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Collage of Engineering & Technology

Civil and Architectural Engineering Department

Structure Engineering

Graduation Project

Project Title :

Structural And Environmental Design, a study of using green roofs system in construction.

Palestine – Hebron

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كلية الهندسة والتكنولوجيا

دائرة الهندسة المدنية والمعمارية

هندسة مباني وهندسة بيئة

مشروع التخرج

التصميم الإنشائي والبيئي، دراسة استخدام الأسطح الخضراء في المنشآت

فـريـق الـعمـل

غيداء نواجعة | **صفاء عويسي**

سجى طه | **آية جواعدة**

بناء على توجيهات الأستاذ المشرف على المشروع وبموافقة جميع أعضاء اللجنة الممتحنة، تم تقديم هذا المشروع إلى دائرة الهندسة المدنية والمعمارية في كلية الهندسة والتكنولوجيا للوفاء بمتطلبات الدائرة لدرجة البكالوريوس.

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الإهـــــــداء

إلى القدوة الذين كانوا معنا في كل خطواتنا

إلى من زرعوا في داخلنا فكرة الحلم

من قدموا من أجل أن يرونا هنا حيث وصلنا

إلى فخرنا الذين نتكئ عليهم في كل المرات التي نكون بحاجة إلى سند ونحن نثق أنهم لن يخذلونا يومًا

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إلى أولئك العظيمات اللواتي يبتدئ عندهن الكلام ولا يعرف النهايات

إلى من آمنّ بقدراتنا على الوصول

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شـــكـــر وتـــقـــديـــر

"كن عالما .. فـإن لم تستطع فكن متعلما ، فـإن لم تستطع فـأحب العلماء ،فـإن لم تستطع فـلا تبغضهم"

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كما لا يسعنا إلا أن نخص بأسمى عبارات الشكر و التقدير الدكتور "بلال المصري" لما قدمه لنا من جهد و نصح و معرفة طيلة انجاز هذا المشروع

كما نتقدم بالشكر الجزيل لكل مكان وإنسان أسهم في تقديم علمه لنا، و نخص بالذكر جامعتنا العزيزة جامعة بوليتكنك فلسطين, وإلى كلية الهندسة والتكنولوجيا. وإلى دائرة الهندسة المدنية والمعمارية، بطاقمها التدريسي و الإداري

و إلى الذين كانوا عونا لنا في إنجازنا هذا ونورًا يضيء الظلمة التي كانت تقف أحيانا في طريقنا .إلى من زرعوا التفـاؤل في دربنا وقدموا لنا المساعدات والتسهيلات والمعلومات ، فـلهم منا كل الشكر

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فـريـق الـعـمـل

Abstract

Structural And Environmental Design, a study of using green roofs system in construction.

Green or sustainable architecture considered as one of the new directions of architectural thinking which is interested in the relationship between the environment and the building. So, it meets the present needs without omission of the future needs of the next generations, and it contributes to decrease the effect of buildings on environment, also decrease the buildup and working costs , so, it is a high quality system meets the surrounding environment with the least side effects. It is an invitation to better deal with our environment.

Our building consists of a basement floor consisting of a garage, a ground floor consisting of shops, and two residential floors repeated three times with a total area of (9113) m2.

The project contains a detailed structural study, analysis of the structural elements, different expected loads, the structural design of these elements, and preparing the executive plans according to the existing design for all structural elements which forms the structural frame of the building. And from the environmental side the concentration was on the green roofs, that provide ecosystem services in urban areas, including improved storm-water management, better regulation of building temperatures, reduced urban heat-island effects, and increased urban wildlife habitat.

There was a meeting point between the environmental and structural section of the work in terms of loads. The expected load was calculated from the addition of the Green Roof. Dead and live loads were increased due to green roofs weight and systems. so, we had to use special structural system so the solid slabs were used under green surfaces, and it keeps the structural cost in reasonable limits.

All architectural and structural plans for the building were prepared. It was drawn with a three-dimensional technique. The distribution of the green surfaces was shown in the building, and attached with the project.

Key words: structural design, green roof, green building, environmental study.

God grants success

List Of Contents

Index	Title	Page No.
Preface pages		
-	Report of the introductory graduation project	I.
	Dedication	II.
	Thanks and appreciation	III.
	Abstract	IV
	Contents List	V
	Figure List	VII
	Contents List	IX
	List of Abbreviations	X
Chapter one: Introduction		
1.1.	Introduction	2
1.2.	General definition of the project	3
1.3.	Reasons of choosing the project	3
1.4.	Project objectives	4
1.5.	Standards	5
1.6.	Project problem	5
1.7.	Project procedures	6
1.8.	Project timeline	7
Chapter two: Literature review		
2.1.	Introduction.	10
2.2	Sustainable Buildings.	11
2.3	Green Building	11
2.4	Environmental Impacts of Buildings	12
2.5	Green building assessment systems used over the world	13
2.6	Comparison of green building assessment systems used over the world	14
2.7	Benefits of ecological design	16
2.8	Types of green roofs	18
2.9	Components of green roofs	20
Chapter three: Architectural Description		
3.1	Introduction	23
3.2	Project overview.	23
3.3	the site of the project.	24
3.3.1	The importance of the site.	24
3.3.2	The movement of sun and wind.	25
3.3.3	Architectural elements.	26
3.4	Plans Description.	27
3.5	Elevation Description.	31
3.6	Movement and Section Description.	34
Chapter three: Structural studies		
4.1	Introduction	37
4.2	The purpose of the structural design	37

4.3	Stages of structural design	37
4.4	Loads	38
4.4.1	Dead loads	38
4.4.2	Live loads	38
4.4.3	Environmental loads	39
4.4.3.1	Wind loads	39
4.4.3.2	Snow loads	39
4.4.3.3	Earthquake loads	40
4.5	Geotechnical studies	40
4.6	Structural elements of the building	40
4.6.1	Slabs	41
4.6.2	Stairs	43
4.6.3	Beams	43
4.6.4	Columns	44
4.6.5	Shear walls	45
4.6.6	Footings	45
4.6.7	Piles	46
4.6.8	Expansion joint	46
Chapter four: Structural Analysis And Design		
6.1	Introduction.	48
6.2	Design method and requirements.	49
6.3	Check of Minimum Thickness of Structural Member.	49
6.4	Design of topping.	49
6.5	Design of One Way-ribbed Slab (RS1,RS2,RS3).	51
6.6	Design of Beam(BS1).	64
6.7	Basement wall	70
6.8	Design stair	73
6.9	Design column	76
6.10	Design footing	78
Chapter six: Environmental Methodology		
6.1	Methodology Flow Chart.	82
6.2	Concept of the project.	83
6.3	Selected site study.	84
6.7.1	The importance of the site.	84
6.7.2	The movement of sun and wind.	84
6.4	Reasons for choosing the green roof company .	88
6.5	Structural loads of green roof system	90
6.6	Green roof components	92
6.7	Green roofs Installation	98
6.7.1	6.7.1Main steps of green roofs installation	98
6.7.2	6.7.2Sections of green roofs	101
6.8	Drainage and Irrigation system	104
6.9	Planting	106
6.10	Financial cost of green roofs	110

Chapter seven: Results and Recommendations		
7.1	Introduction.	112
7.2	Recommendations.	112
-	References	114

List Of Figures

Index	Figure Name	Page No.
Chapter two: Literature review		
2.1	Impact of building (sources ,waste) on environment	10
2.2	Green roof technology originated in Germany	16
2.3	Green roofs reduce “heat island” effect	16
2.4	Provides Rainwater Management	17
2.5	Green roofs act as thermo-insulators	17
2.6	Green roof types	18
2.7	Green roof components	20
Chapter three: Architectural Description		
3.1	The general location of the land	24
3.2	Movement of the sun and wind.	26
3.3	Basement Plan.	27
3.4	Ground Floor Plan	28
3.5	First Floor plan	29
3.6	Second Floor plan	30
3.7	North Elevation	31
3.8	East Elevation	32
3.9	South Elevation	33
3.10	West Elevation	34
3.11	Section A-A	35
3.12	Section B-B	35
Chapter four: Structural studies		
4.1	Some of the structural elements of the building	40
4.2	One way solid slab	41
4.3	Two way solid slab.	41
4.4	One way ribbed slab	42
4.5	Two way ribbed slab	42
4.6	Stair	43
4.7	Types of beams.	44
4.8	Types of column	44
4.9	Shear wall.	45
4.10	Footings	46
Chapter five: Structural Analysis And Design		

5.1	Topping load.	50
5.2	One Way Rib slab (R01, R03, R03)	51
5.3	Shear & Moment Envelope Diagram (R01)	53
5.4	Shear & Moment Envelope Diagram (R02)	57
5.5	Shear & Moment Envelope Diagram (R03)	61
5.6	B10	66
5.7	Loading and Moment /Shear Envelope. B10	66
5.8	Loading and Moment /Shear Envelope Basement wall	71
5.9	Stair Plan.	73
5.10	Stair Section	74
5.11	Stair Reinforcement	76
5.12	section of column -19	76
Chapter six: Environmental Methodology		
6.1	Environmentally study Methodology	82
6.2	The desired area of the building for green roof system in brown colure	83
6.3	Site desired for the building	84
6.4	Maximum temperature days	86
6.5	Movement of wind in the selected location	86
6.6	cloudy,sunny, and precipitation days	88
6.7	The cross section area for the green roof components of background garden of the building	90
6.8	cross section area of the green roof components for the roof of the building	91
6.9	A sample of the Substrate layer[	92
6.10	A sample of the Filter Sheet layer	93
6.11	A sample of the Mineral Substrate layer	94
6.12	A sample of the Drainage And water storage layer	95
6.13	A sample of the Protection Material layer	96
6.14	A Sample of the Root Barrier layer	97
6.15	Installing water proofing, root barrier ,and protection material layers	98
6.16	Installing drain access boxes	99
6.17	Installing drainage layer	99
6.18	Spreading gravel perimeter	100
6.19	Laying separation fabric	100
6.20	Spreading soil	101
6.21	Planting	101
6.22	System build up for Green Roof .	102
6.23	Wall connection for Roof Garden	102
6.24	Roof outlet with inspection chamber for Roof Garden.	103
6.25	Foundation for supporting structures / roof shelter	103
6.26	Root ball anchorage	104
6.27	drainage system of green roof.	104

6.28	drainage and irrigation system of green roof	105
6.29	Bougainvillea, Paper Flower	106
6.30	Treasure Flower	106
6.31	jacquemontia	107
6.32	Pink Jasmine	107
6.33	Crape Myrtle	108
6.34	Lantana, Shrub Verbena	109
6.35	enab	109

List Of Tables

Index	Table Name	Page No.
Chapter one: introduction		
Table 1.1	Project timeline for structural design	7
Table 1.2	Project timeline for environmental study	8
Chapter two: Literature review		
2.1	set of three-dimensional sustainability criteria (environmental, social and economic)	11
2.2	Green roof types	19
Chapter four: Structural studies		
4.1	The densities for used materials	38
4.2	The live load which was determined by the Jordanian code	38
4.3	snow loads according height of sea level.	39
Chapter five: Structural Analysis And Design		
5.1	MINIMUM THICKNESS OF NONPRESTRESSED BEAMSOR ONE-WAY SLABS UNLESS DEFLECTIONS ARE CALCULATED. (ACI 318M-11)	49
5.2	Dead load calculation Topping	50
5.3	Dead load calculation Topping of ribs	52
5.4	Dead Load Calculations for Beam(BS10)	64
5.5	Dead Load Calculation of Flight	73
Chapter six: Environmental Methodology		
6.1	maximum temperature days each month	85
6.2	wind speed table for each month	87
6.3	Number of sunny, partly cloudy, over cast and precipitation days	88
6.4	structural loads of green roof for the background garden	91
6.5	structural loads of green roof for the roof garden.	91
6.6	Chemical and Physical Propertiesof the Substrate layer	93
6.7	Properties of the Filter Sheet layer	94
6.8	Properties of the Mineral Substrate layer	95
6.9	Properties of the Drainage And water storage layer	95
6.10	Properties of the Protection Material layer	97
6.11	Properties of the Root Barrier layer	97
6.12	Properties of Bougainvillea, Paper Flower	106

6.13	Properties of Treasure Flower	107
6.14	Properties of jacquemontia	107
6.15	Properties of Pink Jasmine	108
6.16	Properties of Crape Myrtle	108
6.17	Properties of Lantana, Shrub Verbena	109
6.18	Properties of enab	110
6.19	Financial cost of green roofs	110

List of Abbreviations

- Ac = area of concrete section resisting shear transfer.
- As = area of non-prestressed tension reinforcement.
- A_s̀ = 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.
- C_c = compression resultant of concrete section.
- C_s= compression resultant of compression steel.
- DL = dead loads.
- d = distance from extreme compression fiber to centroid of tension

reinforcement.

- Ec = modulus of elasticity of concrete.
- f_c̀ = compression strength of concrete .
- fy = specified yield strength of non-prestressed reinforcement.
- h = overall thickness of member.
- Ln = length of clear span in long direction of two- way construction، measured face-to-face of supports in slabs without beams and face to face of beam or other supports in other cases.

- LL = live loads.
- Lw = length of wall.
- M = bending moment.
- Mu = factored moment at section.
- Mn = nominal moment.
- Pn = nominal axial load.
- Pu = factored axial load.
- S = Spacing of shear in direction parallel to longitudinal reinforcement.
- Vc = nominal shear strength provided by concrete.
- Vn = nominal shear stress.
- Vs = nominal shear strength provided by shear reinforcement.
- Vu = factored shear force at section.
- Wc = weight of concrete.
- W = width of beam or rib.
- Wu = factored load per unit area.
- Φ = strength reduction factor.
- ε_c = compression strain of concrete = 0.003.
- ε_s= strain of tension steel.
- $\acute{\varepsilon}_s$= strain of compression steel.
- ρ = ratio of steel area.
- ASHRAE: American Society of Heating and Air-Conditioning Engineers (U.S1894).
- EPA :Environmental Protection Agency .
- GB Tool: Green Building Tool (Canada, 2002).
- LEED-NC: Leadership in Energy and Environment Design for New Construction and Major Renovations (U.S., 2000).
- No2 : Nitrogen dioxide.

- PMV : Predicted mean vote .
- PPD : Predicted percentage dissatisfied.
- PM10 : Particular matter.
- USGBC: United States Green Building Council.
- VOC : Volatile organic compound.
- WGBC : World green building council.

Chapter 1

Introduction

1

1.1. Introduction

1.2. General definition of the project

1.3. Reasons of choosing the project

1.4. Project objectives

1.5. Standards

1.6. Project problem

1.7. Project procedures

1.8. Project timeline

1.1.Introduction:

Human being started since its beginning to search for residence and fled to the caves and rock grooves surrounding it, also its attempts to develop methods of life,and to adapt to its environment, and thought to develop his residence using the surrounding materials to create this shelter of wood, animal hides, stones and mud, to the using of iron and cement which is currently used in construction.

In response to the requirements of progress and development it started to trend to the specialized buildings in the areas of public and private life, making for each need its special premises such as universities and schools, hospitals, health centers and residential apartments, etc…

As well, with the development of human being and the development of his life and with continued industrial revolution it was necessary to keep up with the developing events to meet the needs of the people of various categories and jobs, here comes the role of the engineer who puts his ideas and solutions in order to moving forward in Human Revolution.

Green or sustainable architecture considered as one of the new directions of architectural thinking, which is interested in the relationship between the environment and the building. So it should meets the present needs without omission of the future needs of the next generations and it contributes to decrease the effect of buildings on environment and also decrease the buildup and working costs , so it is a high quality system meets the surrounding environment with the least side effects. So it is an invitation to better deal with our environment.

A lot of wonder when we hear about green roofs and green buildings and we wonder why they are planting roofs of buildings? We are terrified of the idea of permanent trees, plants and water above our heads and the impact on homes. It is a risk that we cannot accept it , especially since we have planted inside us the fear of leakage of water from the roofs of our homes, despite the modern technologies that provide complete isolation of water. Therefore, this Bishop is absent from our Arab countries and there are few who speak of them in our Arab world except from a few shy attempts by the friends of the environment here and there.

The focus of study in this project is the construction design procedure of a residential and commercial building and environmental study of itespecially for green roof And clarify its image to be used in the Arab world. which proposed to be constructed in Hebron.

1.2.General definition of the project:

The project is a commercial residential building on a piece of land in Hebron, the total area of the land 2303 m^2, and the total area of building 9113m^2. The building consists of 8 floors, as follows: The basement area is 2190 m^2 , the ground floor area is 665 m^2, The first floor area is 1042 m^2 and the second floor area is 1042m^2. The first and second floors are repeated three times in a row.

1.3.Reasons of choosing the project:

The importance of the choice of the project back to several things, from the structural side the most important one is skill acquisition in the design of structural elements in buildings, particularly of huge buildings such as the project, which we are introducing in this search. In addition to increase in knowledge of construction systems, as we learned in our university courses, as well as the acquisition of scientific and practical knowledge in the design and construction implementation of projects, which will confront us after graduation. From the environmental side to the most important is to answers the following question: Is the building that was created considered Somewhat supportive of the environment? And the following sub question, Will we be able to change people's thinking about green roof? What are the benefits to the building of this technique?

And there are several reasons that led to the selection of this project, including the reasons for the nature of the project, and other reasons for personal can be summarized as follows:

1.3.1. Reasons depend on project's nature:

Palestine suffers from limited natural resources because of occupation policy and misuse the resources such as water .Therefore, these resources are imported from Israel and neighboring countries.

In addition, Palestine suffers from environmental pollution in its different types water, air, soil and noise pollution.

There are many challenges for the future , such as taking a responsible approach towards nature .you need to look for a particular method or a particular replacement without decreasing either comfort level or living standard.

The building sector contributes up to 30% of global annual greenhouse gas emissions

Therefore, we need a technique that reduces pollution and acts as a filter for air purification. Noise reduction, which is considered a problem of modern times especially in cities. Increase the life of the buildings so that they act as thermal insulation. Reduce the cost of air conditioning during the summer and heating during the winter.

So, the design and construction of the buildings affects a large proportion of these resources, and the good construction effect positively on the climate for a long time so it's must be planned and constructed according to the , climatic aspects, and water conservation.

1.3.2. Personal reasons:

We thought to getting out of the box, by doing a different project, with a distinctive idea, that brings to our specialties a different flavor. "Such as add barbecue flavor to our dishes".

The desire to come out with an idea that benefits society by providing a healthy home environment, with minimal costs. So that the available resources will be exploited and the operation of the building as appropriate.

1.4.Project Objectives:

1.4.1. Architectural Objectives

The general shape of the building usually gives an impression of its techniques and attraction to tenants and citizens. And therefore it should be focused on the architectural aspects, and through these projects, the architect can make it a historical event through the coordinated blocks and the elements used in the interfaces.

1.4.2. Structural Objectives:-

a- The ability to choose the suitable construction system for different projects and the distribution of structural elements on the drawings, taking responsibility for the preservation of the architectural character.

b- To employ all the information we have acquired during our study life through different courses in order to reach a complete project.

c- Identify new models and methods of construction that we did not acquire during our university study and know how to deal with them as needed.

1.4.3. Environmental Objective:-

a- Reduce storm water runoff

b- Increasing home value and return on investment

c- Reduce smog and improve air quality

d- Provide green space.

e- Improve aesthetics

1.5.Standards

a- using ACI code.

b- Using analysis programs and structural design such as (Atir, Sap , safe , Etabs)

c- Other programs (Microsoft word, Microsoft power point).

1.6.Project Problem

The problem of this project is the analysis and structural design of all the structural elements of our building. In this field, each element of the structural elements such as tiles, columns, bridges, etc. will be analyzed by identifying the loads that are placed on it, and then define the dimensions and design of reinforcing required, taking responsibility the safety factor of the origin and then will be the work of the operational plans and drawings of construction elements that are designed to lead this project to be constructed in reality.

From the environmental side the problem of this project is analysis the all the environmental elements of our buildingAnd a general study of green buildings and focus on green roof and then Make appropriate changing decisions that make it economic and environmental building.

1.7.Project procedures:

1. Studying the architectural plans and drawings in order to ensure their correctness from the architectural aspects and their compatibility with the objectives of the project.
2. Determine the Structural loads of green roof system In order to add them to the original load.
3. Studying structural elements of the building and the most appropriate way for the distribution of these elements such as columns, bridges, in a way that does not collide with the architectural design and achieve the economic aspect and safety factor.
4. Selecting structural elements and determining the loads affecting them.
5. Design of structural elements based on analysis results.
6. Design by different design programs.
7. Design of the building by technology 3D
8. Add our report result.

1.8.Project Timeline:

1. First Semester

Tables number (1-1)and (1.2) shows the timeline of the stages of the work on the project with the steps shown during first semester of 2017-2018.

Table 1. 1project timeline for structural design

Week #	Project Selection	Study site	Gather information about the project	Study the building architecturally	Studying the building constructively	Preparing an introduction to the project	Presentation the project	Structural analysis	Structural design	Preparing project plans	Writing the project	View the project
1	■											
2	■											
3	■											
4	■											
5	■	■										
6		■										
7		■	■									
8			■									
9				■								
10				■								
11				■	■							
12					■							
13					■							
14						■						
15						■						
16							■					
17								■				
18								■				
19								■				
20								■	■			
21								■	■			
22									■			
23									■			
24										■		
25										■		
26										■		
27										■	■	
28											■	
29											■	
30											■	
31											■	
32												■

Table 1. 2project timeline for environmental study

Week #	Studying of Sustainable Buildings	Studying of Green Building	Studying of Green roof	Studying of Types of green roofs	Studying of Components of green roofs	Preparing an introduction to the project	Presentation the project	Reasons for choosing the green roof company t	Structural loads of green roof system	Design of green roofs using sketch up program	Writing the project	View the project
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
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Chapter 2

Literature review

2

2.1 Introduction.

2.2 Sustainable Buildings.

2.3 Green Building.

2.4 Environmental Impacts of Buildings.

2.5 Green roof

2.6 History of green roofs.

2.7 Benefits of Green Roofs.

2.8 Types of green roofs

2.8.1Comparative review

2.9Components of green roofs

2.1 Introduction

Buildings are the major consumers of energy and material resources and significant polluters of the environment during all stages of their entire life cycle. Buildings are responsible for more than thirty sixpercentof global energy use and contribute up to thirty percent of global annual greenhouse gas emissions [1]. Negative impacts from each stage of building life cycle on the environment are a result of the following factors: the depletion of non-renewable raw materials and energy sources, pollution and contamination by harmful emissions, the negative effect of technology on the environment (noise, vibration etc.), excessive water consumption and faster depletion of renewable sources than their ability to regenerate. [2]

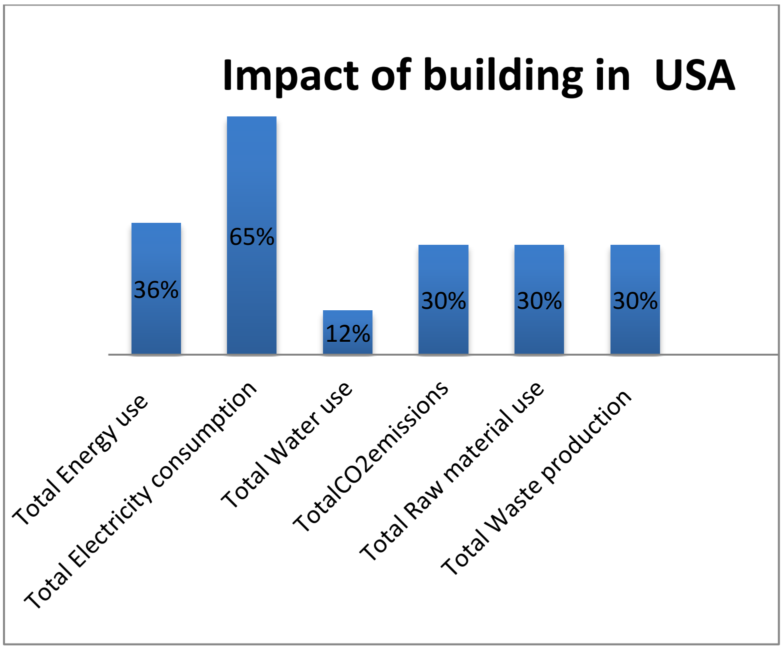


Figure 2.1 Impact of building (sources ,waste) on environment [1].

Green buildings are characterised as those providing the required building performance over the building life-cycle whilst minimising consumption of non-renewable resources and the environmental loadings to land, air and waters. [3]. However, the assessment of new buildings covers only performance aspects from the initial planning stage through to building completion. Actual performance during building use depends on what has been achieved in terms of improved design and construction quality, as confirmed by final testing and commissioning, the quality of management, operation and maintenance practices, as well as the activities of building users[4].

2.2 Sustainable Buildings

Buildings have massive direct and indirect impacts on the environment, society, and the economy, which are commonly referred to as the 3 P's ('People', 'Planet', 'Pocketbook') [5].

The main objectives of sustainable design are to reduce depletion of critical resources like energy, water, land, and raw materials; prevent environmental degradation caused by human activities, and create an environments that are safe and comfortable[6].

Buildings use resources (energy, water, raw materials, etc.) and generate waste (solid waste, wastewater), and emit potentially harmful atmospheric emissions, and fundamentally change the function of land, and the ability of that land to make self-purification [7].

Sustainable design attributes reduces operation costs and environmental impacts, and can increase building resiliency. The "embodied energy" of the existing building (a term expressing the cost of resources in both human labor and materials consumed during the building's construction[8].Table2.1 presents the most prominent Criteria of sustainable design.

Table 2. 1 set of three-dimensional sustainability criteria (environmental, social and economic) [5].

Social	Environmental	Economical
Convince for user	Waste recycling	Affordability
Safety	Green space	Business opportunities in the area
Community organization	Access to service	Resource conservation
Location	Resource conservation	Willing to pay more for environmentally friendly housing .
Inside housing condition	Building durability	Community energy tariff
Heritage value of the building	Renewable Energy	
External housing condition	Environmental quality	

2.3 Green Building

There is a need of concentrating on a Green Home, which is one of the most important and one of the most discussed topics throughout the globe, in the age of global warming and climate change worldwide[9].

Green buildings are characterised as those providing the required building performance over the building life-cycle whilst minimising consumption of non-renewable resources and the environmental loadings to land, air and waters[10]. However, the assessment of new buildings covers only performance aspects from the initial planning stage through to building completion. Actual performance during building use depends on what has been achieved in terms of improved design and construction quality, as confirmed by final testing and commissioning, the quality of management, operation and maintenance practices, as well as the activities of building users[11].

"A green building is one which uses less water, optimises energy efficiency, conserves natural resources, generates less waste and provides healthier spaces for occupants, as compared to a conventional building" [12] .The practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or 'high performance' building [13].

Buildings can incorporate many green features, but if they do not use energy efficiently, it is difficult to demonstrate that they are truly green. In fact, given that the term "green building" can be somewhat vague, some people prefer to use the term[14].

2.4 Environmental Impacts of Buildings

The buildings affect greatly the surrounding environment either because of its consumption of resources or because of pollution of the environment dramatically. The impact of buildings both in the period construction , operation of demolition is as follow [15].

1- Construction:

Materials Use

- Depletion of non-renewable resources
- Pollution and by products from materials manufacture
- Construction materialspackaging waste

Site Preparation and Use

- Disturbance of animal habitats.

- Destruction of natural vistas.
- Construction-related runoff.
- Soil erosion.
- Destruction of trees that absorb CO_2.
- Water quality degradation from using pesticides, fertilizers, and other.

2- Operation:

Energy Use

- Air pollution: emissions of SO_2, NO_x, mercury, and other heavy metals and particulate matter from power plants; the building's energy consumption; and transportation to the building
- Greenhouse gas (CO_2 and methane) emissions, which contribute to global warming
- Water pollution from coal mining and other fossil fuel extraction activities, and thermal pollution from power plants
- Habitat destruction from fuel extraction

Building Operations

- Runoff and other discharges to water bodies and groundwater
- Groundwater depletion
- Changes in microclimate around buildings and urban heat island effects
- Ozone-depleting substances from air conditioning and refrigeration
- Water consumption
- Production of wastewater that requires treatment
- Production of solid waste (garbage) for disposal
- Degradation of indoor air quality and water quality from using cleaning chemicals

3- Demolition

- Demolition waste (used steel, concrete, wood, glass, metals, etc.)
- Energy consumption for demolition
- Dust emissions
- Disturbance of neighboring properties
- Fuel use and air pollutant emissions associated with transporting demolition waste

2.5 Green Roof

A green roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a Water proofing membrane. It may also include layers such as a root barrier , drainage and irrigation systems.[16] Container gardens on roofs, where plants are maintained in pots, are not generally considered to be true green roofs, although this is debated. Rooftop ponds are another form of green roofs which are used to treat greywater.[17] Vegetation, soil, drainage layer, roof barrier and irrigation system constitute green roof.[18]

Green roofs serve several purposes for a building, such as absorbing rainwater, providing insulation, creating a habitat for wildlife, decreasing stress of the people around the roof by providing a more aesthetically pleasing landscape, and helping to lower urban air temperatures and mitigate the heat island effect.[19] Green roofs are suitable for redevelopment projects as well as new buildings and can be installed on small garages or larger industrial, commercial and municipal buildings.[16] They effectively utilize the natural functions of plants to filter water and treat air in urban landscapes.[20] There are two types of green roof: intensive roofs, which are thicker, with a minimum depth of 12.8 cm (5.0 in), and can support a wider variety of plants but are heavier and require more maintenance, and extensive roofs, which are shallow, ranging in depth from 2 cm (0.79 in) to 12.7 cm (5.0 in), lighter than intensive green roofs, and require minimal maintenance.[21]

The term green roof may also be used to indicate roofs that use some form of green technology, such as, a roof with solar thermal collectors or photovoltaic panels.

2.6 History of Green roofs

In ancient times green roofs consisted of cave like structures or sod roofs covered with earth and plants commonly used for agriculture, dwelling, and ceremonial purposes. These early shelters provided protection from the elements, good insulation during the winter months, and a cool location in the summer. Unfortunately for modern conveniences, these were neither waterproof nor was there any system to keep out unwanted burrowing wildlife.[22]

The origins of green roofs began thousands of years ago. One of the seven wonders of the world, the Hanging Gardens of Babylon, are perhaps the first example of draping buildings in flora to make them more appealing. Built in what is now Iraq around 500 BC, they were designed by King Nebuchadnezzar II for his wife who missed the green fields and flowers of her homeland. The gardens were grown over stone pillars and roofs which were waterproofed with layers of reeds and tar. Plants and trees were then planted. In more recent times, people used sod to cover their roof tops for the purpose of insulation, it kept their homes cool in summer and warm in winter. Modern green roofs may have had their "roots" in ancient times but technological advances have made them far more efficient and expensive than their ancient counterparts.[23]

Modern green roofs, which are made of a system of manufactured layers deliberately placed over roofs to support growing medium and vegetation, are a relatively new phenomenon. However, green roofs or sod roofs in northern Scandinavia have been around for centuries. The modern trend started when green roofs were developed in Germany in the 1960s, and has since spread to many countries. Today, it is estimated that about 10% of all German roofs have been “greened”[24].

Modern green roof technology began in the early seventies in Germany when the first green roof systems were developed and marketed on a large scale. Unlike former “green roofs” this first approach offered reliable technology that provided sophisticated irrigation and protection against root ingress for rooftop gardens.[23]

The second big step was the development of extensive green roofs in the late eighties. The goal was to create lighter and cheaper systems which could be applied to large flat roofs. The main motivation for extensive green roofs was the restoration of nature and protection of the roof membranes from the elements and temperature fluctuations. [22]

In the 18 and 19th centuries in North America, prairie settlers took green roofing to the extreme when building their homes. Because there was a lack of trees to build cabins, many constructed dwellings out of pure sod, with the ‘bricks’ laid root side up so that they would grow into the one another, creating a more solid foundation.

By the early 1900s, Germany was building flat green roofs in urban areas and continued to do so throughout the century. In the 1970s, when the oil crisis was at its height, Germany was one of the first countries to investigate the use of green roofs for energy conservation and by the middle of the noughties there were an estimated 13 million square meters of roofing in the country covered with greenery.

In America, New York has made a big push for green roofs in the last few years to help create a better environment and reduce the effects of rain from storm downpours on the city’s infrastructure. The first green roof in New York, however, was actually built on the Rockefeller Centre in the mid-1930s.

There’s no doubt that in the historical sense green roofs were created either because of convenience or to create something aesthetic the owner could enjoy. More and more in recent years, we are coming to understand the ecological and energy efficiency properties of constructing something like a green roof in towns and cities across the world[23].

Figure2.2. Greenroof technology originated in Germany over 30 years ago[23].

2.7 Benefits of Green Roofs

- **Esthetic**

They offer an attractive alternative to standard roofs due to presence of vegetation that attracts different birds, insects, and similar animals[25].

Commercial and industrial roofs no longer need to be eyesores of endless concrete, asphalt or gravel. They certainly are unattractive, to say the least, and aesthetics are rarely considered in their design. intensive green roofs could alleviate the harsh, stark anddownrightuglyviews[26].

- **Environmental**

1. Green roofs reduce “heat island” effect, creating a favorable micro-climate. If constructed and maintained properly, they can lower the concrete temperature even for about 40°C in summer days. Therefore, the ambient temperature is lower for a couple of degrees during summer months.as it shown on figure2.3 [27]

Figure 2.3 Green roofs reduce “heat island” effect[28].

2. Vegetation absorbs air pollution and, therefore, air is cleaned from carbon monoxide, lead and other adverse pollutants induced by traffic, industry, etc.
3. Green roofs absorb precipitation and reduce the excess weight on sewage system during rain and snow melting, and this water is being returned to the atmosphere through evaporation. Moreover, investment into sewage system to prevent possible flooding is not necessary, but the city authority also benefit from green roofs.as it shown on figure2.4

Figure2.4 Provides Rainwater Management[29]

4. Reduce noise level for about 50 dB (which is at the ado level in a restaurant).
5. Except esthetic effect, green roofs offer habitats for birds, insects and small animals, contributing to the conservation of biodiversity of these species.
6. They increase environmental awareness of local population.

- **Economical**

1. Green roofs act as thermo-insulators so the building on which they are constructed is colder during summer and warmer during winter. This contributes to preservation of energy which would normally be spent for air conditioning and heating. as it shown in figure 2.5

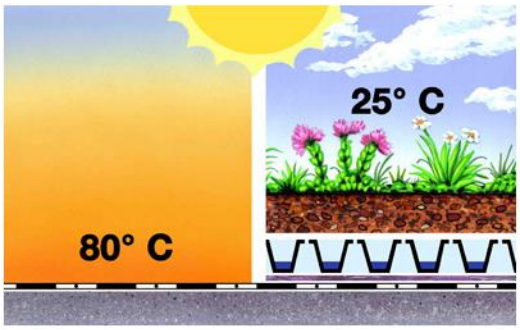


Figure 2.5 Green roofs act as thermo-insulators[30].

2. Buildings with this architectural solution have a higher market value so the invested funds often pay off when selling the property.
3. Green roofs protect the roof insulation and material from UV radiation and they reduce daily temperature fluctuations, which prolongs the roof system lifetime sometimes even double.

2.8Types of green roofs

According to the International Green Roof Association (IGRA), green roofs are divided into three types: **intensive**, **semi-intensive** and **extensive** green roofs. as shown on Figure 2.6 This division is based according to the green roof construction (which depends on the depth of the growing media). Construction choice depends on several conditions such as roof slope, financial investments, maintenance possibilities, climate conditions, purpose of use, construction of the building itself, etc.

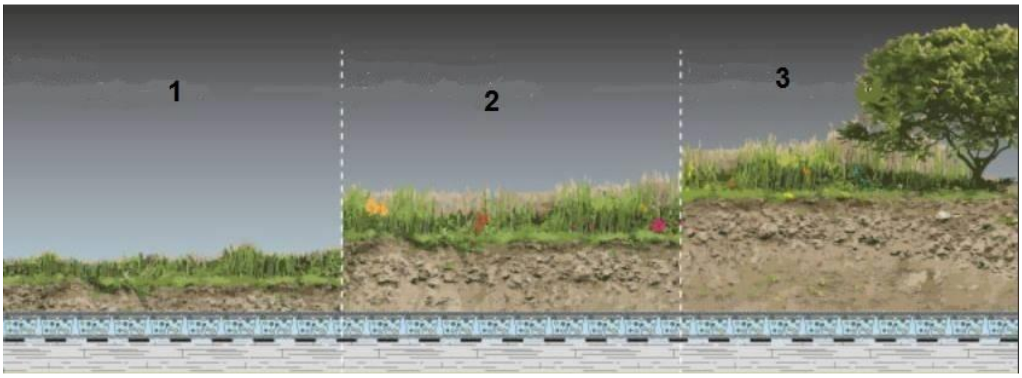


Figure 2.6 Green roof types: 1.extensive , 2.semi-intensive , 3.intensive

- **Extensive type**

Extensive green roofs are thinner, growing medium depth is from 2-10 cm, and they allow installation of vegetation that is less demanding in maintenance and is suitable for life in extreme environmental conditions (drought, direct sunlight, etc.). these plants are moss, grass, and low growing plants of 5-25 cm in height, and succulents (plants which retain higher amounts of water in their body) are also suitable. These roofs are relatively easy to install, they are economical, easier to maintain and often do not require an additional structural support (extra weight to the building accounts for around 100 kg/m2). Despite everything, extensive green roofs still have high ecologic and energy values. Their maintenance should be done once per year.

- **Semi-intensive type**

This type of green roofs is designed with vegetation of medium height, from 25-50 cm, and growing medium depth is around 20 cm (extra weight to the building accounts for around 250 kg/m2). This type is actually a combination of intensive and extensive green roofs. Maintenance is required every 6 months and plants are usually those from reed family as well as middle-growth sedums, which are easy to maintain.

- **Intensive type**

The depth of intensive roofs' growing medium normally ranges from 10-50 cm but it can also be deeper. This allows for installation of vegetation that leaves the impression of real gardens, due to the presence of bushes, flowers, lawns and even small trees up to 4 meters in height, creating an ideal green oasis within urban environment. However, due to the depth of the growing medium, amount of vegetation and presence of drainage layers, these roofs are very heavy (extra weight to the building accounts for around 400 kg/m2). Therefore, it is necessary to install necessary structural elements which would support the green roof construction. A civil engineer should be consulted for these calculations. Moreover, trees have to be additionally secured as there is danger from plucking and falling during storms and high winds. This type of green roofs requires intensive maintenance (every month), irrigation, plant care, etc.

2.8.1 Comparative review

The following layers are other standard layers: roof thermal insulation, hydro insulation, etc. This construction applies for designing flat green roofs, where roof slope is less than 8 degrees.Table 2.2 shows a comparison among the three basic green roof types:

Table 2.2 Green roof types[31].

Type	Extensive	Semi-intensive	Intensive
Depth (growing medium+ vegetation)	6 – 20 cm	12 – 25 cm	15 – 60+ cm
Excess weight	60 – 150 kg/m²	120 – 200 kg/m²	180 – 400+ kg/m²
Plants	Mosses, sedums, cactus, herbs and some grasses	Several perennials, sedums, ornamental grasses, herbs and small shrubs	Perennials, lawns, shrubs and trees
Irrigation	No, not recommended	Partly, when needed	Yes, automatic/manual
Maintenance	Low	Middle	High

Construction	Fast	Fast	Slower
Use	Esthetic	Diversity, habitat	Garden, park
Costs	Low	Middle	High

2.9 Components of green roofs

When designing a green roof, the components required will depend on the type of vegetation specified and how the balance between water retention and drainage is achieved to meet the demands of the vegetation and of the local rainfall levels.In general it consists mainly of several components its shown on Figure 2.7.

Figure2.7 Green roof components

1. Vegetation – the choice of plants depends on the type of a green roof, climate conditions, roof slope, surrounding vegetation, etc. in general, intensive green roofs support a bigger amount and weight of vegetation (such as perennials, bushes, smaller trees, etc.), extensive green roofs support mainly lawns, sedums, smaller perennials, etc., while semi-intensive roofs are a transitional form between the two and support bulrush, smaller bushes, flowers, lawns, etc[27].

2. Growing medium – the depth of this layer depends on the green roof construction type. It is made of mineral and organic components in an appropriate ratio which is suitable for plant growth. Usually, additional mineral materials are added as the soil is shallow and plants are growing in unfavorable environmental conditions. When a plant has enough food in the soil (mineral materials) its roots will not spread extensively and damage other construction layers of the green roof. Moreover, soils with too much organic material should be avoided as they encourage extra energetic plant growth. The depth of this layer ranges from minimum 2 cm for extensive roofs, to more than 10 cm for intensive ones[27].

3. Filter material – prevents fine particles from being washed into the drainage layer, i.e. allows only water and a part of the roof to ..

The main function of the filter fabric/membrane is to hold the engineered soil in place and still prevent small media particles, such as plant debris and fines, from entering and clogging the drainage layer below. Air and water are thus permitted to flow through while the drainage layer and the actual drains are protected.[33]

.**4. Drainage layer** – drains the water surplus from the growing media and it allows the root to breathe as the air is available in cavities of this layer. This is important in order to prevent plant roots from rotting due to excess water in the soil. Moreover, it serves to store rainwater which plants use during dry periods. It can be made of different materials: several types of plastic channels, or simply any granulated material such as gravel, brick rubble, lava stone, sand, pumice, pebbles, vermiculite, etc. a special attention should be put to drainage layer material weight and find a compromise among the price, weight, and water retention capability. Drainage layer is not necessary for roofs with slope greater than 7 degrees; moreover, in that case it is unfavorable as it leads to the growing medium drying out too quickly[27].

6. Protection material – Protection materials or boards are used to protect the waterproof membrane from damage following installation. The most common materials used are water-permeable, hard wearing and dense synthetic fibers Protection matting is installed directly on the waterproofing layer (for root-resistant membranes) or atop the installed root barrier layer, providing further (uncertified) protection against root penetration and doubling as a separation sheet. The protection matting may provide some noise-absorbing capability[32]

7. Root-protection barrier – It is a plastic layer that prevents root expansion and prevent penetrating the roof of the building (Reinforced concrete) .The waterproof membrane can be dispensed If Root-protection barrier have sufficient features to protect surfaces from water leakage And coating the bottom layer to prevent surface rot.

3

Chapter 3

Architectural Description

3.1 Introduction

3.2 Project overview.

3.3 the site of the project.

3.3.1 The importance of the site.

3.3.2 The movement of sun and wind.

3.3.3 Architectural elements.

3.4 Plans Description.

3.5 Elevation Description.

3.6 Movement and Section Description.

3.1 Introduction:

Architecture is one of the most prominent engineering sciences, which is not a product of this era ; it is since God created the human being which unleashed talents and thoughts. It proceed with these talents from the life of the caves to the best form of luxury, taking advantage of God's gift for this beautiful nature.

The simplicity of the building is not an indication of the simplicity of the architectural work, the building despite its simplicity, may contain interior beauty and architecture in its interior parts. And whatever the function of the building the architectural beauty can be achieved by mixing between the real beauty in the interfaces also the shape of the building and the function to be performed by that building, because the architectural concept is not limited to the form, as some think, but also achieve function.

The design process of any building is carried out in several stages until it is completed to the fullest. It starts with the architectural design stage, at this stage, the form of building is determined , in addition to the different functions and requirements for which the building is being constructed are considered. With the aim of achieving the required spaces, dimensions and the location of columns and axis. Also, in this process we have the studying of the ventilation, movement and other functional requirements.

After the completion of the architectural design stage, the structural design process begins with the aim of determining the dimensions and characteristics of the structural elements depending on the different loads that are transported through these elements to the foundations and then to the soil.

3.2 Project Overview:

The idea of the project is the structural design and environmental study of a current residential building located in the city of Hebron, which is characterized by its very beautiful architectural style and it also achieves the goal to be designed for it.

We obtained the architectural drawings of the project from the students of the Faculty of Engineering, specializing in architectural engineering at the Polytechnic University of Palestine, in order to carry out the design work and environmental studies after an analytical and detailed study of these architectural plans prepared by the student Tuqa Talahma under the supervision of Dr. "Ghassan Dweik". The total area of the building is about 9113m^2, distributed over several floors as follows:The basement area is 2190 m^2 , the ground floor area is 665 m^2, The first floor area is 1042 m^2 and the second floor area is 1042m^2. The first and second floors are repeated three times in a row.

3.3 The site of the project.

The design of any project should have a study of the construction site, taking into consideration the geographic location and impact of climatic conditions in the region. So that we maintain existing elements and fit with the proposed design.

Therefore, a general idea of the elements of the site should be given an explanation of the proposed land measurements for the building, the relationship of the location to the streets and the surrounding services, the height of the surrounding buildings, the direction of the winds and the correct path of the sun.

This proposed project is located in the land of Hebron city in aensarah street and it should be said that the infra structure of roads, electricity and communications reach to that site and meet the needs of this project.

Figure 3.1the general location of the land

3.3.1 The importance of the site.

Hebron has a unique location between the cities of Palestine, both geographically and economically. There are several reasons why this area was chosen for the study, in addition to the vitality of the area and the other conditions necessary to choose the appropriate location and the advantages available in the site of this project are as follows:

1- Provide a suitable area of land to combine the architecture with its own garden.
2- The vitality of the region.
3- Easy access to the site and that it is located in the center of the city, and its environmental impression suitable for all parts of the city.
4- The site has natural features qualify it to contain the project as well, the proximity to Al Hussain Bin Ali Stadium and Childhood Happiness Complex it other features.

3.3.2 The movement of Sun, Wind and moisture:

Hebron is exposed to the northeastern winds, which are very cold and dry winds. This is due to the low temperatures in the highlands. It is also exposed to the southwest winds, which are windy with rain and humidity. Because of its geographical location, the western wind blows on them and collides with warm currents. Those coming from the east meet with the winds coming from the west, reducing their moisture and making them more harmonious. They make the air moderate and dry, and the city blows dry wind like the five winds in the late spring.

The movement of the sun and wind are important factors in the analysis of the building, and the effect of the sun and wind on the building should be taken into consideration. So that it can be divided into spaces suitable for climate and to meet the design requirements related to ventilation and natural lighting.

Sun: The movement and angles of the sun is one of the most important things to consider when directing and arranging buildings within the site, in order to avoid its direct radiation, especially in the summer, and here comes the role of solutions and environmental considerations that help us to avoid high temperatures. Also, trying to exploit the sun to serve renewable energy taking into consideration the movement and the horizontal and vertical angles of the sun.

Wind: In the region the wind speed is about 3.27 km / h throughout the year. The direction of the wind changes during the day from the southern winds in the early hours of the morning to the winds of northwesterly evening, and the southern wind that starts from the shores of the Dead Sea.

<u>***Moisture:***</u> The climate of Hebron is affected by the climate of Palestine, which is known as dry and hot in summer, moderate and rain in winter. Despite the small area[of Hebron, its climate varies according to the terrain and the water bodies adjacent to and away from the desert. As for precipitation, rainfall rates vary depending on the geography of the area, as rainfall in Hebron ranges between (400-600 mm) annually.

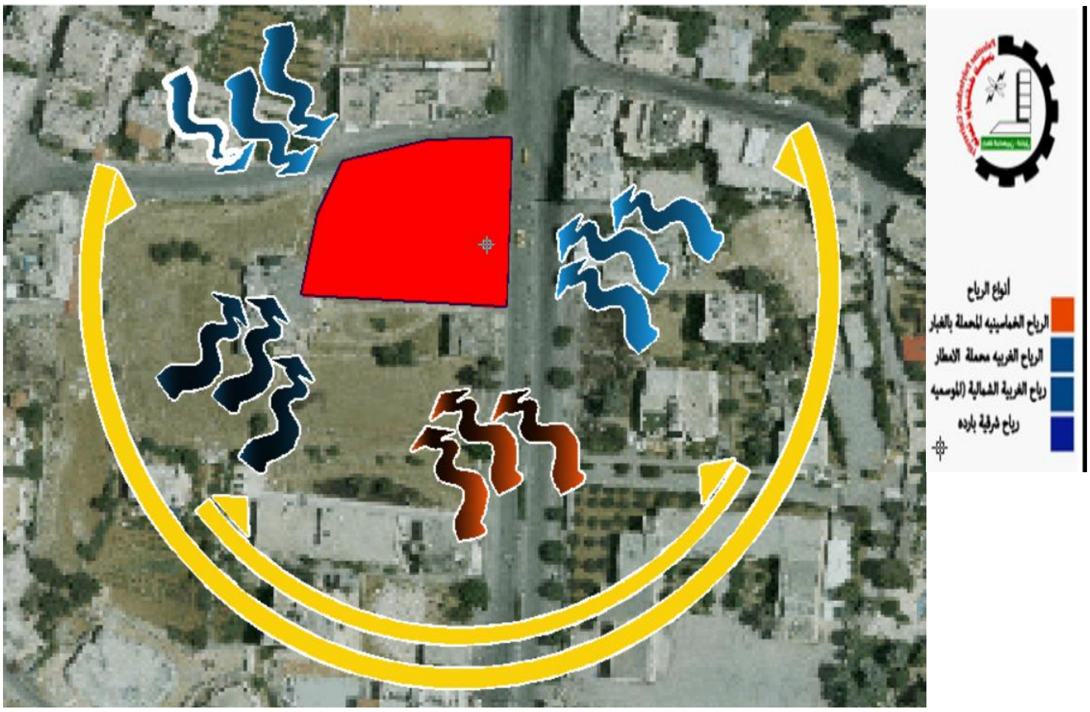


Figure 3.2Movement of the sun and wind.

3.3.3 Architectural Elements:

Hebron city is located to the south of the west bank in addition of its high mountains, and this has given it a strategic location between cities. The city has an increasing in population in recent decades including several buildings and facilities. Also, the nature of its economic activity, which is mostly commercial and industrial, which earns it a unique architectural model.

3.4 Plans Description.

The building in its engineering structure depends on the rectangular and circular shape. This is governed by the nature of the land. The building area is [9113] m^3. It is distributed over several floors as follows:

3.4.1 Basement:

The area of the floor is= [2190] m2 . The floor level is -02.70 m. It includes the parking. As shown in figure(3.3).

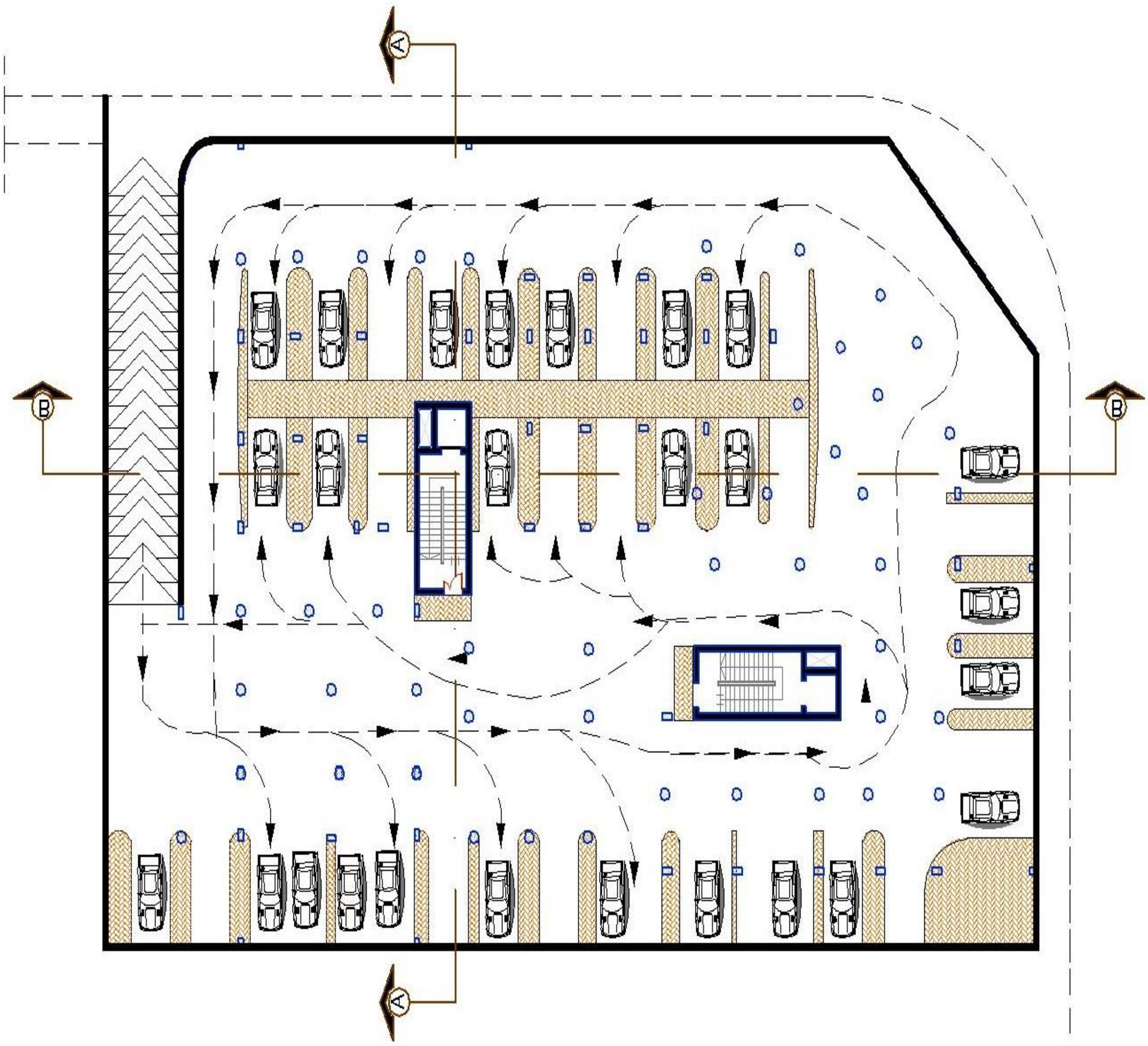


Figure 3.3Basement Plan.

2.4.2 Ground Floor:

The area of the floor is= [665] m2 . The floor has several level to solved the defiance of land level, it's as follow +0.45m, +0.90m, +1.35m, +1.80m, +2.25m . It is include seventeen deferent store as shown in the figure(3.4).

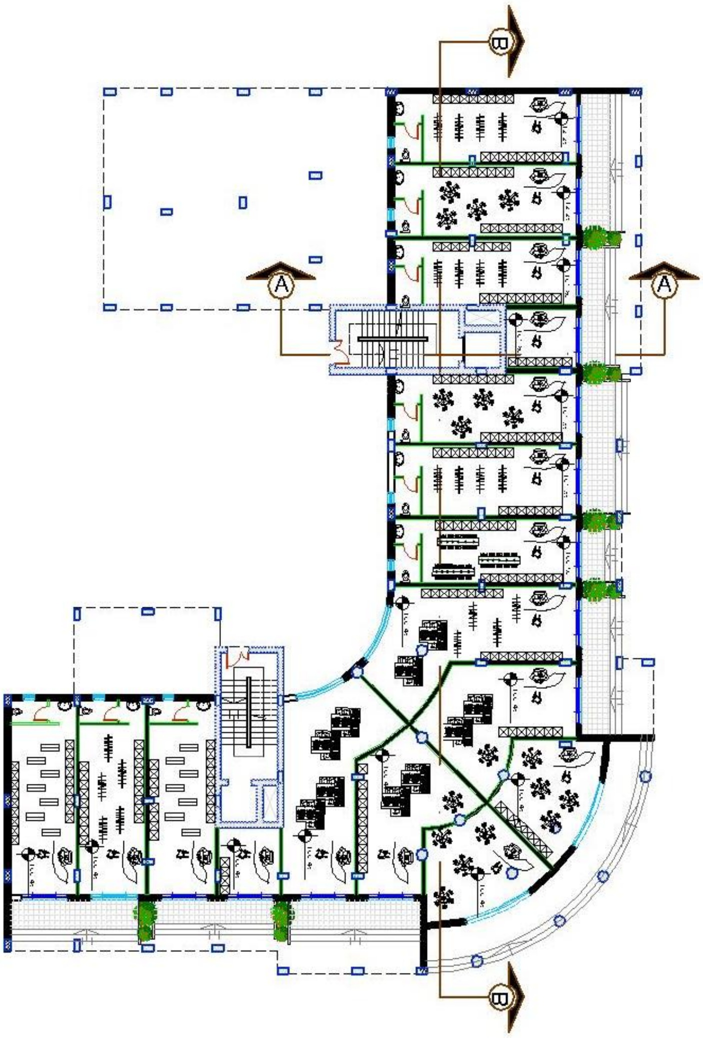


Figure 3.4Ground Floor Plan

3.4.2 First Floor

The floor area equal [1042] m^2. it's repeated in third and fifth floor. The floors level is +6.30 m, +13.50, +20.70. It is include four deferent apartments, each apartment include master bedroom, two bedrooms, two bathrooms, W.C, kitchen, guestroom, living room and dining room , and two partial from two another apartments include two guestroom, W.C, kitchen, living room, dining room and stair to move to other partial of the apartment as shown in the figure(3.5).

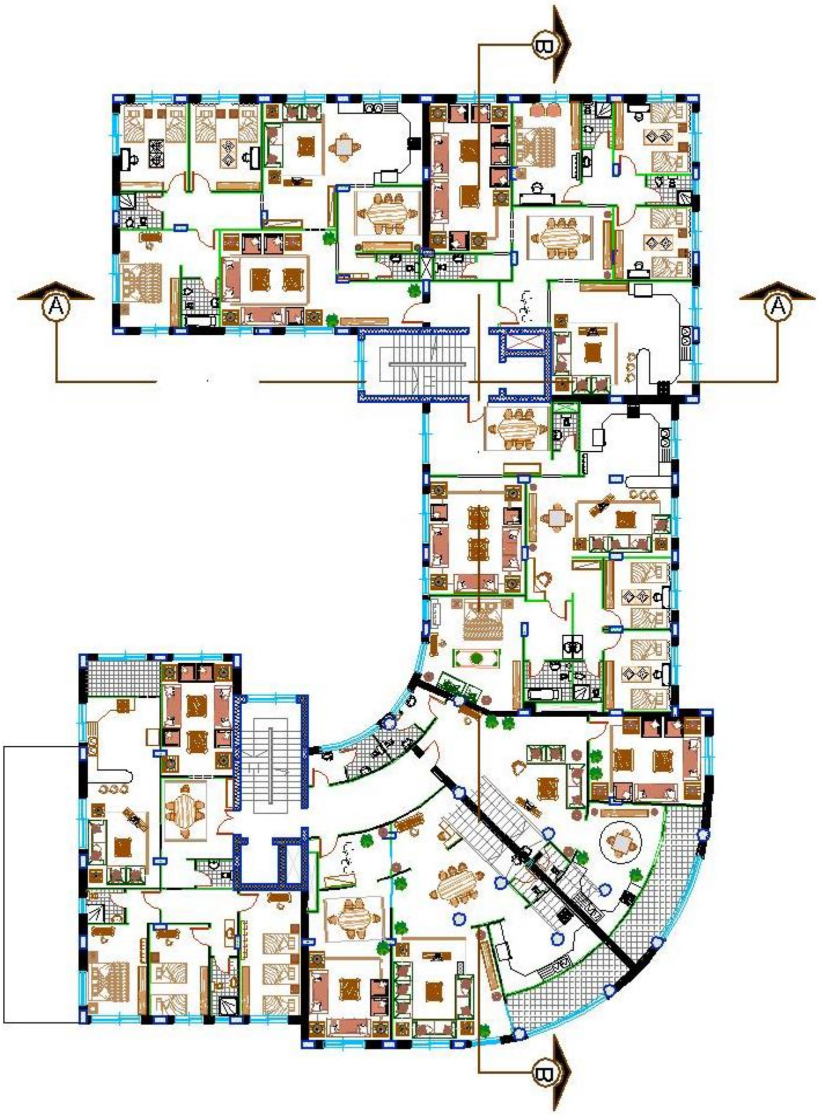


Figure 3.5 First plan

3.4.3 Second Floor

The floor area equal [1042] m^2. it's repeated in four and sixth floor. The floors level is +9.90 m, +17.10, +24.30. It is include four deferent apartments, each suite include master bedroom, two bedrooms, two bathrooms, W.C, kitchen, guestroom, living room and dining room , and the second two partial from the one of two other apartment include master bedroom, two bedrooms, two bathrooms, and living area and the other apartments include master bedroom, bedroom, two bathrooms, and living area as shown in the figure(2.6).

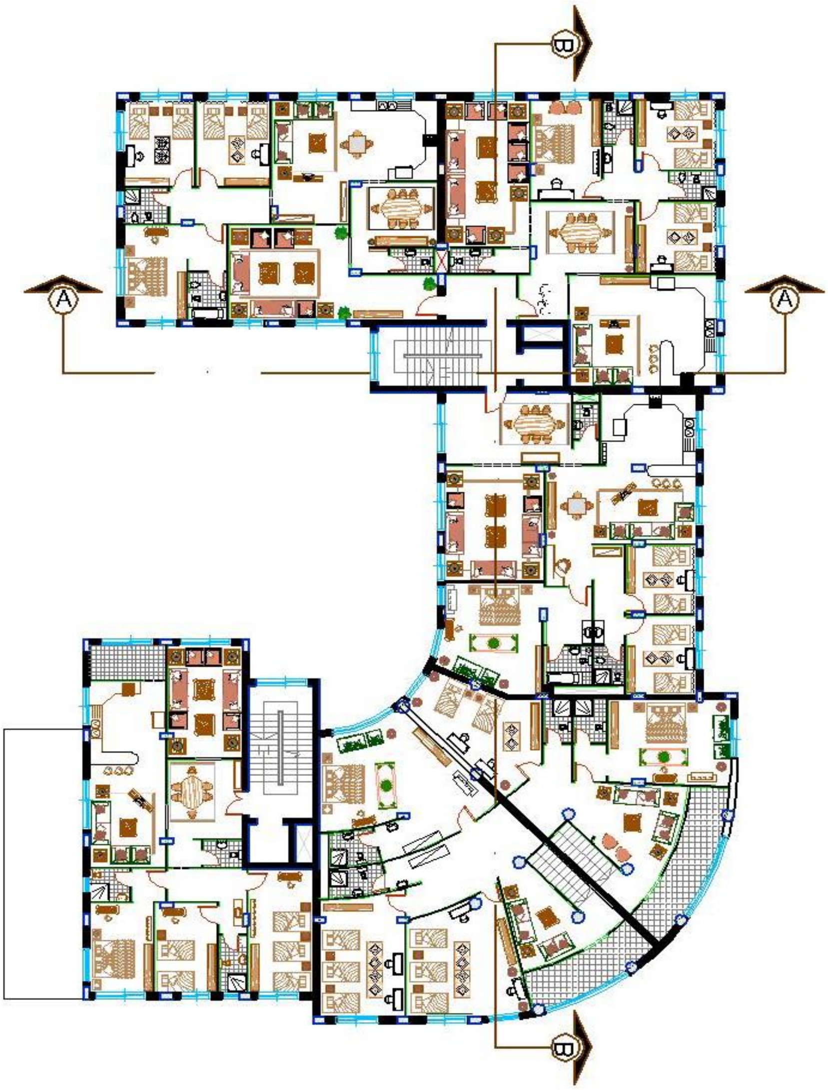


Figure3.6 Second Floor

3.5 Elevation Description

There is no doubt that the elevation of any design give the first impression of the building and its relationship with the surrounding environment. It also shows the differences in the function performed by the spaces reflected by the facade. and this comes through the openings that appear in the elevation, which must fit with the function of this spaces.

3.5.1 North Elevation

This elevation is the main elevation of the project because it has a full view of the building and its main entrance, it is include a good view for the viewer of the size of the project. And also highlights the main entrance that drives the people who comes to the building to enter through it without the need for a reference or guide. As shown in the figure(3.7).

Figure 3.7 North Elevation

3.5.2 East Elevation

This elevation shows the continuity of the windows along the building, and this highlights the architectural beauty of the elevation. Here also used the same type of stone used in other elevations and the same arrange for openings and windows as in otherelevations. In addition, this elevation contains a set of windows that are consistent with each other, this gives a unique architectural layout. As shown in the figure(3.8).

Figure 3.8East Elevation

3.5.3 South Elevation

In this elevation, there is some overlap in the building so it gives a kind of beauty and vitality. The openings and windows are arranged as in the other elevations this gives it a special character with a wonderful architectural touch, and it is shown the entrance to the first staircase. On the other hand, this elevation was characterized by the use of glass along the floors in the area of Stairs As shown in the figure(3.9).

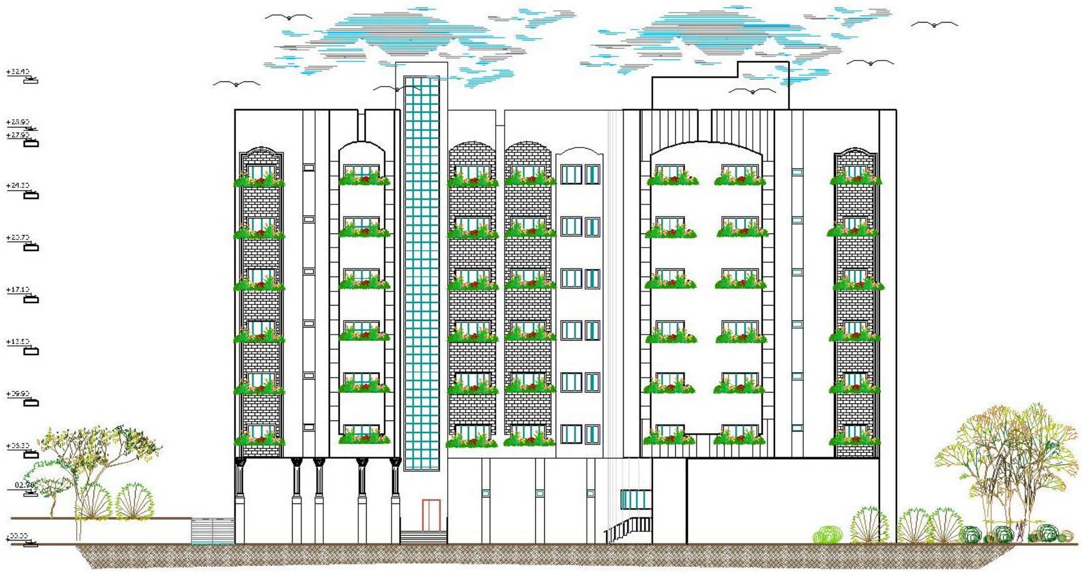


Figure 3.9 South Elevation

3.5.4 West Elevation

This elevation resembles the southern elevation in which horizontal and vertical blocks overlap, giving the building a beautiful view. Also using the same kind of stone and the same arrangement of windows and openings. It shows the entrance to the second staircase of the apartments. As shown in the figure(310).

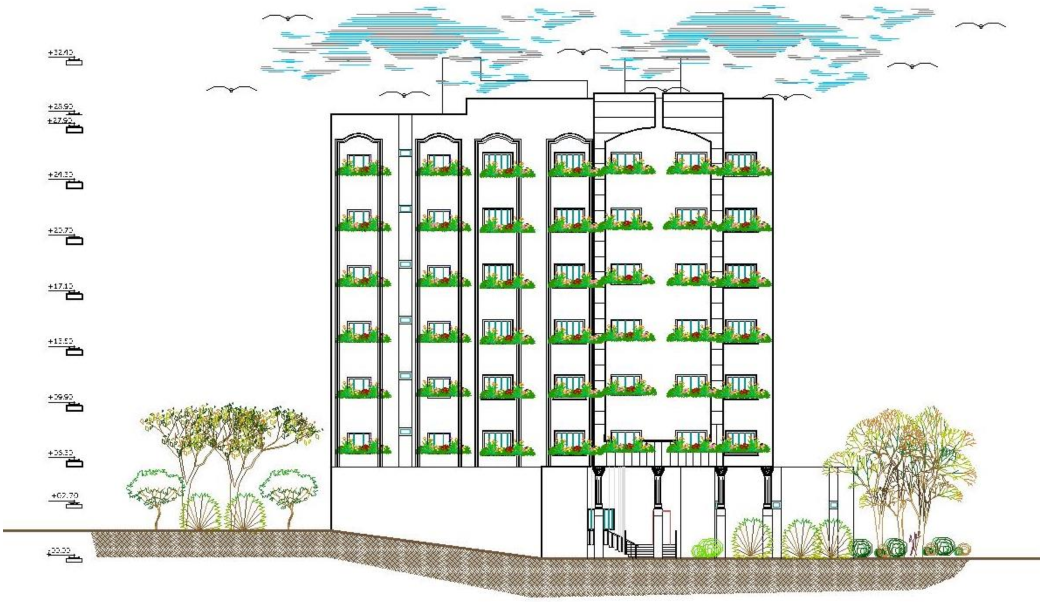


Figure 3.10 West Elevation

3.6 Movement Description.

The movement from the outside and the inside takes many forms. And it's very smooth; so the renter can reach him apartments from the stairs, and elevator. which in turn allows free entry and exit from and to the building.

And each store has its own entertain, that gives it its privacy. Below are some sections of the building shown I n figure (3.11)and(3.12)

Figure 3.11 Section A-A

Figure 3.12 Section B-B

4

Chapter 4

Structural studies

4.1 Introduction

4.2 The purpose of the structural design

4.3 Stages of structural design

4.4 Loads

4.4.1Dead loads

4.4.2 Live loads

4.4.3 Environmental loads

4.4.3.1Wind loads

4.4.3.2Snow loads

4.4.3.3Earthquake loads

4.5 Geotechnical studies

4.6 Structural elements of the building

4.6.1 Slabs

4.6.2 Stairs

4.6.3 Beams

4.6.4 Columns

4.6.5 Shear walls

4.6.6 Footings

4.6.7 piles

4.6.8 Expansion joint

4.1 Introduction:

After studying the project from the architectural point of view, it is necessary to move to the structural aspect to study the structural elements and describe them accurately. Where the loads acting on the building will be studied. To come out with a structural design that meets all safety and architectural requirements as well as taking into consideration the economic factor.

The structural design also requires the selection of the suitable structural elements for the project to be constructed. And to make sure of its possibility to be safely constructed on the ground, and keep the architectural design without any change.

4.2 The purpose of the structural design

Structural design is a complete process that depends on every deign steps, as it meets a set of goals and factors that will come out with an achieved the desired aim structure. These aims are as follows:

1- Safety: Where the building is safe in all cases and resist the various natural changes, through the selection of sections of the structural elements which can resist forces and stresses resulting from them.
2- Economic cost: achieving a structure with high safety and lowest economical cost.
3- Efficient use (Serviceability) : avoiding any defect in the building like cracks, some types of deflection which affect negatively on the architecture view and annoy the building users.
4- Keeping the architectural design of the building.

4.3 Stages of structural design.

Structural design can be divided into two basic stages:

Stage one: a primary study for the size and the nature of the project, In addition to understand the project in its all different aspects. And identify the materials that will be approved for the project, then the basic structural analysis of this system and the expected initial dimensions.

Stage two: It’s the structural design of each part of the building, In a detailed manner according to the selected structural system and make the required structural detail ssuch as horizontal plans, vertical sections, and details of reinforcing steel.

4.4 Loads

Structural elements that are designed must be able to carry the loads acting on it without collapsing. The loads of the building are divided into different types as follows:

4.4.1 Dead loads

Are the loads resulting from the self-weight of the main elements that the building contains, Dead loads means the loads which acts on the structure since it is construct and remains constant in magnitude and fixed in its position throughout the lifetime of the structure. As well as additional parts, such as internal partitions, and any mechanical work or additions are carried out permanently and consistently in the building

This category can be calculated in a high range of accuracy using the design configuration, dimension of the structure and density of the materials, Table (4-1) shows several values of density for materials used in this project according to the Jordanian code.

Table 4.1 the densities for used materials

No.	Used materials	Density
1	Tiles	23 KN/ m^3
2	Reinforced concrete	25 KN/ m^3
3	Concrete block	15 KN/ m^3
4	Mortar and plaster	22 KN/ m^3
5	Sand	16 KN/ m^3

4.4.2 Live loads

Live loads are loads their magnitude and distribution at any given time are uncertain and their location can also be changed, and even their maximum intensities through the lifetime of the structure are not known with precision. These loads consist mainly of occupancy loads in building and traffic loads on bridges.

It’s a continuously changeable loads in amount and location, such as people, furniture, appliances, equipment. Its value depends on the use of the building and it is usually taken from special tables in different codes.

Table 4.2 The live load which was determined by the Jordanian code

No.	Used	Live
1	Parking	4 KN/ m2
2	Stores	3 KN/ m2
3	Stairs	4 KN/ m2
4	Ceilings	4 KN/ m2
5	Bedroom	2kN/m2

6	Bathrooms	2kN/m2
7	Living rooms ,Hall, Billiard	2kN/m2
8	Corridors, entrances, drawers, terraces, and high corridors that are connected between building	3 KN/ m2
9	Kitchens and laundry rooms	3 KN/ m2
10	Boilers, engines, fans and the like including weighing machines	7.5 KN/ m2

4.4.3 Environmental Loads

Loads come on the building that are caused by natural changes such as snow, wind and earthquake loads, also loads caused by soil pressure. The loads differ from one region to another. And these are :

4.4.3.1Wind loads

Horizontal forces affects building with more than 6 floors. These forces caused by the wind affects buildings. It may be positive if it's caused by compression or negative if it's caused by tension. Its unit is N/ m^2

Wind loads are determined depending on the speed and height of the building, the loads increasing by the increasing of height, also it depends on the height of the surrounding buildings in the location. Shear walls are designed according to wind pressure from the Jordanian code with a value of 0.4 KN/m^2

4.4.3.2 (Snow loads)

Loads that the building can be faced because of the accumulation of snow.These loads can be evaluated according to the following bases:

1- The height of the building above sea level.
2- The inclination of the surface faces the snowfall.

The ability of the roof to carry the snow can be determined by this equation: Sd = μi* So.

Where : So= the snow load on ground in KN/ m2

And μi= shape factor for snow load.

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

Table 4.3 snow loads according height of sea level.

(KN/$\boldsymbol{m^2}$)snow loads	(M)the height above sea level
0	h < 250
(h-250)/1000	500 > h > 250
(h-400) / 400	1500 > h > 500
(h – 812.5)/ 250	2500 > h > 1500

4.4.3.3 Earthquake loads

One of the most important environmental loads that affect the building, it's a horizontal and vertical forces cause moments such as torque moment, Due to the relative movement of the rocky earth layers, resulting cutting forces affecting the building. In design , this loads should be taken in consideration and it must be designed according to horizontal forces to make sure that the building is resisting the earthquakes in case it happen. thus minimizing of earthquake damage.

These loads will be dealt through shear walls, which will be distributed in this project according to its' structural calculations.

4.5 Geotechnical studies:

Before studying of building, a geotechnical studies for the location should be done. It means all the works related to the exploration of the site and the study of soil, rocks and groundwater, also analysis for the information to predict how the soil behaves when building constructed. The civil engineer looks for the bearing capacity of soil, which is needed to design the footings.

4.6 Structural elements of the building

Buildings usually consist of a set of structural elements that intersect with each another to resist loads on the building, this includes: slabs, beams, columns, shear walls, stairs and footings.

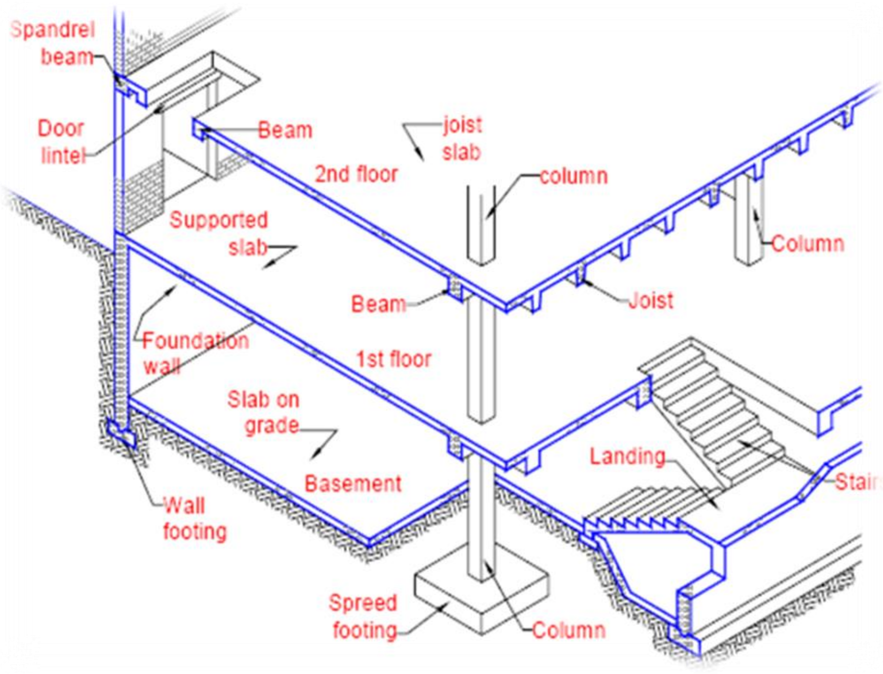


Figure 4.1 some of the structural elements of the building

The project contains the following elements:

4.6.1 Slabs

A slab is a structural element whose thickness is small compared to its own length and width. According to the way loads are transferred to supporting beams and columns, without being deformed, slabs are classified into several types:

1- Solid slabs, divided into:
   a. One way solid slab.
   b. Two way solid slab.

2- Ribbed slab, divided into:
   a. One way ribbed slab.
   b. Two way ribbed slab.

One way solid slab:

Where the ratio of the longer to the shorter side (L/S) of the slab is less or equal to 2.0. They are used in areas that face heavy live loads, in order to avoid vibration due to low thickness.

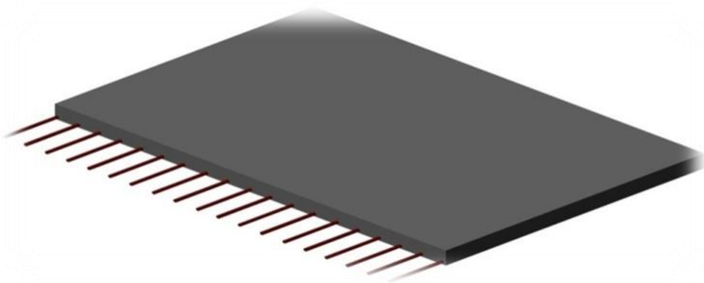


Figure 4.2 One way solid slab

Two way solid slab:

Where the ratio of the longer to the shorter side (L/S) of the slab is larger than 2.0. it is used in case the loads affecting the slab are more than the one way solid slab can take. It has a larger resistant for loads where the reinforcement distribution is in two directions.

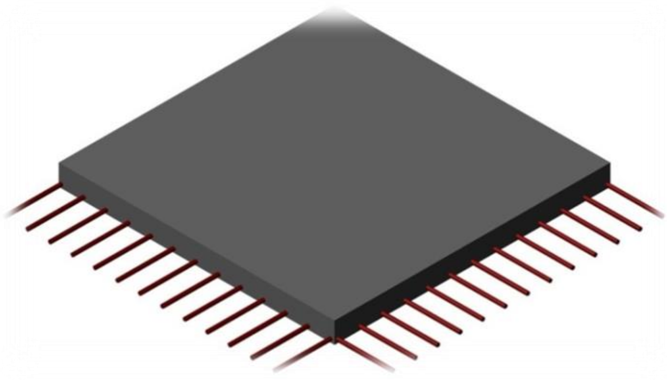


Figure 4. 3 Two way solid slab.

One way ribbed slab:

One of the most famous methods used in the design of slabs in Palestine , the rib is provided in one way only, since resistance of concrete in tension is too small compared with that in compression, concrete in the tension zone may be gathered in regularly spaced ribs cast monolithically with topping slab on top of these ribs. Hollow blocks are arranged between the ribs. The use of these blocks makes it possible to have smooth ceiling which is often required for architectural considerations and have a good sound and temperature insulating. These slabs are most economical for buildings such as hospitals, schools and hotels. The reinforcement bars are in one direction and we used this type in most of the slabs.

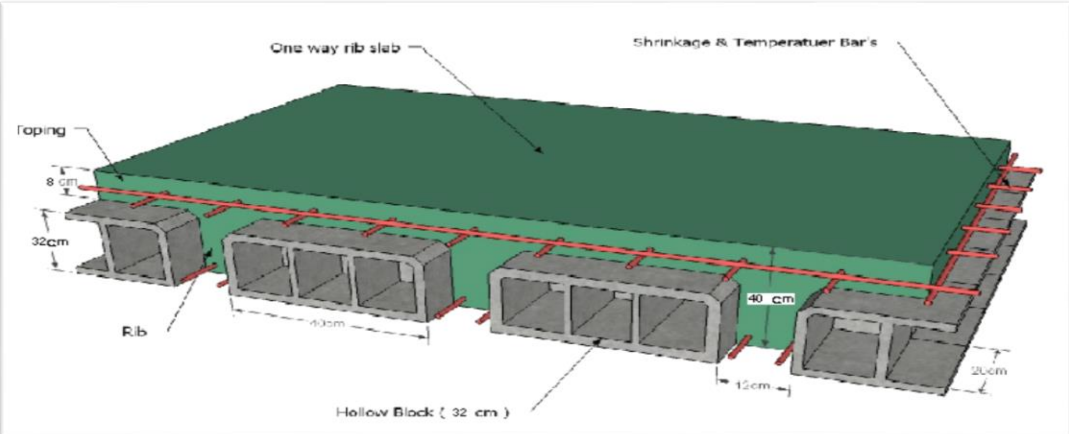


Figure 4. 4 One way ribbed slab

Two way ribbed slab:

It resemble in contents the previous type of slab, but the difference here that the reinforcement bars are in two directions including the rib, also the load distribution is in all directions. This of slabs was used in the project.

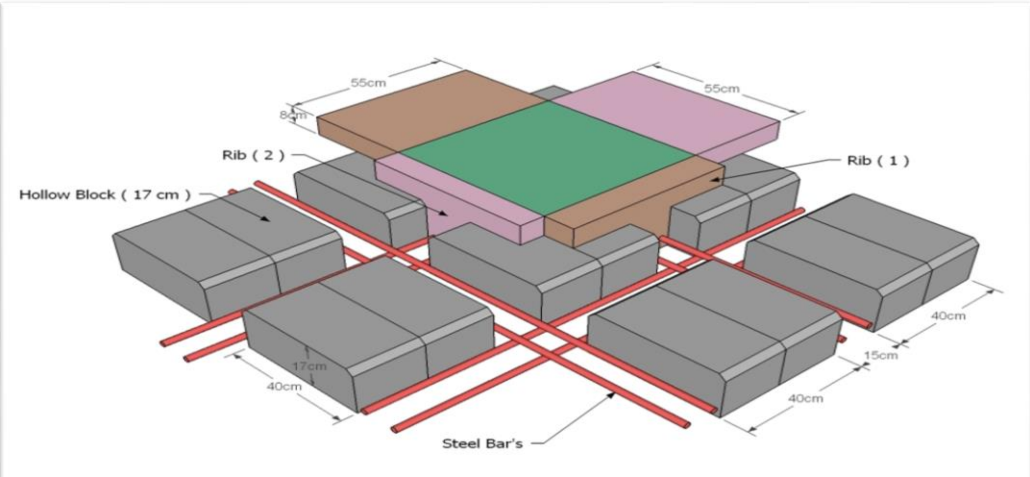


Figure 4. 5 Two way ribbed slab

4.6.2 Stairs

Stairs an architectural element is found in buildings to move between two levels on the same floor or between a number of floors through the building. There are usually designed as one way solid slab and that’s obvious in our project. Also taking into consideration in structural design the loads caused by elevators.

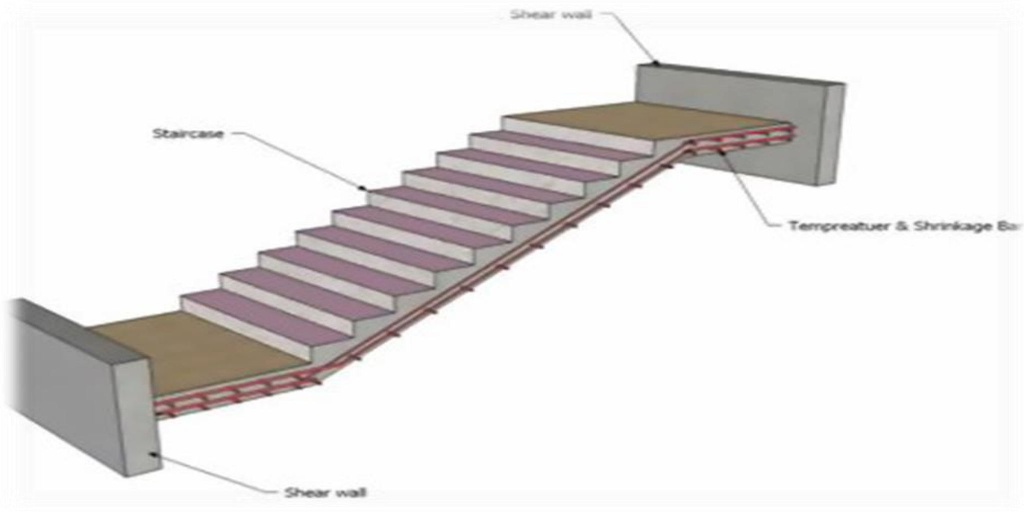


Figure 4. 6 Stair

4.6.3 Beams

Horizontal or inclined structural member spanning a distance between one or more supports and carrying vertical loads across its longitudinal axis, as a girder, joist or rafter. Three basics types of beams are: Simply supported beam (supported at both ends), Continuous (supported at more than two points) and Cantilever (supported at one end with the other end overhanging and free).

Also, beams are divided into:

1- Hidden beams: its height equals the height of slab.
2- Drop beams: its height is larger than the height of slab, the extra part of the beam is shown in one of the up (up stand beam) or down (down stand beam) directions, where these bridges called T-section and L-section.

Due to the different distances between columns in the building in this project including the loads acting on it, beams that will be used in the slab will be hidden beams and other drop. The horizontal reinforcement bars to resist the moment acting on it. And using stirrups to resist shear forces.

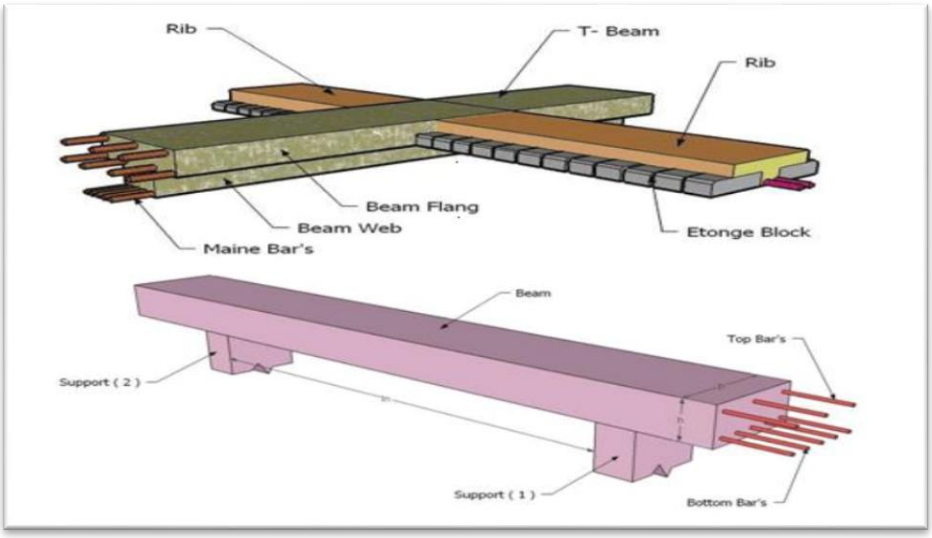


Figure 4. 7 Types of beams.

4.6.4 Columns

Columns are basic elements in the structure, where the loads transferred from the slab to the beams, which in turn transferred them into columns, then to the footings, therefore, columns are an important elements in the building, and must be design to be able to transfer and distribute the loads acting on it. So, columns are divided into two types according to deal with it in structural design:

1- Long columns.

2- Short columns.

And according to of architectural form or geometry: there are rectangular, circular and square columns. The project contains two shapes of columns, rectangular and circular ones.

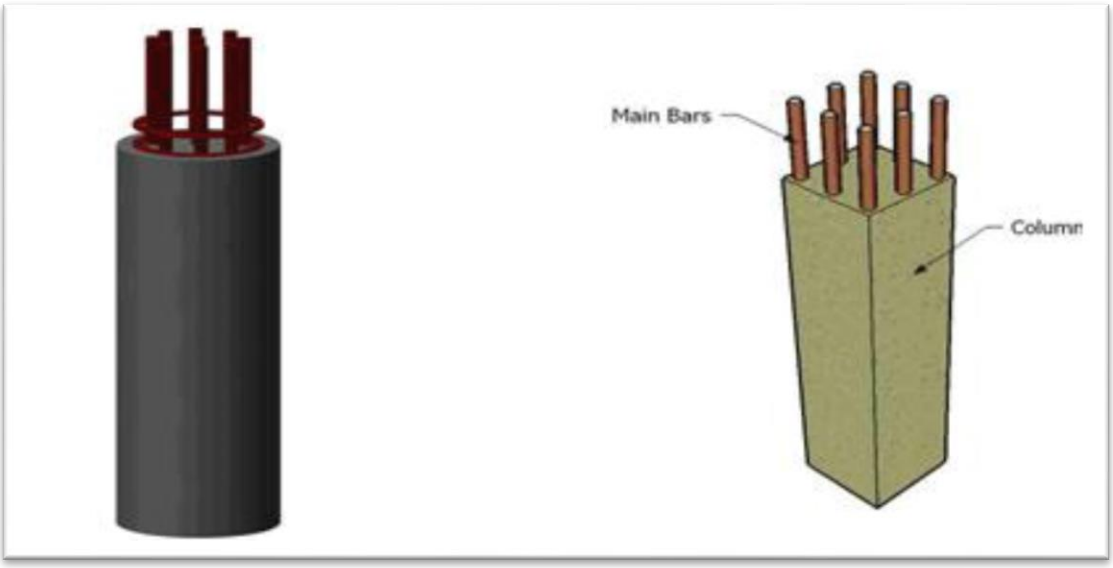


Figure 4. 8 Types of column

4.6.5 Shear walls

Walls surrounds the stairs and elevators, including some areas of the building as necessary. the function of the shear walls, is to resist horizontal shear forces that face the building as a result of the loads of earthquakes and winds. These walls also considered as carrier walls. It is provided in two perpendicular directions in the building so that the distance between the resistance center formed by the shear walls in each direction and the center of gravity of the building as little as possible, to provide full stability of the building, the following figure shows a reinforced shear wall.

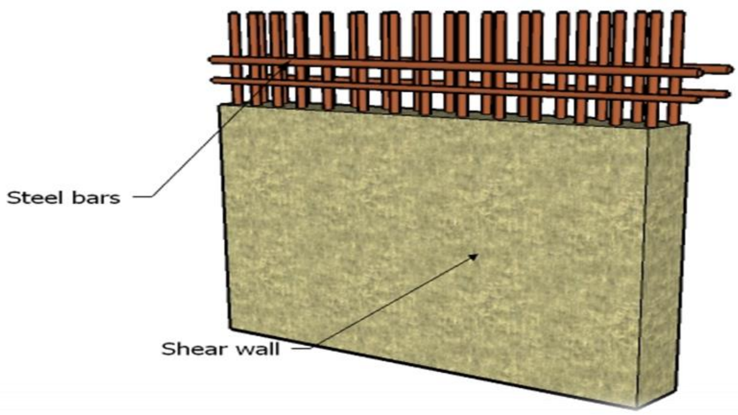


Figure 4. 9 Shear wall.

4.6.6 Footings

Footings are the first to be constructed in the building, while its design is completed after the design of all the structural elements in the building. It is the link between the structural elements of the building and the ground, it transferred the loads from columns and carrier walls to the soil as a pressure, and on several types as follows:

1- **Isolated footings.**
2- **Strip (wall) footings.**
3- **Raft footings.**
4- **Combined footings.**

A different types of footings will be used depending on the type of soil, the carrying capacity and the loads.

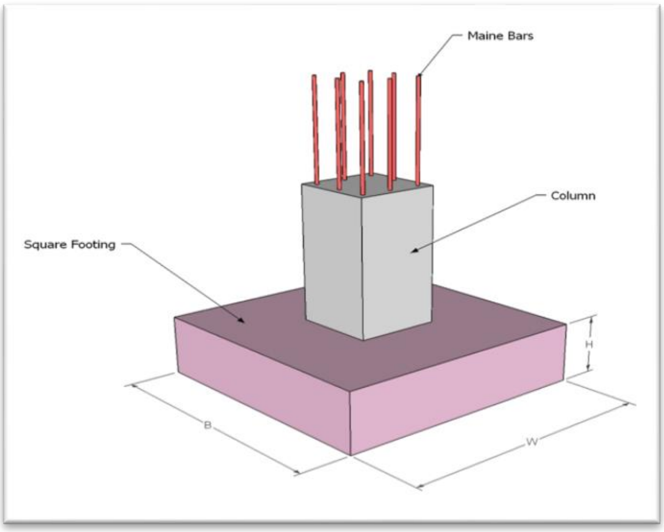


Figure 4. 10 Footings

4.6.7 Piles

Piles are a thin, large length elements compared to the dimensions of its section, piles are used for many purposes, the most important one is receiving columns and walls loads and transferring them to the soil. Piles extend within the soil with its full length or a part of it, to perform the task of transferring loads, stabilizing the soil, controlling the settlement, reducing the effects of dynamic loads and increasing the resistance of horizontal forces,, etc.

Piles are classified according to the type of soil into: (Bearing piles) or (Friction piles).

4.6.8 Expansion separators

Are constructed in building with large horizontal dimensions or shapes and special conditions, including thermal expansion joints or landing joints, or it's may be for the both purposes. When analyzing the structures for studying as a resistant to earthquakes, these intervals are called seismic separators. These separators have some specific requirements and recommendations as follows:

Thermal expansion joints should be used in the building according to the approved code, These joints must reach the top of the foundations face without penetrating them. The maximum distances of the building are considered as follows:

1- (40m) in regions with high moisture.
2- (36m) in regions with average, normal moisture.
3- (32m) in region with moderate moisture.
4- (28m) in dry regions.

Also, the width of the separator must be at least (3cm) or larger.

Chapter 5

Structural Analysis And Design

5

5.1 Introduction.

5.2 Design method and requirements.

5.3 Check of Minimum Thickness of Structural Member.

5.4 Design of topping.

5.5 Design of One Way-ribbed Slab (RS1,RS2,RS3).

5.6 Design of Beam(BS10).

5.7 Basement wall

5.8 Design stair

5.9 Design column

5.10 Design footing

5.1 Introduction:

Many structures are built of reinforced concrete: bridges, buildings, retaining walls, tunnels, and others. Reinforced concrete is logical union of two materials: plain concrete, which possesses high compressive strength but little tensile strength, and steel bars embedded in the concrete, which can provide the needed strength in tension. Plain concrete is made by mixing cement, fine aggregate, coarse aggregate, water, and frequently admixtures. Understanding of reinforced concrete behavior is still far from complete, building codes and specifications that give design procedures are continually changing to reflect latest knowledge.

Structural concrete can be classified into:

- Lightweight concrete with unit weight from about 1350 to 1850 kg/m^3.
- Normal weight concrete with unit weight from about 1800 to 2400 kg/m^3.
- Heavyweight concrete with unit weight from about 3200 to 5600 kg/m^3.

5.2 Design method and requirements:

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

- ✓ Strength design method:

In ultimate strength design method, the service loads are increased by factors to obtain the load at which failure is considered to be occurring.

This load called factored load or factored service load. The structure or structural element is then proportioned such that the strength is reached when factored load is acting. The computation of this strength takes into account the nonlinear stress-strain behavior of concrete.

The strength design method is expressed by the following,

Strength provided ≥ strength required to carry factored loads.

NOTE:

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

- ✓ Code : ACI 2008
  UBC
- ✓ Material :

Concrete: B300…. $Fcu = 30N/mm^2 (MPa)$ For circular section but for rectangular section ($fc' = 30 * 0.8 = 24MPa$) .

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

✓ Factored loads:

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

$W_u = 1.2\ D_L + 1.6\ L_L$ ACI-code-318-08(9.2.1).

5.3 Check of Minimum Thickness of Structural Member:

Table (5. 1) MINIMUM THICKNESS OF NONPRESTRESSED BEAMSOR ONE-WAY SLABS UNLESS DEFLECTIONS ARE CALCULATED. (ACI 318M-11)

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

- For Rib :

  $h_{min}$for (one end continuous)=L/18.5=512/18.5=27.86cm

  $h_{min}$for (both end continuous)=L/21=519/21=24.71m

- ForBeam :

  h_{min} for(one end continuous)=L/18.5=625/18.5=33.78cm

  $h_{min}$for(both end continuous)=L/21=699/21=33.28cm

The minimum thickness will be h_{min}=35cm

select 35cm for rib slab with hidden beam

h=35cm (27 cm Hollow Block+8 cm Topping)

5.4 Design of topping:

Statically system for topping :

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

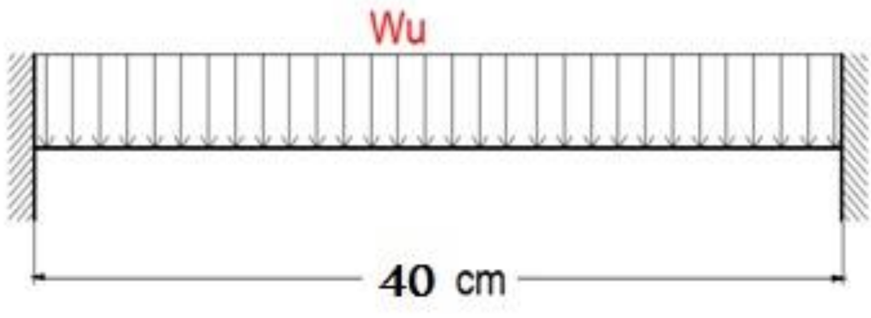


Figure 5. 1 topping load.

✓ Load calculations:

Dead load calculations:

Table (5. 2) Dead load calculation Topping

Dead load from:	δ×γ×1	KN/m
Tiles	0.03×23×1	0.69
Mortar	0.02×22×1	0.44
Coarse sand	0.07×17×1	1.19
Topping	0.08×25×1	2
Interior partitions	2.3×1	2.3
	∑	6.62KN/m

- Live Load :

  L_L =2 KN/m^2

  L_L =2 KN/m^2×1m=2KN/m

- Factored Load :

  W_U = 1.2 ×6.62 + 1.6×2 =11.144 KN/m

  Check the strength condition for plain concrete, $øM_n \geq M_u$, where ø = 0.55

  $M_n = 0.42\ \lambda \sqrt{f_c'}\ S_m$ (ACI 22.5.1, equation 22-2)

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

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

  $M_u = \frac{W_u L^2}{12} = 0.1358\ \text{KN.m}$ (negative moment)

  $M_u = \frac{W_u L^2}{24} = 0.0679\ \text{KN.m}$ (positive moment)

  $øM_n >> M_u = 0.1358\ \text{KN.m}$

No reinforcement is required by analysis. According to ACI 10.5.4, provide $A_{s,min}$ for slabs as shrinkage and temperature reinforcement.

$\rho_{shrinkage}$= 0.0018 ACI 7.12.2.1

$A_s = \rho \times b \times h_{topping}$ =0.0018 ×1000×80 = 144 mm^2/m

Step (s) is the smallest of:

1. 3h = 3×80 =240 mm control by ACI 10.5.4
2. 450mm.
3. S =$380\left(\frac{280}{f_s}\right) - 2.5C_c = 380\left(\frac{280}{\frac{2}{3}420}\right) - 2.5 . 20 = 330mm$ ACI 10.6.4 OR

   S $\leq 300\left(\frac{280}{f_s}\right)$=300 mm

Take ø 8 @ 200 mm in both direction , S = 200 mm <S_{max} = 240 mm … OK

5.5 Design of One-Way Ribbed Slab(RS01, RS02, RS03, RS04) :

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

bw ≥ 10cm……………………………………………ACI(8.13.2)

Select bw=12cm

h ≤ 3.5*bw ……………………………….…….. ACI(8.13.2)

Select h=35cm<3.5*12=42 cm

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

Select tf=8cm

- ✓ Statically system and Dimensions

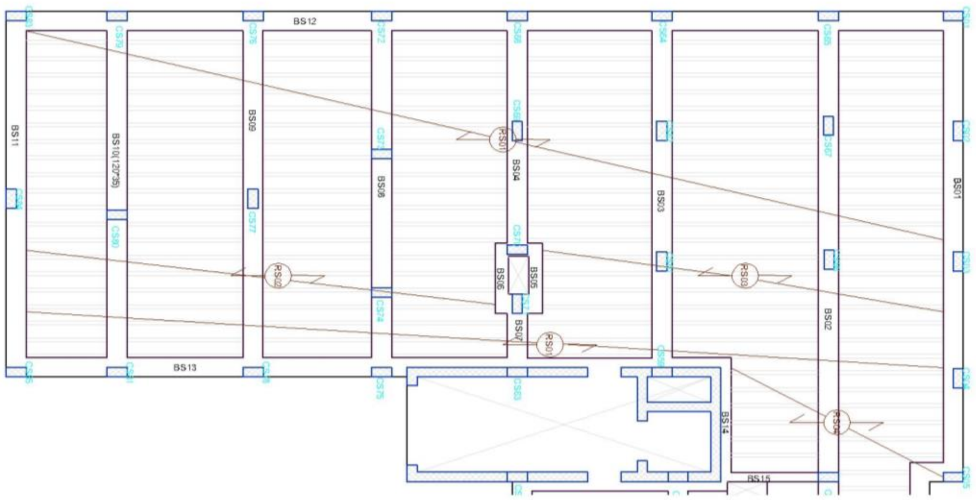


Figure 5. 2 One Way Rib slab (RS01, RS03, RS03)

Load calculations :

- Dead load:

Table (5. 3) Dead load calculation Topping of ribS

Dead load from:	**h×γ×b**	**KN/m**
Tiles	0.03×23×0.52	0.359
Mortar	0.03×22×0.52	0.343
Coarse sand	0.07×17×0.52	0.619
Topping	0.08×25×0.52	1.04
R.c rib	0.27×25×0.12	0.81
Hollow block	0.27×10×0.4	1.08
Plaster	0.03×22×0.52	0.343
Interior partitions	2.3×0.52	1.196
	∑	5.79 KN/m

Dead load /rib = 5.79KN/m

- Live load =2KN/M^2

Live load /rib = 2KN/m^2 × 0.52m = 1.04 KN/m.

- <u>The effective flange (be) :</u>

1) be $\leq \frac{L}{4} = \frac{3000}{4} = 750\text{mm}$

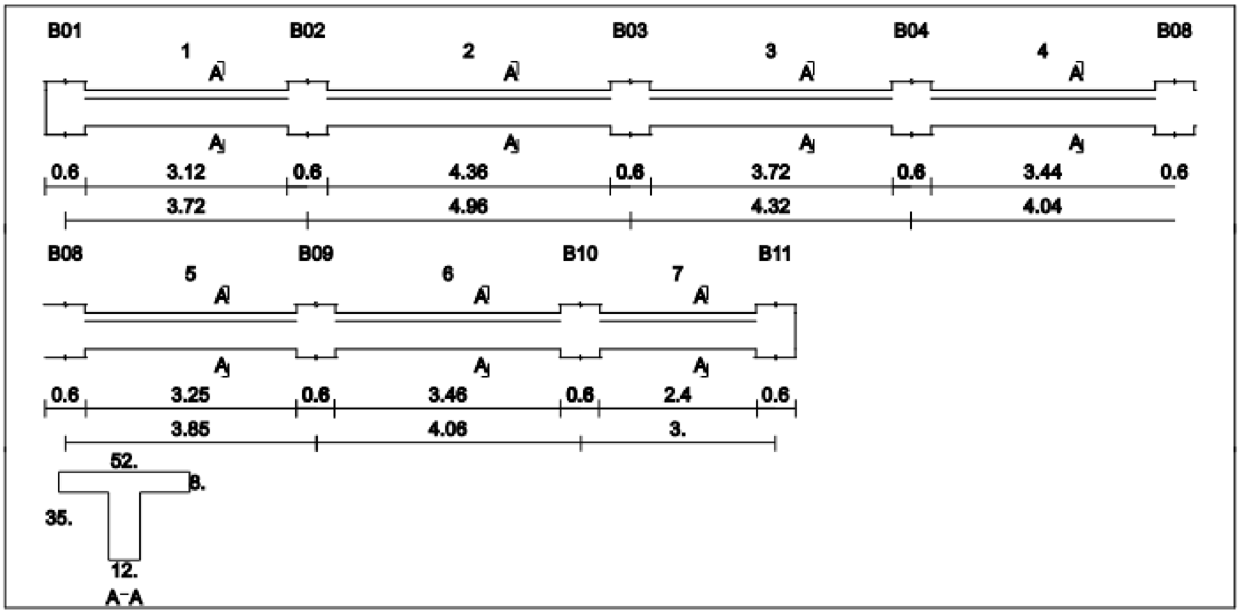
2) be≤ bw +16hf=120+16*80=1400mm

3) be≤ center to center spacing between adjacent beam = $\frac{400}{2} + \frac{400}{2} + 120 = 520mm$

Take be=520 mm

1- Rib (RS01)

Geometry Units:meter,cm



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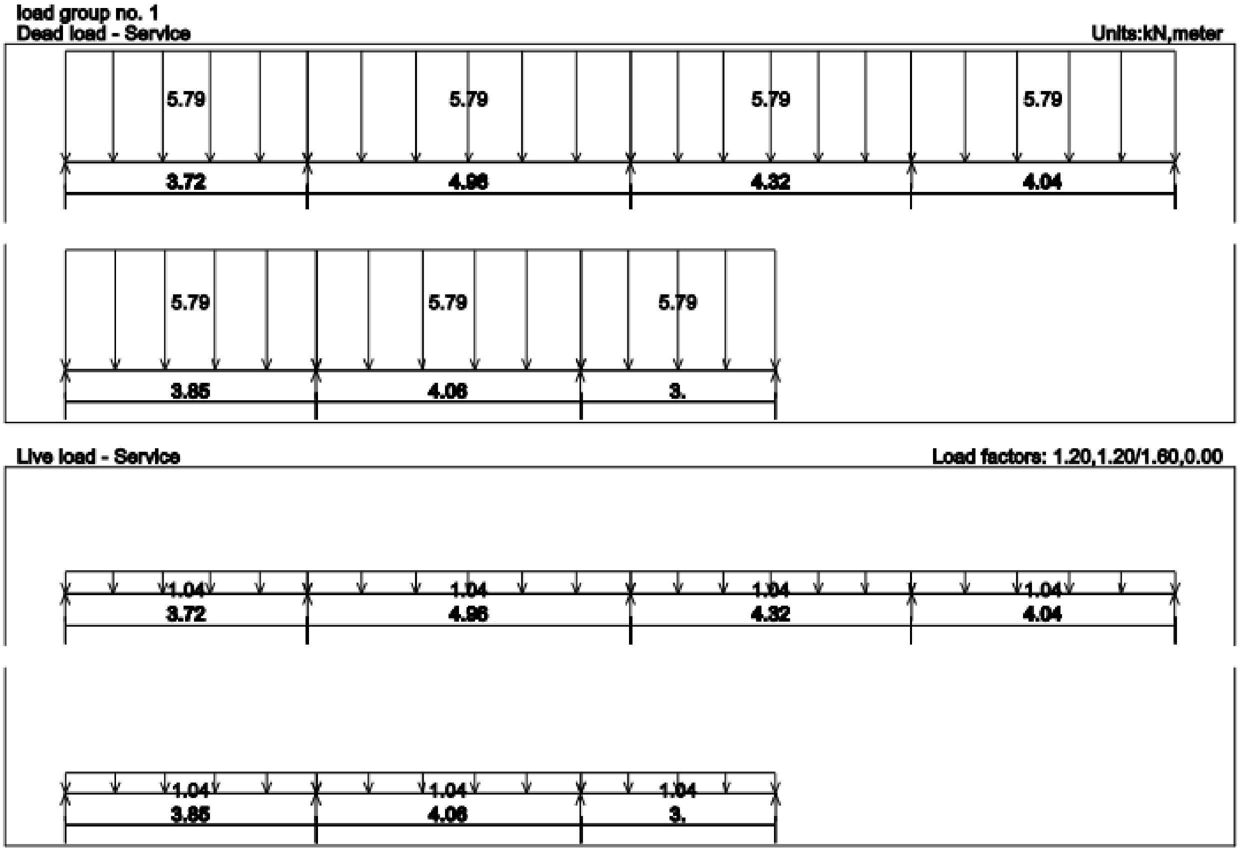
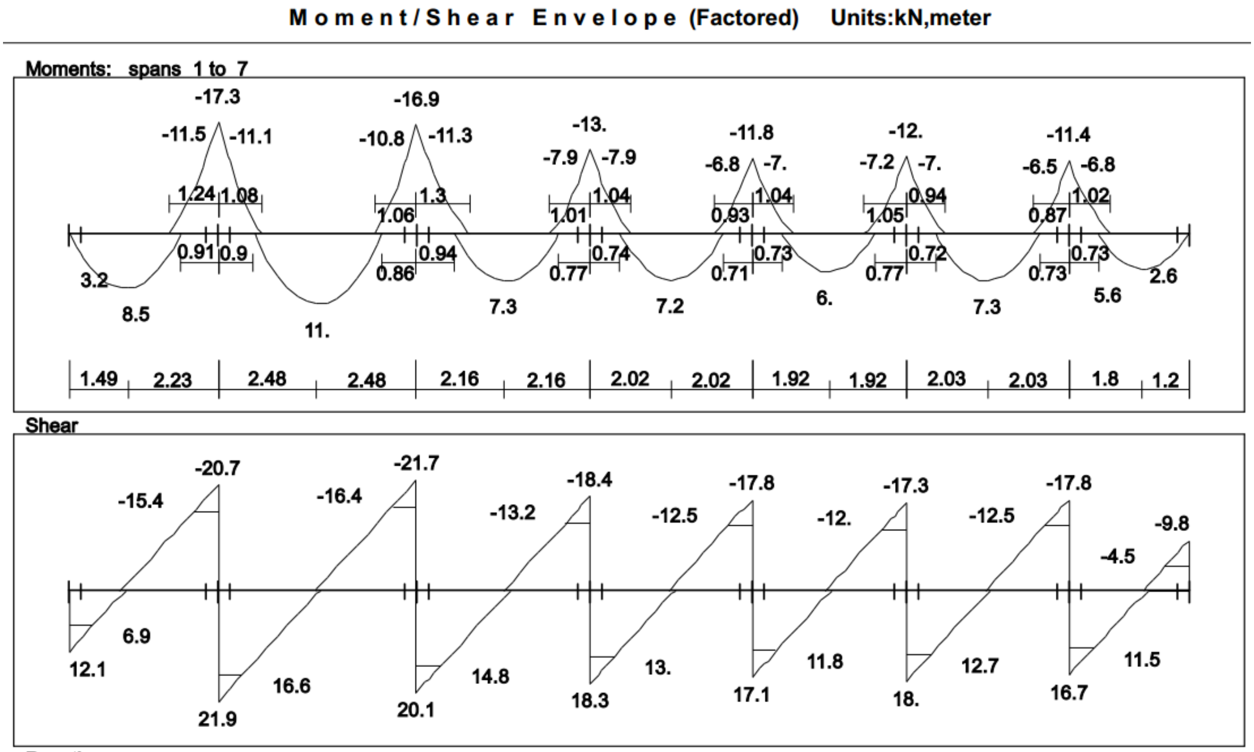




Reactions

Factored								
DeadR	9.26	33.93	32.9	28.5	27.09	27.64	27.43	7.45
LiveR	2.86	8.63	8.82	8.19	7.78	7.57	7.08	2.34
Max R	12.12	42.56	41.72	36.68	34.87	35.21	34.51	9.79
Min R	8.62	37.2	35.86	30.99	29.65	30.24	29.9	6.89
Service								
DeadR	7.72	28.28	27.41	23.75	22.57	23.03	22.86	6.21
LiveR	1.79	5.39	5.51	5.12	4.86	4.73	4.43	1.46
Max R	9.5	33.67	32.93	28.86	27.44	27.76	27.29	7.67
Min R	7.32	30.32	29.27	25.3	24.17	24.66	24.4	5.86

Figure 5. 3 Shear & Moment Envelope Diagram (RS01)

- Design of positive moment:

M_u = 11 KN.m.

Assume bar diameter ø 12 for main positive reinforcement.

d =h- cover - $d_{stirrups} - \frac{d_b}{2} = 350 - 20 - 8 - \frac{12}{2} = 316\ mm.$

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

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

$= 0.85 \times 24 \times 520 \times 80 \times \left(316 - \frac{80}{2}\right) \times 10^{-6} = 234.22 KN.m$

$M_{nf} \gg \frac{M_u}{\varphi} = \frac{11}{0.9} =$ 12.22 KN.m

the section will be designed as rectangular section with b_e =520 mm.

$R_n = \frac{M_u}{\emptyset b d^2} = \frac{11\times10^6}{0.9\times520\times316^2} = 0.235 Mpa.$

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

$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times0.235}{420}}\right) = 0.000563$

$A_{s,req}$ = ρ.b.d = 0.000563×520×316= 92.512mm^2

- Check for $A_{s,min}$.

$A_{s,min}$is the maximum of :-

$A_{s,min} = 0.25\frac{\sqrt{f'_c}}{f_y} b_w.d \geq \frac{1.4}{f_y} b_w.d$

1. $A_{s,min} = 0.25\frac{\sqrt{24}}{420}\ 120\times316 = 110.6mm^2$
2. $A_{s,min} = \frac{1.4}{420}120\times316 = 126.4mm^2\ \ Control$

A_s = 92.512 mm^2 ≤$A_{s,min}$ = $126.4mm^2$

Use 2ø10 , $A_{s,provided}$= 157 mm^2>$A_{s,required}$= 126.4 mm^2. Ok

Check for strain:

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

$c = \frac{a}{\beta_1} = \frac{6.22}{0.85} = 7.32\ mm$

$$\varepsilon_s = 0.003\left(\frac{d-c}{c}\right) = 0.003\left(\frac{316-7.32}{7.32}\right) = 0.127 > 0.005 \quad 0k$$

- Design of negative moment:

M_u = -11.5 KN.m.

Assume bar diameter ø 12 for main positive reinforcement.

d =h- cover - $d_{stirrups} - \frac{d_b}{2} = 350-20-8-\frac{12}{2} = 316mm.$

$R_n = \frac{M_u}{\emptyset b d^2} = \frac{11.5\times10^6}{0.9\times120\times316^2} = 1.066\ Mpa.$

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

$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times1.066}{420}}\right) = 0.00261$

$A_{s,req}$ = ρ.b.d = 0.00261 ×120×316 = 98.971 mm^2

- Check for $A_{s,min}$.

$A_{s,min}$is the maximum of :-

$A_{s,min} = 0.25 \frac{\sqrt{f'_c}}{f_y} b_w.d \geq \frac{1.4}{f_y} b_w.d$

1. $A_{s,min} = 0.25 \frac{\sqrt{24}}{420}\ 120 \times 316 = 110.6\ mm^2$
2. $A_{s,min} = \frac{1.4}{420} 120 \times 316 = 126.4\ mm^2\ Control$

$A_s = 98.971\ mm^2 \leq A_{s,min} = 126.4 mm^2$

Use 2ø10 , $A_{s,provided} = 157\ mm^2 > A_{s,required} = 126.4\ mm^2$.   Ok

Check for strain:

$a = \frac{A_{s}.f_y}{0.85 b\ f_c'} = \frac{157 \times 420}{0.85 \times 120 \times 24} = 26.94\ mm$

$c = \frac{a}{\mathcal{B}_1} = \frac{26.94}{0.85} = 31.69\ mm$

$$\varepsilon_s = 0.003 \left(\frac{d-c}{c}\right) = 0.003 \left(\frac{316-31.69}{31.69}\right) = 0.0269 > 0.005 \qquad 0k$$

- ✓ Shear Design for (RS01):

V_u at distance d from support= 16.6 KN

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

$V_c = \frac{1.1}{6}\ \lambda \sqrt{f_c'} b_w d = \frac{1.1}{6}\sqrt{24}\ \times 120 \times 316 \times 10^{-3} = 34.05 KN$

ø V_c =0.75×34.05 =25.55 KN.

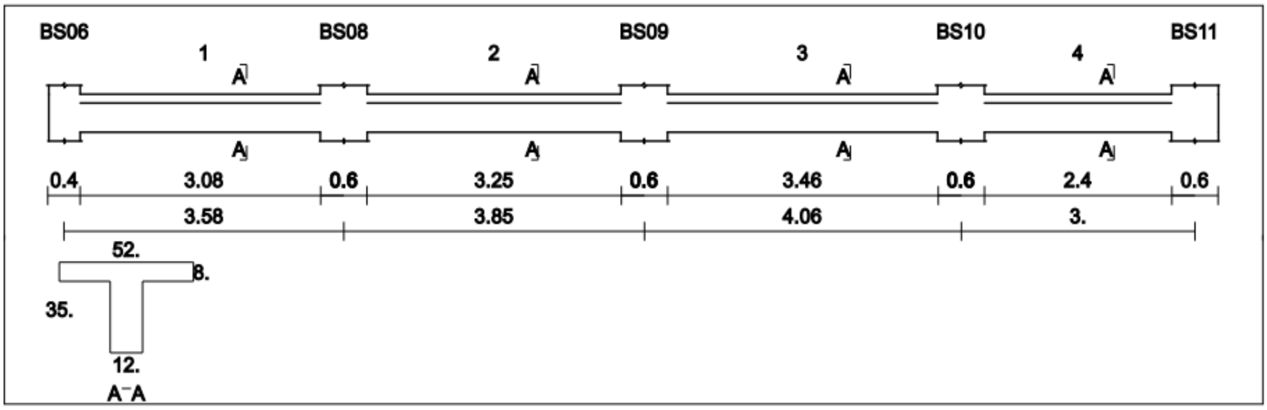
0.5 ø V_c =0.5×25.55 =12.78 KN

0.5 ø V_c< V_u< ø V_c ……………. NO

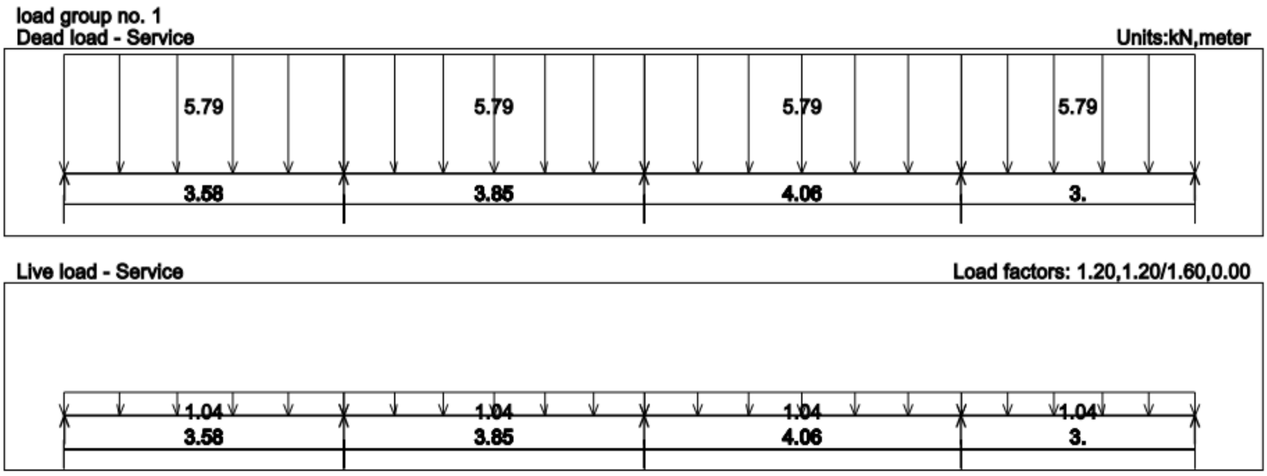
Minimum shear reinforcement is required except for concrete joist construction. So, No shear reinforcement is provided

2- Rib (RS02)

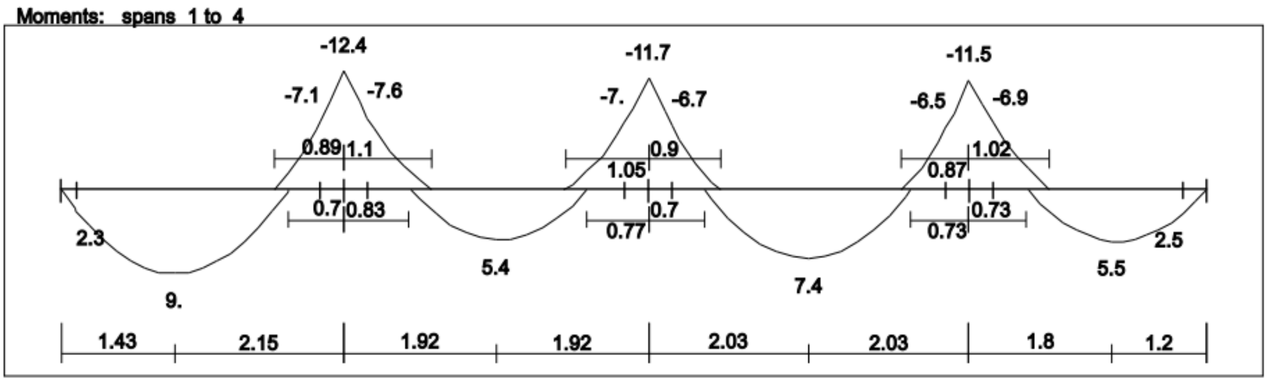
Geometry Units:meter,cm

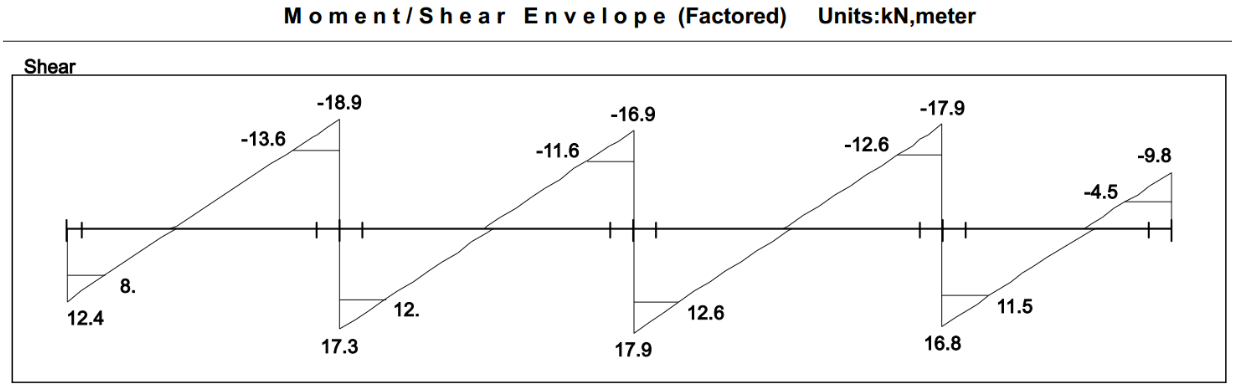


Loading



Moment/Shear Envelope (Factored) Units:kN,meter





Reactions

Factored					
DeadR	9.72	28.73	27.27	27.53	7.43
LiveR	2.7	7.46	7.45	7.13	2.33
Max R	12.42	36.19	34.72	34.66	9.76
Min R	9.35	31.7	29.97	30.05	6.88
Service					
DeadR	8.1	23.94	22.72	22.94	6.19
LiveR	1.69	4.66	4.65	4.45	1.46
Max R	9.79	28.6	27.38	27.4	7.65
Min R	7.87	25.79	24.41	24.52	5.84

Figure 5. 4 Shear & Moment Envelope Diagram (RS02)

- Design of positive moment:

M_u = 9 KN.m.

Assume bar diameter ø 12 for main positive reinforcement.

d =h- cover - $d_{stirrups} - \frac{d_b}{2} = 350 - 20 - 8 - \frac{12}{2} = 316\ mm.$

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

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

$= 0.85 \times 24 \times 520 \times 80 \times \left(316\ - \frac{80}{2}\right) \times 10^{-6} = 234.22 KN.m$

$M_{nf} \gg \frac{M_u}{\varphi} = \frac{9}{0.9} =$ 10 KN.m

the section will be designed as rectangular section with b_e =520 mm.

$R_n = \frac{M_u}{\emptyset b d^2} = \frac{9\times10^6}{0.9\times520\times316^2} = 0.193 Mpa.$

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

$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2\times20.6\times0.193}{420}}\right) = 0.000462$

$A_{s,req}$ = ρ.b.d = 0.000462×520×316= 75.92mm^2

- Check for $A_{s,min}$.

$A_{s,min}$ is the maximum of :-

$A_{s,min} = 0.25 \frac{\sqrt{f'_c}}{f_y} b_w.d \geq \frac{1.4}{f_y} b_w.d$

3. $A_{s,min} = 0.25 \frac{\sqrt{24}}{420}\ 120 \times 316 = 110.6 mm^2$
4. $A_{s,min} = \frac{1.4}{420} 120 \times 316 = 126.4 mm^2\ \ Control$

$A_s = 75.92\ mm^2 \leq A_{s,min} = 126.4 mm^2$

Use 2ø10 , $A_{s,provided} = 157\ mm^2 > A_{s,required} = 126.4\ mm^2$.   Ok

Check for strain:

$a = \frac{A_s.f_y}{0.85b\ f_c'} = \frac{157 \times 420}{0.85 \times 520 \times 24} = 6.22\ mm$

$c = \frac{a}{\mathcal{B}_1} = \frac{6.22}{0.85} = 7.32\ mm$

$$\varepsilon_s = 0.003\left(\frac{d-c}{c}\right) = 0.003\left(\frac{316-7.32}{7.32}\right) = 0.127 > 0.005 \quad 0k$$

- Design of negative moment:

$M_u = -7.6$ KN.m.

Assume bar diameter ø 12 for main positive reinforcement.

$d = h - cover - d_{stirrups} - \frac{d_b}{2} = 350 - 20 - 8 - \frac{12}{2} = 316 mm.$

$R_n = \frac{M_u}{\emptyset b d^2} = \frac{7.6 \times 10^6}{0.9 \times 120 \times 316^2} = 0.705\ Mpa.$

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

$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 0.705}{420}}\right) = 0.00171$

$A_{s,req} = \rho.b.d = 0.00171 \times 120 \times 316 = 64.84\ mm^2$

- Check for $A_{s,min}$.

$A_{s,min}$ is the maximum of :-

$A_{s,min} = 0.25 \frac{\sqrt{f'_c}}{f_y} b_w.d \geq \frac{1.4}{f_y} b_w.d$

3. $A_{s,min} = 0.25 \frac{\sqrt{24}}{420}\ 120 \times 316 = 110.6\ mm^2$
4. $A_{s,min} = \frac{1.4}{420} 120 \times 316 = 126.4\ mm^2\ Control$

$A_s = 64.84\ mm^2 \leq A_{s,min} = 126.4 mm^2$

Use 2ø10 , $A_{s,provided} = 157\ mm^2 > A_{s,required} = 126.4\ mm^2$.   Ok

Check for strain:

$a = \frac{A_{s}.f_y}{0.85b\ f_c'} = \frac{157\times420}{0.85\times120\times24} = 26.94\ mm$

$c = \frac{a}{\mathcal{B}_1} = \frac{26.94}{0.85} = 31.69\ mm$

$$\varepsilon_s = 0.003\left(\frac{d-c}{c}\right) = 0.003\left(\frac{316-31.69}{31.69}\right) = 0.0269 > 0.005 \qquad 0k$$

- ✓ Shear Design for (RS02):

V_u at distance d from support= 13.6 KN

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

$V_c = \frac{1.1}{6}\ \lambda\sqrt{f_c'}b_w d = \frac{1.1}{6}\sqrt{24}\ \times 120 \times 316 \times 10^{-3} = 34.05KN$

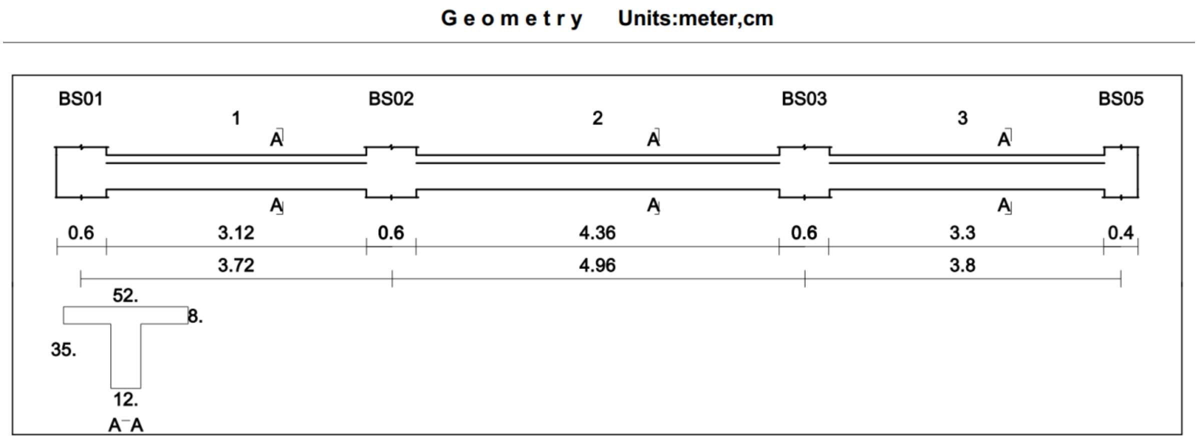
ø V_c =0.75×34.05 =25.55 KN.

0.5 ø V_c =0.5×25.55 =12.78 KN

0.5 ø V_c< V_u< ø V_c ……………. NO

Minimum shear reinforcement is required except for concrete joist construction. So, No shear reinforcement is provided

Rib (RS03)



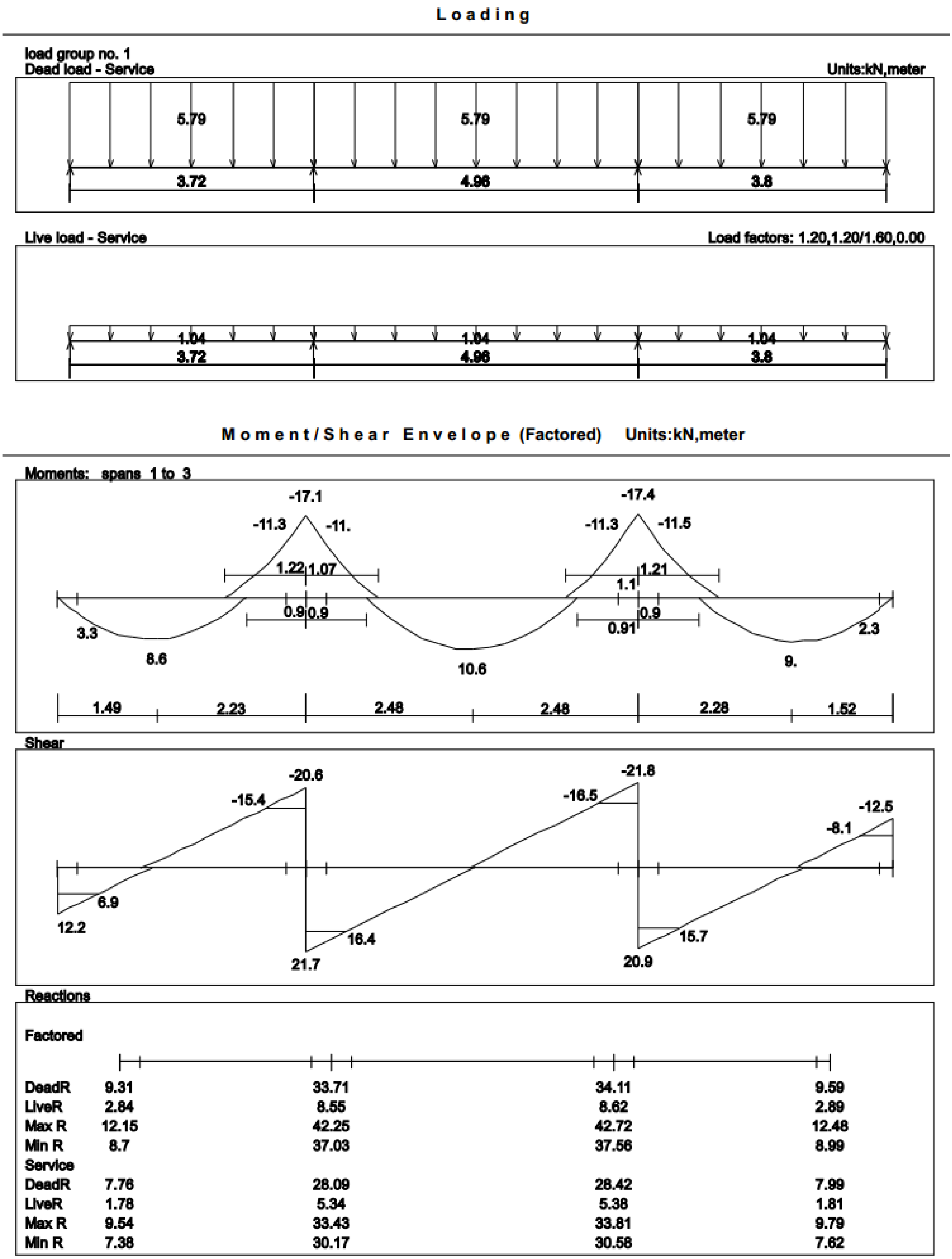


Figure 5. 5 Shear & Moment Envelope Diagram (RS03)

- Design of positive moment:

M_u = 10.6 KN.m.

Assume bar diameter ø 12 for main positive reinforcement.

d =h- cover - $d_{stirrups} - \frac{d_b}{2} = 350 - 20 - 8 - \frac{12}{2} = 316\ mm.$

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

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

$= 0.85 \times 24 \times 520 \times 80 \times \left(316\ - \frac{80}{2}\right) \times 10^{-6} = 234.22 KN.m$

$M_{nf} \gg \frac{M_u}{\varphi} = \frac{10.6}{0.9} =$ 11.78 KN.m

the section will be designed as rectangular section with b_e =520 mm.

$R_n = \frac{M_u}{\emptyset b d^2} = \frac{10.6 \times 10^6}{0.9 \times 520 \times 316^2} = 0.227 Mpa.$

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

$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 0.227}{420}}\right) = 0.000544$

$A_{s,req}$ = ρ.b.d = 0.000544×520×316= 89.39mm^2

- Check for $A_{s,min}$.

$A_{s,min}$ is the maximum of :-

$A_{s,min} = 0.25 \frac{\sqrt{f'_c}}{f_y} b_w.d \geq \frac{1.4}{f_y} b_w.d$

5. $A_{s,min} = 0.25 \frac{\sqrt{24}}{420}\ 120 \times 316 = 110.6 mm^2$

6. $A_{s,min} = \frac{1.4}{420} 120 \times 316 = 126.4 mm^2\ \ Control$

A_s = 89.39 mm^2 ≤$A_{s,min}$ = $126.4 mm^2$

Use 2ø10 , $A_{s,provided}$= 157 mm^2>$A_{s,required}$= 126.4 mm^2. Ok

Check for strain:

$a = \frac{A_s.f_y}{0.85 b\ f_c'} = \frac{157 \times 420}{0.85 \times 520 \times 24} = 6.22\ mm$

$c = \frac{a}{\mathcal{B}_1} = \frac{6.22}{0.85} = 7.32\ mm$

$$\varepsilon_s = 0.003\left(\frac{d - c}{c}\right) = 0.003\left(\frac{316 - 7.32}{7.32}\right) = 0.127 > 0.005 \quad 0k$$

- Design of negative moment:

M_u = -11.5 KN.m.

Assume bar diameter ø 12 for main positive reinforcement.

d =h- cover - $d_{stirrups} - \frac{d_b}{2} = 350 - 20 - 8 - \frac{12}{2} = 316mm.$

$R_n = \frac{M_u}{\emptyset b d^2} = \frac{11.5\times10^6}{0.9\times120\times316^2} = 1.066\ Mpa.$

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

$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1 - \sqrt{1 - \frac{2\times20.6\times1.066}{420}}\right) = 0.00261$

$A_{s,req} = \rho.b.d = 0.00261 \times 120 \times 316 = 98.97\ mm^2$

- Check for $A_{s,min}$.

$A_{s,min}$ is the maximum of :-

$A_{s,min} = 0.25 \frac{\sqrt{f'_c}}{f_y} b_w.d \geq \frac{1.4}{f_y} b_w.d$

5. $A_{s,min} = 0.25 \frac{\sqrt{24}}{420}\ 120 \times 316 = 110.6\ mm^2$
6. $A_{s,min} = \frac{1.4}{420} 120 \times 316 = 126.4\ mm^2\ Control$

$A_s = 98.97\ mm^2 \leq A_{s,min} = 126.4 mm^2$

Use 2ø10 , $A_{s,provided} = 157\ mm^2 > A_{s,required} = 126.4\ mm^2$.   Ok

Check for strain:

$a = \frac{A_s.f_y}{0.85 b\ f_c'} = \frac{157\times420}{0.85\times120\times24} = 26.94\ mm$

$c = \frac{a}{\mathcal{B}_1} = \frac{26.94}{0.85} = 31.69\ mm$

$$\varepsilon_s = 0.003\left(\frac{d-c}{c}\right) = 0.003\left(\frac{316 - 31.69}{31.69}\right) = 0.0269 > 0.005 \qquad 0k$$

✓ Shear Design for (RS03):

V_u at distance d from support= 16.5 KN

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

$V_c = \frac{1.1}{6}\ \lambda \sqrt{f_c'} b_w d = \frac{1.1}{6}\sqrt{24}\ \times 120 \times 316 \times 10^{-3} = 34.05KN$

ø V_c =0.75×34.05 =25.55 KN.

0.5 ø V_c =0.5×25.55 =12.78 KN

0.5 ø V_c < V_u < ø V_c ……………. NO

Minimum shear reinforcement is required except for concrete joist construction. So, No shear reinforcement is provided

5.6 Design of Beam(BS10) :

- ✓ Load calculations:

Load calculations for BS10:

Dead Load Calculations for Beam(BS10):-

Table (5. 4)Dead Load Calculations for Beam(BS10)

Dead load from:	h×γ×1	KN/m
Tiles	0.03×23×1	0.69
Mortar	0.03×22×1	0.66
Coarse sand	0.07×17×1	1.19
Reinforced concrete	0.35×25×1	8.75
Plaster	00.2×22×1	0.44
	∑	11.7 KN/m

The distributed Dead and Live loads acting upon BS10 can be defined from the support reactions of the RS01, RS02

From RS01 & RS02

The maximum support reaction (Service) from Dead Loads for RS01 upon BS10 is 22.86 KN . The distributed Dead Load from the RS01 on BS10:

DL =22.86/ 0.52= 43.96 KN/m

The maximum support reaction (Service) from Dead Loads for RS02 upon BS10 is 22.94 KN . The distributed Dead Load from the RS02 on BS10:

DL =22.94/ 0.52= 44.12 KN/m

Live Load calculations: The maximum support reaction (Service) from Live Loads for RS01 upon BS10 is 4.43 KN .

The distributed Live Load from the RS01 on BS10:

LL =4.43/ 0.52= 8.52 KN/m

Live Load calculations: The maximum support reaction (Service) from Live Loads for RS02 upon BS10 is 4.45 KN .

The distributed Live Load from the RS02 on BS10:

LL =4.45/ 0.52= 8.56 KN/m

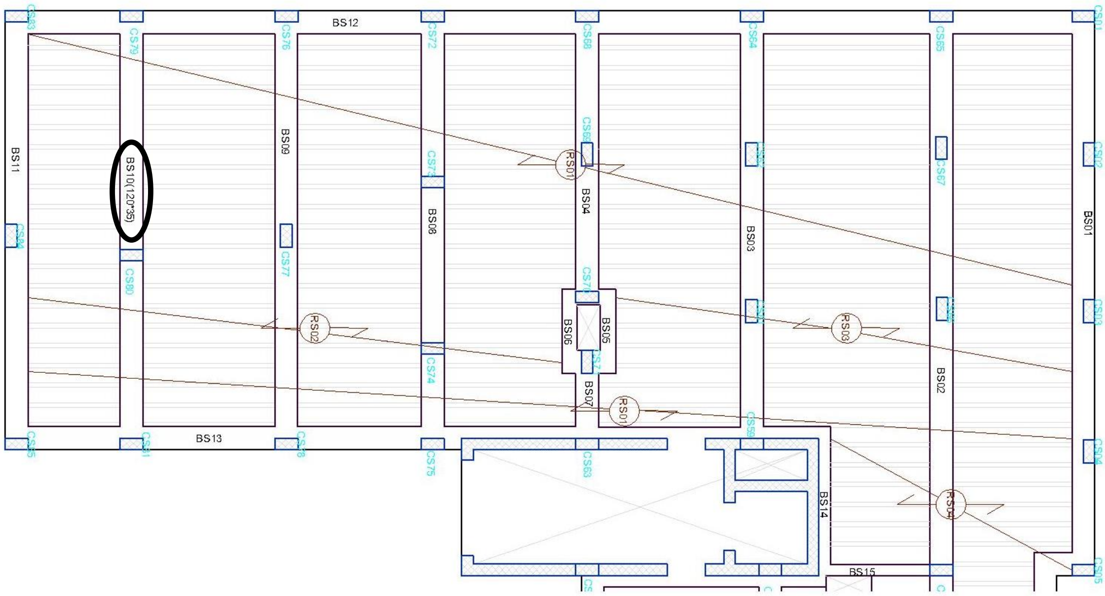
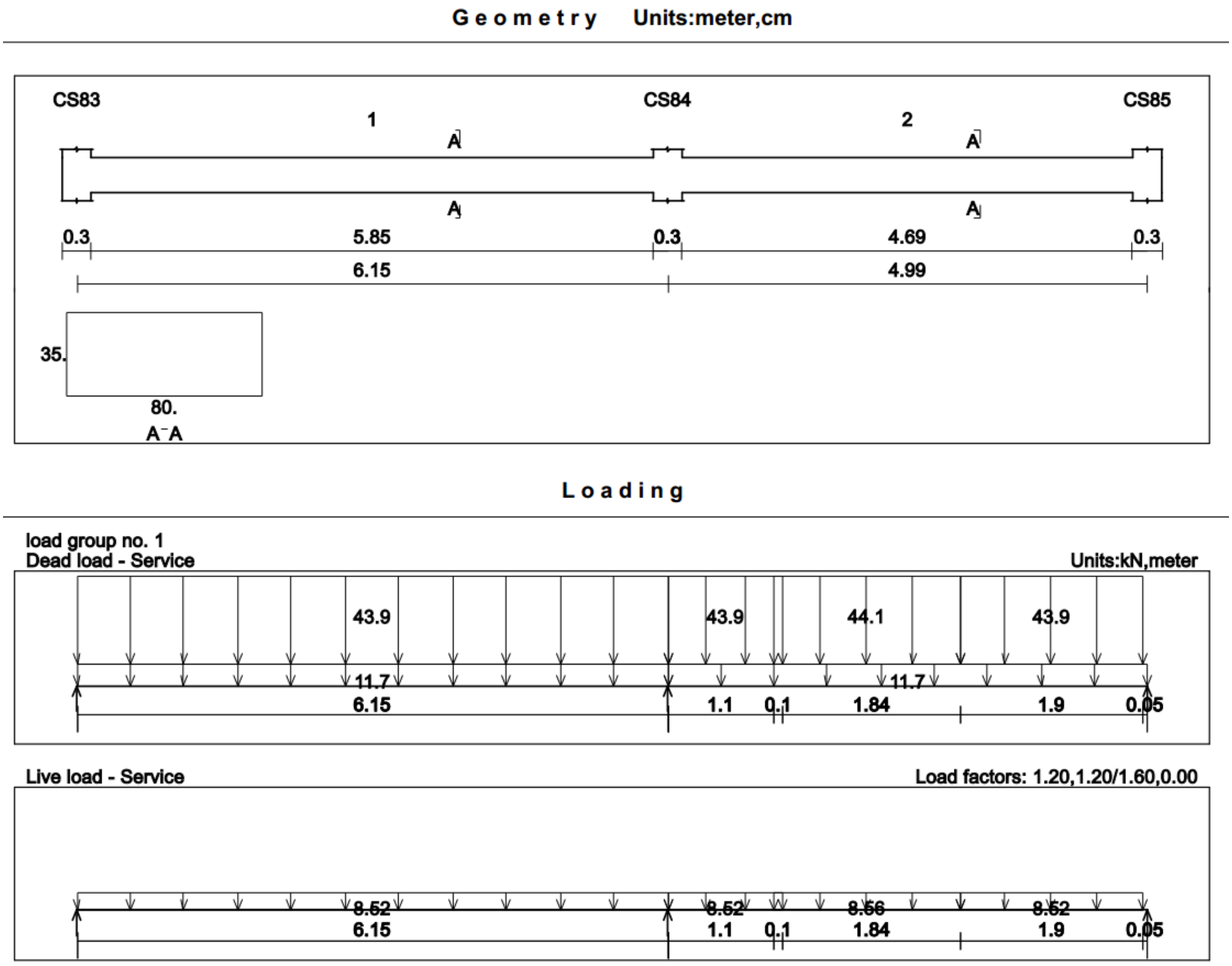


Figure 5. 6 BS10



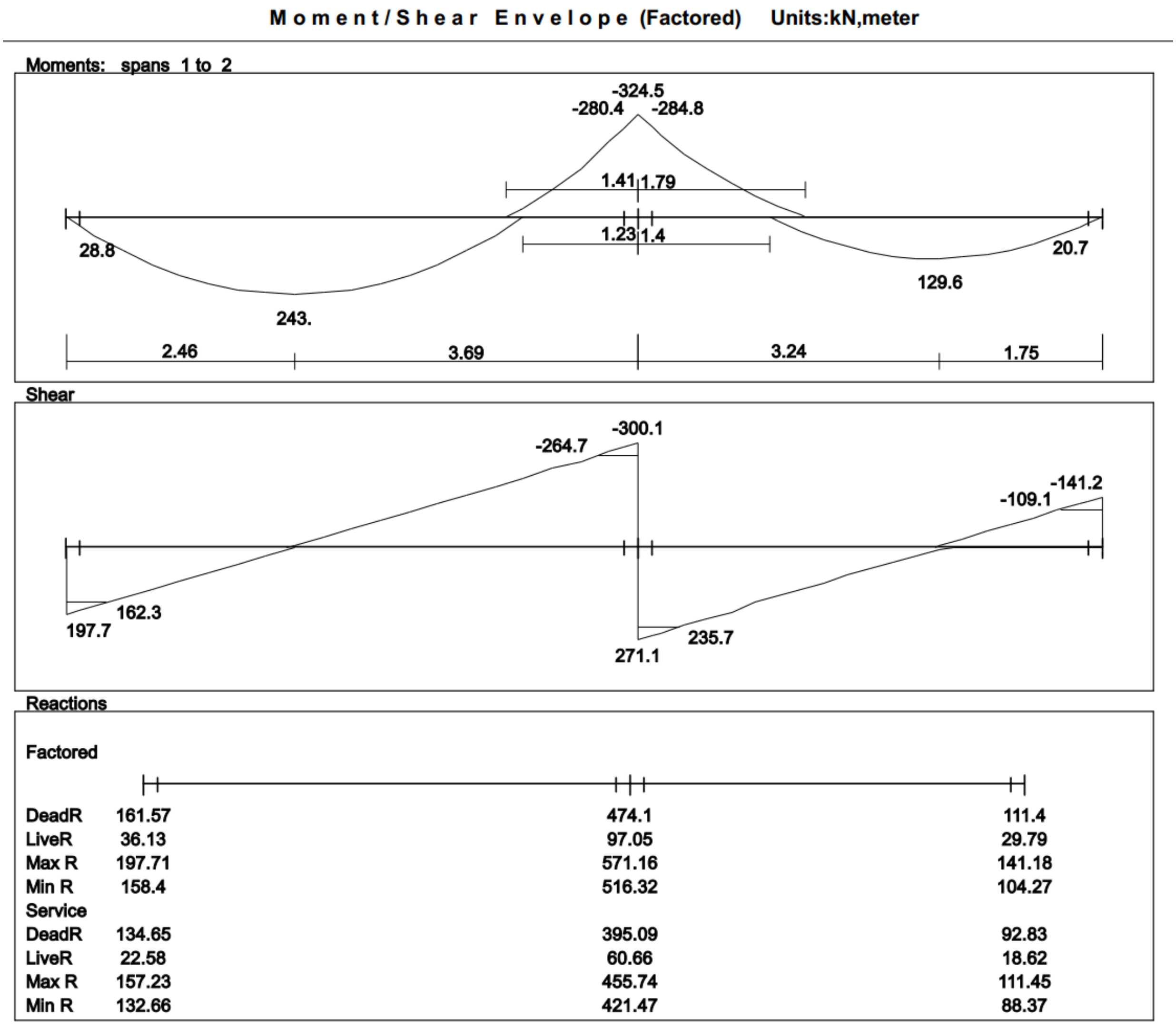


Figure 5. 7Loading and Moment /Shear Envelope.

- ✓ Flexural Design for (BS10) :

Determine of $M_{n,max}$:

$$d = 350 - 40 - 8 - \frac{18}{2} = 293\ mm$$

$$c = \frac{3}{7}d = \frac{3}{7} \times 293 = 125.75\ \ mm$$

$$a = \mathcal{B}.c = 125.75\ \times 0.85 = 106.736mm$$

Mn_{max} = $0.85f'_c ab(\ d - \frac{a}{2}\ )$ = 0.85×24×106.736×1000×(293-106.736/2) ×10^{-6}= 521.778

KN.m

$\emptyset$ Mn_{max} = 0.82× 313.07 = 427.858 KN.m> -284.8

Design as singly reinforcement

Design for positive moment :

1) $\boldsymbol{Mu = 243}$

$$Rn = \frac{M_u}{\emptyset b d^2} = \frac{243 \times 10^6}{0.9 \times 1200 \times 293^2} = 2.62\ Mpa.$$

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

ρ= $\frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times2.62}{420}}\right) = 0.00670$

A_s = ρ.b.d = 0.00670×1200×293 =2355.72mm^2

Check for $A_{s,min}$.

$A_{s,min}$ =$0.25\frac{\sqrt{f'_c}}{f_y} b_w.d \geq \frac{1.4}{f_y} b_w.d$

$A_{s,min}$ =$0.25\frac{\sqrt{24}}{420}\ 1200\times293 = 1025.28\ mm^2$

$A_{s,min}$ =$\frac{1.4}{420}1200\times293 = 1172\ mm^2\ Control.$

$A_{s,min=}$1172mm^2< A_s =2355.72 mm^2

Use10ø 18 Bottom, $A_{s,provided}$= 2545mm^2>$A_{s,required}$= 2396.74 mm^2. Ok

Check spacing :

S_{max}= $380\left(\frac{280}{f_y}\right) - 2.5C_c = 203.33\ control$ OR $S = 300\left(\frac{280}{f_s}\right) = 200$

$S = \frac{1200-40\times2-10\times2-(18\times10)}{9} = 102.22mm > 25$ ... OK

< 203.33 ... OK

Check for strain:

a =$\frac{A_s.f_y}{0.85b\ f_c'} = \frac{2545\times420}{0.85\times1200\times24} = 43.66\ mm$

c= $\frac{a}{B_1} = \frac{43.66}{0.85} = 51.36\ mm$

$$\varepsilon_s = 0.003\left(\frac{d-c}{c}\right) = 0.003\left(\frac{293-51.36}{51.36}\right) = 0.0141 > 0.005 \qquad 0k$$

2) M_u = 129.6KN.m

R_n= $\frac{M_u}{\emptyset b d^2} = \frac{129.6\times10^6}{0.9\times1200\times293^2} = 1.398 Mpa.$

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

ρ= $\frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times1.677}{420}}\right) = 0.00345$

A_s = ρ.b.d = 0.00345 ×1200×293= 1212.02 mm^2.

Check for $A_{s,min}$.

$A_{s,min} = 0.25 \frac{\sqrt{f'_c}}{f_y} b_w.d \geq \frac{1.4}{f_y} b_w.d$

$A_{s,min} = 0.25 \frac{\sqrt{24}}{420}\ 1200 \times 293 = 1025.28\ mm^2$

$A_{s,min} = \frac{1.4}{420} 1200 \times 293 = 1172\ mm^2\ Control.$

$A_{s,min} = 1212.02\ mm^2 > A_s = 1172\ mm^2$

Use 5ø 18 Bottom, $A_{s,provided} = 1272.5\ mm^2 > A_{s,required} = 1212.02\ mm^2$. Ok

Check spacing :

$$S = \frac{1200-40\times2-2\times10-(5\times18)}{4} = 252.5\ mm > 25$$

$$> S_{max}$$

Use 5ø 18 Bottom, $A_{s,provided} = 1781.5\ mm^2 > A_{s,required} = 1212.02\ mm^2$. Ok

$$S = \frac{1200-40\times2-2\times10-(7\times18)}{6} = 162.3\ mm > 25 \ldots ok$$

Check for strain:

$$a = \frac{A_s.f_y}{0.85b\ f'_c} = \frac{1272.5\times420}{0.85\times1000\times24} = 26.2\ mm$$

$$c = \frac{a}{\beta_1} = \frac{26.2}{0.85} = 30.82\ mm$$

$$\varepsilon_s = 0.003\left(\frac{d-c}{c}\right) = 0.003\left(\frac{293-30.82}{30.82}\right) = 0.0255 > 0.005 \qquad 0k$$

<u>Design for Negative moment :</u>

M_u = -284.8KN.m

$$R_n = \frac{M_u}{\emptyset bd^2} = \frac{284.8\times10^6}{0.9\times1200\times293^2} = 3.083 Mpa.$$

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

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.6}\left(1-\sqrt{1-\frac{2\times20.6\times3.083}{420}}\right) = 0.008$$

$A_s = \rho.b.d = 0.008\times1200\times293 = 2812.\ 8\ mm^2$.

Check for $A_{s,min}$.

$A_{s,min} = 0.25 \frac{\sqrt{f'_c}}{f_y} b_w.d \geq \frac{1.4}{f_y} b_w.d$

$A_{s,min} = 0.25 \frac{\sqrt{24}}{420}\ 1200 \times 293 = 1025.28\ mm^2$

$A_{s,min} = \frac{1.4}{420} 1200 \times 293 = 1172\ mm^2\ Control.$

$A_{s,min} = 1172\ mm^2 < A_s = 2812.8\ mm^2$

Use 12 ø 18Top , $A_{s,provided}$= 3054 mm^2>$A_{s,required}$= 2812. 8mm^2. Ok

Check spacing :

$S = \frac{1000-40*2-2*10-(18\times12)}{11} = 62.18\,mm > 25\ \ldots.\quad OK$

Check for strain:

$a = \frac{A_{s}.f_y}{0.85b\,f_c'} = \frac{2859.68\times420}{0.85\times1200\times24} = 49.06mm$

$c = \frac{a}{\mathcal{B}_1} = \frac{49.06}{0.85} = 57.72mm$

$$\varepsilon_s = 0.003\left(\frac{d-c}{c}\right) = 0.003\left(\frac{293-57.72}{57.72}\right) = 0.0122 > 0.005 \qquad 0k$$

- ✓ Shear Design for (BS10):

1. Vu = 264.7, 235.7 KN

$V_c = \frac{1}{6}\sqrt{fc'}b_w\,d == \frac{1}{6}\sqrt{24}*1200*293*10^{-3} = 257.08$KN

Φ V_c= 0.75*257.08 =215.31 KN

$V_{s,min} = \frac{1}{3}b_w\,d == \frac{1}{3}\,1200*\ 293*10^{-3} = 117.19\,KN$control

$V_{\ s,min} = \frac{1}{16}\sqrt{fc'}b_w\,d = \frac{1}{16}*\sqrt{24}*1200*293*10^{-3} = 74.75KN$

$V_{s'} = \frac{1}{3}\sqrt{fc'}b_w\,d = \frac{1}{3}\sqrt{24}*1200*293*10^{-3} = 574.15$

$$\emptyset V_c < V_u \le \emptyset(V_c + V_{s,\min})$$

215.31 < 264.7, 235.7 < 0.75(257.08+117.19)

252.66 < 264.7 < 280.7 …ok

shear reinforcement are required .

Use 4 leg Φ 8 .

Av =201.2 mm^2 .

$V_s = V_n - V_c = \frac{264.7}{0.75} - 257.08 = 95.85$ KN

$$S = \frac{A_v f_{yt}\,d}{v_s} = \frac{201.2*420*293}{75.05*1000} = 210.71\,mm$$

$$s_{max} \le \frac{d}{2} = \frac{293}{2} = 146.5\,mm \qquad (control) \qquad or\ s_{max} \le 600\,mm$$

Use 4 leg Φ 8 @150 mm .

2. V_u = 162.3 KN, 109.1

$V_c = \frac{1}{6}\sqrt{fc'}b_w\, d == \frac{1}{6}\sqrt{24} * 1200 * 293 * 10^{-3} = 257.08$KN

Φ V_c= 0.75*257.08 =215.31 KN

$\frac{1}{2}$ Φ V_c= 0.5×179.42 =107.655 KN

$V_{s,min} = \frac{1}{3} b_w\, d == \frac{1}{3}\, 1200 *\; 293 * 10^{-3} =\; 117.19\; KN$control

$V\;_{s,min} = \frac{1}{16}\sqrt{fc'}b_w\, d = \frac{1}{16} * \sqrt{24} * 1200 * 293 * 10^{-3} = 74.75KN$

$V_{s'} = \frac{1}{3}\sqrt{fc'}b_w\, d = \frac{1}{3}\sqrt{24} * 1200 * 293 * 10^{-3} = 574.15$

$$\frac{1}{2}\emptyset V_c < V_u \leq \emptyset V_c$$

$107.655 < \; 162.3,109.1 \leq 215.31$

Minimum shear reinforcement is required .

$$\frac{A_s}{s} = \frac{1}{3}\cdot\frac{b}{f_y} \to \frac{201.2}{s} = \frac{1}{3}\cdot\frac{1200}{420} \to s = 211.26\, mm$$

$$\frac{A_s}{s} = \frac{1}{16}\cdot\sqrt{\acute{f_c}}\frac{b}{f_y} \to \frac{100.6}{s} = \frac{1}{16}\cdot\sqrt{24}\cdot\frac{1200}{420} \to s = 229.99\, mm$$

$$s_{max} = \frac{d}{2} = \frac{293}{2} = 146.5mm \;\; CONTROL \qquad or\;\; 600$$

Use 4 leg Φ 8 @150 mm .

5.7 Design of Basement wall

4.6.1 Load Calculation:-

$\gamma = soildensity = \; 18KN/m^3.$

$\emptyset = angleofinternalfriction = 30°.$

LL=5 KN/m^2 .

Thickness = 30cm, cover = 4cm .

The design will be for 1m width .

Neglect the axial load, since its low value

$q1 = soilpressure = Ko * \gamma * h.$

$q2 = surchargepressure = \; Ko * LL.$

$Ko = soilpressurecoefficientatrest = \;\; 1 - \sin\emptyset.$

So ,

$Ko = 1 - \sin\emptyset = 0.5.$

$q1 = 0.5 * 19 * 2.70 = 25.65\frac{KN}{m^2}.$

$$q2 = 0.5 * 5 = \quad 2.5\frac{KN}{m^2}.$$

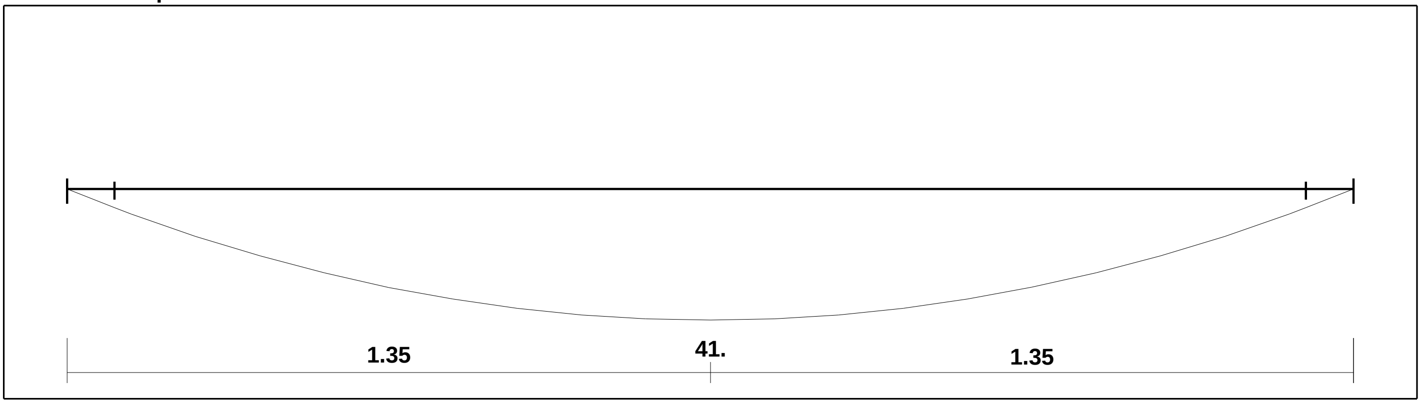
Factored Load :-

$$q1u = 25.65 * 1.6 = 41.04\ KN/m^2$$

$$q2u = 2.5 * 1.6 = 4\ KN/m^2$$

Moment/Shear Envelope (Factored) Units:kN,meter

Moments: spans 1 to 1



Shear

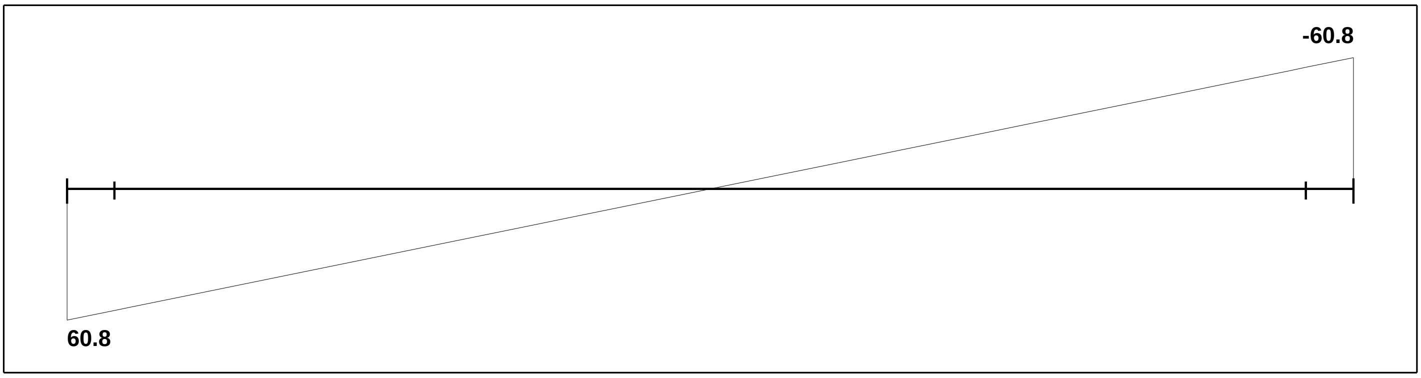


Figure 5. 8 Loading and Moment /Shear Envelope

Design of bending moment of wall :-

Design for positive moment Mu =41 KN.m .

$$d = 300 - 40 - \frac{16}{2} = 252\ mm.$$

$$Mn = \frac{Mu}{0.9} = \frac{41}{0.9} = 45.56\ KN.m$$

$$Rn = \frac{Mn * 10^6}{b * d^2} = \frac{45.56 * 10^6}{1000 * 252^2} = 0.717\ Mpa.$$

$$m = \frac{Fy}{0.85 * fc'} = \frac{420}{0.85 * 25} = 19.76$$

$$\rho = \frac{1}{m} * \left(1 - \sqrt{1 - \frac{2 * Rn * m}{Fy}}\right) = \frac{1}{19.76} * \left(1 - \sqrt{1 - \frac{2 * 1.25 * 19.76}{420}}\right)$$

$$= 1.74 * 10^{-3}$$

$Asreq \ = \rho * b * d = 1.74 \ * 10^{-3} * 1000 * 252 = 437.71 \, mm^2/m. \ldots .control.$

$Asminv = 0.0012 * b * h = 0.0012 * 1000 * 300 = 360 \, mm^2/m.$

$$Asminforflexture \ = 0.25 * \frac{\sqrt{fc'}}{fy} * bw * d = 0.25 * \frac{\sqrt{25}}{420} * 1000 * 252$$

$$= 750 \, mm^2/m.$$

$$Asminforflexture \ = \frac{1.4}{fy} * bw * d = \frac{1.4}{420} * 1000 * 252 = 840 mm^2/m \ldots .control.$$

For inside wall Select $\emptyset 12@25cm = 452.4 \, mm^2 > 437.71 mm^2$.

For outside wall Select $\emptyset 12@12.5cm = 904 mm^2 > 840 mm^2$.

4.12.3 Design of shear force :-

$d = 300 - 40 - 8 = 252mm$

$$\emptyset Vc = 0.75 * \frac{1}{6} * \sqrt{fc'} * b * d = 0.75 * \frac{1}{6} * \sqrt{25} * 1000 * 252 * 10^{-3} = 157.5 \, KN.$$

$(\emptyset Vc = 157.5) > (Vu = 60.8)$.

No shear Reinforcement is required and thickness of wall is adequate enough.

But horizontal Reinforcement due to Cracking:

$Asreqh = 0.002 * b * h = 0.002 * 1000 * 300 = 600 mm^2/m.$

For one side $As = 300 \, mm^2/m.$

Select for one side horizontal reinforcement $\emptyset 10@25cm = 314.16 \, mm^2 > 300 \, mm^2$

5.8 Design of Stair:

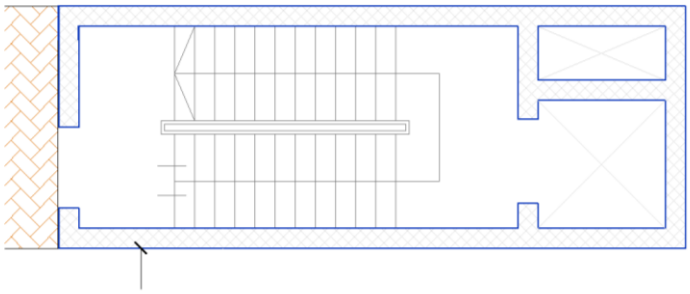


Figure 5.9: Stair Plan.

✓ Material :-

⇒ concrete B300 Fc' = 24 N/mm^2

⇒ Reinforcement Steel Fy = 420 N/mm^2

✓ Design of Flight :-

✓ Determination of Thickness:-

h_{min} = L/20

h_{min} = 5.8/20 =29 cm

Take h = 30cm

The Stair Slope by $\theta = \tan^{-1}(15/30) = 26.56^o$

✓ Load Calculation:-

Dead Load For Flight For 1m Strip:-

Table5-5:Dead Load Calculation of Flight.

No.	Parts of Flight	Calculation	
1	Tiles	27*0.03*1*(0.35+0.15/0.3) = 1.35 KN/m	
2	Mortar	22*0.02*1*(0.3+0.15/0.3) = 0.66 KN/m	
3	Stair	25*1*(0.3+0.15/2)/0.3 = 1.875 KN/m	
4	Slab	25*0.25*1 / COS 26.56 = 6.99 KN/m	
5	Plaster	22*0.03*1 / COS 26.56^o = 0.738 KN/m	
		Sum	13 KN/m

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

Factored Load For Flight :-

W_U = 1.2 ×13+ 1.6×4 =23.6KN/m

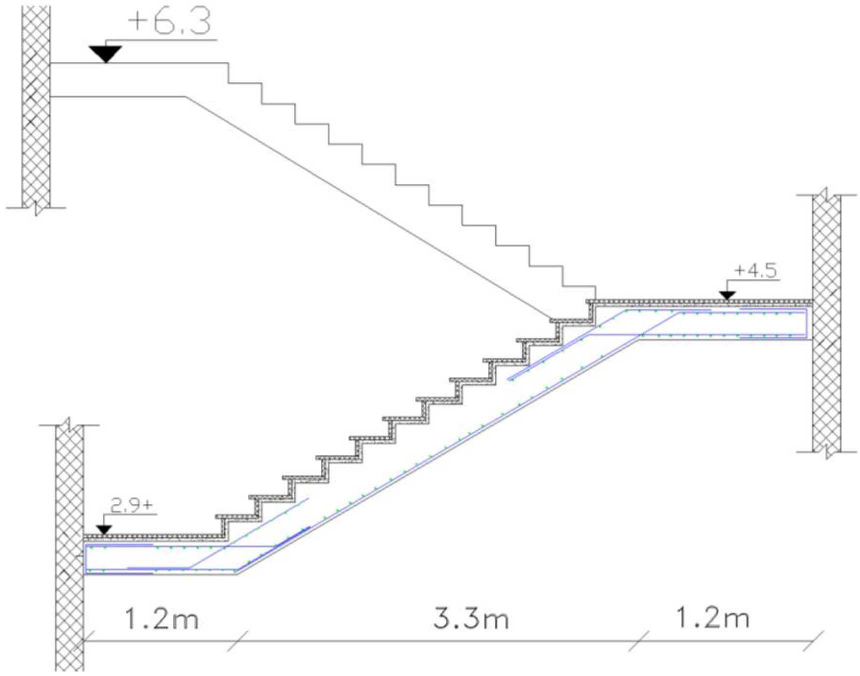


Fig 5.10: Stair Section.

R = (W*L)/2=23.6*3.31/2=42.3 KN

1- Design of Shear for Flight :- (Vu=27.45 KN)

Assume bar diameter ø 14 for main reinforcement

d =h- cover $-\frac{d_b}{2} = 300 - 20 - \frac{14}{2} = 273mm$

Vu = 42.3KN

$V_c = \frac{1}{6}\sqrt{fc'}b_w\, d = \frac{1}{6}\sqrt{24} * 1000 * 273 = 222.9\text{KN}/m$

$\Phi\ V_{c\,=}\ 0.75 * 222.9 = 167.2$KN /m

Vu = 42.3 <$\Phi\ V_{C\,=}$ 0167.2KN /m

<u>The thickness is enough .</u>

2- Design of Bending Moment for Flight :- (Mu=80.25KN.m)

$$\text{Mu}= \mathbf{80.25} * (\mathbf{1.5} + \mathbf{1.6}) - \frac{\mathbf{23.6*1.35^2}}{\mathbf{2}} = \mathbf{89.1}.\boldsymbol{m\ KN}$$

$R_n = \frac{M_u}{\emptyset b d^2} = \frac{89.1\times10^6}{0.9\times1000\times273^2} = 1.2\ \ Mpa$

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

$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.m.R_n}{420}}\right) = \frac{1}{20.59}\left(1 - \sqrt{1 - \frac{2\times20.59\times1.2}{420}}\right) = 0.00294$

$A_{s,req} = \rho.b.d = 0.00294 \times1000\times273 = 804.2\text{mm}^2$

$A_{s,min}$= 0.0018*1000*300 = 540 mm^2

As_{req}>$A_{s,min}$=540 mm^2

As_{req}=804.2 mm^2

Check for Spacing :-

1) S = 3h = 3*300 =900 mm
2) S = 380*(280/(2/3 * 420)) – 2.5*20 = 330 ≤ S = 300*(280/(2/3 * 420)) = 250mm
3) S = 450 mm

S = 250 mm ……… is control

Use ø14 @ 250 mm

3- Lateral or Secondary Reinforcement For Flight :-

$A_{s,req}$= $A_{s,min}$ =0.0018*1000*300= 540mm^2

Use ø14@ 300 mm ,$A_{s,provided}$= 461.7 mm^2>$A_{s,required}$= 450mm^2… Ok

- ✓ Design of Landing :
- ✓ Load Calculation:-

Dead Load For Landing For 1m Strip:-

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

Factored Load For Landing :-

W_U = 1.2 ×9.26+ 1.6×4=19.3KN/m

- ✓ System of Landing :-

$$R= \frac{19.3*1.7}{2} + 21.15 * 1.9 = 75.45\ KN$$

1- Design of Shear:- (Vu=75.45 KN)

Assume bar diameter ø 14 for main reinforcement

$$d = h\text{- cover} - \frac{d_b}{2} = 300 - 20 - \frac{14}{2} = 273mm$$

$$V_c = \frac{1}{6}\sqrt{fc'}b_w\ d == \frac{1}{6}\sqrt{24} * 1000 * 273 = 222.9KN$$

Φ* V_c = 0.75* 222.9= 1167.2 KN> Vu = 75.45 KN…... Thickness of slab is enough

2- Design of Bending Moment :- (Mu=70.6KN.m)

Assume bar diameter ø 14 for main reinforcement

$$d = h\text{- cover} - \frac{d_b}{2} = 250 - 20 - \frac{14}{2} = 273mm$$

$$R_n = \frac{M_u}{\emptyset bd^2} = \frac{70.6\times10^6}{0.9\times1000\times273^2} = 1.052\ Mpa$$

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

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2.m.R_n}{420}}\right) = \frac{1}{20.59}\left(1-\sqrt{1-\frac{2\times20.59\times0.382}{420}}\right) = 0.002575$$

$A_{s,req}$ = ρ.b.d = 0.002575×1000×273 = 703 mm^2

$A_{s,min}$ =0.0018*1000*273 = 540mm^2

$A_{s,req}$ = 703 mm^2……… is control

Check for Spacing:-

4) S = 3h = 3*300 =900mm

5) S = 380*(280/(2/3 * 420)) – 2.5*20 = 330 ≤ S = 300*(280/(2/3 * 420)) = 200mm

6) S = 450 mm

S = 200 mm ……… is control

Use ø14 @ 200 mm

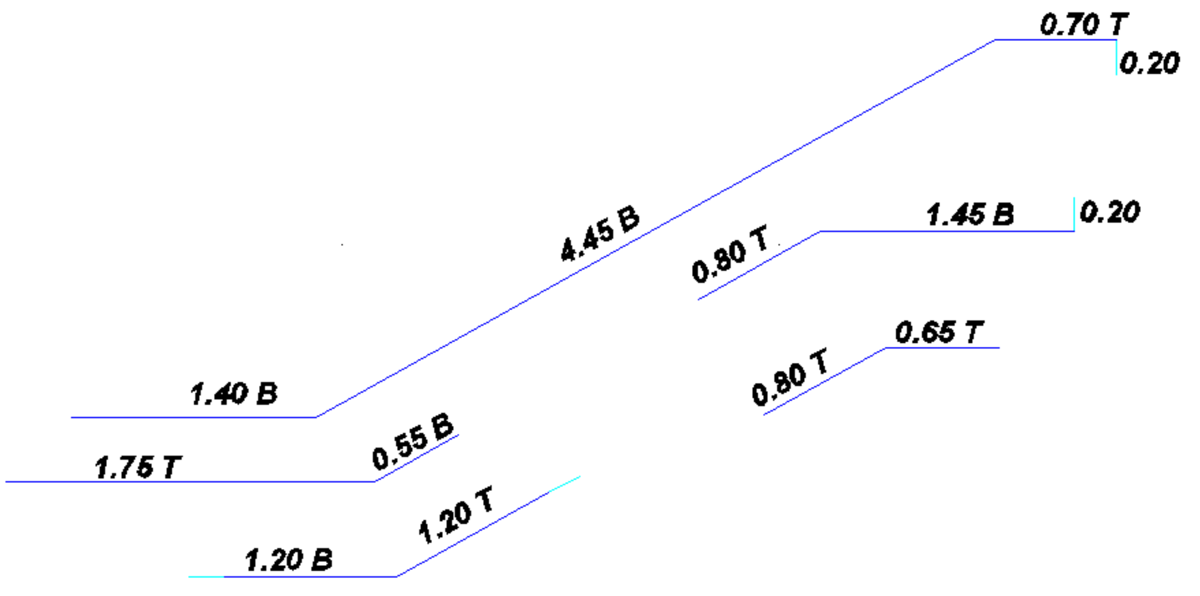


Fig 5.11: Stair Reinforcement.

5.9 Design of Column:

Column : C-9……. (within basement floor)

PD= 537.18KN

PL = 78.28KN

Use Fc' = 24 Mpa

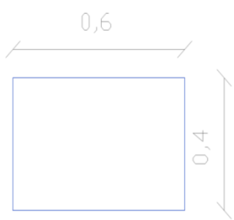


Fig 5.12:section of column -19

$$P_u = 1.2DL + 1.6LL = 1.2 \times 537.18 + 1.6 \times 78.28 = 769.864KN$$

$$P_n = \frac{P_u}{\phi} = \frac{769.864}{0.65} = 1184.4\ KN \Rightarrow \phi = 0.65 - for\ tied\ column$$

Assume rectangular section with:

$\rightarrow Use\ \rho\ =\ 2.5\ \%$

$P_n\ = 0.8 \times A_g\left(0.85 \times f_c' + \rho_g\left[f_y - 0.85 \times f_c'\right]\right)$

$\rightarrow Use\ 0.8\ for\ tied\ column$

$1184.4 * 10\text{^}3 = 0.8 \times A_g(0.85 \times 24 + 0.025[420 - 0.85 * 24])$

$A_g\ = 48716.68mm^2$

$\rightarrow Use 0.6 \times 0.4m^2 with A_g = 240000mm^2 > A_{g.required} = 48716.68mm^2$

$1)\ Check\ for\ Slenderness:$

$$\frac{K \times l_u}{r} \leq 34 - 12\left(\frac{M_1}{M_2}\right) \leq 40$$

$$\left(\frac{M_1}{M_2}\right) = 1 - for\ braced\ frame\ with\ M_{min}.$$

$l_u: Actual\ unsupported\ (unbraced)\ length.$

$r: radius\ of\ gyration\ of\ its\ crosssection =\ 0.3h$

$l_u\ = 2.6m$

$K = 1.0 - for\ columns\ in\ nonsway\ frame.$

$a)\ In\ 40cm\text{–}\ Dirction:$

$$\frac{K \times l_u}{r} \leq 34 - 12 \times 1.0 = 22 < 40$$

$$\frac{K \times l_u}{r_x} = \frac{1 \times 2.6}{0.3 \times 0.4} = 21.6 < 22$$

$\therefore short\ Column\ for\ bending\ about\ X - axis.$

$b)\ In\ 600cm\text{–}\ Dirction:$

$$\frac{K \times l_u}{r} \leq 34 - 12 \times 1.0 = 22 < 40$$

$$\frac{K \times l_u}{r_y} = \frac{1 \times 2.6}{0.3 \times 0.6} = 14.4 < 22$$

$\therefore short\ Column\ for\ bending\ about\ Y - axis.$

Selecting Longitudinal Bars:

$4000*1000 = 0.65 \text{x}\ 0.8 \times \text{Ag}\ \{0.85*24(537.18 - Ast) + Ast*420\}$

Ast=2735mm2

Use12ϕ25 ,Ast,prov=5890.4mm^2>Ast=2735mm^2

ρg =Ast/Ag= 0.00114

- ✓ **Design of the tie reinforcement :**

S ≤16 db (longitudinal bar diameter)

S≤ 48dt (tie bar diameter).

S ≤ Least dimension.

spacing ≤16×d_b=16×2.5=40cm ….

spacing ≤48×dt=48×1.0 = 48 cm

spacing ≤least.dim=40 cm control

Useϕ10@25 cm

5.10 Design of Isolated Footing (F11):

P_D = 690KN (service).

P_L = 220KN (service).

P_U =1180 KN (factored).

Column Dimensions = a*b=35*35 cm

Allowable bearing capacity q_{all}= 350 KN/m^2.

Area of Footing:

Soil Density = 18 KN/ m^3

assume h = 40 cm.

$q_{all\cdot net}$ = 350 - 5 - 0.4×25- 0.11×18 = 315.2 KN/m^2

$$\text{Area} \quad A = \frac{PD + PL}{qall\ln et} = \frac{832.96 + 55.73}{379.9} = 2.88$$

Use B,L(min) = 1.7m,take B =L= 1.8 m, A = 3.24m^2 for foundation.

Depth of footing:

Assume h = 40 cm.

Check one way shear:

$$= \frac{1180}{3.24} = 364.2 \text{ KN/ m}^2 . q_{ult} = \frac{P_u}{Area}$$

d =400 – 75 – 20 = 305 mm

$$= \frac{0.75}{6} * \sqrt{24} * 2.4 * 0.305 * 1000 = 336.19KN \quad \Phi V_c = \Phi \frac{1}{6}\sqrt{f_c'}\, b_w d$$

$$Vu = q_{ult} \times \left(\frac{B-a}{2} - d\right) \times L$$

$$Vud = 364.2 \times \left(\frac{1.8 - 0.35}{2} - 0.305\right) \times 1.8 = 275.34KN$$

øV_c =336.19 KN >V_{ud} = 275.34KN →→→→ *ok*

- Check two-way shear:

$$\frac{d}{2} = \frac{505}{2} = 252.5mm.$$

To calculate V_u at the critical section which take rectangular shape with dimension equal (0.35 +0.305) equals (0.655)

Inner area =0.655* 0.655=0.429m ^{2}

Outer area = area of the footing = 3.24 m^2

V_u = q_u (outer area – inner area) = 364.2 ×(5.76–0.8090) =1023.77 KN

According to ACI , Vc shall be the smallest of :

$= 0.5\sqrt{f_c'}\, b_o d \quad V_c = \frac{1}{6}\left(1+\frac{2}{\beta_c}\right)\sqrt{f_c'}\, b_o d$

$= 0.447\sqrt{f_c'}\, b_o d \quad V_c = \frac{1}{12}\left(\frac{\alpha_s}{b_o/d}+2\right)\sqrt{f_c'}\, b_o d$

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

Where:

= a / b = 35 /35 = 1 β_c

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

= 2×(0.655+0.655)= 3. 62 m

= 40 for interior column. α_s

$\phi V_c = 0.75\times 0.33\sqrt{24}\times 3.62\times 0.305\times 1000 = 1338.7KN$

$\varphi Vc = 1338.7\ KN > Vu = 1023.77\ KN$

SO h = 40 cm Is OK.

Design of flexural reinforcement both directions :

Mu = $\left(q_{ult}\times L\times\left(\frac{C\wedge 2}{2}\right)\right)$

$= (364.2\times 1.8\times 1\times 1)\div 2$ = 163.89KN.m

Mn = 163.89/0.9 = 182.1KN.m.

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

Rn = $\frac{252*10^6}{2400*(505)^2}$ =1.088Mpa

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

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

$\rho = \frac{1}{20.59}(1 - \sqrt{1 - \frac{2(20.6)(1.088)}{420}}) = .00266$

A req = ρ × b × d = .00266 × 1800 × 305=1462.29mm²….. control

$A_{s\ min}$ = 0.0018 × 1800 × 400 = 1296 mm^2

So , Use 8Φ 16 with As = 1608.5 mm²> As req = 1462.29mm²…for each direction x and y.

Chapter 6

6

Environmental Methodology

6.1 Methodology Flow Chart.

6.2 Concept of the project.

6.3 Selected site study.

6.3.1 The importance of the site.

6.3.2 The movement of sun and wind.

6.4 Reasons for choosing the green roof company .

6.5 Structural loads of green roof system

6.6 Green roof components

6.7 Green roofs Installation

6.7.1 Main steps of green roofs installation

6.7.2 Sections of green roofs

6.8 Drainage and Irrigation system

6.9 Planting

6.10 Financial cost of green roofs

6.1 Methodology Flow Chart

During this study the following Methodology will be followed of as shown in Figure 6.1 It starts with Concept of the project, which shows the overall objective of the project, followed by Site study in terms of heat, wind and rain , then choosing the green roof company and determine its advantages, after that, calculation of excess construction loads analyzing, Finally find the financial cost of green roofs and design it using sketch up program.

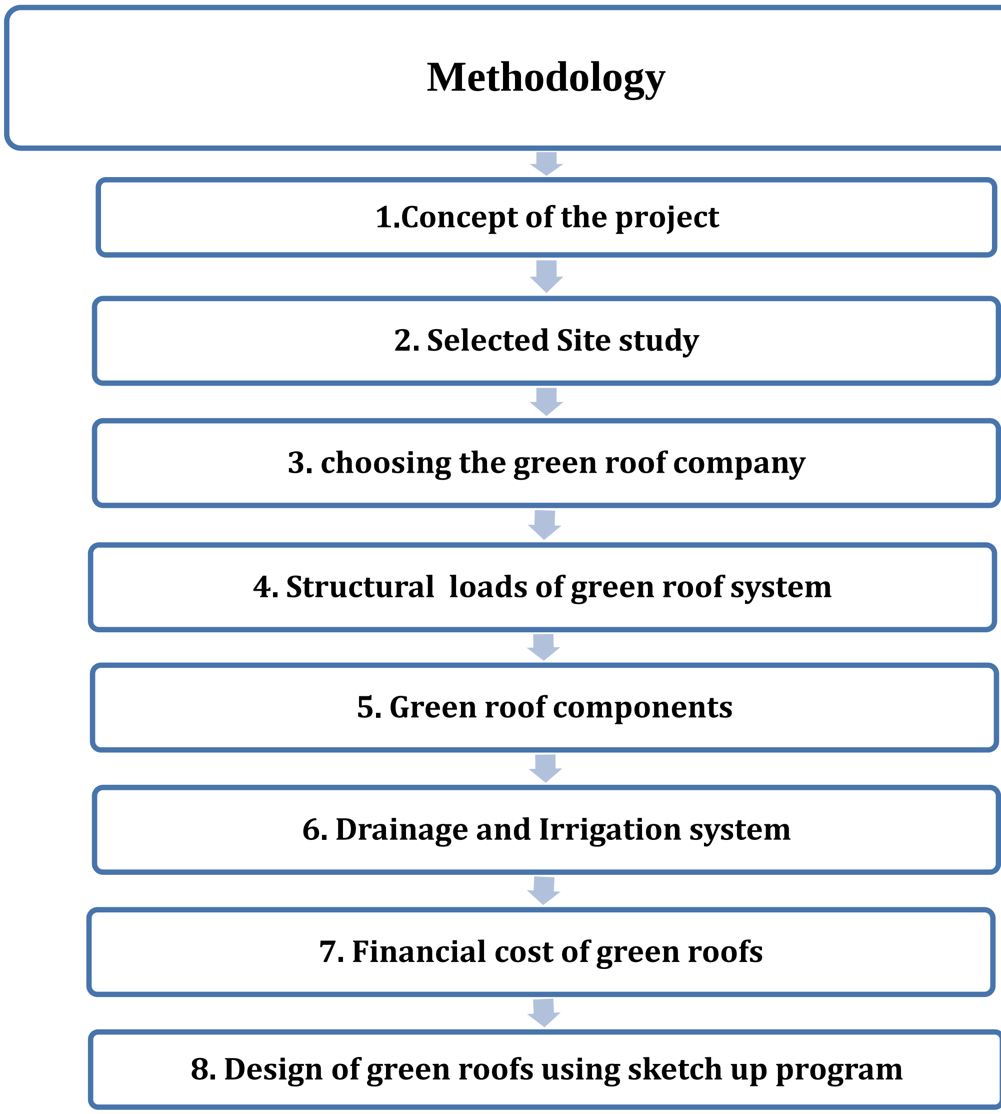


Figure 6.1 Methodology of environmental study .

6.2 Concept of the project

The objective of this project is to design a green roof system for a commercial-residential complex building to be an entertaining and environment place for the people who live in this building. Which have a total area of 9113 m^2, and consists of eight floors (two floor is basements) and have a background ,the background of the system is on slab roof (which is basement of garage) so we can apply the green roof system on the background too. As it shown in Figure 6.2 it is describe the area of the building Which will be used for green roof system

Figure 6.2 The desired area of the building for green roof system in brown colure

The design of the building dependent on an intensive green roof system with zero slope that make an equal distribution for the water on the floor, provided with drainage and irrigation system to prevent any leakage in the building.

6.3 Selected site study

6.3.1The importance of the site

The site of the building is located in the city of Hebron, specifically in the area of Ein Sara, which is known as the center of the city with high population area, located near the city's main street . In addition this area is considered to be poor in green spaces due to its urban location. The Figure 6.3 shown the site desired for the building

Figure 6.3.Site desired for the building

6.3.2 The movement of Sun ,Wind and Moisture

Hebron is exposed to the northeastern winds, which are very cold and dry winds. This is due to the low temperatures in the highlands. It is also exposed to the southwest winds, which are windy with rain and humidity. Because of its geographical location, the western wind blows on them and collides with warm currents. Those coming from the east meet with the winds coming from the west, reducing their moisture and making them more harmonious. They make the air moderate and dry, and the city blows dry wind like the five winds in the late spring.

The movement of the sun and wind are important factors in the analysis of the building and selecting plants on the surface. So that it can be divided into spaces suitable for climate and to meet the design requirements related to ventilation and natural lighting.

Sun: The movement and angles of the sun is one of the most important things to consider when directing and arranging buildings within the site, in order to avoid its direct radiation, especially in the summer, and here comes the role of solutions and environmental considerations that help us to avoid high temperatures. Table 6.1 Displays maximum temperature days each month for Ein Sara site. Also that Figure 6.4 for Ein Sara site displays how many days per month reach certain temperatures.

Table 6. 1. maximum temperature days each month[34].

	Temp >40Cº (day)	**Temp >35Cº (day)**	**Temp >30Cº (day)**	**Temp >25Cº (day)**	**Temp >20Cº (day)**	**Temp >15Cº (day)**	**Temp >10Cº (day)**	**Temp >5Cº (day)**	**Frost day**
Jan	0	0	0	1.2	6.2	13.6	9.2	0.8	0.9
Feb	0	0	0.4	2.4	7.7	10.1	6.6	1	0.1
Mar	0	0.5	2.4	5.5	10.3	8.8	3.3	0.1	0.1
Apr	0.3	3	6.2	9.1	8.5	2.7	0.4	0	0
May	0.7	5.6	11.2	9.8	3.5	0.2	0	0	0
Jun	0.7	6.7	16.9	5.4	.3	0	0	0	0
Jul	0.4	13	16.3	1.3	0	0	0	0	0
Oug	0.5	13.5	16.2	1.1	0	0	0	0	0
Sep	0.1	5.1	20.4	4.4	0	0	0	0	0
Oct	0.1	2.5	10.2	14.7	3.1	0.5	0	0	0
Nov	0	0	2.7	10.4	12.3	3.9	.7	0	0
Dec	0	0	0.3	2.8	9.8	13.1	4.6	0.4	0.3

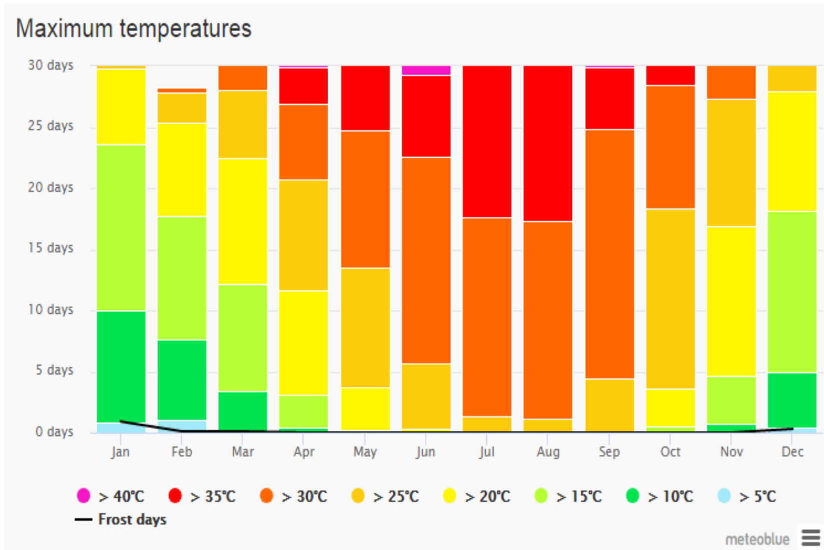


Figure 6.4 Maximum temperature days[34]

Wind: In the region the wind speed is about 3.27 km / h throughout the year. The direction of the wind changes during the day from the southern winds in the early hours of the morning to the winds of northwesterly evening, and the southern wind that starts from the shores of the Dead Sea.

:Pentaxian winds loaded with dust**.**

: Western winds and North West

: Cooled Eastern winds .

Figure 6. 5 Movement of wind in the selected location.

The Table.6.2 shows how many days within one month can be expected to reach certain wind speeds for Ein Sara. Strong winds from December to April, but calm winds from June to October.

Table 6.2: wind speed table for each month[34].

	Wind speed >5km/h (day)	Wind speed >12km/h (day)	Wind speed >19km/h (day)	Wind speed >28km/h (day)	Wind speed >38km/h (day)	Wind speed >50km/h (day)
Jan	12.3	11.4	5.3	1.6	0.4	0
Feb	8.2	11	5.4	3	0.5	0.2
Mar	4.3	14.5	9.2	2.5	0.5	0
Apr	2.3	12.7	12.7	2	0.2	0
May	0.6	8	20.5	2	0	0
Jun	0.1	2.8	23.9	3.3	0	0
Jul	0	3.3	24.9	2.8	0	0
Oug	0	3.6	26.6	0.8	0	0
Sep	0.5	8.4	20.2	0.9	0	0
Oct	3.3	16.9	10.5	0.4	0	0
Nov	11.2	13.3	4.4	1.1	0.1	0
Dec	15	10	4.4	1.3	0.3	0

Moisture: The climate of Hebron is affected by the climate of Palestine, which is known as dry and hot in summer, moderate and rain in winter. Despite the smallness of Hebron, its climate varies according to the terrain and the water bodies adjacent to and away from the desert. As for precipitation, rainfall rates vary depending on the geography of the area, as rainfall in Hebron ranges between (400-600 mm) annually.

The Figure.6.6 and Table 6.3 of the graph shows the monthly number of sunny, partly cloudy, overcast and precipitation days. Days with less than 20% cloud cover are considered as sunny, with 20-80% cloud cover as partly cloudy and with more than 80% as overcast.

Table 6.3: Number of sunny, partly cloudy, over cast and precipitation days[34].

	Sunny (day)	Partly cloudy (day)	Over cast (day)	Precipitation (days)	Precipitation (mm)
Jan	9.9	11.4	9.7	7.4	33
Feb	9	11.7	7.6	6.3	29
Mar	12	14.1	4.9	5	20
Apr	14.5	12.9	2.6	2.4	5
May	19.5	10.3	1.3	1.8	5
Jun	25.6	4.4	0	.5	1
Jul	24.6	6.4	0	.8	1
Oug	22	9	.1	.4	0
Sep	22.5	7.5	.1	.4	0
Oct	17.5	12.5	1	2	6
Nov	15.2	10.9	3.9	3.7	14
Dec	10.5	12.1	8.3	5	28

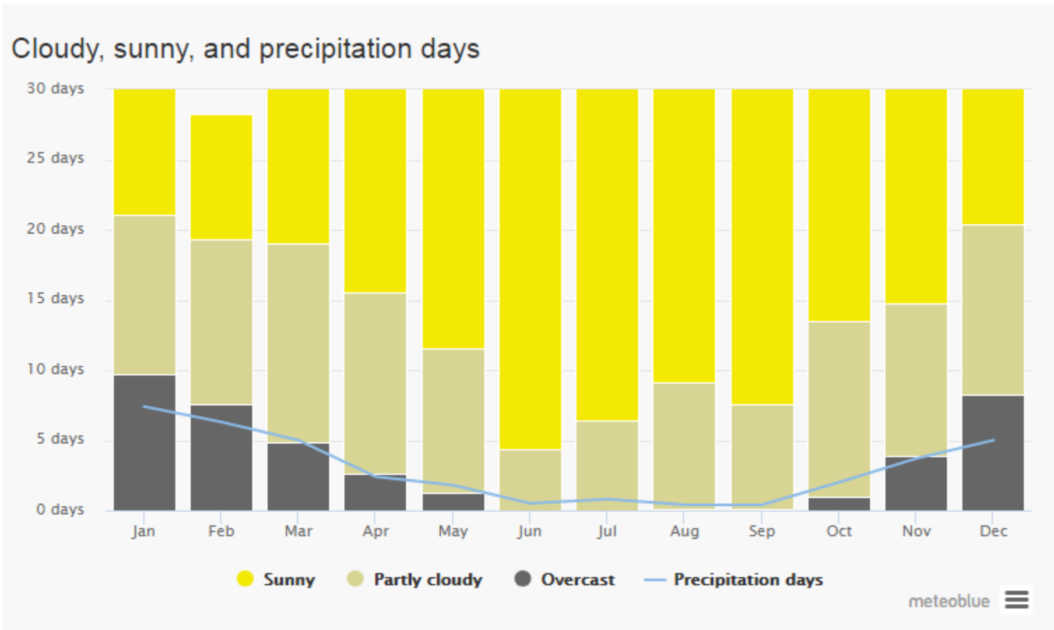


Figure 6.6 cloudy,sunny, and precipitation days[34].

6.4Reasons for choosing the green roof company

Germany is one of the most countries interested in green roofs, We have searched for several companies in Germany ,We have had difficulty communicating with companies and understanding their principals because of German language, until we found Zinco company ,Its website is written in English

ZinCo – one of the leading manufacturers – are pioneers and innovators in terms of extensive and intensive roof greening .We quickly contacted them and found a branch for company in the occupied Palestinian territories

This company had several advantages like:

1. its green roof system based on renewable raw materials, unique worldwide.
2. the aim of manufacturing the functional layers required for green roofing on a fully environmental basis
3. Looking towards that the protection mat, filter mat and drainage element will in future be based on bioplastics

Standards have been applied

The green roof layers have been chosen which contain characteristics that conform to the international specifications and are the most prominent international specifications that have been applied. First in properties of the Filter Sheet layer that the Effective opening width value It was taken according to (ASTM D-4751) Standard Test Methods for Determining Apparent Opening Size This test method shows the values in both SI units and inch-pound units. SI units is the technically correct name for the system of metric units known as the International System of Units.[35]

Secondly in the Properties of the Protection Material layer in Protection efficiency Have been adopted according to ISO 13428 describes an index test for the determination of the protection efficiency of a geosynthetic on a hard surface, exposed to the impact load of a hemispherical object The index test measures the change in thickness of a thin lead plate lying between the geosynthetic and a rigid support. As for the Static puncture it is according to ISO 12236 specifies a method for the determination of the puncture resistance by measuring the force required to push a flat-ended plunger through geosynthetics .[36]

Thirdly in the properties of the Root Barrier layer in Breaking strength and Tensile strength its standard according to (ASTM D751, Grab method) These test methods provide for this testing ensure the quality of Coated fabrics and rubber products made from coated fabrics.[35]

So it can be observed to international standard :

ASTM: International known as the American Society for Testing and Materials is a globally recognized leader in the development and delivery of international voluntary consensus standards. 12,000 ASTM standards are used around the world to improve product quality, enhance safety, facilitate market access and trade, and build consumer confidence.

International Organization for Standardization ISO: The International Organization for Standardization is an international standard-setting body composed of representatives from various national standards organizations.

6.5Structural loads of green roof system

The loading of the green roof must be established before the survey is carried out to ensure capacity. Once the building's general loading capacity is known and any strong or weak loading points identified, the green roof can be designed to suit, or the capacity of the building can be adapted. Deeper substrate depths can be placed where loading capacity is higher i.e. above supporting columns. in Figure 6.6 its show cross section area for the green roof components of background garden and in Table6.4 show the structural loads of green roof for the background garden. While in Figure 6.7its show the cross section area of the green roof components for the roof and in Table.6.4 it is shown the structural loads of green roof for the roof garden.

1. **For background garden.**

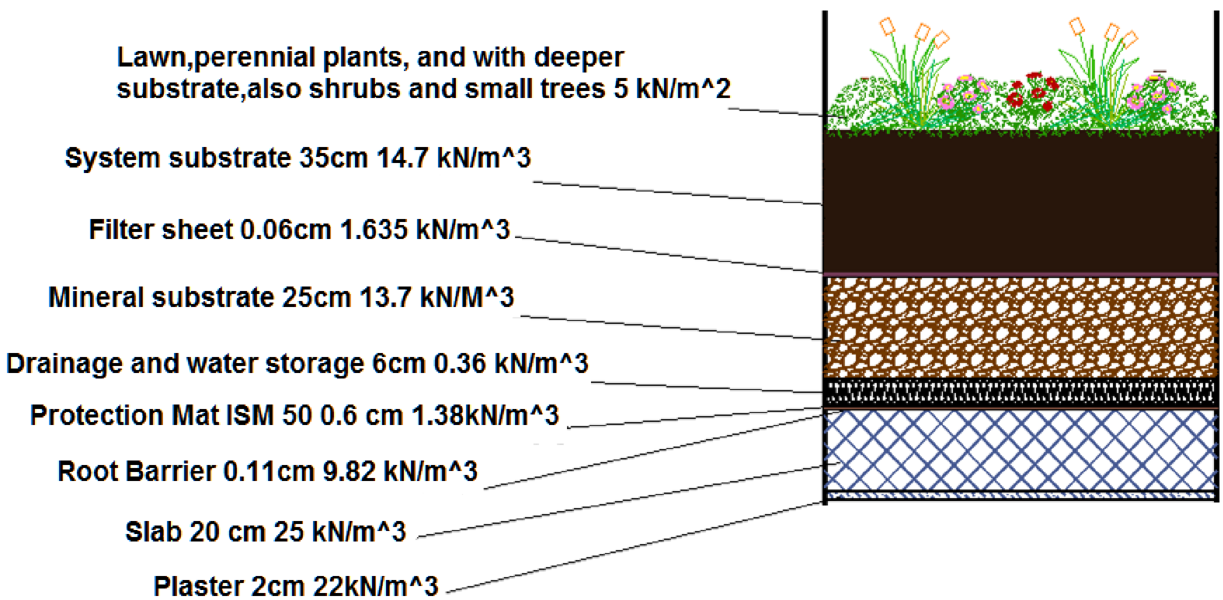


Figure.6.7.The cross section area for the green roof components of background garden of the building.

Table6.4 structural loads of green roof for the background garden

Layer name	Thickness (cm)	Density (Kn/m^3)
Planets	-	5
System substrate	35	14.7
Filter sheet	0.06	1.635
Mineral substrate	25	13.7
Drainage layer	6	0.36
Protection material	0.6	1.38
Root barrier	0.11	9.82
Slab	20	25
plaster	2	22

2. For roof garden.

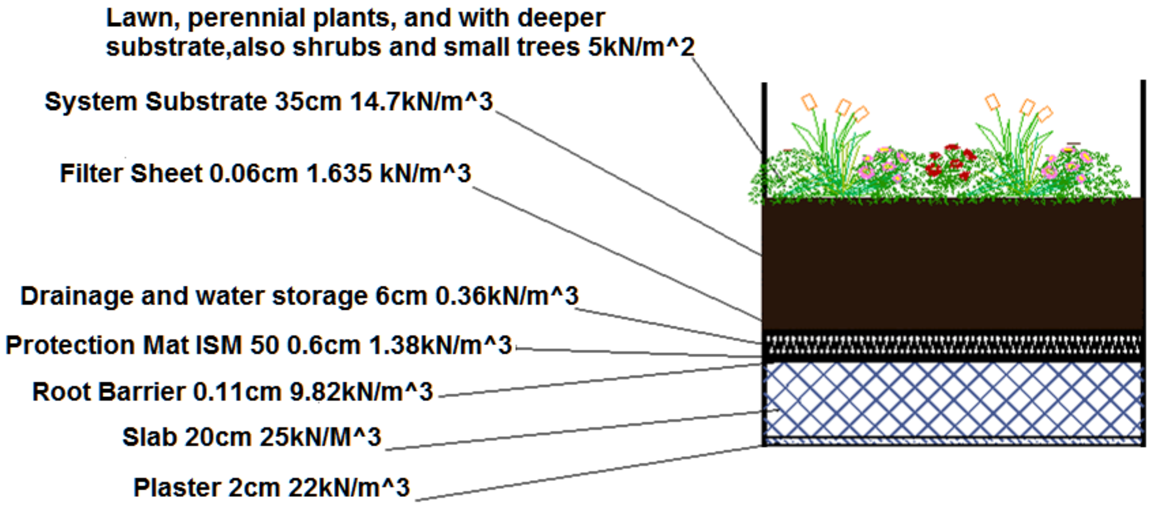


Figure.6.8 cross section area of the green roof components for the roof of the building.

Table.6.5 structural loads of green roof for the roof garden.

Layer name	Thickness (cm)	Density (Kn/m^3)
Planets	-	5
System substrate	35	14.7
Filter sheet	0.06	1.635
Drainage layer	6	0.36
Protection material	0.6	1.38

Root barrier	0.11	9.82
Slab	20	25
plaster	2	22

6.6Green roof components

1. System Substrate

System Substrate "Roof Garden". Order No. 616101

High-quality recycled Substrate consisting of (crushed brick with selected mineral aggregates) and other components, such as sandy sample of the Substrate layer sample of the Substrate layer sample of the Substrate layer sample of the Substrate layer sample of the Substrate layer sample of the Substrate layer sample of the Substrate layer sample of the Substrate layer soil, enriched with substrate compost enriched with fiber materials. Particularly suitable for intensive green roofs with demanding perennials. Deeper thicknesses can support shrubs, bushes and trees. The vegetation can be established by planting plug plants. Its most prominent features are also excellent water retention, high air content – even at max, frost resistant and stable in structure and neutral ph. Table 6.6Displaysthe Chemical and Physical Properties of the Substrate layer. And all these components control by the University of Hohenheim (Germany).Intensive roof gardens require irrigation during dry periods. For optimal plant development the use of an appropriate slow release fertilizer is recommended in . Figure 6.9 shows the sample of the Substrate layer[37] .

Figure6.9.A sample of the Substrate layer[37].

Table 6.6.Chemical and Physical Properties of the Substrate layer[37].

Parameter	Value
Volume weight - dry - at max. water capacity	1000 g/l (+/- 100 g/l) 1500 g/l (+/- 100 g/l)
Maximum water capacity	50 Vol. %
Water permeability	0.3–30 mm/min
pH value	6.5–8.0
Salinity	< 2.0 g/l
Organic content	< 90 g/l
Compaction factor	1.3

2.Filter layer

Filter Sheet SF .Order No. 2101

Geotextile of thermally strengthened polypropylene, applicable for normal mechanical stress. Made of non-rotatable materials, resistant to all naturally occurring acids and alkalis. Its advantages are high water-passing ability, fast and easy installation, and are suitable for many applications. Table 6.7. appears Properties of the Filter Sheet layer[5]. In Figure 6.10 its show the sample of the Filter Sheet

Figure6.10. A sample of the Filter Sheet layer[38] .

Table 6.7.Properties of the Filter Sheet layer [38].

Parameter	Value	Standard
Color	Grey	
Thickness	0.6 mm	
Weight	100 g/m²	
Static puncture	1100 N	
Maximum tensile strength	7.0 kN/m	
Flow rate Q under 4 inch (100 mm) water column:	70 l/(m²·s)	
Effective opening width, O95%	0.15 mm	(according to ASTM D-4751)
Dimensions:	2.00 m x 10.00 m	

3. Mineral Substrate

"Zincolit® Plus". Order No. 607102

High-quality recycled Substrate consisting of crushed brick, enriched with selected, non-flammable mineral aggregates; it is also frost resistant and stable in structure. Particularly suitable for sub-substrate for intensive green roofs with a total substrate depth of more than 350 mm or as infill of drainage layers. Fig 3.Displays a sample of the Mineral Substrate layer . in Figure 6.11 its show the sample of the Mineral substrate layer

Fig 6.11. A sample of the Mineral Substrate layer [39].

It is characterized by its high water permeability and high pore size. suitable for pumping and quality control of the University Hohenheim (Germany).For optimal plant development the use of an appropriate slow release fertilizer is recommended .Table 6.8 Displays Properties of the Mineral Substrate layer [39].

Table 6.8. Properties of the Mineral Substrate layer [6].

Parameter	Value
Volume weight - dry - at max. water capacity	 1020 g/l (+/- 100 g/l) 1300 g/l (+/- 100 g/l)
Maximum water capacity	28 vol. %
Water permeability mod.	60–400 mm/min
pH value (in CaCl2)	6.5–8.5
Salinity (water extract)	< 2.5 g/l
Compaction factor	1.1
Thickness	25cm

4. Drainage And water storage layer

Floradrain® FD 60 neo . Order No. 3062

High efficient recycled drainage and water storage element made of profiled plastic, suitable for intensive green roofs. Considered as Drainage and water storage element of thermoformed recycled polyolefin.it is Own a channel system for ventilation and drainage. applicable in combination with dam-up irrigation on 0° roofs. irrigated by diffusion and capillary action. In the end apply as permanent formwork e.g. under driveways and foundations. Fig 6.12 Displays a sample of the Drainage And water storage layer .and Table 6.9 Displays the Properties of the Drainage And water storage layer[40].

Figure 6.12. A sample of the Drainage And water storage layer [40].

Table 6.9. Properties of the Drainage And water storage layer[40].

Parameter	Value
Material	Polyolefin, mainly PE
Color	Black
Height	60 mm
Weight	2.2 kg/m²

Water retention capacity with infill	13 l/m²
Filling volume	27 l/m²
Compressive strength (at 10 % compression) *without filling*	40 kN/m²
In-plane Water Flow Rate - roof slope 1 %: -roof slope 2 %: -roof slope 3 %:	 1.1 l/(s·m) 1.6 l/(s·m) 2.0 l/(s·m)
Net dimensions:	1.00 m x 2.25 m
Amount per pallet	450 m² (net)

5.Protection Material

Protection Mat ISM 50 . Order No. 2050

Synthetic recycled fiber material , highly resistant to mechanical stress; for use as protection layer under intensive green roofs, walkways and driveways, etc. High-quality, extremely stable fiber material of polyester/polypropylene, bottom sided fiber impregnation using acrylic compounds. In Figure 6.13. Displays A sample of the Protection Material layer .

Figure 6.13. A sample of the Protection Material layer[41] .

It is also High quality for sound insulation, non-rotting synthetic fiber material as water and nutrient storage with proven protective effect according to European Standard EN ISO 13428, bottom sided fiber bonding using acrylic dispersions, thickness 6 mm, weight 850 g/m², penetration forces according to Standards EN ISO 12236 > 3500 N, delivery and installation according to manufacturer´s instructions as a Protection layer against mechanical impact on top of the water proofing. Table 6.10.Displaysthe Properties of the Protection Material layer[41].

Table 6.10. Properties of the Protection Material layer[41].

Parameter	Value	Standard
Color	grey mottled	
Thickness	6 mm	
Weight	850 g/m²	
Water retention capacity	4 l/m²	
Protection efficiency according to EN ISO 13428	Residual thickness ≥ 40 %	Protection efficiency according to EN ISO 13428
Static puncture	> 3500 N	ISO 12236
Strength class	5	
Improves footstep sound insulation (with concrete slabs in gravel bedding):	(delta L w,R=25 dB)	
Dimensions	2.00 m x 25.00 m	

6. Root Barrier

WSB 100-PO Order No. 1084

Recyclable polyolefin, applicable as root protection on extensive and especially on intensive green roofs ,hot air weld able layer , Resistant to bitumen, microorganisms, but not resistant to bamboo. .flexible at low temperatures and excellent weld able sheet, superb weather-profess, resistant for short time for oil, made of flexible polyolefin (FPO), with polyester weft-inserted reinforcement, root proof FLL tested according to the German FLL method of 2002.Figure.6.14.Displays A Sample of the Root Barrier layer .And Table 6.11. Display Properties of the Root Barrier layer[42] .

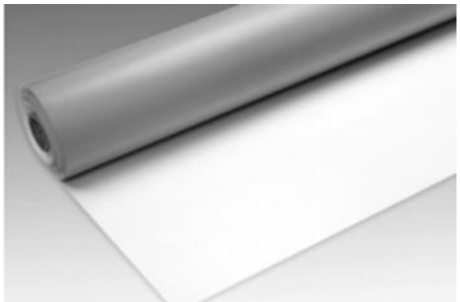


Figure 6.14. A Sample of the Root Barrier layer[42].

Table 6.11 Properties of the Root Barrier layer[42] .

Parameter	Value	Standard
Thickness	1.1 mm	
Weight	1.1 kg/m²	
Breaking strength	1.500 N	(ASTM D751, Grab method)
Tensile strength	> 20 %	(ASTM D751, Grab method)
Water vapor permeability of air layer thickness	sd = 280 m	
Dimensions	2.44 m x 30.50 m	
Accessories:	EDP No. 1192 (inside/outside corner): EDP No. 1195 (Unsupported flashing):	
roll size	0.60 m x 15.00 m	
weight per roll	9 kg	

6.7 Green roofs Installation

6.7.1Main steps of green roofs installation

1. At the beginning, the surface is prepared with Waterproofing coating , to avoid the possibility of water leakage and be humid. Secondly, Installing the Root Barrier layer above the water proofing dyeing, the layer are to be hot air welded root proof. The root barrier has to be taken above the Growing Media along edges and at roof penetrations. Cut the root barrier in situ at roof penetrations. Thirdly ,Install the Protection Material above root barrier. The protection material has to be taken above the Growing Media along edges and at roof penetrations. Cut the protection material in situ at roof penetrations. Consider the roof is completely covered. As in the Figure 6.15.

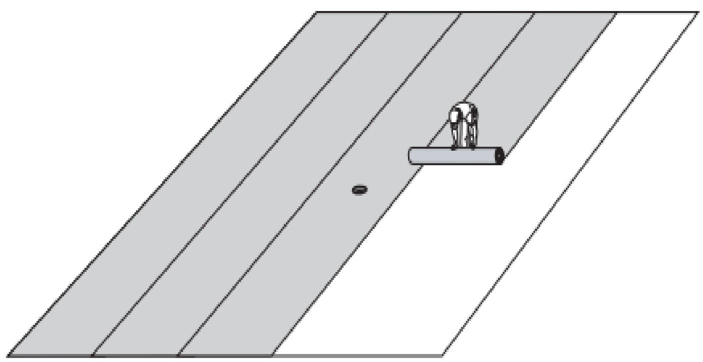


Figure 6.15: Installing water proofing, root barrier ,and protection material layers[43] .

2. Install drain access boxes: Position drain access boxes bringing its height to cultivated plants . As in the Figure 6.16.Adding sidewall elements as required, excess water flows through small holes and spills over the edges to be carried off the roof. A gap between the high-water level of the plates and the top of the drainage layer assures proper soil drainage at all times. All the drainage boxes are Connected together to form a network and eventually the water will be drained from the final channel. Since drainage layer are lightweight and easy to install, they have become the most popular drainage system for green roofs.

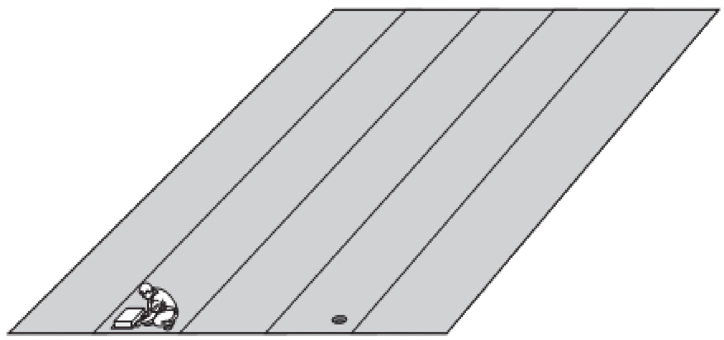


Figure 6.16: Installing drain access boxes, [43].

3. Lay drainage layer: Lay drainage layer (Fig 6.17) in a staggered pattern. layer of plastic plates can be easily cut with a circular saw, or half-sheets can be purchased to speed installation. The plates should tit tightly but are not overlapped. The thickness available to match drainage and water storage requirements is60 mm .

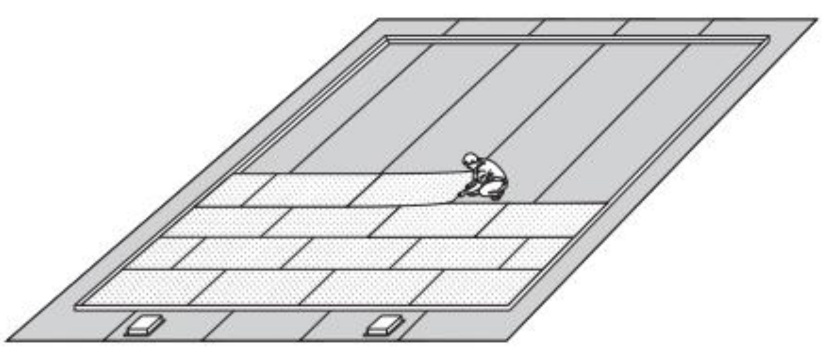


Figure 6.17:Installing drainage layer [43]

4. Spread gravel perimeter/mineral substrate : Spread well-washed gravel (Figure 6.18) screened to (95mm) minimum particle size. Whenever possible, the gravel should be dispensed from super sacks suspended from cranes to minimize the potential for damage .

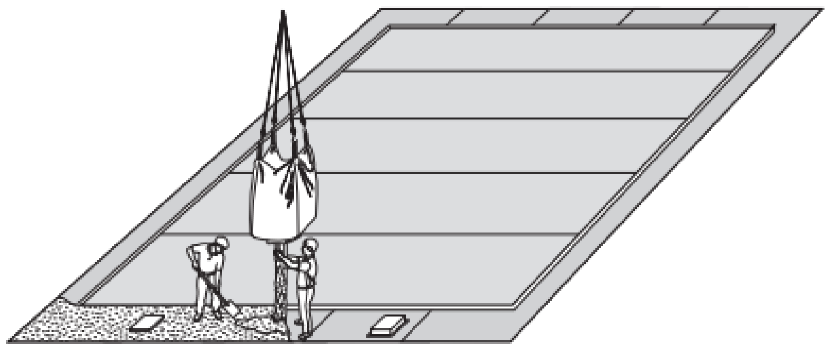


Figure 6.18: Spreading gravel perimeter [43]

5. Lay separation fabric/filter sheet : Separation fabric (Figure 6.19) is engineered to retain soil without clogging while allowing plant roots to easily penetrate to reach water in the drain plates. Unroll Separation Fabric over the drain plates, overlapping adjacent sheets at least six inches (152 mm) .

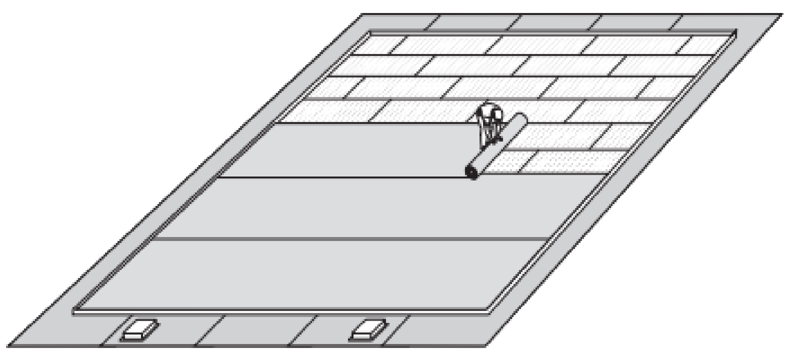


Figure 6.19: Laying separation fabric [43]

6. Spread soil: For intensive roofs, spread intensive green roof is soil as needed to obtain the required system thickness. Where possible, the media should be dispensed from super sacks suspended from cranes to minimize the potential for damage(Figure 6.20).

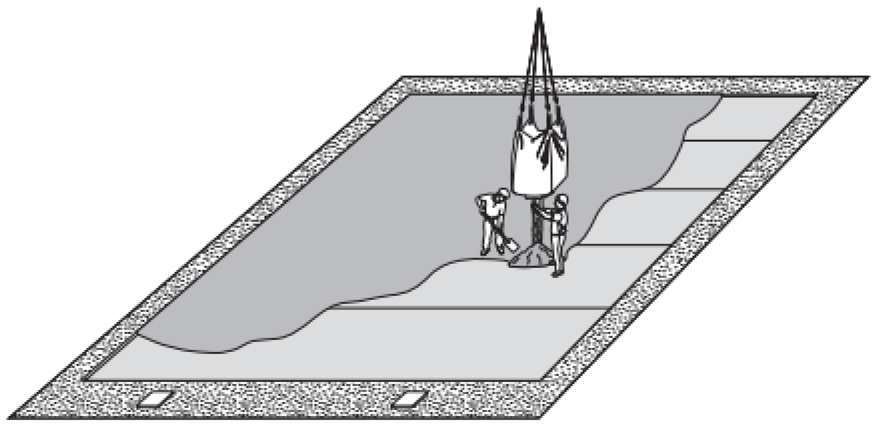


Figure 6.20: Spreading soil [43]

7. Plant: Insert green roof plants (Figure 6.21) in a random pattern. Irrigation should be during dry periods for the first two years during extended dry periods for the first two years[43].

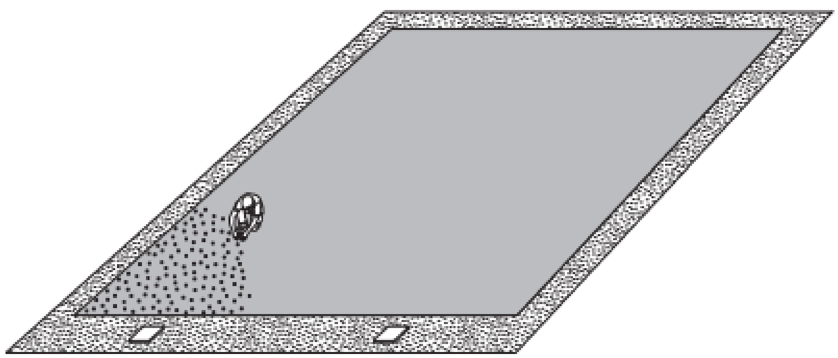


Figure 6.21: Planting [43]

6.7.2Sections of green roofs

1. System build up for Green Roof .

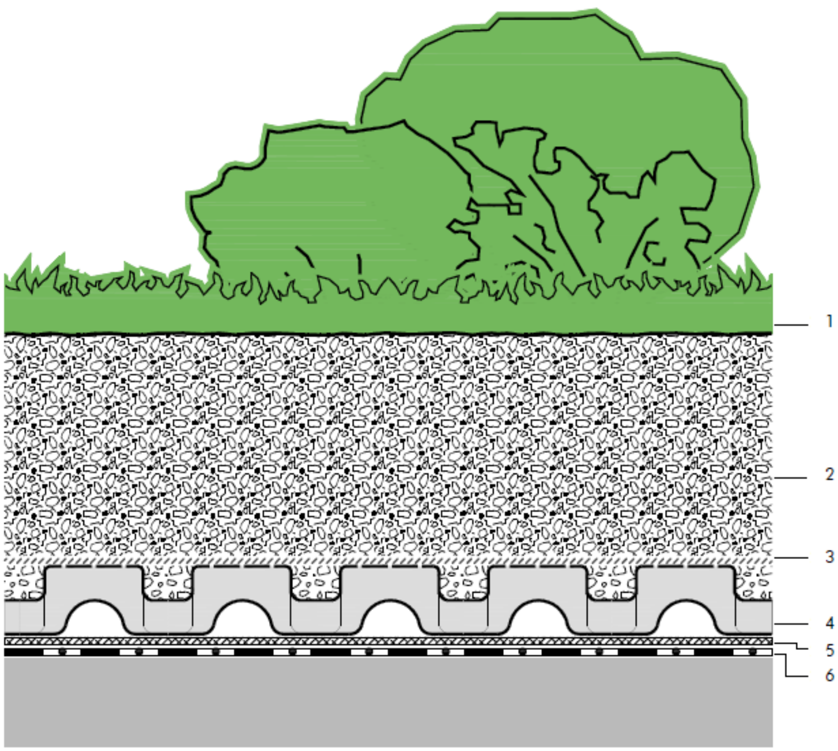


Figure.6.22, 1. Lawn, perennials, shrubs and trees.2. System Substrate.3 .Filter Sheet .4 Drainage Element . 5 .Protection Material . 6 .Roof construction with root-resistantwaterproofing.

2. Wall connection for Roof Garden.

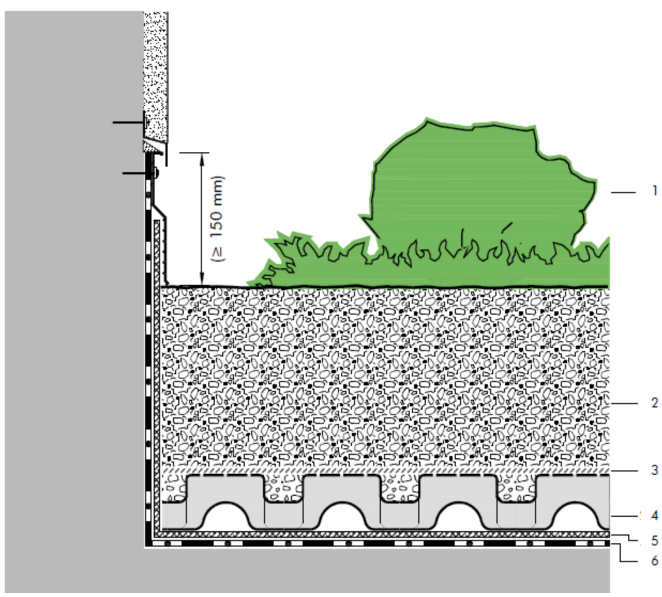


Figure6.23.1. Lawn, perennials, shrubs and trees.2 .System Substrate .3.Filter Sheet .4. Drainage Element .5.Protection.6.Roof construction with root-resistant and waterproofing.

3. Roof outlet with inspection chamberfor Roof Garden.

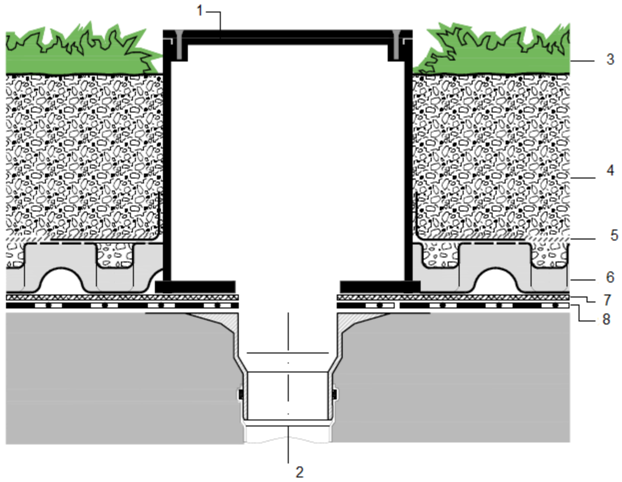


Figure.6.24 1. Inspection Chamber /drainage box.2. Roof outlet.3. Lawn, perennials, shrubs and small trees.4. System Substrate .5. Filter Sheet .6. Drainage Element .7. Protection, Material .8. Roof construction with root-resistant waterproofing.

4. Foundation for supporting structures / roof shelter .

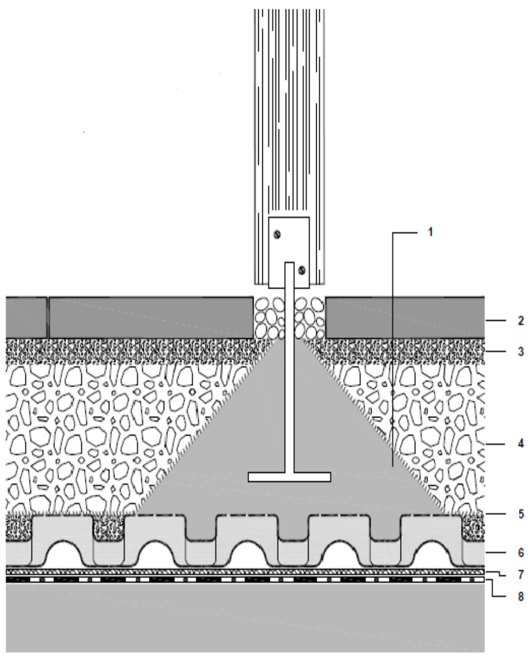


Figure.6.25, 1.Concrete foundation for supporting structures.2 .Concrete paving slab.3 .Stone chippings, height (30 - 50 mm).4. Gravel base layer.5. Filter Sheet .6. Drainage Element 7.Protection Material .8. Roof construction with root-resistant waterproofing.

5. Root ball anchorage

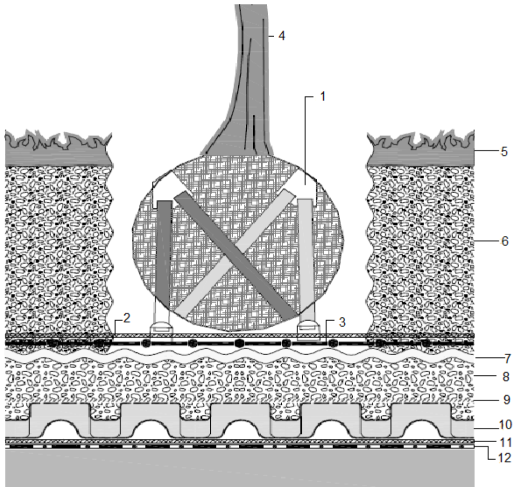


Figure.6.26, 1. Root ball anchorage.2. Biodegradable fiber ,e.g. coco-material (optional) .3 .Reinforcement steel mesh.4. Tree.5. Lawn.6. System Substrate.7. Drainage pipes.8. mineral substrate.9. Filter Sheet .10. Drainage Element, filled with mineral substrate11. Protection Material .12. Roof construction with root-resistant waterproofing.

6.8Drainage and irrigation system

The drainage system of the project dependent on drainage network, consists of drainage boxes (inspection champer) and a collection of pipes. The inspection champer inserted at the height of the substrate Surrounded with a gravel soil to protect and drain the roof outlet in intensive green roof system asin Figure 6.27. And the drainage pipes installed through the slab connected with each other to flow the water for the final discharge passing through a filter before pumping by the drain pump to the reservoir . Drainage box have an upper filter layer to drain excessive of the surface water, and a sides filter connected to the drainage layer to drain the water infiltration, at the end of drainage box there is Dam_up element to control the exit of water working as a valve for the roof outlet.

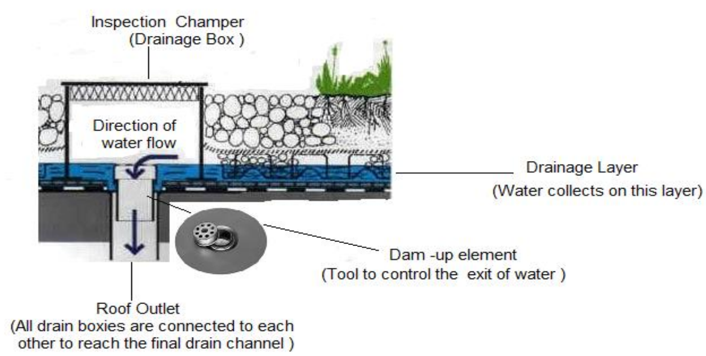


Figure 6.27 drainage system of green roof.

The irrigation system principle depend on soil moisture sensor ,indicates the humidity percent in the soil, send the signs to water level controller ,its work principle on the percent of the humidity if there is increasing in the humidity percent from the allowable range in the soil ,the controller send a signal to the drain pump to work and drain the excessive water to the tank. And if there is reducing in the percent of humidity from the allowable range the controller send a signal for the pump to work and irrigate the roof garden by the same water of the tank. in Figure 6.28 it is show the drainage and irrigation system of green roof.

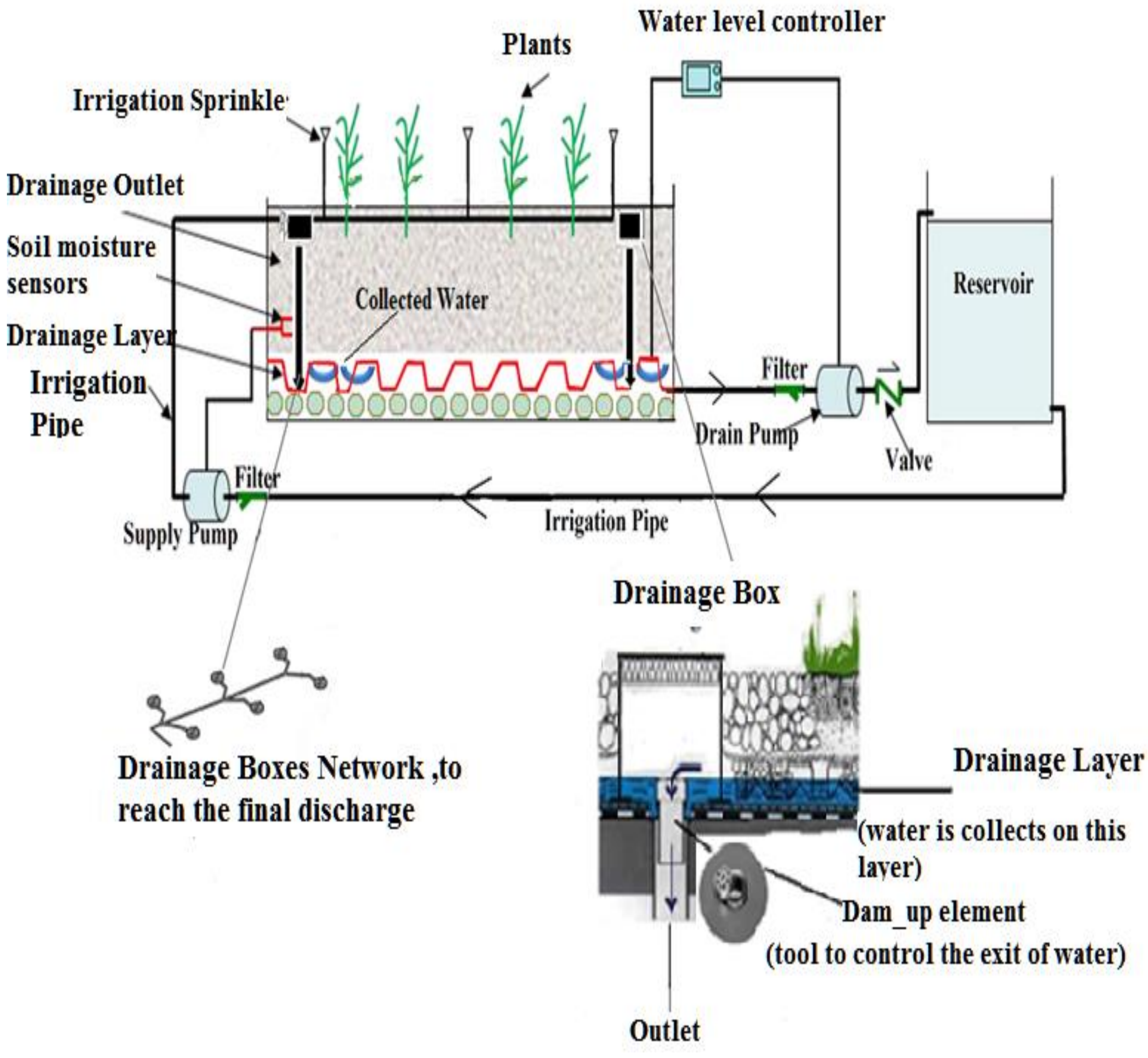


Figure 6.28 drainage and irrigation system of green roof

6.9Planting

The appropriate origin environment for the growth of selected plants has been taken into consideration ,plants that grow in temperate, Mediterranean, almost moderate humidity were selected in accordance with the climate of Palestine especially Hebron.n the system of green roofing we need plants that are permanent greens this was taken into consideration only fruit trees were excluded that their leaves are falling due to need to their nutritional values .when choosing a plant type you can note that most selected plants are small size type to reduce the load on the building, most of the plants were chosen with flowers had beautiful colors to give an aesthetic view to the building.

1. Bougainvillea, Paper Flower

Figure6.29 Bougainvillea, Paper Flower

Table 6.12 Properties of Bougainvillea, Paper Flower

Origin	Mediterranean
Vigour	fairly fast
Humidity	semi humid
Type	Climbers, evergreen , semi evergreen
Height	10 m-25 m Spread : 4 m-10 m
Irrigation	Medium
Flowers Colour	red, purple, pink, white
Period	April – June

2.Treasure Flower

Figure6.30 Treasure Flower

Table 6.13 Properties of Treasure Flower

Origin	Mediterranean,
Vigour	normal growth
Humidity	semi-humid
Irrigation	medium
Type	Perennial , evergreen
Height	0.3 m
FLOWER Colour	yellow
Period	March - June

3.Jacquemontia

Figure6.31 jacquemontia

Table 6.14 Properties of jacquemontia

Origin	Mediterranean,
Vigour	fast growing
Humidity	semi-humid
Irrigation	medium
Type	Climbers , evergreen
Height	2 m
FLOWER Colour	blue
Period for flower	January - December

4.Pink Jasmine

Figure6.32 Pink Jasmine

Table 6.15 Properties of Pink Jasmine

Origin	sub-Mediterranean, Mediterranean
Vigour	fairly fast growing
Humidity	semi humid
Irrigation	high
Type	climbers , evergreen
Height	3 m-6 m
FLOWER Colour	white, pink
Period for flower	February - August

5.Crape Myrtle

Figure6.33 Crape Myrtle

Table 6.16 Properties of Crape Myrtle

Origin	Mediterranean
Vigour	fast growing
Humidity	semi-arid, semi humid
Irrigation	Medium
Type	Shrub
Height	5 m-10 m
FLOWER Colour	Pink
Period	July – September

6.Lantana, Shrub Verbena

Figure6.34 Lantana, Shrub Verbena

Table 6.17 Properties of Lantana, Shrub Verbena

Origin	Mediterranean
Vigour	normal growth
Humidity	semi-arid, semi humid
Irrigation	Medium
Type	Shrub, evergreen
Height	1 m-1.8 m
FLOWER Colour	orange, red, yellow, pink
Period for flower	May – October

7.Grape Vine, enab

Figure6.35 enab

Table 6.18 Properties of enab

Origin	sub-Mediterranean, Mediterranean
Vigour	fast growing
Humidity	semi-arid, semi humid
Irrigation	Medium
Height	0.5 m-1.5 m
Type	Climbers , deciduous
FLOWER Colour	light green
Period	May – June

6.10Financial cost of green roofs

The cost of the green roofs was calculated based on the prices of the company ZinCo after it was visited, which has a branch in the city of Ramlah located in the occupied Palestinian,kknowing that the area of 1442 is the area of the back garden in addition to the area of green surface, the number of drainage boxes were estimated because of the lack of expansion of its characteristics in the project.

Table 6.19 Financial cost of green roofs

	Component	**Unit**	**Price**	**Total area**	**price**
1.	Filter layer	1m2	0.106	1442	152.85
2.	Drainage And water storage layer	1m2	0.825	1442	1189.65
3.	Protection Material layer	1m2	0.246	1442	354.72
4.	Root Barrier	$1m^2$	0.233	1442	335.99
Total layer prices = 2033.21ILS					
1.	Drainage boxes	Pcs (Unit)	162	Assume 10 boxes	1620
2.	Head System	-	3500		3500
3.	Accompaniment / guidance / supervision	Work hours	300		300
4.	Root ball anchorage	Pcs (Unit)	200	Assume 50ball anchorage	10000
Total prices = 17453.21 ILS					

Chapter 7

Results and Recommendations

7

7.1 Introduction.

7.2 Recommendations.

7.1 Introduction:

In this project, architectural designs were obtained lacking much of the necessary work to qualify the building as a green building. These requirements have been studied, the focus on the green roof side and its study of structural and environmental aspects.

The building plans and the green roof plans have been prepared in a detailed, precise and clear manner to facilitate the construction process and to construct the roofs in their correct form as a new entrance to the country. This report provides an explanation of all the architectural and structural steps of the building. In addition, a detailed study of the surfaces, their loads and their costs was carried out.

7.2 Recommendations

Most likely, many leading edge, high profile projects will be necessary to propel green roof philosophy into the national consciousness. Overall, green roofs offer unlimited application and design possibilities, and provide so many ecological, economic and aesthetic benefits that we would be irresponsible not to consider their potential.

Urban ecology and environmental quality issues need to become an integral part of development and construction practices. Individuals, businesses, and municipalities need to promote green development by example; it simply about doing the right thing. If utilized on a wide scale basis, green roofs could help raise local and regional environmental awareness and health, while providing substantial global benefits to our earth.

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