بسم الله الرحمن الرحيم

Palestine Polytechnic University

College Of Engineering

Department Of Civil Engineering

Building Engineering

Graduation project

Structural design of the proposed Faculty of Medicine building at Palestine Polytechnic University

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يشهد الموقعون أدناه أنهم اطلعوا وفحصوا وأوصوا دائرة الهندسة المدنية في كلية الهندسة في جامعة بوليتكنيك فلسطين بالموافقة على مشروع **بعنوان التصميم الانشائي لكلية الطب في جامعة بوليتكنك فلسطين**

مقدم من موسى ابريق وفادي علان واحمد دويات واحم دحسين استيفاءً للحصول على متطلبات درجة البكالوريوس في الهندسة المدنية.

المشرف : د. حمدي ادعيس

التوقيع : .... التاريخ : ....

تمت الموافقة على المشروع من قبل :

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Abstract

The main idea of this project is to design a new building for medical school students. We worked on preparing the structural designs for this residential building, which consists of six floors in addition to a ground floor and a basement, with a total area of 18,199.55 m². Our goal is to provide complete structural designs for all building elements, including slabs, beams, columns, walls, and foundations, among others.

The Jordanian Load Code was approved, while the American codes (ACI 318-14) were adopted for various structural designs, and the American code (ASCE) was used for seismic loads.
Structural analysis and design programs such as BEAMD, ETABS 18, and SAFE were utilized, along with other software like Microsoft Office (Word, PowerPoint, Excel) and AutoCAD. Finally, the required construction drawings for all structural elements were prepared to ensure the design is ready for implementation.

الملخص

الفكرة الرئيسية لهذا المشروع هي إنشاء مبنى جديد لطلاب كلية الطب .ولذلك عملنا على إعداد التصاميم الإنشائية لهذا المبنى السكني الذي يتكون من ستة طوابق بالإضافة إلى الطابق الأرضي وطابق التسوية بمساحة إجمالية (١٨١٩٩,٥٥ م٢)، وهدفنا هو عمل كافة التصاميم الإنشائية لجميع عناصر المبنى من عقدات وجسور وأعمدة وجدران وقواعد ...الخ .

تمت الموافقة على الكود الأردني للأحمال، واعتماد الكود الأمريكي في التصاميم الإنشائية المختلفة (ACI-٣١٨-١٤)، واعتماد الكود الأمريكي (ASCE) لأحمال الزلازل.

تم استخدام برامج التحليل والتصميم الانشائي مثل (BEAMD) و(ETABS ١٨) و(SAFE)، وبرامج أخرى مثل AutoCAD ،(Microsoft office Word، Powerpoint، Excel وفي النهاية تم عمل الرسومات التنفيذية اللازمة لجميع العناصر الانشائية لجعلها قابلة للتنفيذ .

DEDICATION

Speech is not sweet except by thanking the one who says:

((وَقُل رَّبِّ زِدْنِي عِلْمًا

. Glory be to You, my Lord.

To the honest and trustworthy teacher of all humanity and supporter of the oppressed, our intercessor on the Day of Judgment, **Muhammad Bin Abdullah**, may God's prayers and peace be upon him.

He who nurtured me with the light of his heart...and protected me with his wisdom...to the one who gave me drink and fed me, raised me and disciplined me...to the one from whom I learned life lessons...**To my dear father.**

The flower that does not wither...the spring of tenderness...to whom words cannot describe...and the waves of the sea calm down to hear her name...to whom God singled out Paradise under her feet...**To my mother**.

Pure hearts and innocent souls... Earth angels... Anemones... To those who showed me what is beautiful in life... **To my brothers and sisters**.

Those who raised my head high proud of their friendship.. my companions... **To my dear friends.**

Those who raised the flags of knowledge and knowledge and extinguished the flags of ignorance and ignorance, who was the turn?

The greatest in guiding us to the path of knowledge is…….. **To my Honorable teachers.**

Acknowledgements

This project was a great opportunity to acquire important information and skills in our specialty, and this information was provided to us by people and entities that must be mentioned, praised and thanked.

We would like to express our endless gratitude to everyone who helped us during our project, starting with Palestine Polytechnic University, College of Engineering, Department of Civil and Architectural Engineering for providing us with everything we need to complete the project.

We would like to thank everyone who helped us during our project, and helped us obtain any information that would benefit us in our project.

We would like to sincerely thank our supervisor, **Dr. Hamdi Idais**
, who made every effort in encouraging us to do a great job, and providing our team with valuable information and advice to be better every time. Thanks for the constant support and kind communication which makes a huge impact in terms of feeling interested in what we're working on.

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LIST OF ABBREVIATIONS :

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 Introduction.

1.2 Research question.

1.3 Aims.

1.4 Objectives.

1.5 Hypothesis.

1.6 Methodology.

1.1 Introduction:

The human being is the main axis around which the various and diverse research and studies revolve, as all these works aim to try to make this person happy and protect him at all levels and levels and work to reduce the risks surrounding him or avoid their effects , as these research and projects vary between environmental fields and urban projects and so on . The goal is always the human being, regardless of his geographical location As a result of that, human from his very beginnings has been searching for all the ways and means that help him to facilitate his life and to provide all means in order to reach the comfort and services that would provide the requirements of his life and his needs . With the pursuit of man and his insistence, humans have reached the science of engineering , and if we discuss in general, we will find that engineering is the body that combines the available technical tools and knowledge activities. It is the professional activity that uses imagination, wisdom and intelligence in the application of science, technology, mathematics and practical experience so that humans can Designs, produces, and manages processes that fit human needs .

Due to the presence of the medicine specialty at Palestine Polytechnic University and the large number of students interested in the specialty, we designed this building, which contains six floors in addition to the ground floor and basement, to meet the needs of students and educational staff.

The architectural shape of the building has become one of the most important attractive elements of the building and is also considered an advertising element, which gives this building fame. The spread of these large buildings such as university colleges, complexes, etc. is considered one of the main reasons that led to the emergence of a new architectural style that gives the city a modern character due to the urban expansion we are witnessing.

In line with this construction development, the choice was made to design a College of Medicine building consisting of Six floors in addition to the ground floor and basement.This project meets all special architectural design requirements in the design of university colleges in a way that is compatible with the function of these buildings and the services they provide in terms of the project location and the necessary large spaces for various activities.

It appears from the plans that the proposed building is a College of Medicine building with a total area of 18199.55 square meters It consists of Eight floors divided into: a basement floor, which includes garages, ground , first, second, third ,forth , fifth, and sixth floor, which includes University college departments, including lecture rooms, laboratories, and spaces for intelligence games, in addition to teachers' offices, libraries, and study spaces..

1.2 Research question:

Is it possible to design or complete this project structurally according to the used codes, methods and programs?

The research problem here is to make the structural design of a College of Medicine building. The project will be studied comprehensively, and this requires complete knowledge of the load-bearing structural elements in order to find optimal construction solutions that provide safety and economic factors, as the economic factor is very important, provided that this factor does not affect the Safety factor. Also, through this project, all designs are made for all structural elements, including foundations, columns, nodes, shear walls, and retaining walls, and they are produced in the form of complete implementation plans.

1.3 Aims:

is to make all the structural designs necessary to make the building safe by using the necessary programs and codes and linking all the information that has been studied to complete the structural design for this project.

1.4 Objectives:

1. Acquiring the skill in the ability to choose the appropriate structural system for different projects and distributing its structural elements on plans, in proportion to its architectural planning.

2. Proficiency in the use of structural design software.

3. The ability to balance different design methods.

4. Dealing with various problems encountered in the design process.

5. Structural knowledge that enables us to handle various other projects.

1.5 Hypothesis:

If we use the approved programs, codes, and design parties in the correct order and form, we will arrive at a correct and safe structural design that fulfills the required purpose..

1.6 Methodology:

In this project, we went through several stages in order to reach the final stage, and the stages were as follow:

1. Project Selection.

1.1: Search for architectural plans.

We went to the Department of Architecture in order to obtain a suitable project, and this process took time and effort until we got to the appropriate project.

1.2: Study the project plan.

At this stage, we studied the architectural plans and identified the architectural elements in order to start the structural design, as studying the project before starting the design process is considered one of the important stages.

2. Structural elements study.

2.1: Study columns.

At this stage, we study the columns that the architect has placed, and if these columns do not affect the structural design, then we adopt these columns, but if there is a structural conflict with the columns, we work after that to change their location in accordance with the structural design.

2.2: slabs plans.

At this stage, after making sure of the columns, we determine an initial width of the Beams and draw them on the slabs plans, and we determine a direction, and after that we choose the method of loading that we will adopt for the ribs so that it gives us a safe and economical design, and after that we name the structural elements.

3. structural design.

3.1: slabs design.

At this stage of the design, we initially determine the thickness of the Slab, based on the American code ACI 318-14, then we design the topping of the slabs, after that we could start designing the ribs on the structural design program (Atir).

3.2: Beams design.

After slab designing, we could take the reactions of the ribs supports to carry the loadings of the ribs on the beams to start the beam designing by the structural design program (Atir).

3.3: columns design.

Now after designing the ribs and the beams, I can design the columns after carrying the loads of the beams.

3.4: wall design.

At this stage of the design, we design all the shear walls in the plan, which come in the staircase walls, and elevator walls, and the design is according to the American code ACI 318-14.

3.5: Foundations design

The foundations are designed at the end after designing all the structural members of the building and after calculating the loads on the foundations.

4. Finishing the project.

4.1: Preparing the final blueprints.

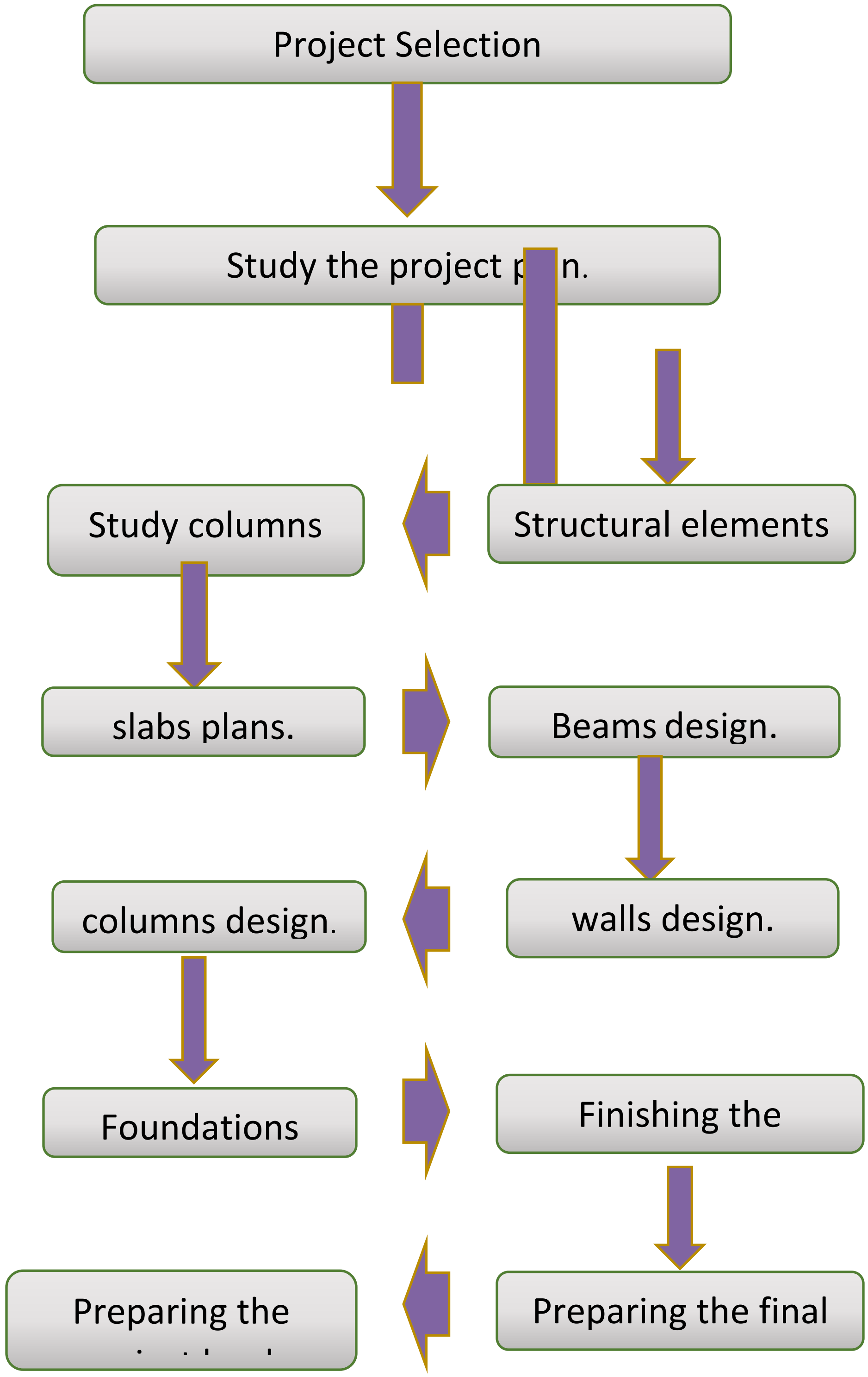
After completing the structural design process, we prepare the plans for all the architectural and construction elements, as each element must have a plan to study each element separately during the implementation process.

4.2: Preparing the project book.

Where the project book contains an explanation that explains the constituent elements of the project and also explains the mechanism of work in the project until reaching the end of the project.

Section	Activity	D.Start	Duration	D.Finish
1	Project Selection.	4/2/2024	20 days	24/2/2024
1.1	Search for architectural plans.	4/2/2024	7 days	11/2/2024
1.2	Study the project plan.	12/2/2024	13 days	25/2/2024
2	Structural elements study.	26/2/2024	44 days	11/4/2024
2.1	Study columns.	26/2/2024	21 days	18/3/2024
2.2	slabs plans.	19/3/2024	23 days	13/4/2024
3	structural design.	14/4/2024	106 days	30/7/2024
3.1	slabs design.	14/4/2024	17 days	1/5/2024
3.2	Beams design.	2/5/2024	15 days	18/5/2024
3.3	columns design.	19/5/2024	23 days	12/6/2024
3.4	walls design.	13/6/2024	25 days	8/7/2024
3.5	Foundations design.	9/7/2024	26 days	4/8/2024
4	Finishing the project.	5/8/2024	30 days	5/9/2024
4.1	Preparing the final blueprints.	5/8/2024	20 days	25/8/2024
4.2	Preparing the project book.	26/8/2024	10 days	5/9/2024

Table (1-1): Timetable for the project



Figure(1-1) : Methodology for the project.

Chapter 2

"Architectual Description"

2.1 **An overview of the project.**

2.2 **Project Location.**

2.3 **importance of the site.**

2.4 **Movement of the sun and wind.**

2.5 **Humidity.**

2.6 **Description of the project floors.**

2.7 **Elevations.**

2.8 **Longitudinal sections.**

2.9 **Description of movement and entrances.**

2.1 An overview of the project:

With the economic and social development and population increase and The increasing interest of students in universities and the opening of new university specializations, including medicine , there was a need to initiate a design proposal for a new building for the Faculty of medicine, in order to meet all the services needed by the citizens.

It appears from the plans that The proposed building is a new building for the College of Medicine With a total area of 18199.55 square meters It consists of Eight floors divided into: a basement floor, which includes garages, ground , first, second, third ,forth , fifth, and sixth floor, which includes University college departments, including lecture rooms, laboratories, and spaces for intelligence games, in addition to teachers' offices, libraries, and study spaces... Figure (2-1) shows the general location of the project.

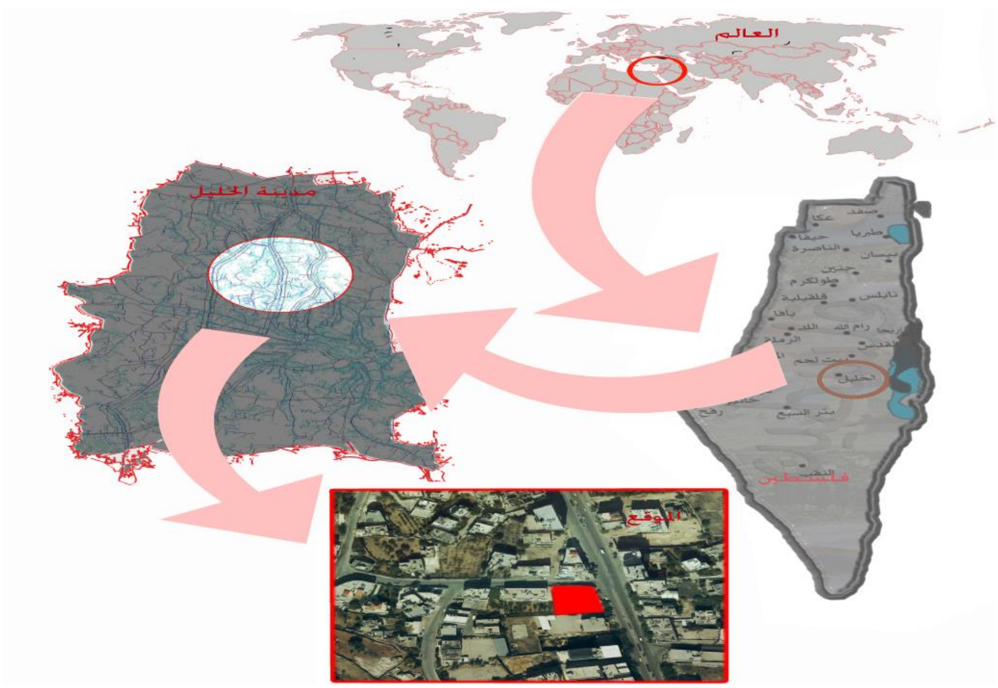


Figure (2-1) : A picture showing the location of the plot of land.

2.2 project Location :

The plot of land is located in the Hebron city In the Palestine polytechnic University. The site also shows the surrounding streets from all sides .And its distinctive geographical location.

2.3 importance of the site:

There are foundations and criteria that help in making a decision that takes the project towards integration and compatibility with the general urban fabric. The following are several important points in the site selection process:

- **Geography of the site** : It is the aspect that specializes in studying the location of the land in relation to the urban fabric in general, and the impact of the site on the function of the building, and the study of the climate and topography of the land.
- **Transportation network** : The building is easily accessible from roads and transportation.
- **Vegetation**: It is the aspect that talks about the nature of the land in terms of vegetation, including trees and plants.
- **Patterns and types of surrounding buildings**: commercial, industrial, residential, or service, and how these buildings affect the plot of land and their impact on the building to be built .

2.4 Movement of the sun and wind:

The city of Hebron is exposed to southwesterly winds that bring rain and lower the temperature in the highlands. It is also exposed to cold eastern winds in winter, and dry winds such as the Khamaseen winds blow in late spring.

Studying the movement of the sun and the wind is one of the important factors in analyzing the building, because the sun is a desirable energy, and directing the building towards the sun while protecting it from the brightness that falls on it from the western region is a successful way to obtain the largest possible amount of solar energy in cold days, and reduce the amount of energy consuming heating, and the wind has a great impact on buildings, as it is considered a horizontal load that affects the walls of the building, and therefore on its structural structure, so the effect of wind and sun on the building must be taken into account in order to be designed in a way that meets the design requirements related to ventilation.

2.5 Humidity :

The average humidity in Hebron ranges between 43-67% in the winter season. The city's elevation above sea level reduces the moisture

content of the air coming from the sea. Hebron is located at an altitude of 1025 meters above sea level.

2.6 Description of the project floors:

Where the project consists of three floors in addition to the ground floor.

2.6.1 Basement floor:

Its level is (- 4.00 m) and an area estimated at (4019.33 m2).The basement floor is the garage floor, It also contains an electrical room, and the following picture shows the details.

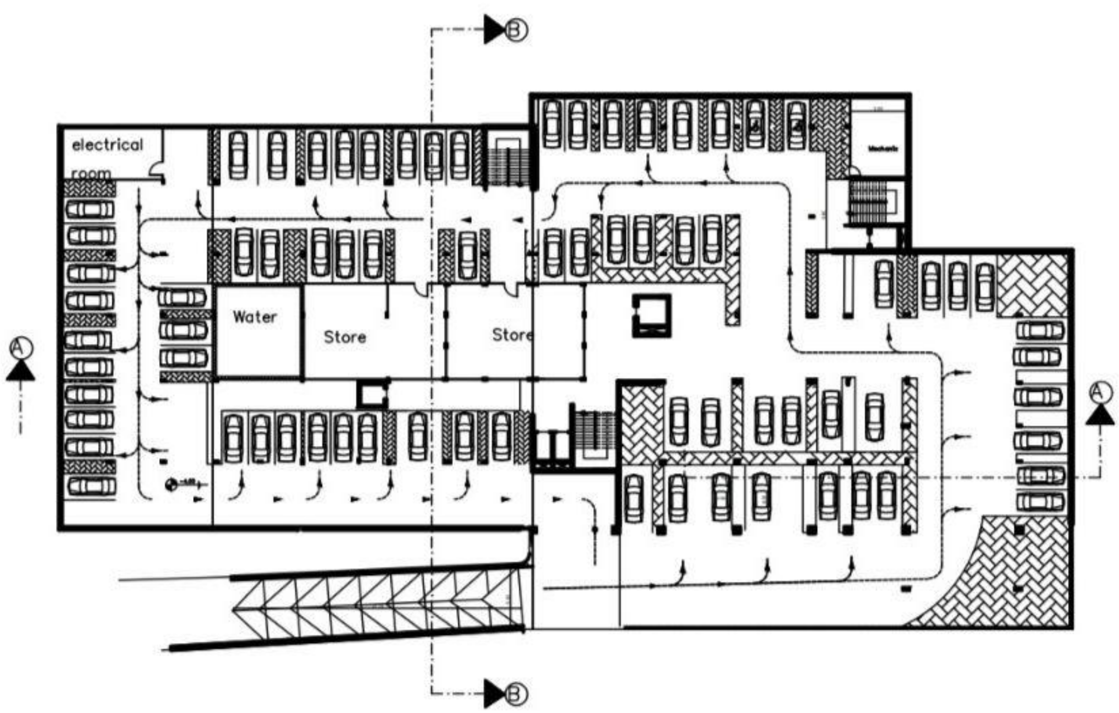


Figure (2-2):basement floor.

2.6.2 Ground floor :

Its level is (+0.00 m) and an area estimated at (2132.9m2).This floor contains a theater, lecture halls, teachers' offices, a cafeteria, bathrooms, in addition to shops., and the picture below shows the details.

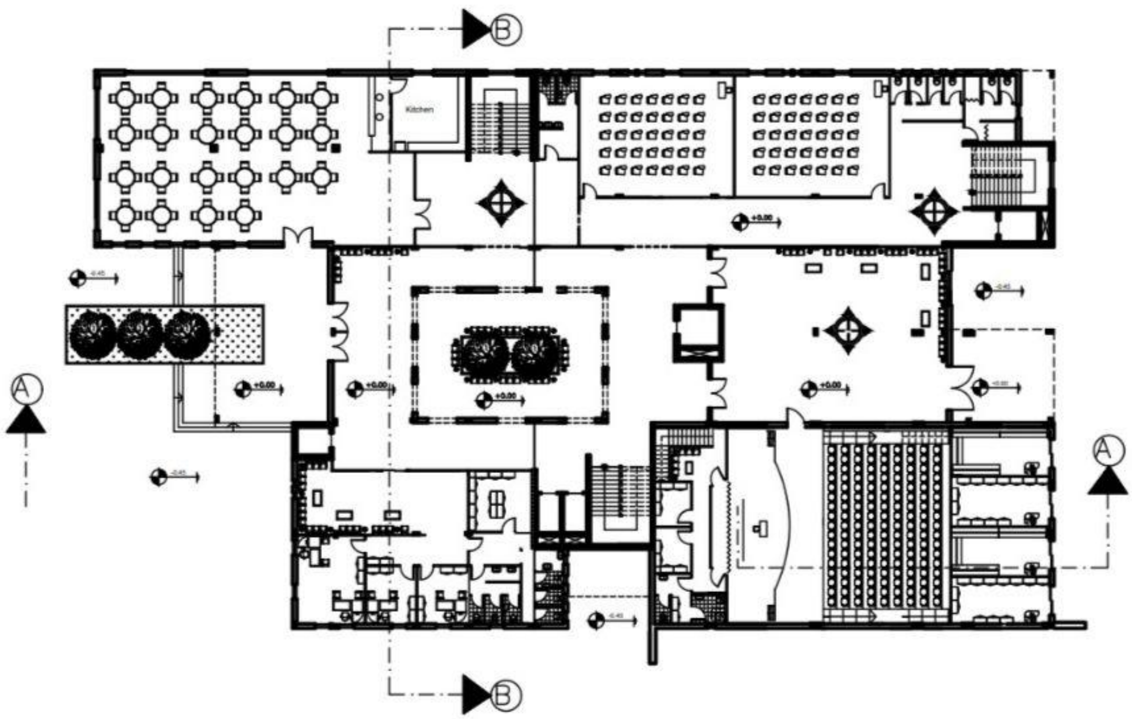


Figure (2-3): ground floor.

2.6.3 First Floor:

Its level is (+4.00 m) and an area estimated at (2132.9m2).This floor contains lecture halls, teachers' offices, laboratories, bathrooms, in addition to meeting rooms. and the picture below shows the details.

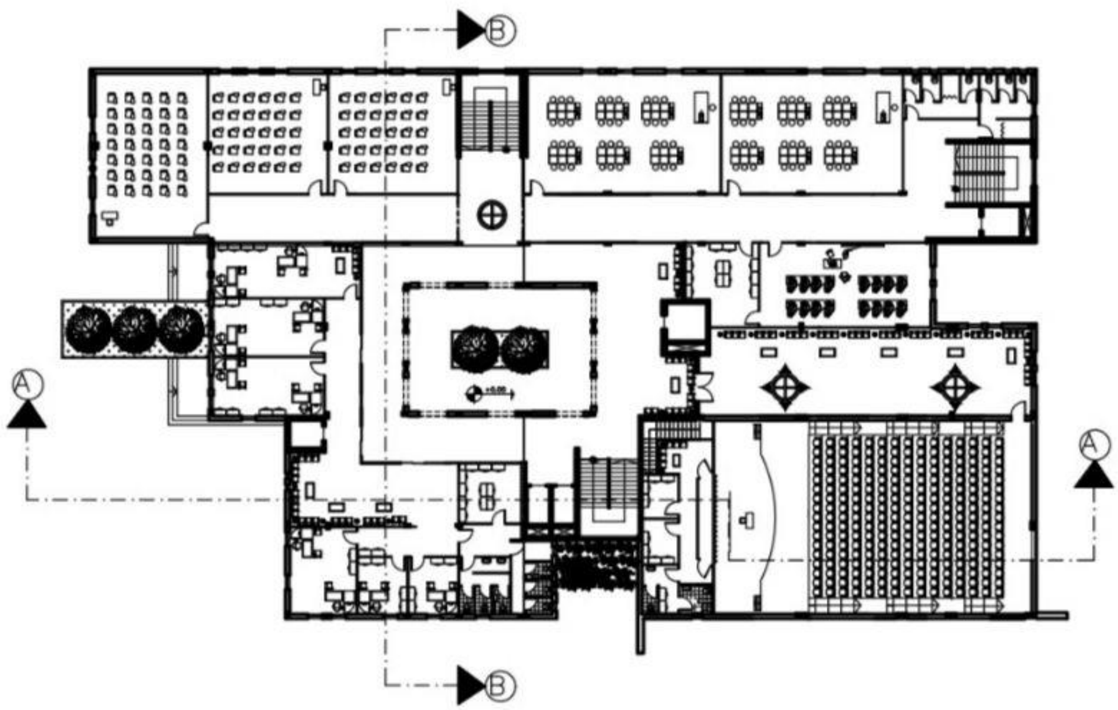


Figure (2-4): first floor.

2.6.4 Second Floor:

Its level is (+8.00 m) and an area estimated at (2132.9m2).This floor contains lecture halls, teachers' offices, laboratories, bathrooms, in addition to Special spaces for games. and the picture below shows the details..

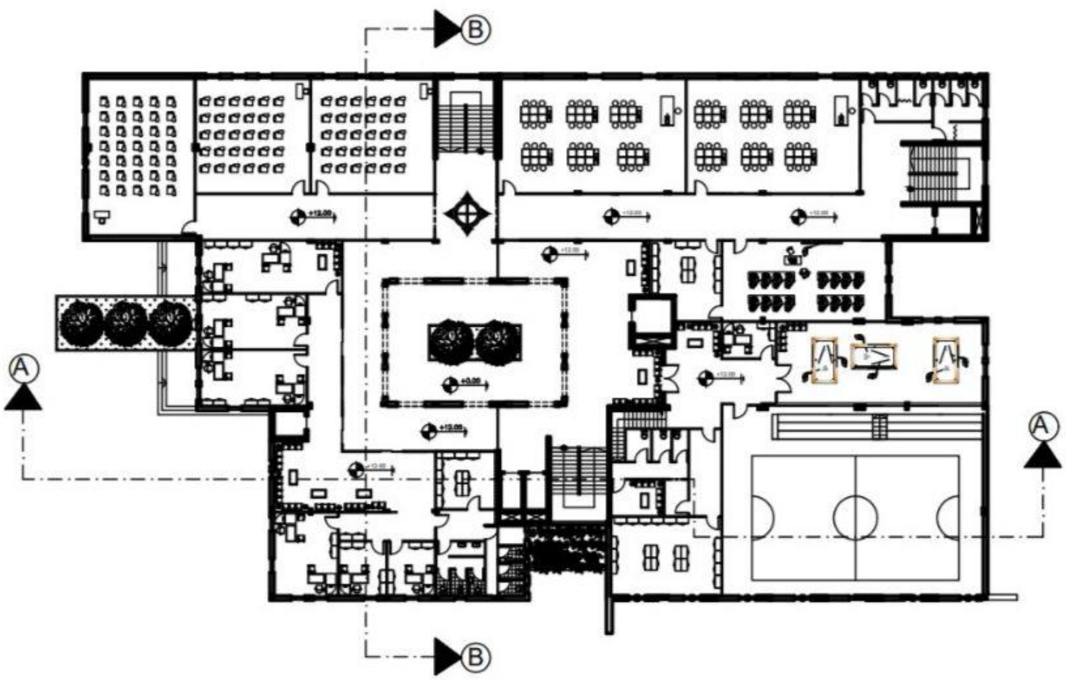


Figure (2-5): second floor.

2.6.5 Third Floor:

Its level is (+12.00 m) and an area estimated at (2132.9m2).This floor contains lecture halls, teachers' offices, laboratories, bathrooms, in addition to Special spaces for games. and the picture below shows the details.

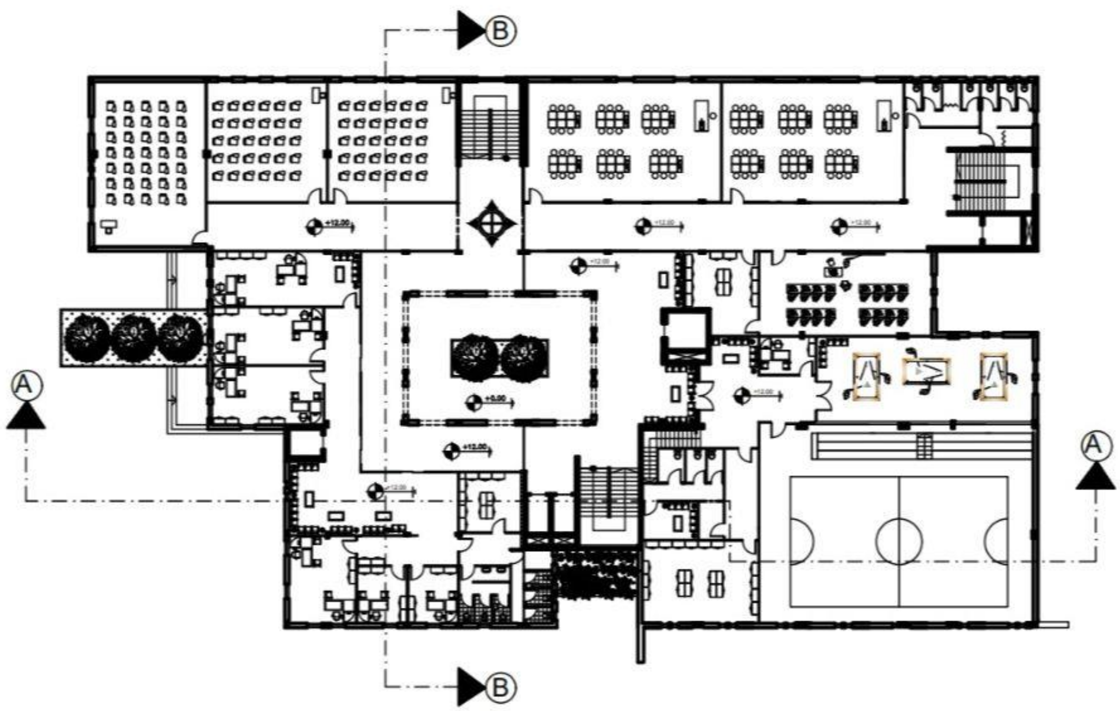


Figure (2-6): Third floor.

2.6.6 Fourth Floor:

Its level is (+16.00 m) and an area estimated at (2132.9m2).This floor contains lecture halls, teachers' offices, laboratories, bathrooms, in addition to Library and computer laboratories. and the picture below shows the details..

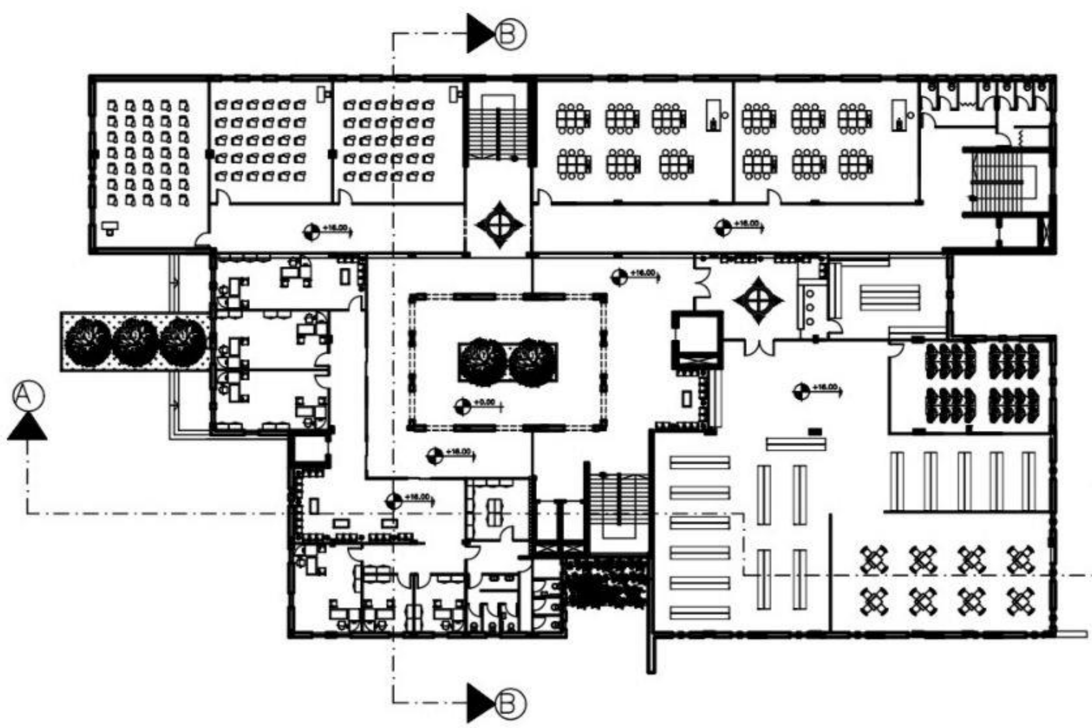


Figure (2-7): fourth floor.

2.6.7 Fifth Floor:

Its level is (+20.00 m) and an area estimated at (1757.887m2).This floor contains lecture halls, teachers' offices, laboratories, bathrooms. and the picture below shows the details.

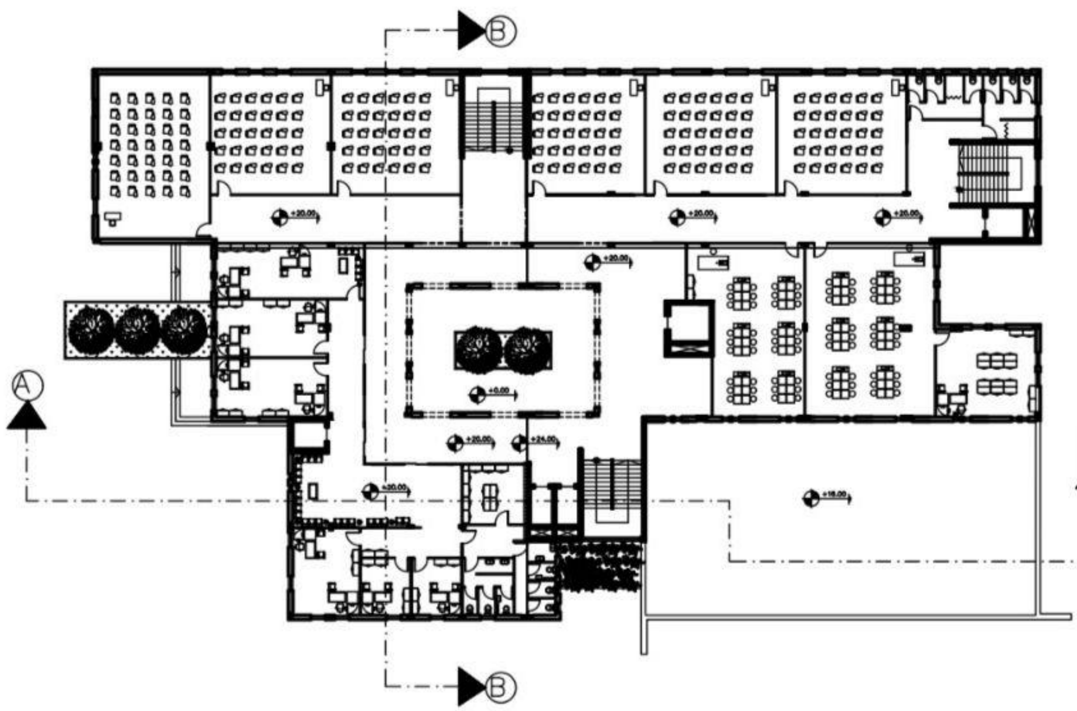


Figure (2-8): fifth floor.

2.6.8 Sixth Floor:

Its level is (+24.00 m) and an area estimated at (1757.887m2).This floor contains lecture halls, teachers' offices, laboratories, bathrooms. and the picture below shows the details.

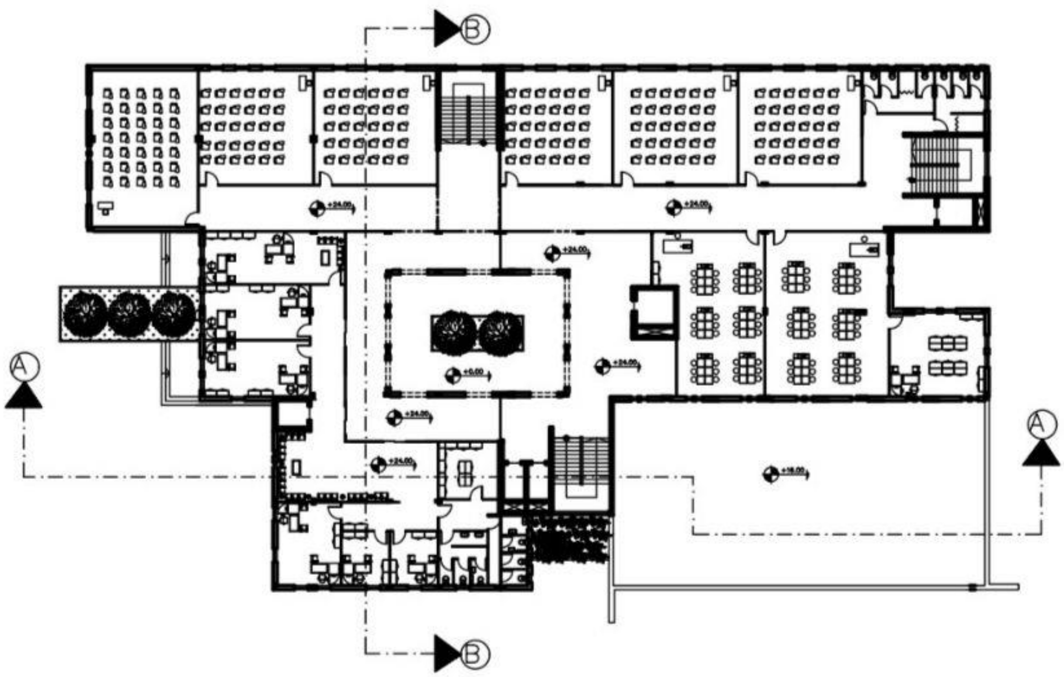


Figure (2-9): sixth floor.

2.7 Elevations :

2.7.1 Northern Elevation:

The northern façade ,windows appear in this façade in addition to protrusions and architectural shapes, and it contains various structural elements of stone, glass, and aluminum, as this diversity gives the building a special aesthetic. As shown in the following figure .

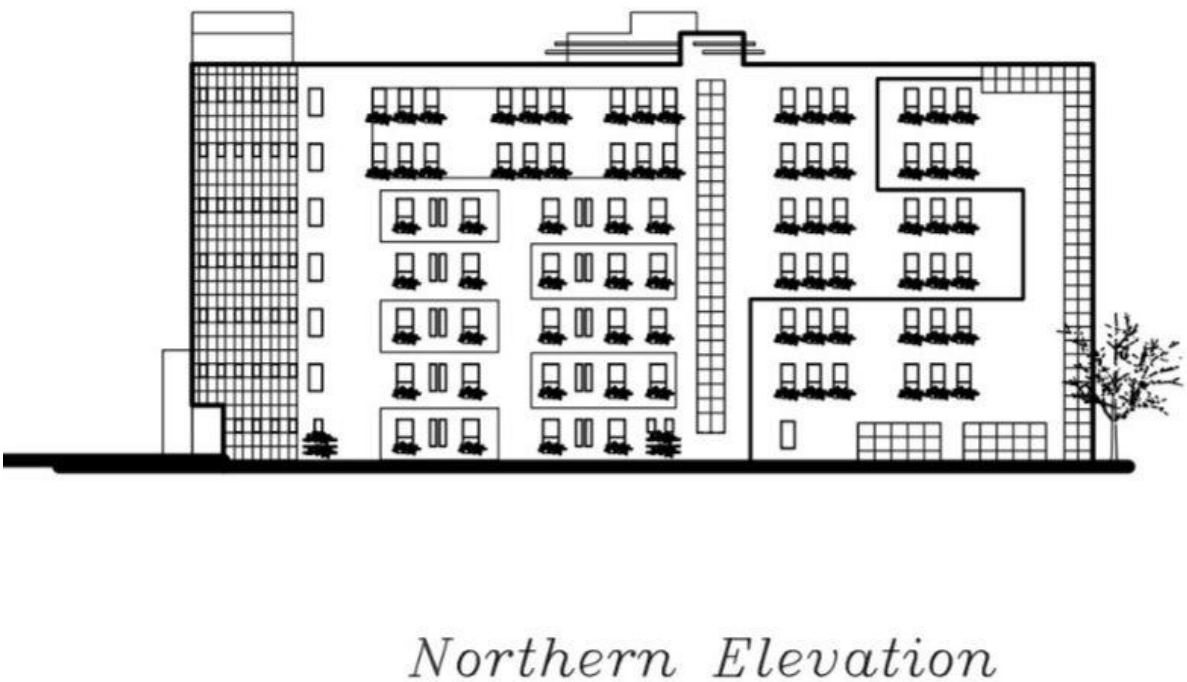


Figure (2-10):Northern Elevation.

2.7.2 Eastern Elevation:

This Elevation shows the eastern side . It shows the main entrance to the building.This elevation shows the building's floors, and it contains various structural elements of stone, glass, and aluminum, as this diversity gives the building a special aesthetic. It also shows aesthetic architectural features. As shown in the following figure.

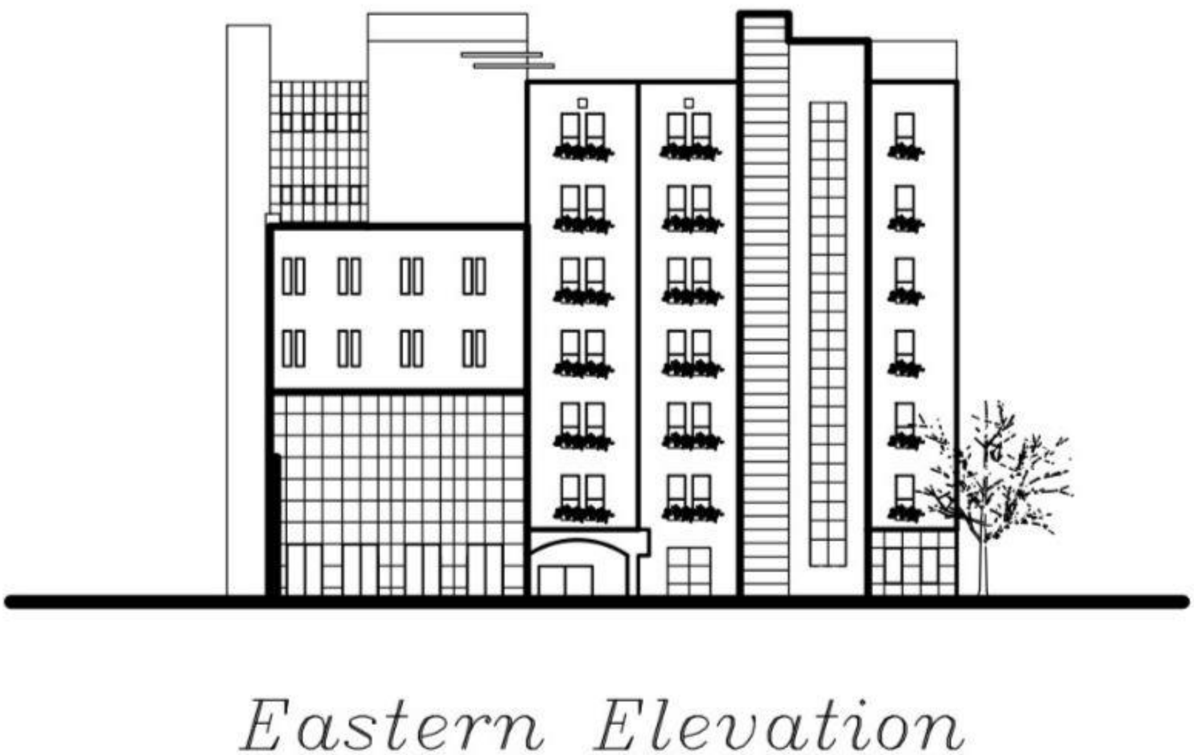


Figure (2-11):Eastern Elevation.

2.7.3 Western Elevation:

This Elevation shows the western side. This facade contains another entrance to the building. This elevation shows the building's floors, and it contains various structural elements of stone, glass, and aluminum, as this diversity gives the building a special aesthetic . As shown in the following figure.

Figure (2-12):Western Elevation.

2.7.4 Southern Elevation:

This Elevation shows the southern side , this elevation shows the building's floors, and it contains various structural elements of stone, glass, and aluminum, as this diversity gives the building a special aesthetic. As shown in the following figure

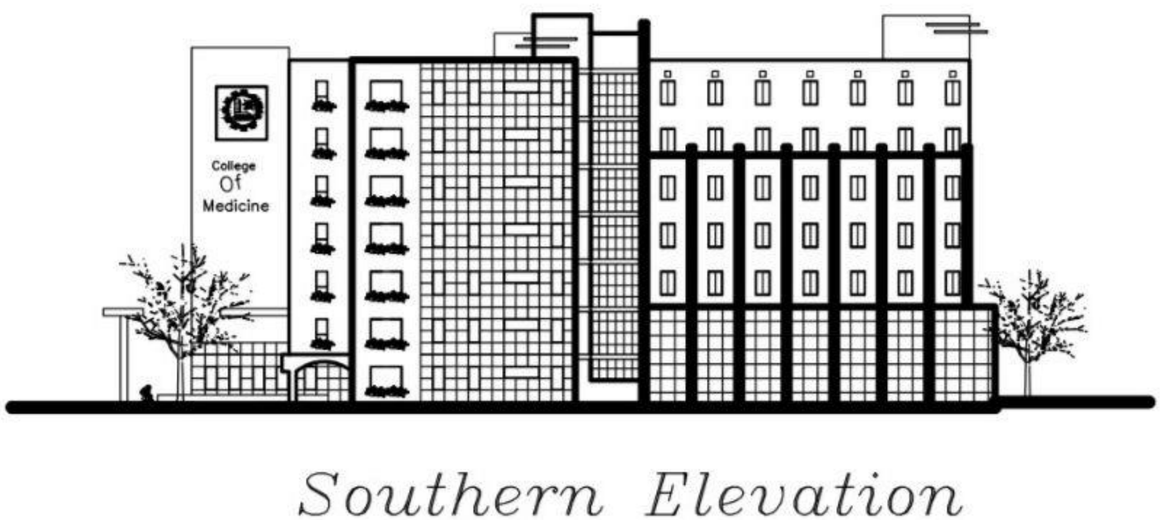
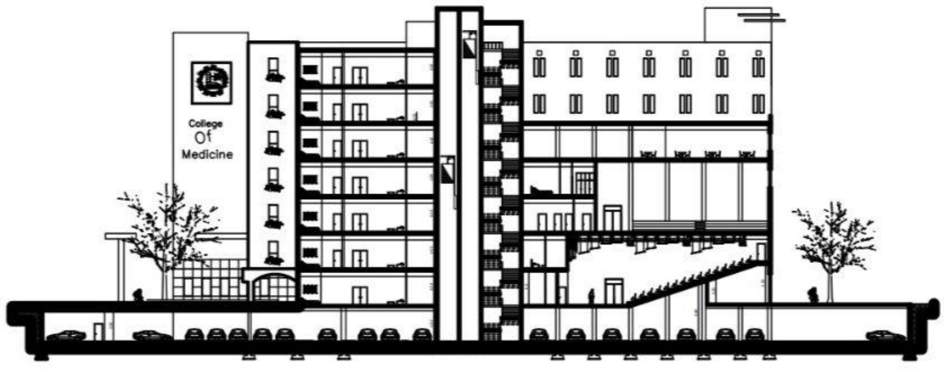


Figure (2-13):Southern Elevation.

2.8 Longitudinal sections:

The sections show the internal details of the building, such as partitions, drawers, and doors. The number of sections increases the more ambiguous details within the project. The more details there are, the more we take a section for each detail to clarify it separately in the sections drawing, so that each section illustrates a different idea in the design until we have the result. The end is a complete explanation through drawings of the apparent or ambiguous details so that the executive engineer can perform his task without any problems or without returning to you for your question.

Therefore, the greater the number of ambiguous internal details of the design, the more sections are drawn. Therefore, we may find in a project that one section is sufficient to clarify its design idea, and in another project its idea is not explained except by drawing 6 sections, for example, each drawing illustrates a different idea in a different part of the design. The project, until the project finally becomes readable and understandable, and the pictures below show the sections in our project.



Section A–A

Figure(2-14):section A-A.

Section B–B

Figure (2-15):Section B-B.

2.9 Description of Movement and Entrances :

Movement takes many forms, whether from outside the building towards the inside, or movement inside the building itself. Movement from outside the building to inside it is smooth because there is no significant difference in the external level of the building and its internal level. As for movement inside the building, it is divided into horizontal movement within one floor and vertical movement between different floors.

Movement on floors takes two forms: linear movement and vertical movement. Linear movement takes place in the corridors on floors, unlike vertical movement between floors, which takes place through stairs and elevator, and this in turn facilitates horizontal movement within floors and vertical movement between them, The building contains three stairs in addition to four elevators distributed throughout the entire building .

Chapter 3

“Structural Description”

3.1 **Introduction.**

3.2 **The objective of the structural design.**

3.3 **stages of structural design.**

3.4 **loads.**

3.5 **practical tests.**

3.6 **the structural elements of the project.**

3.7 **expansion joints.**

3.1 Introduction:

After studying the project from the architectural point of view, it is necessary to move to the structural side to study the structural elements and describe them accurately, where the nature of the loads placed on the building and how to deal with them are studied to come out with a structural design that meets all the requirements of safety and use and takes into account the economic aspect of the project.

The project also requires the structural design of the building and the selection of appropriate structural elements for the project to be constructed and taking into account the feasibility of its implementation on the ground so that the building is safe, and we preserve the architectural designs.

3.2 The objective of the structural design:

Structural design is an integrated, interdependent process that satisfies a range of Objectives and factors that will lead to a facility that achieves the desired objective, and these objectives are as follows:

- **Safety**: Where the building is safe in all circumstances and is resistant to changes and various natural disasters.
- **Economical cost** : It is to achieve the greatest degree of security for the origin at the lowest possible economic cost.

- **Ensure the efficiency of use (Serviceability)**: Avoid any defect in the origin, such as the presence of some cracksAnd some types of landing that would annoy the users of the building.

- **Preserving the architectural design of the establishment.**

3.3 Stages of structural design:

The structural design stages can be divided into two main stages:-

1- The first stage:-

It is the preliminary study of the project in terms of the nature and size of the project, in addition to understanding the project in all its various aspects and determining the building materials that will be approved for the project, then doing the basic structural analysis of this system, and the expected preliminary dimensions of it.

And study the nature of the climate and the land on which the building is located.

2- The second stage: -

It is represented in the structural design of each part of the structure, in a detailed and accurate manner, according to the structural system that was chosen, and the work of the necessary structural details and designs for it in terms of drawing horizontal projections, vertical sectors, and details of the reinforcement steel.

3.4 loads:

The loads to which the building is exposed are divided into different types, which are as follows:

3.4.1 Dead Loads:-

They are the loads resulting from the self-weight of the main elements that make up the structure, on a permanent and fixed basis, such as tiles, cement mortar, and reinforced concrete, in terms of quantity and location, in addition to additional parts such as internal partitions of different types and any mechanical works or additions that are carried out permanently and permanently in the building, and can be calculated by determining the dimensions The structural element, and the densities of its constituent materials, and **Table (1-3**) shows the specific densities of the materials used in the project.

Item No	Material	Specific Weight (KN/m3)
1	Tile	23
2	Mortar	22
3	Sand	17
4	Hollow Block	10
5	Reinforced Concrete	25
6	Plaster	22
7	Topping	25

Table (3-1): Specific density of the materials used.

In addition to the dead load resulting from the breakers (Partition load) = 2.38 kN/m^2

3.4.2 live loads:

They are the loads that change in terms of amount and location on an ongoing basis, such as people, furniture, devices, equipment, and execution loads such as wood and equipment. The value of these loads depends on the nature of the use of the facility.

Its amount is usually taken from special tables in the different codes. The value of the live loads was approved at 5 KN/m2 , which are specified by reference to the Jordanian code.

3.4.3 Environmental loads: -

It includes the loads that result from the natural changes that pass through the structure, such as snow, winds, and heavy loads

Earthquakes and loads resulting from soil pressure, which vary in magnitude and direction and from one region to another, can be considered as part of the live loads.

3.4.4 Snow Loads:

It is the load resulting from snow on various surfaces.As for its value, it depends on the height of the geographical area in which the building is located above sea level. It also depends on the degree of inclination of the snow-covered surfaces from the horizontal. Snow loads can be calculated using the Jordanian code.

Due to the scarcity of snowfall in the project area, in addition to the small loads it affects on building roofs compared to live loads, they will not be calculated in the project.

3.4.5 Earthquake loads:

Earthquakes result from horizontal and vertical vibrations, due to the relative movement of the rock layers of the earth, which results in shear forces that affect the facility. These loads must be taken into account when designing in order to ensure the building's resistance to earthquakes in the event that they occur, and thus reduce potential damages as a result of an earthquake.

In this project, it will be resisted by the shear walls distributed in the building based on the structural calculations for it, which will be used for it, to avoid the effects resulting from earthquakes such as:

- The limits of the validity of the building for operation (Serviceability) in terms of avoiding any excessive subsidence (Deflection) and avoiding (Cracks) that negatively affect the required architectural appearance.
    - The shape and aesthetic aspects of the establishment.

3.5 practical tests:

The construction study of any building precedes the geotechnical studies of the site, and it means all the work related to the exploration of the site and the study of soil, rocks and groundwater, and the analysis of information and its translation to predict the way the soil behaves when building on it, and what the structural engineer is most interested in is obtaining the necessary soil bearing strength To design the foundations of the building, and from this step, the type of foundation that will be used for the building can be approved.

3.6 Structural Elements:

Buildings usually consist of a group of structural elements that intersect with each other to withstand the loads on the building, and they include:Slabs, Beams, columns, stairs, walls, and foundations. Figure (3-1) shows an illustration of some structural elements of the building.

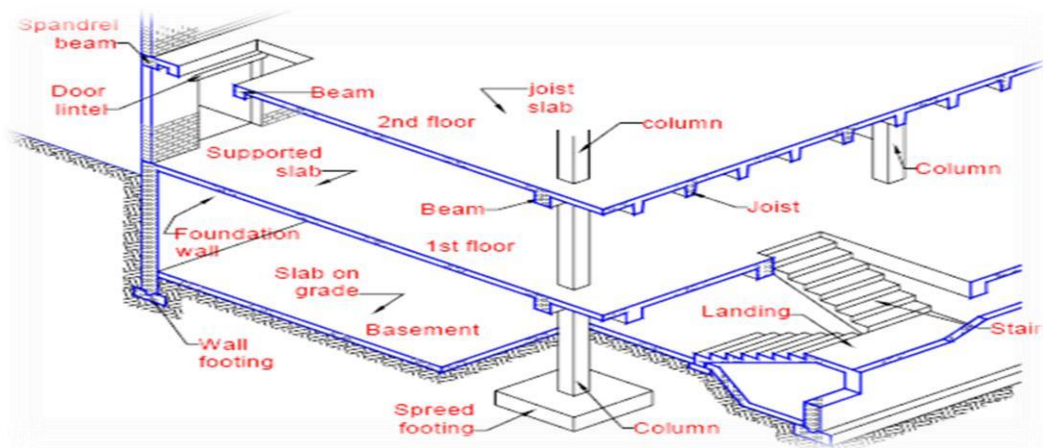


Figure (3-1): Illustration of some structural elements of the building.

The elements are divided into:

3.6.1 Slabs: -

They are the structural elements that are capable of transferring vertical forces due to the loads affecting them to the load-bearing structural elements in the building such as bridges, columns, walls, steps and foundations, without subjecting them to deformations.

3.6.1.1 Solid slabs:

are divided into:

- One way solid slab .
- Two way solid slab.

3.6.1.2 Ribbed Slabs:

which are divided into:

- One way ribbed slab
- Two way ribbed slabs.

Where one way ribbed slab was used in the design of the building in the project.

The one-way ribbed slabs are used to cover the spaces in which the dimensions between the columns range from six to seven meters. As for the two-way ribbed slab, they are used in the case of relatively large areas.

- **One way ribbed slabs:**

It is one of the most famous methods used in designing slabs in these countries, and it consists of a row of bricks followed by nerves, and the reinforcement is in one direction as shown in Figure (3-2). It is characterized by its light weight and effectiveness, and it is the most widely used in Palestine and in our project as well.

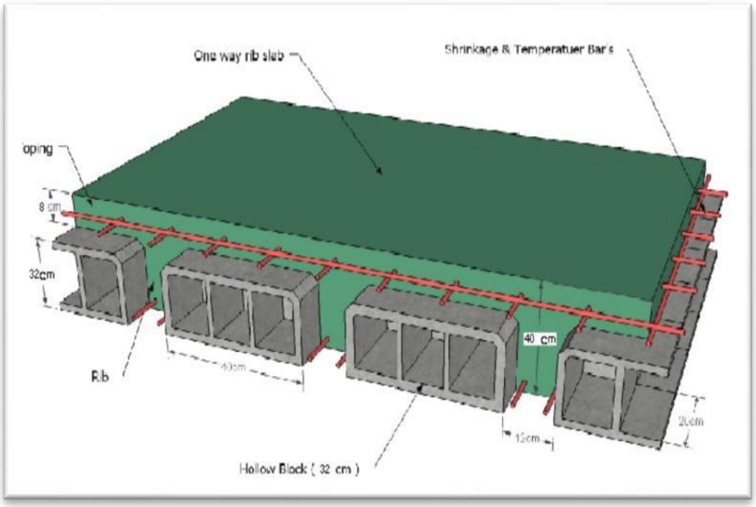


Figure (3-2):One-way ribbed slabs.

- **Two-way ribbed slabs:**

It is similar to the previous one in terms of components, but differs in terms of the reinforcement being in two directions, and the load is distributed in all directions, and two bricks and a beam are taken into account when calculating their weight in both directions, as shown in Figure (3-3)

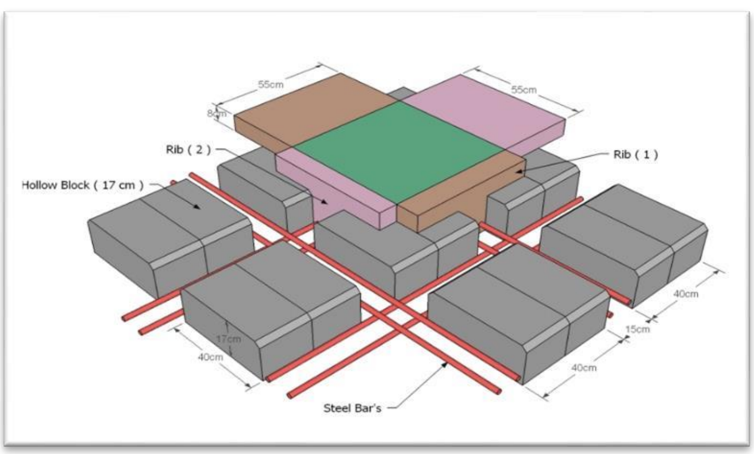


Figure (3-3): Two-way ribbed slabs.

- **One way solid slabs:**

They are used in areas that are frequently subjected to dynamic loads, in order to avoid vibration due to the low thickness. They are usually used in stairs slabs, as in Figure (3-4).

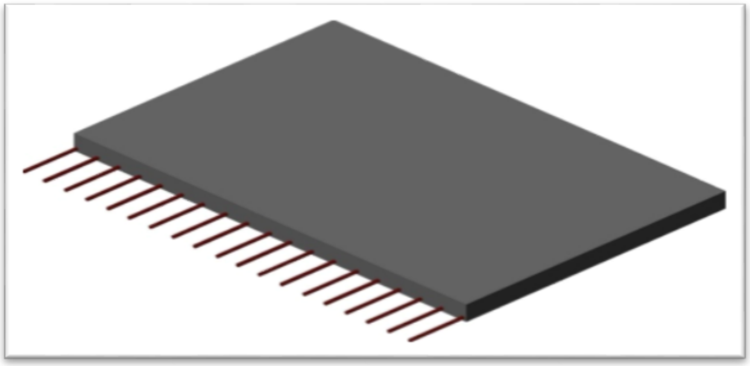


Figure (3-4):One-way solid slabs.

- **Two way solid slabs:**

It is used in the event that the effective loads are greater than the amount that the one-way solid slabs, and at that time the design of this type of slabs is resorted to, because this can resist the loads more, as the main reinforcement is distributed in two directions as shown in Figure (3-5).

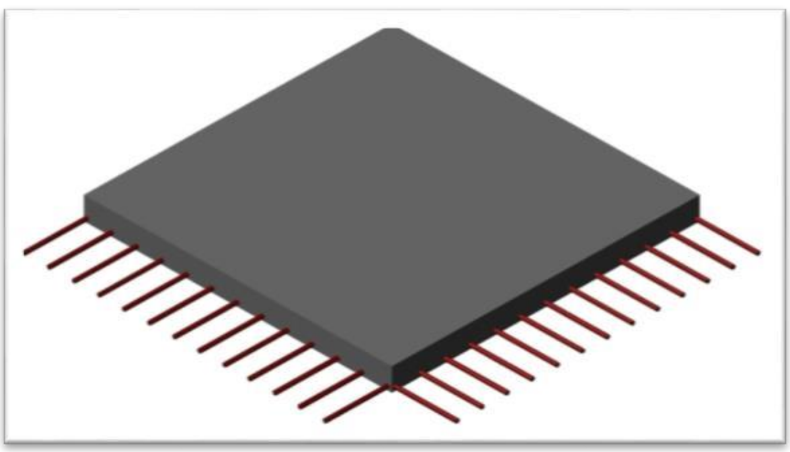


Figure (3-5): Two-way solid slabs.

3.6.2 Beams:-

They are basic structural elements in the building that transfer the loads on the ribs to the columns, as they are divided into:

1- Hidden beams, whose height is equal to the height of the slab.

2- Dropped beams, which are higher than the height of the slab, and the extra part of the beam is highlighted in one of the lower or upper directions, and it is called L-section or T= section

The reinforcement shall be with horizontal steel bars to resist the moment on the beam, and with stirrups to resist shear forces. Figure (3-6) shows the types of beams that were used in the project.

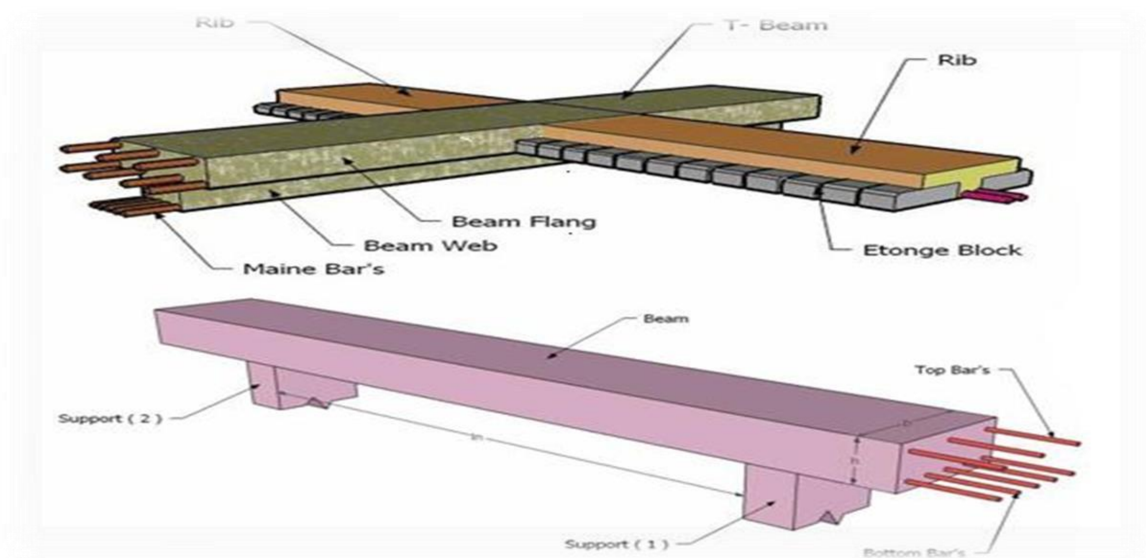


Figure (3-6): Types of beams that were used in the project.

3.6.3 Columns:

They are basic and major structural elements in the structure, where the loads are transferred from the slab to the beams, and the beams transfer them in turn to the columns, then to the foundations of the building, so they are an essential intermediate element, and they must be carefully designed to be able to transfer and distribute the loads located on them and the columns are of two types in terms of dealing with them In structural design:-

1- Short columns.

2- Long columns.

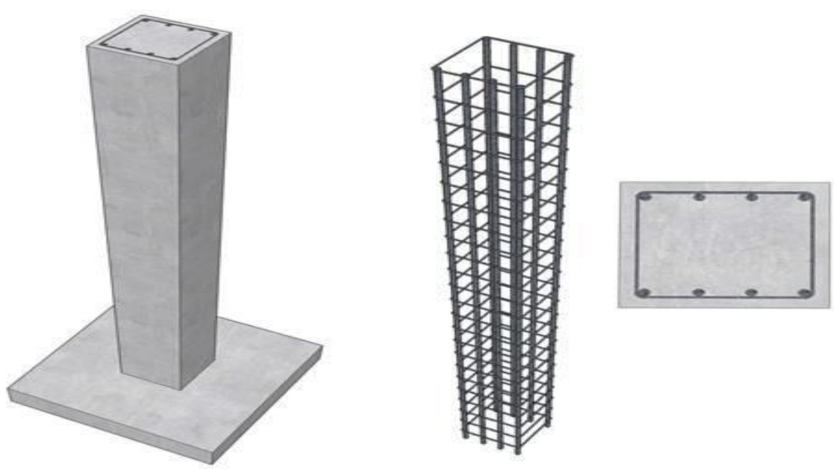


Figure (3-7): Some Types of columns that were used in the project.

3.6.4 foundation :

The first thing that begins to be implemented when constructing a building is the foundations, but their design comes after the completion of the design of all the structural elements in the building, as they transfer and distribute the loads transferred from the walls and columns to the soil. Based on the loads imposed on them and the nature of the site, the type of foundations used was determined.

They are of several types:

- Isolated footing: They are used as a foundation for concrete and metal columns and are often square in shape.
- Combined footing: These are foundations for two or more columns for a specific purpose, such as the proximity of two or more columns or resisting the eccentricity of a column, which causes the column bases to overlap.
- Continuous foundations (strip footing): They are used as a foundation for walls of all types and for close columns located in one row, especially if the loads and distances of those columns are close.
- Mat footing: It is the foundation for the entire structure or part of it, to which the loads of the columns are transferred to the soil.

3.7 expansion joints:

In building blocks with large horizontal dimensions or with special shapes and conditions, thermal expansion joints or subsidence joints are implemented. The joints may be for both purposes. When analyzing the facilities to study them as resistant to earthquake actions, these joints are called seismic joints. These joints have some requirements and recommendations for them, and they should also be used Thermal expansion joints in the building block according to the approved code, provided that these joints reach the upper face of the foundations without penetrating them, and the maximum distances for the dimensions of the building block are as follows:

- (40)m in areas with high humidity.
- (36m) in areas with normal humidity.
- (32m) in areas with medium humidity.
- (28m) in dry areas.

The width of the separator shall not be less than 3 cm

In this project, a vertical expansion joint was used.

Chapter 4

“Structural Analysis & Design”

4-1 Introduction.

4-2 Design method and requirements.

4-3 Factored loads.

4-4 Determination of minimum thickness of structural members.

4-5 Design of one way ribbed slab.

4-6 Design of Beam Gf-B2 .

4.1 Introduction:

Concrete is the only major building material that can be delivered to the job site in a plastic state. This unique quality makes concrete desirable as a building material because it can be molded to virtually any form or shape.

Concrete used in most construction work is reinforced with steel. When concrete structure members must resist extreme tensile stresses, steel supplies the necessary strength. Steel is embedded in the concrete in the form of a mesh, or roughened or twisted bars. A bond forms between the steel and the concrete, and stresses can be transferred between both components.

In this project, all of the design calculations for all structural members would be made upon the structural system which was chosen in the previous chapter.

So, in this project, there are many type of slabs such that "one way ribbed slab", They would be analyzed and designed by using finite element method of design, with aid of a computer program called "Beam-D- Software" to find the internal forces, deflections and moments for ribbed slabs, and then handle calculation would be made to find the required steel for all members.

4.2 Design method and requirements:

The design strength provided by a member, its connections to other members, and its cross sections in terms of flexure, and load, shear, and torsion is taken as the nominal strength calculated in accordance with the requirements and assumptions of ACI-318-14 code.

The design strength provided by a member is calculated in accordance with the requirements and assumptions of ACI code (318_14).

- **Strength design method:**

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

The strength design method is expressed by the following,

Strength provided ≥ Strength required to carry factored loads.

- **Material:**

Reinforced Concrete: B300 , $fc' = 24\ N/mm^2$ (Mpa)

Reinforcement Rebars: $fy = 420\ N/mm^2$(Mpa)

- **Strength reduction factors (Ø):**

According to ACI a reduction factor for structural elements must be included in the calculation of concrete sections, these factors are less than 1.0 for safety purposes, 0.9 for tension controlled sections, 0.75 (Spiral) or 0.65 (Stirrups) for compression controlled sections, 0.75 in shear calculation and 0.6 for plain concrete sections. The strength factor (Ø) changes with net tensile strain of the cross section as illustrated in the following figure:

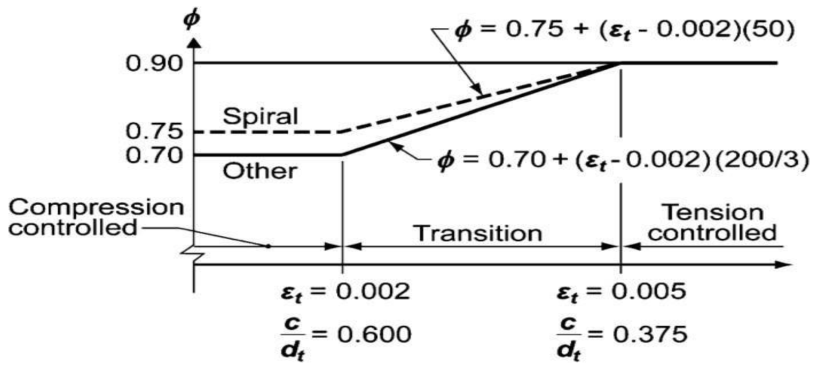


Fig. (4-1):Variation of Ø factor with net tensile strain (ACI 318)

4.3 Factored loads:

The factored loads used in the structural analysis and design according to ACI-318-11(9.2) eq.

, is determined as follows:

$$\mathbf{Wu = 1.2DL + 1.6LL}$$

Where;

Wu: Ultimate Load (kN)

DL: Dead Load (kN)

LL: Live Load (kN)

4.4 Determination of minimum thickness of structural members:

Minimum thickness of non-prestressed beams or one-way ribbed slabs unless deflections are calculated. (ACI 318M-11)

	Minimum Thickness, h			
Member	Simply Supported	One-end continuous	Two-ends continuous	Cantilever
Ribs & Beams	Span(L)/16	Span(L)/18.5	Span(L)/21	Span(L)/8

Table (4-1): Determination of minimum thickness of structural member.

For one end continuous L_{max}=6.54 m then:

$$h_{min} = \frac{L}{18.5} = \frac{6540}{18.5} = 35 \text{ cm}$$

And this value is considered an initial value and is not relied on definitively .

Select h = 35cm .

4.5 Design of one way ribbed slab (R20):

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

4.5.1 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.

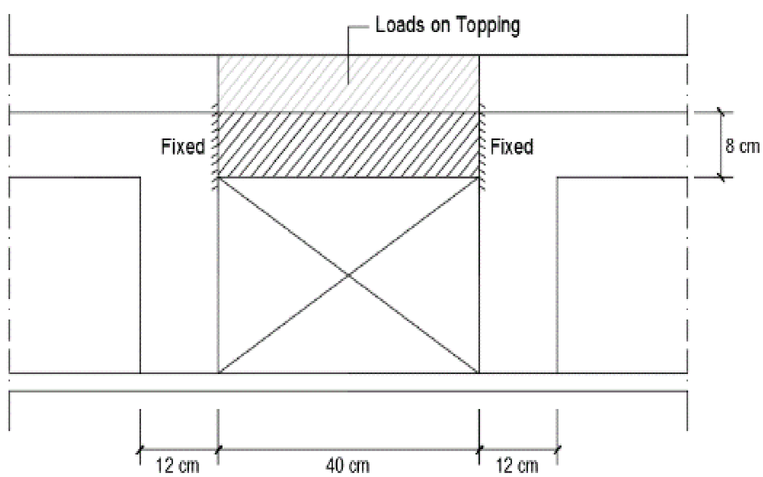


Figure (4- 2):System of Topping

4.5.1.1 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:

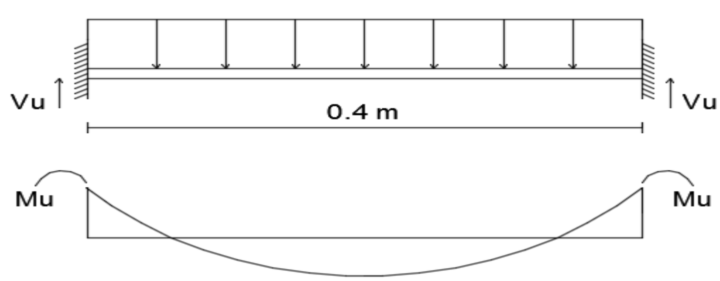
No.	Material	Quality Density KN/m^3	DL (KN/m)		
1	Topping	25	0.08×25 ×1= 2		
2	Coarse Sand	17	0.07×17×1 = 1.19		
3	Mortar	22	0.03×22×1 =0.66		
4	Tile	23	0.03×23×1 =0.69		
5	interior partition	2.3*1=2.3 KN/m			
			∑ =	6.84	KN/m

Table(4- 2): Dead Load Calculation For Topping.

$W_u = 1.2\ DL + 1.6\ LL$

$= 1.2 * 6.84 + 1.6 * 5 = 16.2\ KN/m^2$. (Total Factored Load)

$$M_u = \frac{W_u * l^2}{12} = \frac{16.2 \ * \ 0.4^2}{12} = 0.216\ KN.m/m$$



Figure(4- 3)Moment Shape For Topping.

4.5.1.2Design Strength of Topping

- **Moment Design Strength :**

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

$$\emptyset M_n = 0.55 * 0.42 * \sqrt{fc`} * b * \frac{h^2}{6}$$

$$\emptyset M_n = 0.55 * 0.42 * \sqrt{24} * 1000 * 80^2/6 * 10^{-6} = 1.2\ KN.m$$

$$\emptyset M_n(plane\ concrete\ ) = 1.2KN.m > M_u\ max = 0.216KN.m$$

No structural reinforcement is needed .

Therefore , shrinkage and temperature

reinforcement must be provided.

For the shrinkage and temperature reinforcement :-

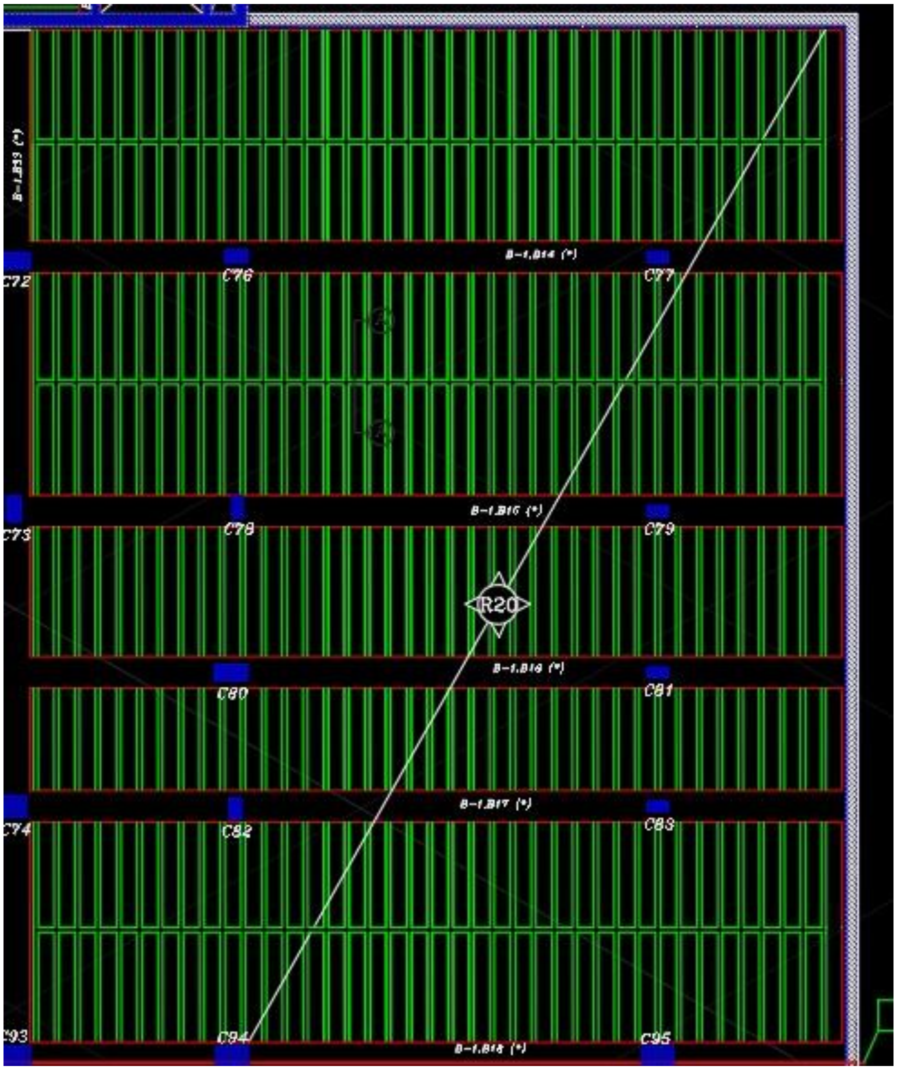
$$\rho_{min} = 0.0018$$

$$A_s = \rho * b * h = 0.0018 * 1000 * 80 = 144\ mm^2.$$

Number 0f Ø8= $\frac{As_{req}}{A_{bar}}$ = $\frac{144}{50.3}$ = 2.87→ Take it 3

- **Select mesh Ø8/20 cm in both directions.**

4.5.2 Design of one way- ribbed slab (R20)



Figure(4-4): Spans of rib (R20

4.5.2.1 Loads Calculation for Rib (R20)

No	Material	Quality Density KN/m³	DL (KN/m)
1	Topping	25	0.08×25 ×0.52= 1.04
2	Coarse Sand	17	0.07×17×0.52 = 0.619
3	RC Rib	25	0.27×25×0.12 = 0.81
4	Mortar	22	0.03×22×0.52 =0.343
5	Hollow block	10	0.27×10×0.4 = 1.08
6	Tile	23	0.03×23×0.52 =0.359
7	Plaster	22	0.03×22×0.52 = 0.343
8	interior partition		2.38*0.52=1.23

∑ =	5.83	KN/m

- DL=5.83 KN/m
- LL = 5*0.52=2.6KN/m

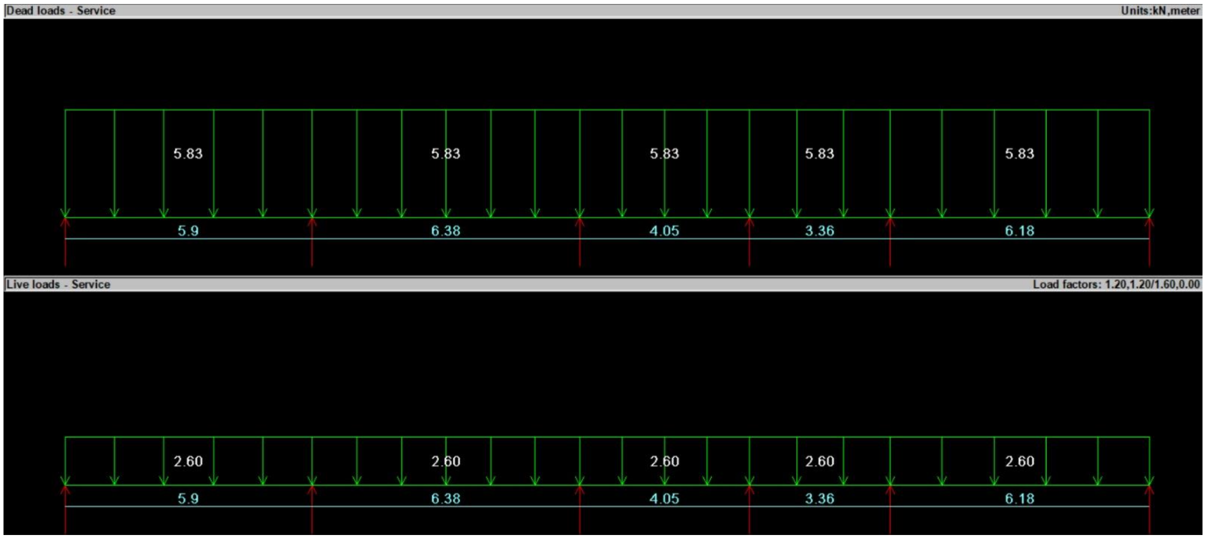


Figure (4- 5): service load For R20

Rib geometry

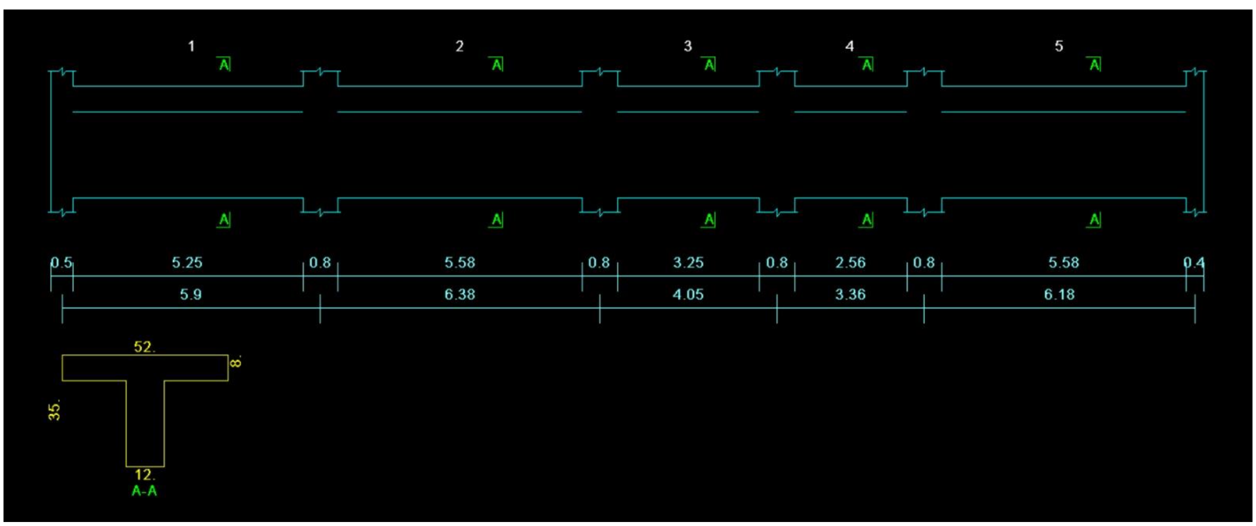


Figure (4- 6):geometry of Rib (R20

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

- bw ≥ 10cm → select bw = 12 cm.
- h ≤ 3.5 bw = 3.5 × 12 = 42 cm → select h =35 cm.
- Tf ≥ $\frac{Ln}{12}$ ≥ 50 mm → select tf = 8 cm.

4.5.2.2 Analysis:

Figure (4-7)& (4-8) shows the shear and Moment envelope of the rib (R20) obtained from Atir:

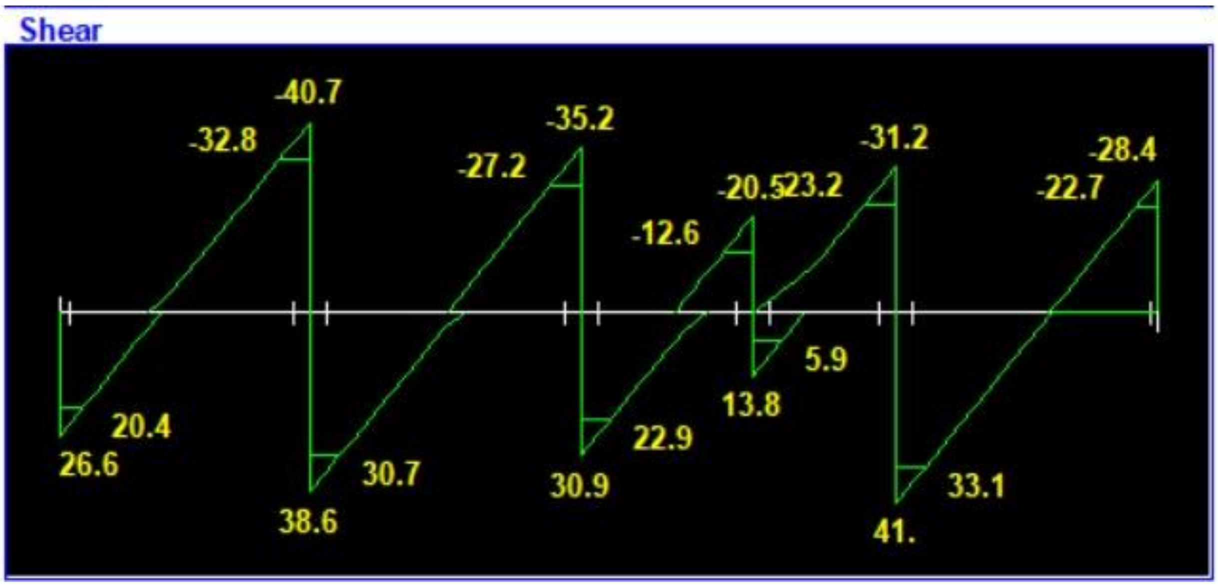


Figure (4- 7):Shear envelope for rib (R20) – (KN)

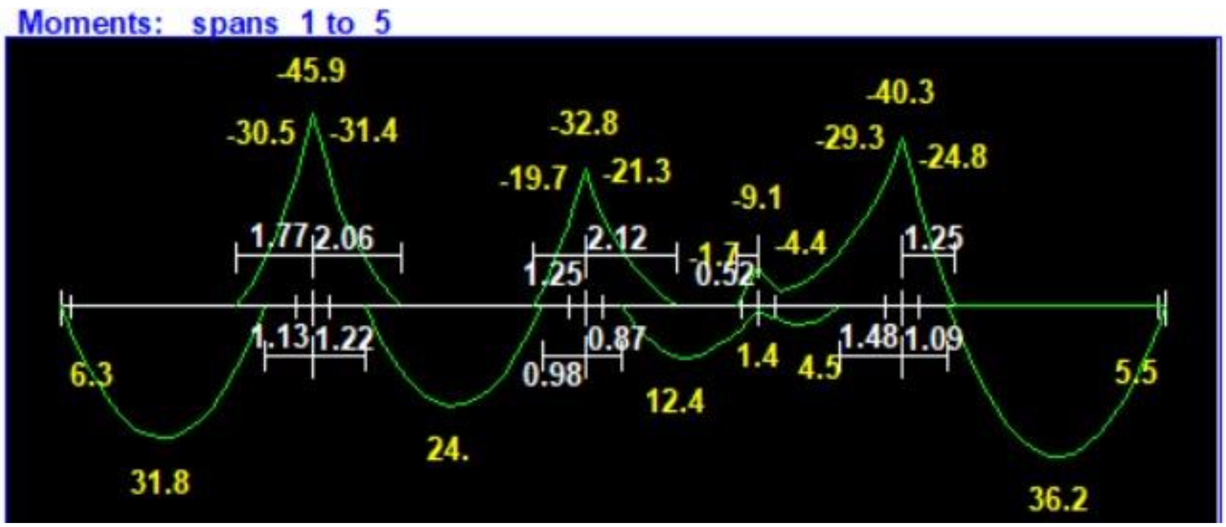


Figure (4- 8):Moment envelope for (R20) – (kN.M)

4.5.2.3 Design of flexure:-

4.5.2.3.1 Design of Positive moment of rib (R20):

Maximum Positive moment Mu (+) = +36.2 KN.m.

*determination whether the rib acts as rectangular or T-section:

For a=t=8cm

d=h-cover-d-d/2=350 - 20 - 10 - (12/2) = 314 mm

$$Mn = \frac{Mu}{0.9} = \frac{36.2}{0.9} = 40.22 \text{ KN.m}$$

$$Mnf = 0.85 * fc` * b_e * h_f \left(d - \frac{h_f}{2}\right)$$

$$= 0.85 * 24 * 520 * 80 (314 - 40) * 10^{-6} = 232.5 \; KN/m$$

Mnf =232.5 KN.m > Mn req = 40.22 KN.m

Design as a rectangular section .

$$Mu = 36.2 \text{ KN .m}$$

$$Mn = \frac{36.2}{0.9} = 40.22 \text{ KN .m}$$

$$Rn = \frac{Mn}{b*d^2} = \frac{40.22 * 10^6}{520 * 314^2} = 0.78 \text{ Mpa}$$

$$m = \frac{fy}{0.85 * fc`} = \frac{420}{0.85 * 24} = 20.58$$

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

$$\rho = \frac{1}{20.58}(1 - \sqrt{1 - \frac{2 * 0.78 * 20.58}{420}})$$

$$\rho = 1.89 * 10^{-3}$$

$As_{req} = \rho.\ b.\ d. = 1.89 * 10^{-3} * 520 * 314 = 309.26 \ mm^2$

$As_{min} = \frac{\sqrt{fc'}}{4fy}$ bw*d $\geq$ $\frac{1.4}{fy}$ bw * d……….. (ACI-318-14)

$As_{min} = 0.25 * \frac{\sqrt{24}}{420} * (120)*(314) \geq \frac{1.4}{420}(120)*(314)$

$= 109.87 \ mm^2 < 125.6 \ mm^2$

As min = 125.6 mm^2

$As_{req} = 309.26 \ mm^2 > As_{min} = 125.6 \ mm^2$

so select **2 Φ 16** with $As_{prov.} = 402.12 \ mm^2 > 309.26 mm^2$

Check for strain :

$$a = \frac{As * f_y}{0.85 * fc` * b}$$

$$a = \frac{402.12 * 420}{0.85 * 24 * 520} = 15.9 \text{ mm}$$

$$c = \frac{a}{B} = \frac{15.9}{0.85} = 18.7$$

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

$$= 0.047 >> 0.005 \quad \Rightarrow ok \quad \therefore \phi = 0.9 \ldots \text{OK!}$$

4.5.2.3.2 Design of negative (R20):

Maximum negative moment Mu (-) = 31.4 KN.m.

d=h-cover-d-d/2=350 - 20 - 10 - (12/2) = 314 mm

Mu = 31.4 KN .m

$$Mn = \frac{31.4}{0.9} = 34.88 \text{ KN .m}$$

$$Rn = \frac{Mn}{b * d^2} = \frac{34.88 * 10^6}{120 * 314^2} = 2.94 \text{ Mpa}$$

$$m = \frac{fy}{0.85 * fc`} = \frac{420}{0.85 * 24} = 20.58$$

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

$$\rho = \frac{1}{20.58}\left(1 - \sqrt{1 - \frac{2 * 2.94 * 20.58}{420}}\right)$$

$$\rho = 7.6 * 10^{-3}$$

$As_{req} = \rho . b. d. = 7.6 * 10^{-3} * 120 * 314 = 286.36 \ mm^2$

$$As_{min} = \frac{\sqrt{fc'}}{4 fy} bw*d \geq \frac{1.4}{fy} bw * d \text{……….}$$ (ACI-318-14)

$$As_{min} = 0.25 * \frac{\sqrt{24}}{420} * (120)*(314) \geq \frac{1.4}{420}(120)*(314)$$

$$= 109.87 \ mm^2 < 125.6 \ mm^2$$

As min = 125.6 mm^2

$As_{req} = 286.36 \ mm^2 > As_{min} = 125.6 \ mm^2$

so select **2 Φ 14** with $As_{prov.} = 307.87 \ mm^2 > 286.36 \ mm^2$

Check for strain :

$$a = \frac{As * f_y}{0.85 * fc` * b}$$

$$a = \frac{307.87 * 420}{0.85 * 24 * 120} = 52.8 \text{ mm}$$

$$c = \frac{a}{B} = \frac{52.8}{0.85} = 62.11 \text{ mm}$$

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

$$= 0.012 >> 0.005 \Rightarrow ok \quad \therefore \phi = 0.9 \text{ … OK!}$$

4.5.2.4 Design of Shear for rib (R20):

Vu max = 33.1 KN

$\Phi\ Vc = \Phi * 1.1 * \frac{1}{6} * \sqrt{fc`} * b * d$

$= \ 0.75 * 1.1 * \frac{1}{6} * \sqrt{24} * 120 * 314 * 10^{-3} = 25.38\ KN$

$\Phi\ Vs\ min = 0.75\ * \frac{1}{3} * 120 * 314 * 10^{-3}\ = 9.42\ KN$

$Vu = 33.1\ KN > \Phi\ Vc = 25.38\ KN$

Use Φ 10 @ 15

4.6 Design of Beam Gf-B2:

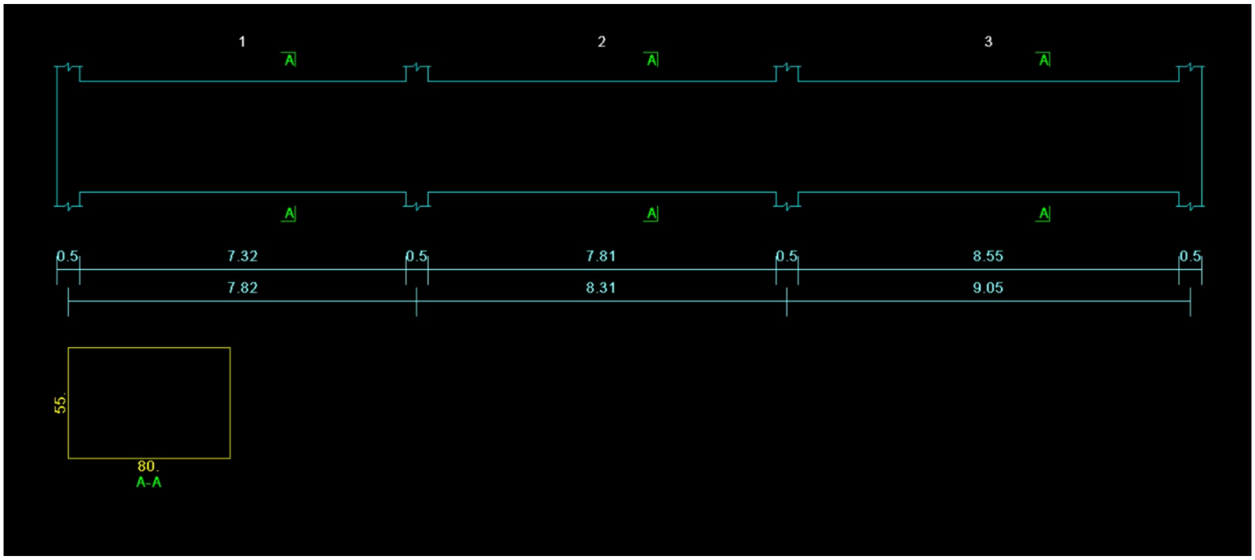


Figure (4- 9):Geometry Of Beam Gf-B2

- Reactions from (rib 22):

Self wieght =0.55*0.8*25 =11

D.L = 32.24/0.52 = 62 kN/m
L.L = 15.288/0.52 = 29.4 kN/m

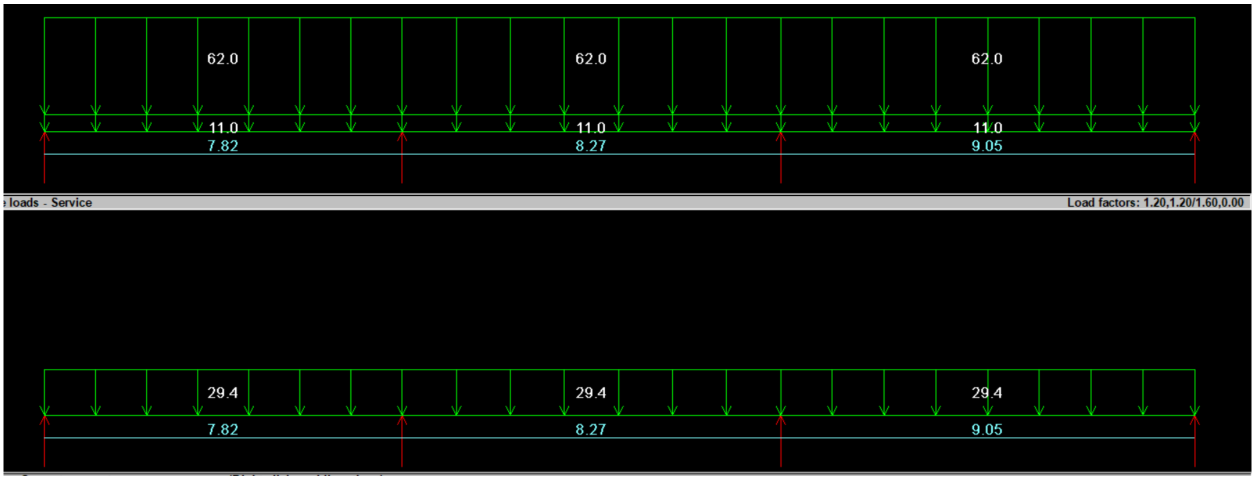


Figure (4- 10): Load On Beam Gf-B2

4.6.1 Design of flexure:-

4.6.1.1 Design of Maximum Positive Moment:

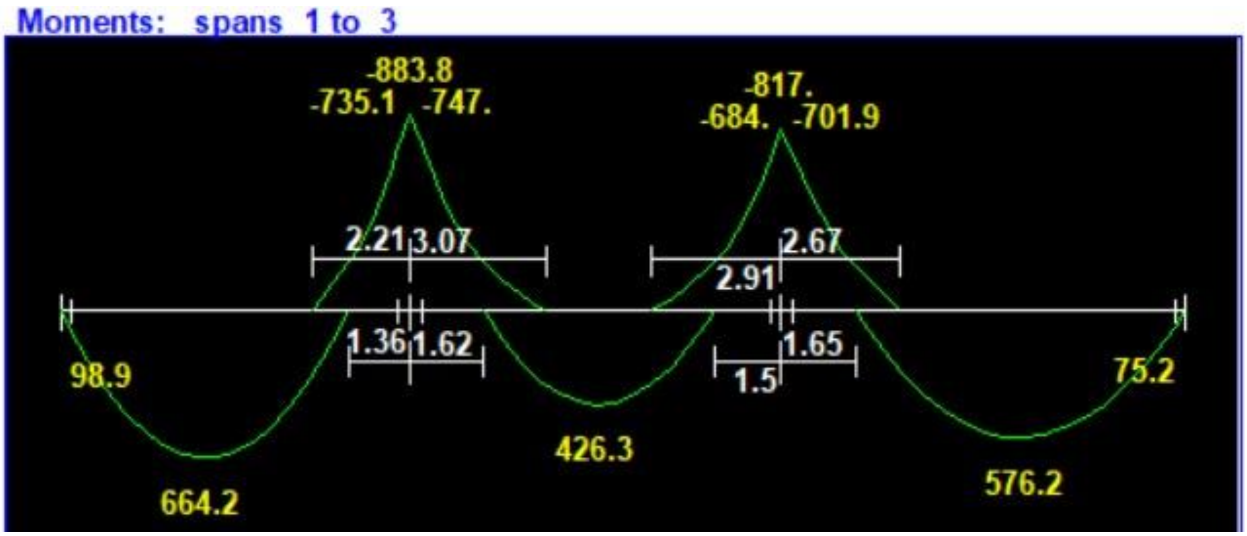


Figure (4- 11): Moment Envelope for beam Gf-B2.

Material: -

concrete B300 Fc' = 24 N/mm^2

Reinforcement Steel fy = 420 N/mm^2

Section: -

B = 80 cm

h = 55cm "choose h = 55 , for deflection requirements L/240"

$\rightarrow$**Mu max = 747 KN.m**

b_w = 80 Cm.   h = 55 Cm.

d = depth - cover – diameter of stirrups – (diameter of bar/ 2)

$=550 - 40 - 10 - \frac{20}{2} = 490$ mm

$C_{max} = \frac{3}{7} * d = \frac{3}{7} * 490 = 210$ mm.

$f_c' = 24$ MPa < 28 MPa $\rightarrow \beta_1 = 0.85$

$a_{max} = \beta_1 * C_{max} = 0.85 * 210 = 178.5$ mm.

*Note:

$M_{n\,max} = 0.85 * f_c' * b * a * (d - \frac{a}{2})$

$= 0.85 * 24 * 0.8 * 0.1785 * (0.490 - 0.1785/2) * 10^3$

= 1167.4 KN.m

$\epsilon_s = 0.004$

$\phi = 0.65 + \frac{250}{3} * (0.004 - 0.002) = 0.82$

$\rightarrow \phi Mn_{max} = 0.82 * 1167.4 = 957.29$ KN.m

$\rightarrow$ Mu = 747 KN.m < ϕMn_{max} = 957.29 KN.m

∴**Singly reinforced concrete section.**

1) Maximum positive moment $Mu^{(+)}$ = 664.2 KN.m

Mn = Mu /ф= 664.2/ 0.9 = 738 KN.m .

→**m=20.58**

$R_n = \frac{M_n}{b*d^2} = \frac{738*10^6}{800*(490)^2}$ = 3.84MPa

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

$\frac{1}{20.58}\left(1 - \sqrt{1 - \frac{2*3.84*20.58}{420}}\right) = 0.01$

$A_s = \rho * b * d = 0.01 * 800 * 490 = 3920\ mm^2$

$$As_{min} = \frac{\sqrt{f_c'}}{4\,(f_y)} * b * d \geq \frac{1.4}{f_y} * b * d$$

$$\frac{\sqrt{24}}{4*420} * 800 * 490 \geq \frac{1.4}{420} * 800 * 490$$

= 1143.1 mm^2 < 1306.66 mm^2 …. Larger value is CONTROL

As= 3920 mm^2

Use Φ25…. As=490.8 mm^2

#of bars= (3920 / 490.8) = 8

∴ **Use 8 Φ 25 …As = 3926.4** > 3920 mm^2

→ **Check for strain:-($\varepsilon_s \geq 0.005$)**

Tension = Compression

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

3926.4 * 420 = 0.85 * 24 * 800 * a

a = 101.04 mm.

f_c' = 24 MPa <   28 MPa → β_1 = 0.85

$c = \frac{a}{\beta_1} = \frac{101.04}{0.85}$ = 118.8 mm.

$\varepsilon_s = \frac{d-c}{c} * 0.003$

$= \frac{490 - 118.8}{118.8} * 0.003 = 0.0093 > 0.005$ ∴ ϕ =0.9 … OK!

4.6.1.2 Design of Maximum Negative Moment :

→Mu max = 747 KN.m

$R_n = \frac{M_n}{b*d^2} = \frac{747 * 10^6}{0.9 * 800 * 490^2}$ = 4.3 MPa

m= 20.58 mm

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

$= \frac{1}{20.58}\left(1 - \sqrt{1 - \frac{2*4.3*20.58}{420}}\right)$= 0.011

$As_{req} = \rho \times b \times d$ =0.011 × 800 × 490= 4312 mm^2

$$As_{min} = \frac{0.25\sqrt{f_c'}}{(f_y)} * b_w * d \geq \frac{1.4}{f_y} * b_w * d$$

$= \frac{0.25*\sqrt{24}}{420} * 800 * 490 \quad \geq \quad \frac{1.4}{420} * 800 * 490$

=606 mm^2 < 1306.66 mm^2 ....

→As_{min} = 1143.1mm^2<$As_{req=}$ 2419 mm^2.

Use **9 Ø 25** with As = 4417.86 mm^2> As req= 4312 mm^2

→ **Check for strain:-($\varepsilon_s \geq 0.005$)**

Tension = Compression

$A_s * fy = 0.85 * f_c' * b * a$

4417.86 * 420 = 0.85 * 24 * 800 * a

a = 113.69 mm.

f_c' = 24 MPa < 28 MPa → β_1 = 0.85

$c = \frac{a}{\beta_1} = \frac{113.69}{0.85} = 133.75$ mm.

$\varepsilon_s = \frac{d-c}{c} * 0.003$

$= \frac{490 - 133.75}{133.75} * 0.003 = 0.0079 > 0.005$ ∴ ϕ =0.9 … OK!

4.6.2 Design of Shear For Beam Gf-B2:

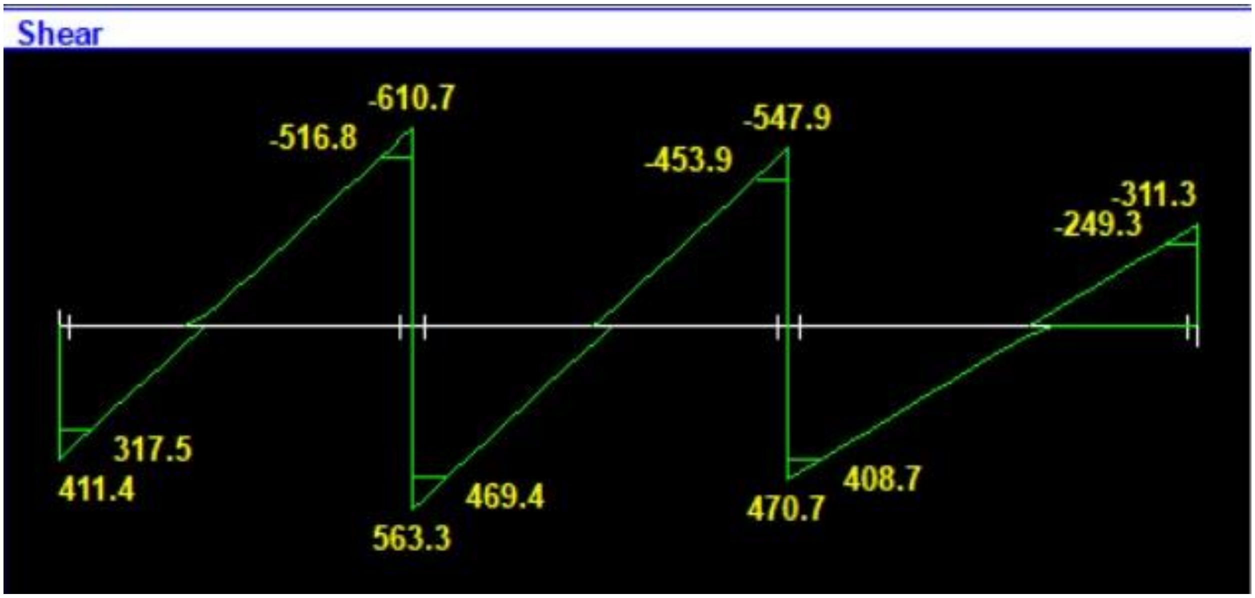


Figure (4- 12): Shear Envelope for beam Gf-B2.

1) Vu = 516.8 KN .

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

$= 0.75 * \frac{\sqrt{24}}{6} * 800 * 490 * 10^{-3} = 240$ KN.

\→ Check For Cases:-

1- <u>Case1 :</u>

$V_u \leq \frac{\phi V_c}{2}$.

$516.8 \leq \frac{240}{2} = 120$

$\therefore$ **Case (1) is NOT satisfied**

Case 2 :

$\frac{\phi V_c}{2} < V_u \leq \phi V_c$

$120 < 516.8 \leq 240$

$\therefore$ **Case (2) is NOT satisfied**

3- Case 3

$\phi V_c < V_u \leq \phi V_c + \phi Vs_{min}$

$\phi\ Vs_{min} \geq \frac{\phi}{16}\sqrt{f_c'} * b_w * d = \frac{0.75}{16}\sqrt{24} * 0.8 * 0.490 * 10^3 = 90$ KN.

$\geq \frac{\phi}{3} * b_w * d = \frac{0.75}{3} * 0.8 * 0.490 * 10^3 = 98$ KN ….

CONTROL.

$\therefore \phi Vs_{min} = 98$ KN.

$\phi V_c + \phi Vs_{min} = 240 + 98 = 338$ KN.

$\phi V_c < V_u \leq \phi V_c + \phi Vs_{min}$

$240 < 516.8 \leq 338$

$\therefore$ **Case (3) is NOT satisfied**

4.case(4):

$\phi V_c + \phi Vs_{min} \leq v_u \leq \phi(v_c + v_s`)$

$Vs` = \frac{1}{3}\sqrt{f_c}$ *bw*d

$Vs` = \frac{1}{3}\sqrt{24}$ * 800 * 490 *10^-3 = 640.13 KN

$\phi V_c + \phi Vs_{min} \leq V_U \leq \phi(v_c + v_s`)$

$338 \leq 516.8 \leq 720$ OK

Case (4) is satisfied

Try Φ10 with 4 legs =4 * 78.5 = 314 mm^2.

$s \leq \frac{d}{2} = \frac{490}{2} = 245$ mm .... CONTROL

≤ 600 mm.

∴ **Use Φ10 @ 10 Cm .**

4.8 Design of Column (C4) :

✔ **Material :-**

⇒ concrete B350 Fc' = 28 N/mm^2

⇒ Reinforcement Steel Fy = 420 N/mm^2

Load Calculation:-

Service Load:-

Dead Load = 1000 KN
Live Load = 500 KN

Factored Load:-

P_U = 1.2 ×1000 + 1.6×500 = 2000 KN

✔ Dimensions of Column:-

Assume b = 500 mm , h = 300 mm

Check for slenderness :

$\frac{K\,lu}{r}$ < 34 - 12

$$\rightarrow \lambda = \frac{1 * 4.00}{0.3 * 0.5} = 26.6$$

$$\lambda \leq 34 - 12(1) = 26.6 \quad \leq 40$$

$\lambda = 26.6 < 22$ **long about X**

System about Y

$$\rightarrow \lambda = \frac{1 * 4.00}{0.3 * 0.3} = 44$$

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

$$\lambda = 44 > 22$$

∴ Short about X and long about Y.

∴ Column is long about Y, so slenderness effect will be considered.

✓ Minimum Eccentricity: -

e_{min}= 15+0.03*h= 15+0.03*300 = 24 mm

✓ Magnification Factor: -

Pu= 2000 kN

M_{min} = Pu* e_{min}= 2000*0.024 = 48 KN.m

Ec= 4700 $\sqrt{fc}$ = 4700*$\sqrt{28}$ = 24870 MPa

Ig= $\frac{bh^3}{12} = \frac{500*300^3}{12} = 1.125 * 10^9 mm^4$

$$\beta_{dns} = \frac{1.2D}{1.2D + 1.6L} = \frac{1.2^* 1000}{2000} = 0.6$$

$$EI = \frac{0.4E_C Ig}{1 + B_{dn5}} = \frac{0.4 * 24870 * 1.125}{1 + 0.6} = 6016.9 \, kN \cdot m^2$$

$$P_c = \frac{\pi^2 EI}{(kl_u)^2} = \frac{\pi^2 * 6016.9}{(1 * 3.06)^2} = 6342.1$$

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

$$\delta_{ns} = \frac{c_m}{1 - \frac{p_u}{0.75p_c}} = \frac{1}{1 - \frac{560}{0.75 * 6342.1}} = 1.13 > 1$$

$e = e_{min} * \delta_{ns}$ = 24 * 1.13 = 27.12 mm

$M_2 = M_{min} = 13.44 \, kN.m$

$$M_c = \delta_{ns}^* M_2 = 1.13 * 13.44 = 15.18 \, kN.m$$

$$\frac{e}{h} = \frac{27.12}{300} = 0.09$$

✓ Longitudinal bars: -

2000 * 10^3 = 0.65 * 0.8 { 0.85 * 24 (150000 - Ast) + 420 Ast }

Ast = 1539.9 mm^2

Select 10∅14 with As prov = 1539.3 mm2

ρ = Ast / Ag = 1539.3 / 150000

= 0.010262

Check spacing between the bars:

$$S = \frac{500 - 2*40 - 2*10 - 4*14}{3} = 114.6\ mm$$

S = 114.6 mm ≥ 40mm

≥ 1.5db = 21 mm

Design of the Stirrups:

b = 50 cm, h = 30 cm

Lap splice at the foot of column:

Try 100% – lap splice (10 ∅ 14 with 10 ∅ 14)

ρ =As/Ac =(20*153.86)/(500*300) = 2.05% < 8 % … OK

closely stirrups :S smallest of

1) 48*dbs. = 48*10 = 480 mm

2)16*db. = 16*14 = 224 mm……… control ~~~

3) The least dimension of the column = 250 mm.

At end support and below:

X= max (Ldc OR b) + cover – (h slab or beam)

Ldc = (0.24*420*14)/ (1*√28) = 266.7 mm > 200 mm ⋯ OK

→ b > Ldc → 50 cm > 26.67 cm

X= (50) + 2 – (26.67) = 25.33 cm

X > 0.5 h → 25.33 cm > (0.5*30) = 30.5 cm … OK

X< 2 h column →25.33cm < 50 cm … OK

→ Selected X = 25.33 cm e = 8 cm → control

#NO of Stirrups = 25.33/8 +1 ≈ 5

→ **Selected 5Ø10/8 cm**

Below and above beam or slab:

Fy = 420 Map   Fc = 24 Mpa.

Lsc = 0.071 *420*14 = 417.48 mm > 300 mm

b =50 cm.

Selected b = 50 cm with e = 10 cm

#NO of Stirrups = 50/10 +1 ≈ 6

→ Selected 6Ø10/10 cm

Normal Region:

Select S normal =20 cm.

(L1/20)+1 = (209.6/20)+1≈12

→ Selected 12Ø10/20 cm.

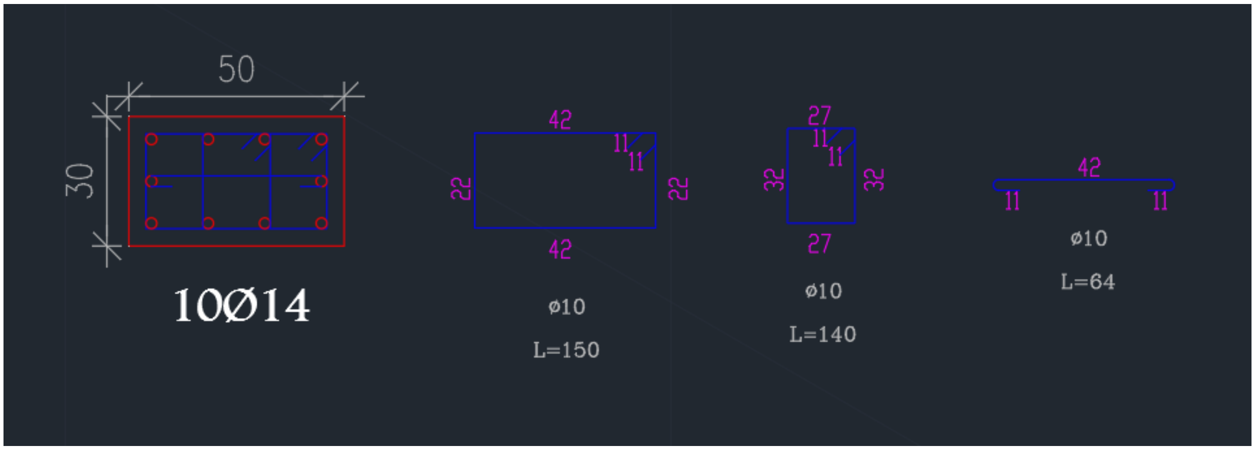


Fig.(4-7).
Detail column (C4)

4.9 Design of Isolated Footing:

Loads that act on footing F1 are :

- PD = 1000 kN , PL = 500kN
- Pu = 1.2 * 1000 + 1.6*500 = 2000 kN

The following parameters are used in design :

- $\gamma_{\text{concrete}} = 25\ kN/m^3$
- $\gamma_{\text{soil}} = 17\ kN/m^3$
- $\sigma_{allow} = 500\ kN/m^2$
- clear cover = 5cm

Determination of footing dimension (a)

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

→ Assume h = 45 cm

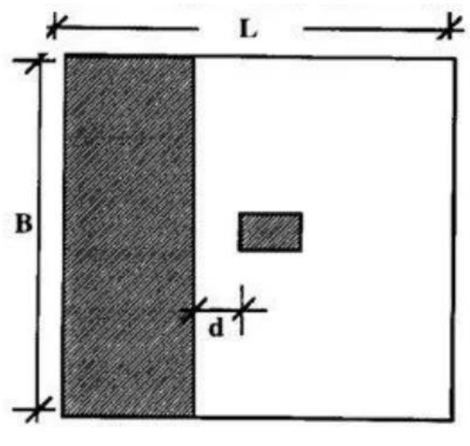
→ $\sigma_{b(allow)\text{net}}$ = 500 – 25*0.45 – 0.25*17 - 5 = 480.75 kN/m²

→ $A = \frac{P_n}{q_{a.net}} = \frac{1000 + 500}{480.75} = 3.1\ m^2$

→ $l = \sqrt{A} = \sqrt{3.1} = 1.76\ m$

→ Select $l = 1.80\ m$

Determination of footing depth (h)



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

→ $q_u = \frac{P_u}{A} = \frac{2000}{3.234} = 617.284\ KN/m^2$

Design of one way shear

d = h − $cover$ − ∅ = 450− 50− 10 = 390mm

→ Vu at distance d from the face of column $V_u = q_u b(\frac{l}{2} - \frac{a}{2} - d)$

$$= 617.284 * 1.8\ \left(\frac{1.8}{2} - \frac{0.3}{2} - 0.390\right) = 400\ KN$$

Ø Vc = 0.75 * $\frac{1}{6}$ * $\sqrt{fc'}$ * b * d

= 0.75 * $\frac{1}{6}$ * $\sqrt{28}$ * 1800* 390 = 464.329 kN > Vu

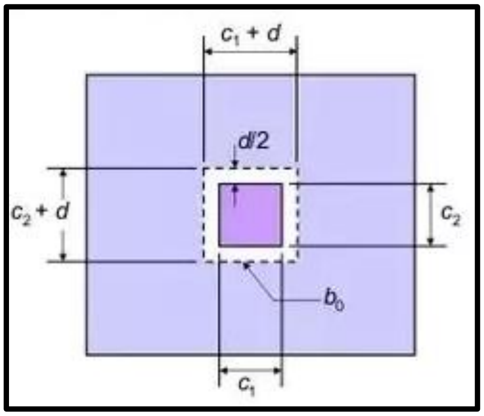
∴ **h = 45 cm is correct**

Design of Punching (two way shear)

→ $d = 390\ mm$

→ $b_{\circ}$ = 2(0.3 + 0.390) + 2(0.5 + 0.390) = 3.16 mm

→ αs = 40 (interior column)



Vu =

617.284 (1.8*1.8 - (0.3+0.390)(0.5+0.390)) = **1317.66 kN**

ØVc is the smallest of :

1. $Vc = \frac{1}{6}\left(1 + \frac{2}{\beta}\right) \times \sqrt{fc} \times b_o \times d \quad = \frac{1}{6}\left(1 + \frac{2}{1}\right) \times \sqrt{28} \times 3160 \times 390 \times 10^{-3} = 3727.95KN$

2. $Vc = \frac{1}{12}\left(\frac{\propto_s \times d}{b_o} + 2\right) \times \sqrt{fc} \times b_o \times d$

$$= \frac{1}{12}\left(\frac{40 \times 940}{3160} + 2\right) \times \sqrt{28} \times 3160 \times 340 \times 10^{-3} = 6584.7\ KN$$

3. $Vc = \frac{1}{3} \times \sqrt{fc} \times b_o \times d$

$$= \frac{1}{3} \times \sqrt{28} \times 3160 \times 390 \times 10^{-3} = 2143.7\ \ kN$$ ℘ **cont.**

→ ØVc = 0.75 × 2143.7 = **1507.775** kN > Vu = **1317.66** kN

∴ **h = 45 cm is correct**

Design of Reinforcement long direction

Mu = 617.284 * 1.8 * 0.3 * (0.3/2) = 50 kN.m

→ $m = \frac{Fy}{0.85 * Fc'} = \frac{420}{0.85 * 28} = 17.6$

$\rightarrow$ Mn = $50/0.9$ = 55.5 kN.m

$\rightarrow$ Rn = $\frac{Mn}{b*d^2}$ = $\frac{55.5*10^6}{1800*390^2}$ = 0.202 MPa

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

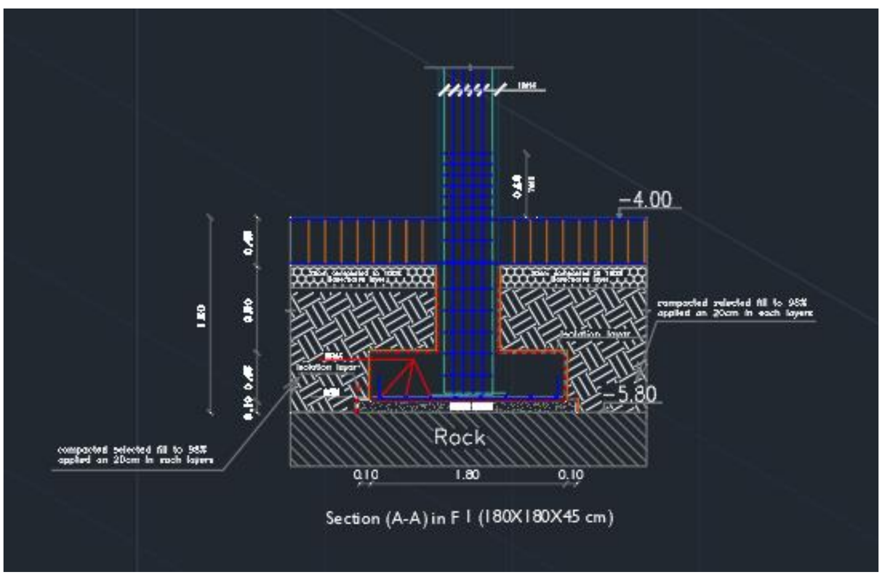
$= \frac{1}{17.6} * (1- \sqrt{1-\frac{2*0.202*17.6}{420}})$ = 0.000482

$\rightarrow$ Asreq = $\rho * b * d = 0.000482 * 1800 * 390 = 340.62$ mm^2

$\rightarrow$ As (min) = 0.0018*b*h = 0.0018*1800 * 450= 1458 mm^2

$\rightarrow$ Asreq < As (min)

∴ **Select for long directions: 8 Ø 16with As = 1612.8 mm^2 > As min… (ok)**



Section (A-A) in F I (180X180X45 cm)

Fig (4-8): Footing (1) Detail.

4. 10 Design of stairs:

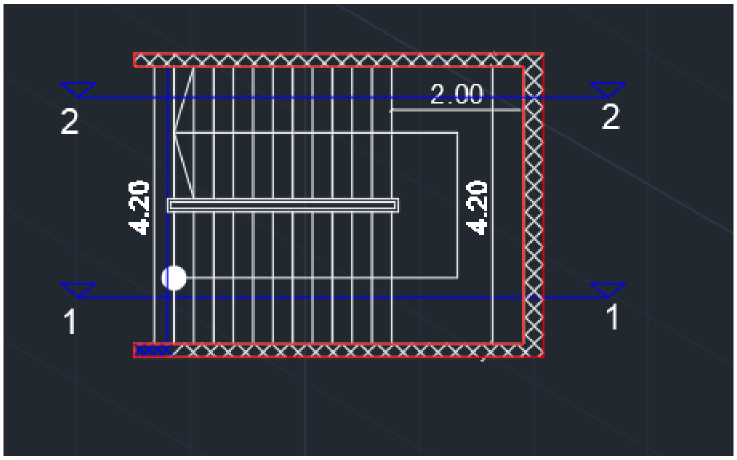


Fig.(4-9): Stair Details

Design of flight

The structural system of the flight is shown in figure (4-9) and the following steps explain the design procedure of the flight :

1. Determination of flight thickness :

Limitation of deflection: h ≥ minimum h

h (min) = L/20 = 390/20 = 19.5cm

∴ Select h = 20 cm, but shear and deflection must be checked

Angle (α): tan(α) = 17/30 → α = 29.5

2. Loads calculation

Load calculation for the flight		
Concrete Block	Quality Density	$W = \gamma \cdot V$
	$KN/\ m3$	KN
Tiles	27	=27*((0.17+0.35)/0.3)*0.03*1=1.4
Mortar	22	=22*((0.17+0.3)/0.3)*0.02*1=0.69
Stair step	25	=(25/0.3)*((0.17*0.3)/2)*1=2.1
R.C solid slab	25	(25*0.20*1)/(cos 29.5) = 5.74
Plaster	22	(22*0.03*1)/(cos 29.5) = 0.75
Total Dead Load, KN		10.68 KN/m

Table(4- 2): Calculation of Dead Loads that act on Flight

Live load= 5 KN/m^2

Wu= 1.2*10.68 + 1.6*5= 20.816 KN/m

3. Analysis :

The following figures show shear and moment Diagrams resulted from analysis of the flight:

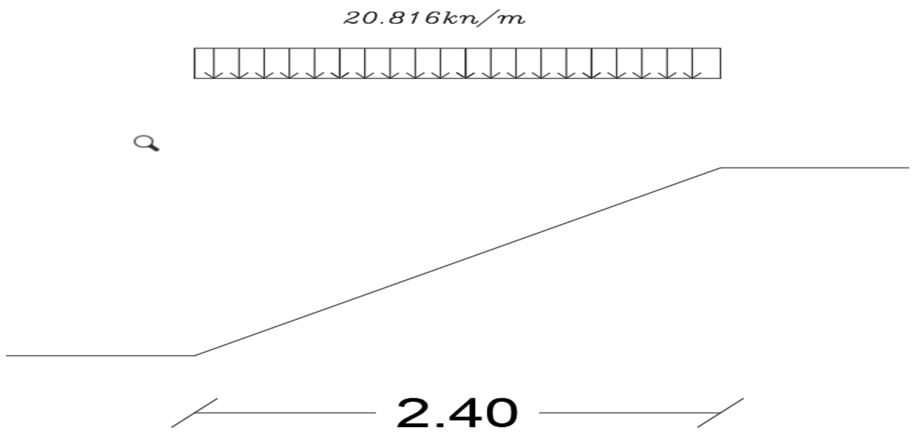


Figure (4-10) : Load distribution for flight.

4. Design :

Design for shear:

R=W*L/2= (20.816*2.4)/2= 24.97 KN

d=200-20-(14/2) = 173 mm

$\text{ØVc} = 0.75 * \frac{1}{6} * \sqrt{Fc'} * bw * d$

$= 0.75 * \frac{1}{6} * \sqrt{24} * 1000 * 0.173$

= 105.9 KN

0.5* ØVc= 0.5*105.9= 52.9 KN

0.5 ØVc = 52.9 > Vu max = 24.97 kN

∴ No Shear Reinforcement is Required

Design of bending moment:

Mu= 24.97 (0.75 + 1.2)- 23.5*(1.2^2/2) = 31.77 KN/m m =$\frac{Fy}{0.85*Fc'} = \frac{420}{0.85*24} = 20.59$

Rn = $\frac{Mu/\emptyset}{b*d^2}$ = $\frac{31.77 *10^6/0.9}{1000*173^2}$ = 1.2 MPa

$\rho = \frac{1}{m} * (1- \sqrt{1-\frac{2*Rn*m}{Fy}}) = \frac{1}{20.59} * (1- \sqrt{1-\frac{2*1.2*20.59}{420}}) = 2.895*10^{-3}$

As, req $= \rho * b * d = 2.895 * 10 - 3 * 1000 * 173 = 500.77$ mm²

As min = 0.0018 *1000*200 = 360mm^2
As, req > As, min

Select 5Ø14 with As= 769.5 mm^2 > As, req=500.77

For secondary Reinforcement select Ø14 /20 with As = 769.5 mm2 > As min

Check Strain:

C = T

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

0.85*24*a*1000 = 769.5 *420

a = 15.84 mm

c = a/β = 15.84/0.85 = 18.64 mm

εs =((d-c)/c) * 0.003

= ((173-18.64)/18.64) *0.003

= 0.025 < 0.005

Check spacing:

S= 20cm > 3h = 3*200= 600 mm

= 450 mm

= 380*($\frac{280}{0.67*420}$)- 2.5*20= 32.8 mm

Design of Landing

- Determination the thickness:

Limitation of deflection: h ≥ minimum h

∴ Select h = 20 cm, but shear and deflection must be checked

d=200-20-(14/2) = 173 mm

- Load calculation:

Load calculation for the landing		
Concrete Block	Quality Density	$W = \gamma \cdot V$
	$KN/m3$	KN
Tiles	22	22*0.03*1=0.66
Mortar	22	22*0.02=0.44
R.C solid slab	25	25*0.20*1=5
Plaster	22	22*0.02=0.66
Total Dead Load, KN		6.76 KN/m

Table(4- 3) : Load calculation for the landing

Live load= 5 KN/m^2

Wu= 1.2*6.76+ 1.6*5= 16.112 KN/m

- Analysis.

The following figures show shear and moment Diagrams resulted from analysis of the landing:

- Design.

Design for shear:

R= 36.975 KN

$ØVc = 0.75 * \frac{1}{6} * \sqrt{Fc'} * bw * d$

$= 0.75 * \frac{1}{6} * \sqrt{24} * 1000 * 0.173 = 105.94$ KN

0.5* ØVc= 0.5*105.94 = 52.97KN

0.5 ØVc = 52.97 > Vu max = 36.975 KN

∴ thickness is enough

Select h = 20m

Design of bending moment:

Mu= 36.975 * 0.75 - (16.1 * 0.75^2)/2-(16.6 * 0.75^2)/2-(16.6 * 0.75^2)/2 = 13.866 KN/m

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

Rn = $\frac{Mu/\emptyset}{b*d^2} = \frac{13.866*10^6/0.9}{1000*173^2}$ = 0.514 MPa

$\rho = \frac{1}{m} * (1- \sqrt{1-\frac{2*Rn*m}{Fy}}) = \frac{1}{20.59} * (1- \sqrt{1-\frac{2*0.514*20.59}{420}}) = 0.001247$

As, req $= \rho * b * d = 0.001247 * 1000 * 173 = 215.73$ mm^2

As min = 0.0018 *1000*200 = 360 mm^2

As, req < As, min

Select 5Ø12 with As= 565.5 mm^2> As, req

For secondary Reinforcement select Ø12 /20 with as=565.5 mm2 > As req

Check Strain:

C = T

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

0.85*24*a*1000 = 565.5 *420

a = 11.6 mm

c = a/β = 11.6/0.85 = 13.7 mm

εs =((d-c)/c) * 0.003

= ((173-13.7)/13.7) *0.003

= 0.035 > 0.005

Check spacing:

S= 20cm > 3h = 3*200= 600 mm

= 450 mm

$$= 380*(\frac{280}{0.67*420}) - 2.5*20 = 32.8 \text{ mm}$$

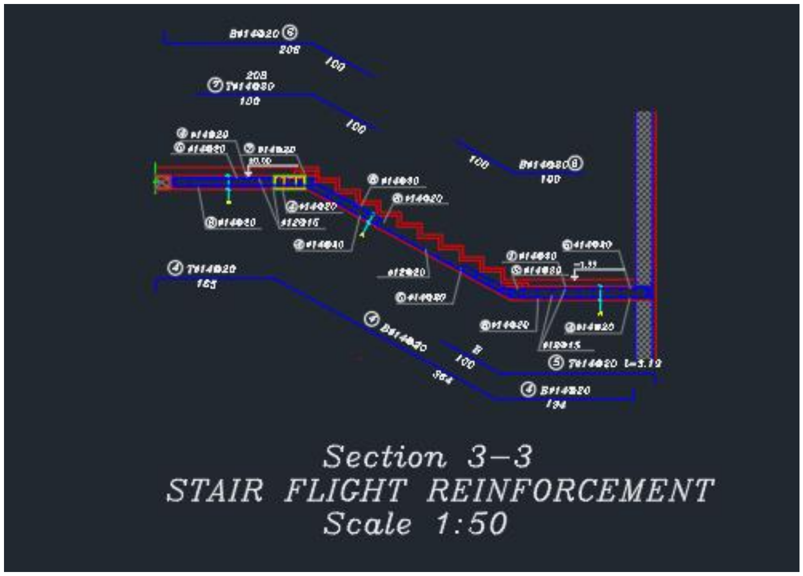


Figure (4- 12) : Stair reinforcement

4.11 Design of Basement wall

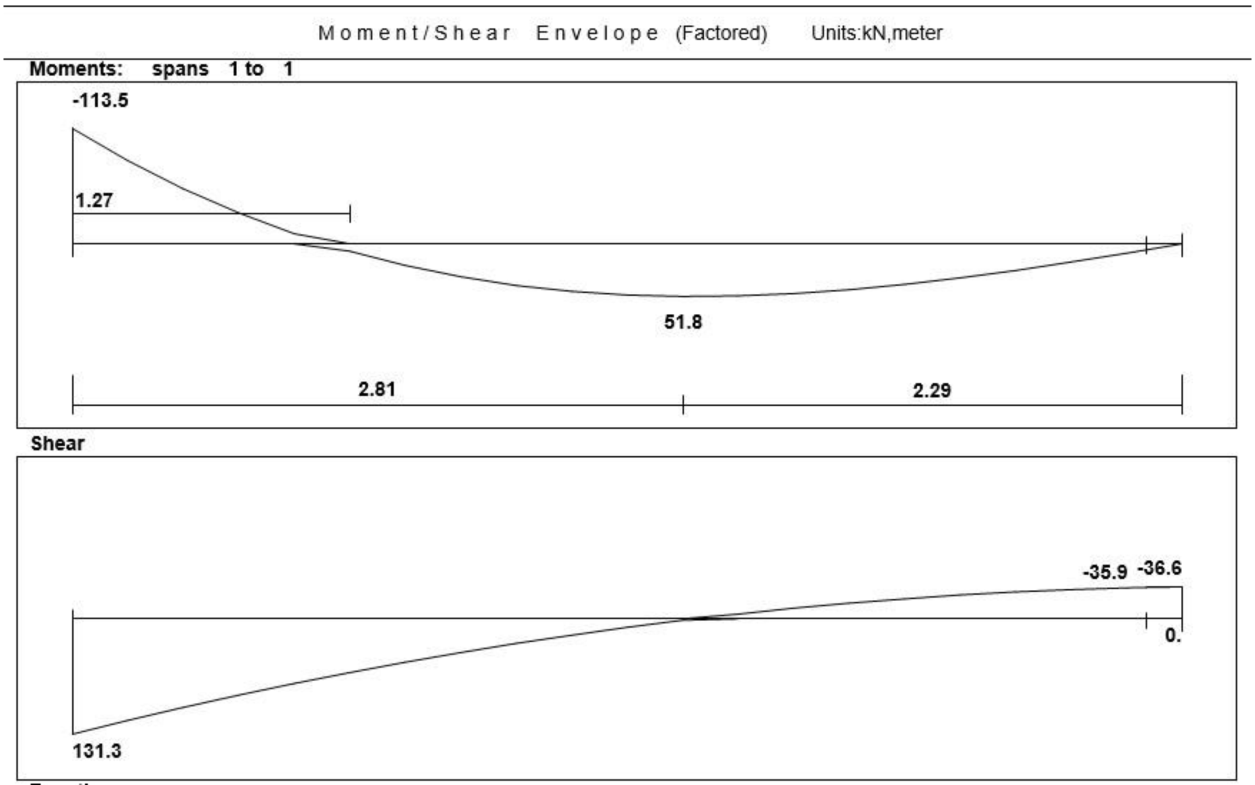


Figure 4-17: Moment & Shear Envelope deagram for Basement Wall

- Maximum moment $Mu^{(-)}$ = 113.5 kN.m

m = $\frac{fy}{0.85 f_c'} = \frac{420}{0.85\times28}$ = 17.6

d = depth - cover – (diameter of bar/ 2)

$= 300 - 70 - \frac{16}{2}$ = 222 mm

$R_n = \frac{M_n}{0.9*b*d^2} = \frac{113.5 \ *10^6}{0.9*1000*(222)^2} = 2.22$ MPa

$\rho = \frac{1}{17.6}\left(1 - \sqrt{1 - \frac{2*17.6*2.22}{420}}\right) = 0.00666$

$A_s = \rho$ * b *d =0.00666*1000*222 = 1479.2 mm^2 /m

$\sqrt{f_c'}$ 1.4 $As_{min} = d$

$$\frac{}{4\,(f\ )} * b * d \ \geq\ \frac{}{f_y} * b * \ y$$

$$= \frac{\sqrt{28}}{4 * 420} * 1000 * 222 \ \geq \ \frac{1.4}{420} * 1000 * 222$$

= 699.23 mm^2 /m < 740 mm^2 /m …. As, min = 740 mm^2

/m A_s = 1479.2 mm^2 > As, min = 740 mm^2 **OK**

Use ф16/10cm …. As= 2010.62 mm^2 /m for Negative reinforcement

$\boldsymbol{A_{sprovid}} = 2010.62$ mm2 /m > $\boldsymbol{A_{sreq}} = 1479.2$ mm2 /m

 Maximum positive moment $Mu^{(+)}$ = 51.8 kN.m

R_n 9∗b∗ 2 2 $= \frac{M_n}{d} = \frac{51.8 * 10^6}{0.9*1000*(222)}$ 0. = 1.16 MPa

$$\rho = \frac{1}{17.6}\left(1 - \sqrt{1 - \frac{2*17.6*1.16}{420}}\right) = 0.00285$$

As = ρ * b *d =0.00285*1000*222 = 633.12 mm2 /m

As = 633.12 mm2 < As, min = 740 mm2

❾ As, min = 740 mm2 .... control

Use ф16/25cm …. As= 803.84 mm^2 /m for Positive reinforcement

$\boldsymbol{A_{sprovid}} = 803.84$ mm2 /m > $\boldsymbol{A_{sreq}} = 740$ mm2 /m

 Design for Shear

 $(\boldsymbol{V_{u,d} = 131.3\ KN})$

$\phi V_c = \phi \frac{\sqrt{f_{c'}}}{6} * * b * d = \frac{\sqrt{28}}{6} *1000* 222 * 10^{-3} = 146$ 0.75 * KN.

$V_u \leq \phi V_c$

131.3 > 146

Thickness is ok .....

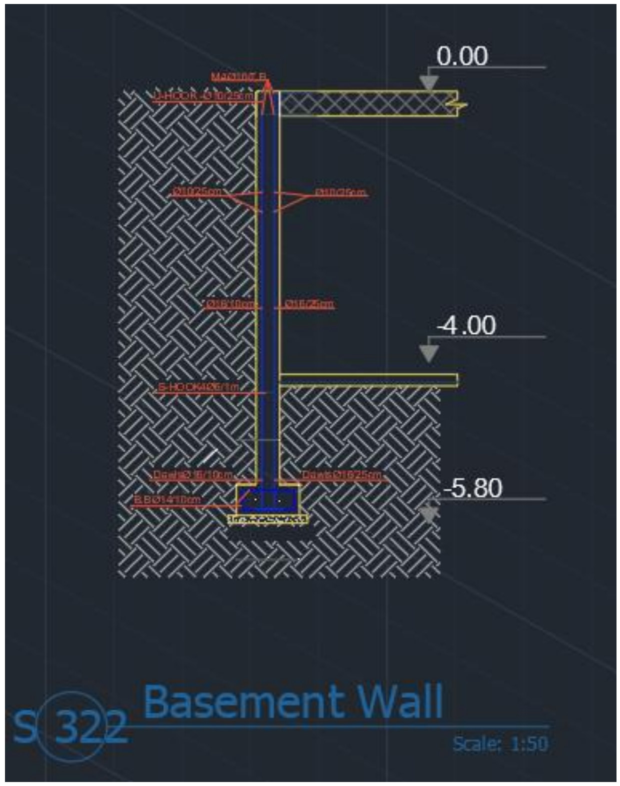


Figure 4-18 : Basement Wall detailing

الفصل الخامس

الاستنتاجات و التوصيات

٥-١ الاستنتاجات :

١- تعد إحدى أهم خطوات التصميم الإنشائي هي كيفية الربط بين العناصر الإنشائي المختلفة من خلال النظرة الشمولية للمبنى و من ثم تجزئة هذه العناصر للتصميم بشكل منفرد .

٢- يجب على أي مصمم إنشائي تصميم العناصر بشكل يدوي حتى يستطيع امتلاك الخبرة والقدرة على استخدام البرامج التصميمية المحوسبة .

٣- من العوامل التي يجب أخذها بعين الاعتبار هي العوامل الطبيعية المحيطة بالمبنى وطبيعة الموقع وتأثير القوى الطبيعية عليها .

٤- تم تصميم أساسات هذا المبنى باستخدام قوة تحمل للتربة مقدارها(٥Kg/cm٢) .

٥- أما بالنسبة لبرامج الحاسوب المستخدمة فقد تم استخدام برنامج (Atir Software)وبرنامج (safe) وبرنامج (ETABS) في التحليل وفي تصميم بعض العناصر الإنشائية بعد مقارنتها بأحد التصاميم اليدوية وكانت النتائج متطابقة.

٦- بعد ذلك تم عمل مراجعة لكافة المخططات التنفيذية لتعديل ما اختلف فيها من أمور.

٧- الأحمال الحية المستخدمة في هذا المشروع كانت من كود الاحمال الأردني ،وتم اعتماد الكود الأمريكي في تحليل جدران القص.

٨- من الصفات التي يجب أن يتصف بها المصمم هي الحس الهندسي الذي يقوم من خلاله بتجاوز أية مشكلة ممكن أن تعترضه في المشروع وبشكل مقنع ومدروس .

٥-٢ التوصيات:

- ينصح بتنفيذ المشروع من خلال لجنة هندسية متخصصة تتابع العمل و مطابقة ما يتم على أرض الواقع ما بداخل المخططات .
- ينصح أثناء التنفيذ بمراجعة كتاب المواصفات الفنية والهندسية الأردني الصادر عن وزارة الأشغال العامة .
- في حال تبين أن قوة تحمل التربة (Bearing Capacity) أقل من القوة المعمول بها في التصميم يجب إعادة تصميم الأساسيات للمشروع وفقا للقوى الجديدة .
- يجب استكمال عمل التصميم الكهربائي و الميكانيكي للمشروع قبل المباشرة في التنفيذ لإدخال أي تعديلات محتملة .
- بعد المراجعة الشاملة للمخططات التنفيذية و الإعداد المفصل للمخططات الإنشائية فإن المشروع جاهز للتنفيذ.

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[٣] كود البناء الاردني ، كود الأحمال والقوى ، عمان،الأردن: مجلس البناء الوطني الأردني، ٢٠٠٦م .