 mm2

Check for As min:

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

$A_s \min = \frac{\sqrt{24}}{4(420)}(120)(314) = 110mm^2$

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

A s min = $\frac{1.4}{420}(120)(314) = 125.6mm^2$ controls

Asreq = 148.8mm2 >Asmin= 125.6 mm2OK

Use 2 ø 10 ,As,provided= 157.1 mm2>As,required= 148.8 mm2… Ok

$S = \frac{120-40-20-(2\times10)}{1} = 40 \text{ mm} > d_b = 10 > 25 \text{ mm}$ OK

Check for strain:-

a =$\frac{A_{s.f_y}}{0.85b\ f_c'} = \frac{157.1\times420}{0.85\times120\times24} = 26.95$ mm

x= $\frac{a}{\mathcal{B}_1} = \frac{26.95}{0.85} = 31.7$ mm

$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{314-31.7}{31.7}\right) = 0.0267 > 0.005$ 0k

Design of Negative Moment for (Rib12):- (Mu= -18.5 KN.m)

Assume bar diameter ø 12 for main positive reinforcement

d =h- cover - dstirrups$-\frac{d_b}{2} = 350 - 20 - 10 - \frac{12}{2} = 314$ mm

Rn= $\frac{M_u}{\emptyset bd^2} = \frac{18.5\times10^6}{0.9\times120\times314^2} = 1.74$ Mpa

m= $\frac{f_y}{0.85f_c'} = \frac{420}{0.85\times24} = 20.6$

ρ= $\frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times1.74}{420}}\right) = 0.00434$

As,req = ρ.b.d = 0.00434×120×314 = 163.5 mm2

Check for As min:-

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

$A_s \min = \frac{\sqrt{24}}{4(420)}(120)(314) = 110mm^2$

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

$A_s \min = \frac{1.4}{420}(120)(314) = 125.6mm^2$ controls

Asreq = 163.5mm2 >Asmin= 125.6 mm2OK

Use 2 ø 12 ,As,provided= 226 mm2>As,required= 163.5 mm2… Ok

$S = \frac{120-40-20-(2\times12)}{1} = 36\text{ mm} > d_b = 12 > 25\text{ mm}$ OK

Check for strain:-

$a = \frac{A_{s.}f_y}{0.85b\, f_c'} = \frac{226\times420}{0.85\times120\times24} = 38.77\text{ mm}$

$x = \frac{a}{\mathcal{B}_1} = \frac{38.77}{0.85} = 45.62\text{ mm}$

$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{314-45.62}{45.62}\right) = 0.0176 > 0.005$ 0k

Design of Negative Moment for (Rib12):- (Mu=-9.5 KN.m)

Assume bar diameter ø 12 for main positive reinforcement

$d = h\text{- cover - dstirrups} - \frac{d_b}{2} = 350 - 20 - 10 - \frac{12}{2} = 314\text{ mm}$

$Rn = \frac{M_u}{\emptyset bd^2} = \frac{9.5\times10^6}{0.9\times120\times314^2} = 0.892\text{ Mpa}$

$m = \frac{f_y}{0.85f_c'} = \frac{420}{0.85\times24} = 20.6$

$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2\times20.6\times0.892}{420}}\right) = 0.00217$

As,req = ρ.b.d = 0.00217 ×120×314 = 81.76 mm2

Check for As min:

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

$A_s \min = \frac{\sqrt{24}}{4(420)}(120)(314) = 110m^2$

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

$A_s \min = \frac{1.4}{420}(120)(314) = 125.6mm^2$ controls

Asreq = 125.6 mm2

Use 2 ø10 ,As,provided= 157.08 mm2>As,required= 125.6 mm2… Ok

$S = \frac{120-40-20-(2\times10)}{1} = 40 \text{ mm} > d_b = 10 > 25 \text{ mm}$ OK

Check for strain:

$a = \frac{A_{s.fy}}{0.85b\, f_c'} = \frac{157\times420}{0.85\times120\times24} = 6.22 \text{ mm}$

$x = \frac{a}{\mathcal{B}_1} = \frac{6.22}{0.85} = 7.31\text{mm}$

$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{284-7.31}{7.31}\right) = 0.125 > 0.005$ 0k

Design of Negative Moment for (Rib12): (Mu=-9.1 KN.m)

Assume bar diameter ø 12 for main positive reinforcement

d =h- cover - dstirrups$-\frac{d_b}{2} = 350 - 20 - 10 - \frac{12}{2} = 314$ mm

Rn= $\frac{M_u}{\emptyset bd^2} = \frac{9.1\times10^6}{0.9\times120\times314^2} = 0.855$ Mpa

m= $\frac{f_y}{0.85f_c'} = \frac{420}{0.85\times24} = 20.6$

ρ= $\frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times0.855}{420}}\right) = 0.00208$

As,req = ρ.b.d = 0.00208×120×314 = 78.37 mm2

Check for As min:

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

$A_s \min = \frac{\sqrt{24}}{4(420)}(120)(314) = 110m^2$

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

$A_s \min = \frac{1.4}{420}(120)(314) = 125.6mm^2$ controls

Asreq = 125.6 mm2

Use 2 ø10 ,As,provided= 157.08 mm2>As,required= 125.6 mm2… Ok .

$S = \frac{120-40-20-(2\times10)}{1} = 40$ mm $> d_b = 10 > 25$ mm OK

Check for strain:

a =$\frac{A_{s.}f_y}{0.85b\ f_c'} = \frac{157\times420}{0.85\times120\times24} = 6.22$ mm

$x=\frac{a}{\mathcal{B}_1}=\frac{6.22}{0.85}=7.31\text{mm}$

$\varepsilon_s=0.003\left(\frac{d-x}{x}\right)=0.003\left(\frac{284-7.31}{7.31}\right)=0.125>0.005$ 0k

Design of Negative Moment for (Rib12): (Mu=-27.8 KN.m)

Assume bar diameter ø 12 for main positive reinforcement

d =h- cover - dstirrups$-\frac{d_b}{2}=350-20-10-\frac{12}{2}=314$ mm

$Rn=\frac{M_u}{\emptyset bd^2}=\frac{27.8\times10^6}{0.9\times120\times314^2}=2.61$ Mpa

$m=\frac{f_y}{0.85f_c'}=\frac{420}{0.85\times24}=20.6$

$\rho=\frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right)=\frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times2.61}{420}}\right)=0.00667$

As,req = ρ.b.d = 0.00667 ×120×314 = 251.3 mm2

Check for As min:

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

$A_s\ \min=\frac{\sqrt{24}}{4(420)}(120)(314)=110m^2$

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

$A_s\ \min=\frac{1.4}{420}(120)(314)=125.6mm^2$ controls

Asreq = 251.3 mm2 >Asmin= 125.6 mm2OK

Use 2 ø14 ,As,provided= 308 mm2>As,required= 251.3mm2… Ok

$S = \frac{120-40-20-(2\times14)}{1} = 36\ \text{mm} > d_b = 14 > 25\ \text{mm}$ OK

Check for strain:

$a = \frac{A_{s.}f_y}{0.85b\ f_c'} = \frac{308\times420}{0.85\times120\times24} = 12.2\ \text{mm}$

$x = \frac{a}{\mathcal{B}_1} = \frac{12.2}{0.85} = 14.35\ \text{mm}$

$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{284-14.35}{14.35}\right) = 0.0626 > 0.005$ 0k

Design of Negative Moment for (Rib12): (Mu=-25.3KN.m)

Assume bar diameter ø 12 for main positive reinforcement

d =h- cover - dstirrups$- \frac{d_b}{2} = 350 - 20 - 10 - \frac{12}{2} = 314\ \text{mm}$

$Rn = \frac{M_u}{\emptyset bd^2} = \frac{25.3\times10^6}{0.9\times120\times314^2} = 2.38\ \text{Mpa}$

$m = \frac{f_y}{0.85f_c'} = \frac{420}{0.85\times24} = 20.6$

$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times2.38}{420}}\right) = 0.00604$

As,req = ρ.b.d = 0.00604 ×120×314 = 227.59 mm2

Check for As min:-

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

$A_s\ min = \frac{\sqrt{24}}{4(420)}(120)(314) = 110m^2$

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

$A_s \min = \frac{1.4}{420}(120)(314) = 125.6 mm^2$ controls

Asreq = 227.59 mm2 >Asmin= 125.6 mm2OK

Use 2 ø14 ,As,provided= 308 mm2>As,required= 227.59 mm2… Ok

$S = \frac{120-40-20-(2\times14)}{1} = 36 \text{ mm} > d_b = 14 > 25 \text{ mm}$ OK

Check for strain:-

$a = \frac{A_{s.}f_y}{0.85b\ f_c'} = \frac{308\times420}{0.85\times120\times24} = 12.2 \text{ mm}$

$x = \frac{a}{\mathcal{B}_1} = \frac{12.2}{0.85} = 14.35 \text{ mm}$

$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{284-14.35}{14.35}\right) = 0.0626 > 0.005$ 0k

Shear Design for (R 12):

Vu at distance d from support= 30.9 KN

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

$Vc = \frac{1.1}{6}\sqrt{f_c'}b_w d = \frac{1.1}{6}\sqrt{24} \times 120 \times 314 \times 10^{-3} = 33.84 \text{ KN}$

øVc =0.75×33.84 =25.38 KN

0.5 ø Vc =0.5×25.38 =12.69 KN

0.5 ø Vc< Vu< ø Vc

Vu> ø Vc

For shear design, shear reinforcement is required ($A_{v,}$), Vsmin $=\frac{1}{16}\sqrt{f_c'}$bw d $\geq \frac{1}{3}$ bw d

Vs min=$\frac{1}{16}\sqrt{24} * 120 * 314 = 11.54$kn

Vsmin $=\frac{1}{3}$ bw d=$\frac{1}{3} * 120 * 314 = 12.56$kn

ø(Vc+Vsmin)= 0.75(33.84+12.56)=34.8kn

øVc<Vu <ø (Vc+Vsmin)

25.38 < 30.9 <34.8

For shear design, minimum shear reinforcement is required ($A_{v,min}$), Reinforcement.

Use stirrups (2 leg stirrups) ø 8@150 mm , Av = 2 × 50.24 = 100.5 mm2

Avmin $=\frac{1}{16}\sqrt{f_c'}\frac{b_w s}{fyt} \geq \frac{1}{3}\frac{b_w s}{fyt}$

Avmin=100.5 $=\frac{1}{16}\sqrt{24}\frac{120s}{420} \rightarrow s = 1.145$m

100.5 $=\frac{1}{3}\frac{120s}{420} \rightarrow s = 1.055$m

S max$\rightarrow\frac{d}{2} = 157$mm

S max →≤600mm

Take (2 leg stirrups) ø 8 @ 150 mm

$A_v = \frac{2*50.3}{0.15} = 670.67$ mm2/mstrip

Vu at distance d from support= 24.7 KN

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

Vc $=\frac{1.1}{6}\sqrt{f_c'}b_w d = \frac{1.1}{6}\sqrt{24} \times 120 \times 314 \times 10^{-3} = 33.84$ KN øVc =0.75×33.84 =25.38 KN

0.5 ø Vc =0.5×25.38 =12.69 KN

Vu=24.7< 0.5 ø Vc =12.69 no

0.5 ø Vc< Vu< ø Vc

12.69< 24.7 < 33.84 ok.

Minimum shear reinforcement is required except for concrete joist construction.

So, no shear required reinforcement is provided.

Vu at distance d from support= 20.8 KN

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

Vc $=\frac{1.1}{6}\sqrt{f_c'}b_w d = \frac{1.1}{6}\sqrt{24} \times 120 \times 314 \times 10^{-3} = 33.84$ KN

øVc =0.75×33.84 =25.38 KN

0.5 ø Vc =0.5×25.38 =12.69 KN

Vu=20.8< 0.5 ø Vc =12.69 no

0.5 ø Vc< Vu< ø Vc

12.69< 20.8 < 33.84 ok.

Minimum shear reinforcement is required except for concrete joist construction.

So, no shear required reinforcement is provided.

Vu at distance d from support= 24.8KN

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

Vc =$\frac{1.1}{6}\sqrt{f_c'}b_w d = \frac{1.1}{6}\sqrt{24} \times 120 \times 314 \times 10^{-3} = 33.84$ KN

øVc =0.75×33.84 =25.38 KN

0.5 ø Vc =0.5×25.38 =12.69 KN

Vu=24.8< 0.5 ø Vc =12.69 no

0.5 ø Vc< Vu< ø Vc

12.69< 24.8 < 33.84 ok.

Minimum shear reinforcement is required except for concrete joist construction.

So, no shear required reinforcement is provided.

So we take for all rib the maximum case:

Take (2 leg stirrups) ø 8 @ 150 mm

$A_v = \frac{2*50.3}{0.15} = 670.67$ mm2/mstrip

4-6 Design of Beam

Material : concrete B300 Fc' = 24 N/mm2

Reinforcement Steel fy = 420 N/mm2

Section :

B = 60 cm

h= 35cm

d=350-40-10-18/2= 291 mm

Statically System and Dimensions:

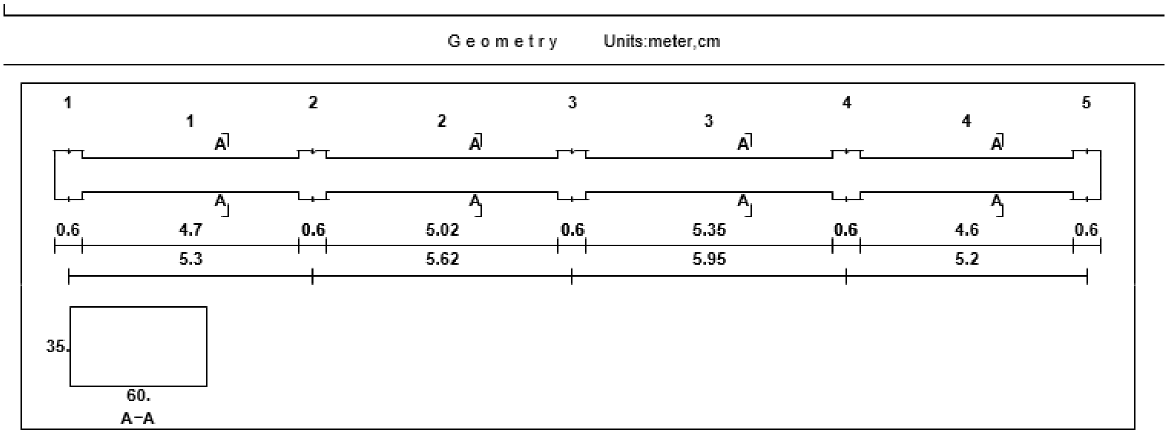


Figure 4-7: Geometry of beam (B1).

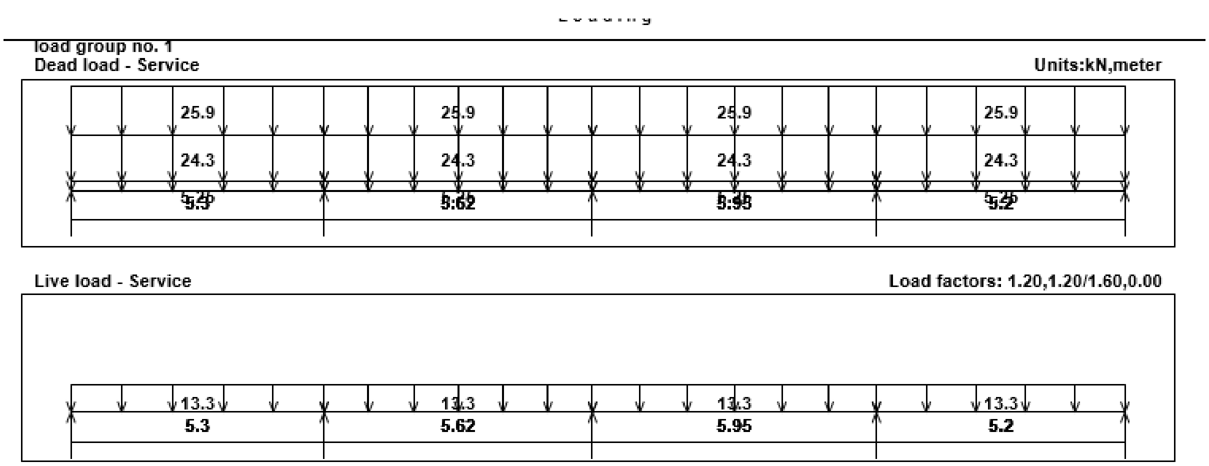


Figure 4-8: Statically system and loads distribution of beam (B 1).

Load Calculations:

Dead Load Calculations for Beam (B1):

The distributed Dead and Live loads acting upon B1 can be defined from the support reactions of the R12.

From Rib12

The maximum support reaction from Dead Loads for R12 upon B1 is7.54 KN, The distributed Dead Load from the R12 on B1.

DL =(12.68/ 0.52) = 24.38 KN / m

Self-weight of beam = 0.35*0.6*25 = 5.25 KN / m

DL =24.38+5.25 = 18.83 KN / m

Dead Load from External wall

D = 3.45*0.3 *25 = 25.9 Kn/m

Live Load calculations for Beam (B1):

From Rib12

The maximum support reaction from Live Loads for R12upon B 1 is 6.69 KN The distributed Live Load from the Rib 12 on B1.

LL =6.69/ 0.52= 13.38 KN/m.

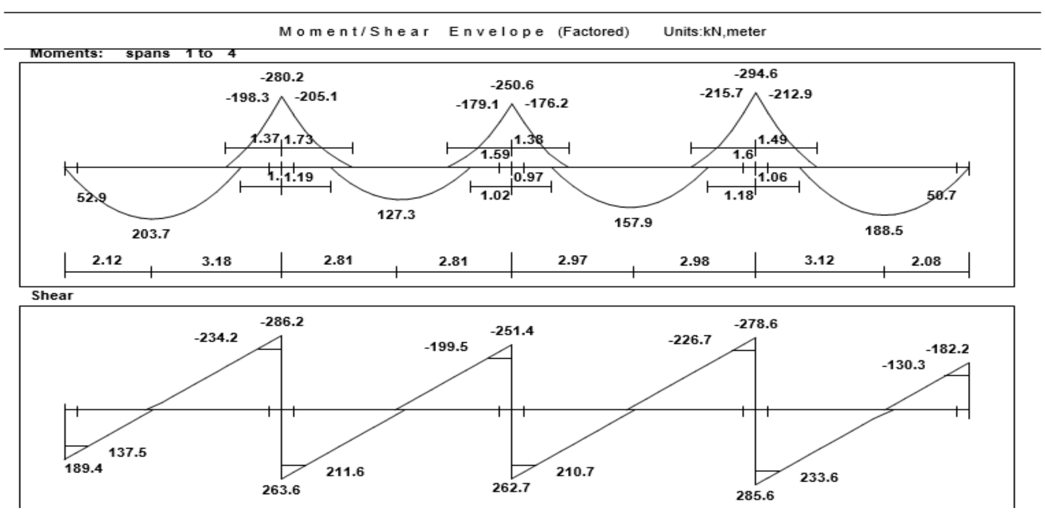


Figure 4-9: Shear and moment envelope diagram of beam (B1).

Moment Design for (B11):

Flexural Design of Positive Moment for(B1):-(Mu=203.7 KN.m)

Determine of Mn,max

d =350 – 40 -10 – 18\2 = 291 mm

$x = \frac{3}{7} d = \frac{3}{7} . 291 = 124.7$ mm

$a = \mathcal{B}. x = 124.7 * 0.85 = 106$ mm

Mnmax= $0.85 * f_c' * a * b(d - \frac{a}{2})$ = 0.85*24*106*600*(291-106/2) *10-6= 308.8 KN.m

∅ Mnmax = 0.82* 308.8 = 253.22 KN.m >203.7 KN.m .

Design as singly reinforcement

$$Rn = \frac{M_u}{\emptyset bd^2} = \frac{203.7 \times 10^6}{0.9 \times 600 \times 291^2} = 4.45 Mpa$$

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

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 4.45}{420}}\right) = 0.0121$$

As = ρ.b.d = 0.0121×600×291 = 2112.66 mm2

Check for As,min:

$$Asmin = \frac{\sqrt{fc'}}{4(fy)}(bw)(d) = \frac{\sqrt{24}}{4 * 420} * 600 * 291 = 509.14 \text{ mm2}$$

$$Asmin = \frac{1.4}{(fy)}(bw)(d) = \frac{1.4}{420} * 600 * 291 = 582 \text{ mm2}$$ Controls

As= 2112.66 mm2

Use 7ø 20 Bottom, As,provided= 2200 mm2>As,required= 2112.66 mm2… Ok

Check spacing :

$S = \frac{600-40*2-20-(7\times20)}{6} = 60 \text{ mm} > d_b = 20 > 25 \text{ mm}$ OK

Check for strain:-

$a = \frac{A_{s.}f_y}{0.85b\, f_c'} = \frac{2200\times420}{0.85\times600\times24} = 75.5 \text{ mm}$

$x = \frac{a}{\mathcal{B}_1} = \frac{75.5}{0.85} = 88.8 \text{ mm}$

$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{291-88.8}{88.8}\right) = 0.00683 > 0.005$ 0k

Flexural Design of Positive Moment for (B1):-(Mu=127.3 KN.m)

$Rn = \frac{M_u}{\emptyset bd^2} = \frac{127.3\times10^6}{0.9\times600\times291^2} = 2.78\text{Mpa.}$

$m = \frac{f_y}{0.85f_c'} = \frac{420}{0.85\times24} = 20.6$

$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times2.78}{420}}\right) = 0.00714$

As = ρ.b.d = 0.00714×600×291 = 1246.6 mm2.

Check for As,min:

Asmin = $\frac{\sqrt{fc'}}{4(fy)}(bw)(d)$ = $\frac{\sqrt{24}}{4*420}*600*291$ = 509.14 mm2

Asmin = $\frac{1.4}{(fy)}(bw)(d)$ = $\frac{1.4}{420}*600*291$ = 582 mm2Controls

As= 1246.6 mm2.

Use 5ø18Bottom, As,provided= 1272.35 mm2>As,required= 1246.6 mm2 … Ok

Check spacing :

$S = \frac{600-40*2-20-(5*18)}{4} = 102.5\text{mm} > d_b = 18 > 25$ OK

Check for strain:-

$a = \frac{A_{s.f_y}}{0.85b\, f_c'} = \frac{1272.35 \times 420}{0.85\times600\times24} = 43.66$ mm

$x = \frac{a}{\mathcal{B}_1} = \frac{43.66}{0.85} = 51.36$ mm

$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{291-51.36}{51.36}\right) = 0.01399 > 0.005$ 0k

Flexural Design of Positive Moment for(B1):-(Mu=157.9 KN.m)

$Rn = \frac{M_u}{\emptyset bd^2} = \frac{157.9\times10^6}{0.9\times600\times291^2} = 3.45$ Mpa

$m = \frac{f_y}{0.85f_c'} = \frac{420}{0.85\times24} = 20.6$

$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times3.45}{420}}\right) = 0.00906$

As = ρ.b.d = 0.00906 ×600×291 = 1581.9 mm2

Check for As,min:

Asmin = $\frac{\sqrt{fc'}}{4(fy)}(bw)(d)$ = $\frac{\sqrt{24}}{4*420}*600*291$ = 509.14 mm2

Asmin = $\frac{1.4}{(fy)}(bw)(d)$ = $\frac{1.4}{420}*600*291$ = 582 mm2

As = 1581.9 mm2Controls

Use 7ø 18, As,provided= 1781.3 mm2>As,required= 1581.9 mm2… Ok

Check spacing:

$$S = \frac{600-40*2-20-(7*18)}{6} = 62.33\ \text{mm} > d_b = 18 > 25 \qquad \text{OK}$$

Check for strain:

$$a = \frac{A_{s}.f_y}{0.85b\ f'_c} = \frac{1781.3\times420}{0.85\times600\times24} = 61.12\ \text{mm}$$

$$x = \frac{a}{\mathcal{B}_1} = \frac{61.12}{0.85} = 71.9\text{mm}$$

$$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{291-71.9}{71.9}\right) = 0.00914 > 0.005 \qquad 0k$$

Flexural Design of Positive Moment for(B1):-(Mu=188.5 KN.m)

$$Rn = \frac{M_u}{\emptyset bd^2} = \frac{188.5\times10^6}{0.9\times600\times291^2} = 4.12\ \text{Mpa}$$

$$m = \frac{f_y}{0.85f'_c} = \frac{420}{0.85\times24} = 20.6$$

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times4.12}{420}}\right) = 0.0111$$

As = ρ.b.d = 0.0111 ×600×291 = 1938.1 mm2

Check for As,min:

$$Asmin = \frac{\sqrt{fc'}}{4(fy)}(bw)(d) = \frac{\sqrt{24}}{4*420}*600*291 = 509.14\ \text{mm2}$$

$$Asmin = \frac{1.4}{(fy)}(bw)(d) = \frac{1.4}{420}*600*291 = 582\ \text{mm2}$$

As = 1938.1mm2Controls

Use 8 ø 18 ,As,provided= 2035.75 mm2>As,required= 1938.1 mm2… Ok

Check spacing :

$$S = \frac{600-40*2-20-(8*18)}{7} = 50.85\ \text{mm} > d_b = 18 > 25 \qquad \text{OK}$$

Check for strain:-

$$a = \frac{A_{s.f_y}}{0.85b\ f'_c} = \frac{2035.75 \times 420}{0.85 \times 600 \times 24} = 70\ \text{mm}$$

$$x = \frac{a}{\mathcal{B}_1} = \frac{70}{0.85} = 82.35\ \text{mm}$$

$$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{291-82.35}{82.35}\right) = 0.00758 > 0.005 \qquad \text{0k}$$

Flexural Design of Negative Moment for(B1):-(Mu=-198.3 KN.m)

$$Rn = \frac{M_u}{\emptyset bd^2} = \frac{198.3 \times 10^6}{0.9 \times 600 \times 291^2} = 4.34\ \text{Mpa}$$

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

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2 \times 20.6 \times 4.34}{420}}\right) = 0.0118$$

As = ρ.b.d = 0.0118 ×600×291 = 2060.28 mm2

Check for As,min:

$$Asmin = \frac{\sqrt{fc'}}{4(fy)}(bw)(d) = \frac{\sqrt{24}}{4*420}*600*291 = 509.14\ \text{mm2}$$

$$Asmin = \frac{1.4}{(fy)}(bw)(d) = \frac{1.4}{420}*600*291 = 582\ \text{mm2}$$

As =2060.28 mm2Controls

Use7 ø 20 ,As,provided= 2200 mm2>As,required= 2060.28mm2… Ok

Check spacing :

$$S = \frac{600-40*2-20-(7*20)}{6} = 60 \text{ mm} > d_b = 20 > 25 \qquad \text{OK}$$

Check for strain:

$$a = \frac{A_{s.}f_y}{0.85b\, f'_c} = \frac{2200\times420}{0.85\times600\times24} = 75.5 \text{ mm}$$

$$x = \frac{a}{\mathcal{B}_1} = \frac{75.5}{0.85} = 88.8\text{mm}$$

$$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{291-88.8}{88.8}\right) = 0.00683 > 0.005 \qquad 0k$$

Flexural Design of Negative Moment for(B1):-(Mu=-205.1 KN.m)

$$Rn = \frac{M_u}{\emptyset bd^2} = \frac{205.1\times10^6}{0.9\times600\times291^2} = 4.49 \text{ Mpa}$$

$$m = \frac{f_y}{0.85f'_c} = \frac{420}{0.85\times24} = 20.6$$

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times4.49[}{420}}\right) = 0.0122$$

As = ρ.b.d = 0.0122 ×600×291 = 2130.12 mm2

Check for As,min:

$$Asmin = \frac{\sqrt{fc'}}{4(fy)}(bw)(d) = \frac{\sqrt{24}}{4*420}*600*291 = 509.14 \text{ mm2}$$

$$Asmin = \frac{1.4}{(fy)}(bw)(d) = \frac{1.4}{420}*600*291 = 582 \text{ mm2}$$

As =2130.12 mm2Controls

Use7 ø 20 ,As,provided= 2200 mm2>As,required= 2130.12 mm2… Ok

Check spacing :

$$S = \frac{600-40*2-20-(7*20)}{6} = 60 \text{ mm} > d_b = 20 > 25 \qquad \text{OK}$$

Check for strain:

$$a = \frac{A_{s.}f_y}{0.85b\, f'_c} = \frac{2200\times420}{0.85\times600\times24} = 75.5 \text{ mm}$$

$$x = \frac{a}{\mathcal{B}_1} = \frac{75.5}{0.85} = 88.8\text{mm}$$

$$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{291-88.8}{88.8}\right) = 0.00683 > 0.005 \qquad 0k$$

Flexural Design of Negative Moment for(B1):-(Mu=-179.1 m)

$$Rn = \frac{M_u}{\emptyset bd^2} = \frac{179.1\times10^6}{0.9\times600\times291^2} = 3.9 \text{ Mpa}$$

$$m = \frac{f_y}{0.85f'_c} = \frac{420}{0.85\times24} = 20.6$$

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times3.9}{420}}\right) = 0.0104$$

As = ρ.b.d = 0.0104 ×600×291 = 1815.84 mm2

Check for As,min:

$$Asmin = \frac{\sqrt{fc'}}{4(fy)}(bw)(d) = \frac{\sqrt{24}}{4*420}*600*291 = 509.14 \text{ mm2}$$

$$Asmin = \frac{1.4}{(fy)}(bw)(d) = \frac{1.4}{420}*600*291 = 582 \text{ mm2}$$

As = 1815.84 mm2Controls

Use 6 ø 20 ,As,provided= 1885 mm2>As,required= 1815.84 mm2… Ok

Check spacing :

$S = \frac{600-40*2-20-(6*20)}{5} = 76 \text{ mm} > d_b = 20 > 25$ OK

Check for strain:

$a = \frac{A_{s.}f_y}{0.85b\, f'_c} = \frac{1885\times 420}{0.85\times 600\times 24} = 64.7 \text{ mm}$

$x = \frac{a}{\mathcal{B}_1} = \frac{64.7}{0.85} = 76.12\text{mm}$

$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{291-76.12}{76.12}\right) = 0.00847 > 0.005$ 0k

Flexural Design of Negative Moment for(B1):-(Mu=-176.2m)

$Rn = \frac{M_u}{\emptyset bd^2} = \frac{176.2\times 10^6}{0.9\times 600\times 291^2} = 3.85 \text{ Mpa}$

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

$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times 20.6\times 3.85}{420}}\right) = 0.0106$

As = ρ.b.d = 0.0106 ×600×291 = 1850.76 mm2

Check for As,min:

Asmin = $\frac{\sqrt{fc'}}{4(fy)}(bw)(d)$ = $\frac{\sqrt{24}}{4*420}*600*291$ = 509.14 mm2

Asmin = $\frac{1.4}{(fy)}(bw)(d)$ = $\frac{1.4}{420}*600*291$ = 582 mm2

As = 1850.76 mm2Controls

Use 6 ø 20 ,As,provided= 1885 mm2>As,required= 1850.76 mm2… Ok

Check spacing :

$$S = \frac{600-40*2-20-(6*20)}{5} = 76\ \text{mm} > d_b = 20 > 25 \qquad \text{OK}$$

Check for strain:

$$a = \frac{A_{s.f_y}}{0.85b\ f_c'} = \frac{1885\times420}{0.85\times600\times24} = 64.7\ \text{mm}$$

$$x = \frac{a}{\mathcal{B}_1} = \frac{64.7}{0.85} = 76.12\text{mm}$$

$$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{291-76.12}{76.12}\right) = 0.00847 > 0.005 \qquad 0k$$

Flexural Design of Negative Moment for(B1):-(Mu=-215.7 kn.m)

$$Rn = \frac{M_u}{\emptyset bd^2} = \frac{215.7\times10^6}{0.9\times600\times291^2} = 4.72\ \text{Mpa}$$

$$m = \frac{f_y}{0.85f_c'} = \frac{420}{0.85\times24} = 20.6$$

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times4.72}{420}}\right) = 0.013$$

As = ρ.b.d = 0.013 ×600×291 = 2269.8 mm2

Check for As,min:

$$Asmin = \frac{\sqrt{fc'}}{4(fy)}(bw)(d) = \frac{\sqrt{24}}{4*420}*600*291 = 509.14\ \text{mm2}$$

$$Asmin = \frac{1.4}{(fy)}(bw)(d) = \frac{1.4}{420}*600*291 = 582\ \text{mm2}$$

As =2269.8 mm2Controls

Use 8ø 20,As,provided= 2513.3 mm2>As,required= 2269.8 mm2… Ok

Check spacing :

$S = \frac{600-40*2-20-(8*20)}{7} = 48.6 \text{ mm} > d_b = 20 > 25$ OK

Check for strain:-

$a = \frac{A_{s.}f_y}{0.85b\, f'_c} = \frac{2513.3\times420}{0.85\times600\times24} = 86.24 \text{ mm}$

$x = \frac{a}{\mathcal{B}_1} = \frac{86.24}{0.85} = 101.46 \text{ mm}$

$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{291-101.46}{101.46}\right) = 0.0056 > 0.005$ 0k

Flexural Design of Negative Moment for(B1):-(Mu=-212.9 kn.m)

$Rn = \frac{M_u}{\emptyset bd^2} = \frac{212.9\times10^6}{0.9\times600\times291^2} = 4.66 \text{ Mpa}$

$m = \frac{f_y}{0.85f'_c} = \frac{420}{0.85\times24} = 20.6$

$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times4.66}{420}}\right) = 0.0128$

As = ρ.b.d = 0.0128 ×600×291 = 2234.88 mm2

Check for As,min:

Asmin = $\frac{\sqrt{fc'}}{4(fy)}(bw)(d)$ = $\frac{\sqrt{24}}{4*420}*600*291$ = 509.14 mm2

Asmin = $\frac{1.4}{(fy)}(bw)(d)$ = $\frac{1.4}{420}*600*291$ = 582 mm2

As =2234.88 mm2Controls

Use 8ø 20,As,provided= 2513.3 mm2>As,required= 2234.88 mm2… Ok

Check spacing :

$S = \frac{600-40*2-20-(8*20)}{7} = 48.6\text{ mm} > d_b = 20 > 25$ OK

Check for strain:-

$a = \frac{A_{s.}f_y}{0.85b\,f'_c} = \frac{2513.3\times420}{0.85\times600\times24} = 86.24\text{ mm}$

$x = \frac{a}{\mathcal{B}_1} = \frac{86.24}{0.85} = 101.46\text{ mm}$

$\varepsilon_s = 0.003\left(\frac{d-x}{x}\right) = 0.003\left(\frac{291-101.46}{101.46}\right) = 0.0056 > 0.005$ 0k

Shear Design for (B 1):

Case 3 :

for shear design, minimum shear reinforcement is required ($A_{v,min}$), Reinforcement.

Use stirrups (2 leg stirrups) ø 8/ 150 mm , Av = 2 × 50.24 = 100.5 mm2

Vu = 234.2 KN

$Vc = \frac{1}{6}\sqrt{fc'}b_w\,d = \frac{1}{6}\sqrt{24} * 600 * 291 = 142.56$ KN

Check for section dimensions:

$Vs = \frac{Vu}{\Phi} - Vc = \frac{234.2}{0.75} - 142.56 = 169.71$

$Vs,max = \frac{2}{3}\sqrt{fc'}b_w\,d = \frac{2}{3}\sqrt{24} * 600 * 291 = 570.24$ KN

Vs= 169.71< Vs,max = 570.24 - the section is large enough .

Find the maximum stirrups spacing:

If $Vs < V'_s = \frac{1}{3}\sqrt{fc'}b_w\,d$ then $Smax \le \frac{d}{2}$ or $Smax \le 600$ mm

$V'_s = \frac{1}{3}\sqrt{fc'}b_w\,d = \frac{1}{3}\sqrt{24} * 600 * 291 * 10\text{-}3 = 285.12$ KN

Smax ≤ 600 mm, Smax ≤ $\frac{d}{2}$ = $\frac{291}{2}$ = 145.5 mm Control

Check for Vs, min:

Av, min = $\frac{1}{16}\sqrt{fc'}\frac{bw\ S}{fyt}$ but not less than

Av, min = $\frac{1}{3}\frac{bw\ S}{fyt}$ Control ($\frac{1}{16}\sqrt{fc'} = \frac{4.9}{16} < \frac{1}{3}$)

Vs,min= $\frac{1}{16}\sqrt{fc'}b_w$ d = $\frac{1}{16}\sqrt{24} * 600 * 291$ * 10-3 = 53.5 KN

Vs,min= $\frac{1}{3}b_w$ d = $\frac{1}{3} * 600 * 291$ * 10-3 = 58.2 KN Control

Φ Vc= 0.75*142.56 =106.92 KN

Φ Vsmin≥ 0.75 ($\frac{1}{3}$) * bw * d =0 .75* ($\frac{1}{3}$)*600*291*10-3 = 43.65 KN Controls

Φ Vsmin ≥ 0.75 ($\frac{\sqrt{fc'}}{16}$) * bw * d = 0.75*($\frac{\sqrt{24}}{16}$) * 600 * 291*10-3 = 40.1 KN

Φ Vc<Vu ≤ Φ Vc + Φ Vsmin

106.92<234.2 ≤ 106.92+43.65= 150.57 …… not satisfied

Cases 1&2&3 is not suitable

Case 4 :

$v_{s'} = \frac{1}{3}\sqrt{fc'}b_w$ d = $\frac{1}{3}\sqrt{24} * 600 * 291$ = 285.12KN

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

0.75(142.56+ 43.65) < 234.2< 0.75(142.56 + 285.12)

139.66 < 234.2 <320.76

Use 2 leg Φ 10

As =158 mm2

$Vs = Vn – Vc = \frac{234.2}{0.75} – 142.56 = 169.7KN$

$$S = \frac{A_v f_{yt}\, d}{v_s} = \frac{158 * 420 * 291}{169.7 * 1000} = 113.95 \text{ mm}$$

$$s_{max} \le \frac{d}{2} = \frac{291}{2} = 145.5 \text{ mm} \qquad \text{control}$$

or $s_{max} \le 600$ mm

Use 2 leg Φ 10 @120

4-7 Design of One Way Solid Slab.

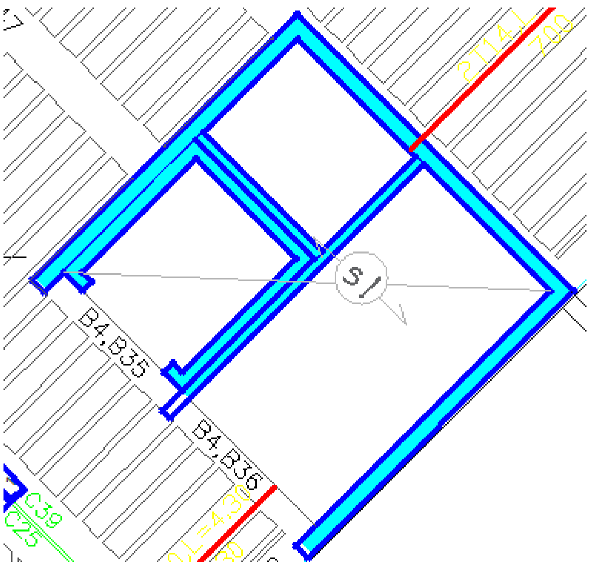


Figure 4-10: One way solid slab(S1).

Material:-

concrete B300 Fc' = 24 N/mm^2

Reinforcement Steel Fy = 420 N/mm^2

Slab Thickness Calculation:-

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

Min H (deflection requirement) : “For one end continuous”

$$\frac{L}{24} = \frac{3.5}{24} = 0.15m$$

For One way solid slab, will use thickness of slab 15 cm.

Load Calculation:-

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

-Load Calculation For the Horizontal Slab:- (For one Meter Strip)

#	material	calculation
1	**Tiles**	**0.03*22=0.66**
2	**mortar**	**0.03*22=0.66**
3	**Coarse sand**	**0.07*16=1.12**
4	**RC concrete**	**0.15*25=3.75**
5	**plaster**	**0.02*22=0.44**
	Sum	**6.63**

Table 4-4: Dead Load Calculation of Solid Slab.

Live load =5 KN/m

- ✓ Design of Positive Moment :

Design of Positive Moment :-(Mu=16.5 KN.m)

Assume bar diameter Φ12 for main reinforcement .

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

Rn = $\frac{Mu/\phi}{b*d^2}$

Rn = $\frac{16.5*10^{6}/0.9}{1000*(124)^2}$ = 1.19(Mpa)

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

ρ = $\frac{1}{20.59}(1 - \sqrt{1-\frac{2(20.59)(1.19)}{420}})$ = 0.0029

As=ρ * b * d = 0.0029* 100 *12.4= 3.6cm²

Check for As min:

$As\ min = \rho_{min} * b * h = 0.0018*100*15 = 2.7cm^2$

As_{req}= 3.6cm² >As_{min}= 2.7cm² **OK**

Use ø 12/25cm , $A_{s,provided}$= 4.52cm²>$A_{s,required}$= 3.6cm² …. Ok

Design of Positive Moment :-(Mu=12.2KN.m)

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

Rn = $\frac{Mu/\phi}{b*d^2}$

Rn = $\frac{12.2*10^{6}/0.9}{1000*(124)^2}$ = 0.88 (Mpa)

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

$$\rho = \frac{1}{20.59}(1 - \sqrt{1-\frac{2(20.59)(0.88)}{420}}) = 0.0021$$

As=ρ * b * d = 0.0021* 100 *124= 2.6cm²

Check for As min:

$$As\ \min = \rho_{\min} * b * h = 0.0018*100*15 = 2.7cm^2$$

As_{req}= 2.6cm^2 <As_{min}= 2.7cm^2 **Not OK**

Use 3ø12/1m strip , $A_{s,provided}$= 3.39cm^2≥$A_{s,required}$= 2.6cm^2 …. Ok

- ✓ Design of Negative Moment:

Design of Negative Moment:- (Mu=15.9 KN.m)

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

$$Rn = \frac{Mu/\phi}{b*d^2}$$

$$Rn = \frac{15.9*10^{6}/0.9}{1000*(124)^2} = 1.15\ (Mpa)$$

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

$$\rho = \frac{1}{20.59}(1 - \sqrt{1-\frac{2(20.59)(1.15)}{420}}) = 0.0028$$

As=ρ * b * d = 0.0028* 100 *124= 3.47 cm²

Check for As min:-

$As\ \min = \rho_{\min} * b * h = 0.0018*100*15 = 2.7cm^2$

As_{req}= 3.47cm^2 > As_{min}= 2.7cm^2 **OK**

Use ø12/25cm , $A_{s,provided}$= 4.52cm^2≥$A_{s,required}$= 3.47cm^2 …. Ok

Shrinkage and Temperature:-

$\rightarrow \rho = 0.0018$

$As\ \min = \rho_{\min} * b * h = 0.0018*100*15 = 2.7cm^2$ (control)

Use 3Φ12/1m strip.

Shear Design:-

Check Whether Thickness Is Adequate For Shear:-

$V_{u,\max}$ = 29.3 KN/ 1m strip

d = h – 15 – db = 200 – 15 – (12 /2) = 124 mm

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

$= \frac{1}{6} * 0.75 * \sqrt{24} * 1000 * 124$ = 75.9 KN / 1 m strip

ΦVc/2= 37.95 KN > $V_{u,\max}$ = 29.3 KN/ 1m strip.

The thickness of the slab is adequate enough.

4-8 Design of Column (C28/GF).

Material :

concrete B350 Fc' = 24 N/mm^2

Reinforcement Steel Fy = 420 N/mm^2

Load Calculation:-

Service Load:-

Dead Load =1553.9KN

Live Load =858.65 KN

Factored Load:-

P_U = 1.2 ×1553.9+ 1.6×858.65 =3238.52KN

Dimensions of Column:-

$$Assume \rho g = 0.01$$

$$\phi * \text{Pn} = 0.65 \text{ x } 0.8 \times \text{Ag}\{0.85 \; fc^{'}(1-\rho g) + \rho g * Fy\}$$

$$3238.52*1000 = 0.65 \text{ x } 0.8 \times \text{Ag}\{0.85*24(1-0.01)+0.01*420\}$$

Ag= 255605.37 mm2

Assume Rectangular Section

Try h = 600mm

b = 450mm

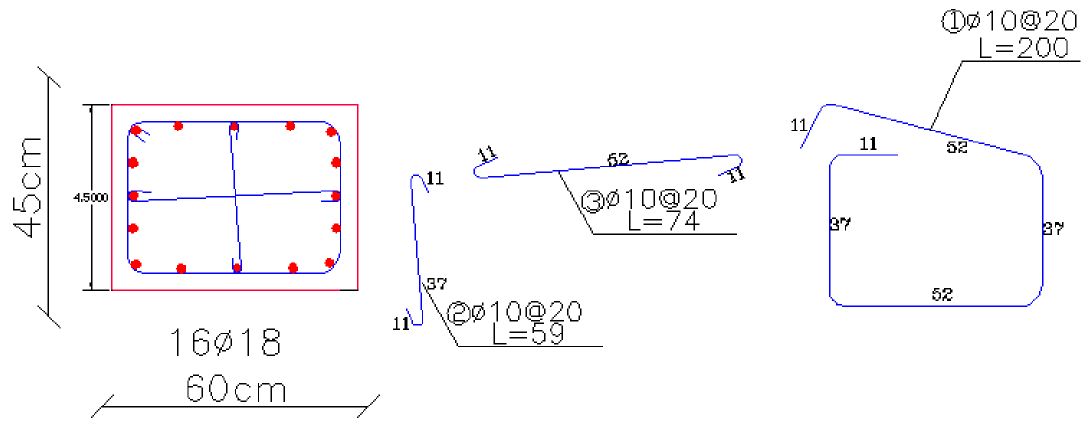


Figure 4-11: Column (C28) section and reinforcement.

Design of the tie reinforcement :

S ≤16 db (longitudinal bar diameter)

S≤ 48dt (tie bar diameter).

S ≤ Least dimension.

spacing $\leq 16\times d_b = 16\times 2.8 = 44.8$cm ….

spacing $\leq 48\times dt = 48\times 1.0 = 48$ cm

spacing ≤ least.dim =45cm control

Useϕ10@40 cm

For Using Column We have using 16ν18.

4-9 Design of Isolated Footing.

Material :-

concrete B350 Fc' = 24 N/mm^2

Reinforcement Steel Fy = 420 N/mm^2

Load Calculations:-

Dead Load = 2207.78 Kn , Live Load = 1066.15 Kn

Total services load = 2207.78 + 1066.15 = 3273.93 Kn

Total Factored load = 1.2*2207.78 + 1.6*1066.15 = 4355.18Kn

Column Dimensions (a*b) = 60*60 cm

Soil density = 20 Kg/cm3

Allowable Bearing Capacity = 350 Kn/m2

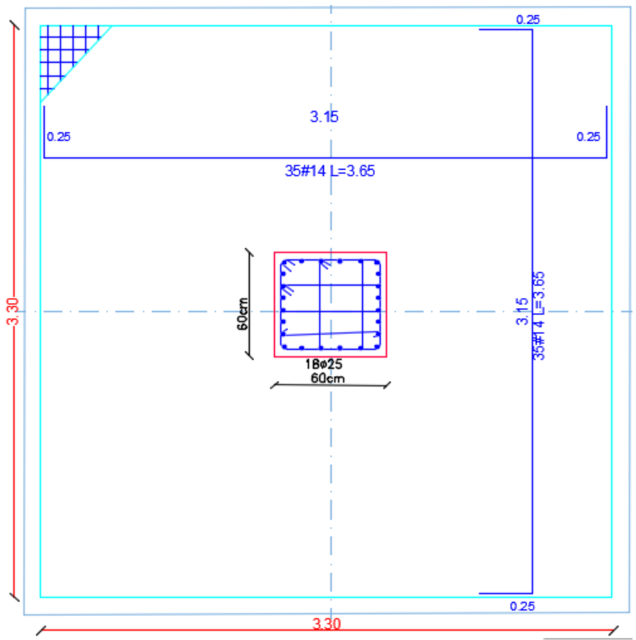


Figure 4-12 :Foot plan.

Assume h = 80cm

$q_{net-allow}$ = 350 – 25*0.8 – 20*0.6 – 0.7*25 = 300.5kn/m2

Area of Footing :-

$$A = \frac{Pt}{q_{net-allow}} = \frac{3273.93}{300.5} = 10.89m^2$$

Assume Square Footing

B required = 3.3 m

Select B = 3.3 m

Bearing Pressure :-

q_u = 4355.18/3.3*3.3= 399.92 Kn/m^2

Design of Footing :-

Design of One Way Shear Strength :-

Critical Section at Distance (d)From The Face of Column

Assume h = 80cm , bar diameter ø 14 for main reinforcement and 7.5 cm Cover

d = 800 – 75 – 14 = 711 mm

Vu = $q_u * \left(\frac{B-a}{2} - d\right) * L$

Vu = 399.92 $* \left(\frac{3.3-0.6}{2} - 0.711\right) * 3.3$ = 843.31Kn

$$\phi.Vc = \phi.\frac{1}{6} * \sqrt{fc'} * b_w * d$$
$$\phi.Vc = 0.75 * \frac{1}{6} * \sqrt{24} * 3300 * 711 = 1436.8Kn$$
$$\phi.Vc = 1436.8KN > Vu = 843.31Kn$$
$$\therefore \quad Safe$$

Design of Two Way Shear Strength :-

$$Vu = Pu - FR_b$$

$$FR_b = q_u * area \ \ of \ \ critical \ \ section$$

$$Vu = 4355.18 - 399.92[(0.6+0.711)*(0.6+0.711)] = 3667.8Kn$$

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

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

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

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

Where:-

$$\beta_C = \frac{Column\ Length\ (a)}{Column\ Width\ (b)} = \frac{60}{60} = 1$$

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

$b_o = (0.6 + 0.711) * 4 = 5244\ mm$

α_s = 40 for interior column

$$\phi.V_C = \phi.\frac{1}{6}\left(1+\frac{2}{\beta_c}\right)\sqrt{f_c'}\,b_o d = \frac{0.75}{6}*\left(1+\frac{2}{1}\right)*\sqrt{24}*5244*711 = 6849.7Kn$$

$$\phi.V_C = \phi.\frac{1}{12}\left(\frac{\alpha_s}{b_o/d}+2\right)\sqrt{f_c'}\,b_o d = \frac{0.75}{12}*\left(\frac{40*711}{5244}+2\right)*\sqrt{24}*5244*711 = 8474.6Kn$$

$$\phi.V_C = \phi.\frac{1}{3}\sqrt{f_c'}\,b_o d = \frac{0.75}{3}*\sqrt{24}*5244*711 = 4566.4Kn$$

ΦVc =4566.4 Kn>Vu=3667.8Kn

Design of Bending Moment :-

Critical Section at the Face of Column

FR = $q_u * \left(\frac{B-a}{2}\right) * L$ = 399.92 * $\left(\frac{3.3-0.6}{2}\right)$ *3.3 =1781.6Kn

Mu = 1781.6*0.675 = 1202.58 Kn.m

$R_n = \frac{M_u}{\emptyset b d^2} = \frac{1202.58\times10^6}{0.9\times3300\times711^2} = 0.8Mpa$

$m = \frac{f_y}{0.85 f_c'} = \frac{420}{0.85\times24} = 20.59$

$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.59}\left(1-\sqrt{1-\frac{2\times20.59\times0.8}{420}}\right) = 0.00194$

$A_{s,req}$ = ρ.b.d = 0.00194×3300×711 = 4551.82mm^2

$A_{s,min}$ = 0.0018*3300*800 = 4752 mm^2

$A_{s,req} < A_{s,min}$ = 4752 mm^2,

As,min is control.

Check for Spacing :-

S = 3h = 3*80 = 240cm

S = 380*$(\frac{280}{\frac{2}{3}*420})$ – 2.5*75 = 192.5 cm

S = 45 cm **……… is control**

Use 35ø14 in Both Direction, $A_{s,provided}$= 5033.7mm^2>$A_{s,required}$= 4752 mm^2… Ok

Check for strain:

Tension = Compression

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

$$5033.7 \times 420 = 0.85 \times 24 \times 3300 \times a$$

$$a = 31.4mm$$

$$c = \frac{31.4}{0.85} = 36.9$$

$$\varepsilon_s = \frac{711 - 36.9}{36.9} \times 0.003 = 0.0548 > 0.005 ...ok$$

Design of Dowels :-

$$\Phi Pn.b = \Phi(0.85 fc' A_1 \times \sqrt{\frac{A_2}{A_1}})$$

A_1 = 60* 60 = 0.36 m^2

A_2 = 3.3* 3.3 = 10.89 m^2

$$\sqrt{\frac{A_2}{A_1}} = \sqrt{\frac{10.89}{0.36}} = 5.5 > 2 \ldots\ldots\ldots\ldots\ldots \sqrt{\frac{A_2}{A_1}} = 2$$

$$\Phi Pn.b = 0.65 \times (0.85 \times 24 \times 0.36 \times 2) = 9547.2Kn$$

$$\Phi Pn = 9547.2 > Pu = 4355.18 \ldots\ldots\ldots ok$$

No Need For Dowels

As,min = 0.005 * Ac = 0.005 * 600* 600 = 1800 mm2

Use 12ø14, $A_{s,provided}$= 1847.25 mm^2>$A_{s,required}$= 1800mm^2… Ok

Development Length In Footing :-

Tension Development Length In Footing :-

$$Ld_{T\ req} = \frac{9}{10} * \frac{F_y}{\lambda\sqrt{f_c}} * \frac{\psi_e\psi_s\psi_t}{\frac{ktr+cb}{db}} * db > \ 300mm$$

$$Ktr = 0\ (Nostripes)$$

$$\frac{ktr + cb}{db} = 2.5$$

$$Ld_{T\ req} = \frac{9}{10} * \frac{420}{1*\sqrt{24}} * \frac{1*1*0.8}{2.5} * 14 = 345.7mm > 300mm$$

$Ld_{T\ available} = \frac{3300-600}{2}$ -75= 1275 mm

$Ld_{T\ available}$ = 1275 mm >ld_{req} = 345.7 mm…….. **OK**

Compression Development Length In Footing :-

Ld_{Creq}= $\frac{0.24*Fy*dB}{\sqrt{24}}$ >0.043*Fy*dB >200mm

Ld_{Creq}= $\frac{0.24*420*14}{\sqrt{24}}$ = 288.05 >0.043*420*14 = 252.84>200mm

Ld_{Creq}= 288.05mm

$Ldc_{available}$ = 800 – 75 – 14 – 14 = 697mm >Ld_{Creq}= 288.0 mm **…….. Ok**

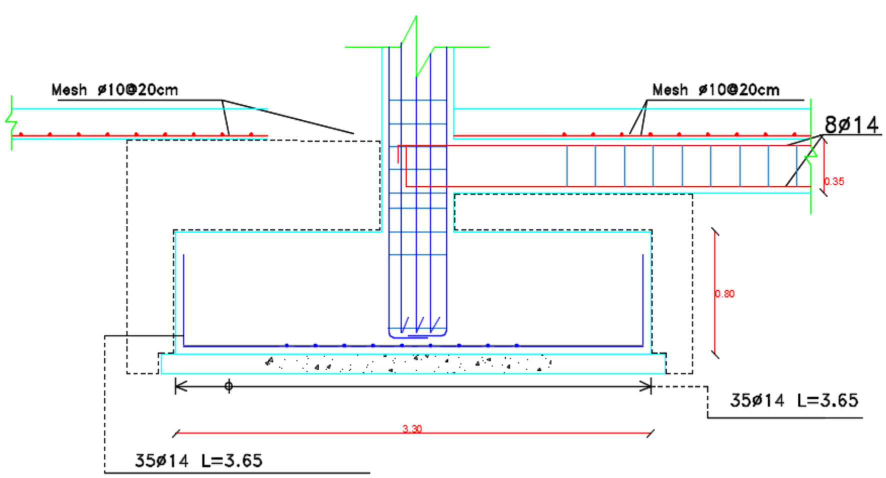


Figure 4-13:Foot reinforcement details.

4-10 Design of Stair.

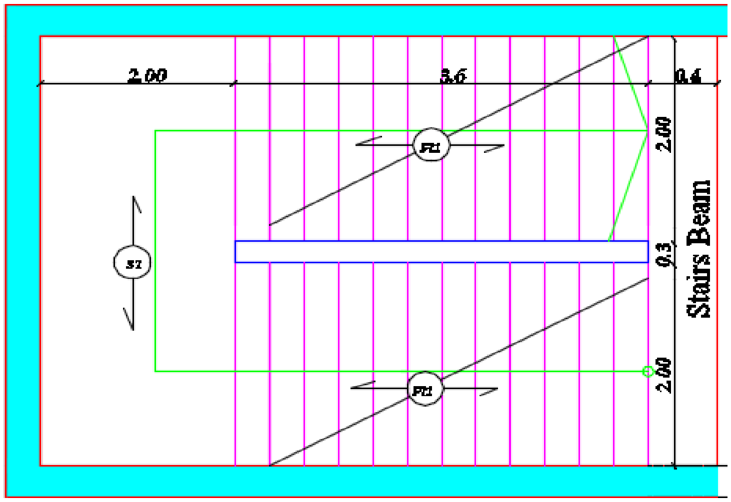


Figure 4-14: Stair plan.

Material:-

Concrete B300 Fc' = 24 N/mm^2

Reinforcement Steel fy = 420 N/mm^2

Determination the Thickness of Slab (flight and landing):

L = 4.4m

h_{req} = 4.4/ 20 =**0.22m**

Take h= 25cm.

$\Rightarrow$ **Use h = 25cm**.

Rise = 15cm, run = 30cm

$\theta = tan^{-1}(\frac{rise}{run}) = tan^{-1}(\frac{15}{30}) = 26.57$

Cos θ = 0.894

Load Calculations at section:

Load on Flight:

Dead Load:

For 1m strip:

Flight = (25*0.20)/(Cos26.57) = 5.59KN/m.

Horizontal Mortar = 0.03*22*1 = 0.66 KN/ m.

vertical Mortar = 0.03*22*1*(15/30) = 0.33 KN/ m.

Plaster = (0.02*22)/ (Cos 26.57) = 0.49 KN/ m.

Horizontal tiles =23*0.04*(33/30) = 1.012KN / m.

Vertical tiles =23*0.03*(15/30) =0.345 KN/m

Triangle = 25*0.15*1*0.5 = 1.875KN/m

Total dead load = 10.564 KN/ m.

Live load:

Live load for stairs =5 KN/ m^2.

Factor Loads:

Q_u=1.2*10.502+1.6*5 = 20.67 KN/m.

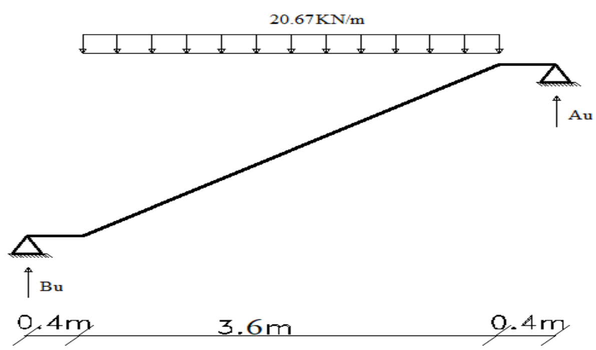


Figure 4-15: structural system of flight.

Au = 20.67*3.6*0.5 = 37.21 KN

Max Vu =37.21

Max Mu =(37.21×(0.4+1.5))-(20.67×(1.5*1.5 /2))

=47.4 KN.m

Design of Shear:

Assume Ø 12 for main reinforcement:-

So, d = 250-20 -12\2 = 224 mm

Max Vu = 37.21 KN.

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

$$\phi Vc = \frac{0.75 * \sqrt{24} * 1000 * 224}{6} = 137.2KN$$

Vu = 37.21 KN< ϕVc = 137.2 KN.

No shear Reinforcement is required. So the depth of the stair is OK.

Design of Bending Moment:

Max Mu = 61.4 kN.m

$Mn = \frac{mu}{0.9} = \frac{47.4}{0.9}$ = 52.7 KN.m.

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

$k_n = \frac{52.7 \times 10^6}{1000 \times 224^2} = 1.05 MPa$.

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

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

$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mk_n}{f_y}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2*20.6*1.05}{420}}\right) = 0.0026$

As_{req} = 0.0026*1000*224 = 682.4mm2.

$As_{min} = 0.0018 * b * h = 0.0018*1000*250 = 450 mm$

As_{min} = 450mm≤ As_{req} = 682.4mm2

Use Φ 12@15cm

As provided =753.9 mm2>As req.

Step(s) is the smallest of :

3h = 3*250 = 750mm.

450mm

S= 380($\frac{280}{fs}$)- 2.5cc = 380($\frac{280}{280}$)- 2.5*20 = 330mm .

S= 150mm < Smax

Check Strain:

T=C

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

$420\times753.9 = 0.85\times24\times1000\times a$

a=15.5 mm

$x = \frac{a}{\beta_1} = \frac{15.5}{0.85} = 18.3mm$ × Note: $f_c' = 24$ MPa< 28 MPa→ $\beta_1 = 0.85$

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

$= (\frac{224-18.3}{18.3})\times 0.003 = 0.0337 > 0.005$

∴ ∅ = 0.9 .... OK.

5 -Lateral reinforcement:

As min = 4.5 cm2

Use Φ10 @ 20 cm

As = 4.74cm2/m

Design of landing:

Load on landing:

Dead Load:

Slab = 0.25 *25*1 = 6.25 KN/ m.

Tiles = 0.03*23*1 = 0.69 KN/m.

Mortar = 0.02*22*1= 0.44 KN/ m.

Plaster = 0.03*22*1 = 0.66 KN/ m.

Sand = 17*0.08*1= 1.36 KN/m

Total dead load =8.15 KN/ m.

Live load:

Live load for stairs = 5 KN/ m.

Qu=1.2*8.15+1.6*5=17.78KN/m.

Au or Bu from Analysis:

Au = 37.21 KN

$W = \frac{AU}{B} = \frac{37.21}{2.15}$

W= 17.3KN/m

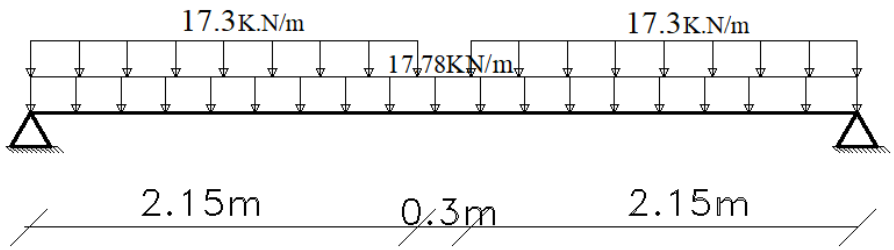


Figure 4-16: Structural system of landing.

Vu = (17.78×4.6/2) + (17.3×2.15)

Vu = 78.1KN.

Mu max =(78.1×2.3)-(17.78×2.3*2.3/2)-(17.3×2.15×1.225)

Mu max= 87.04 KN/m

Design of Shear for landing:

Assume Ø12 for main reinforcement:-

So, d = 250-20 -12\2 = 224 mm

Max Vu As the support reaction = 78.1KN.

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

$$\phi Vc = \frac{0.75 * \sqrt{24} * 1000 * 224}{6} = 137.2KN$$

Vu = 78.1KN< ϕVc = 137.2 KN.

No shear Reinforcement is required. So the depth of the stair is OK.

Design of Bending Moment for landing :

Max Mu = 87.04 kN.m

$Mn = \frac{mu}{0.9} = \frac{87.04}{0.9}$ = 96.71 KN.m.

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

$$k_n = \frac{96.71 * 10^6}{1000 * 224^2} = 1.93MPa$$.

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

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

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mk_n}{f_y}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 1.93}{420}}\right) = 0.0048$$

As_{req} = 0.0048*1000*224= 1075.2mm2.

$As_{min} = 0.0018 * b * h = 0.0018 * 1000 * 250 = 450mm$

As_{min} = 450mm2≤ As_{req} = 1075.2mm2

Use Φ 12@15cm

As provided =1130 mm2>As req.

Step(s) is thr smallest of :

3h = 3*250 = 750mm .

450mm

S= 380($\frac{280}{fs}$)- 2.5cc = 380($\frac{280}{280}$)- 2.5*20 = 330mm .

S= 150mm < Smax

Check Strain:

T=C

As×fy = 0.85× f_c' ×b×a

420×1130= 0.85×24×1000×a

a=23.26 mm

$x = \frac{a}{\beta_1} = \frac{23.26}{0.85}$ = 27.37 mm × Note: f_c' = 24 MPa< 28 MPa→ $\beta_1 = 0.85$

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

$= \left(\frac{224-27.37}{27.37}\right) \times 0.003$ = .0215> 0.005

∴ ∅ = 0.9.... OK.

Lateral reinforcement:

As min = 4.5 cm2

Use Φ10 @ 20 cm

As = 5.53cm2/m

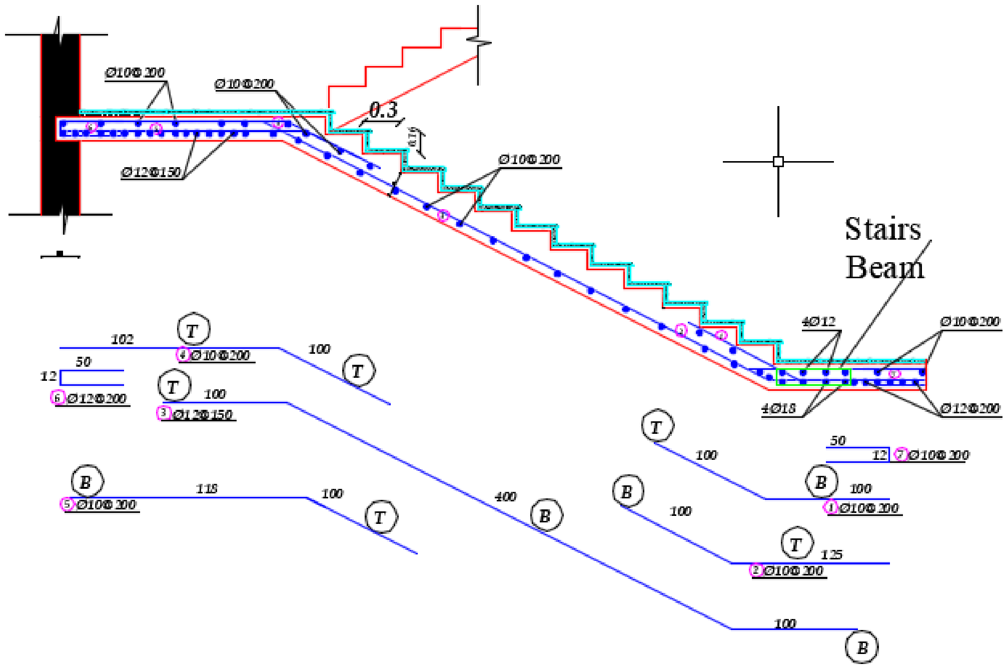


Figure14-17: Reinforcement for stairs.

4-11 Design of Basement Wall .

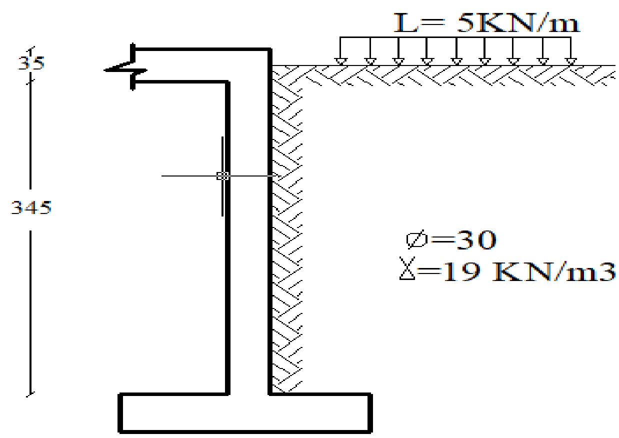


Figure 4-18: Geometry of basement.

Material:-

Concrete B350 Fc' = 28 N/mm^2

Reinforcement Steel fy = 420 Mpa

$\emptyset = 30° \quad \gamma = 19.00 KN/m^3$

- Soil at rest

$Ko = 1 - \sin \emptyset$

$= 1 - \sin 30$

$= 0.50$

Load on basement wall:

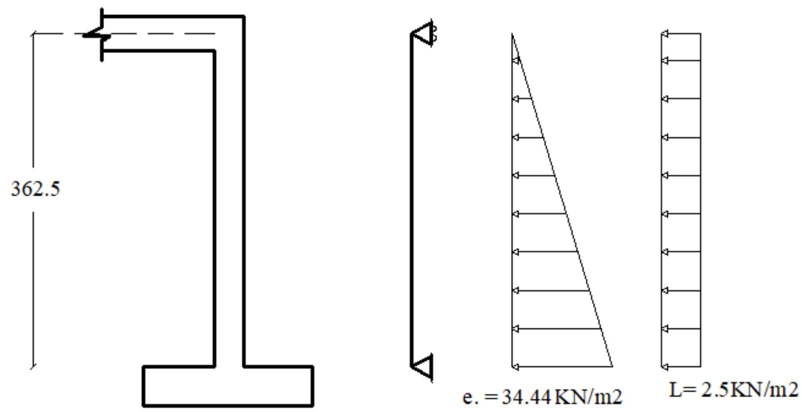


Figure 4-19: system and loads of basement.

For 1m length of wall:

- **Weight of backfill:**

$e = Ko * \gamma * h$

$= 0.50 \times 19.0 \times 3.625 = 34.44 KN/m$

$q_{1\ (Factored)} = 1.6 \times e$

$q_{1\ (Factored)} = 1.6 \times 34.44 = 55.1 KN/m$

- **Load from live load:**

LL=5 KN/m2

$q2 = Ko \times LL$

$= 0.50 * 5 = 2.50$ KN/m

$q_{2\ (Factored)} = 1.6 * 2.50 = 4.0$ KN/m

Design of the shear force:

- Assume Ø14 for main reinforcement.
- Assume h = 300 mm,

$d = 300 - 20 - 14 = 266$ mm

By using **ATIR** program, we get the envelope moment and shear force diagram

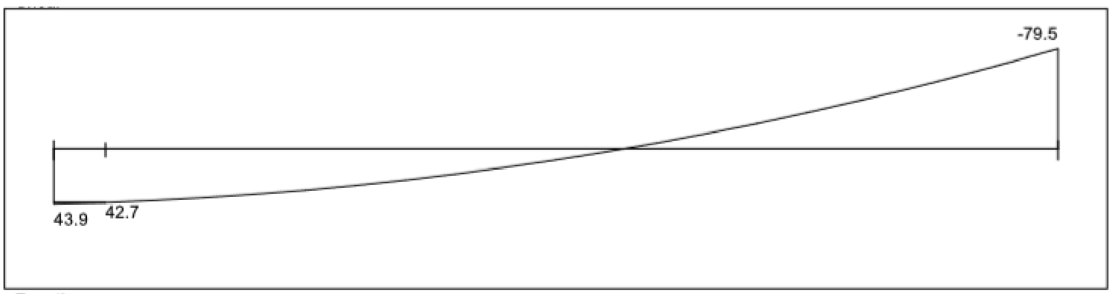


Figure 4-20 shear of basement.

Max Vu = 79.5 KN.

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

$$\phi Vc = \frac{0.75 \times \sqrt{24} \times 1000 \times 266}{6} = 162.9 KN$$

Vu = 79.5 KN < ϕVc = 162.9 KN.

No shear Reinforcement is required.

Design of bending moment:

By using **ATIR** program, we get the envelope moment and moment force diagram

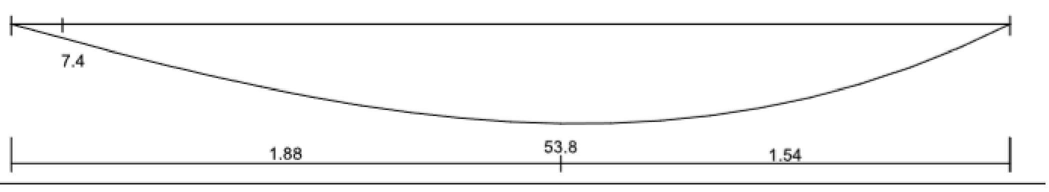


Figure 4-21 moment of basement.

Mu max =53.8 KN.m

$$\mathrm{Mn} = \frac{\mathrm{Mu}}{0.9} = \frac{53.8}{0.9} = 59.8\ \mathrm{KN.m}$$

$$\mathrm{Kn} = \frac{\mathrm{Mn} \times 10^6}{\mathrm{b} \times \mathrm{d}^2} = \frac{59.8 \times 10^6}{1000 \times 266^2} = .845\ \mathrm{Mpa}$$

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

$$\rho = \frac{1}{\mathrm{m}} \times \left(1 - \sqrt{1 - \frac{2 \times \mathrm{kn} \times \mathrm{m}}{\mathrm{Fy}}}\right)$$

$$= \frac{1}{20.60} \times \left(1 - \sqrt{1 - \frac{2 \times 0.845 \times 20.6}{420}}\right)$$

$$= 2.06 \times 10^{-3}$$

$$\mathrm{Asreq} = \rho \times \mathrm{b} \times \mathrm{d} = 2.06 \times 10^{-3} \times 1000 \times 266 = 5.4674\ \mathrm{cm}^2/\mathrm{m}$$

$$\mathrm{Asmin} = 0.0012 \times \mathrm{b} \times \mathrm{h} = 0.0012 \times 1000 \times 300 = 3.60\ \mathrm{cm}^2/\mathrm{m}$$

As_{min} = 3.60 cm^2/m $\leq As_{req}$ = 5.4674 cm^2/m

Use Φ 14@20cm

As provided =6.16 cm^2/m >As req =5.4674 cm^2/m.

Step(s) is the smallest of :

- 3h = 3*300 = 900mm .
- 450mm
- S= 380($\frac{280}{fs}$)- 2.5c_c = 380($\frac{280}{280}$)- 2.5*20 = 330mm .

S= 200mm < Smax

Select ∅14@20cm/m in one direction.

With as =6.16 cm^2/m

Select ∅10@20cm/m in the other direction.

With as =3.92 cm^2/m

Design of the horizontal reinforcement:

$$\mathrm{Asmin} = 0.0012 * \mathrm{b} * \mathrm{h} = 0.0012 * 1000 * 300 = 360\mathrm{cm}^2/\mathrm{m}$$

Select $\emptyset\mathbf{10@20cm/m}$, in two layer.

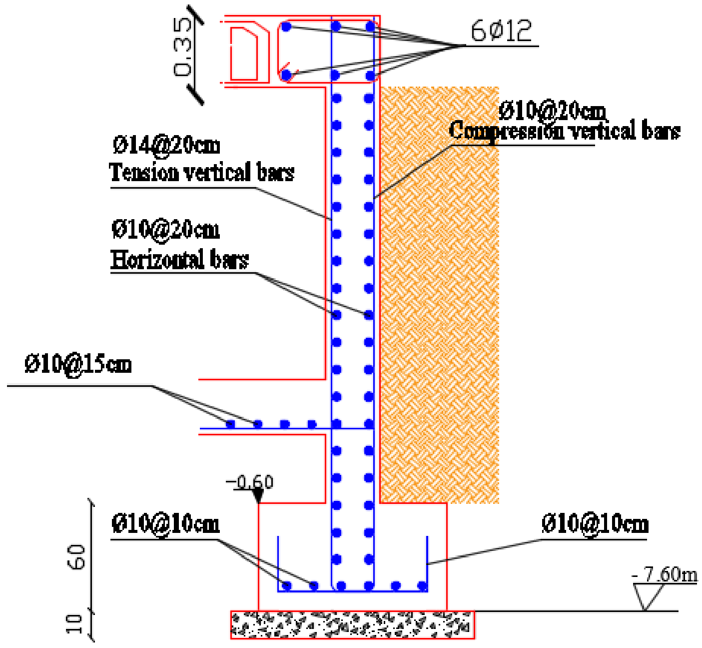


Figure 4-22: Reinforcement for basement wall.

4-12 Design of Shear Wall (SW1, F2).

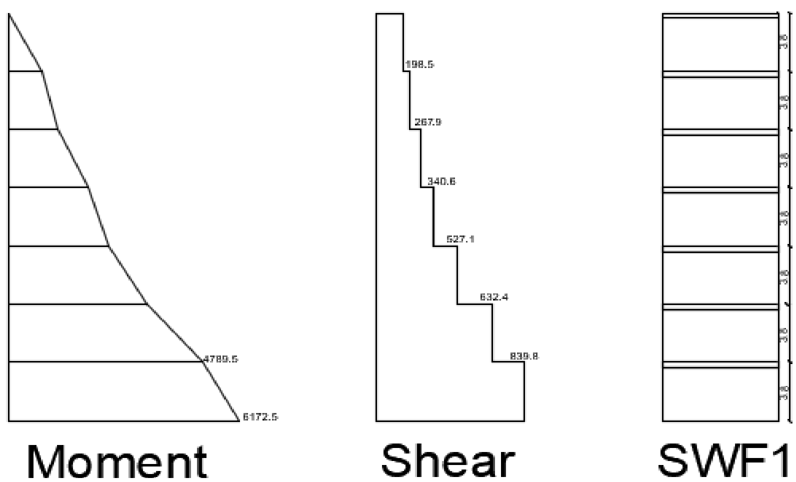


Figure 4-23: Moment and shear diagram for shear wall.

Material:-

Concrete B300 Fc' = 24 N/mm^2

Reinforcement Steel fy = 420 N/mm^2

h=30cm .shear wall thickness

Lw = 6.12m .shear wall width

Hw for one wall = 3.8 m story height

***Design of shear**

$$\sum Fx = Vu = 840KN$$

Design of the Horizontal reinforcement:

The critical Section is the smaller of:

$$\frac{lw}{2} = \frac{6.12}{2} = 3.06m \ldots\ldots \quad control$$

$$\frac{hw}{2} = \frac{26.6}{2} = 13.3m$$

$$storyheigh(Hw) = 3.8m$$

$$d = 0.8 \times lw = 0.8 \times 6.12 = 4.9m$$

Design as rectangular section:

d=4.9m, b=h=30cm

$$\emptyset V_{nmax} = \emptyset \frac{5}{6}\sqrt{f_c'}hd$$

$$= 0.75 \times 0.83 \times \sqrt{24} \times 300 \times 4900 \times 10^{-3} = 4482.93KN > V_u$$

V_c is the smallest of :

$$1 - V_c = \frac{1}{6}\sqrt{f_c'}hd = \frac{1}{6}\sqrt{24} \times 300 \times 4900 \times 10^{-3} = 1200.2KN$$

$$2 - V_c = 0.25\sqrt{f_c'}hd + \frac{N_u d}{4l_w} = 0.25\sqrt{24} \times 300 \times 4900 \times 10^{-3} + 0 = 1800.4KN$$

$$3 - V_c = \left[0.5\sqrt{f_c} + \frac{l_w\left(0.1\sqrt{f_c'} + 0.2\frac{N_u}{l_w h}\right)}{\frac{M_u}{V_u} - \frac{l_w}{2}}\right]\frac{hd}{10}$$

$$= \left[0.5\sqrt{24} + \frac{6.12\left(0.1\sqrt{24} + 0\right)}{3}\right]300 \times \frac{4900}{10} = 830.4KN \dots\dots cont$$

$$\frac{6172.5 - 4789.5}{3.8} = \frac{M_u - 4789.5}{3.8 - 3.06} \Longrightarrow M_u = 5058.8KN.m$$

$$\frac{M_u}{V_u} - \frac{l_w}{2} = \frac{5058.8}{840} - \frac{6.12}{2} = 3$$

Vu = 840KN>0.75*830.4 = 622.8KN. **'Horizontal reinforcement is required'**

$$\emptyset V_c + \emptyset V_s = V_u$$

$$V_s = \frac{V_u}{\emptyset} - V_c$$

$$V_s = 289.6$$

$$\frac{Avh}{s} = \frac{V_s}{fy \times d}$$

$$\frac{Avh}{s} = \frac{289.6 * 10^{\wedge}3}{420 \times 4900} = 0.14$$

$(\frac{Avh}{s})\boldsymbol{min} = 0.0025 \times h = 0.0025 \times 300 = 0.75 > 0.14 \dots cont$

Maximum spacing is the least of:

$\frac{lw}{5} = \frac{6120}{5}$ = 1224mm

3×h = 3×300 = 900mm

450 mm ……. Control

Try ϕ12 (As = 113.09 mm2) for two layers

$$\rho = \frac{Avh}{h*S2} = \frac{2*113.09}{S2} = 0.75$$

S2 = 301.57 mm , select ϕ12@250 mm

→useϕ12@250 mm in two layer

Design of uniform Vertical reinforcement:-

$\frac{h_w}{L_w} = \frac{26.6}{6.12} = 4.3$

$\rho_{vmin} > 0.0025 + 0.5\left(2.5 - \frac{h_w}{l}\right)(\rho_t - 0.0025) > 0.0025$

For this wall with $\frac{hw}{lw}$ = 4.3 > 2.5

$\frac{Avv}{sv} = 0.0025 + 0.5\left(2.5 - \frac{h_w}{l}\right)\left(\frac{Avh}{s \times h} - 0.0025\right) \times h$

$\frac{Avv}{sv}$ = 0.82

Select Φ 12@200mm. In two layer

-Maximum spacing is the least of :

$\frac{lw}{5} = \frac{6120}{5}$ = 1224mm

3×h = 3×300 = 900mm

450 mm ……. Control

Select Φ 12@200mm In tow layer

Design of bending moment (vertical steel in boundary) :

$A_{sv} = \left(\frac{6120}{200}\right) \times 226.2 = 6921.72mm^2$

$w = \left(\frac{A_{st}}{L_w h}\right)\frac{f_y}{f_c'} = \left(\frac{6921.72}{6120 * 300}\right)\frac{420}{24} = 0.066$

$\alpha = \frac{P_u}{l_w h f_c'} = 0$

$\frac{C}{l_w} = \frac{w + \alpha}{2w + 0.85\beta_1} = \frac{0.066 + 0}{2 \times 0.066 + 0.85 \times 0.85} = 0.077$

$\emptyset M_n = \emptyset\left[0.5 A_{sv} f_y l_w (1 + \frac{P_u}{A_{st} f_y})(1 - \frac{c}{l_w})\right]$

$= 0.9[0.5 \times 6921.72 \times 420 \times 6120(1 + 0)(1 - 0.077)] = 7389.7KN.m > Mu.$

Select Φ 12@200mm for vertical reinforcement.

4-13 Column Coordinates.

Column NO.	X-AXIS	Y-AXIS
C1	33.23	48.48
C2	26.54	48.48
C3	21.2	48.48
C4	51.73	43.95
C5	45.97	43.95
C6	40	43.95
C7	33.23	43.95
C8	25.94	43.95
C9	20.37	43.95
C10	16.7	43.95
C11	51.73	39.67
C12	45.97	39.67
C13	40	39.67
C14	33.38	39.67
C15	26.54	39.67
C16	20.37	40.13
C17	13.4	40.9
C18	51.73	30
C19	45.97	34.2
C20	40	34.2
C21	34.45	34.2
C22	27.15	34.2
C23	20.37	34.13
C24	17.38	36.38
C25	23.5	30.8
C26	51.73	25.72
C27	45.97	27.43

C28	**40**	**27.43**
C29	**34.45**	**27.43**
C30	**27.15**	**27.43**
C31	**30.32**	**24**
C32	**51.86**	**20.39**
C33	**45.97**	**20.39**
C34	**40**	**20.39**
C35	**33.76**	**20.6**
C36	**33.38**	**20.2**
C37	**29.95**	**23.63**
C38	**26.54**	**27**
C39	**23.11**	**30.47**
C40	**19.84**	**33.6**
C41	**17.1**	**36.5**
C42	**12.97**	**40.46**
C43	**9.16**	**36.5**
C44	**6.63**	**33.95**
C45	**2.1**	**29.56**
C46	**12.97**	**32.5**
C47	**10.34**	**30**
C48	**6.03**	**25.4**
C49	**8.62**	**22.55**
C50	**4.5**	**18.52**
C51	**0.44**	**13.98**
C52	**13.4**	**17.97**
C53	**9.16**	**13.74**
C54	**4.5**	**9.22**
C55	**7.72**	**6.46**
C56	**10.34**	**3.82**
C57	**14.64**	**8.27**

C58	**18.88**	**12.5**
C59	**23.5**	**17.11**
C60	**25.94**	**19.6**
C61	**29.59**	**15.94**
C62	**33.23**	**12.1**
C63	**27.15**	**13.43**
C64	**22.57**	**8.81**
C65	**18.33**	**4.58**
C66	**13.95**	**0.46**
C67	**74.4**	**4.58**
C68	**69.1**	**4.58**
C69	**63.5**	**4.58**
C70	**57.5**	**4.58**
C71	**52.33**	**4.58**
C72	**52.28**	**10.87**
C73	**57.5**	**10.87**
C74	**63.5**	**10.87**
C75	**69.1**	**10.87**
C76	**73.96**	**10.87**
C77	**74.4**	**15.97**
C78	**69.27**	**15.97**
C79	**63.5**	**15.97**
C80	**57.5**	**15.97**
C81	**52.33**	**20.39**
C82	**57.5**	**20.39**
C83	**60.45**	**20.39**
C84	**63.5**	**20.39**
C85	**69.1**	**20.39**
C86	**73.96**	**20.39**
C87	**74.4**	**25.72**

C88	**70.51**	**25.72**
C89	**66.2**	**25.72**
C90	**61.8**	**25.72**
C91	**57.5**	**25.72**
C92	**52.33**	**25.72**
C93	**61.95**	**30**
C94	**58.23**	**33.8**
C95	**55.95**	**36**
C96	**52.28**	**39.67**
C97	**52.28**	**30**
C98	**70.51**	**30.23**
C99	**66.55**	**34.32**
C100	**62.6**	**38.16**
C101	**59.69**	**40.9**
C102	**56.7**	**43.95**
C103	**52.18**	**43.95**
C104	**52.18**	**48.48**
C105	**52.28**	**52.24**
C106	**56.5**	**52.24**
C107	**60.96**	**47.96**
C108	**63.64**	**45**
C109	**66.55**	**42.1**
C110	**70.27**	**38.38**
C111	**74.56**	**30.8**
C112	**73.96**	**34.32**
C113	**73.96**	**42.6**
C114	**70.76**	**46.3**
C115	**67.84**	**49.32**
C116	**64.9**	**52.24**
C117	**64.9**	**52.24**

C118	**69.65**	**52.24**
C119	**74.56**	**47.34**
C120	**69.65**	**56.91**
C121	**73.96**	**60.89**
C122	**76.57**	**57.95**
C123	**97.52**	**55.1**
C124	**83.2**	**51.32**
C125	**87.41**	**47.18**
C126	**83.43**	**43.13**
C127	**78.67**	**38.38**
C128	**79.22**	**47.34**
C129	**75.85**	**51**
C130	**51.73**	**34.32**
C131	**52.18**	**34.32**

Table 4-5: Column coordinates.

Chapter V

Results and recommendations

Contents:

5-1 Results

Through this research, and after analyse each part of the project, the results we got can be summarized as:

1- study the architectural plans and understand them have a major role in finding the most appropriate solutions to find the best type of construction system used in the building.

2- The ability to do manual calculation for the elements is necessary to create a good structural designer and to compare the manual solutions with the structural programs results and understand how they work.

3- Identify the structural elements, and how to deal with it, with its mechanism, and it is very important to design it taking into consideration safety and structural strength.

5-2 Recommendations:

1- There should be coordination between the architect and the structural designer during the design process to build an integrated building structurally and architecturally.

2- Recommends executing the project according to the architectural plans attached with the least changes.

3- It is advised to have a structural engineer in the project site to insure executing the work according to the required structural drawings.

4-it is essential to complete the electrical and mechanical design of the project before the start of any editing on it according to the final structural design of the project.

5-3 References:

1- Jordan's national building codes, coded loads and forces, the National Building Council
Jordan, Amman, Jordan, 1990.
2- Supervising professor notes.
3- ACI Committee 318 (2008), ACI 318-08: Building Code Requirements for Structural Concrete and Commentary, American Concrete Institute, ISBN 0-87031-264.

4- Nawy, Edward, Prestressed Concrete Fifth Edition Upgrade: ACI, AASHTO, IBC Codes
Version (5th Edition), 2009.

5-4 Appendix:

1-Appendix (A): Architectural Drawings"this appendix is an attachment with this project".

2.Appendix (B): Structural Drawings "this appendix is an attachment with this project".

3.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	**ℓ/20**	**ℓ/24**	**ℓ/28**	**ℓ/10**
Beams or ribbed one-way slabs	**ℓ/16**	**ℓ/18.5**	**ℓ/21**	**ℓ/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 ($0.4 + f_y/700$).

Figure 5-1: Minimum thickness of nonprestressed beams or one way slabs unless deflections are calculated.