Palestine Polytechnic University
College of Engineering
Civil Engineering Department

Graduation Project

"STRUCTURAL DESIGN OF TOURIST SPA CENTER"

Project Team

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Supervisor:

Dr. Nafeth Nasereddin

This project is going to be submitted to the College of Engineering in partial fulfillment of requirements of the Bachelor degree in Civil Engineering

Hebron - Palestine

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The undersigned hereby certify that they have read, examined, and recommended to the Department of Civil Engineering in the College of Engineering at Palestine Polytechnic University the approval of a project entitled: **Structural Design of a Tourist Spa Center,** submitted by Raneen Emad Saafin and Rahma Yousef Qawasmi for partial fulfillment of the requirements for the bachelor's degree.

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DEDICATION

To those who have always believed in us …

To those who have been our source of inspiration …

To those who gave us strength …

To those who provide us their endless support and encouragement …

To our families …

Project Team

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First of all, we would like to thank everyone who helped, supported, and encouraged us:

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Project Team

Structural Design of a Tourist Spa Center

Supervisor: Dr. Nafeth Nasereddin

Project Team: Raneen Emad Saafin & Rahma Yousef Qawasmi

ABSTRACT

This project aims to apply the theoretical knowledge that has been acquired during the years of study through making a complete analysis and design of a 3-story spa center with an estimated total area of 3230 m^2.

Generally, structural design is divided into three phases, planning, design, and construction, and in this project, we will take the theoretical aspects i.e., planning and design.

1. Planning involves consideration of the various requirements and factors affecting the general layout and dimensions of the structure and results in the choice of one or perhaps several alternative types of structure, which offer the best general solution.

2. Design involves a detailed consideration of the alternative solutions defined in the planning phase and results in the determination of the most suitable proportions, dimensions, and details of the structural elements and constructing each alternative structural arrangement being considered.

In this regard, the architectural plans of the building are studied. Then structural planning of the building is done, in which the location of columns and beams are determined to fit with the architectural plans. A detailed structural study also is carried out to estimate loads that act on each member using the Jordanian code for gravity loads estimation and (ASCE7-16) code for the definition of lateral seismic loads. Analysis and design then were done following ACI 318-14 Building code based on the ultimate strength method for concrete design and working stress method for soil design. Finally, structural working drawings were prepared to present the reinforcement details of all members.

التصميم الانشائي لمركز علاجي سياحي

فريق العمل: رنين عماد السعافين ورحمة يوسف قواسمي

إشراف: د. نافذ ناصر الدين

الملخص

يهدف المشروع الى عمل تصميم انشائي لجميع العناصر الانشائية المكونة لمركز علاجي سياحي مكون من 3 طوابق تقدر مساحتها الاجمالية بـ 3230 $م^2$. وذلك لما للتصميم الانشائي من اهمية فهو من اهم المراحل التي يمر بها المبنى والتي يتم فيها تحديد اماكن الاعمدة والانظمة الانشائية لمختلف عناصر المبنى وبذلك يتم تحويل المخططات المعمارية الأولية إلى مخططات قابلة للتنفيذ.

بشكل عام، التصميم الإنشائي يشمل ثلاثة مراحل، التخطيط، والتصميم، والبناء، وفي هذا المشروع سوف نتطرق للجوانب النظرية ألا وهي التخطيط والتصميم.

1. التخطيط، ويتضمن النظر في المتطلبات والعوامل المختلفة التي تؤثر على التخطيط العام وأبعاد المبنى، والحل الإنشائي الأفضل حسب نوع المبنى.
2. التصميم الإنشائي، ويشمل دراسة تفصيلية للحلول البديلة المحددة في مرحلة التخطيط، وتحديد النسب والأبعاد والتفاصيل المناسبة للعناصر الإنشائية، وكذلك يؤخذ بعين الاعتبار البدائل الإنشائية.

وتحقيقا لهدف المشروع تم في البداية دراسة المخططات المعمارية واختيار انسب الية لتوزيع العناصر الانشائية بما لا يتعارض مع التصميم المعماري للمبنى، ثم تم عمل دراسة انشائية مفصلة تم فيها تقدير الاحمال المتوقعة على جميع العناصر الانشائية بالاعتماد على الكود الاردني والكود الامريكي ASCE-16 لتقدير احمال الزلازل. بعد ذلك تم تحليل وتصميم جميع تلك العناصر بالاعتماد على الكود الامريكي ACI318-14 وباستخدام مجموعة من البرامج الهندسية. وفي النهاية تم إعداد المخططات التنفيذية لجميع العناصر الانشائية المكونة لهيكل المبنى ليصبح المبنى قابلاً للتنفيذ.

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As	Area Of Non-Prestressed Tension Reinforcement.
As′	Area Of Non-Prestressed Compression 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.
d	Distance From Extreme Compression Fiber To Centroid Of Tension Reinforcement.
Ec	Modulus Of Elasticity Of Concrete.
fy	Specified Yield Strength Of Non-Prestressed Reinforcement.

h	Overall Thickness Of Member.
I	Moment Of Inertia Of Section Resisting Externally Applied Factored Loads.
ln	Length Of Clear Span , Measured Face-To-Face Of Supports In Slabs Without Beams And Face To Face Of Beam Or Other Supports In Other Cases.
M	Bending Moment.
Mu	Factored Moment At Section.
Mn	Nominal Moment.
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.
ρ	Ratio Of Steel Area.
εc	Compression Strain Of Concrete=0.003mm /Mm
Fsd,r	Total Additional Tension Force Above The Support.
Ved,0	Shear Force At Critical Section.
Vu	Factored Shear Force At Section.
Wu	Factored Load Per Unit Length.
Φ	Strength Reduction Factor.

CHAPTER 1

INTRODUCTION

1.1. General Background
1.2. Project Problem
1.3. Project Objectives
1.4. Work Procedure
1.5. Project Scope
1.6. Project Timeline
1.7. Programs Used in The Project

1.1 Background

Any building is supported by a framed arrangement known as Structure which is a system formed from the interconnection between structural members. The structural design requires an intelligent manner in making decisions regarding the systems of different structural elements and that cannot be achieved by an understanding of basic concepts of structures only. Rather, that understanding must be applied through practice.

From this point of view, a spa center was chosen to be designed. The building was designed by applying the acquired knowledge in the design of different structural elements to provide a safe design that achieves the required engineering specifications and standards.

Since the project that was chosen is a tourist resort that contains architectural spaces and large swimming pools, it must be kept empty of columns in the middle of the architectural spaces and swimming pools as much as possible. Therefore, the most important initial structural decisions that have been taken and on which the project depends mainly are:

1. A design of the slab above the swimming pools (Ribbed Slab) with drop beams.
2. We need to use a construction joint between the bridge and the two blocks.

1.2 Problem Statement

Structural design is the methodical investigation of the stability, strength, and rigidity of structures. The basic objective in structural analysis and design is to produce a structure capable of resisting all applied loads without failure during its intended life. The primary purpose of a structure is to transmit or support loads. If the structure is improperly designed or fabricated, or if the actual applied loads exceed the design specifications, the device will probably fail to perform its intended function, with possible serious consequences. A well-engineered structure greatly minimizes the possibility of costly failures.

As a result of the variety of construction systems and the need of making a balance between costs and safety in the design, it was necessary to find the most appropriate structural system that satisfies the strength and serviceability requirements for the chosen tourist resort.

1.3 Aims and Objectives

We aim to propose a constructional system capable of supporting the structure of a tourist resort, a 3-story building (basement, ground, and first floors), with an estimated total area of 3230 m^2.

To achieve the aim, there are several objectives we need to follow:

- An architectural study of the project, including a brief description of the architectural spaces, and the purpose of each space.
- The structural planning of the project, selecting the suitable system which obtains the structural stability and strength while maintaining the architectural aspect.
- In the structural study, after connecting the structural elements, loads transferred will also be estimated.
- Structural design, where we analyze the loads on structural elements and set the dimensions of each element.

- Preparing the structural drawings, including all plans and detailed drawings for each element.

1.4 Literature review

Hamad (2017), Sudan University of Science and Technology had designed a water life resort (in Port Sudan), it is a water sports and entertainment tourism resort project that aims to attract tourists from Inside and outside the city of Port Sudan. It provides the finest services to meet the tourism requirements, residential, commercial, health, sports, and water entertainment using modern methods new mainly depend on the element of water. It highlights the importance of the Red Sea and the extent of its abundance, it contains marine and natural treasures and hidden and unknown secrets in the depths of the sea.

In this project, the flooring system consists of concrete slabs from marinetek concrete house type pontoons which are concrete slabs vacuum filled with EPS material, which is one of the compounds Polyurethane that allows these concrete slabs to float above the surface of the water with the use of an insulator for the water of a special foam type and wood shell as a finishing layer for the corridors as well as Wooden floor in the interior spaces of treated oak wood. A Finnish company manufactures and imports this type of tiles.

On another hand, the rest of the structural structure of the building in this project consists of prefabricated fittings, which are the parts that are manufactured in the factory and transported by ships, and installed on-site by cranes .The cause of the design of buildings from the steel structure pre-installed to the need for light buildings, the weight is attached to the structure that is floating on surface water.

And since our project is also a tourist resort project that contains two swimming pools, this project is a good example to follow. By looking at the previous project, we can notice the basic structural differences between this project and ours:

1. Since the previous project depends on slabs from marinetek concrete house type pontoons, but we depend on ribbed slabs (one-way) .
2. The previous project depends on prefabricated fittings, which are the parts are manufactured in the factory and transported to the site. On another hand, we depend on the casting of structural elements on site.

Zaro (2013), Palestine Polytechnic University had designed the Arab Evangelical School, a five-story school building, it combines the different departments of education and also has a special aspect focused on sports including a gym, swimming pool, and changing rooms for each of them. It contains teaching rooms for the educational process, in addition to the presence of a special section for kindergarten, the music room, and the corridors connecting them, and also characterized the presence of the mechanical department for maintenance and fire services, and the water tank located on the first basement floor.

Some classrooms had spans larger than eight meters and required no columns interrupting the space of the room, two-way ribbed slabs were designed to hold those spaces.

Those slabs were connected horizontally by T-section beams, making the beams thicker than the slab, which means drop beams were designed to connect the two-way ribbed slabs, due to the higher loads they carry.

In our project, ribbed slabs are also required for a span above the swimming pool, a large span with no columns interrupting, which put this project up as a suitable model to follow. But there are some basic structural differences between this project and ours:

1. Some large spans in this project were covered with two-way ribbed slabs, those spans were required to have no columns interrupting, while in our project, one-way ribbed slabs are sufficient to play the role of the two-way, but drop beams are required in some places.

2. This project included two steel structures, one for the playground, and the for the swimming pool, otherwise, we do not have a steel structure to design, and the swimming pools are in the basement of the building.

1.5 Methodology

To achieve the objectives of the project following steps were followed:

1. Architectural study in which the site, building plans, and elevations were been studied.
2. Structural planning of the building, in which the location of columns, beams, and shear walls was determined to fit with architectural design.
3. Structural study in which all structural members were identified and different loads were been estimated.

4. A complete analysis and design for all elements were done according to the ACI Code.
5. Preparation of Structural drawings of all existing elements in the building.
6. Project Writing in which all these stages were presented in detail.

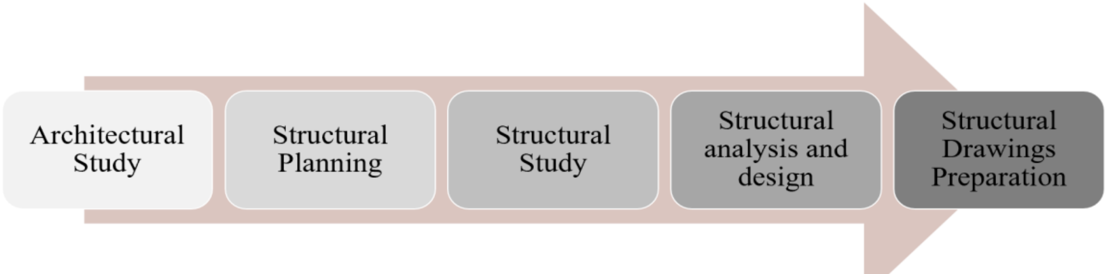


Figure 1.1 : Work Procedure

1.6 Project Scope

This Project contains the following Chapters:

CHAPTER 1: A general introduction, pointing out the idea and aim of the project, also the steps we intend to follow to achieve that aim.

CHAPTER 2: An architectural description of the project, defines the concept of the architectural design, along with the architectural plans, elevations, and sections of the project.

CHAPTER 3: A general description of the structural elements, clarifying each type of structural element we intend to use in the design of the structural system, including its functional role in the structure.

CHAPTER 4: Structural analysis and design of all structural elements, where the loads supposed to exist on the constructed system are analyzed into the structural elements, then these elements are designed to carry the loads transmitted into them.

CHAPTER 5: Results and Recommendations, determine whether our system was capable of achieving the aim we set at the beginning of the project.

1.7 Project Timeline

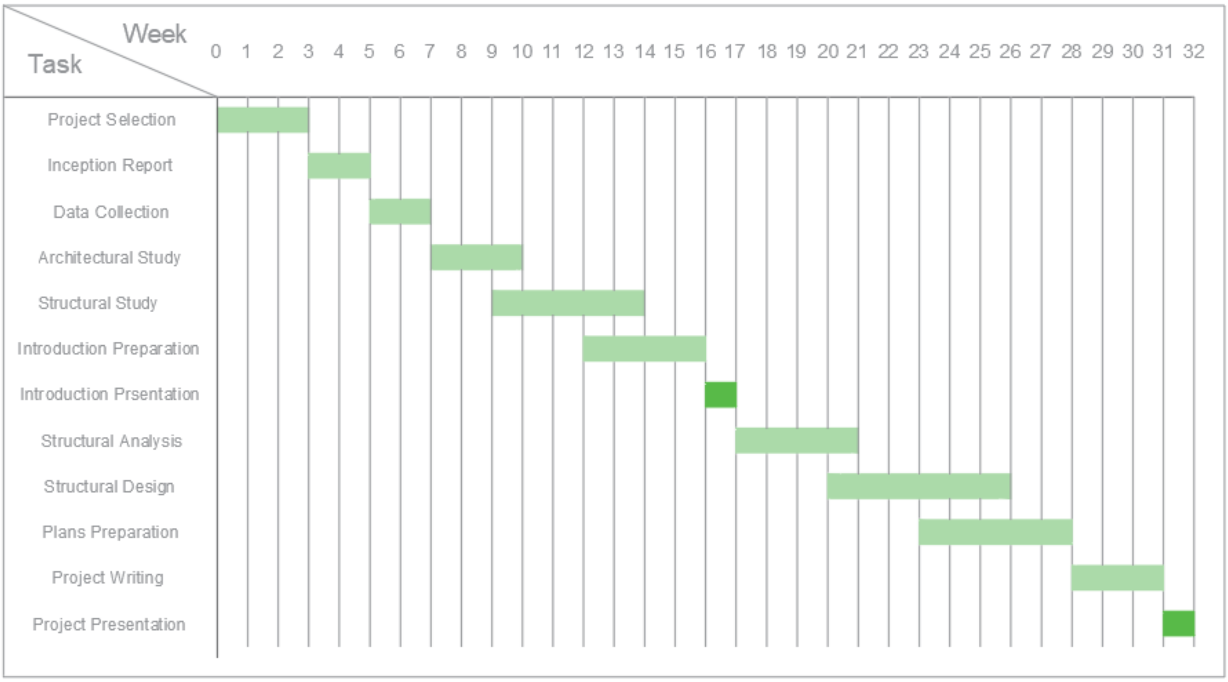
The following chart shows the project plan and timeline:

1.8 Programs used in the project

There are several computer programs used in this project:

1. Microsoft Office: It was used in various parts of the project such as text writing, formatting, and project output.
2. AUTOCAD 2016: for detailed drawings of structural elements.
3. ATIR18: Structural design and analysis of structural elements.
4. SP Column: design of columns.
5. Etabs18: design and analysis of structural elements especially for walls.
6. Safe16: design of neighbor and matt foundation.

Figure 1.2 : Project Timeline



CHAPTER 2

ARCHITECTURAL DESCRIPTION

2.1. Introduction
2.2. General Identification of the Project
2.3. General Site Description
2.4. Floors Description
2.5. Elevations Description
2.6. Sections of the Building

2.1 Introduction

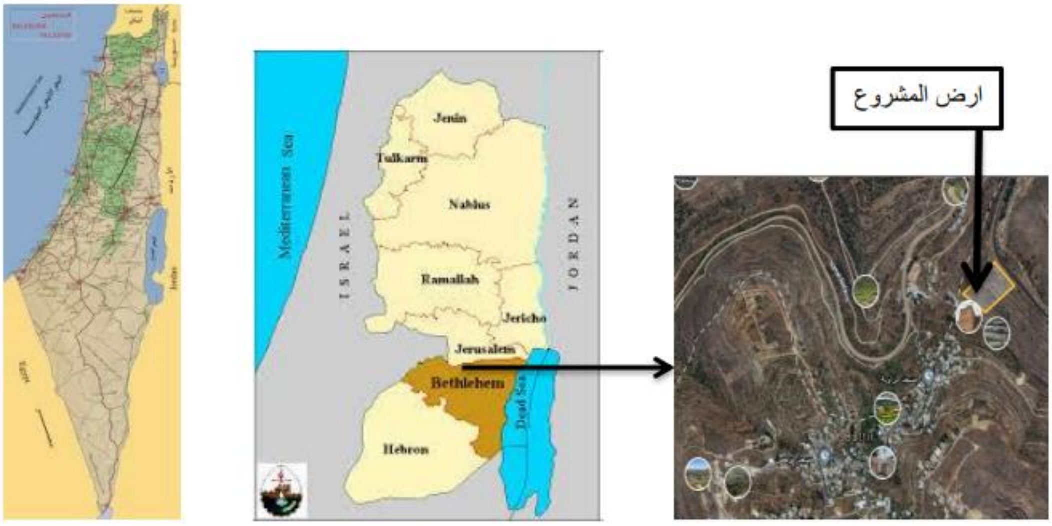
Building any structure is an integrative process between several engineering specializations and the design process for any building takes place through several stages until it is fully accomplished.

Starting first with the architectural design stage, at this stage, the shape of the structure is determined and take into account the inquiry of the various functions and requirements for which you will create this building, here the initial distribution of the facilities is made, to achieve the required spaces and dimensions, and in this process, lighting, ventilation, movement, mobility, and other functional requirements are also studied.

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

2.2 General Identification of the Project

The proposed project is a tourist resort consists of two buildings with a bridge in between, each building is composed of three floors, one basement, ground floor and first floor, the basement of each building has a swimming pool, spa treatment rooms, the ground floor of each building is centered by an indoor unroofed garden, surrounded by seating areas, and the offices of the employees, first floor plan is almost the same as the ground except for the sauna room which is not existed in the first floor.



The building is proposed to be built on a land with the area of twenty dunam , the spa is not the only structure on the area, other facilities including a hotel, a restaurant, a multi-use hall, a mosque, also we have the administration building, and an external parking area.

2.3 General Site Description

The project is located in the village of Bater west of the Palestinian city of Bethlehem, it is in the wooded area of the village, with a look out on the terraced agriculture of the area, also on a railway was built in the Ottoman era used for transporting between Jerusalem and Jaffa.

Figure 2. 1: Site Location

2.4 Floors Description

The project consists of three types of floors: Basement, Ground, and First floors. With a total area of 3230 square meters. Each floor has two separated masses, except for the second floor, which has a bridge connecting the two masses. The following is a brief description of each floor:

1. BASEMENT FLOOR

The basement floor level is 3.90 m below the level of Main Street with a total floor area of 1011m^2. This floor contains two indoor swimming pools in the center of each building, changing rooms and rest rooms, spa rooms, a sauna, also there are also seating areas.

The entrance to the basement is from the staircase in each building, the eastern building has the staircase in the southern side, while the western one has the staircase in the northen side.

Figure 2.2: Basement Floor Furniture Plan

2. GROUND FLOOR

The center of each building is an open-roof indoor garden with glass panels covering all round the area, this garden is surrounded by seating areas, employees' offices, a gym, a sauna, changing rooms rest rooms, and the reception area, with a total floor area of 1080 m^2.

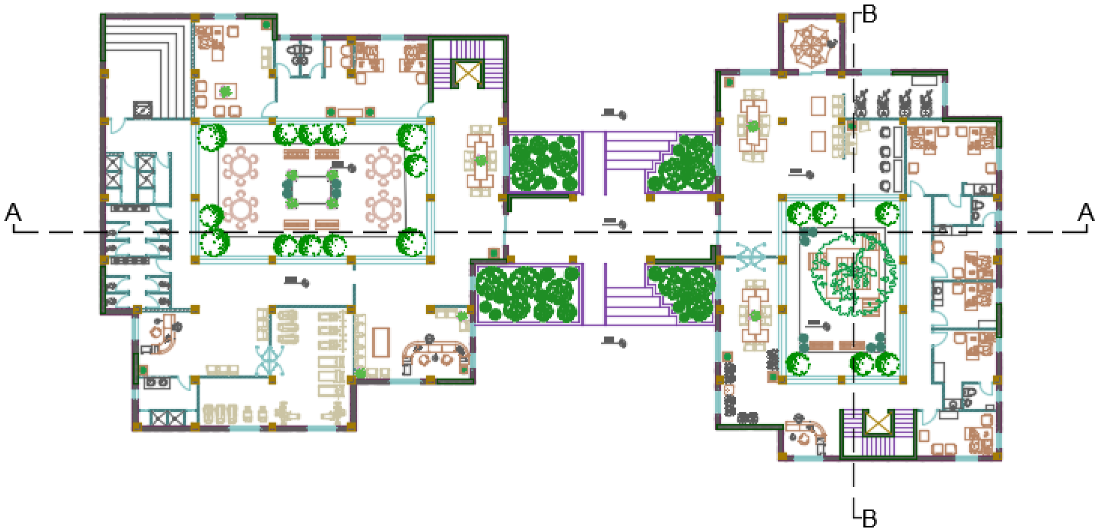


Figure 2.3: Ground Floor Furniture Plan

3. FIRST FLOOR

It is similar to the ground floor, the indoor garden in the ground floor is also unroofed in the first floor. And there's a 13 meters long bridge connecting the two masses of the first floor, with a total area of 1140 m^2.

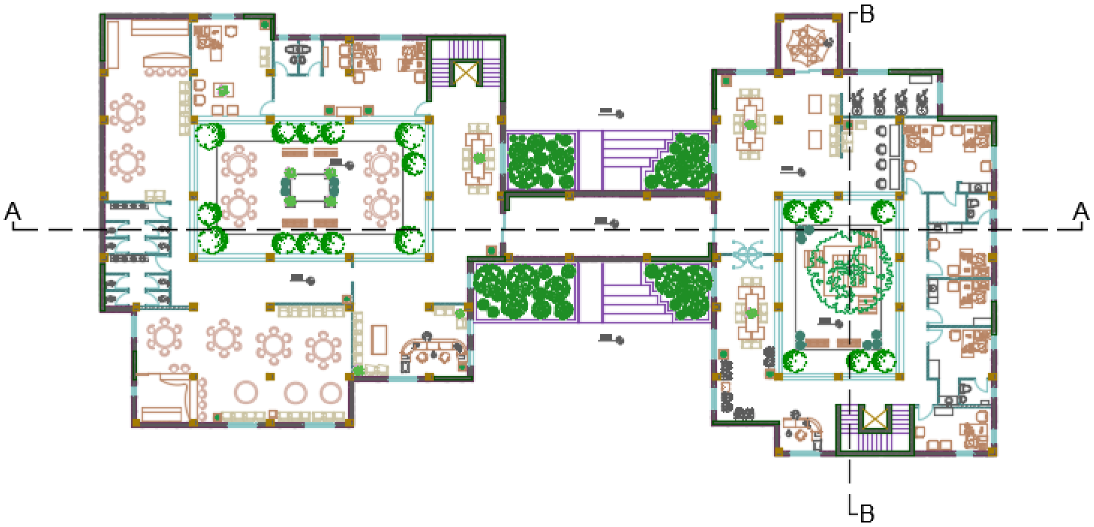


Figure 2.4: First Floor Furniture Plan

4. MOVEMENT AREAS

This building contains the external stairs directing into the building, two staircases and two elevators. The stairs are close to the entrance of the building in the ground floor, which makes it easier for the attenders of the resort to transport between floors.

2.5 Elevations Description

2.5.1 NORTHERN ELEVATION

It’s the main elevation of the building, leads to the two main entrances of the two buildings of the center. They are both separated by an open walkway along the bridge. This elevation is characterized by its glass that is integrated with stones.

2.5.2 SOUTHERN ELEVATION

This elevation of the building is leading to the other parts of the resort, it also leads to the two main

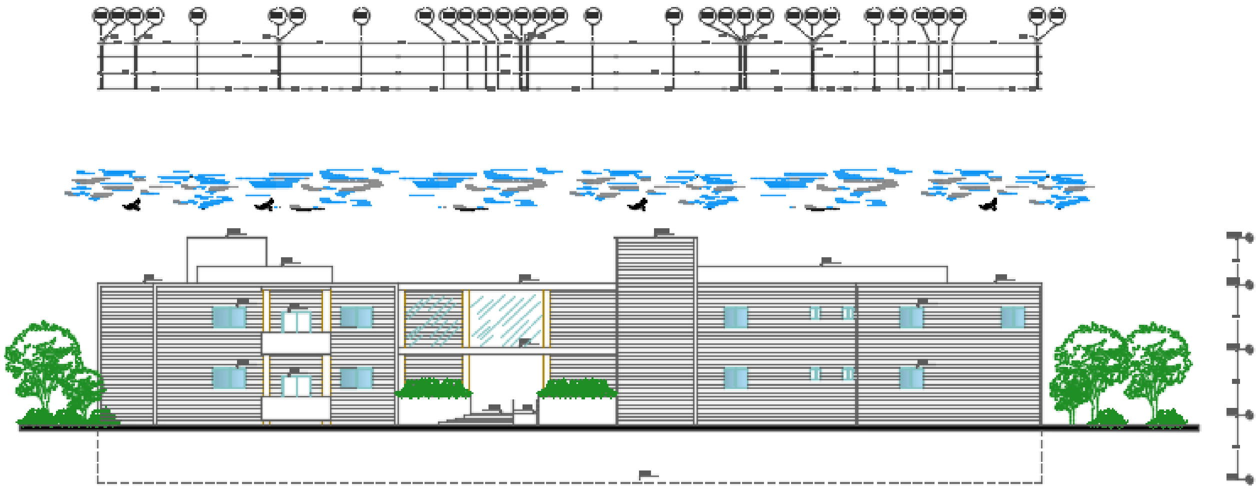
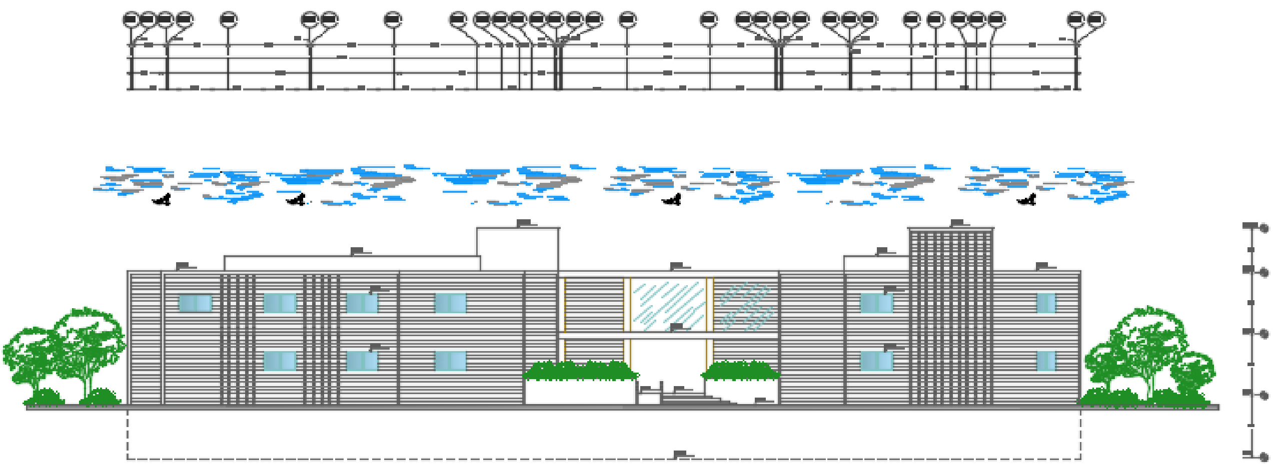


Figure 2.6: Southern Elevation

entrances to the two buildings. This elevation is also characterized by its glass that is integrated with stones.

2.5.3 EASTERN ELEVATION

This elevation is characterized by its glass and prominent colored stones that give the aesthetic



appearance and architectural beauty that reflects the luster of the building.

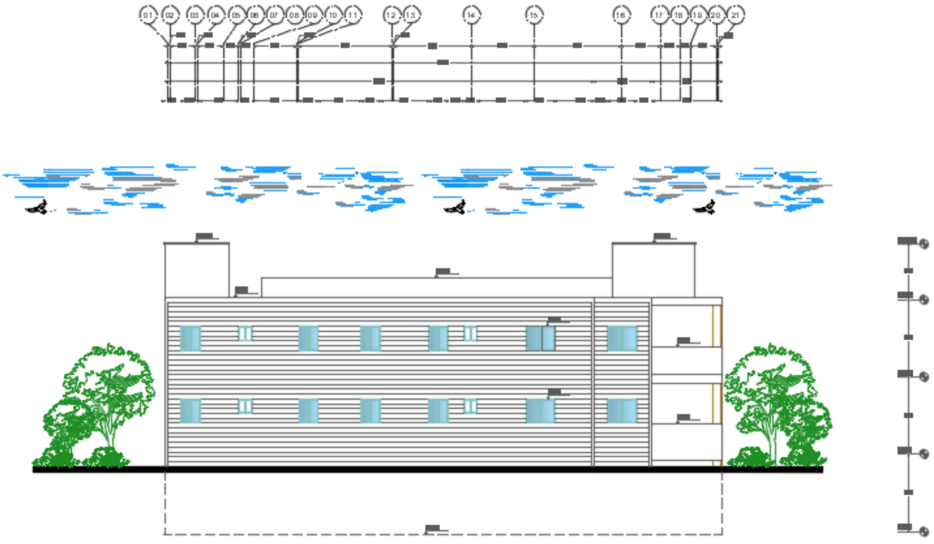


Figure 2.7: Eastern Elevation

2.5.4 WESTERN ELEVATION

This elevation of the building is on most likely the back elevation, it is on the side of the rest rooms. Ad this elevation is characterized by stone.

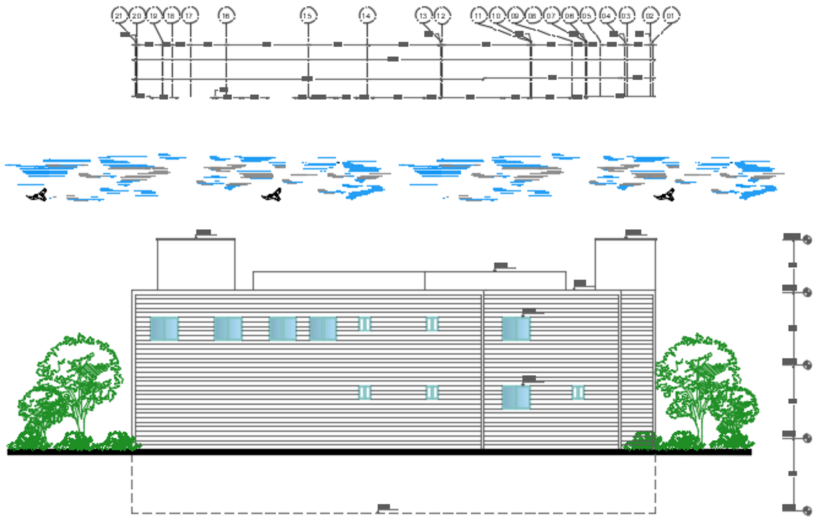


Figure 2.8: Western Elevation

2.6 Sections of the Building

These sections explain the movement inside the building through the stairs and elevator. It also shows more details for the heights and levels for slabs, windows, and doors.

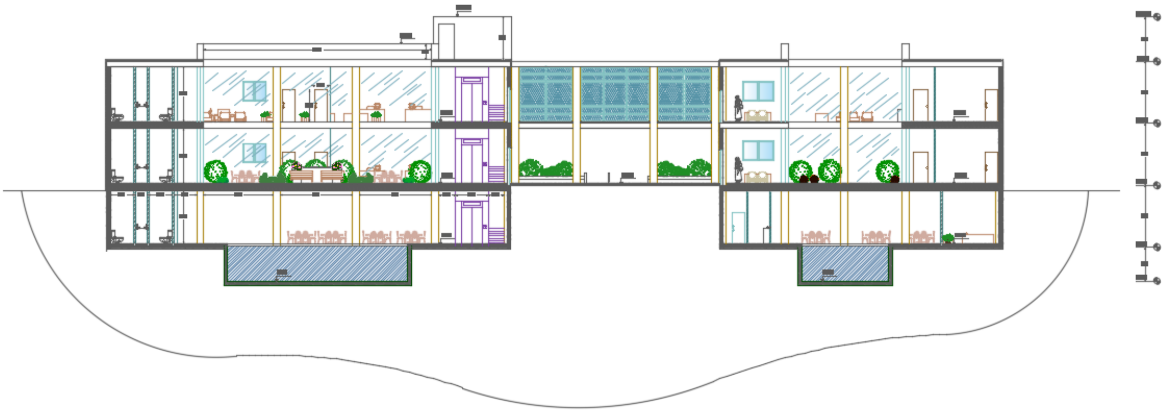


Figure 2.9: Section A-A

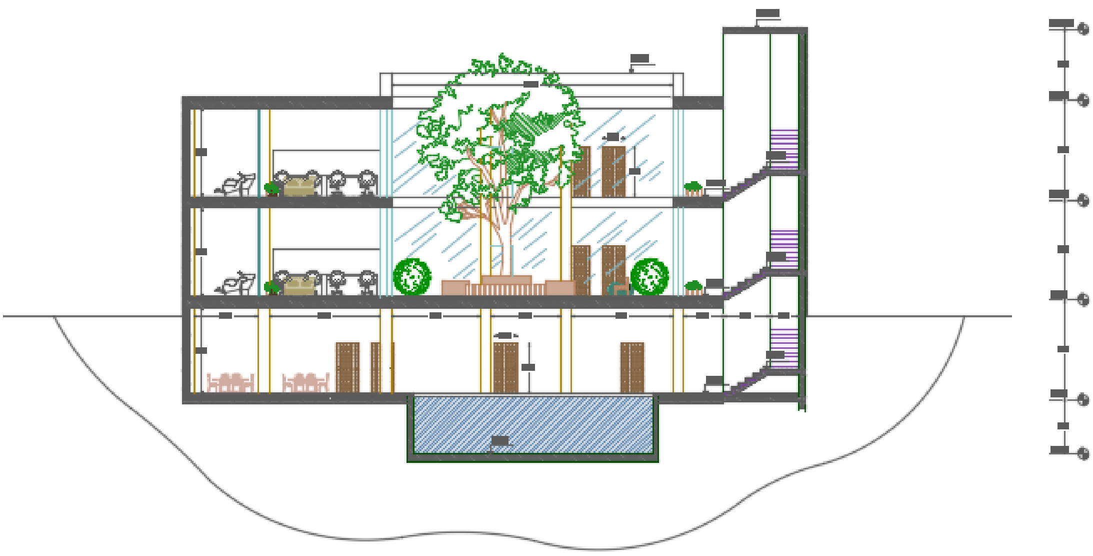


Figure 2.10: Section B-B

CHAPTER 3

STRUCTURAL DESCRIPTION

3.1 Introduction
3.2 The Aim of the Structural Design
3.3 Scientific Tests
3.4 Loads Acting on the Building
3.5 Structural Elements of the Building

3.1 Introduction

After completion of the architectural study of the building, A study of the structural elements was done to determine the optimal structural system for the building to make the best design of all structural elements.

The knowledge of structural elements of any project is essential in the design of reinforced concrete structures. In this chapter, a study of the different structural elements such as columns, beams, foundations, and other elements was conducted. Also, different loads were estimated in accordance with the requirements, standards, and standard specifications that will be mentioned later.

3.2 The Aim of the Structural Design

The main purpose of structural design is to make a safe, economic, and serviceable design, so in designing a structure the following objectives must be taken into consideration:

1- **Safety**: The structure should be able to carry all expected loads safely, without failure, that is, without breaking or collapsing under the loads.

2- **Durability:** The structure should last for a reasonable period of time.

3- **Stability:** to prevent overturning, sliding, or buckling of the structure, or parts of it, under the the action of loads.

4- **Strength:** to resist safely the stresses induced by the loads in the various structural members.

5- **Serviceability**: To ensure satisfactory performance under service load conditions - which implies providing adequate stiffness and reinforcements to contain deflections, crack-widths, and vibrations within acceptable limits, and also providing impermeability and durability (including corrosion-resistance), etc.

There are two other considerations that a sensible designer must bear in mind, economy and aesthetics. As any engineer can always design a massive structure, which has more than adequate stability, strength, and serviceability, but the ensuing cost of the structure may be exorbitant, and the end product, far from aesthetic.

3.3 Scientific Tests

Before the structural study of any building, there is the work of geotechnical studies of the site, which means all work related to exploring the site and studying soil, rocks, and groundwater, then analyzing information and translating it to predict the way the soil behaves when building on it, and the most important thing is to obtaining soil durability (Bearing Capacity) required to design the building's foundations.

3.4 Loads Acting on the Building

Loads that acting on the building must be calculated and selected carefully because any error in identifying and calculating loads reflects negatively on the structural design of various structural elements. The building is exposed to loads of live and dead loads, and loads of earthquakes.

3.4.1 dead loads

Dead loads consist of the weight of all materials of construction incorporated into the building including but not limited to walls, floors, roofs, ceilings, stairways, built-in partitions, finishes, cladding and other similarly incorporated architectural and structural items, and fixed service equipment including the weight of cranes

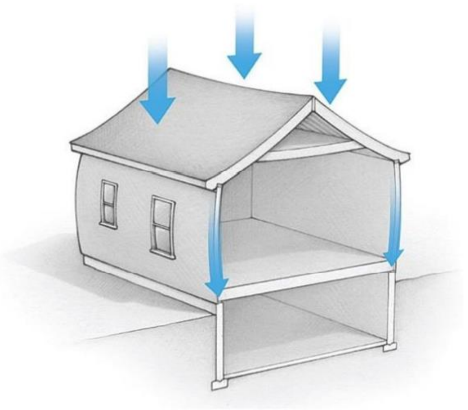


Figure (3- 1): Dead Load

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3.4.2 live load

Live loads are those loads produced by the use and occupancy of the building or other structure and do not include construction or environmental loads such as wind load, snow load, rain load, earthquake load, flood load, or dead load.

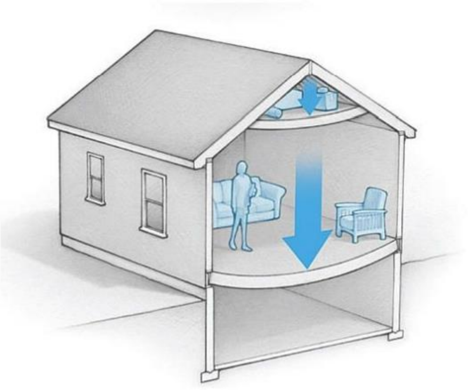


Figure (3- 2): Live Load

3.4.3 Environmental loads

It is the third type of load that must be taken into account in the design, and these loads include:

1. Seismic Loads

One of the most important environmental loads that affect the building, which are horizontal and vertical forces that generate torque, and can be resisted by using shear walls designed with thicknesses and sufficient reinforcement to ensure the safety of the building when it is exposed to such loads that must be observed in the design process to reduce Risks and maintenance of the building's performance of its function during earthquakes.

Figure (3- 3): Seismic Loads

2. Shrinkage and expansion loads

As a result of the contraction and expansion of the concrete elements of the building due to the variation in temperature during the seasons of the year, stresses have generated that lead to cracks in the building, where they are avoided and prevented from appearing using the phi 8 reinforcement mesh and also using expansion joints.

3.5 Structural Elements of the Building

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

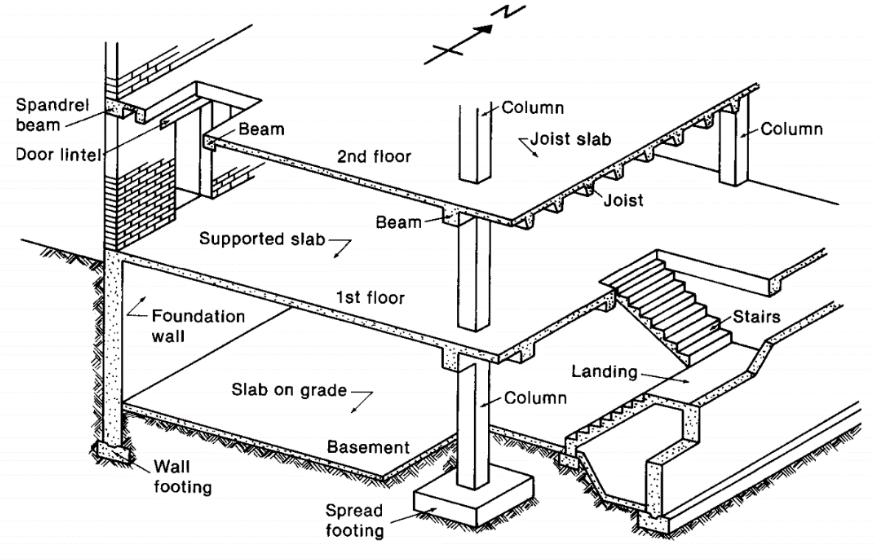


Figure (3-4): Structural elements of a typical RC structure

3.5.1 Slabs

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

There are many different Structural systems of reinforced concrete slabs, including the following:

3.5.1.1 Solid slab (one or two way)

Solid Slabs are fully customizable concrete slabs of varying width, length, and thickness. They can be used in a variety of applications such as bridges, piers, and building floors. It is known that solid slabs should be supported by drop beams.

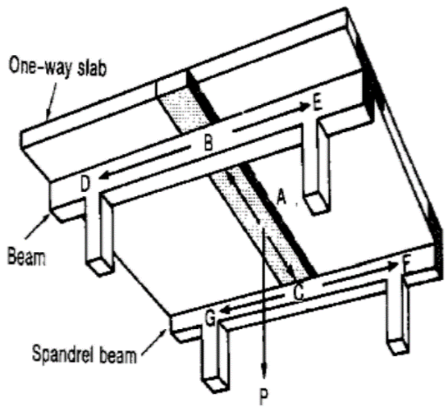


Figure (3- 5): Solid slab

3.5.1.2 Ribbed slab (one -way)

It's the most common system used in Palestine. They are made up of wide band beams running between columns with narrow ribs spanning the orthogonal direction. Normally the ribs and the beams are the same depth. A thin topping slab completes the system. It can be designed to carry loads either in one direction only, or in two directions.

Figures (3-6) describe one-way and two-way ribbed slabs respectively.

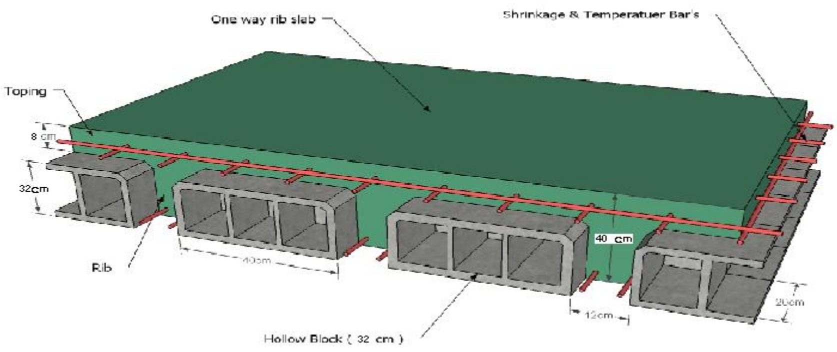


Figure (3- 6): One-way ribbed slab

3.5.2 Beams

They are basic structural elements in transferring loads from slabs to the columns, and they are of two types, hidden inside the slab and Dropped Beam that emerge from the slab from the bottom.

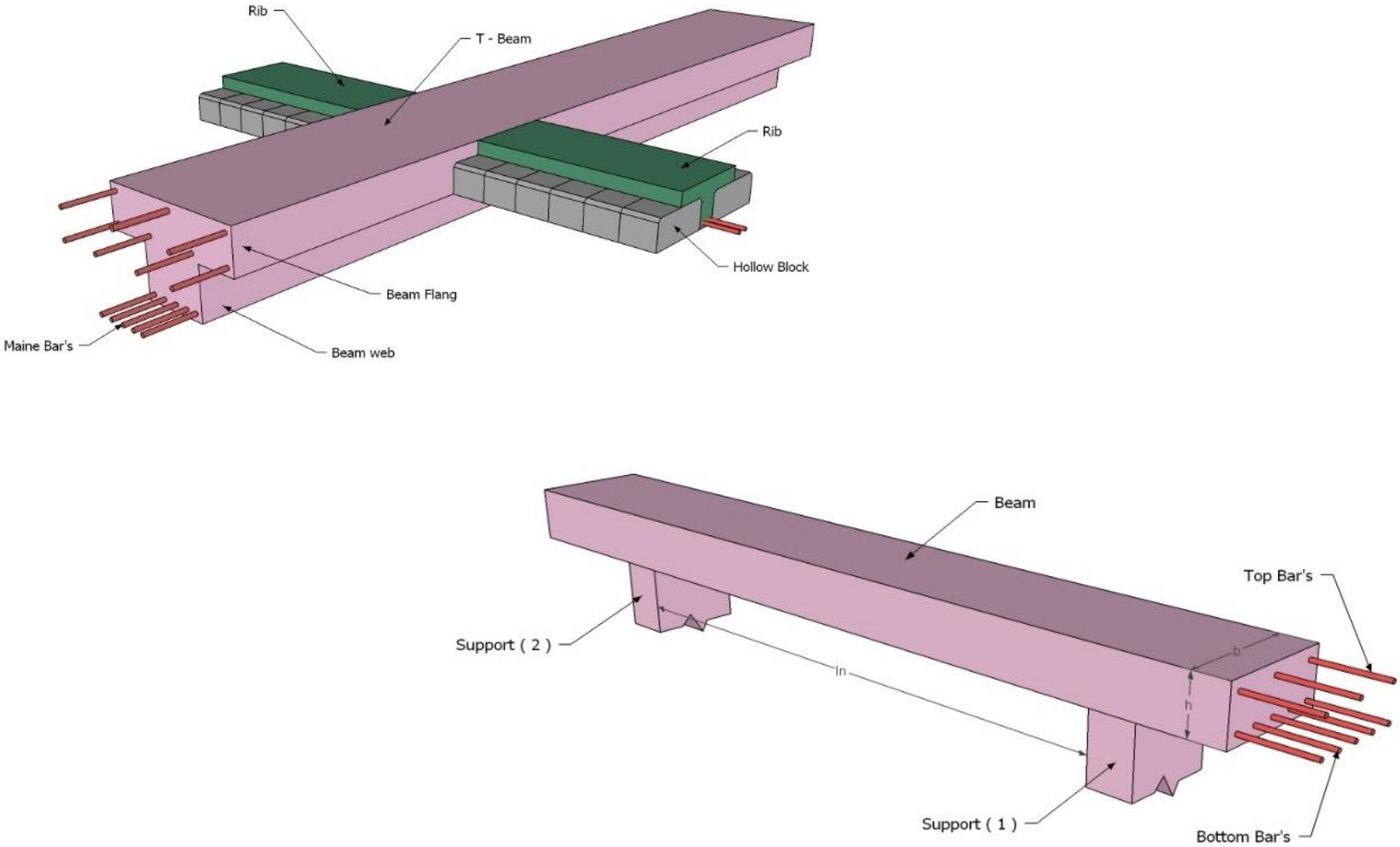


Figure (3- 7): Beams

3.5.3 Columns

Columns are the main member in transporting loads from slabs and beams to foundations, and as such, they are a necessary structural component for conveying loads and building stability. Therefore, they must be designed to be able to carry and distribute the loads on them

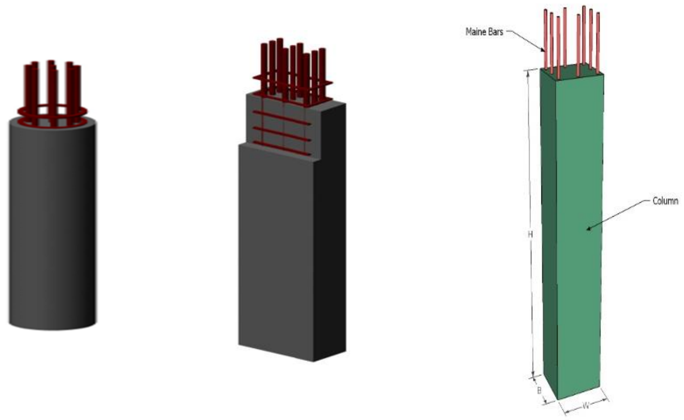


Figure (3- 8): Different types of Columns

3.5.4 Shear walls

They are structural load-bearing elements that resist vertical and horizontal forces located on them and are mainly used to resist horizontal loads such as wind and earthquake forces.

These walls are reinforced with two layers of steel to increase their efficiency to resist the horizontal forces. The two directions taking into consideration that the distance between the center of resistance formed by the shear walls in each direction and the center of gravity of the building is minimal. And that these walls are sufficient to prevent or reduce the generation of torque waves and their effects on the walls of the building resisting horizontal forces.

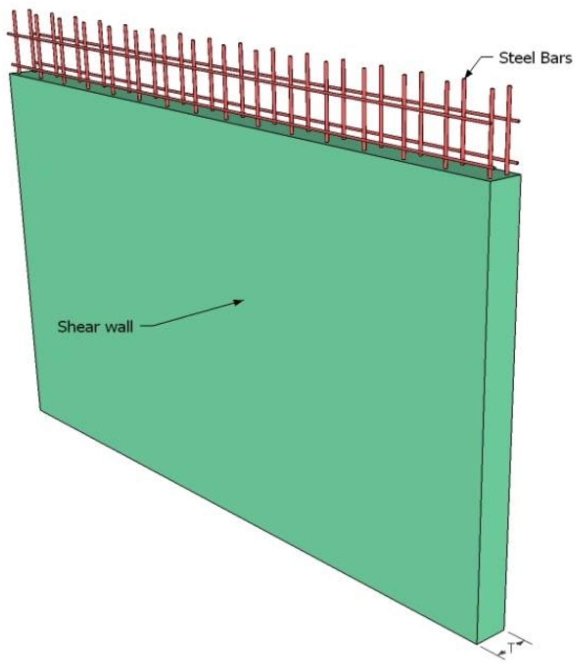


Figure (3 -9): Shear wall

3.5.5 Basement walls

A basement wall is a wall that is used on the floor and ceiling to provide support to the side walls as well as to the structure. It handles the pressure of the sidewalls and provides space for living inside the walls. Basement walls bear the load of the whole structure.

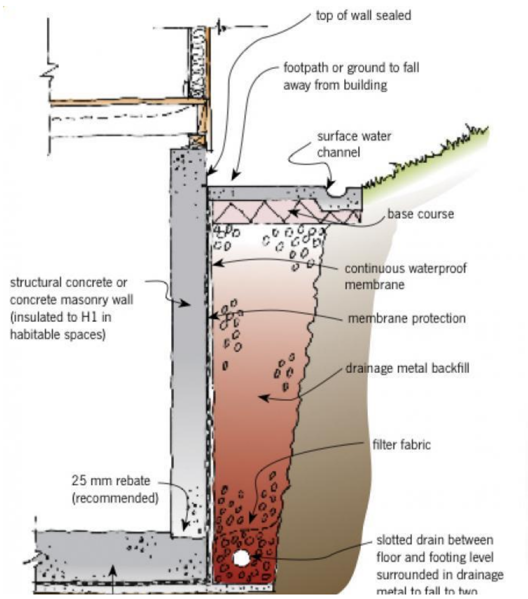


Figure (3- 10): Basement Wall

3.5.6 Foundations

Although the foundations are the first to start with the construction of the structure, their design takes place after the completion of the design of all structural elements in the building.

Loads act on foundations came from the loads on the slabs which transferred to the beams, then to columns, and finally to foundations. and these loads are the design loads for the foundations.

There are many types of foundations that can be used in each project it depends on the type of loads and the nature of the soil in the site.

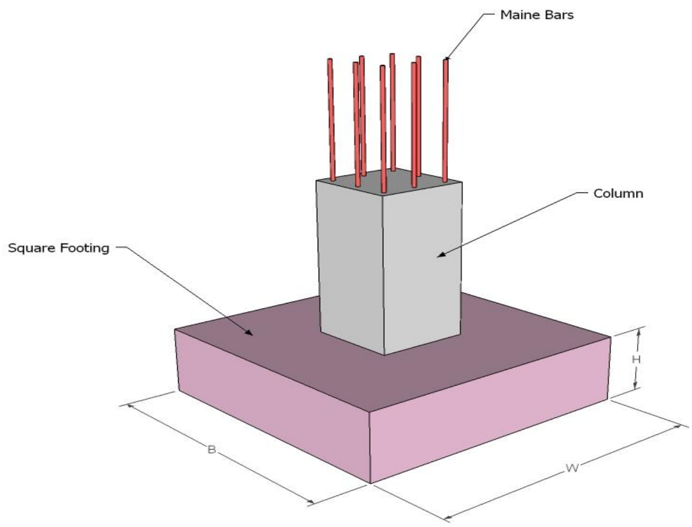


Figure (3- 11): Isolated Footing

3.5.7 Stairs

Stairs must be provided in almost all buildings. It consists of rises, runs, and landings. The total steps and landings are called a staircase

There are different types of stairs, which depend mainly on the type and function of the building and the architectural requirements.

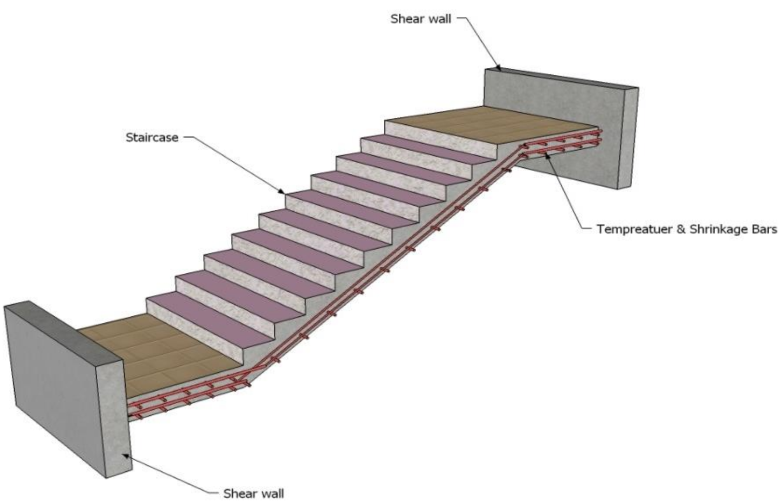


Figure (3- 12): General Section of stairs

CHAPTER 4

STRUCTURAL ANALYSIS AND DESIGN

4.1. Introduction
4.2. Determination of slab thickness
4.3. Design of one-way ribbed slab
4.4. Design of beam B57
4.5. Design of column A16
4.6. Design of isolated footing for column B13
4.7. Design of basement wall
4.8. Design of shear wall 18
4.9. Design of strip footing for B.W 13
4.10. Design of stair case 1

4.1. Introduction

After finishing the structural planning of the building, in which the location of columns and beams was determined. A complete design for all elements was done for flexure, shear, and deflection.

In this chapter, the analysis and design procedure for a sample of each structural element in the building are explained in detail.

The following General considerations are taken throughout the analysis and design processes of this project:

1. All members were designed according to ACI 318-14 Building code.
2. Gravity loads were estimated using the Jordanian code.
3. (ASCE7-16) is used for the definition of lateral seismic loads.
4. The ultimate strength design method is used during the analysis and design of this project.
5. Working Stress Method is used for soil design.
6. The compressive strength of concrete is B350 which equals to $Fc' = 28$ MPa for all elements, **except** the foundations with compressive strength of concrete is B300 which equals to $Fc' = 24$ MPa.
7. Yield strength of reinforcing rebars $Fy = 420$ MPa.

4.2. Determination of slab thickness

The thickness of the one-way ribbed slab is obtained according to the ACI code to achieve deflection requirements. The following table summarizes the determination of thickness for ribs that gives maximum values:

Table (4- 1): Determination of thickness for ribs from maximum values of cases

Supporting type	min. h equation	Rib	Span	min. h (cm)
Simply Supported	L/16	36&21	1	$= \frac{560}{16} = 35$
One end continues	L/18.5	9	1	$= \frac{560}{18.5} = 30.27$
Both ends continuous	L/21	18&19	4	$= \frac{540}{21} = 25.71$

Since the previous are approximate equations for determining the thickness of a slab, it will be selected (32cm) and deflection will be checked later.

Included the rib (21&36) the thickness will be selected (32 cm), although the initial calculations showed that we need a thickness of 35 cm, after solving these ribs using the BEAMD program and checking the deflection it illustrates that the thickness of 32 cm is enough and we can use it.

∴ **Select slab thickness = 32cm with 24cm block & 8cm topping.**

❖ The following figure shows a typical section in a 32cm thick one-way ribbed slab.

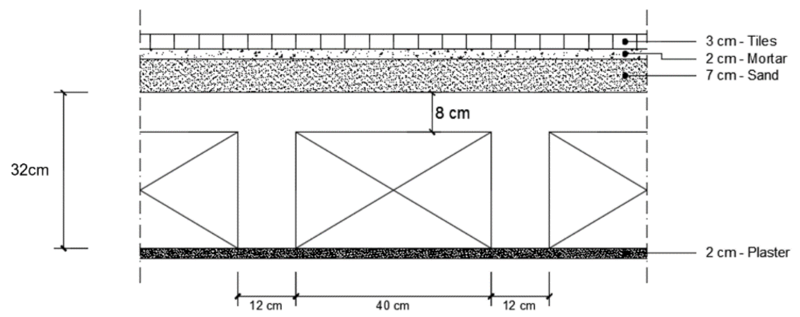


Figure (4-1): Typical section of one-way ribbed slab

4.3. Design of one-way ribbed slab

One-way ribbed slab Design procedure is explained in the following steps:

4.3.1. Design of topping

Topping in One-way ribbed slab can be considered as a strip of 1-meter width and span of hollow block length with both ends fixed in the ribs.

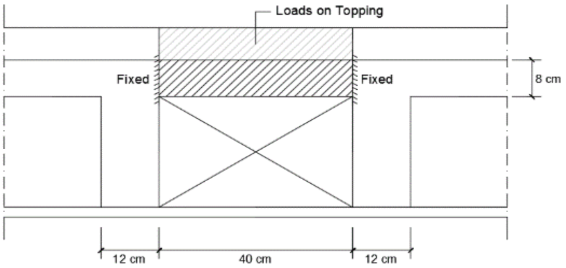


Figure (4-2): System of topping

4.3.2. Calculation of Loads on Topping

Dead loads that act on Topping can be calculated as shown in the following table:

→ Dead Load For 1m strip:

Table (4- 2): Dead Load Calculation for topping

Material	Quality Density (kN/m^3)	Calculation	Dead Load (kN/m)
Tiles	22	= 0.03×22×1	0.66
Mortar	23	= 0.02×23×1	0.46
Sand	16.4	= 0.07×16.4×1	1.148
Topping	25	= 0.08×25×1	2
Partitions		= 2×1	2
∴ Dead Load for 1m strip of topping 6.268 kN/m			

→ Live Load for 1m strip = 4 × 1 **= 4 kN/m**

→ Factored load (W_u) = 1.2 × D.L + 1.6 × L.L = 1.2 * 6.268 + 1.6 * 4 = **13.92 kN/m.**

4.3.3. Analysis of Topping

- $Vu = \frac{W_u \times L}{2} = \frac{13.92 \times 0.4}{2} = \mathbf{2.784kN}$
- $Mu = \frac{W_u \times L^2}{12} = \frac{13.92 \times 0.4^2}{12} = \mathbf{0.186\ kN.m}$

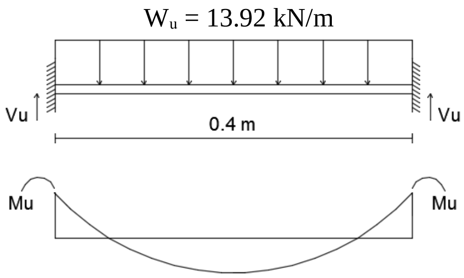


Figure (4-3): System and analysis of topping

4.3.4. Design Strength of Topping

→ **Shear Design Strength**

For Plain concrete section one way shear is calculated using the following equation:

$\Phi.\ Vc = \Phi \times 0.11 \times \lambda \times \sqrt{Fc'} \times bw \times h$

$\Phi.\ Vc = 0.6 \times 0.11 \times 1 \times \sqrt{28} \times 1000 \times 80 =$ **27.94 kN > Vu → SAFE**

→ **Moment Design Strength:**

For Plain concrete section with "b = 1 m & h = 8 cm"

$\Phi.\ Mn = 0.6 \times 0.42 \times \sqrt{Fc'} \times \frac{b\ h^2}{6}$

$\Phi.\ Mn = 0.6 \times 0.42 \times \sqrt{28} \times \frac{1000 \times 80^2}{6} =$ **1.42 kN.m > Mu → SAFE**

∴ **Plain Concrete Section is SAFE**

- But According to ACI, As_{min} shall be provided for slabs as shrinkage and temperature reinforcement.

$\rho_{\text{shrinkage}} = 0.0018$ According to ACI

Minimum (As) = $\rho_{\text{shrinkage}} \times Ag$

$= 0.0018 \times b \times h$

$= 0.0018 \times 100 * 8$

$= 1.44\ cm^2/m$

- Step (s) is the smallest of:

1. 3h = 3×80 =**240 mm** **« control**
2. 450 mm.
3. $S = 380(\frac{280}{fs}) - 2.5*\text{Concrete cover} = 380\ (\frac{280}{\frac{2}{3}*420}) - 2.5*20 = 330m$

But $S \leq 300(\frac{280}{fs}) = 300\ (\frac{280}{\frac{2}{3}*420}) = 300mm$ Take S=200mm < Smax= 240mm

∴ **Select Mesh Ø8/20cm in both directions.**

Provided As = $(\pi \times 8^2/4) * (100/20) = 2.5\ cm^2/m > \text{min } As = 1.44\ cm^2/m$

4.3.5. Design of rib (17)

4.3.5.1. Rib 17 Geometry

❖ Rib (17) is selected to be designed; the following figure shows its location in ground floor slab:

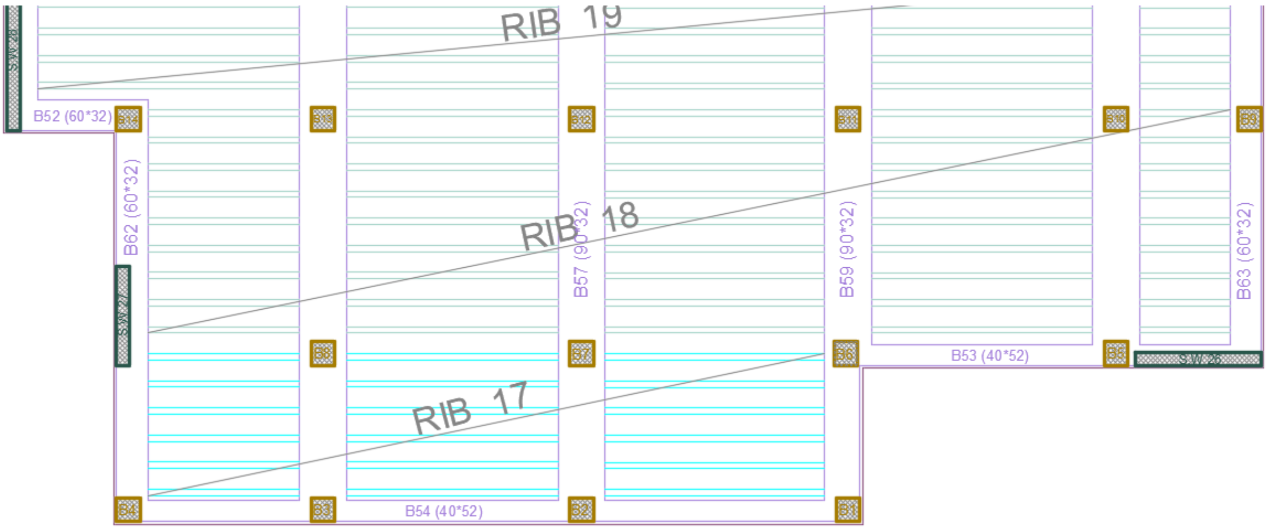


Figure (4-4): Location of the rib 17

- Requirements for Ribbed Slab (T-Beam Consideration According to ACI) are as follows:

- $bw \geq 10cm$ → select bw = **12 cm**
- $h \leq 3.5\ bw = 3.5 \times 12 = 42cm$ → select **h = 32 cm**
- $tf \geq \frac{Ln}{12} \geq 50$ mm → select **tf = 8cm**

4.3.5.2. Loads Calculation for Rib (R17)

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

→ **Dead loads:**

Table (4- 3):3 Dead Load Calculation for rib (R17)

Material	Quality Density (kN/m^3)	Calculation	Dead Load (kN/m/Rib)
Tiles	22	= 0.03×22×0.52	0.343
Mortar	23	= 0.02×23×0.52	0.239
Sand	16.4	= 0.07×16.4×0.52	0.597
Topping	25	= 0.08×25×0.52	1.04
Block	10	= 0.24×10×0.40	0.96
Rib	25	= 0.24×25×0.12	0.72
Plaster	23	= 0.02×23×0.52	0.239
Partitions		= 2×0.52	1.04
∴ Dead Load = 5.18 kN/m/Rib			

→ **Live loads** = 4 × 0.52 = **2.08 kN/m/rib**

→ **Factored Total Load (W_u)** = 1. 2×D.L + 1.6×L.L

WuD = 1.2×5.18= **6.22kN/m/rib**

WuL = 1.6×2.08 = **3.33 kN/m/rib**

4.3.5.3. Analysis

- figure (4-5) shows the shear and Moment envelope of the rib (17) obtained from Atir 2018 software.

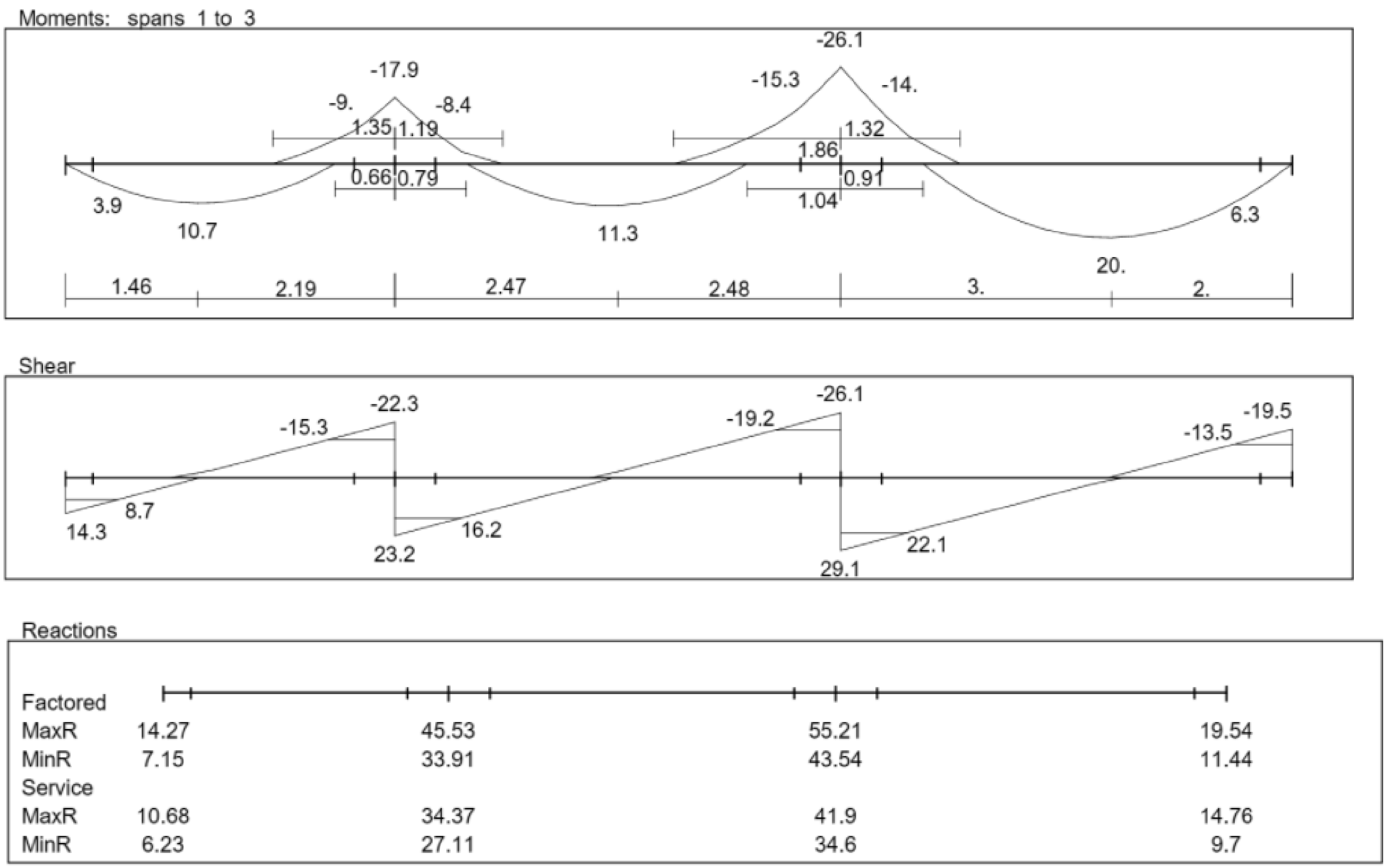


Figure (4-5): Moment envelope (kN.m), shear envelope (kN), and reactions (kN) of rib 17

4.3.5.4. Design of Rib for Shear

- Shear strength Vc, provided by concrete for the ribs may be taken greater than that for beams. This is mainly due to the interaction between the slab and the closely spaced ribs.

  → **Max. Vu at the critical section at distance d from the face of support is obtained from figure (4-5), where Vu = 22.1 kN**

If $\frac{1}{2}\text{Ø}. Vc < Vu \leq \text{Ø}. Vc$ …. No shear Reinforcement is required for slabs.

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

$\rightarrow$ Ø. Vc = Ø * 1.1 * $\frac{1}{6}$ * $\sqrt{Fc'}$ * bw * d

= 1.1 * 0.75 * $\frac{1}{6}$ * $\sqrt{28}$ * 120 * 283 *10^{-3}

= **24.71 kN**

Ø. Vc= **24.71 kN** >$V_{u, max}$ = 22.1 kN … No shear Reinforcement is required.

∴ **Select Ø8/30cm as montage for construction requirements .**

4.3.5.5. Design Rib for Flexure

4.3.5.5.1. Design of positive moment – Bottom reinforcement

Check for chosen effective flange width (***be***):

According to (ACI 318-14) (be) is the smallest of:

- be ≤ min clear span/4 ≤ (290/4) = 72.5 cm
- be ≤ 16*hf + bw = 16*8 + 12 = 140 cm
- be ≤ bw + ½ Lc = 12 + ½ * 40 + ½ * 40 = **52 cm** « **Control**

⇒ **Design of span (1) Max Mu^+ = 10.7 kN.m**

1. **Check if (a ≤ t) or (a > t)**

   Assume a= t= 8cm

   Ø * Mn = Ø * C or T * (d – ½*t)

   C = (0.85 * Fc' * t * be)

   Ø * Mn = Ø * C or T * (d – ½*t)

   = 0.9 * 0.85 * 28 * 80 * 520 * (283 - $\frac{80}{2}$) *10^{-6}

   = **216.53 kN.m** > Mu^+ = 10.7 kN.m

   ∴ **a < t → Compression zone is in the flange**

2. **Design as Rectangular Section with b=be**

- m = $\frac{fy}{0.85*fc'}$ = $\frac{420}{0.85*28}$ =17.65
- Rn = $\frac{Mu/\emptyset}{b*d^2}$ = $\frac{10.7*10^6/0.9}{520*283^2}$ = 0.29 MPa
- $\rho = \frac{1}{m} * (1- \sqrt{1-\frac{2*Rn*m}{fy}}) = \frac{1}{17.65} * (1- \sqrt{1-\frac{2*0.29*17.65}{420}}) = 6.95 *10^{-4}$

- $A_{s,\,req} = \rho * b * d = 6.95 * 10^{-4} * 520 * 283 = 102.28\ mm^2$

∴ **<u>Select 2Ø10 with As = 157.08 mm²</u>**

3. Check As min:

$A_{s,\,min} = 0.25 * \frac{\sqrt{fc'}}{fy} * bw * d = 0.25 * \frac{\sqrt{28}}{420} * 120 * 283 = 106.96\ mm^2$

Or

$A_{s,\,min} = \frac{1.4}{Fy} * bw * d = \frac{1.4}{420} * 120 * 283 =$ **113.2 mm²** « **Control**

∴ **Use 2Ø10 with As = 157.08mm²> Asmin =113.2 mm²**

4. Check Strain:

C=T

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

0.85 * 28 * a * 520 = 157.08* 420

a= 5.33 mm ⇒ X = a / β = 5.33 / 0.85 = 6.27 mm

$\varepsilon_s = \frac{0.003d}{x} - 0.003 = \frac{0.003*283}{6.27} - 0.003 = 0.132 > 0.005 \Rightarrow Ø = 0.9$ … (OK)

⇒ Design of span (2) Max Mu+ = 11.3 kN.m

Check if (a ≤ t) or (a > t)

Assume a=t=8cm

Ø * Mn = **216.53 kN.m** > Mu^+ = **11.3** kN.m

∴ **a < t → Compression zone is in the flange**

Design as Rectangular Section with b=bE

- $Rn = \frac{11.3*10^6/0.9}{520*283^2} = 0.30\ MPa$
- $\rho = \frac{1}{17.65} * (1- \sqrt{1 - \frac{2*0.30*17.65}{420}}) = 7.19*10^{-4}$
- $A_{s,\,req} = 7.19 * 10^{-4} * 520 * 283 = 105.81\ mm^2$

∴ **Use 2Ø10 with As = 157.08 mm² > Asmin =113.2 mm²**

Check Strain:

C=T

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

0.85 * 28 * a * 520 = 157.08* 420

a= 5.33 mm ⇒ X = a / β = 5.33 / 0.85 = 6.27 mm

$\varepsilon_s = \frac{0.003d}{x} - 0.003 = \frac{0.003*283}{6.27} - 0.003 = 0.132 > 0.005$ ⇒ Ø = 0.9 … (OK)

⇒ Design of span (3)   Max Mu+ = 20 kN.m

Check if (a ≤ t) or (a > t)

Assume a= t= 8cm

Ø * Mn = **216.53 kN.m** > Mu^+ = **20** kN.m

∴ **a < t → Compression zone is in the flange**

Design as Rectangular Section with b=bE

- Rn = $\frac{20*10^6/0.9}{520*283^2}$ = 0.53MPa
- $\rho = \frac{1}{17.65} * (1- \sqrt{1 - \frac{2*0.53*17.65}{420}}) = 1.28 *10^{-3}$
- $A_{s,\ req} = 1.28 *10^{-3} * 520 * 283 = 188.36\ mm^2$

∴ Use 2Ø12 with As = 226.19 mm^2> Asmin = 113.2 mm^2

Check Strain:

C=T

0.85 * 28 * a * 520 = 226.19* 420

a=7.68 mm, ⇒ X = a / β = 7.68/ 0.85 = 9.04 mm

$\varepsilon_s = \frac{0.003*283}{9.04} - 0.003 = 0.091 > 0.005$ ⇒ Ø = 0.9 … (OK)

4.3.5.5.2. Design of negative moment – top reinforcement

⇒ **Design at support (B) Max Mu^- = 9 kN.m**

(Compression zone in web ⇒ design as rectangular RC section)

- Rn = $\frac{9*10^6/0.9}{520*283^2}$ = 0.24 MPa
- $\rho = \frac{1}{17.65} * (1- \sqrt{1-\frac{2*0.24*17.65}{420}}) = 5.74*10^{-4}$
- $A_{s,\,req} = \rho * b * d = 5.74*10^{-4} * 520 * 283 = 84.47\ mm^2$

∴ **Select 2Ø10with As = 157 .08 mm2 > As min = 113.2 mm^2**

Check Strain:

C=T

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

0.85 * 28 * a * 520 = 157.08* 420

a= 5.33 mm ⇒ X = a / β = 5.33 / 0.85 = 6.27 mm

$\varepsilon_s = \frac{0.003d}{x} - 0.003 = \frac{0.003*283}{6.27} - 0.003 = 0.132 > 0.005$ ⇒ Ø = 0.9 … (OK)

4.3.5.5.3. Design of negative moment – top reinforcement

⇒ **Design at support (C) Max Mu^- = 15.3 kN.m**

(Compression zone in web ⇒ design as rectangular RC section)

- Rn = $\frac{15.3*10^6/0.9}{520*283^2}$ = 0.41 MPa
- $\rho = \frac{1}{17.65} * (1- \sqrt{1-\frac{2*0.41*17.65}{420}}) = 9.85*10^{-4}$
- $A_{s,\,req} = \rho * b * d = 9.85*10^{-4} * 520 * 283 = 144.95 mm^2$

∴ **Select 2Ø10with As = 157 .08 mm2 > As min = 113.2 mm^2**

Check Strain:

C=T

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

0.85 * 28 * a * 520 = 157.08* 420

a= 5.33 mm ⇒ X = a / β = 5.33 / 0.85 = 6.27 mm

$$\varepsilon_s = \frac{0.003d}{x} - 0.003 = \frac{0.003*283}{6.27} - 0.003 = 0.132 > 0.005 \;\Rightarrow \varnothing = 0.9 \ldots (OK)$$

4.3.5.6. Check Deflection

- The value of Deflection should not exceed Δlimit, Which according to ACI Code $= \frac{L}{240}$. The following figure shows values of Δlimit compared with deflection calculated by Atir software.

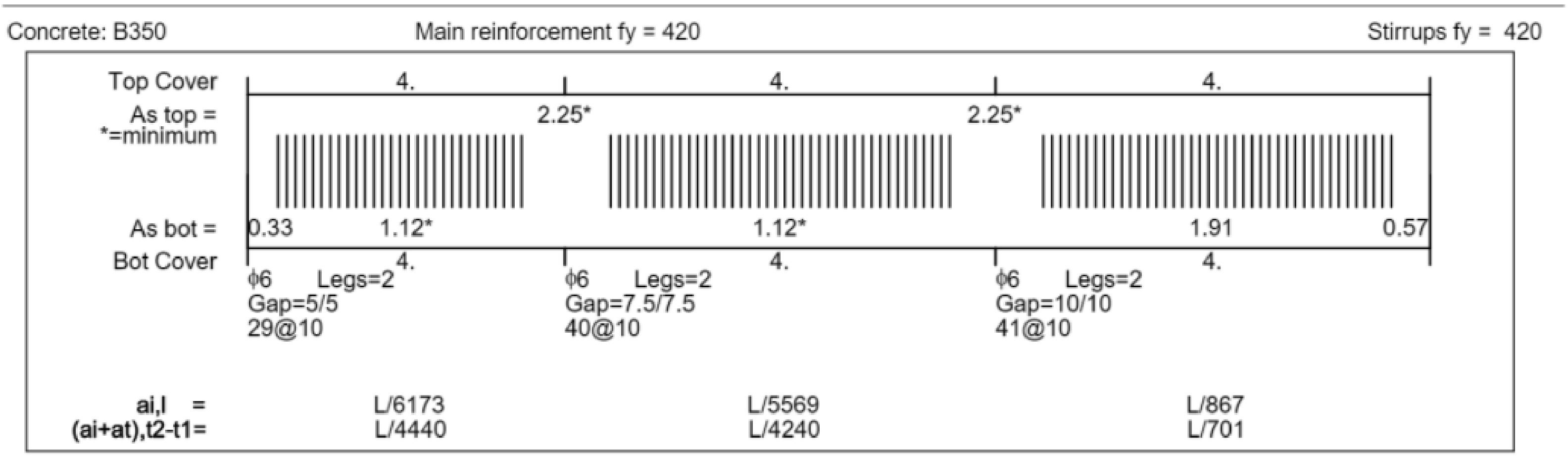


Figure (4-6):Deflection, and required reinforcement area (in cm²) of rib 17according to BEAMD software

4.4. Design of Beam 57

Beam (B57) is selected to be designed; the following figure shows its location in ground floor slab:

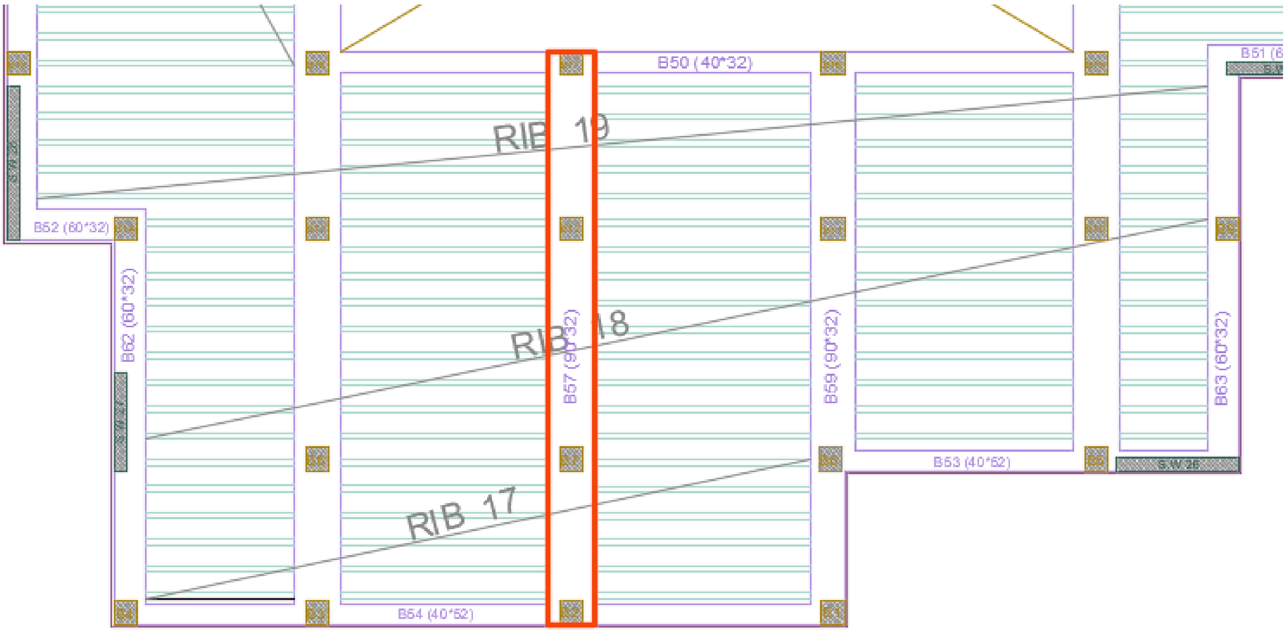


Figure (4-7):Loccation of Beam B57

4.4.1. Load Calculation for beam

The following figure shows the geometry of beam and loads that act on it:

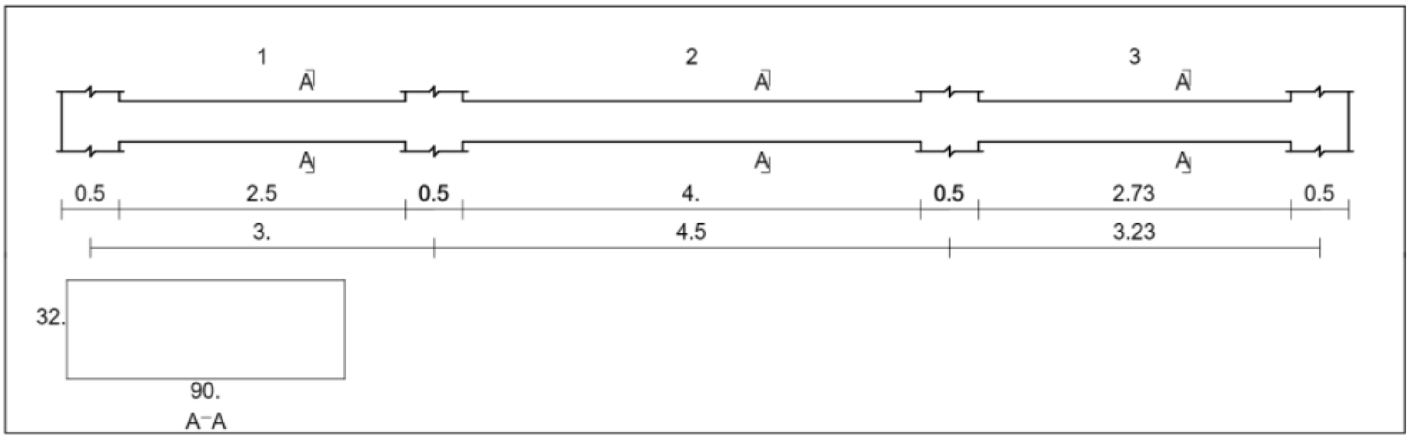


Figure (4-8):Geometry of Beam B57

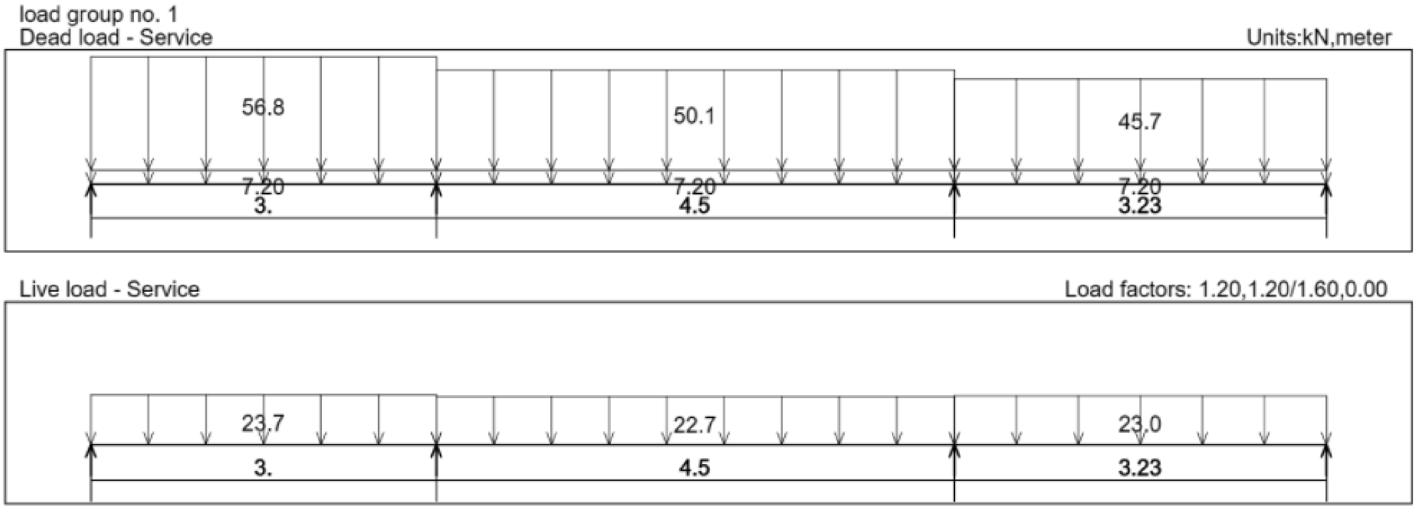


Figure (4-9):Loads on Beam B57

❖ Calculation of Loads that acts on beam B57:

1. Own weight of the beam:

   Own wt. = 25*0.32*0.90= **7.2 kN/m**

2. Reactions of ribs that acting on it.

   The following table shows calculation of loads that act on B57from ribs.

Table (4- 4): Loads on B57 from ribs

	Rib(R17)	**Rib(R18)**	**Rib (R19)**
quD(kN/m)	29.54/0.52=56.81	26.05/0.52 = 50.1	23.76/0.52 = 45.69
quL (kN/m)	12.32/0.52 = 23.69	11.80/0.52=22.69	11.96/0.52 = 23

4.4.2. Design of beam B57 for Flexure

- The following figure shows moment, shear envelopes and reactions resulted from analysis of beam (B57) using Atir 2018 Software:

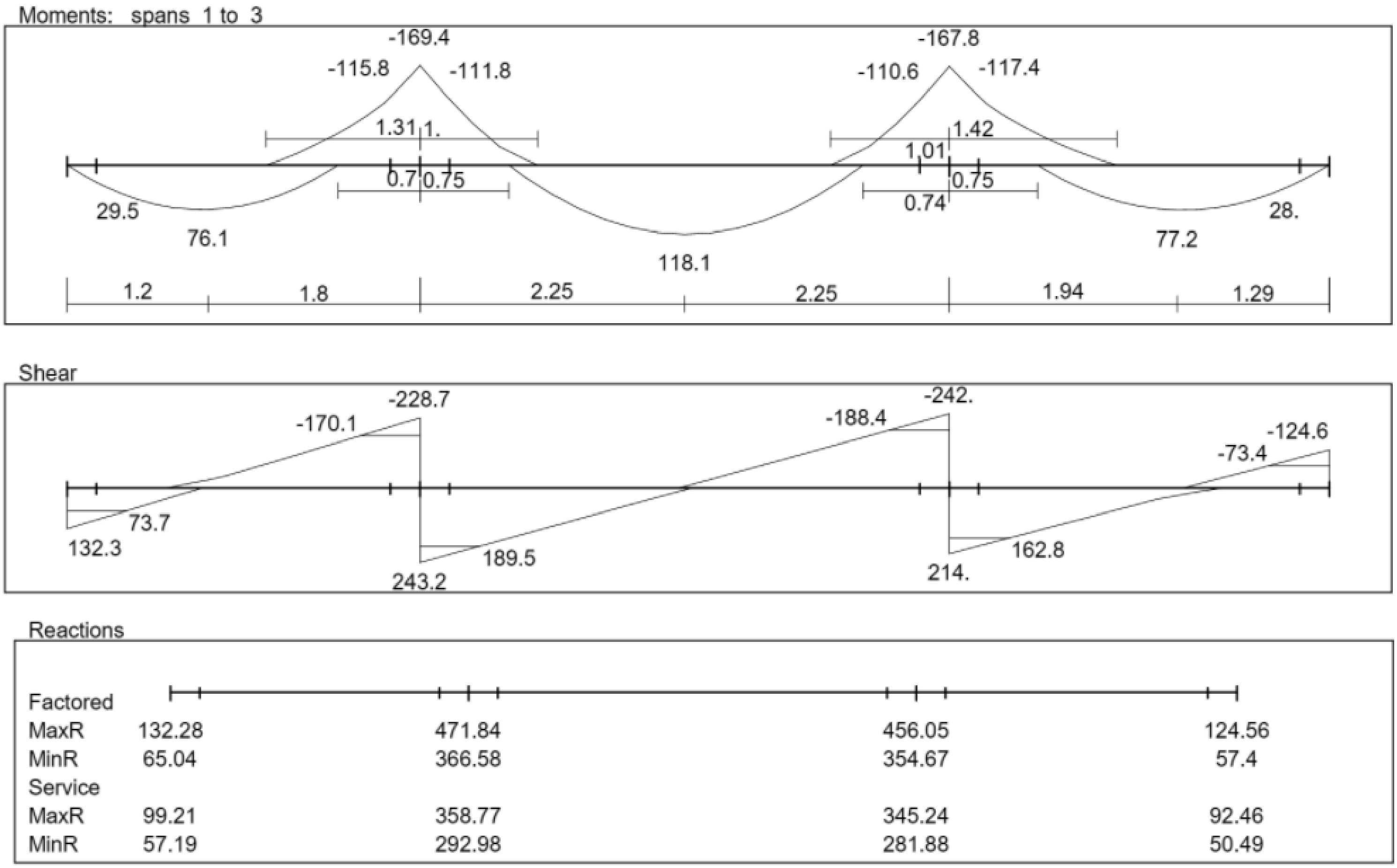


Figure (4-10): Moment envelope (kN.m), shear envelope (kN), and reactions (kN) of beam B57

4.4.3. Design of beam B57 for Flexure

Design of the negative moment – top reinforcement

⇒ **Design of negative moment Mu = -115.8 kN.m @ support (2)**

1. **Check whether the section will be act as singly or doubly reinforced section:**
   Maximum nominal moment strength from strain condition $\varepsilon_s = 0.004$.

   $\boldsymbol{d}$ = 320 – 40 -10 - 18/2 = 261 $\boldsymbol{mm}$

- $M_{n,\,req} = \frac{Mu}{\emptyset}$, Take $\emptyset$ = 0.9 for flexure as tension-controlled section.
- $M_{n,\,req} = \frac{115.8}{0.9}$ = 128.67 kN.m

- $m = \frac{Fy}{0.85*fc'} = \frac{420}{0.85*28} = 17.65$
- $Rn = \frac{Mn\ req}{b*d^2} = \frac{128.67*10^6}{1000*261^2} = 1.89$ MPa
- $\rho_{req} = \frac{1}{m} * (1-\sqrt{1-\frac{2*RN*m}{fy}}) = \frac{1}{17.65} * (1-\sqrt{1-\frac{2*1.89*17.65}{420}}) = 4.69*10^{-3}$

$$\mathbf{c = \frac{3}{7} * d = \frac{3}{7} * 261 = 111.86mm}$$

$\mathbf{a = b.c = 111.86 * 0.85 = 95.08mm.}$

$M_{n,\ max} = 0.85\ fc'ab\ (d - \frac{a}{2}) = 0.85*28*95.08*1000*(261 - \frac{95.08}{2})*10^{-6}$

$= 483.04$ kN.m

$\emptyset M_{n,\ max} = 0.82*483.04 = 396.09$ KN.m > Mu=115.8 kN.m

∴ $\rho_{req} < \rho_{max}$ ... Design the section as singly reinforced concrete section.

2. Design the section as singly reinforced concrete section:

Assume rectangular & tension control section.

- $As_{req} = 4.69*10^{-3} * 1000 * 261 = 1224.09\ mm^2$

∴ **Select 5Ø18with As = 1272.35 mm^2.**

3. Check $A_{s,\ min}$:

$A_{s,\ min} = 0.25 * \frac{\sqrt{fc'}}{fy} * bw * d = 0.25 * \frac{\sqrt{28}}{420} * 1000 * 261 = 822.07\ mm^2$

Not less than:

$A_{s,\ min} = \frac{1.4}{fy} * bw * d = \frac{1.4}{420} * 1000 * 261 =$ **870mm²** « **Controlled**

As = 1272.35 mm²> $A_{s,\ min}$ =870 mm² … (OK)

4. Check Strain for Ø and Asmax

C=T

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

0.85 * 28 * a *1000 = 1272.35* 420

a = 22.45mm

X = a / β = 22.45 / 0.85 = 26.41 mm

$\varepsilon_s = \frac{0.003d}{x} - 0.003 = \frac{0.003*261}{26.41} - 0.003 = 0.027$

∴ $\varepsilon_s = 0.027 > 0.005$ then Ø = 0.9 … (OK)

also, $\varepsilon_s = 0.027 > 0.004$ then $As < As,max$ ... (OK)

5. **Check for spacing**

$$s = \frac{1000-2(40)-2(10)-5(18)}{4} = 202.5 \text{ mm} \quad >25 \text{ mm} \ldots \text{(OK)}$$

$$> db=18\text{mm} \ldots \text{(OK)}$$

⇒ Design of negative moment Mu= -117.4 kN.m @ support (3)

1. **Check whether the section will be act as singly or doubly reinforced section:**

Maximum nominal moment strength from strain condition $\varepsilon_s = 0.004$.

$\boldsymbol{d}$ = 320 – 40 -10 - 18/2 = 261$\boldsymbol{mm}$

- Mn req = $\frac{Mu}{\emptyset}$, Take $\emptyset$ = 0.9 for flexure as tension-controlled section.
- Mn req = $\frac{117.4}{0.9}$ = 130.44 kN.m
- m =$\frac{fy}{0.85*fc'}$ = $\frac{420}{0.85*28}$ =17.65
- Rn = $\frac{\text{Mn req}}{b*d^2}$ = $\frac{130.44*10^6}{1000*261^2}$ = 1.91 MPa
- ρreq = $\frac{1}{m}$ * (1- $\sqrt{1-\frac{2*RN*m}{fy}}$) = $\frac{1}{17.65}$ * (1- $\sqrt{1-\frac{2*1.91*17.65}{420}}$) = 4.75*10^{-3}

$$\mathbf{c = \frac{3}{7} * d = \frac{3}{7} * 261 = 111.86mm}$$

$\mathbf{a = b.c = 111.86 * 0.85 = 95.08\ mm}$.

$M_{n,\ max}$ = 0.85 fc'ab (d -$\frac{a}{2}$) =0.85*28*95.08*1000*(261 -$\frac{95.08}{2}$)* 10^{-6}

= 483.04 kN.m KN.m

$\emptyset M_{n,\ max}$ = 0.82* 483.04 kN.m =396.09KN.m > Mu=117.4 kN.m

∴ ρreq < ρmax ... Design the section as singly reinforced concrete section.

2. **Design the section as singly reinforced concrete section:**

Assume rectangular & tension control section.

- Asreq = 4.75*10^{-3} $*$ 1000 $*$ 261 = 1239.75 mm^2

∴ **Select 5Ø18with As = 1272.35 mm^2.**

3. **Check $A_{s,\ min}$:**

$A_{s,\ min}$ = 0.25 * $\frac{\sqrt{fc'}}{fy}$ * bw * d = 0.25 * $\frac{\sqrt{28}}{420}$ * 1000 * 261 = 822.07 mm²

Not less than:

$A_{s,\ min}$ = $\frac{1.4}{fy}$ * bw * d = $\frac{1.4}{420}$ * 1000 * 261 = **870mm²** « **Controlled**

As = 1272.35 mm^2> $A_{s,\,min}$ =870 mm² … (OK)

4. **Check Strain for Ø and Asmax**

C=T

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

0.85 * 28 * a *1000 = 1272.35* 420

a = 22.45mm

X = a / β = 22.45 / 0.85 = 26.41 mm

$\varepsilon_s = \frac{0.003d}{x} - 0.003 = \frac{0.003*261}{26.41} - 0.003 = 0.027$

$\therefore\ \varepsilon_s = 0.027 > 0.005$ then Ø = 0.9 … (OK)

also, $\varepsilon_s = 0.027 > 0.004$ then $As < As, max$ … (OK)

5. **Check for spacing**

$s = \frac{1000-2(40)-2(10)-5(18)}{4} = 202.5$ mm >25 mm … (OK)

> db=18mm … (OK)

Design of Positive Moment – Bottom Reinforcement

⇒Design of span 1 - Max Mu = + 76.1 kN.m

Since max Mu in this span=76.1 kN.m < max Mu @ support 3=117.4 kN.m, which was designed as singly reinforced section, then also this section must be designed as singly reinforced concrete section.

- Mn req=76.1 /0.9 =84.56 kN.m
- m = 17.65
- $Rn = \frac{84.56*10^6}{1000*261^2} = 1.24$MPa
- $\rho req = \frac{1}{17.65} * (1- \sqrt{1 - \frac{2*1.24*17.65}{420}}) = 3.03*10^{-3}$
- Asreq = $3.03*10^{-3} * 1000 * 261 = 790.83$ mm^2

∴ **Select 9Ø12 with As = 1017.88 mm^2**

- As =1017.88 mm^2> Asmin =870 mm² … (OK)

→ **Check Strain for Ø and Asmax:**

C=T

0.85 * 28 * a *1000 = 1017.88 * 420

a=17.96 mm, X = 17.96 / 0.85 =21.13 mm

$\varepsilon_s = \frac{0.003*261}{21.13} - 0.003 = 0.034$

$\therefore\ \varepsilon_s = 0.034 > 0.005$ *then* Ø = 0.9 … (OK)

also, $\varepsilon_s = 0.034 > 0.004$ then As < Asmax … (OK)

→ **Check for spacing:**

$S = \frac{1000-2(40)-2(10)-9(12)}{8}$ = 99 mm >25 mm … (OK)

> db=12mm … (OK)

⇒ Design of span 2 - Max Mu = +118.1 kN.m

1. Check whether the section will be act as singly or doubly reinforced section:

Maximum nominal moment strength from strain condition $\varepsilon_s = 0.004$.

$\boldsymbol{d}$ = 320 – 40 -10 – 18/2 = 261$\boldsymbol{mm}$

- Mn req = $\frac{Mu}{\emptyset}$, Take ∅ = 0.9 for flexure as tension-controlled section.
- Mn req = $\frac{118.1}{0.9}$ = 131.2 kN.m
- m =$\frac{fy}{0.85*fc'} = \frac{420}{0.85*28}$ =17.65
- Rn = $\frac{Mn\ req}{b*d^2} = \frac{131.2*10^6}{1000*261^2}$ = 1.93 MPa
- ρreq = $\frac{1}{m}$ * (1- $\sqrt{1-\frac{2*RN*m}{Fy}}$) = $\frac{1}{17.65}$ * (1- $\sqrt{1-\frac{2*1.93*17.65}{420}}$) = 4.8 *10^{-3}

$$\mathbf{c = \frac{3}{7} * d = \frac{3}{7} * 261 = 111.86\ mm}$$

$\mathbf{a = B.c = 111.86 * 0.85 = 95.08\ mm}$.

$M_{n,\ max}$ = 0.85 Fc'ab (d -$\frac{a}{2}$) =0.85*28*95.08*1000*(261 -$\frac{95.08}{2}$)* 10^{-6}

= 483.04 KN.m

Ø$M_{n,\ max}$ = 0.82* 483.04 = 396.09 KN.m > Mu=118.1 kN.m

∴$\rho_{req} < \rho_{max}$ ... Design the section as singly reinforced concrete section.

2. Design the section as singly reinforced concrete section:

Assume rectangular & tension control section.

- Asreq = 4.8 *$10^{-3} * 1000 * 261 = 1252.8$ mm^2

∴ **Select 5Ø18 with As = 1272.35 mm^2.**

3. **Check As min:**

$A_{s,\,min} = 0.25 * \frac{\sqrt{fc'}}{fy} * bw * d = 0.25 * \frac{\sqrt{28}}{420} * 1000 * 261 = 822.07\ mm^2$

Not less than:

$A_{s,\,min} = \frac{1.4}{fy} * bw * d = \frac{1.4}{420} * 1000 * 261 =$ **870mm²** « **Controlled**

As = 1272.35 mm² > $A_{s,\,min}$ =870 mm² … (OK)

4. **Check Strain for Ø and Asmax**

C=T

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

0.85 * 28 * a *1000 = 1272.35* 420

a = 22.45mm

X = a / β = 22.45 / 0.85 = 26.41 mm

$\varepsilon_s = \frac{0.003d}{x} - 0.003 = \frac{0.003*261}{26.41} - 0.003 = 0.027$

$\therefore\ \varepsilon_s = 0.027 > 0.005$ then Ø = 0.9 … (OK)

also, $\varepsilon_s = 0.027 > 0.004$ then $As < As,max$ … (OK)

5. **Check for spacing**

$s = \frac{1000-2(40)-2(10)-5(18)}{4} = 202.5$ mm >25 mm … (OK)

> db=18mm … (OK)

Design of span 3 - Max Mu = +77.2 kN.m

Since max Mu in this span=77.2 kN.m < max Mu @ support 3=117.4 kN.m, which was designed as singly reinforced section, then also this section must be designed as singly reinforced concrete section.

- Mn req= 77.2 /0.9 = 85.78 kN.m
- m = 17.65
- $Rn = \frac{85.78*10^6}{1000*261^2} = 1.26$ MPa
- $\rho req = \frac{1}{17.65} * (1- \sqrt{1 - \frac{2*1.26*17.65}{420}}) = 3.08*10^{-3}$
- $Asreq = 3.08 *10^{-3} * 1000 * 261 = 803.88\ mm^2$

∴ **Select 9Ø12 with As = 1017.88 mm²**

- As =1017.88 mm² > Asmin =870 mm² … (OK)

→ **Check Strain for Ø and Asmax:**

C=T

0.85 * 28 * a *1000 = 1017.88 * 420

a=17.96 mm, X = 17.96 / 0.85 =21.13 mm

$\varepsilon_s = \frac{0.003*261}{21.13} - 0.003 = 0.034$

$\therefore\ \varepsilon_s = 0.034 > 0.005$ *then* Ø = 0.9 … (OK)

also, $\varepsilon_s = 0.034 > 0.004$ then As < Asmax … (OK)

→ **Check for spacing:**

$S = \frac{1000-2(40)-2(10)-9(12)}{8}$ = 99 mm >25 mm … (OK)

> db=12mm … (OK)

4.4.4. Design Beam B57 for Shear

The following are steps of shear force design:

1. **Check for dimensions:**

If Vu max ≤ Ø. Vc + $Ø\frac{2}{3}\sqrt{fc'}$ * bw * d, then section dimensions are adequate. If not, section must be increased.

Overall maximum shear value = 189.5 kN as shown in figure (4-5).

$Ø.\ Vc = Ø * \frac{1}{6} * \sqrt{Fc'} * bw * d$

$= 0.75 * \frac{1}{6} * \sqrt{28} * 1000 * 261 * 10^{-3}$

= **172.64 kN**

Ø. Vc= **172.64 kN** < Vu max = 189.552

kN … shear Reinforcement is required.

∴ shear reinforcement is required.

$Ø\frac{2}{3}\sqrt{Fc'}$ *bw*d = 0.75* $\frac{2}{3}\sqrt{28}$ *1000*261*10^{-3} =**690.54 kN**

Ø. Vc + $Ø\frac{2}{3}\sqrt{Fc'}$ * bw * d = 172.64+690.54 =863.18 kN > Vu max = 189.5 kN ... (OK)

∴ **Section is adequate.**

2. **Category (III):**

$$Ø.\,Vc < Vu \leq Ø.\,Vc + Ø.\,Vs\ min$$

Ø. Vs min is the maximum between:

→ $Ø.\,Vs\ min = 0.75 \times \frac{1}{16} \times \sqrt{fc'} \times bw \times d = 0.75 \times \frac{\sqrt{28}}{16} \times 1000 \times 261 \times 10^{-3} = \mathbf{64.74\ kN}$

OR

→ $Ø.\,Vs\ min = 0.75 \times \frac{1}{3} \times bw \times d = 0.75 \times \frac{1}{3} \times 1000 \times 261 \times 10^{-3} = \mathbf{65.25\ kN}$ « **Cont.**

$$Ø.\,Vc + Ø.\,Vs\ min = \mathbf{172.64 + 65.25 = 237.89\ kN}$$

∴ For all shear values that are ≤ 237.89 kN, minimum shear reinforcement is required
→ And 237.89 kN > Vu max = 189.5 kN ------ ∴minimum shear reinforcement is required

→ Minimum Shear Reinforcement:

$$Sreq = \frac{0.75 * Av * fyt * d}{Ø\,.Vs\ min}$$

→ $Sreq = \frac{0.75 * 157.08 * 420 * 261}{65.25 * 10^3} = \mathbf{197.92\ mm}$

But, $\mathbf{S_{max}} \leq d/2$ → 261/2 = **130.5 mm«   Cont.**

Or $\mathbf{S_{max}} \leq$ **600 mm**

Note:
Assume Ø10 stirrups with 2 legs are used,
Then $Av = 2 * \frac{\pi * 10^2}{4} = 157.08mm^2$

∴ **Select Ø10/10cm ,2legs stirrups**

4.5. Design of column A16

4.5.1. Calculation of Loads act on Column (A16):

$f_c' = 28$ Mpa
fy = 420 Mpa
Dead =1126.07 kN
Live =364.19 kN

Solution:

Factored loads (Pu):

→ Pu = 1.2 DL + 1.6 LL = 1.2 x 1126.07 + 1.6 x 364.19 = 1933.99 kN
→ $\emptyset = \mathbf{0.65\ for\ tied\ column}$
→ Assume $\boldsymbol{\rho g} = \mathbf{2}$ %
→ Ast=0.02 Ag

4.5.2. Selecting column dimensions:

ϕ Pn max = Pu= ϕ 0.8[0.85$f c'$(Ag − Ast) + Ast fy]

→ $1933.99 * 10^3$ =0.65*0.8[0.85*28(Ag -0.02 Ag) + 0.02*Ag * 420]

Ag= 117236.53 mm^2

→ Let a= 450 mm

Ag=a*b
b=260.53 mm

∴ Select (450*450) mm with Ag=202500mm^2

4.5.3. Check Slenderness Effect:

For braced system if $\lambda \le 34 - 12\frac{M1}{M2} \le 40$, then column is classified as short column and slenderness effect shall not be considered.

$$\lambda = \frac{Klu}{r}$$

Where:

Lu: Actual unsupported (unbraced) length =3.68 m

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

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

System about X

$$\rightarrow \lambda = \frac{1 * 3.68}{0.3 * 0.45} = 27.26$$

$$\lambda \leq 34 - 12(1) = \mathbf{22} \quad \leq 40$$

$$\lambda = 27.26 \; > 22 \; \therefore \text{Long about X.}$$

System about Y

$$\rightarrow \lambda = \frac{1 * 3.68}{0.3 * 0.45} = 27.26$$

$$\lambda \leq 34 - 12(1) = \mathbf{22} \quad \leq 40$$

$$\therefore \text{Long about Y.} \quad \lambda = 27.26 \; > 22$$

∴ Column is Long in both dimensions, So Slenderness effect will be considered.

4.5.4.Calculate the minimum eccentricity emin and the minimum Mmin:

→ emin = 15+ 0.03 h = 15 + (0.03*450) = 28.5 mm
→ Pu = 1.2 DL + 1.6 LL = 1.2 x 1126.07 + 1.6 x 364.19 = 1933.99 kN
→ M min = Pu*emin = 1933.99*0.0285 = 55.11 kN .m

4.5.5.Compute EI:

→ Ec= $4700\sqrt{\mathbf{fc}}$=$4700\sqrt{28}$=24870 Mpa

→ Ig= $\frac{bh^3}{12} = \frac{450^3}{12} * \mathbf{450}$ =3.42*109 mm4

→ βdns = $\frac{1.2*D}{1.2D+1.6L} = \frac{1.2*1126.07}{1933.99}$ = 0.7

- EI = $\frac{0.4*EC*Ig}{1+\beta dns} = \frac{0.4*24870*3.42}{1+0.7}$ =20013.04 kN.m^2

4.5.6.Determine the Euler buckling load, Pc:

→ Pc = $\frac{\pi^2 * EI}{(KLu)^2} = \frac{\pi^2 * 20013.04}{(1*3.68)^2}$ = 14585.4 kN

4.5.7.Calculate the moment magnified factor, ẟns:

→ Cm = 0.6 + 0.4$\frac{M1}{M2}$ = 0.6 + (0.4*1) = 1

→ ẟns= $\frac{Cm}{1-\frac{Pu}{0.75*Pc}} = \frac{1}{1-\frac{1933.99}{0.75*14585.04}}$ = 1.215 > 1

The magnified eccentricity and moment:

→ e= emin * ẟns = 28.5*1.215 = 34.63 mm

→ Mc= ðns*M min = 55.11 *1.215 = 66.96 KN.m

4.5.8.Select the column reinforcement:

We will use the tied – column interaction diagrams with bars in four faces (A-9).

- **Compute the ratio e/h:**

  e/h = 34.63 / 450 = 0.08

  To construct the e/h line, take value 0.08 on $\frac{ØMn}{bh^2}$ axis and value 1 on $\frac{ØPn}{bh}$ axis.

- **Compute the ratio ɤ:**

  Assume Ø20 for bars.

  $ɤ = \frac{d-d`}{h} = \frac{450-(2*40)-(2*10)-20}{450} = 0.73$

- Use interaction diagrams A-9a and A9-b to determine ρg for the selected dimensions: h = 450 mm, b = 450mm. The interaction diagrams are entered with:

  → $\frac{ØPn}{Ag} = \frac{Pu}{Ag} = \frac{1933.99*1000}{450*450}$*0.145= 1.38 ksi
  → $Diagram\ A-9a\ (from\ ɤ = 0.6)\ , \rho g < \rho \min = 0.01$
  → $Diagram\ A-9b\ (from\ ɤ = 0.75)\ , \rho g < \rho \min = 0.01$

  From both diagrams A-9a and A-9b the required value for ρg is less than 0.01. Therefore, to satisfy the minimum column longitudinal-reinforcement ratio, use $\rho g = \rho \min = 0.01$

4.5.9. Selecting longitudinal bars:

Ast = $Ag * \rho g = 0.01 * 450 * 450 = 2025 \text{ mm}^2$

$\therefore$ Select 12 Ø 20 As =3769.91mm^2 > Ast = 2025 mm^2

$\rightarrow \boldsymbol{\rho}\text{g} = \frac{\textbf{Ast}}{\boldsymbol{Ag}} = \frac{\textbf{3769.91}}{\textbf{202500}} = \mathbf{0.0186 = 1.86}\%$

4.5.10. Design of Ties:

Use ties ∅ 10 with spacing of ties shall not exceed the smallest of:

→ 48 times the tie diameter, 48ds = 48 · 10 = 480 mm

- 16 times the longitudinal bar diameter, 16db = 16 · 20 = 320 mm − **control**

→ The least dimension of the column = 450 mm.

$\therefore$ Use ties ∅ 10 @ 200 mm.

4.5.11. Check for code requirements:

1. Clear spacing between longitudinal bars:
2. Clear space = $\frac{\mathbf{450 - 40*2 - 10*2 - 20*4}}{\mathbf{3}} = \mathbf{90\ mm}$>40mm >1.5db = 1.5 · 20= 30 mm −control
3. Gross reinforcement ratio:
4. $\mathbf{0.01 < \rho g = 0.0186 < 0.08}$ − OK
5. Number of bars: 12> 4 – for rectangular section − OK
6. Minimum tie diameter: ∅ 10 for ∅ 20 bars − OK
7. Spacing of ties: S= 200 mm − OK
8. Arrangement of ties: 90 < 150 mm− OK (from left side)

BUT 90+90+20=20 >150 mm --- we need to use S hock (from right side)

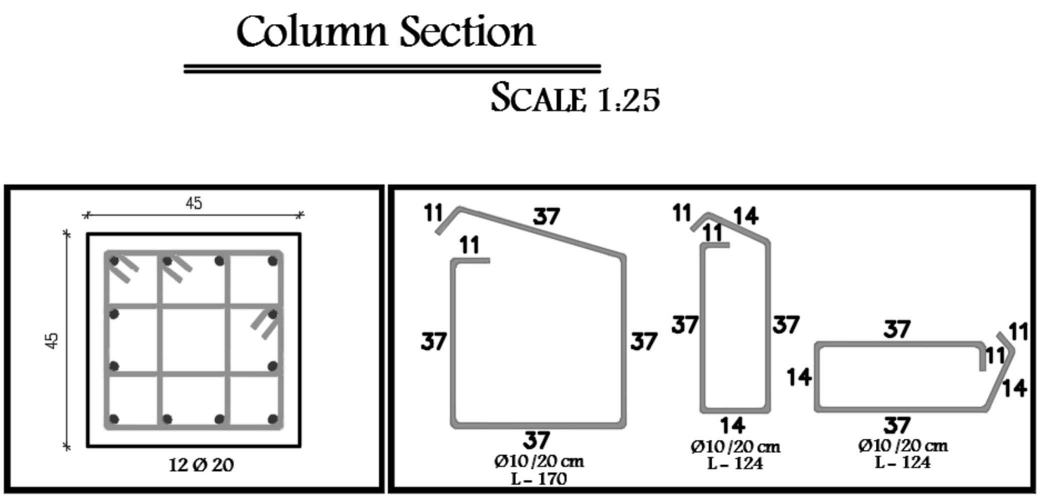
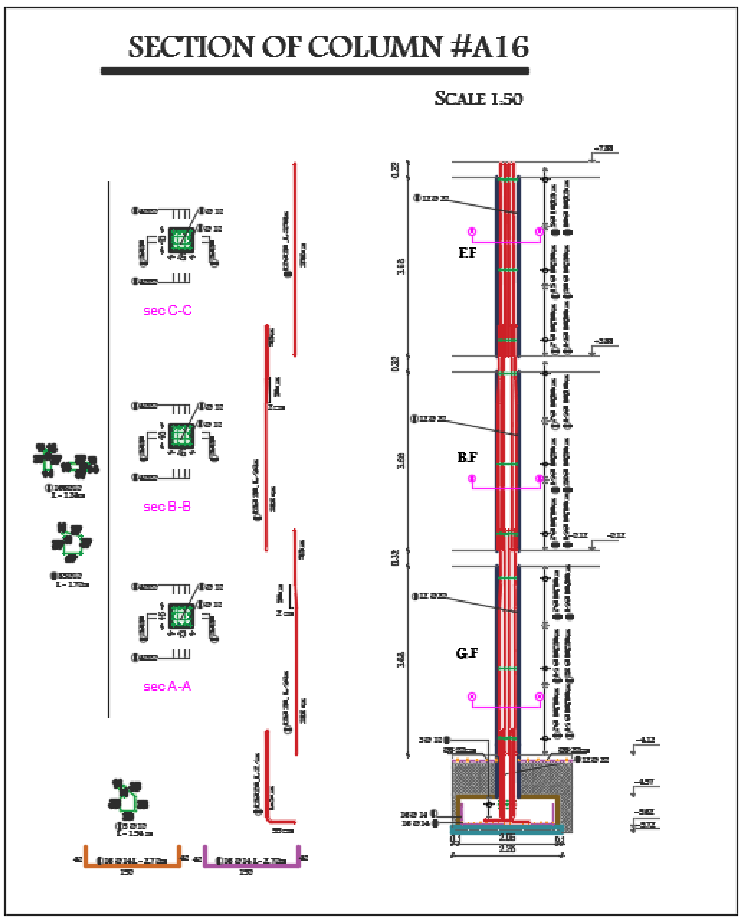


Figure (4.11): Cross Section Details of A16



Figure(4.12): A16 Reinforcement Details

4.6. Design of Isolated Footing For Column B13

- **Loads that act on footing B13 are:**
- PD =822.63 kN , PL = 324.63kN $\rightarrow$ Pu = 1.2 * 822.63 + 1.6*324.63= 1506.564 kN

- **The following parameters are used in design:**
- γ_{concrete} = 25 kN/m^3
- γ_{soil} = 18 kN/m^3
- σ_{allow} = 400 kN/m^2
- clear cover =7.5cm
- Service surcharge 5 kN/m^2
- Hieght of backfill =70 cm
- The compressive strength of concrete is B300 which equals to Fc′ = 24 MPa.

4.6.1.Determination of footing dimension (a):

Footing dimension can be determined by designing the soil against bearing pressure.

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

→ Assume h = 65 cm
→ $W_{footing}$ =0.65*25=16.25 kN/m^2
→ W_{Soil} =0.70*18 =12.6 kN/m^2
→ Total surcharge load on foundation = 16.25+5+12.6=33.85kN/m^2
→ Net soil pressure, $q_{a,net}$ = 400 – 33.85= 366.15kN/m^2

- Required sizes of footing:

→ $A=\frac{Pn}{qa,net}=\frac{822.63+324.63}{366.15}$ =3.133 m^2
→ A =3.133m^2 → L= $\sqrt{3.133}$ = 1.77 m
→ Select L= 2 m
→ $Bearing\ Pressure$ qu = $\frac{pu}{A}=\frac{1506.564}{2*2}$ = 376.64kN/m^2

4.6.2.Determination of footing depth (h)

To determine depth of footing both of one- way and two-way shear must be designed.

4.6.2.1. Design of one-way shear

- Assume cover = 75mm and steel bar of Ø12
- Take h =650 mm

→ $d = \text{h} - cover - \text{Ø} = 650 - 75 - 12 = 563\ mm$

→ Vu at distance d from the face of column:
$\text{Vu} = FRB = \sigma bu \times 0.212 \times b$
$\text{Vu} = 376.64 \times 0.212 \times 2 = 159.7$ KN

→ $\text{Ø} * \text{Vc} = 0.75 * \frac{1}{6} * \sqrt{\text{Fc}'} * \text{b} * \text{d}$
$= 0.75 * \frac{1}{6} * \sqrt{24} * 2000 * 563 = 689.53$ kN

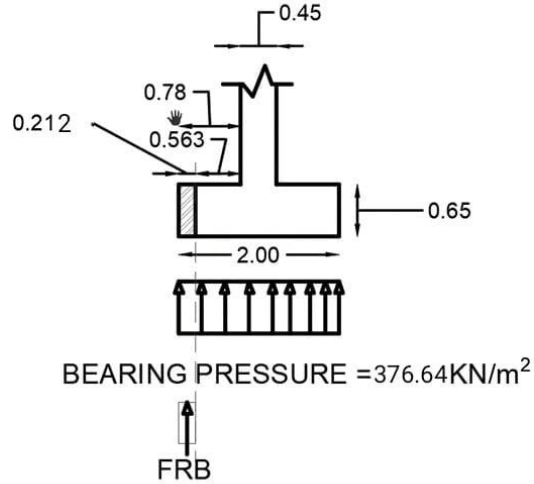


Figure (4- 13) Critical Section of Shear Force

- **Ø Vc =689.53 kN > Vu =159.7 kN**

So, h = 65 cm is adequate for one way shear

∴ **h = 65 cm is correct ✓**

4.6.2.2. Design of Punching (two-way shear)

→ $d = 563\ mm$
→ d/2 = (563/2) = 281.5 mm
→ $\text{b}_\circ$ = 4 × (450+ d/2+ d/2) =
=4 × (450+ 281.5 + 281.5) = 4052 mm
→ β = 450/450 = 1
→ αs = 40 (interior column)

- **Vu = 376.64 (2*2- (0.45+0.563) (0.45+0.563))**

=1120.06 KN

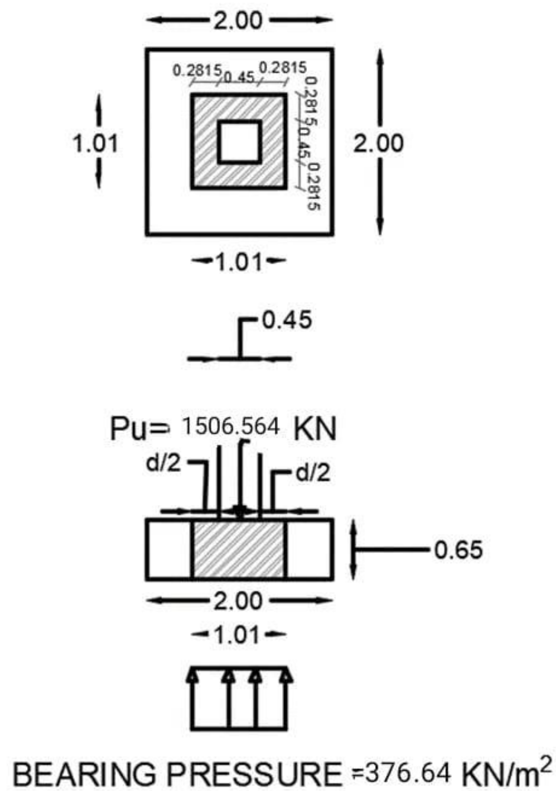


Figure (4- 14): Punching Shear Critical Section

- **Ø×Vc is the smallest of:**

❖ $Vc = \left(2 + \frac{4}{\beta}\right) \times \frac{\sqrt{fc'}}{12} \times b_o \times d$

$= \left(2 + \frac{4}{1}\right) \times \frac{\sqrt{24}}{12} \times 4052 \times 563 \times 10^{-3}$

$= 5588$ kN

❖ $Vc = \left(\frac{\propto_s \times d}{b_o} + 2\right) \times \frac{\sqrt{fc'}}{12} \times b_o \times d$

$= \left(\frac{40 \times 563}{4052} + 2\right) \times \frac{\sqrt{24}}{12} \times 4052 \times 563 \times 10^{-3}$

$= 7038.74$ kN

❖ $Vc = 4 \times \frac{\sqrt{fc'}}{12} \times b_o \times d$

$= 4 \times \frac{\sqrt{24}}{12} \times 4052 \times 563 \times 10^{-3}$

= **3725.31 kN .. ∢ cont.**

- Ø×Vc = 0.75 × 3725.31 = **2794 kN** > **Vu = 1120.06 kN**

∴ **h = 65 cm is correct ✓**

4.6.3.Design of Reinforcement

Mu = 376.64 *0.78*2*(0.78/2) = 114.57 kN.m

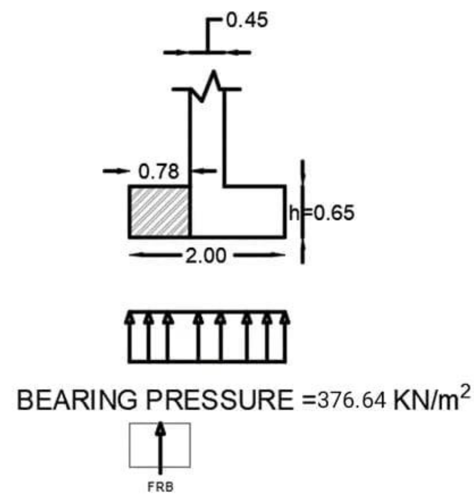


Figure (4- 15): Critical Section of Bending Moment

- $m = \frac{Fy}{0.85 * Fc'} = \frac{420}{0.85*24} = 20.6$

- Mn = 114.57/0.9= 127.3 kN.m

- $Rn = \frac{Mn/\emptyset}{b*d^2} = \frac{127.3 * 10^6}{2000*563^2} = 0.2$ MPa

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

  $= \frac{1}{20.6} * (1- \sqrt{1 - \frac{2*0.2*20.6}{420}}) = 4.785* 10^{-4}$

- Asreq = $\rho * b * d = 4.785 * 10^{-4} * 2000 * 563$
  $=$ 538.85 mm^2

- As (min) = 0.0018*b*h = 0.0018*2000 * 650 = 2340 mm^2

- Asreq = 538.85 mm^2 < As (min) =2340 mm^2

  ∴ **As = As(min) = 2340 mm^2**

Select for both directions: 21 Ø 12 with As = 2375.04 mm^2 > Asreq … (ok)∴

4.6.4.Design the Connection between Column & Footing

→ **Design of bearing pressure at section of column:**

$\emptyset \times Pnb = 0.65 \times 0.85 \times fc' \times A1 \geq Pu$

$= 0.65 \times 0.85 \times 24 \times 450 \times 450 \times 10^{-3} = 2685.15$ kN > Pu =1506.564 kN

Thus, the maximum load that can be transferred by bearing is 2685.15 KN, and dowels are not needed.

Minimum area of dowels = 0.005 Ag = 0.005*450*450 = 1012.5 mm^2

Select for both dowels: 12Ø20 with As= 3769.91 mm^2 > As req … (ok)

∴ **Select 12Ø20 which is just like the reinforcement of column**

→ **Check Compression lap splice between steel of column and dowels (Lsc):**

$Lsc\ creq = 0.071 \times fy \times db = 0.071 \times 420 \times 20 = 596.4$ mm >300mm

∴ ***Select Lsc* = 60 cm > *Lsc req* = 59.6cm**

→ **Design of compression development length (Ldc):**

- $Ldc = 0.24 \times \frac{fy}{\sqrt{fc'}} \times db = 0.24 \times \frac{420}{\sqrt{24}} \times 20 = 411.5$ mm .. ≮ cont.
- $Ldc = 0.043 \times fy \times db = 0.043 \times 420 \times 20 = 361.2$ mm

  ∴ ***Ldc* req = 411.5 mm**

- $Available\ Ldc = 650 - 75 - 12 - 12 =$ **551** mm > Ldc req = 411.5 mm .. ok

→ **Check tension development length using simplified method (Ldt):**

Since we have a footing, it must satisfy two conditions to be considered under category A , otherwise it will considered as category B :

1- $Clear\ lateral\ spacing = \frac{2000-(2*75)-(21*12)}{20} = 79.9$ mm > 2db = 2*12 =24mm ✓

2- $Clear$ cover = 75 mm > 1 db = 12 mm ✓

⇨ Category A

→ **Design of tension development length (Ldt):**

- Ld, req = $\frac{12}{20} \times \frac{fy}{fc'} \times \frac{\varphi t \times \varphi e}{\lambda} \times db = \frac{12}{20} \times \frac{420}{24} \times \frac{1 \times 1}{1} \times 20 = 210$ mm
- Ld, available $= \frac{2000-450}{2}$ - 75 = 700 mm > Ldt, req..... (ok)

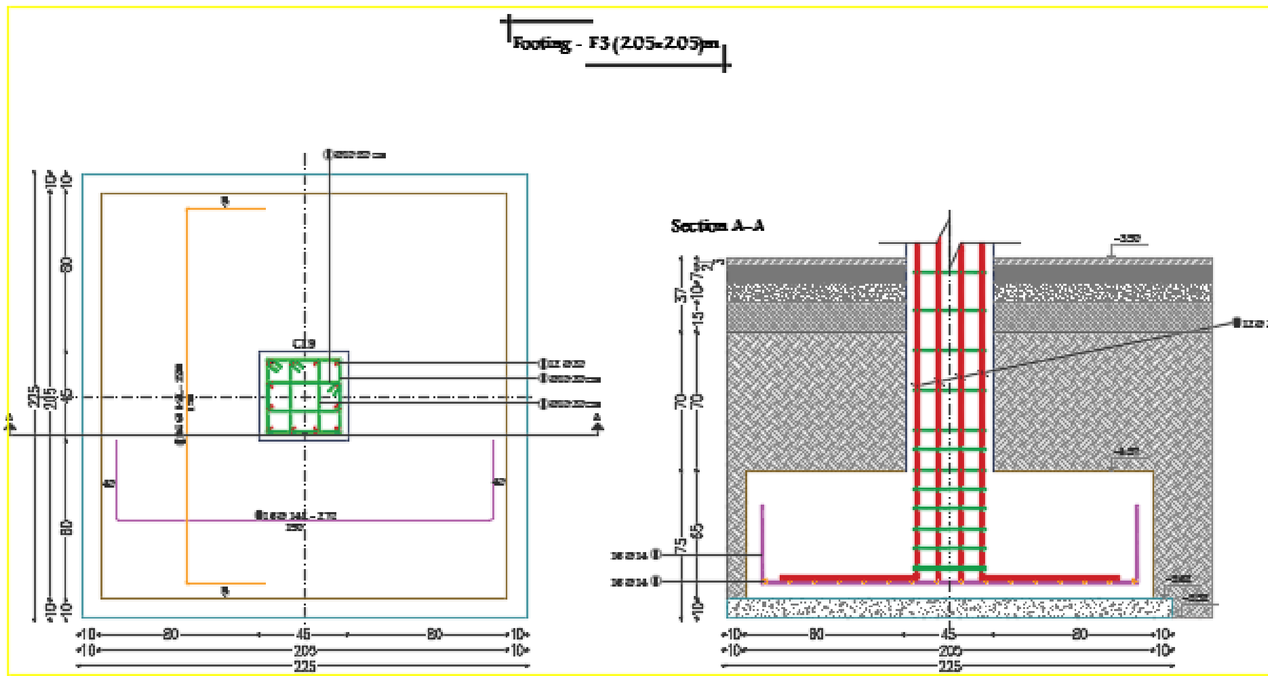


Figure (4- 16):F3 Reinforcement Detail

4.7. Design of Basement Wall

4.7.1. System and Loads

The wall spans vertically and it is considered to be pinned at both ends as shown in figure (4-17) which also illustrate loads that act on the wall.

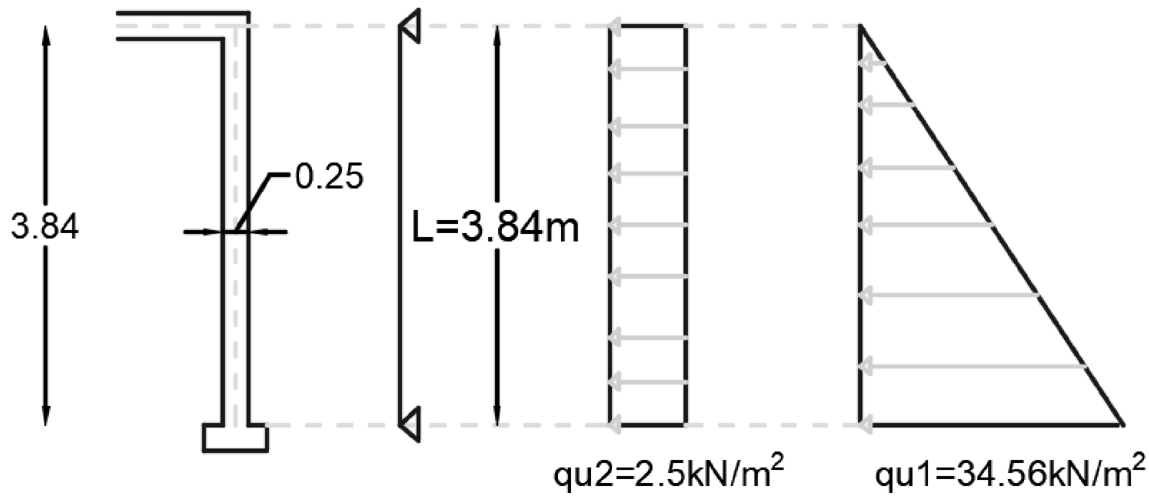


Figure (4- 17): Basement Wall system and loads

- The different lateral pressures on a 1m length of the wall are calculated as follows:

→ $k_o = 1 - \sin 30 = 0.5$

→ Due to soil pressure at rest: qu1 = $k_o * \gamma * h$ = 0.5*18*3.84=34.56 kN/m^2

→ Due to surcharge: qu2 = 5*0.5 =2.5 kN/m^2

The following are shear and moment diagrams that obtained from Atir Software.

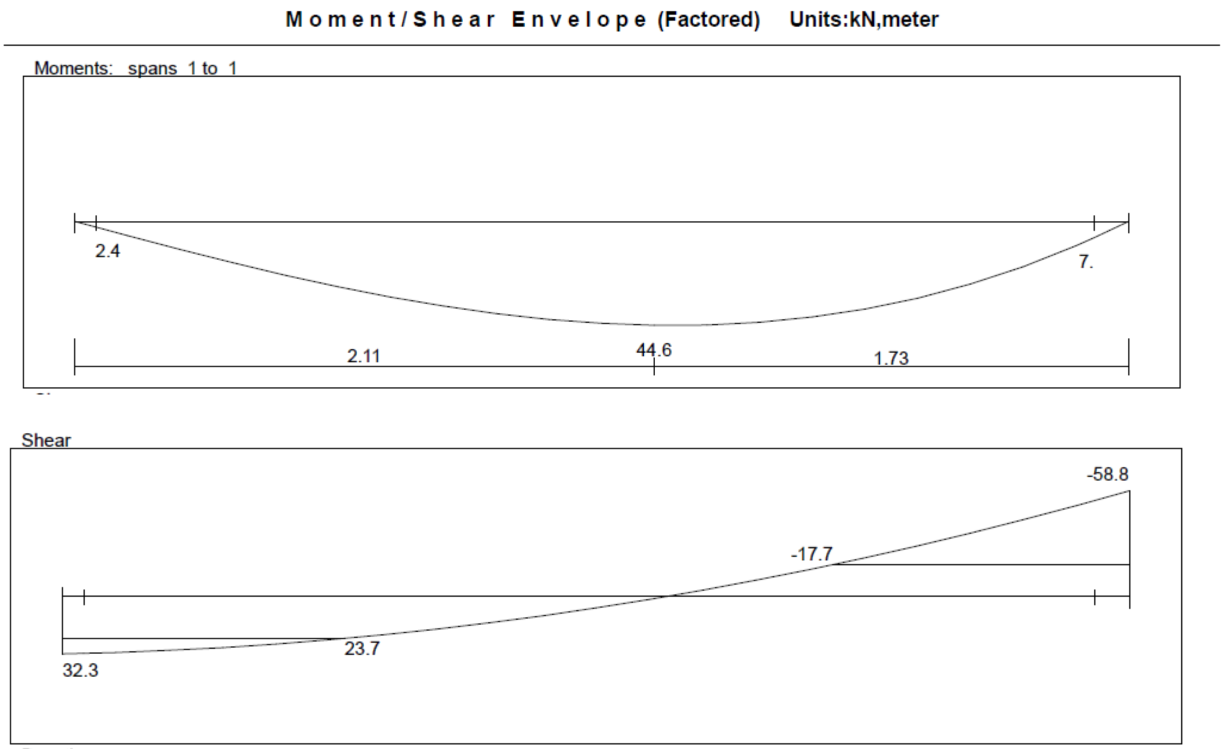


Figure (4- 18): Moment and Shear Envelope of Basement wall

4.7.2. Design of Shear Force

Max value shear force is obtained from figure (4-18), Vu= 23.7 kN

d=250-75-(12/2) = 169 mm

$\text{Ø} * \text{Vc} = 0.75 * \frac{1}{6} * \sqrt{28} * 1000 * 169*10^{-3} = 111.78 \text{ kN} > \text{Vu}=23.7 \text{ kN}$

∴ **h=25cm is correct.**

4.7.3. Design of Wall Reinforcement

1. Design of Vertical Reinforcement at Tension Side:

Max value Moment is obtained from figure (4-18), Mu = 44.6 kN.m

- $\text{m} = \frac{420}{0.85*28} = 17.65$

- $Mn = 44.6 / 0.9 = 49.56$ kN.m
- $Rn = \frac{Mn}{b*d^2} = \frac{49.56*10^6}{1000*169^2} = 1.74$ MPa
- $\rho = \frac{1}{17.65} * (1- \sqrt{1 - \frac{2*1.74*17.65}{420}}) = 4.31*10^{-3}$
- $Asreq = \rho * b * d = 4.31 * 10^{-3} * 1000 * 169 = 728.39\ mm^2/1m$
- As (min) = 0.0015*b*h = 0.0015*1000* 250 = 375 mm^2 /1m

∴ Select Ø12/15cm with As = 753.33mm^2 /m > As req

2. Design of Vertical Reinforcement Compression Side:

- As = As (min) = 0.0012*b*h = 0.0012*1000* 250 = 300 mm^2 /1m

∴ Select **Ø10/25cm with As = 316mm^2 /m**

3. Design of Horizontal Reinforcement:

- As (min) for 2 layers = 0.002 *b*h
- As one layer = 0.001 *1000*250 = 250 mm2 /m for one layer

∴ **Select Ø10/25cm with As = 316mm^2 /m**

4.8. Design of Shear Wall 18

Analysis and design were done using ETABS program in which the seismic loads were taken into account. The following is a sample calculation for one of the walls, S.W#18:

The following data that used in design:

- Shear Wall thickness = h = 25cm
- Shear Wall length Lw = 4.2 m
- Building height Hw=12 m
- Critical section shear: Lw < hw → d =0.8*Lw =3.36 m

4.8.1. Check maximum shear strength permitted

- $ØVn = Ø \times 0.83 \times \sqrt{fc`}$ ×h×d = 0.75 × 0.83× $\sqrt{28}$ ×250×3360× 10^{-3}

  = 2766.93 kN

- Vu max (from ETABS) = 670.79 kN
- $ØVn$ =2766.93 kN > Vu max = 670.79 kN

4.8.2. Calculate shear strength provided by concrete Vc

- **Critical section for shear:**
- Lw/2 = 4.2/2 = 2.1 m .... **Controlled**
- Hw/2 = 12/2 = 6 m
- Story height = 4 m
- **Vc** = $\frac{1}{6}\sqrt{fc'} \times h \times d = \frac{1}{6}\sqrt{28} \times 250 \times 3360 \times 10^{-3}$

  =740.81 kN .... **Controlled**

  OR

- **Vc** = $0.27\sqrt{fc'} \times h \times d + \frac{Nu*d}{4lw} = 0.27\sqrt{28} \times 250 \times 3360 \times 10^{-3} + 0$

  $= 1200.11$ kN

- **Mu (**from ETABS at critical section ------ (4m -2.1 = 1.9 m) = **1058.93 kN.m**
- $\frac{Mu}{Vu} - \frac{lw}{2} = \frac{1058.93}{670.79} - \frac{4.2}{2}$ **= -0.52 < 0 (-Ve Value) …….so, this equation doesn't apply**

$Vc = \left[0.05\sqrt{fc'} + \frac{Lw\left(0.1\sqrt{fc'}+\frac{Nu}{Lw.h}*0.2\right)}{\frac{Mu}{Vu}-\frac{Lw}{2}}\right] \times\ h \times d)$ **…….so, this equation doesn't apply**

4.8.3. Design of Horizontal Reinforcement

Calculation of Shear Strength Provided by concrete Vc:

Vu max = 670.79 kN > 0.5× $ØVc$ = 0.5× 0.75 × 740.81 = 277.8 kN …………… **Horizontal Reinforcement is Required.**

$\rightarrow Vs = \frac{Vu}{Ø} - Vc = \frac{670.79}{0.75} - 740.81 = 153.58$ kN

$\rightarrow \frac{Avh}{s} = \frac{Vs}{fy*d} = \frac{153.58}{420*1000*3.36} = 1.088 \times 10^{-4}$ m^2/m

$\rightarrow \rho t = \frac{Avh}{hS2} = \frac{1.088 \times 10^{-4}}{0.25} = 4.353\times 10^{-4} < 0.0025$

∴**Take ρt= 0.0025**

- **Maximum spacing is the least of:**
- $\frac{lw}{5} = \frac{4200}{5} = 840$ mm
- $3h = 3 \times 250 = 750$ mm
- 450 mm …………………………… **Controlled**

- Avh: For 2 layers of Horizontal Reinforcement

Select Ø10 :

- Avh = 2 *78.5= 157 mm2
- $\rho t = \frac{Avh}{hS2} = \frac{157}{250*S2} = 0.0025 \rightarrow Sreq = 251.2\ mm$

∴ **Select Ø10 @ 250 mm at each side.**

4.8.4. Design of Vertical Reinforcement

- ρl= [0.0025 +0.5 (2.5-$\frac{hw}{lw}$)($\rho t - 0.0025$)] ≥ 0.0025

$\frac{hw}{lw} = \frac{12}{4.2} = 2.86 \geq 2.50$ ………… ∴**Take ρl= 0.0025**

- **Maximum spacing is the least of:**

- $\frac{lw}{3} = \frac{4200}{3} = 1400$ mm
- $3h = 3 \times 250 = 750$ mm
- 450 mm ……………………………. **Controlled**

∴ **Select Ø12 @ 300 mm at each side.**

4.8.5. Design for flexure

- Moment diagram were obtained from ETABS:

Max Mu =1934.21 kN.m

- **Using uniformly distributed flexural reinforcement method:**

$$ØMn= Ø\ [\ 0.5×Ast×fy×Lw\ (1+ \frac{Pu}{Ast×fy})(1-\frac{C}{lw})]$$

> **Check moment strength based on required vertical reinforcement for shear**:
> The uniformly distributed vertical reinforcement Ø 12 @ 300 mm

- Ast =2*113.1 *$\frac{4200}{300} = 3166.8$ mm^2
- $\omega = \frac{Ast}{h*lw} \times \frac{fy}{fc`} = (\frac{3166.8}{4200 \times 250}) \times (\frac{420}{28}) = 0.04524$
- $\alpha = \frac{Pu}{lw \times h \times fc`} = 0$
- $\frac{C}{lw} = (\frac{\omega + \alpha}{2\omega + 0.85\beta1}) = (\frac{0.04524 + 0}{2 \times 0.04524 + 0.85 \times 0.85}) = 0.0556$
- $ØMn= Ø\ [\ 0.5×Ast×fy×Lw\ (1+ \frac{Pu}{Ast×fy})(1-\frac{C}{lw})]$

$$= 0.9 \times [\ 0.5×3166.8×420×4200\ (1 - 0.0556)] \times 10^{-6} = 2374.038 \text{ kN.m}$$

∴ ØMn max=2374.038 kN.m > Max Mu =1934.21 kN.m ……………… **ok**

So, Boundary Element is not required. #

∴ **Use Ø12 @ 300 mm at each side.**

4.9. Design of Strip Footing For B.W13

Loads that act on Wall footing is obtained from ETABS where:

- q_D= 236.8 kN/m & q_L= 36.4 kN/m
- Total Service Loads: P_n=236.8+36.4 = 273.2 kN/m
- Total Factored Loads: P_u =1.2× 236.8 + 1.6 × 36.4 = 342.4 kN/m
- σallow /allowable soil pressure /q_a = 400 kN/m^2
- The compressive strength of concrete is B300 which equals to Fc′ = 24 MPa.
- Assume we have the height of backfill above the foundation surface =70cm.
- γ soil = 18 kN/m

4.9.1.Estimate the size of footing

- Consider a 1-m strip of footing and wall
- Assume h =40cm, steel bars Ø 20
- $q_{a,net}$ = 400 – (0.4× 0.25) – (0.7× 18)= 387.3 kN/m^2
- A=$\frac{Pn}{qa,net}$ = $\frac{273.2}{387.3}$ = 0.705 m^2 per meter length of wall
- A = b× 1 → b = 0.705 m ……. ∴ Take b=0.8 m

∴**b =0.8 m**

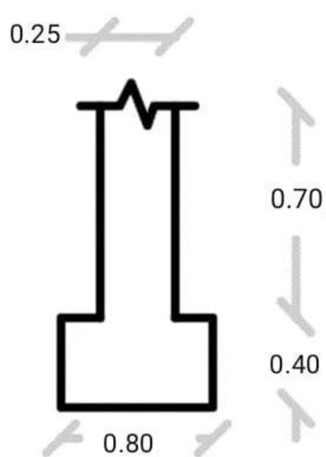


Figure (4- 19): Assumption for Estimate the size of footing

4.9.2. Depth of footing and shear design

- $q_u = \frac{342.4}{0.8} = 428\ kN/m^2$

☒ **One way shear (Beam shear)**

Shear usually govern the thickness of footing. Only one-way shear is significant in a wall footing. Vu at distance d from the face of column:

- $Vu = qu \times 1 \times (\frac{b}{2} - \frac{a}{2} - d) = 428 \times 1 \times (\frac{0.8}{2} - \frac{0.25}{2} - d)$
- $ØVc = Ø \times \frac{1}{6} \times \sqrt{fc`} \times bw \times d = 0.75 \times \frac{1}{6} \times \sqrt{24} \times 1000 \times d = 612.37\ d$
- Let Vu = ØVc

  $428 \times 1 \times (\frac{0.8}{2} - \frac{0.25}{2} - d) = 612.37\ d$

  $55.981 - 447.848\ d = 612.37d$ ➡ ∴ d=0.113 m
- h=113+75+20 = 208mm

  ∴ Take h =40 cm

- $d = 400 - 75 - \frac{20}{2} = 315\ mm$

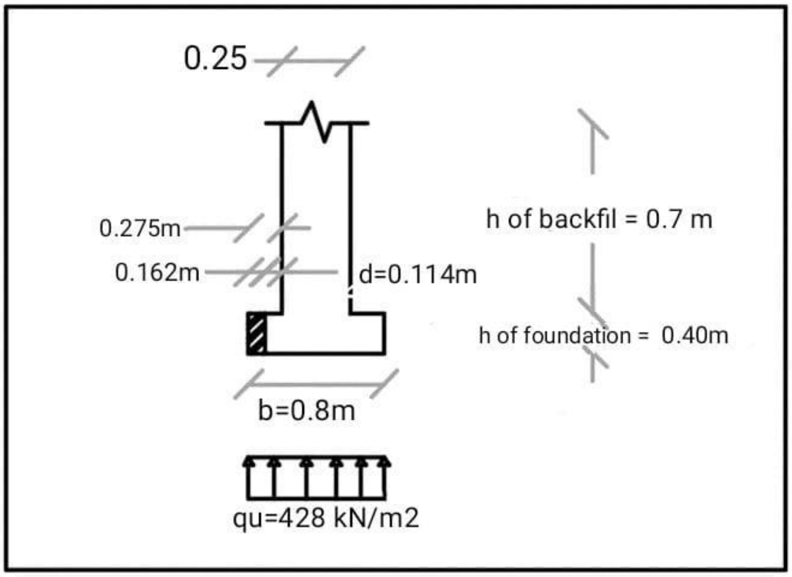


Figure (4- 20): Critical Section of Shear force

4.9.3. Design for flexure

Main Steel:

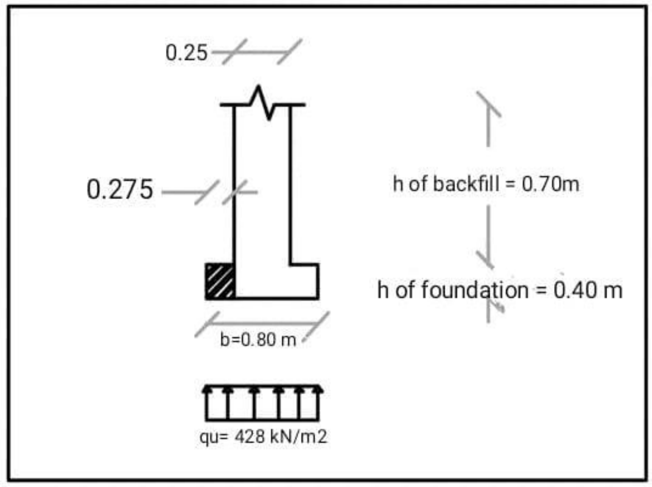


Figure (4- 21): Critical Section of Bending Moment

- Mu =428 ×1×0.275× (0.275/2) = 16.18 kN.m
- $Rn = \frac{Mn}{\emptyset \times b \times d^2} = \frac{16.18 * 10^6}{0.9 \times 1000 \times 315^2}$ = 0.18 MPa
- $m = \frac{fy}{0.85 \times fc'} = \frac{420}{0.85 \times 24} = 20.6$
- $\rho = \frac{1}{20.6} \times (1 - \sqrt{1 - \frac{2 \times 0.18 \times 20.6}{420}}) = 4.3 \times 10^{-4}$
- $As_{req} = \rho \times b \times d$
- $= 4.3 \times 10^{-4} \times 1000 \times 315$

  = 135.45 mm2 /m
- $As_{(min)} = 0.0018 \times b \times h$

  $= 0.0018 \times 1000 \times 400 = 720\ mm^2/m$
- $As_{(min)} = 720\ mm^2/m > As_{req} = 135.45$ mm2 /m

$As_{(min)} = 720\ mm^2/m$………..Controlled

- **Step (S) is the smallest of:**
  1) 3h = 3× 400 = 1200 mm
  2) 450mm ……**Controlled**

∴ **Select Ø12/15cm with As = 754 mm^2 > As_{min}**

Secondary Steel:

- $As_{(min)} = 0.0018 \times b \times h = 0.0018 \times 800 \times 400 =$ **576 mm^2**
- **The maximum spacing**:
  1) 5h = 5× 400 =2000 mm
  2) 450 mm ……………. **Controlled**

∴ **Select 6 Ø 12 As = 678.6 mm^2 > As_{min}**

❖ The Following figure shows details of a section taken in a basement wall and its footing

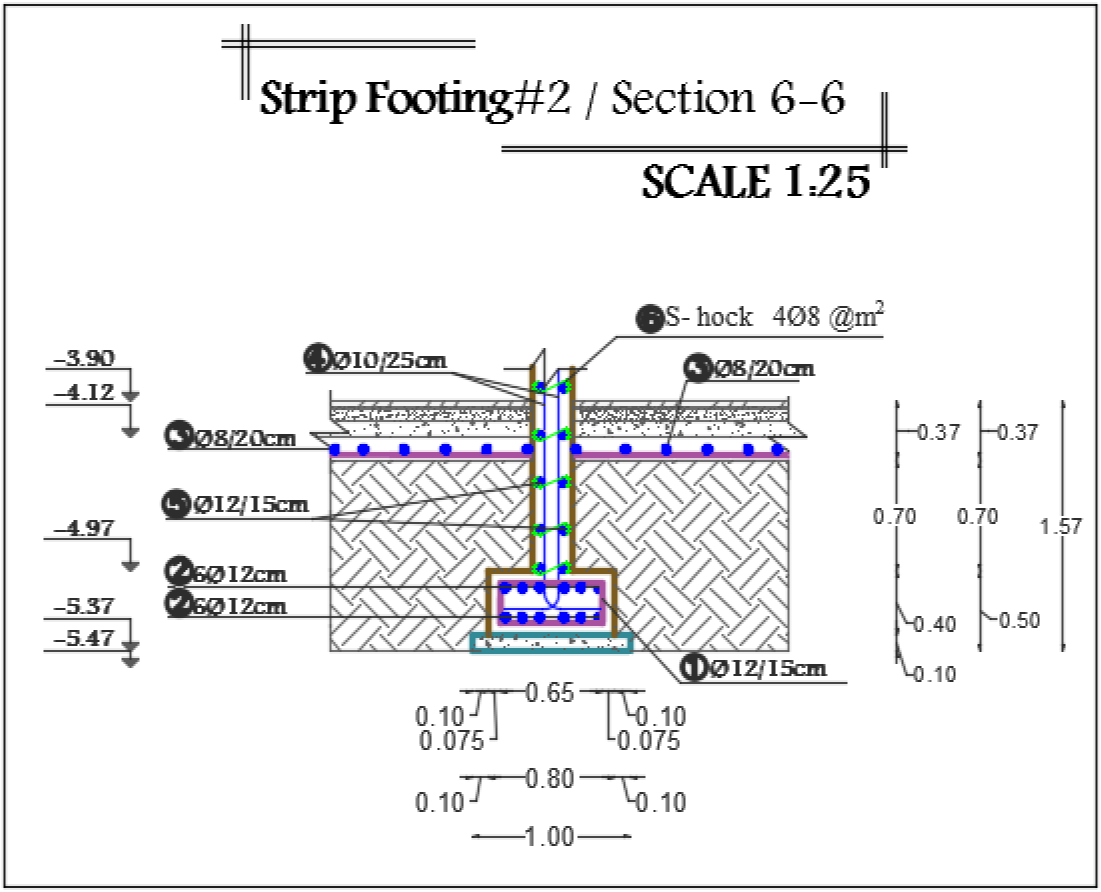


Figure (4- 22): Basement wall And Its Strip Footing Reinforcement Details

4.10. Design of stair case 1

The following figure shows a top view of the stairs:

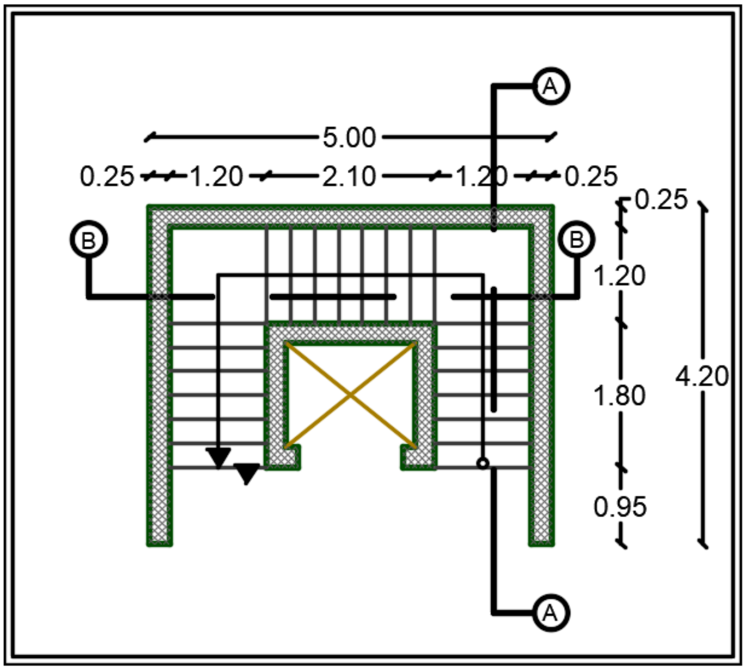


Figure (4- 23): Stair Case Top View

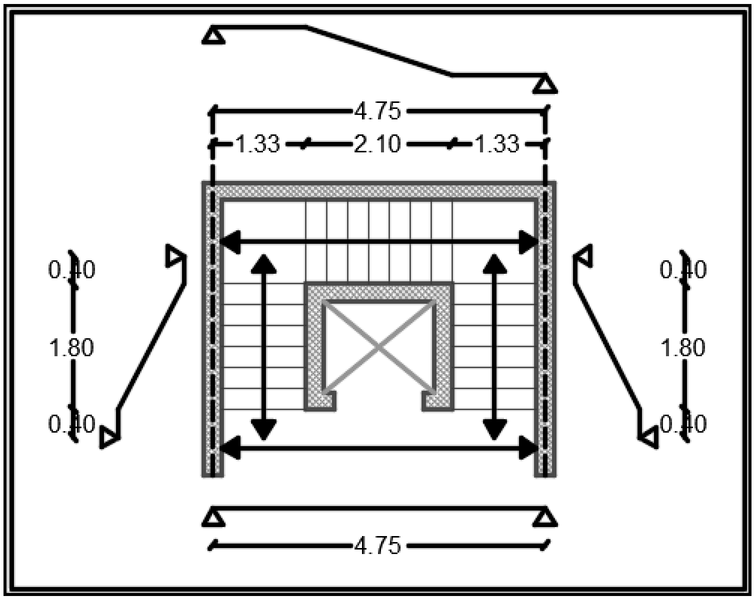


Figure (4- 24): Structural System of Stair Case

4.10.1. Design of Flight for Section A-A: -

The structural system of the flight is shown in figure (4-24) and the following steps explain the design procedure of the flight:

✓ Determination of Thickness: -

- h_{min} = L/20
- h_{min} = 2.6 /20 = 0.13 m

  ∴ **Take h = 250 mm**

✓ Load Calculation:

- The Stair Slope by θ = $\tan^{-1}$ (rise / run)

  = $\tan^{-1}$ (180 / 300)

  = 30.96°

- Dead Load For Flight for 1m Strip:

Table 4.5: Calculation of Dead Loads that act on Flight

Material	Quality Density KN/m^3	Calculation	W KN/m
Tiles	22	$22*\frac{(0.18+0.35)}{0.3}*0.03*1$	1.17
Mortar	23	$23*\frac{(0.18+0.30)}{0.3}*0.02*1$	0.74
Stair Steps	25	$\frac{25}{0.3}*\frac{(0.18*0.30)}{2}*1$	2.25
Reinforced Concrete Solid Slab	25	$\frac{25*0.25*1}{Cos\ 30.96^{\circ}}$	7.29
Plaster	23	$\frac{23*0.02*1}{Cos\ 30.96^{\circ}}$	0.54
Total Dead Load, KN/m			11.99 KN/m

- Live Load For Landing for 1m Strip = 4*1 = 4 KN/m

- Factored Load For Flight:

→ Wu = (1.2 ×11.99) + (1.6×4) = 20. 79 KN/m

✓ Analysis:

The following figures show the load that act on Flight:

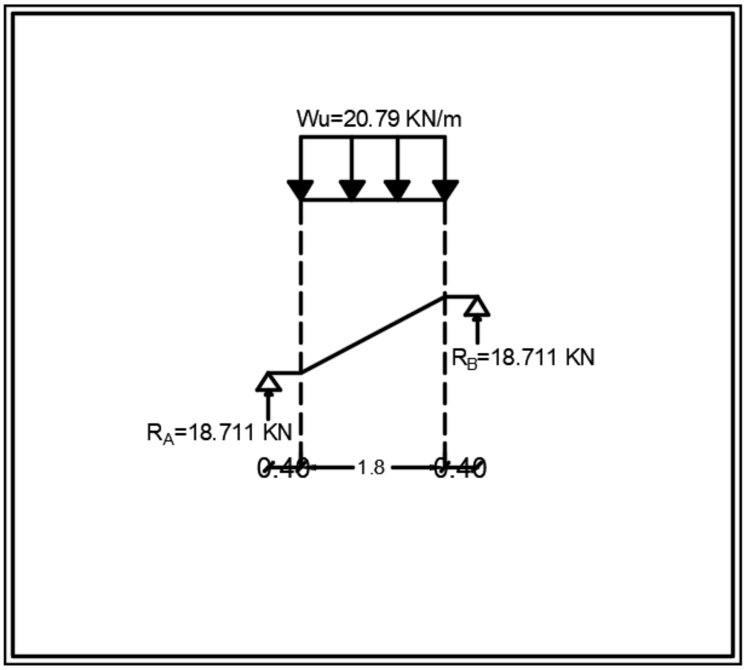


Figure (4- 25): Analysis of the flight A-A

- The reaction at each end:

  R = $\frac{W*L}{2} = \frac{20.79*1.8}{2}$ = 18.711 kN

- Calculate the maximum bending moment and steel reinforcement:

  M_u = 18.711 * (0.40+ 0.9) – 20.79 * $\frac{0.9^2}{2}$ = 15.9 kN.m

✓ Design:

- Design of Shear for Flight: -

<u>Assume bar diameter Ø14 for main reinforcement.</u>

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

→ Take the maximum shear as support reaction V_u = 18.711 KN

→ $ØV_c = 0.75 * \frac{1}{6}\sqrt{fc'}b_w\, d = 0.75 * \frac{1}{6} * \sqrt{28} * 1000 * 223 * 10^{-3} = 147.5$ KN/1m strip

→ Vu, max = 18.711 KN < 0.5 $ØV_c$ = 0.5 ∗ 147.5 = 73.75 KN

∴ <u>The thickness of the slab is adequate enough</u>

- Design of Bending Moment for Flight: - (Mu=+15.9 KN.m)

→ Mn = Mu/0.9 = 15.9 /0.9 = 17.67 KN.m/m
→ Assume bar diameter Ø14 for main reinforcement, d=223 mm.
→ $R_n = \frac{M_n}{bd^2} = \frac{17.67\times10^6}{1000\times223^2} = 0.355\ Mpa$
→ $m = \frac{f_y}{0.85f_c'} = \frac{420}{0.85\times28} = 17.65$
→ $\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{17.65}\left(1-\sqrt{1-\frac{2\times17.65\times0.355}{420}}\right) = 8.52 * 10^{-4}$
→ $As_{,\ req} = \rho*b*d = 8.52 * 10^{-4}\times1000\times223 = 189.996\ mm^2/m$
→ $As_{,\ min} = 0.0018*1000*250 = 450\ mm^2/m$
→ $As_{,\ req} = 189.996\ mm^2 < As_{,\ min} = 450\ mm^2/m$

∴ $As = As_{,\ min} = 450\ mm^2/m$

∴ Use 4 Ø 12 with As=452.4 mm2/m OR Ø 12/250 mm.

- Check for Spacing (s) is the smallest of:
  1. S = 3h = 3*250 =750 mm
  2. S = 450 mm
  3. $S = 380*(\frac{280}{fs}) - 2.5\ C_c = 380*(\frac{280}{\frac{2}{3}*420}) - (2.5*20) = 330$ mm …….. **Controlled**

  But $S \leq 300(\frac{280}{fs}) = 380*(\frac{280}{\frac{2}{3}*420}) = 380$ mm

∴ $S = 250 < S_{max} = 330$ mm - **OK**

✓ Temperature and shrinkage reinforcement:

- $As_{,\ shrinkage\ and\ temperature} = 0.0018*b*h = 0.0018*1000*250 = 450\ mm^2$

∴ Use 4 Ø 12 with As=452.4 mm2/m OR Ø 12/250 mm.

- Check for Spacing (s) is the smallest of:
  1. S = 5h = 5*250 =1250 mm
  2. S = 450 mm …….. **Controlled**

$S = 250 < S_{max} = 400$ - **OK**

✓ Check Strain:

- C = T
  → 0.85*fc'*a*b = As*fy
  → 0.85*28*a*1000= 450*420
  → a = 7.94 mm → c = a/β = 7.94/0.85 = 9.34 mm
- ε_s = 0.003 (d-c / c)
  - ε_s = 0.003 (223 -9.34 /9.34) = 0.0686

∴ ε_s = 0.0686 > 0.005 …. Ø = 0.9 (OK)

4.10.2. Design of Landing:

✓ Determination of Thickness: -

- h_{min} = L/20
- h_{min} = 4.75 /20 = 0.2375m = 23.75 cm

∴ **Take h = 250 mm**

✓ Load Calculation: -

Dead Load For Landing for 1m Strip: -

Table 4.6: Calculation of Dead Loads that act on Landing

No.	Parts of Landing	Quality Density KN/m³	Calculation W=ɤ*h*1 (KN/m)
1	Tiles	22	**23*0.03*1= 0.69 KN/m**
2	Mortar	23	**22*0.02*1=0.44 KN/m**
3	Reinforced Concrete Solid Slab	25	**25*0.25*1=6.25 KN/m**
4	Plaster	23	**22*0.02*1=0.44 KN/m**
Total Dead Load, KN/m			**7.82 KN/m**

- Live Load For Landing for 1m Strip = 4*1 = 4 KN/m
- Factored Load for Landing: -
- Wu = (1.2 ×7.82) + (1.6×4) =15.78 KN/m

✓ Analysis:

The following figures show loads act on landing:

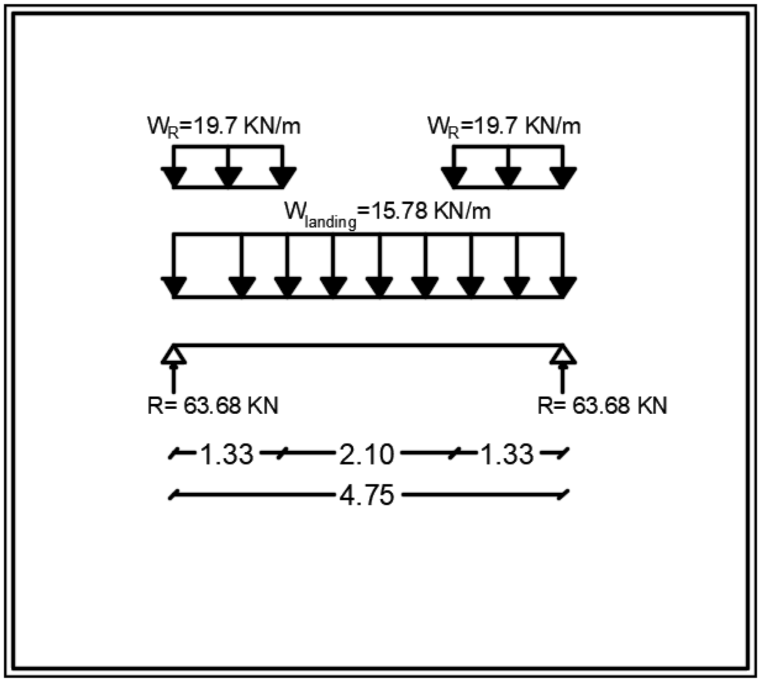


Figure (4- 26): Analysis of the landing

- $W_R = \frac{Rs1\ (per\ meter)}{B} = \frac{18.711}{0.95} = 19.7$ kN/m
- The reaction at each end:

  $R = \frac{15.78*4.75}{2} + (19.7*1.33) = 63.68$ kN
- Calculate the maximum bending moment and steel reinforcement:

  $M_u = 63.68*(\frac{4.75}{2}) - 15.78*\frac{2.375^2}{2} - 19.7*1.33*(\frac{1.33}{2} + 1.05) = 61.8$ kN.m

✓ Design:

- Design of Shear for Landing: -

Assume bar diameter Ø14 for main reinforcement.

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

→ Take the maximum shear as support reaction V_u = 63.68 KN

→ $ØV_c = 0.75 * \frac{1}{6}\sqrt{fc'}b_w\, d = 0.75 * \frac{1}{6} * \sqrt{28} * 1000 * 223 * 10^{-3} = 147.5$ KN/1m strip

→ Vu, max = 63.68 KN < 0.5 $ØV_c = 0.5 * 147.5 = 73.75$ KN

∴ The thickness of the slab is adequate enough

- Design of Bending Moment for Flight: - (Mu=+61.8 KN.m)

→ Mn = Mu/0.9 = 61.8 /0.9 = 68.67 KN.m/m

→ Assume bar diameter Ø14 for main reinforcement, d=223 mm.

→ $R_n = \frac{M_n}{bd^2} = \frac{68.67\times10^6}{1000\times223^2} = 1.38\ Mpa$

→ $m = \frac{f_y}{0.85f_c'} = \frac{420}{0.85\times28} = 17.65$

→ $\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right) = \frac{1}{17.65}\left(1 - \sqrt{1 - \frac{2\times17.65\times1.38}{420}}\right) = 3.39 * 10^{-3}$

→ $As_{,\,req} = \rho*b*d = 3.39 * 10^{-3}\times1000\times223 = 755.97\ mm^2/m$

→ $As_{,\,min} = 0.0018*1000*250 = 450\ mm^2/m$

→ $As_{,\,req} = 755.97\ mm^2 > As_{,\,min} = 450\ mm^2/m$

∴ $As = As_{,\,req} = 755.97\ mm^2/m$

∴ Use 7 Ø 12 with As = 791.7 mm2/m OR Ø 12/125 mm.

- Check for Spacing (s) is the smallest of:

4. S = 3h = 3*250 =750 mm
5. S = 450 mm
6. $S = 380 *(\frac{280}{fs}) - 2.5\,C_c = 380*(\frac{280}{\frac{2}{3}*420})- (2.5*20) = 330$ mm …….. **Controlled**

But $S \le 300(\frac{280}{fs}) = 380*(\frac{280}{\frac{2}{3}*420})$ =380 mm

∴ S= 125 mm < S_{max}=330 mm - **OK**

- Temperature and shrinkage reinforcement:

- $As_{, shrinkage\ and\ temperature} = 0.0018*b*h = 0.0018*1000*250 = 450\ mm^2$

∴ Use 4 Ø 12 with As=452.4 mm2/m OR Ø 12/250 mm.

- Check for Spacing (s) is the smallest of:
  3. S = 5h = 5*250 =1250 mm
  4. S = 450 mm …….. **Controlled**

  $S = 250 < S_{max} = 400$ - **OK**

- Check Strain:

- C = T
  → 0.85*fc'*a*b = As*fy
  → 0.85*28*a*1000= 791.7*420
  → a = 13.97 mm → c = a/β = 13.97/0.85 = 16.44 mm
- $\varepsilon_s = 0.003\ (d\text{-}c / c)$
  - $\varepsilon_s = 0.003\ (223 – 16.44 / 16.44) = 0.0377$

∴ ε_s = 0.0377 > 0.005 …. Ø = 0.9 (OK)

4.10.3. Design of Flight For Section B-B: -

The structural system of the flight is shown in figure (4-24) and the following steps explain the design procedure of the flight:

- Determination of Thickness: -

  - h_{min} = L/20
  - h_{min} = 4.75 /20 = 0.2375 m

  ∴ Take h = 250 mm

- Load Calculation:

  - The Stair Slope by $\theta = \tan^{-1}$ (rise / run)
    $= \tan^{-1}$ (180 / 300)
    $= 30.96^\circ$

- Dead Load For Flight for 1m Strip From Table (4.5):

→ Wu = (1.2 ×11.99) + (1.6×4) = 20. 79 KN/m

✓ Analysis:

The following figures show the load that act on Flight:

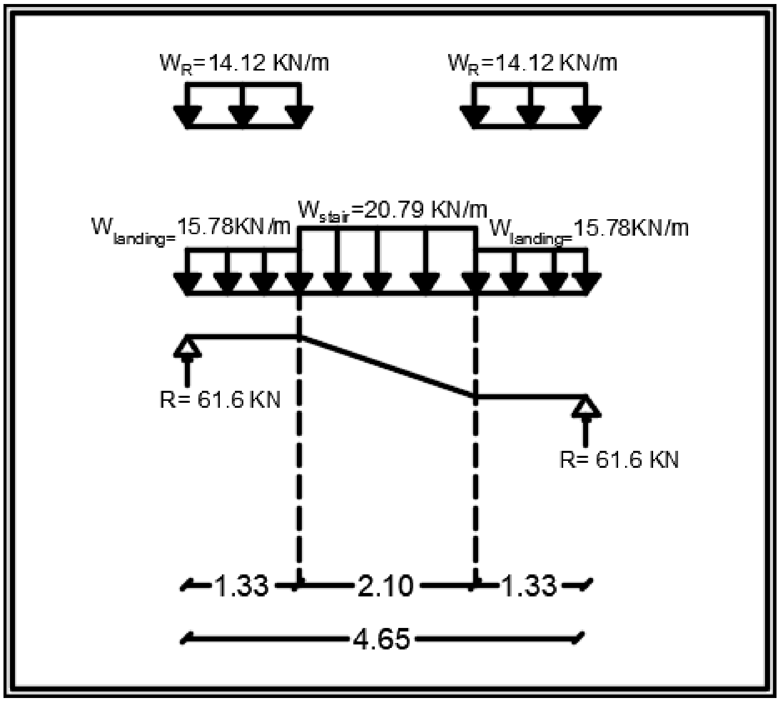


Figure (4- 27): Analysis of the flight B-B

- $W_R = \frac{Rs1\ (per\ meter\ )}{B} = \frac{18.711}{1.33}$ = 14.12 kN/m
- The reaction at each end:
  R = $\frac{20.79*2.10}{2}$ + (15.78* 1.33) + (14.12* 1.33) = 61.6 kN
- Calculate the maximum bending moment and steel reinforcement:

M_u = 61.6* ($\frac{4.75}{2}$) – 20.79* $\frac{1.05^2}{2}$ – 15.78*1.33*($\frac{1.33}{2}$ + 1.05) – 14.12*1.33*($\frac{1.33}{2}$ + 1.05)

= 66.95 kN.m

✓ Design:

- Design of Shear for Flight: -

Assume bar diameter Ø14 for main reinforcement.

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

→ Take the maximum shear as support reaction V_u = 61.6 KN

→ ØV_c = $0.75\ * \frac{1}{6}\sqrt{fc'}b_w\ d = \ 0.75 * \ \frac{1}{6} * \sqrt{28} * 1000 * 223 * 10^{-3}\ = 147.5$ KN/1m strip

→ Vu, max = 61.6 KN < 0.5 ØV_c = 0.5 ∗ 147.5 = 73.75 KN

∴ The thickness of the slab is adequate enough

- Design of Bending Moment for Flight: - (Mu=+66.95 KN.m)

→ Mn = Mu/0.9 = 66.95 /0.9 = 74.39 KN.m/m

→ Assume bar diameter Ø14 for main reinforcement, d=223 mm.

→ $R_n = \frac{M_n}{bd^2} = \frac{74.39\times10^6}{1000\times223^2} = 1.5\ Mpa$

→ $m = \frac{f_y}{0.85f_c'} = \frac{420}{0.85\times28} = 17.65$

→ $\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right) = \frac{1}{17.65}\left(1 - \sqrt{1 - \frac{2\times17.65\times1.5}{420}}\right) = 3.69 * 10^{-3}$

→ $As_{,\ req}$ = ρ*b*d = $3.69 * 10^{-3}\times1000\times223$ = 822.87 mm^2/m

→ $As_{,\ min}$ = 0.0018*1000*250 =450 mm^2/m

→ $As_{,\ req}$ = 822.87mm^2 > $As_{,\ min}$=450 mm^2/m

∴ As = $As_{,\ req}$ = 822.87 mm^2/m

∴ Use 8 Ø 12 with As =904.8 mm2/m OR Ø 12/125 mm.

- Check for Spacing (s) is the smallest of:

7. S = 3h = 3*250 =750 mm
8. S = 450 mm
9. S = 380 *($\frac{280}{fs}$) – 2.5 C_c = 380*($\frac{280}{\frac{2}{3}*420}$)- (2.5*20) = 330 mm …….. **Controlled**

But $S \leq 300(\frac{280}{fs}) = 380*(\frac{280}{\frac{2}{3}*420}) = 380$ mm

$\therefore$ S= 125mm < S_{max}=330 mm - **OK**

✓ Temperature and shrinkage reinforcement:

- $As_{\text{, shrinkage and temperature}}$ = 0.0018*b*h = 0.0018*1000*250 =450 mm^2

∴ Use 4 Ø 12 with As =452.4 mm2/m OR Ø 12/250 mm.

- Check for Spacing (s) is the smallest of:
  5. S = 5h = 5*250 =1250 mm
  6. S = 450 mm …….. **Controlled**

  S= 250 mm < S_{max}=400 mm - **OK**

✓ Check Strain:

- C = T
  → 0.85*fc'*a*b = As*fy
  → 0.85*28*a*1000= 904.8*420
  → a = 15.97 mm → c = a/β = 15.97/0.85 = 18.78 mm
- ε_s = 0.003 (d-c / c)
  - ε_s = 0.003 (223 -18.78 /18.78) = 0.033

∴ ε_s = 0.033 > 0.005 …. Ø = 0.9 (OK)

CHAPTER 5

RESULTS AND RECOMMENDATIONS

5.1 INTRODUCTION

After completing the project and dealing with problems that had been faced during the work on it, it is necessary to summarize the results that were reached and to give some recommendations that will be helpful for students who will work on such projects.

The most prominent of these problems was the existence of a swimming pool with a length of 14.5 m and the other swimming pool with a length of 11.05 m, and therefore we need to preserve these large spans without intermediate columns so that they do not fall in the middle of the swimming pool. That could have been solved by using frames, or two-way ribbed slab, or using drop beams. We decide to solve the problem by changing the bearing direction of ribs and beams and using drop beams above the pools. After dealing with that problem a complete design for all structural members was done and the results of the design are presented in a form of drawing.

5.2 RESULTS

The following are results that had been reached during the work on this project:

1. The most important step before starting a design is to study the architectural plans carefully to distribute the columns correctly.
2. The theoretical background is important but not enough, experience that reached by practicing the design is more important.it helps the engineer to be able to solve any problem that may appear in a project.
3. Gaining experience in using structural programs cannot be reached without an understanding of basic concepts of the structural design.
4. When choosing the structural system, it is better to distribute ribs in the long direction and beams in the short one that will reduce loads that act on beams which leads to reducing of reinforcement which meant reducing costs.

5.3 RECOMMENDATIONS

This project has an important role in expanding the understanding of construction projects. So, after completing this project, some recommendations should be mentioned that may help students who will work on such projects after us.

First of all, the architectural drawings had to be prepared and studied carefully to choose the most appropriate structural system. Collecting data about the project is an important step as the study of the site and the type of soil are important in choosing the construction materials to be used. Before starting the design of the building, a good structural planning must be done to determine the location of columns, beams, and shear walls to fit with architectural plans.

Before implementation, the electrical and mechanical plans of the project must be completed to introduce any possible modifications to the structural or architectural plans. It is recommended that a supervising engineer is present during the implementation of the project, and he admitted to the plans and conditions to complete the project in the best way.