Form: SDP-07
CE 492

SDP2 - Interim Assessment Report
(Supervisors Form for Evaluation)

Scores: 0 = Not exist/acceptable,1 = Weak, 2 = Acceptable, 3 = Good& 4= very good, 5= excellent

No.	Item to be checked	PI	Student score			
			St#1	St#2	St#3	St#4
1	Ability to identify the basic sciences principles that governing the engineering design problem	1.2				
2	Ability to identify design requirements and recognize constraints.	2.1				
3	Ability to produce design alternatives.	2.2				
4	Ability to comprehensively identify research and inquiry methodologies	1.6				
5	Ability to conduct inquiries, investigations, and research for complex issues and problems	1.7				
6	Ability to recognize ethical and professional aspects regarding engineering situations.	4.1				
7	Ability to perform tasks in the planned time with acceptable quality	4.2				
8	Ability to demonstrate leadership skills (planning tasks, assigning work to team members, and evaluating achievements).	5.1				
9	Ability to participate in brain storming, ideas generation and deciding the course of design.	5.2				
10	Contribution in implementing and evaluating the final product	5.2				
11	Ability to develop experiments or test procedure related to the final product	6.4				
12	Ability to conduct experiments related to the project.	6.1				
13	Ability to analyze and present data using statistical, and graphical tools.	6.2				
14	Ability to interpret the obtained data and draw the conclusion	6.3				
15	Ability to gain knowledge of modern tools/devices/apparatus/equipment.	7.1				
16	Ability to acquire new knowledge through pursuing future postgraduate studies or professional training.	7.2				
	Sub-Total (out of 80)					
	X= Modified Sub-Total (out of 40)					

Form: SDP-09
CE 492

SDP2: ME492 (Report Evaluation Checklist)

(Guide for use: Students should attach three-copies of this form with their submitted reports to the principal supervisor after filling the required data. Each copy of this form is to be directed to one of the SDP Examiners to evaluate the submitted SDPs. The form evaluates the written report, the design approach and the SDP product. Examiners are urged to complete the form and handle it to the principal supervisor by the celebration day)

Academic year: 1444- 1445 (2023- 2024), Semester: (■ Fall ☐ Spring)

Department:	**Civil Engineering Department**
Project Title:	**Analysis and Design of a Reinforced Concrete Building**
Supervisor(s):	**Dr. Omar Al-Awwad**
Student Names:	**Salman Alqadi, Amer Ghazi Alharbi, Faisal Al-Shobromi**

I) Submission Time; Planned Date: 10/ 12/ 2023 Actual Date: 10/ 12/ 2023	
■ **On time** ☐ **Late for** .... **days** (in this case **1 mark is reduced** from the total mark for **the first day** of lateness and **Afterwards** extra reduction with a rate of **0.5 mark/day** is applied)	**No of marks to be reduced** **A =**

(II) Evaluation of the Written Report Formality, Style and Quality of Technical Writing

Scores: 0 = Not exist/acceptable,1 = Weak, 2 = Acceptable, 3 = Good& 4= very good, 5= excellent			
No.	**Item to be checked**	PI	**Score**
1	**Report Organization** (Cover page, Acknowledgement, Table of contents, List of figures, List of tables, Nomenclature, Introducing chapter, Main body chapters, Chapter for conclusions and recommendations, References, and Appendices) **and Style** (fonts, titles, page numbers, header and footers, margins, references are cited in the text and written in standard format …etc.)	3.1	
2	**Figures** and **Tables** citations (i.e. all figures and tables have numbers and captions, and are mentioned in the text before they placed) **Graphs Quality** (Size, Axes, Labels, and Legend) and M**athematical equations** (clarity and explanation of the equations)		
3	**English Language Quality** (paragraphs, relations between sentences, using punctuations, grammar, and spell check.)		
4	**Quality** of the I**ntroduction, Review, Conclusions and recommendations** in terms of: the available data, products and works, analysis and deep discussions of the obtained results based on the performance of the final product.		
5	**Poster** quality		
	Sub-Total (1) (out of 25)		**/25**
	B= Modified Sub-Total (1) (out of 5)		**/5**

SENIOR DESIGN PROJECT "SDP"

Form: SDP-09
CE 492 (Cont.)

(III) Evaluation of the SDP2 Approach, Procedures, and Final Product

Scores: 0 = Not exist/acceptable,1 = Weak, 2 = Acceptable, 3 = Good& 4= Very good, 5= Excellent

No.	Item to be checked		Pages*	PI	Weights	Score
1	**Problem description and project objectives** (Report should clearly identify the project purpose besides the problem statement, reality, creativity and impact to the environment, economy and society.)		22-27	1.1	3	
2	**The Literature review clearly reflects, inquiries and investigation of complex issues related to the design problem**		21	1.7	3	
3	**Brain storming, ideas generation and deciding the course of design** (Report should demonstrate the different ideas and design alternatives raised to solve the problem and justify the selected approach for design)		22	2.2	3	
4	**Design inputs**	**Identification of design requirement** (Important characteristics that the design must meet in order to be successful are listed)		2.1	3	
		Recognition of design constraints (technical and other constraints (global, environmental, social, economic, ethical, health and safety, whichever is applicable)		2.3	3	
5	**Design process**	**Approach** is logical, free from technical errors and answers all how and why questions.		2.3	3	
		Steps adopt and adhere to national and/or international standard specifications (Design Codes)		2.3	3	
		Formulating the design problem (mathematically and/or modeling)	39,47	1.2	2	
		Application of appropriate techniques in solving engineering design problem	41,50	1.3	1	
		Evaluation of design problem solution	45,52	1.4	1	
6	**Design Outputs (**Clear and identifiable design outputs that can be evaluated)		137	2.4	3	
7	**Verification of Designed Product**	**Development of experimental/test procedure** to **evaluate** the **final design.**		6.4	2	
		Conduct Experiment based on developed procedure (subjected to comprehensive evaluation.)		6.1	1	
		Analyze and present data using statistical and graphical tools		6.2	1	
		Interpret the data and draw the conclusion		6.3	1	
8	**Final Product**	**Verification** that the **Final Product is complete** and meets the design requirements.		2.4	3	
		The **Final Product** is evaluated and justified against all applicable constraints (technical, environmental, social, economic, ethical, health and safety)		2.4	3	
	Sub-Total (2) = ∑ Weight × Score (out of 195)					/195
	C = Modified Sub-Total (2) (out of 35)			/35		

* In this column students should identify the page(s) in which the corresponding item is demonstrated in the report

Final Mark for the Senior Design Project (Report, Approach and Product)			
Evaluator Name		**Final Mark** **Y = -A+B+C** **(Out of 40)**	**Y=**
Evaluator Signature			
Date			

SDP2 - Presentation Evaluation Form

Academic Year: 144 - 144 (202 - 202) Semester : (☐ Fall ☐ Spring)

Student Names		
St#1...	St#2...	St#3...

Scores: 0 = Not exist/acceptable, 1 = Weak, 2 = Acceptable, 3 = Good& 4= very good, 5 = excellent

(I) Presentation Material (written)

No.	Item to be checked	PI	Score
1	Presentation material is well organized from technical writing point of view (Sandwich format: Title slide, Introduction, Main body with different sections and Conclusion)	3.1	
2	Overall appearance, presentation style and readability		
3	English language of the presentation		
4	Main ideas are presented logically, Objectively and clearly.		
	Sub-Total (1) [out of 20]		

(II-a) Individual Assessment of Presentation Skills (Oral)

No.	Item to be checked	Student Score				
		PI	St#1	St#2	St#3	St#4
1	Student's time management	3.2				
2	Seldom returning to notes/reports, and eye-contact					
3	Ability to explain ideas using proper English.					
4	Clear voice and confidence of the student in presentation					
5	Student's ability to handle questions and discussions (in English)					
	Sub-Total (2) out of 25					
	Sub-Total (3) = Sub-Total (1) + Sub-Total (2) [out of 45]					
	D= Modified Sub-Total (3) [out of 5]					

(II-b) Individual Assessment of Team working & Design (Oral)

No.	Item to be checked	Student Score					
		PI	weight	St#1	St#2	St#3	St#4
1	Student's understanding of task distribution and his role in the project	5.2	2				
2	Student's awareness of the project objectives and the realistic constraints	2.1	3				
3	Student's understanding of the design alternatives	2.2	3				
4	Student's familiarity with the design process and standard specifications (Codes) used.	2.3	3				
5	Ability to describe the final product and related technical aspects.	2.4	3				
	Sub-Total (4) [out of 70]						
	E = Modified Sub-Total (4) [out of 15]						
	Z= D +E [out of 20]						

	Final Mark for Each Student (By Examiners)				
Student	**St#1**	**St#2**	**St#3**	**St#4**	**Date:** / /144
Obtained Marks (Y+ Z) out of (60)					/ /202

Examiner Name: Signature:

SENIOR DESIGN PROJECT "SDP"

Form: SDP-11
CE 492

SDP2 Final Grade Report

(**Guide for use:** This form is to be used by the SDP principal supervisor to report the final student grades. The completed form attached with copies of Forms SDP-09 and SDP-10 are to be submitted to the HOD)

Academic year: 144 - 144 (202 - 202) Semester : (☐ Fall ☐ Spring)

Department			
Project Title			
Supervisor(s)			
Student Names			
St#1.....................	St#2.....................	St#3.....................	St#4.....................

I) Students Performance Assessed by the Supervisors (From interim report- Form SDP-07)

St#1	St#2	St#3	St#4
X = ... /40	X = ... /40	X = ... /40	X = ... /40

II) Evaluation of the Final Report, Approach and Product (From: Form SDP-09)

Examiner #1	Examiner #2	Examiner #3	Average
Y = ... /40	Y = ... /40	Y = ... /40	Y = ... /40

III) Evaluation of the Presentation (From: Form SDP-10)

St#1			St#2			St#3			St#4		
Examr #1	Examr #2	Examr #3	Examr #1	Examr #2	Examr #3	Examr #1	Examr #2	Examr #3	Examr #1	Examr #2	Examr #3
Z = ... /20			Z = ... /20			Z = ... /20			Z = ... /20		

Final Mark and Grade				
Student Name:	St#1	St#2	St#3	St#4 ....
PIN				
Final Mark = (X+Y+Z)	.... /100	.... /100	.... /100	.... /100
Grade				
Supervisor Signature	....			
HOD Approval			Date: / /	

Qassim University جامعة القصيم

كلية الهندسة

College of Engineering
Civil Engineering Department
Senior Design Project
SDP-492

Analysis and Design of a Reinforced Concrete Building

Prepared By:

Salman Alqadi	**392116745**
Amer Ghazi Alharbi	**391108223**
Faisal Alshobromi	**391108221**

A report submitted in partial fulfillment of the requirement for the bachelor’s degree in civil engineering department at college of engineering, Qassim University

Jumada al-Awwal 1445
December 2023

تحليل وتصميم مبنى من الخرسانة المسلحة

إعداد

سلمان القاضي	**392116745**
عامر غازي الحربي	**391108223**
فيصل الشبرمي	**391108221**

نوقش مشروع التخرج هذا بتاريخ. 28 / 5 / 1445 هـ

المشرف على المشروع: د. عمر العواد التوقيع: ....

أعضاء اللجنة:

د/ صالح العقلاء التوقيع: ---------------------------

د/ منصور التركي التوقيع: ---------------------------

بسم الله الرحمن الرحيم

الإهداء

الى كل مسلم يسعى لرقى امته. أهدي هذا العمل المتواضع إلى أبي الذي لم يبخل على يوماً بشيء

وإلى أمي التي زودتني بالحنان والمحبة أقول لهم: أنتم وهبتموني الحياة والأمل والنشأة على شغف الاطلاع والمعرفة وإلى إخوتي وأسرتي جميعاً ثم إلى كل من علمني حرفاً أصبح سنا برقه يضيء الطريق أمامي. إلى من علمني النجاح والصبر إلى من افتقده في مواجهة الصعاب ولم تمهله الدنيا لأرتوي من حنانه.. أبي وإلى من تتسابق الكلمات لتخرج معبرة عن مكنون ذاتها.

ACKNOWLEDGEMENT

As always, I give my praise and thanks to the almighty Allah for giving us the strength and health and providing me with his protection and mercy. I would like to thank my family and my friends who inspired me to work hard during the SDP and to chase my dreams, which I believe are almost a reality.

I would also like to thank the project supervisor, Dr. Omar Alawad for his unwavering support, guidance, and expertise throughout the project. We are grateful for the time he spent reviewing our progress, providing feedback, and challenging us to think critically and creatively.

I would also like to thank my fellow students at Qassim University, who provided me with valuable feedback, support, and motivation throughout the project. Their insights and perspectives helped me to refine my ideas and approaches, and their collaboration and teamwork were essential to the success of the project.

Overall, my special heartfelt thanks go to everybody who have supported me during our SDP, as well as those individuals who give special support.

المُلخص

يركز مشروع التخرج هذا على تحليل وتصميم مبنى إنشائي مسلح، حيث يتم تحديد الأحمال على المبنى وفقًا لكود البناء السعودي. يهدف المشروع إلى تصميم مبنى آمن واقتصادي باستخدام برنامج ETABS، يليه التحقق باستخدام Excel، وأخيراً رسم تخطيطات وتسليح المبنى باستخدام برنامج REVIT.

في المرحلة الأولى، يتم تحديد الأحمال على المبنى من خلال الالتزام باللوائح المحددة في كود البناء السعودي. يحدد الكود الأحمال التي يجب أن يتحملها المبنى، مثل الأحمال الميتة والأحمال الحية وأحمال الرياح والزلازل، ثم يتم أخذ الأحمال في الاعتبار في مرحلة التصميم.

في مرحلة التصميم، يتم استخدام برنامج ETABS لتصميم المبنى. البرنامج قادر على محاكاة أنواع مختلفة من سيناريوهات التحميل لتحديد الاستقرار الهيكلي والقوة للمبنى. يتضمن التصميم اختيار المواد وأبعاد عناصر البناء وتفاصيل التسليح.

في مرحلة التحقق، يتم فحص التصميم باستخدام Excel. تم تصميم ورقة Excel للتحقق من حسابات التصميم والتأكد من أن التصميم يفي بالمتطلبات واللوائح المحددة في كود البناء السعودي.

أخيرًا، يتم رسم مخططات تسليح المبنى باستخدام برنامج REVIT. يسمح هذا البرنامج بإنشاء نموذج ثلاثي الأبعاد للمبنى يمكن استخدامه لتصور التصميم وتحديد أي مشكلات محتملة قبل بدء البناء.

ABSTRACT

This senior design project focuses on the analysis and design of a reinforced structural building, in which the loads on the building are defined according to the Saudi Building Code. The project aims to design a safe and cost-effective building using ETABS software, followed by verification using Excel, and finally drawing the building layouts and reinforcement using REVIT software.

In the first phase, the loads on the building are defined by adhering to the regulations specified in the Saudi Building Code. The code specifies the loads that the building must withstand, such as dead loads, live loads, and wind loads. The loads are then considered in the design phase.

In the design phase, ETABS software is used to design the building. The software is capable of simulating different types of loading scenarios to determine the structural stability and strength of the building. The design includes the selection of materials, dimensions of the building elements, and reinforcement details.

In the verification phase, the design is checked using Excel. The Excel sheet is designed to verify the design calculations, including the dimensions of the building elements, and ensure that the design meets the requirements and regulations specified in the Saudi Building Code.

Finally, the building layouts of the reinforcement are drawn using REVIT software. This software allows for the creation of a 3D model of the building that can be used to visualize the design and identify any potential issues before construction begins.

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List of Symbols

Symbol	Description	Unit
A_s	the minimum area of steel required for the member	m^2
b	width of the member	m
d	the effective depth of the member	m
f'_c	Concrete compressive strength	Mpa
f_y	Steel tensile strength	Mpa

a	The height of the stress block	m
Φ	Reduction factor	unitless
A_f	Area of the foundation	m^2
$Q_{working}$	The load of the column	kN
$q_{all\ net}$	The net allowable gross soil bearing capacity	kN/m^2
q_{all}	Soil bearing capacity	kN/m^2
γ_s	Soil unit weight	kN/m^3
D_f	Distance from the surface to the top of footing	m
γ_c	Unit weight of concrete	kN/m^3
t_f	footing thickness	m
q_s	The Contact Soil Bearing Capacity	kN/m^2
Q_{ult}	The ultimate load of the column	kN
V_u	shear force due to factored load	kN
ΦV_c	design shear strength of concrete	kN
L_f	Length of the footing	m
B_f	Breadth of the footing	m
b_c	Width of the column	m
h_c	Height of the column	m
d_b	Diameter of the rebar	m
A_{bar}	Area of the rebar	m^2
A_v	Area of shear reinforcement within spacing s	mm^2
$A_{v,min}$	Minimum area of shear reinforcement within spacing s	mm^2
V_c	Nominal shear strength provided by concrete	KN
s	Center to center spacing of items	mm

CHAPTER 1. INTRODUCTION

The design and construction of reinforced concrete buildings is a complex and critical process that requires a thorough understanding of structural analysis, load calculations, and material selection. The purpose of this senior design project is to explore the various aspects of reinforced concrete design and construction, with a focus on ensuring safety, durability, and sustainability. Through our project, we will examine the theoretical and practical considerations for designing a reinforced concrete building, including the application of relevant codes and standards, the use of appropriate software tools for structural analysis, and the selection of materials based on their properties and performance. Our goal is to provide a comprehensive overview of the analysis and design of a reinforced concrete building, with a view toward creating structures that are safe and durable.

1.1. Motivation

Reinforced concrete is a versatile and durable construction material that is widely used in building structures such as bridges, high-rise buildings, and residential homes. The analysis and design of a reinforced concrete building are critical to ensure that the structure is safe, reliable, and meets all applicable building codes and regulations.

The importance of proper analysis and design of reinforced concrete buildings cannot be overstated, as a poorly designed or constructed structure can have devastating consequences. In addition to posing a significant risk to the safety of occupants, a building failure can also result in significant economic losses and damage to communities

1.2. Literature survey

Reinforced concrete structures have been a subject of extensive research and interest among scholars and practitioners for many years. Researchers have explored various aspects of reinforced concrete design, including material properties, structural behavior, and design codes.

For this project, a comprehensive review of the literature on reinforced concrete design was conducted, with a focus on two prominent design codes: the Saudi Building Code (SBC) and the American Concrete Institute (ACI) Building Code. These codes are widely recognized and used in the industry, providing guidance and standards on the design of reinforced concrete structures, including critical structural components such as beams, columns, and slabs.

1.3. Problem definition

1.3.1. Problem statement

Develop an efficient and safe design process that incorporates the latest best practices and standards for reinforced concrete buildings. The project aims to address existing design limitations and challenges to ensure the durability and sustainability of the reinforced concrete building.

1.3.2. Problem constrains

The project is constrained by budget limitations and the need to comply with relevant safety codes and regulations. Additionally, the design must meet the specific functional requirements of the building and the needs of its occupants.

1.3.3. Proposed solutions

The project's proposed solution involves analyzing and designing the reinforced concrete building using either a flat slab or solid slab system, depending on which is the most economical option for the specific needs of the building and its occupants. The chosen system will be optimized for cost-effectiveness, durability, and compliance with relevant safety codes and regulations.

1.4. Design requirements

When analyzing and designing a reinforced concrete building, there are several design requirements that should be considered. These include:

- Strength and stability: The building must be designed to withstand the expected loads and forces that it will experience during its service life.
- Durability: Building must resist environmental factors for safety.
- Serviceability: Design to meet functional requirements for user comfort.

- Code compliance: Compliance with codes ensures safe building design.

1.5. Project Description

An office building architectural plane of 7 floors with three different layouts, at which one of them will be repeated 3 more times. Figures 1-1, 1-2, 1-3 and 1-4 show the architectural plan for each story.

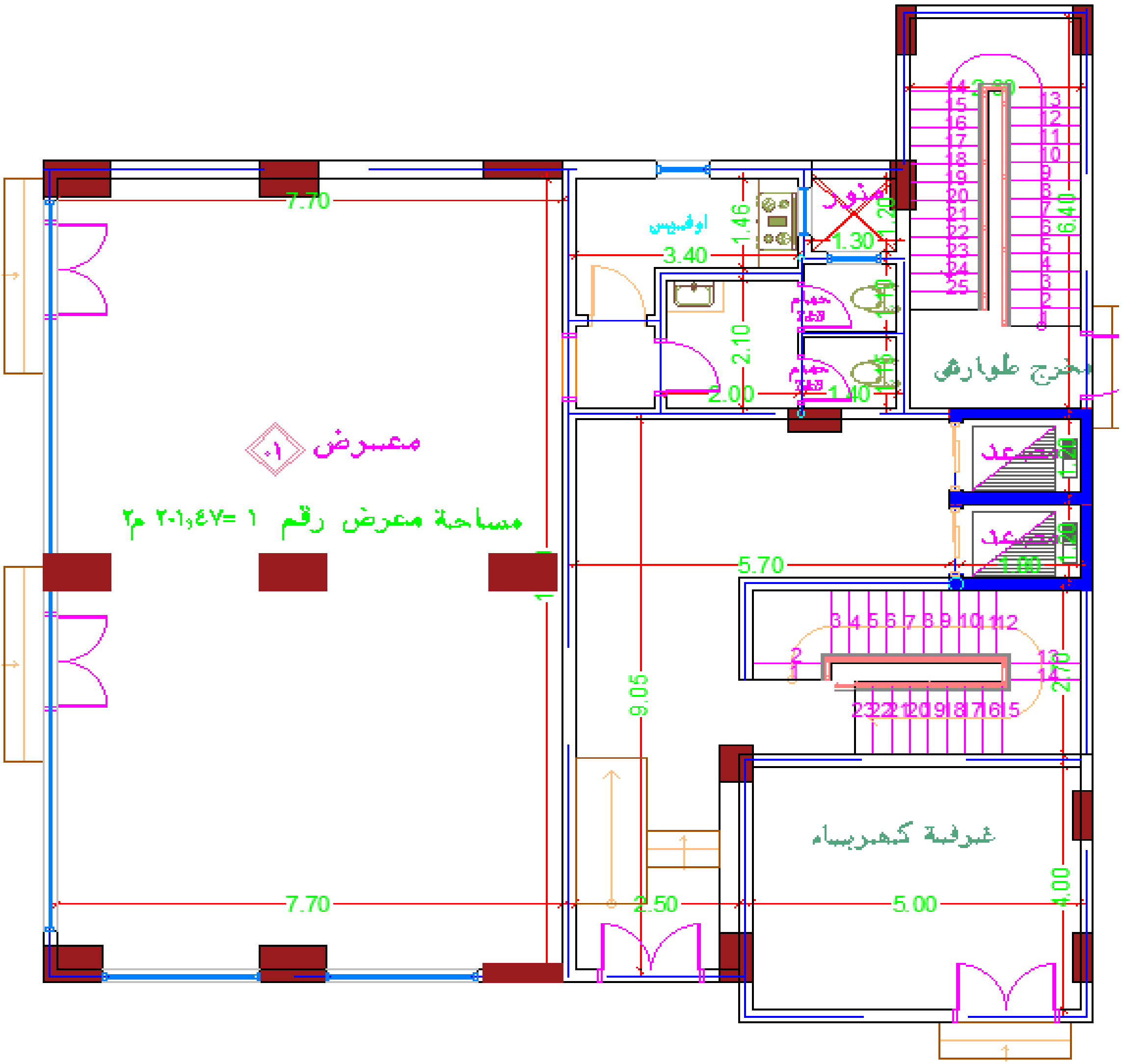


Figure 1-1 Ground floor layout

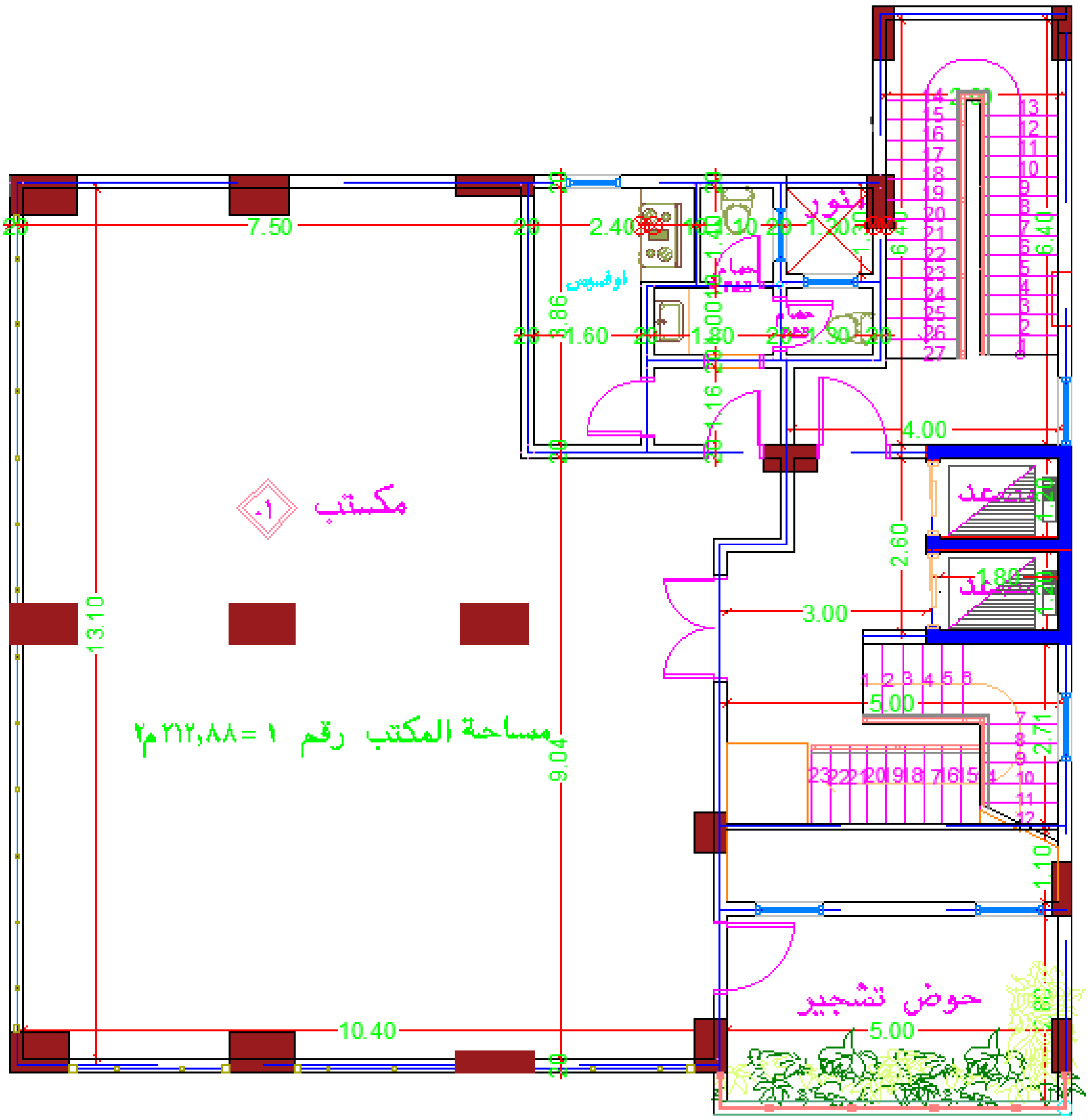


Figure 1-2: First Floor Layout

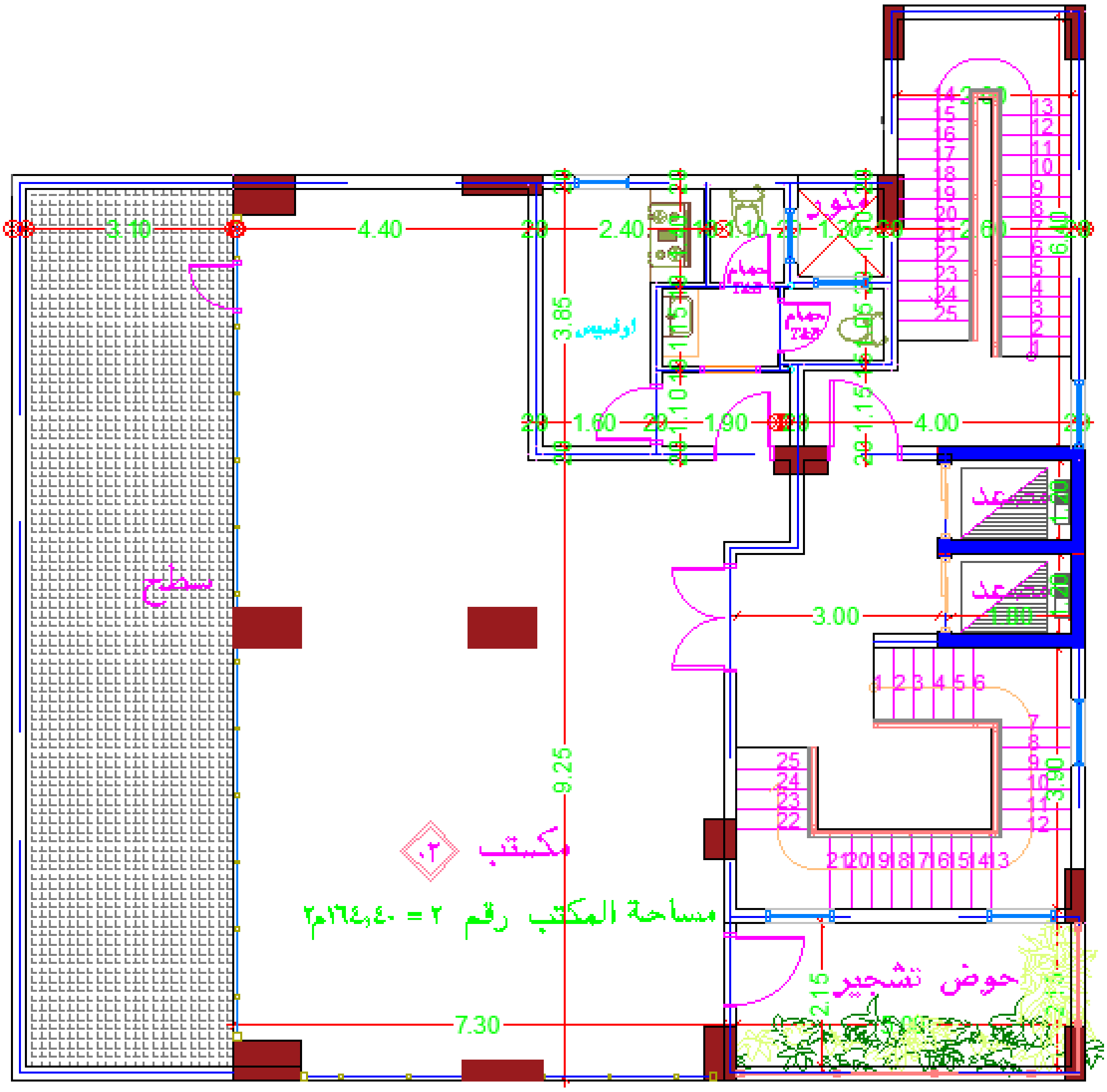


Figure 1-3: Second to the sixth Floor Layout

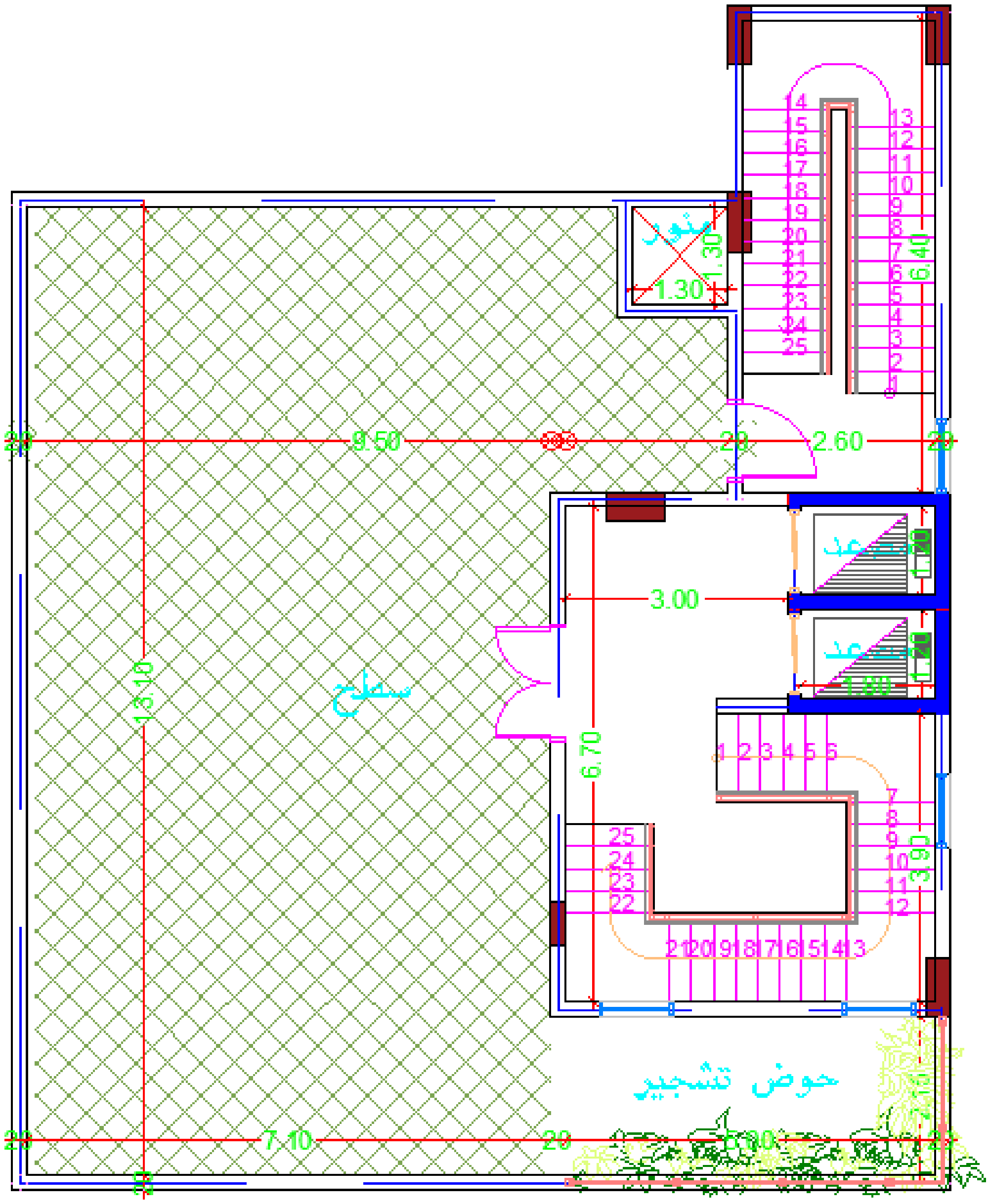


Figure 1-4: End Floor Layout

1.6. Project Objectives

- Understand the architectural plane orientation.
- Design the structural system.
- Modeling and analysis using AutoCAD, ETABS, and REVIT software's

1.7. Outcomes

The project outcomes are correlated to the program's outcomes stated by ABET. The level of achievement of each outcome depends on the nature of the SDP. It is expected that a student, who successfully completes the course, will demonstrate the following outcomes:

1. An ability to apply knowledge of mathematics, science, and engineering.
2. An ability to design and conduct experiments, as well as to analyze and interpret data.
3. An ability to design a system, component, or process to meet the desired needs within realistic constraints.
4. An ability to work in teams.
5. An ability to identify, formulates, and solves engineering problems.
6. An understanding of professional and ethical responsibility
7. An ability to communicate effectively.
8. An ability to engage in, life-long learning.
9. Knowledge of contemporary issues.
10. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
11. The application of all types of knowledge in the various engineering sciences, mathematics and physics on the ground.

1.8. Code of Practice:

The design and analysis of the project had to go through verified standards:

- Saudi building code requirements for concrete structures (SBC 304-2018)
- Saudi building code requirements for structural loading and forces (SBC301- 2018).
- American concrete institute requirements for reinforced concrete (ACI 318- 19)
- American concrete institute requirements for, reinforced concrete detailing (ACI 315- 04)

CHAPTER 2. BUILDING DESCRIPTION

2.1. Structural Layout

Figures 2-1, 2-2, 2-3 and 2-4 show the structural plan for each story.

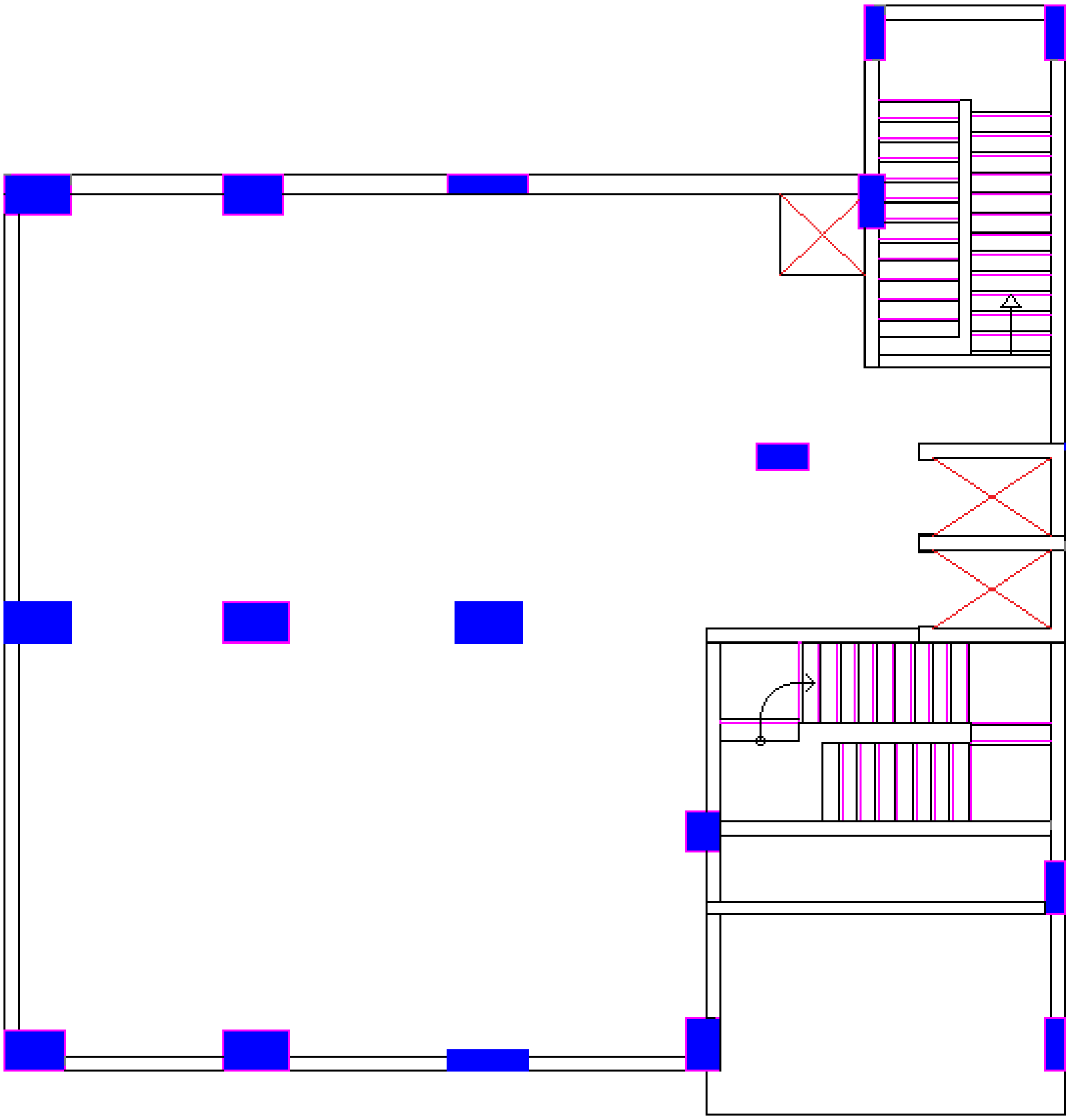


Figure 2-1: Ground floor

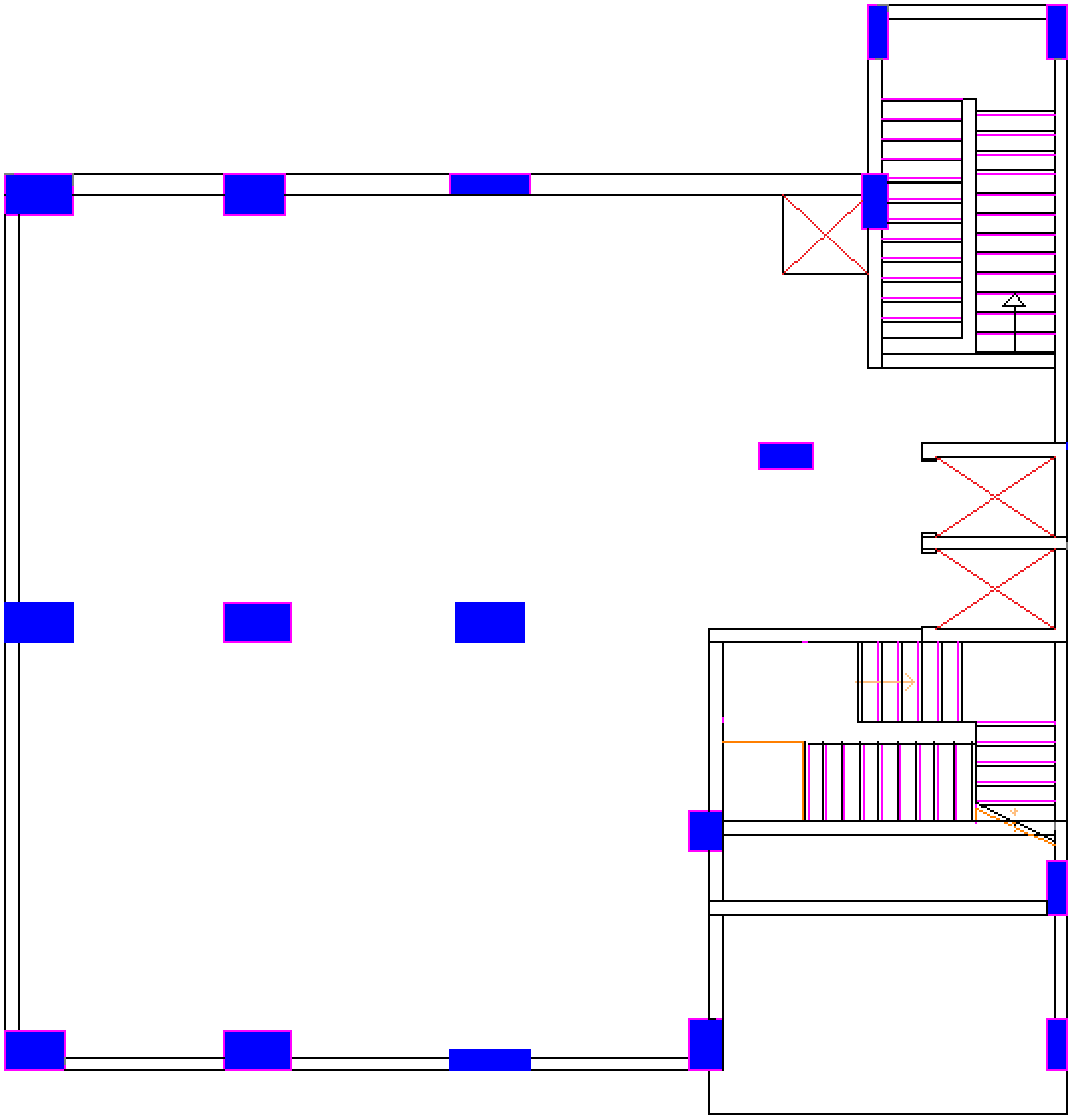


Figure 2-2: First floor

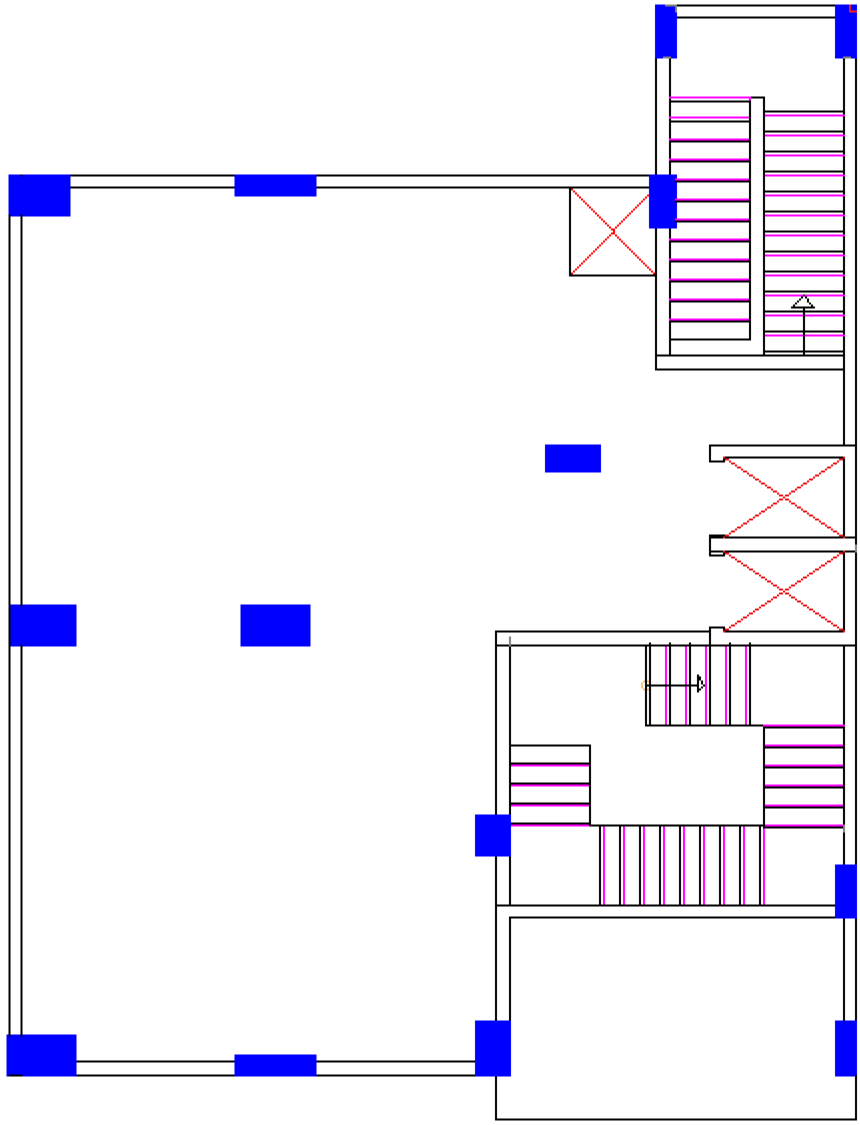


Figure 2-3: Second to the sixth floor

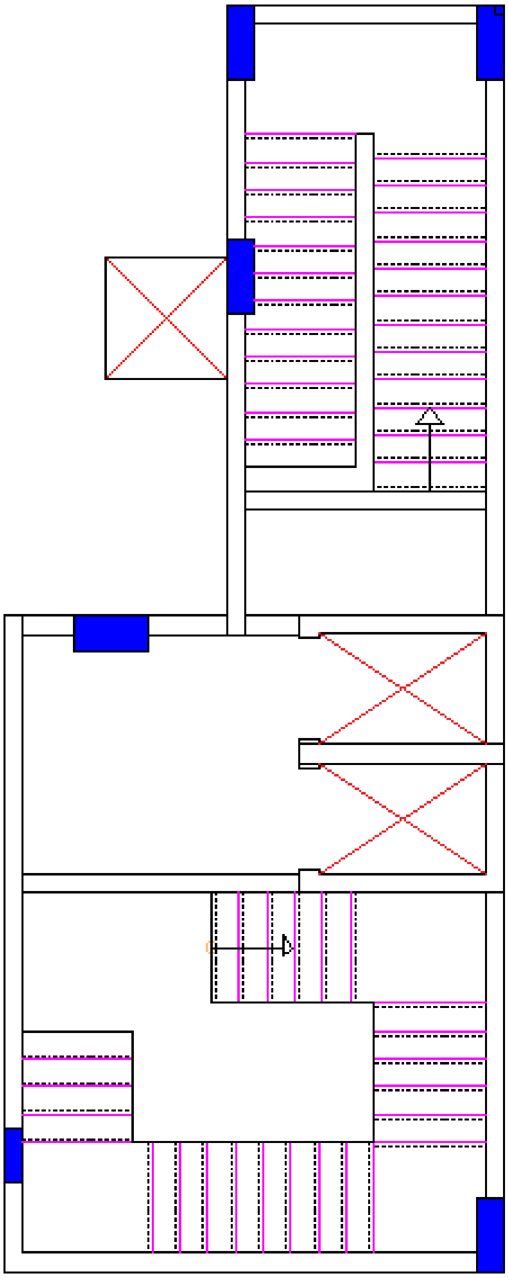


Figure 2-4 End floor

2.2. Materials

In construction, various material is used which among them wood, cement blocks, sand, aggregate, cement, concrete, and steel. However, this project focus primary on concrete and steel parameters.

2.2.1. Concrete

We all know that concrete can be an important and essential product in our lives for instance, it is used to provide strength, durability, and versatility during the construction of a structure. the raw material at which concrete is generally made are cement, aggregate, water, air mixed together at a different percentage for each sediment, inside a huge concrete mixer.

The Compression Strength of Concrete (f'c): is a measure of the concrete's ability to resist loads which tend to compress it.

The compressive strength of concrete chosen for design is 25 Mpa.

Modulus of Elasticity of Concrete (Ec): It is defined as the ratio between the normal stress to normal strain below the proportional limit.

Given by:

$$E_C = 4700 \times \sqrt{f\ 'c} \tag{2-1}$$

2.2.2. Rebar

Concrete is strong under compression, but has low tensile strength, rebar is used as a tension device in reinforced concrete and reinforced masonry structures to strengthen and aid the concrete under tension.

Modulus of Elasticity of Steel (E): is the slope of tensile stress-strain curve up to yielding limit.

The Yield Strength of Steel (fy): is the maximum stress that can be applied before it begins to change shape permanently.

The yield strength and modulus of elasticity chosen for design of steel are: (fy=400 Mpa, E=200 Gpa).

CHAPTER 3. LOADS

The design of a building structure requires careful consideration of various types of loads that the structure may subjected to. Loads, in the context of structural design, refer to the forces that act on the building, such as gravity, wind, and seismic activity. This section aims to provide a comprehensive overview of the different types of loads that need to be considered in the design of the building structure. In addition to the own weight of the building, the loads considered in this project include live load, wind load, and seismic load. Wind and seismic loads are determined manually and using ETABS software, which allows for accurate analysis and evaluation.

3.1. Gravity Load

3.1.1. Dead load

The dead loads are permanent loads which result from the weight of the structure itself or from other permanent attachments.

Floor Loads (Flat Slab)

$$W = \gamma \times ts = 25 \times 0.22 = 5.5\ KN/m^2 \tag{3-1}$$

ETABS, automatically evaluate the own weight, therefore no need to use this value.

Floor Finishes (Plaster, Sand, Mortar, ceramic, and Gypsum board). See Table 3-1**.**

$$W = 0.25 + (0.015 \times 70) + 1.1 + (0.01 \times 16) + 0.4 = 2.96 KN/m^2 \tag{3-2}$$

Table 3-1 Minimum Design Dead Load [2]

Component	**Load KN/m2**

Sand, per mm	0.015
Ceramic (20 mm) on a (25 mm) mortar bed	1.1
Plaster on concrete	0.25
Gypsum board, per mm thickness	0.01
Steel studs, 13 mm Gypsum board each side	0.4

3.1.2. Live load

Also known as applied or imposed loads, may vary over time, and often result from the occupancy of a structure. Typical live loads may include people, the action of wind on an elevation, furniture, vehicles and the weight of the books in a library.

As given in the SBC 303 (Table C4-1) [2] for office buildings use:

$$W = 2.5\ KN/m^2$$

For roof:

$$Wr = 1\ KN/m^2$$

3.1.3. Member Loads (Walls)

According to SBC 303 (Table C3-1) [2]:

For a 20×20×40 cm HCM γb=16,5 KN/m^3

$$W = 16.5 \times (height \times thickness) = 16.5 \times (3.6 \times 0.2) = 11.88 kN / m^2 \quad (3\text{-}3)$$

3.2. Wind Load

Wind is a major force that exerts pressure on the building, and if not properly accounted for; it may lead to structural failure. Following SBC301, wind loads on the Main Wind Force Resisting System (MWFRS) have been determined using Directional Procedure (DP).

The DP is applicable for all building heights; however, it could be applied if the building has a regular shape with absence of response characteristics making it susceptible to the effect of crosswind loading and vortex-induced forces, which unfortunately, is not achieved in this project. Nevertheless, the DP was manually applied to calculate the wind loads on the building and compared to the results obtained from ETABS software, considering the partial suitability of the procedure. This was done for further understanding and verification of the values obtained from the ETABS, considering minor difference.

General requirements are firstly obtained in accordance with SBC301. The design wind pressure (p) acting on the building is then determined at all levels of stories of the building. Wind load cases are defined and illustrated in 3.2.3. Design wind loads cases. Excel spreadsheets were developed to compute wind forces in each story of the building considering all scenarios of the design wind load cases. Furthermore, a comparison between wind forces obtained from ETABS and spreadsheets were done and discussing the minor differences due to partial suitability of the DP to determine design wind loads for irregular building structure.

3.2.1. General requirements for determining wind loads

These requirements are the basic parameters used for determining wind loads on the (MWFRS) and other components of the building. The basic parameters encompass, Ultimate wind speed (V), Wind directionality factor

(K_d), Exposure category, Topographic factor (K_{zt}), Gust effect factor, Enclosure classification, and Internal pressure coefficient (GC_{pi}) were obtained from A-2 , A-3 , A-4 , A-5 , A-6 , A-7 , and A-8 respectively. To assess these parameters, it is required to determine the Risk category of the building based on the SBC301, which has been found to be II category as shown in A-1 . Table 3-2 represents values of each of these parameters obtained from SBC301.

Table 3-2 Basic parameters for determining wind loads on the MWFRS

Parameter	value
Ultimate wind speed, V	47 m/s
Wind directionality factor, K_d	0.85
Exposure Category	C
Topographic factor, K_{zt}	1
Gust-effect factor, G	0.85
Enclosure classification	Enclosed
Internal pressure coefficient, GC_{pi}	± 0.18

3.2.2. Calculation of the design wind pressure for the MWFRS

After obtaining the basic parameters required for determining wind loads on the MWFRS, the velocity pressure (q_z) is then calculated at various height of the building (z) by equation (3-4). It shall be noted that the velocity pressure at mean roof height (h) is referred as (q_h). Therefore, the design wind pressure on the windward walls, leeward walls, and side walls were defined for all heights of the building by equation (3-5).

$$q_z = q_h = 0.613 K_z K_{zt} K_d V^2 \qquad (3\text{-}4)$$

Where:

K_z: Velocity pressure exposure coefficient

K_{zt}: Topographic factor

K_d: Wind directionality factor

V: Ultimate wind speed, (m/s)

q_z: Velocity pressure at height z, (N/m^2)

q_h: Velocity pressure at mean roof height h, (N/m^2)

The design wind pressure is then determined by the following equation:

$$p = qGC_p - q_h(GC_{pi}) \tag{3-5}$$

Where:

$q=q_z$ for windward evaluated at height z

$q=q_h$ for leeward walls, side walls, and roof evaluated at mean roof height

G: Gust-effect factor

C_p: External pressure coefficient

(GC_{pi}): Internal pressure coefficient

3.2.3. Design wind loads cases

The MWFRS shall be designed for the wind load cases those defined in SBC301. The design wind load cases consider the application of wind pressure on the building from different direction, considering eccentricity moment and whether the pressure is applied simultaneously on walls or not. The design can be based on full design pressure or 75% of it. These various cases are illustrated in A-9 .

For each of these cases, it shall be considering the direction of the wind either the wind is on the x-axis or y-axis and considering positive and negative eccentricity if the case containing moment. Therefore, total number of twelve cases are developed as shown in Table 3-3. It shall be noted that the direction of the wind, affecting value of (C_p); since it is a function of (L/B), where B is the dimension perpendicular to wind pressure.

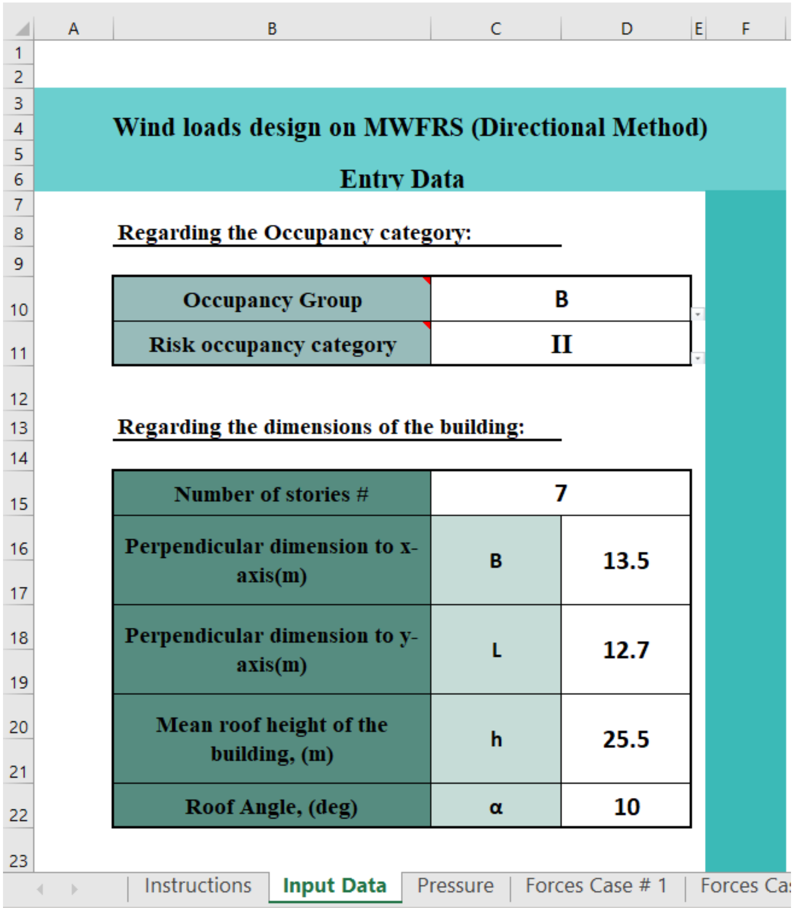
Table 3-3 The design wind load cases

Code case No.	Case No	Wind direction	Eccentricity ratio, e_y	Eccentricity ratio, e_x
1	1	x-axis	0	0
	2	y-axis	0	0
2	3	x-axis	0.15	0
	4	x-axis	-0.15	0
	5	y-axis	0	0.15
	6	y-axis	0	-0.15
3	7	x-axis	0	0
	8	y-axis	0	0
4	9	x-axis	0.15	0.15
	10	x-axis	-0.15	-0.15
	11	y-axis	0.15	0.15
	12	y-axis	-0.15	-0.15

3.2.4. Excel spreadsheet and ETABS results for wind load

Excel spreadsheets were developed for the purpose of computing the design wind forces on each story of a building. These spreadsheets possess an automated functionality, allowing them to be utilized for different buildings simply by modifying the input data.

Figures 3-1, and 3-2 show the input data sheet. The design wind pressure on windward wall and leeward wall is shown in figures 3-3 and 3-4. And the story forces for all wind load cases are calculated; however, the wind forces for case #1 is shown in Figure 3-5 to be compared with the wind forces determined by ETABS. Figure 3-6 shows the modifying window of wind load pattern in ETABS, and it is shown that all twelve cases are created. Comparison of results obtained from ETABS, and the spreadsheet is illustrated in Table 3-4. The analysis reveals an average relative error 3.5% which is believed to arise due to partial suitability of the applied method DP to computing wind loads. To be engaged in knowledge, a simple model with a regular shape and eight story building were developed and calculating wind forces on it; the outcomes obtained from ETABS, and manual calculation were remarkably similar and almost identical as shown in Figure 3-8, and Table 3-5.


Wind loads design on MWFRS (Directional Method)

Entry Data

Regarding the Occupancy category:

Occupancy Group	B
Risk occupancy category	II

Regarding the dimensions of the building:

Number of stories #	7	
Perpendicular dimension to x-axis(m)	B	13.5
Perpendicular dimension to y-axis(m)	L	12.7
Mean roof height of the building, (m)	h	25.5
Roof Angle, (deg)	α	10

Figure 3-1 Input data sheet (part 1)

General Requirements for determining wind loads:

Exposure category	C	
Building Enclosure classification	Enclosed	
Ultimate wind speed, (m/s)	V	47.0
Wind directionality factor	Kd	0.85
Topographic factor	Kzt	1.0
Gust effect factor	G	0.85

Height of each story of the building:

Story#	Height, (m)
Story 1	5
Story 2	4.1
Story 3	4.1
Story 4	4.1
Story 5	4.1
Story 6	4.1
Story 7	3

Instructions | Input Data | Pressure | Forces Case # 1 | Forces Ca

Figure 3-2 Input data sheet (part 2)

Wind Pressure, Px & Py						
Surface	Z, (m)	qz, (N/m^2)	Px "θ=0", (N/m^2)		Py "θ=90°", (N/m^2)	
			+GCPi	-GCPi	+GCPi	-GCPi
Windward Wall	5	995.13	418.29	935.08	418.29	935.08
	9	1128.84	509.21	1026.00	509.21	1026.00
	13	1220.78	571.74	1088.53	571.74	1088.53
	17	1292.32	620.38	1137.17	620.38	1137.17
	21	1351.50	660.62	1177.41	660.62	1177.41
	26	1402.30	695.17	1211.96	695.17	1211.96
	29	1435.52	717.76	1234.55	717.76	1234.55
Leeward wall	-	1435.52	-868.49	-351.70	-914.13	-397.34

Figure 3-3 The design wind pressures on windward and leeward walls

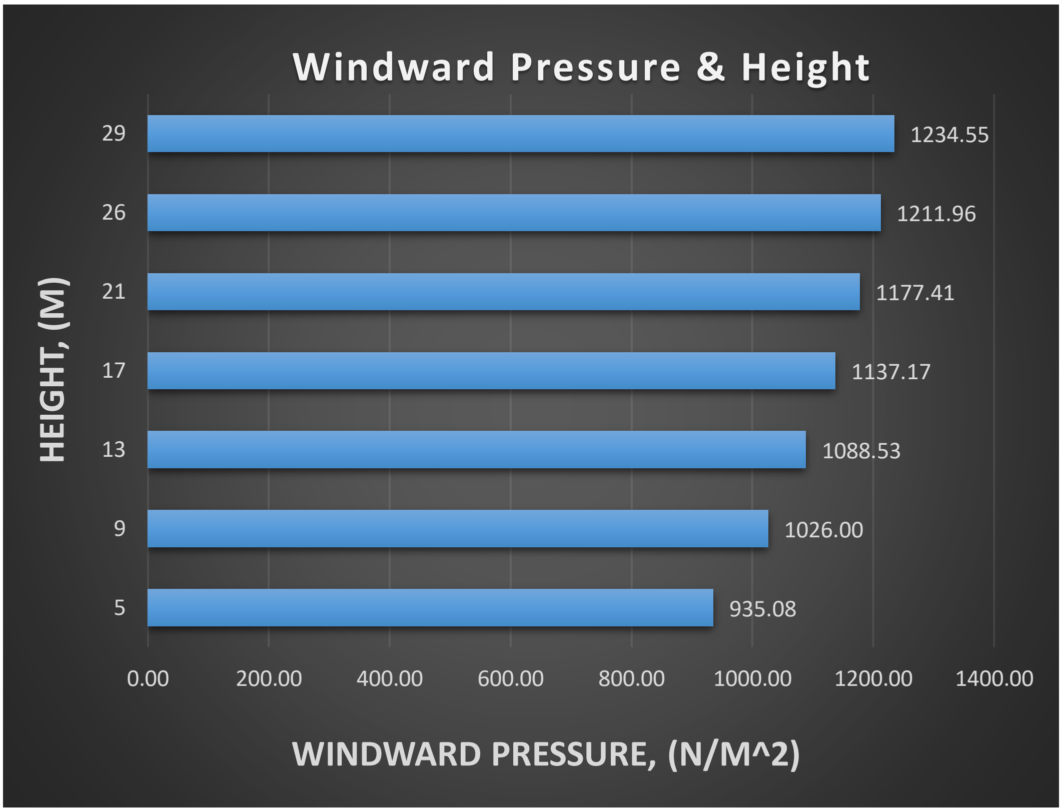


Figure 3-4 The design windward pressure along height of the building

Story Forces Case# 1-1 (θ=0°)				
Story #	**Tributary height, (m)**	**Fx, (KN)**	**Fy, (KN)**	**Mt, (KN.m)**
Story 1	4.55	79.04	-	-
Story 2	4.1	76.26	-	-
Story 3	4.1	79.72	-	-
Story 4	4.1	82.41	-	-
Story 5	4.1	84.64	-	-
Story 6	3.55	74.94	-	-
Story 7	1.5	32.12	-	-

Figure 3-5 Wind forces on the project model manually calculated for case #1

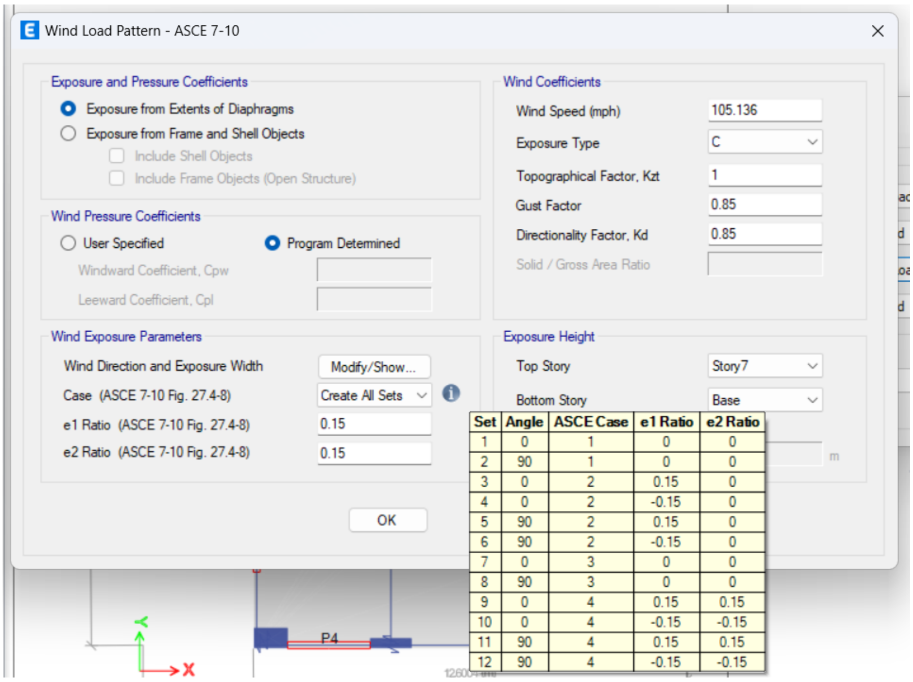


Figure 3-6 Modifying wind load pattern in ETABS

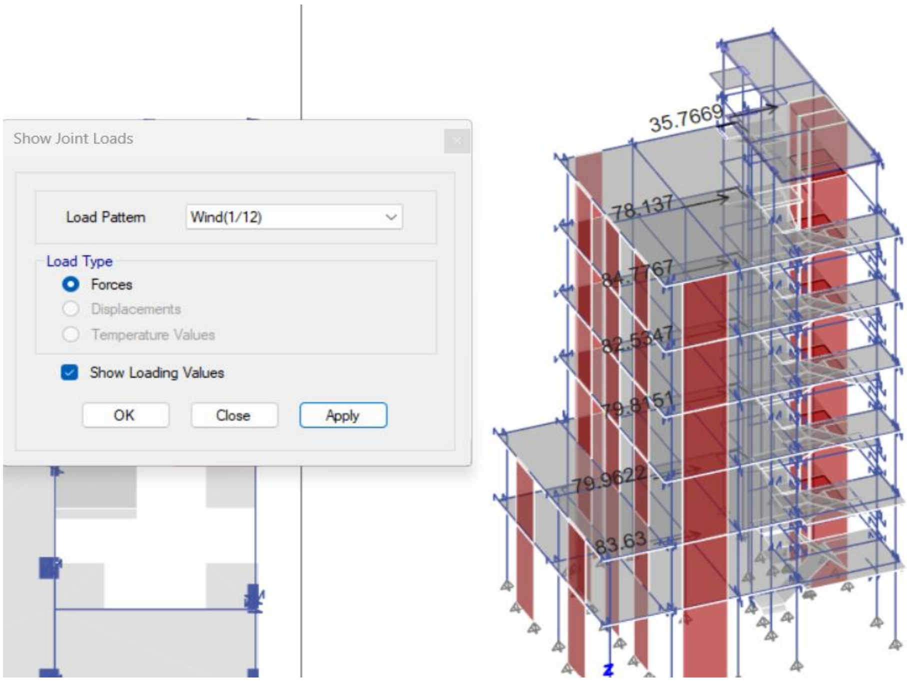


Figure 3-7 Wind forces on the project model results from ETABS for case 1

Table 3-4 Relative Error of manually computed wind forces for the project model

Relative error of manually computed wind force (load case 1) for the project model				
Story #	Manually computed wind force (KN)	ETABS wind force (KN)	Error	Relative Error, Er%
Story 1	79.04	83.63	4.59	5.4875394
Story 2	76.26	79.96	3.70	4.6322523
Story 3	79.72	79.81	0.09	0.116939
Story 4	82.41	82.53	0.12	0.1464826
Story 5	84.64	84.77	0.13	0.1574858
Story 6	74.94	78.13	3.19	4.0848331
Story 7	32.12	35.76	3.64	10.174349
Average				3.5428402

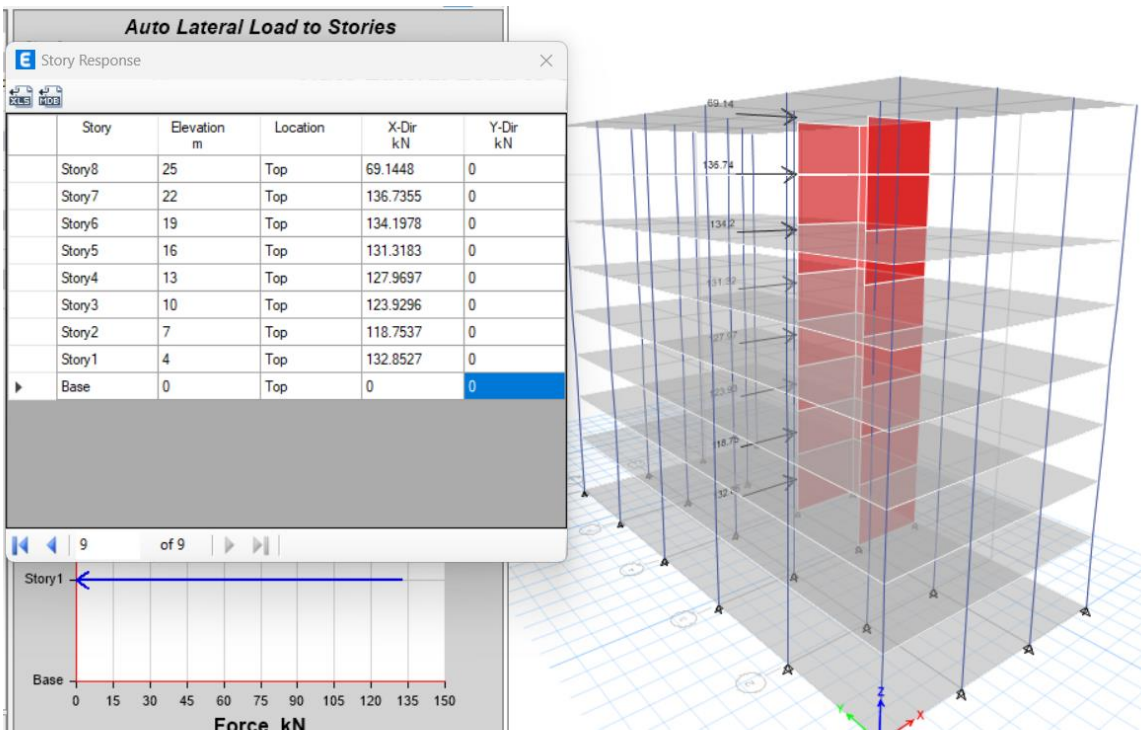


Figure 3-8 Wind forces on the simple model for load case 1 obtained from ETABS

Table 3-5 Relative Error of manually computed wind forces for the simple model

Relative error of manually computed wind force (load case 1) for the simple model				
Story #	Manually computed wind force (KN)	ETABS wind force (KN)	Error	Relative Error, Er%
Story 1	133.37	132.8527	-0.52	-0.3889892
Story 2	118.79	118.7537	-0.03	-0.0282323
Story 3	123.89	123.9296	0.04	0.035986
Story 4	127.89	127.9697	0.08	0.064706
Story 5	131.21	131.3183	0.10	0.079018
Story 6	134.08	134.1978	0.12	0.0871951
Story 7	136.61	136.7355	0.13	0.0923175
Story 8	69.44	69.1448	-0.29	-0.425933
Average				-0.0604915

3.3. Seismic Load

Seismic loads refer to the forces exerted on a structure during an earthquake or seismic event. These loads are caused by the ground shaking, ground displacement, and other seismic effects that occur due to the release of energy in the Earth's crust.

3.3.1. Earthquake maps

To commence, we need to ascertain the Mapped Spectral response acceleration (Ss) and Mapped Spectral response acceleration (S1) by referring to the seismic maps provided in the SBC 301. Figure 3-9 and Figure 3-10 show Ss and S1 maps where the red dot represents the building location.

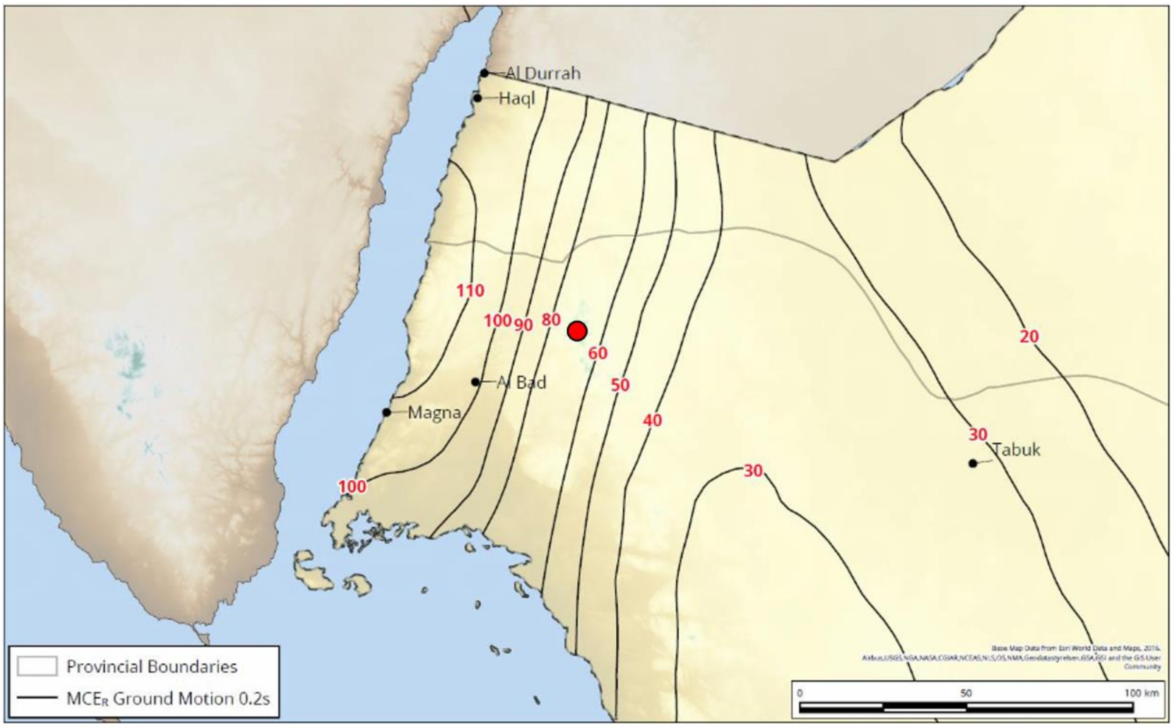


Figure 22-1a: S_S Risk-Targeted Maximum Considered Earthquake (MCE_R) ground motion for 0.2 s spectral response acceleration (5% of critical damping), site class B, North-West (NW-SA).

Figure 3-9 Spectral response acceleration (Ss)

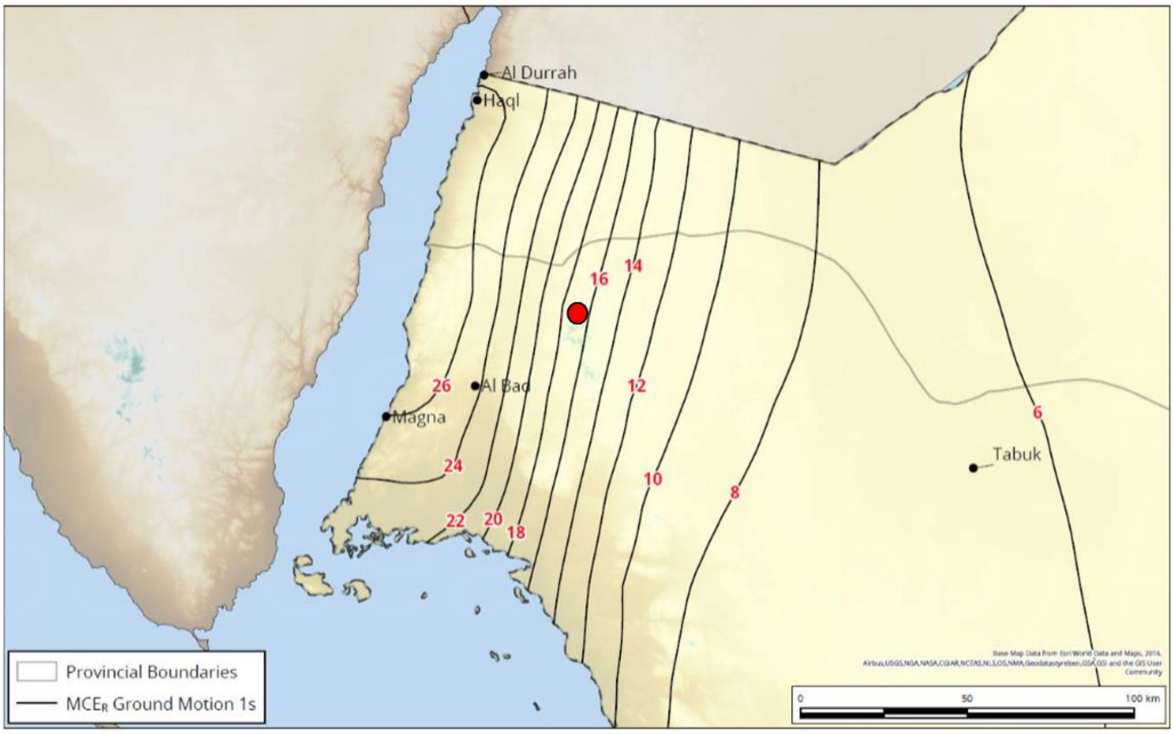


Figure 22-2a: S_1 Risk- Targeted Maximum Considered Earthquake (MCE_R) ground motion parameter for 1 s spectral response acceleration (5% of critical damping), site class B, North-West (NW-SA)..

Figure 3-10 Spectral response acceleration (S1)

3.3.2. Equations and parameters

The needed equations to calculate the seismic loads are as follows:

- ❖ The spectral response acceleration parameters for short periods (S_{ms}) and at 1 second (S_{m1}):

$$S_{ms} = F_a \times S_S \tag{3-6}$$

$$S_{m1} = F_v \times S_1 \tag{3-7}$$

Where:

S_{ms} & S_{m1}: are adjusted response parameters -site class effect (Short period & at 1 second period).

F_a & F_v: are site coefficient and their values are obtained from SBC 301, Tables 11-1 and 11-2.

- ❖ Earthquake spectral response acceleration parameters at short period (S_{DS}) and at 1 second period (S_{D1}):

$$S_{DS} = \frac{2}{3} \times S_{ms} \tag{3-8}$$

$$S_{D1} = \frac{2}{3} \times S_{m1} \tag{3-9}$$

Where:

S_{DS} & S_{D1}: are design spectral response acceleration parameter (Short period and at 1 second period).

- ❖ Seismic base shear:

$$V = C_S \times W \tag{3-10}$$

$$C_S = \frac{S_{DS}}{(R / I_e)} \tag{3-11}$$

The value of C_S calculated above should not exceed the following:

$$C_S = \frac{S_{D1}}{(\mathrm{T} \times (R / I_e))} \quad For \quad T \leq T_L \tag{3-12}$$

$$C_S = \frac{S_{D1} \times T_L}{(\mathrm{T}^2 \times (R / I_e))} \quad For \quad T \geq T_L \tag{3-13}$$

And C_S shall not be less than:

$$C_S = 0.044 \times S_{DS} \times I_e \quad \geq 0.01 \tag{3-14}$$

Where:

V: The seismic base shear (kN).

C_S: Seismic Response Coefficient.

W: The effective seismic weight per Section.

R: Response modification coefficient (SBC 301, table 12-1).

I_e: Importance Factor (Table 1-3).

T: Fundamental T obtained from ETABS.

T_L: Long Period-transition period (SBC 301, Figure 22.4)

❖ Vertical distribution of seismic forces:

$$F_x = C_{vx} \times V \tag{3-15}$$

$$C_{vx} = \frac{w_x \times h_x^k}{\sum_{i=1}^{n} w_i \times h_i^k} \times h_n \tag{3-16}$$

Where:

F_x: Lateral seismic force (kN).

C_{vx}: Vertical distribution factor.

w_x , w_i: Portion of weight that is located at or assigned to level i or x.

h_x , h_i: The height above the base to level i or x respectively.

k: Distribution exponent (Sec 12.8.3)

h_n: Structural height.

❖ Approximate fundamental period:

$$T_a = C_t \times h_n^{\,x} \tag{3-17}$$

Where:

T_a: Approximate fundamental period (SBC 301, 12.8.2.4.1 - Equation 12-18).

C_t: Approximate period parameter (SBC 301, Table 12-7).

x: Approximate period parameter (SBC 301, Table 12-7).

3.3.3. Excel sheets and ETABS results for seismic load

A spreadsheet was created in Excel to calculate the lateral seismic forces acting on the building as per the SBC code. The results were then compared with the results obtained from ETABS, as the following figures show:

Senior Design Project CE492			
Location	Al' ola		
Building height, (m)	28.8		
Number of stories	7		
Seismic Design Parameters			**Source From SBC**
Occupancy Group	B		SBC 201-sec 3.4
Risk occupancy category	II		SBC 301-Table 1-1
Importance Factor	Ie	1.000	Table 1-3
Site Classification	B		11.4.2.2
Mapped Spectral response acceleration (Short period)	Ss	0.700	Figure 22-1a
Mapped Spectral response acceleration (1-sec period)	S1	0.180	Figure 22-2a
Site coefficient	Fa	1.000	Table 11-1
Site coefficient	Fv	1.000	Table 11-2
Adjusted response parameters -site class effect (Short period)	Sms	0.700	11.4.3.1- Equation 11-1
Adjusted response parameters-site class effect (1-sec period)	Sm1	0.180	11.4.3.1- Equation 11-2
Design Spectral response acceleration parameter (Short period)	SDs	0.467	11.4.4.2 Equation 11-3
Design Spectral response acceleration parameter (1-sec period)	SD1	0.120	11.4.4.2 Equation 11-4
Seismic Design Category	C	B	Tables 11-3 & 11-4
Final Seismic Design Category	C		
0.2 (SD1/SDs)	T0	0.051	11.4.5
SD1/SDs	Ts	0.257	11.4.5
Long Period-transition period	TL	6.000	Figure 22-4
Approximate period parameter	Ct	0.049	Table 12-7
Approximate period parameter	x	0.750	Table 12-7
Approximate Fundamental period	Ta	0.607	12.8.2.4.1 - Equation 12-18
Approximate Fundamental period	Ta	0.700	12.8.2.4.2 - Equation 12-19
Response modification coffecient	R	4.000	Table 12-1
Coffecient for upper limit	Cu	1.660	Table 12-6
Maximum time period (Cu * Ta)	T max	1.007	Section 12.8.2.2
Fundemntal T obtained from ETABS (X-direction)	T	0.912	
Fundemntal T obtained from ETABS (Y-direction)	T	0.724	
T Used (X-direction)	T	0.912	
T Used (Y-direction)	T	0.724	

Figure 3-11 Input data

Story	Height	Weight (kN)	Wi * hi^k (X-Direction)	Wi * hi^k (Y-Direction)
Story7	28.8	798.5023575	45951.90738	33505.85071
Story6	25.5	2737.719539	136043.0666	100337.1211
Story5	21.4	3134.347438	126074.1783	94529.47627
Story4	17.3	3134.347438	97550.77772	74619.85529
Story3	13.2	3134.347438	70397.83397	55236.39763
Story2	9.1	3694.180353	52981.22718	43049.89758
Story1	5	4047.317526	28191.94911	24233.82249
Sum	28.8	20680.76209	557190.9403	425512.4211

Figure 3-12 The height and weight of each story obtained from ETABS

EQUIVALENT LATERAl FORCE PROCEDURE (X-Direction) :						
Seismic Response Coefficent	C_s	0.117				
Max Seismic Response Coefficent	C_s	0.033	If $T \le T_L$			
Max Seismic Response Coefficent	C_s	0.216	if T > TL			
Min Seismic Response Coefficent	Min C_s	0.021	≥ 0.01			
Used Seismic Response Coefficent	Used C_s	0.0329				
The effective seismic weight per Section	W (kN)	20680.76209				
The seismic base shear	V (kN)	680.29				
An exponent related to the structure period	K	1.206			ETAB Results	Error (%)
Vertical disturbution factor Cvx and Lateral seismic force Fx	Cv1	0.051	F1	34.42	34.41	0.03
	Cv2	0.095	F2	64.69	64.6702	0.02
	Cv3	0.126	F3	85.95	85.9321	0.02
	Cv4	0.175	F4	119.10	119.0795	0.02
	Cv5	0.226	F5	153.93	153.9006	0.02
	Cv6	0.244	F6	166.10	166.0723	0.02
	Cv7	0.082	F7	56.10	56.0956	0.01

Figure 3-13 Output results and the comparison with ETABS

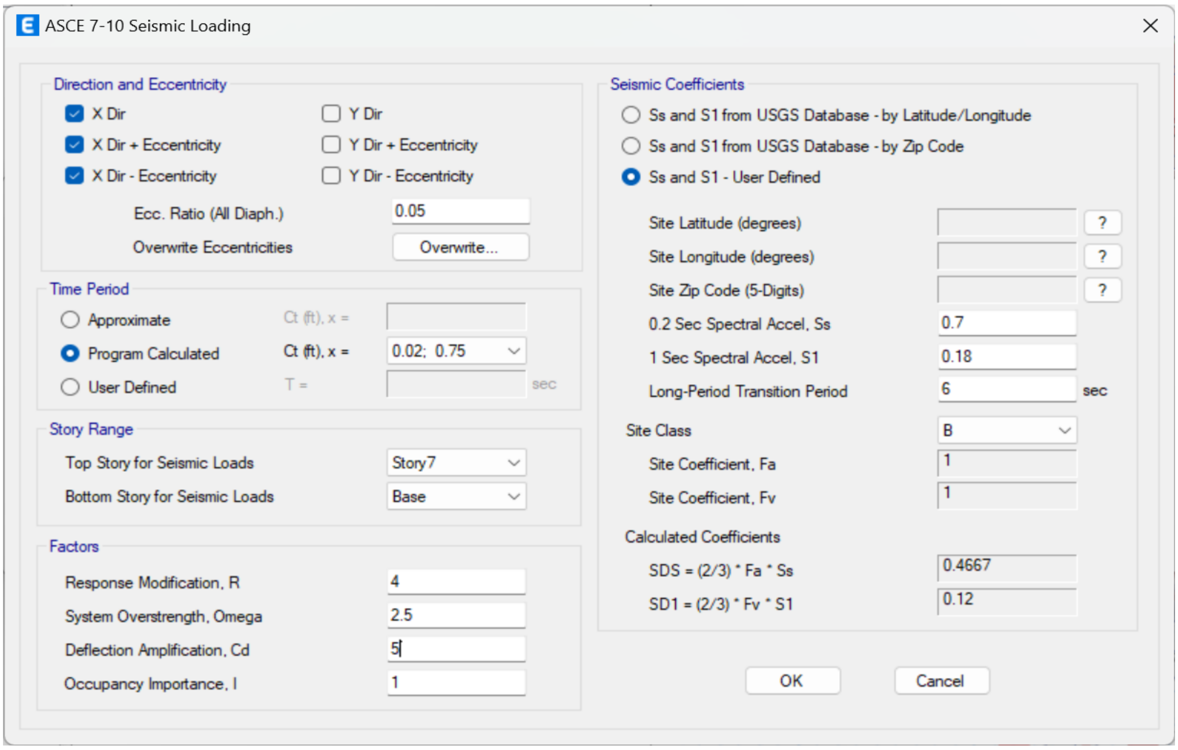


Figure 3-14 The defining of the seismic load in x-direction in ETABS

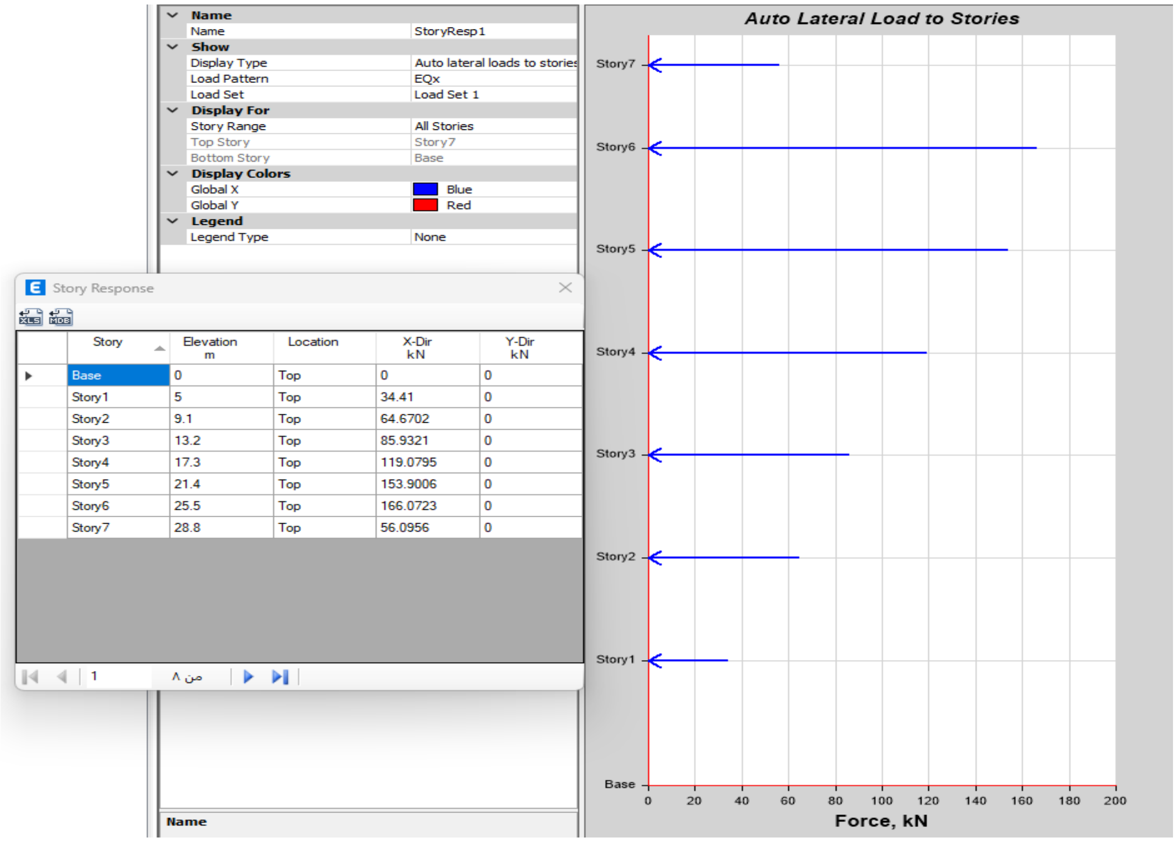


Figure 3-15 ETABS result

CHAPTER 4. DESIGNING OF BUILDING STRUCTURE

4.1. Design Steps

- ❖ Definition of the layout in plan and height of the structure.
- ❖ Calculation of the gravity and lateral loads that act on the structure.
- ❖ Definition of an appropriate floor system.
- ❖ Setting the dimensions of beams and the thickness of slabs.
- ❖ Calculation of the reinforcement for all the members.
- ❖ Production of the structral drwaings and specification.

4.2. Defining the materials

Figures 4-1, 4-2, 4-3 and 4-4 show the material defined in ETABS.

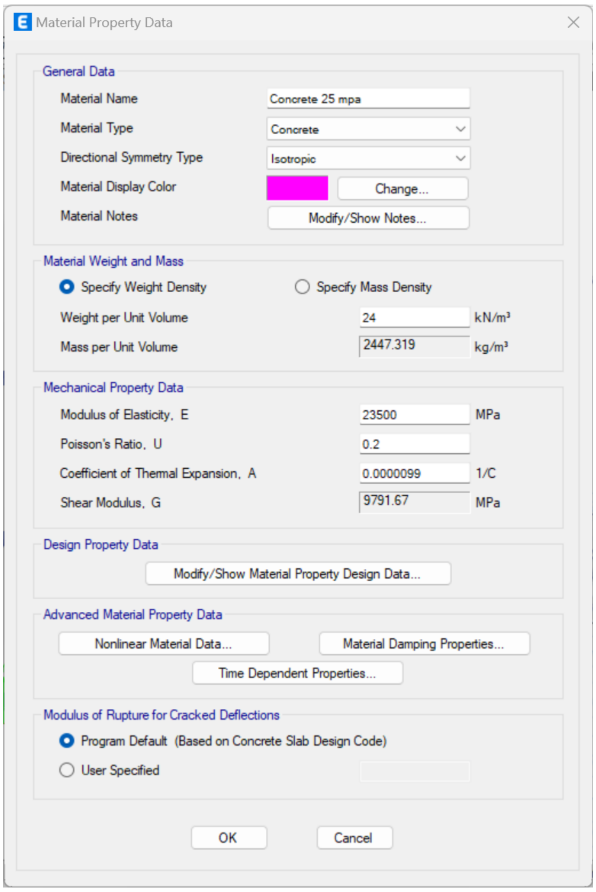


Figure 4-1 Concrete property

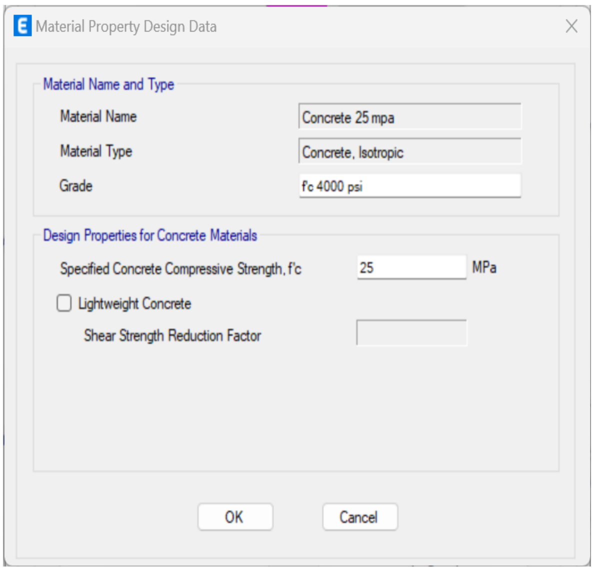


Figure 4-2 Concrete design property

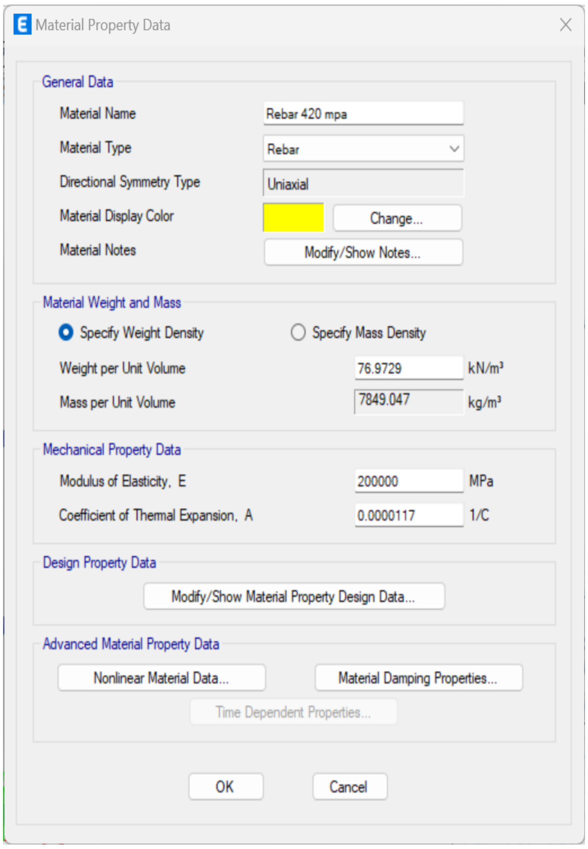


Figure 4-3 Rebar property

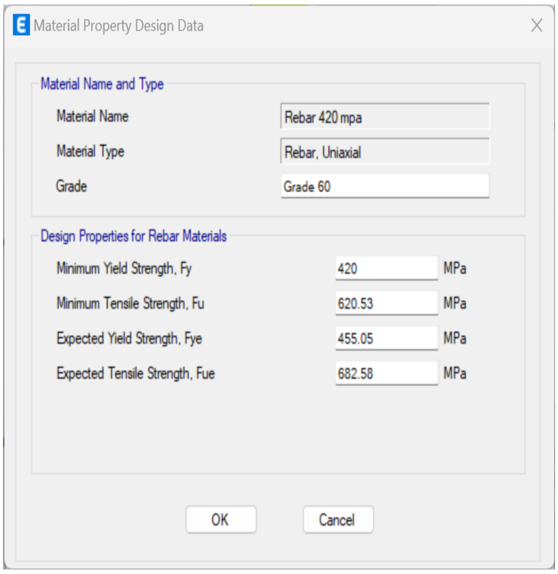


Figure 4-4 Rebar design property

4.3. Defining the structural system

4.3.1. Beams

Figure 4-5 shows the beam property.

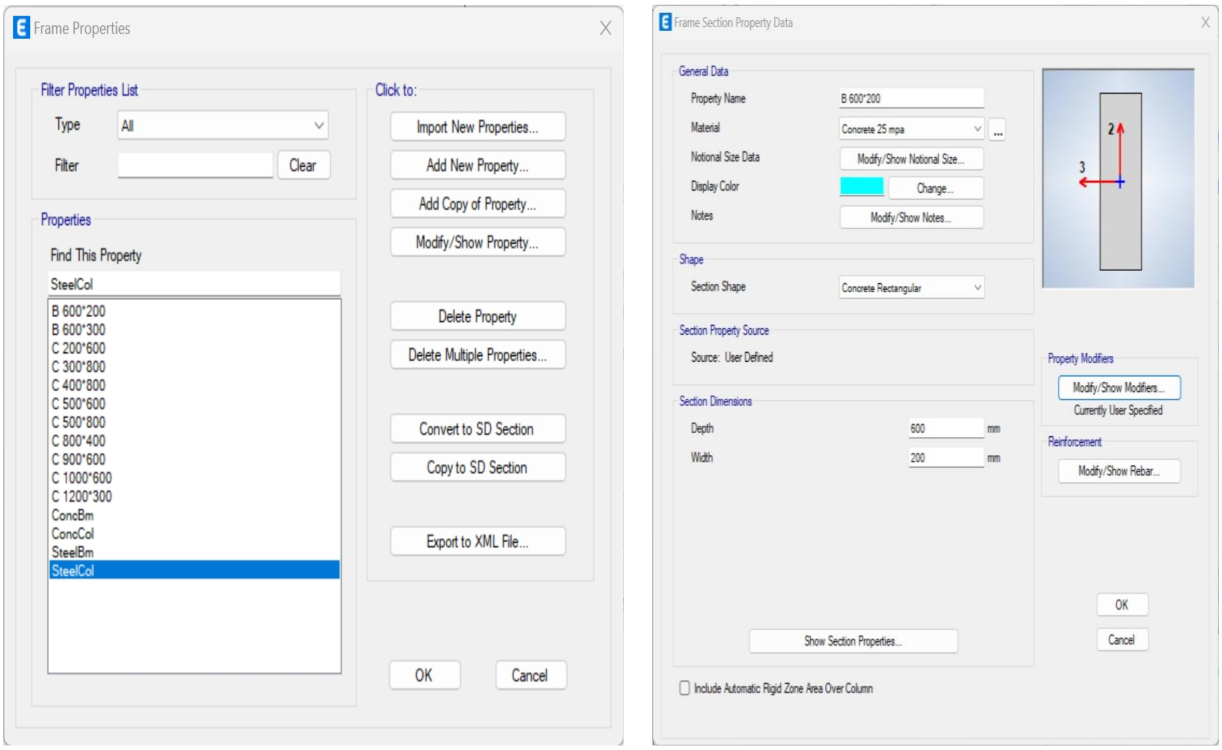


Figure 4-5 Beam property

4.3.2. Columns

The column sizes were given in the architectural plan as mentioned in chapter 1. Figure 4-6 shows the column property.

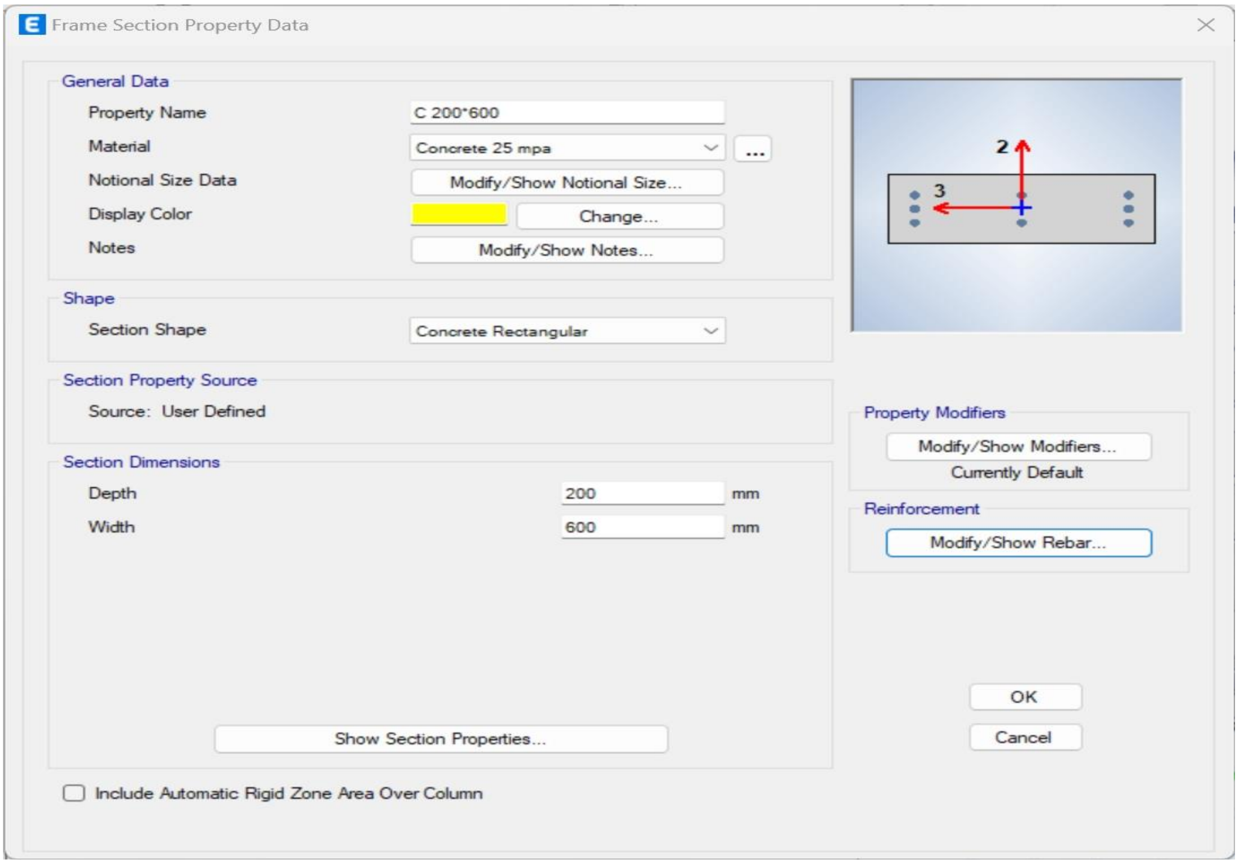


Figure 4-6 Column Property

4.3.3. Slabs

There will be two models for design in this project one with flat slab and the other with solid. The minimum thickness for flat slab for edge beam without drop panels is [1]:

$$M_n = \Phi \times A_s \times f_y \times \left(d - \frac{a}{2}\right) \qquad (4\text{-}1)$$

Where:

L_n: The maximum clear span.

The thickness for the flat slab is 220 mm (because the long-term deflection is not in the boundary with less thickness) and for the solid slab 180 mm is selected for its thickness. Figures 4-7 and 4-8 show the slab properties.

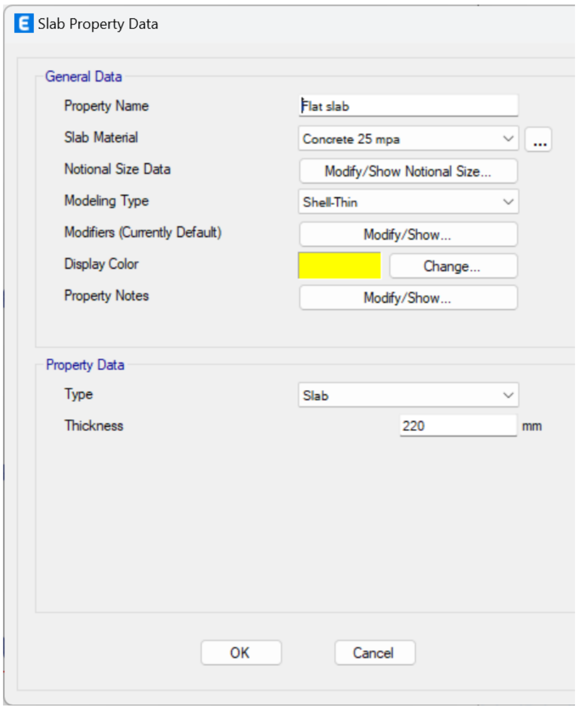


Figure 4-7 Flat slab property

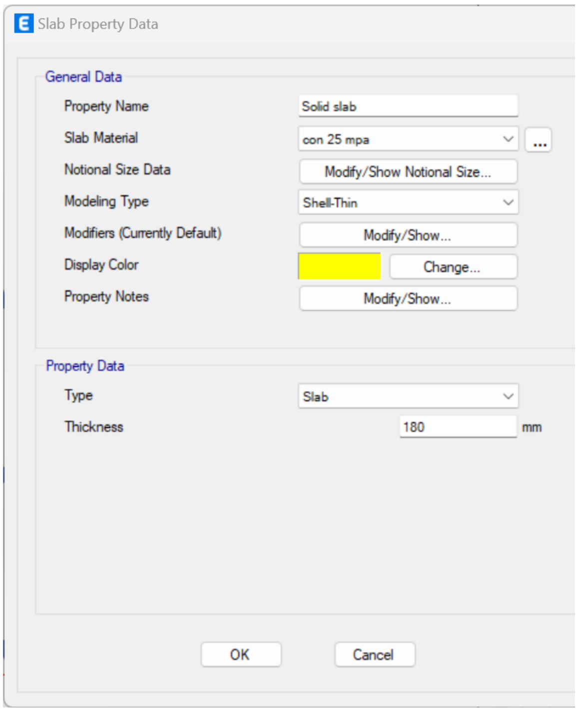


Figure 4-8 Solid slab property

4.3.4. Shear walls

Structural shear walls are vertical elements designed to resist lateral loads and distribute them to the building's foundation, providing stability and reducing the building's sway during seismic events or wind forces. Figure 4-9 shows the defining of the piers.

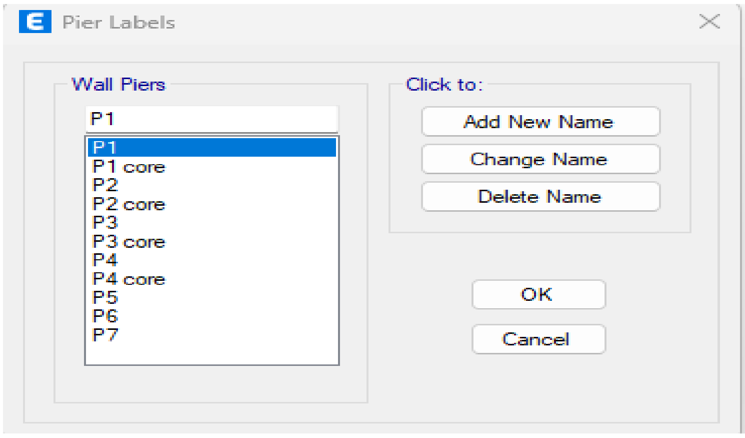


Figure 4-9 Defining piers

4.4. Check model

Once the DXF file has been imported and all the elements have been drawn, it is important to check the model for any warnings. It is better to address any issues early on. Figure 4-10 shows the model check.

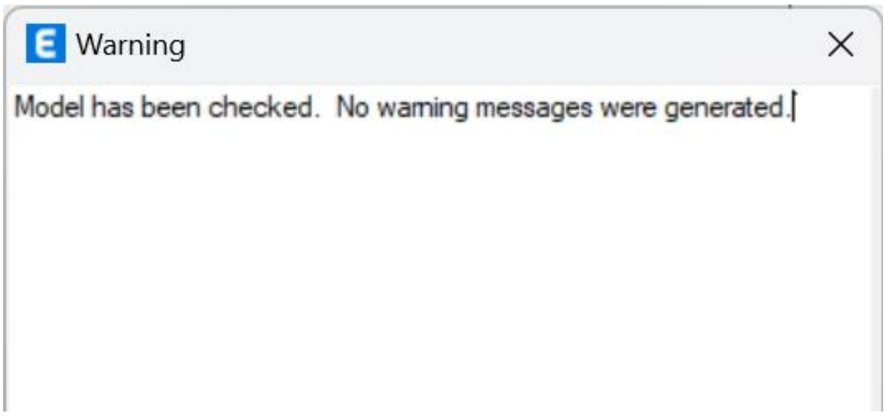


Figure 4-10 Model check

4.5. Defining and assigning the loads

4.5.1 Load patterns

Figure 4-11 shows the load patterns set in ETABS. 1 selected for the own weight meaning that the etabs will calculate the own weight of the structure.

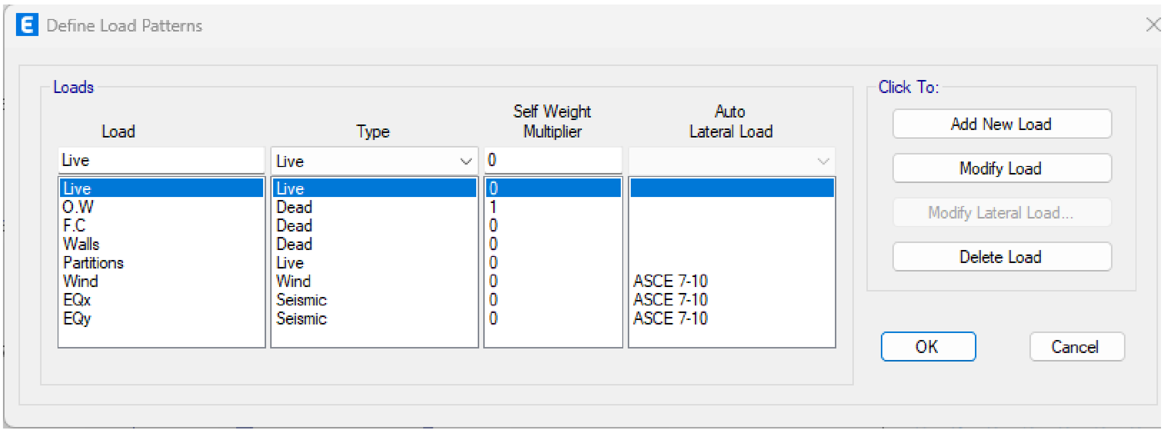


Figure 4-11 Load patterns

4.5.2. Load combination

Figure 4-12 shows the load combination inserted in etabs. The ultimate load which is [1.4 D.L + 1.7 L.L] is the one that will be used for the design.

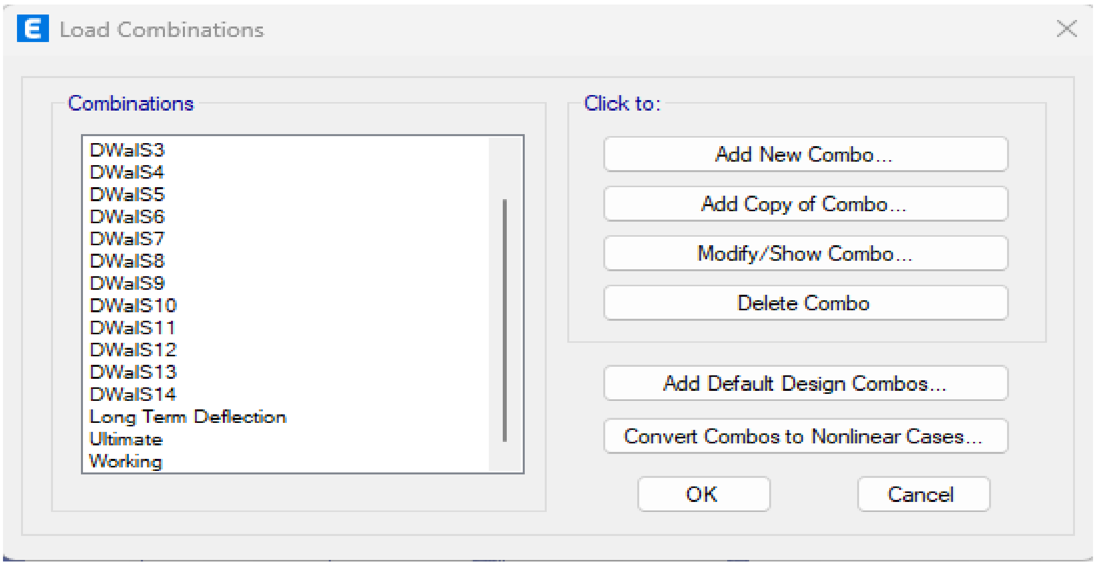


Figure 4-12 Load combination

4.5.3. Assigning the loads

The loads that are calculated in chapter 3 are assigned in etabs. Figures 4-13, 4-14, 4-15 and 4-16 show the shell loads assigned in etabs.

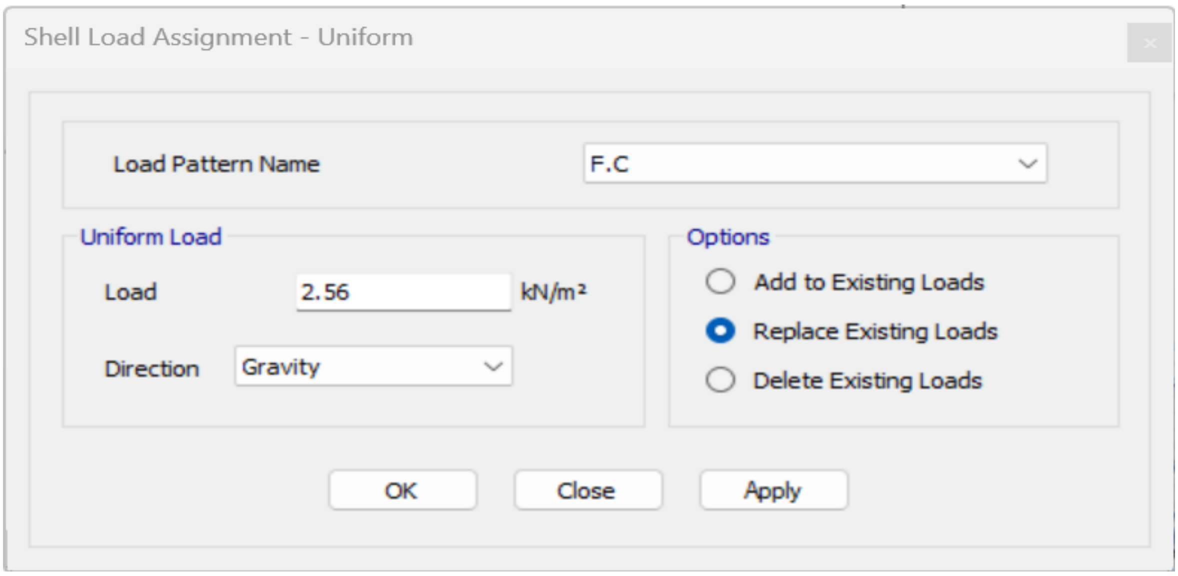


Figure 4-13 Floor finishes

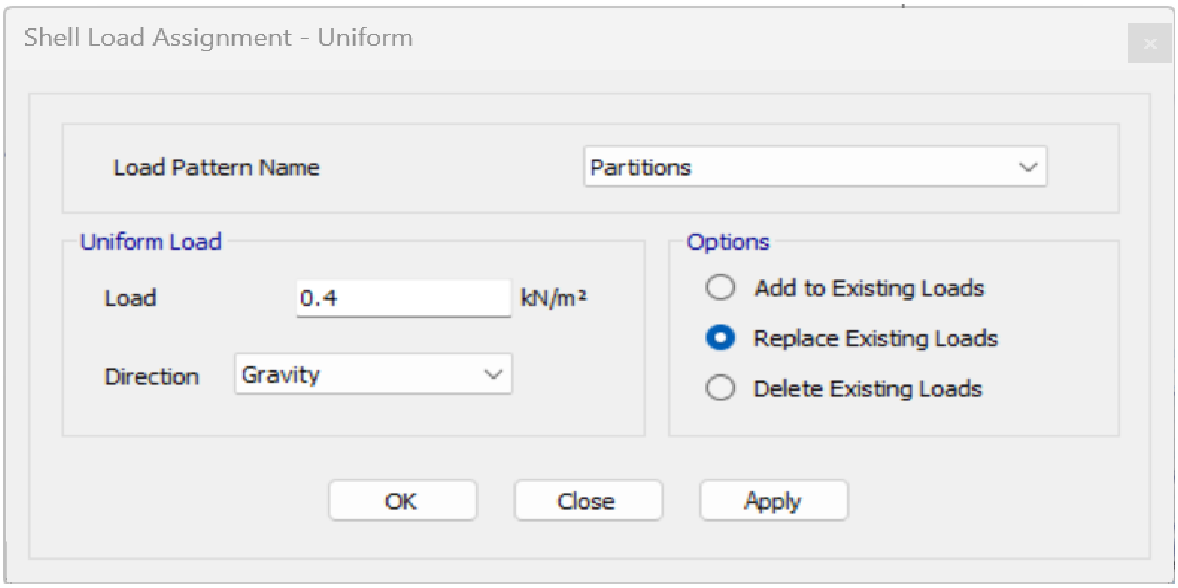


Figure 4-14 Partition

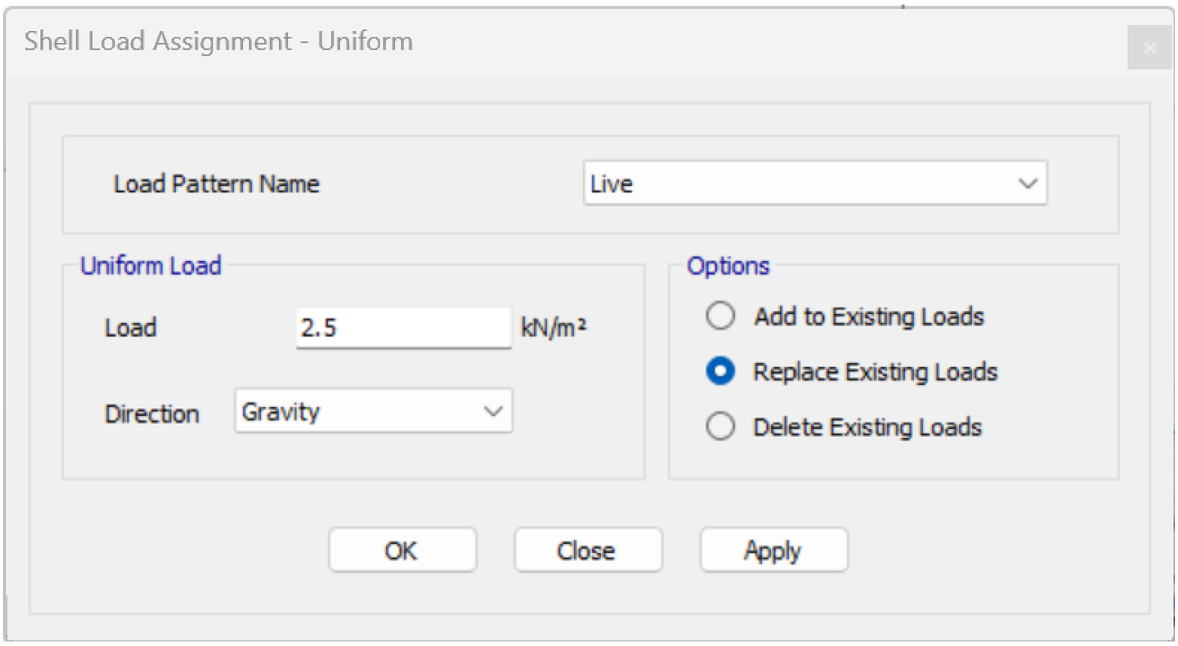


Figure 4-15 Live loads for the floors

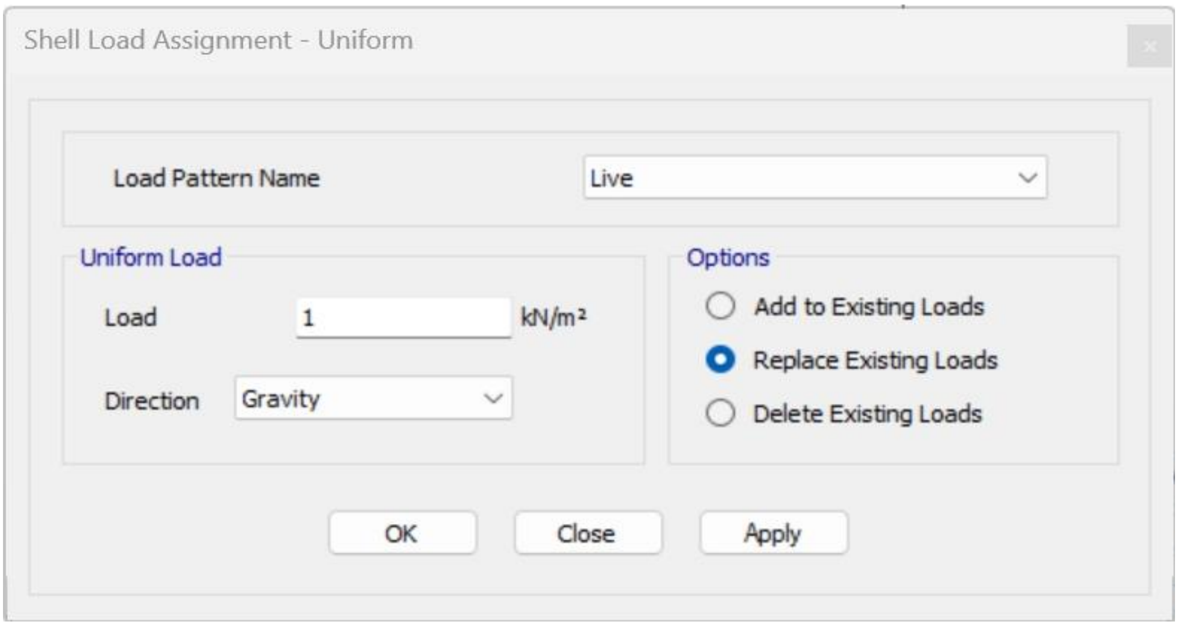


Figure 4-16 Live load for the roofs

Figure 4-17 shows the load of the edge walls that are assigned to the beams.

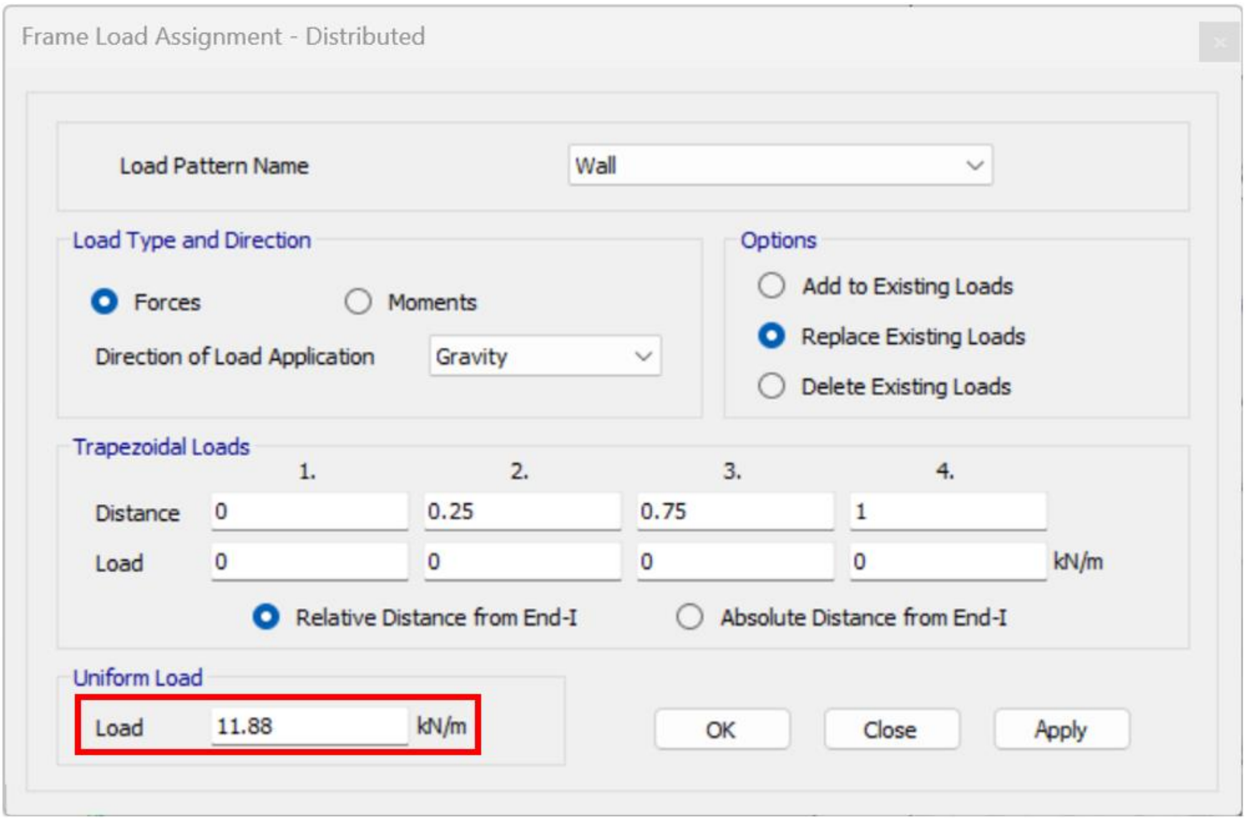


Figure 4-17 Walls load

4.6. Check long term deflection

According to the SBC 304 [1] maximum permissible computed deflection for a roof or floor construction supporting or attached to nonstructural elements not likely to be damaged by large deflections is:

$$\frac{L_n}{240} = \frac{6150}{240} = 25.625\,mm$$

Where L is the maximum span length between the faces of the support. Long term deflection**:** Short-term deflection refers to the immediate deformation of a structural building member under applied loads, while long-term deflection refers to the gradual deformation that occurs over time due to factors such as creep and shrinkage of the materials. According to ACI 318 [3],

LONG TERM DEFLECTION– is the summation of immediate deflection for 75% Live load: (Dead Load + Superimposed Dead Load + Live Load) – (Dead Load + Superimposed Dead Load + 0.25 Live Load) and Long-Term Deflection for Dead Load + Superimposed Dead Load + 25% Sustained Live Load. To calculate it in ETABS, there are three cases that have to be defined:

4.6.1 Case 1: Immediate all loads:

Figure 4-18 shows the load data for case 1.

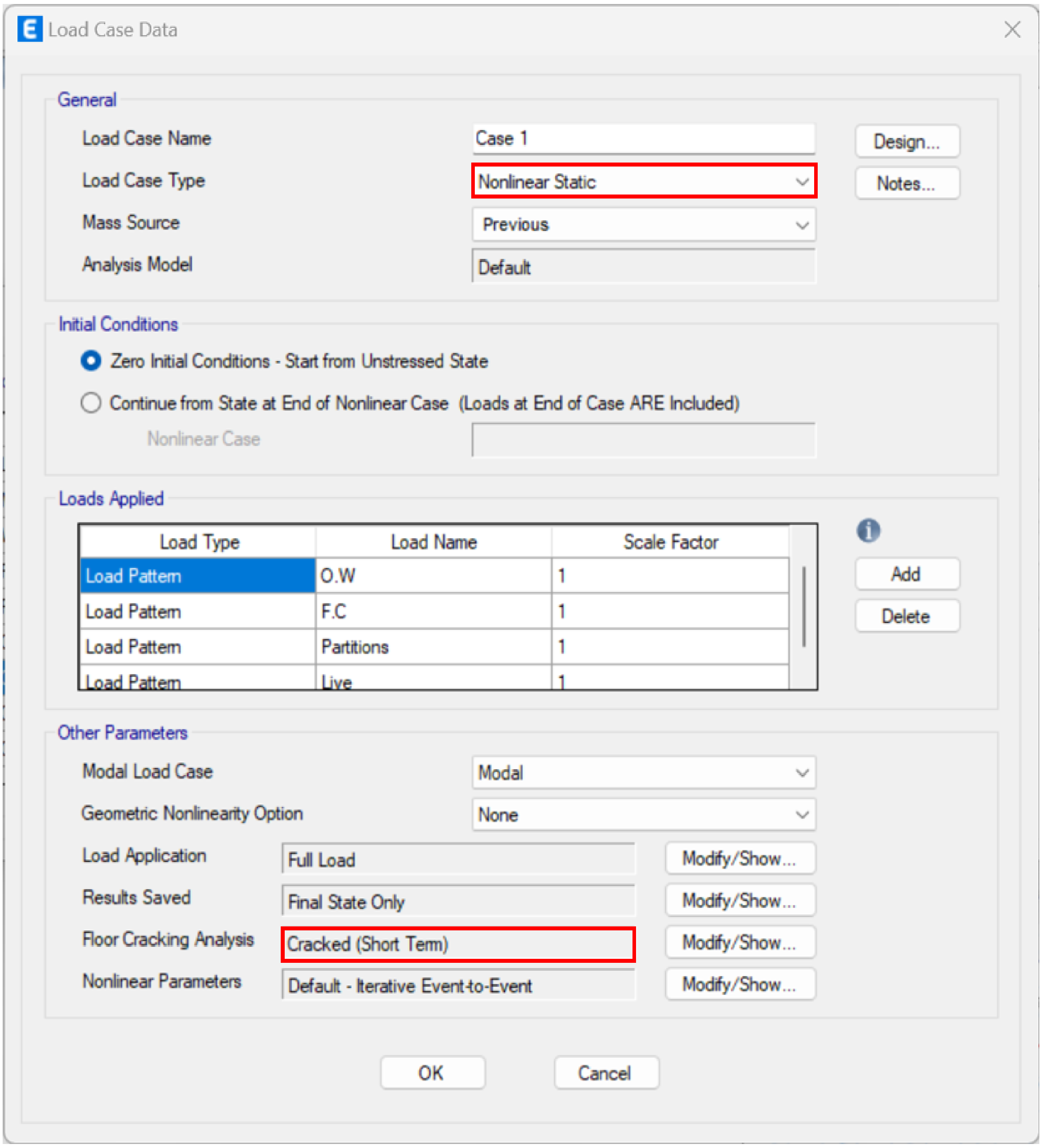


Figure 4-18 Case 1

4.6.2 Case 2: Immediate sustained loads:

Figure 4-19 shows the load data for case 2.

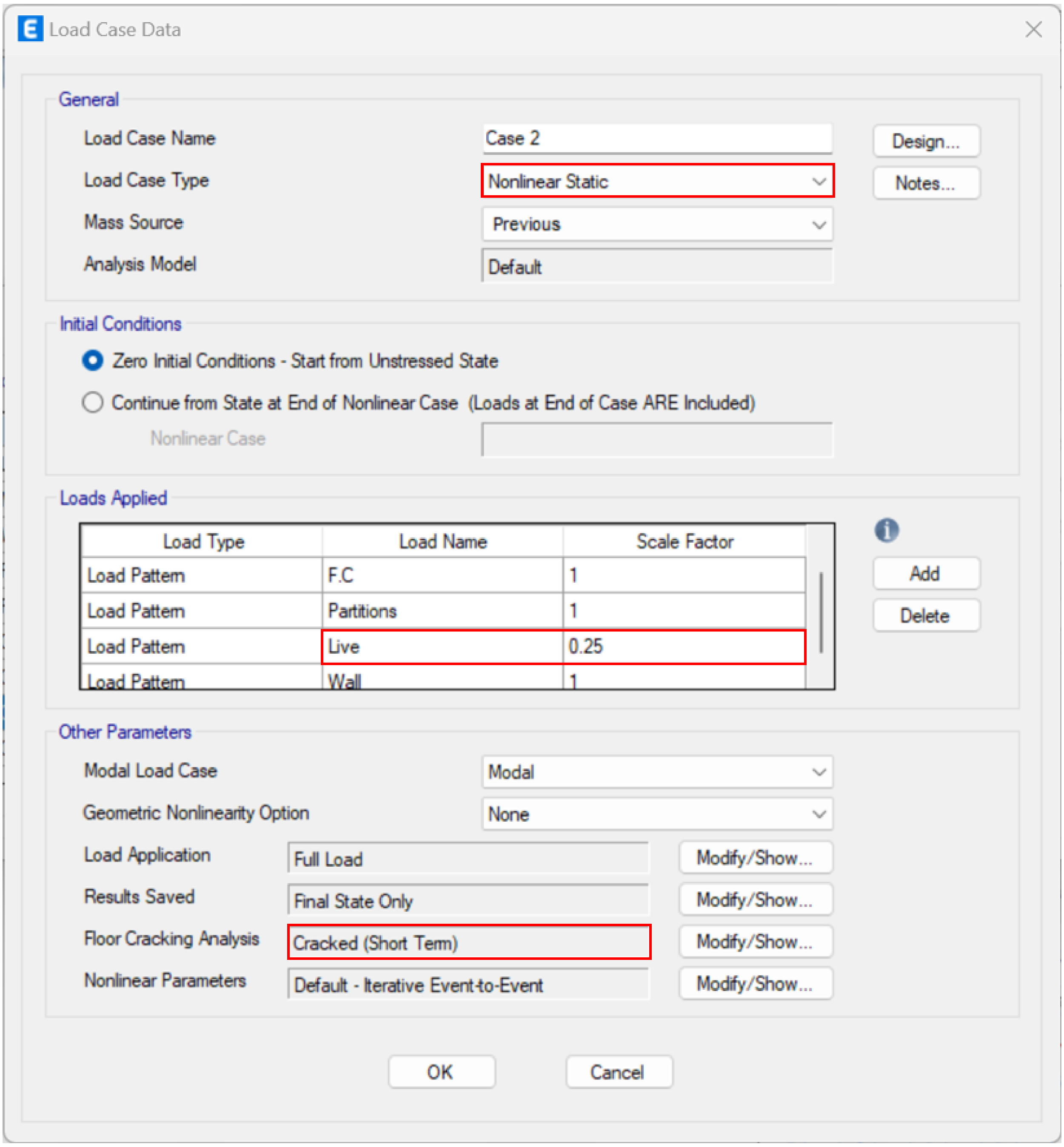


Figure 4-19 Case 2

4.6.3 Case 3: Long - term sustained loads:

Figure 4-20 shows the load data for case 3.

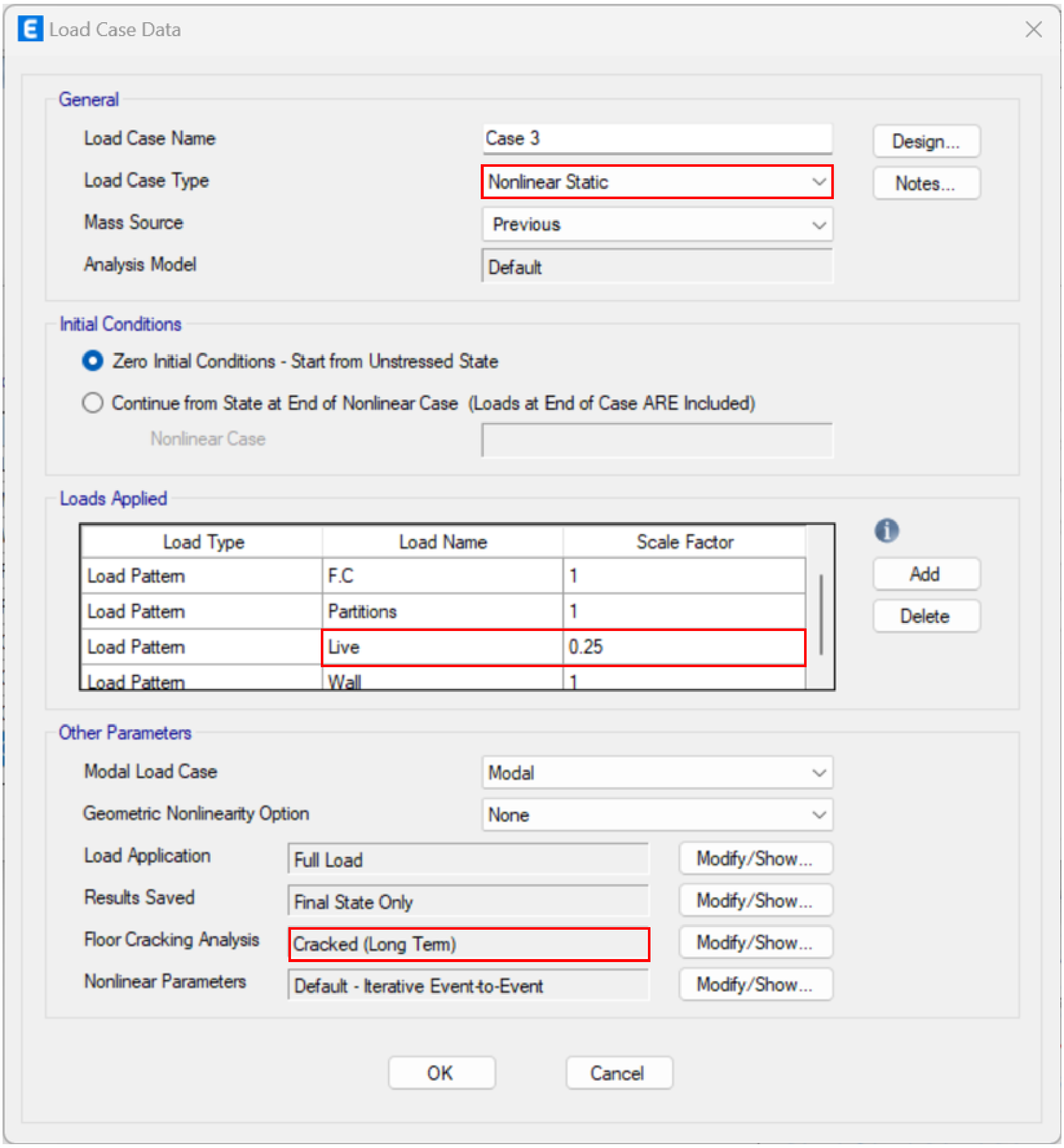


Figure 4-20 Case 3

4.6.4 Load combination for long term deflection

The load combination for long term deflection is shown in Figure 4-21.

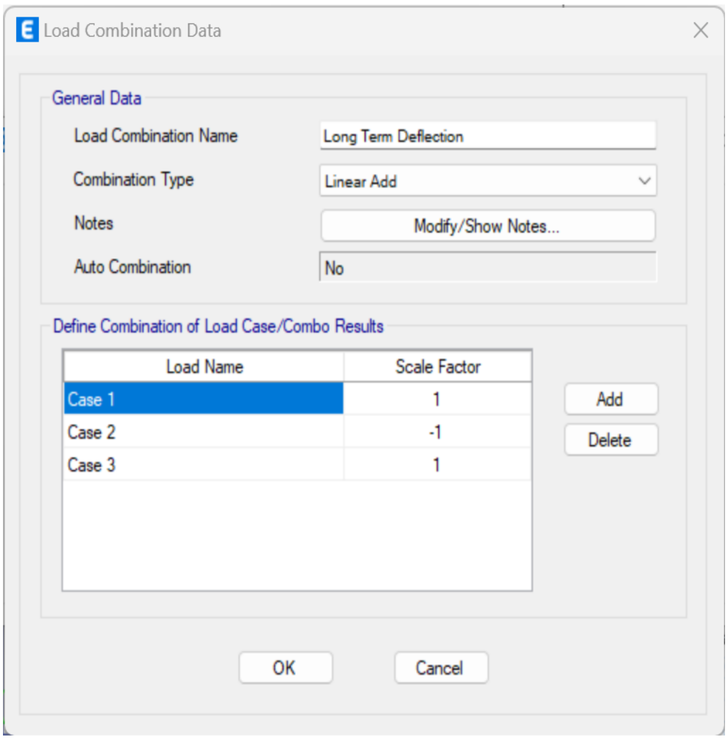


Figure 4-21 Long term deflection combination

4.6.5 Check deflection limits

Once all the load cases and combinations have been established, it is necessary to check the long-term deflection of the model to ensure that it falls within the permissible limits of deflection.

The maximum deflection calculated for flat slab is 21.315 mm as Figure 4-22 shows which is less than the allowable deflection calculated earlier 25.625 mm.

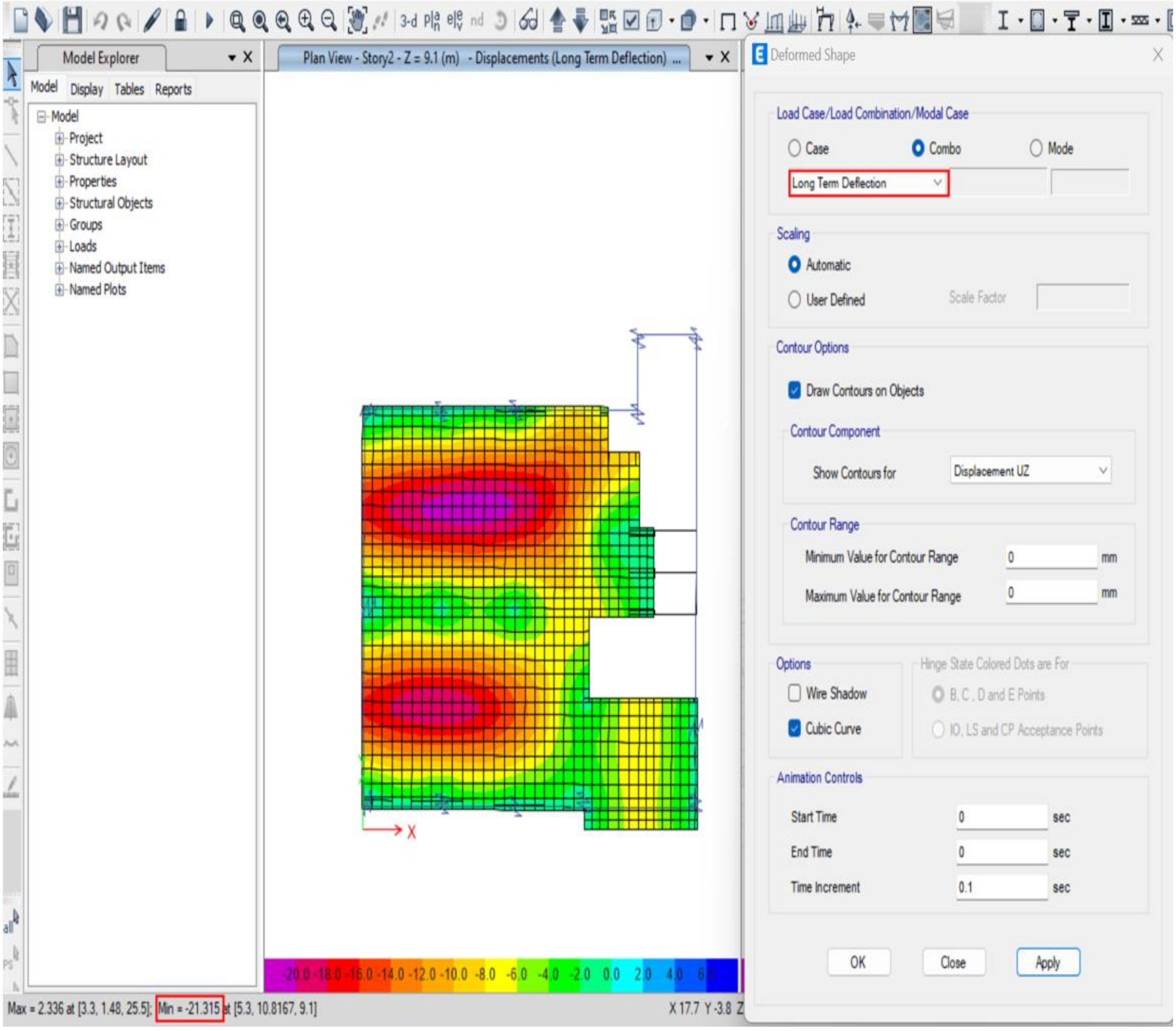


Figure 4-22 Flat slab long term deflection

The maximum deflection calculated for solid slab is 22.334 mm as Figure 4-23 shows which is less than the allowable deflection calculated earlier 25.625 mm. Thus, the long-term deflection is safe for both models according to the limit provided by SBC 304.

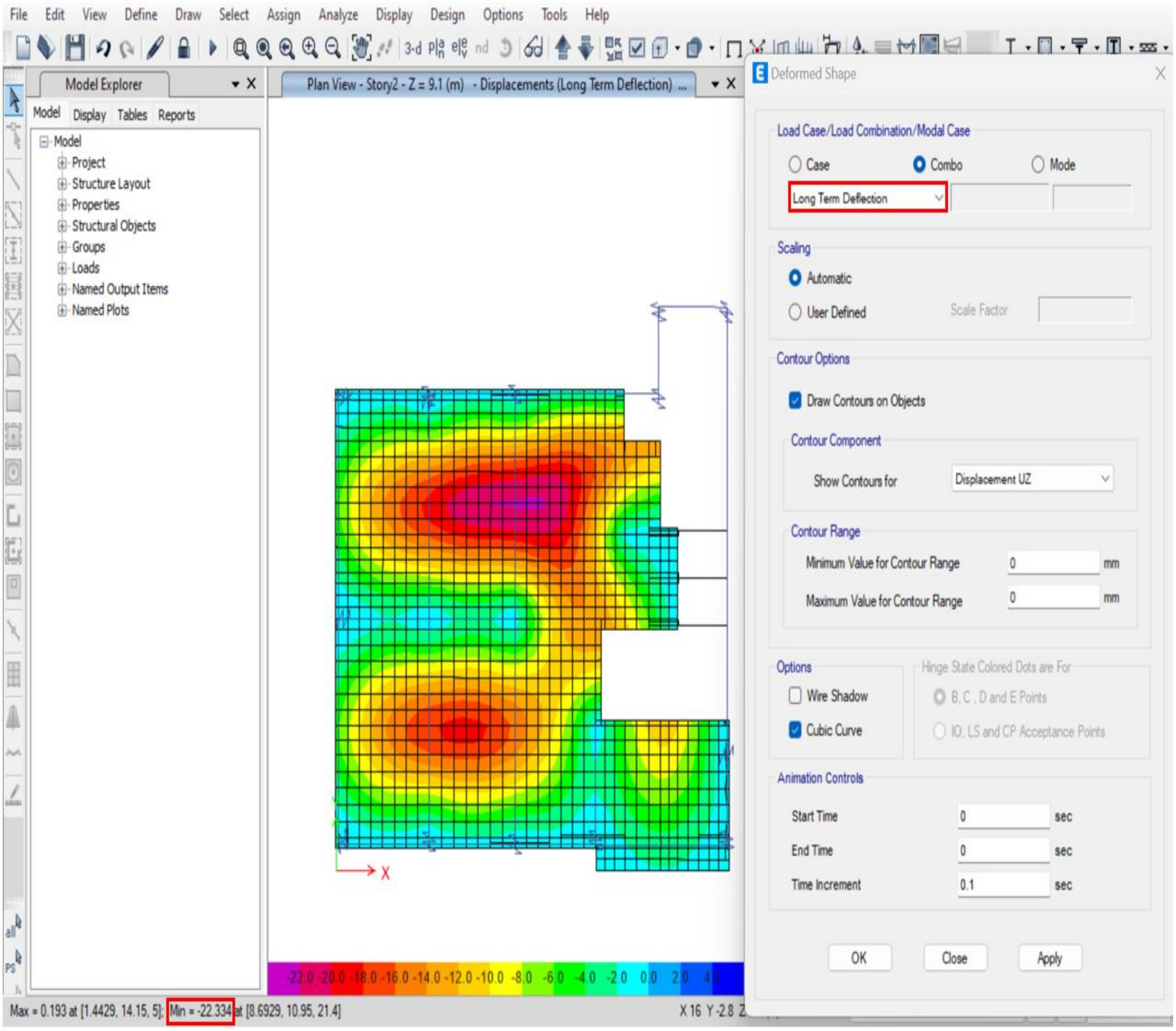


Figure 4-23 Solid slab long term deflection

4.7. Slab design

The finite element method was used to design the slabs, as the strip base method was not applicable due to the model not meeting its requirements. Figure 4-24 shows the finite element based in etabs.

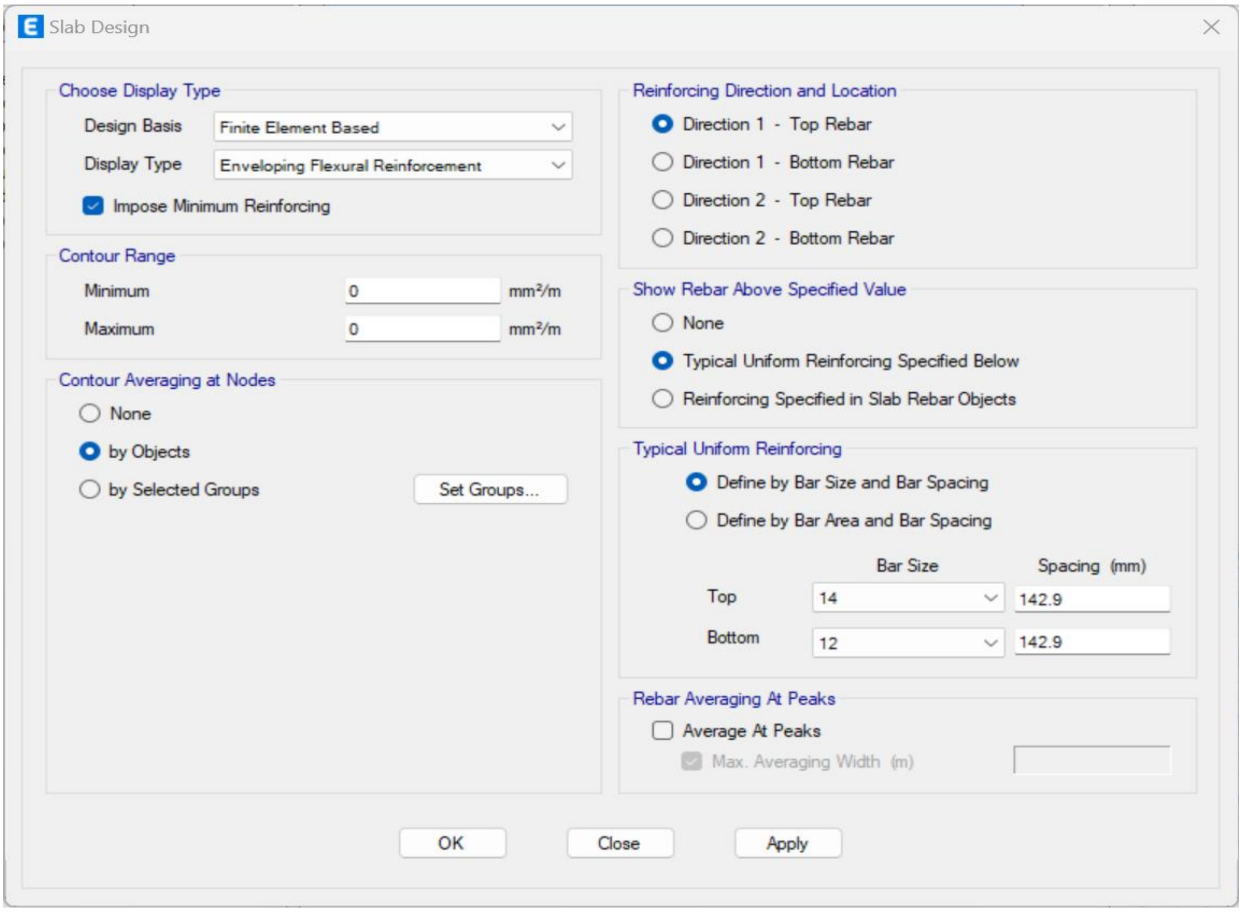


Figure 4-24 Finite element method

4.7.1. Flat slab design

For top reinforcement Φ14 is selected and for bottom reinforcement Φ12. Figures 4-25 and 4-26 show the top reinforcement design for both directions.

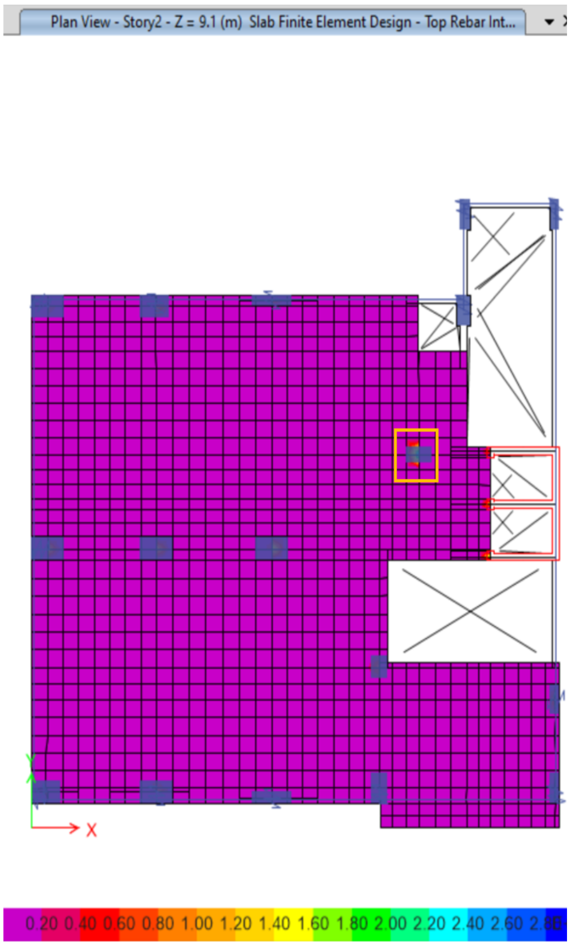


Figure 4-25 Flat slab top rebar direction 1

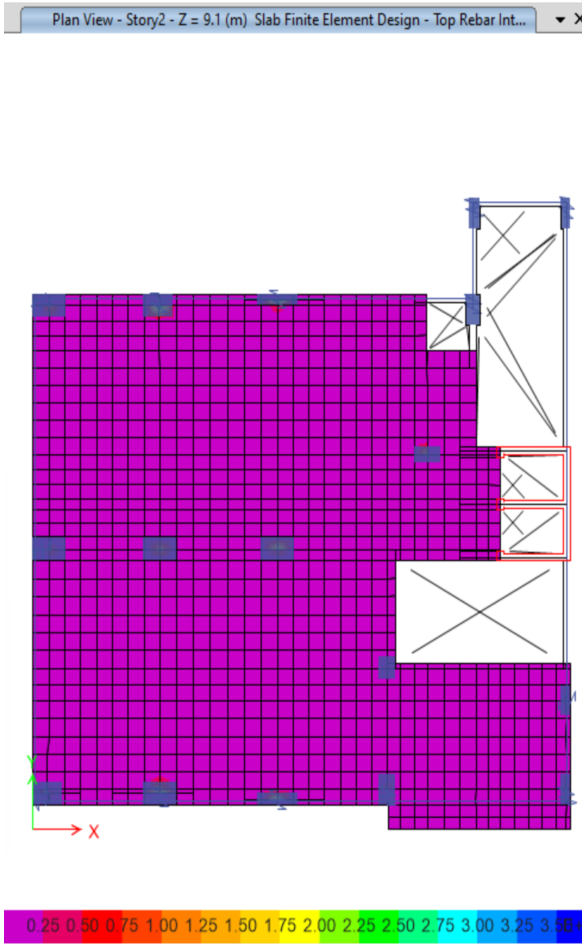


Figure 4-26 Flat slab top rebar direction 2

In Figure 4-25 inside the yellow box there is a red color which means it needs extra reinforcement. The value of this red color is 1400 mm^2/m, so by using

Φ16: $$n = \frac{1400}{\pi * \frac{16^2}{4}} \approx 7\ bars/m$$

Based on the analysis results, it has been determined that the top reinforcement in both directions should consist of 7 Φ14 / m, and an additional 7 Φ16 / m reinforcement is required in both directions for the area surrounding the selected column.

Figures 4-27 and 4-28 show the bottom reinforcement design for both directions. Thus, the bottom reinforcement of the flat slab for both direction is 7 Φ12 / m

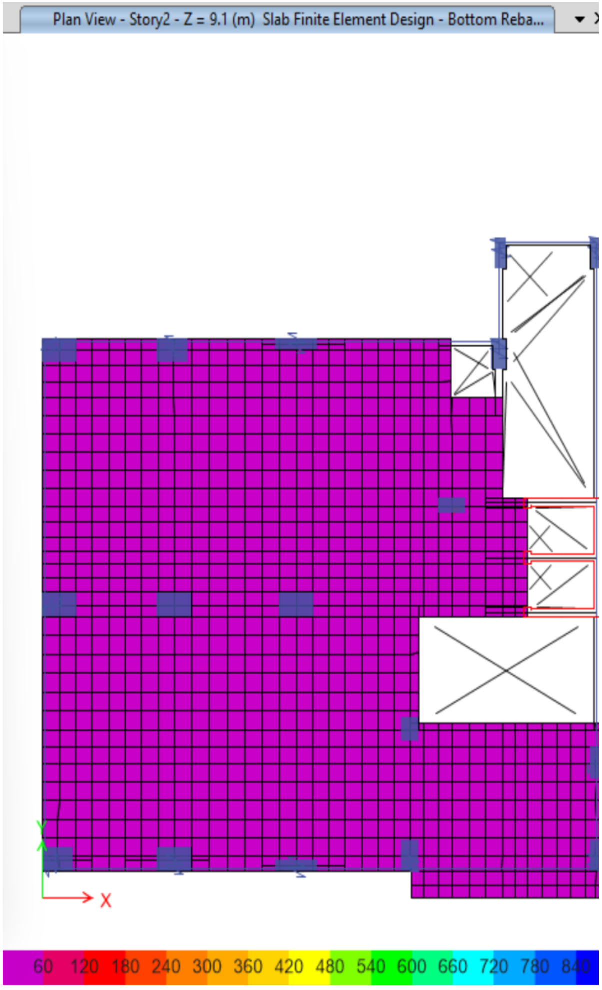


Figure 4-27 Flat slab bottom rebar direction 1

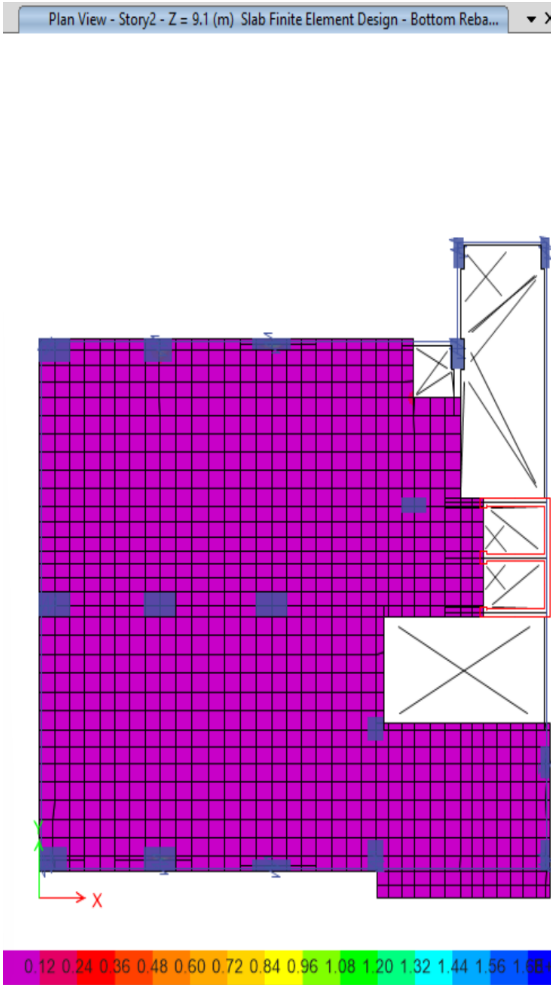


Figure 4-28 Flat slab bottom rebar direction 2

Check of punching:

The punching shear check in ETABS is expressed as the comparison of the calculated punching shear demand to the calculated punching shear capacity of the slab, so if the value is less than 1 it means safe against punching. Figure 4-29 shows the punching check of the flat slab.

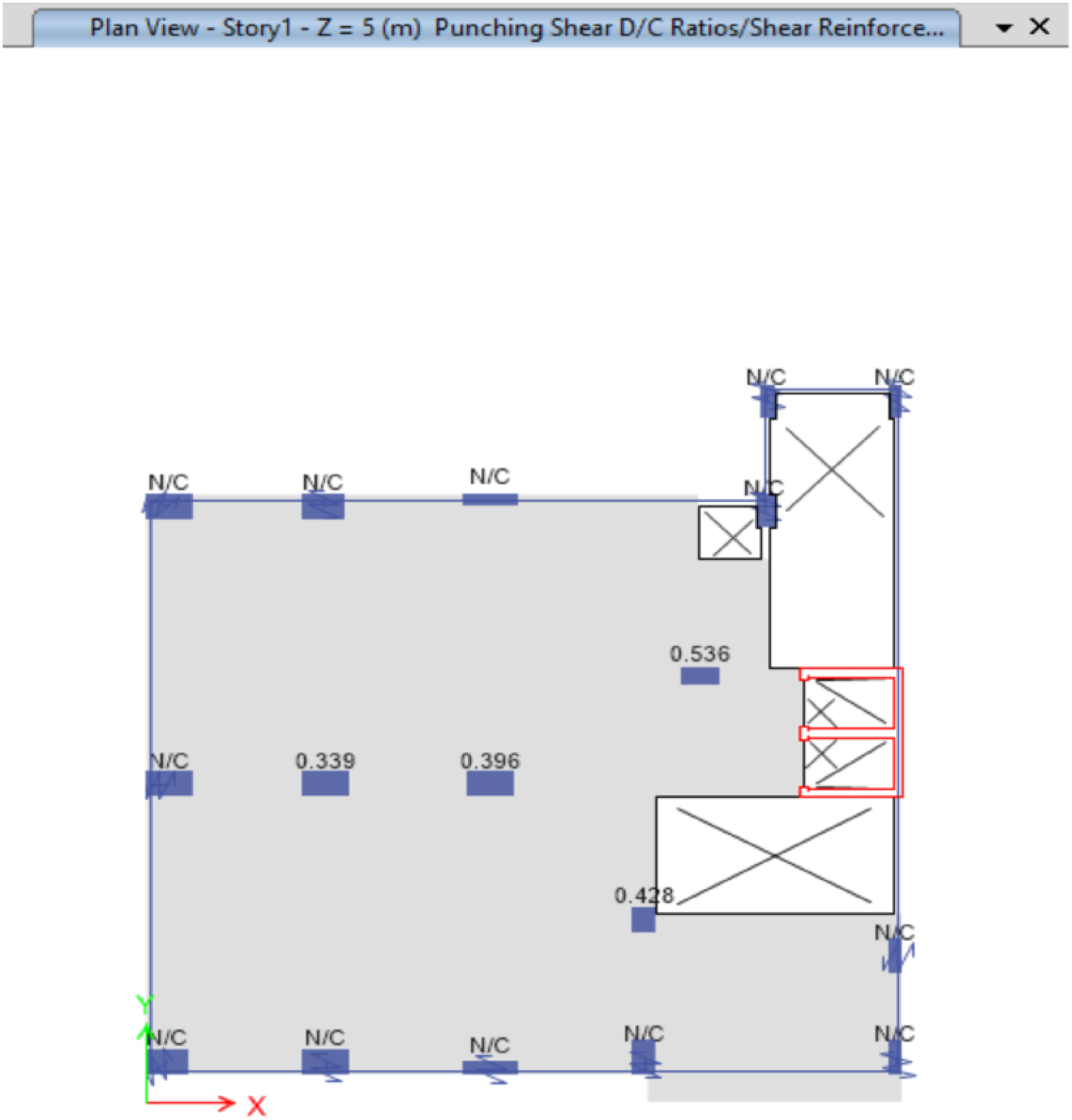


Figure 4-29 Punching Check

4.7.2. Solid slab design

For top and bottom reinforcement 5Φ10/m is selected.

Figures 4-30 and 4-31 show the top reinforcement design for both directions.

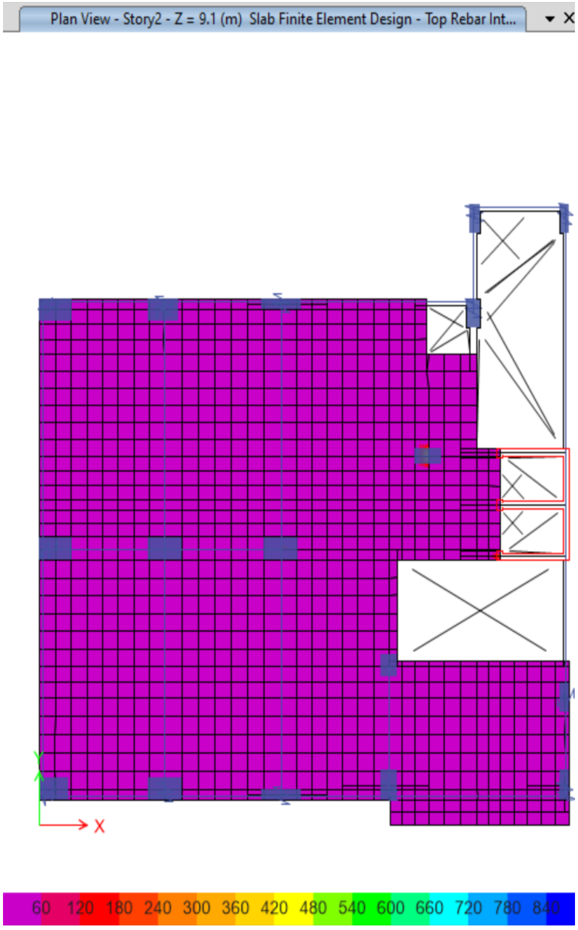


Figure 4-30 Solid slab top rebar direction 1

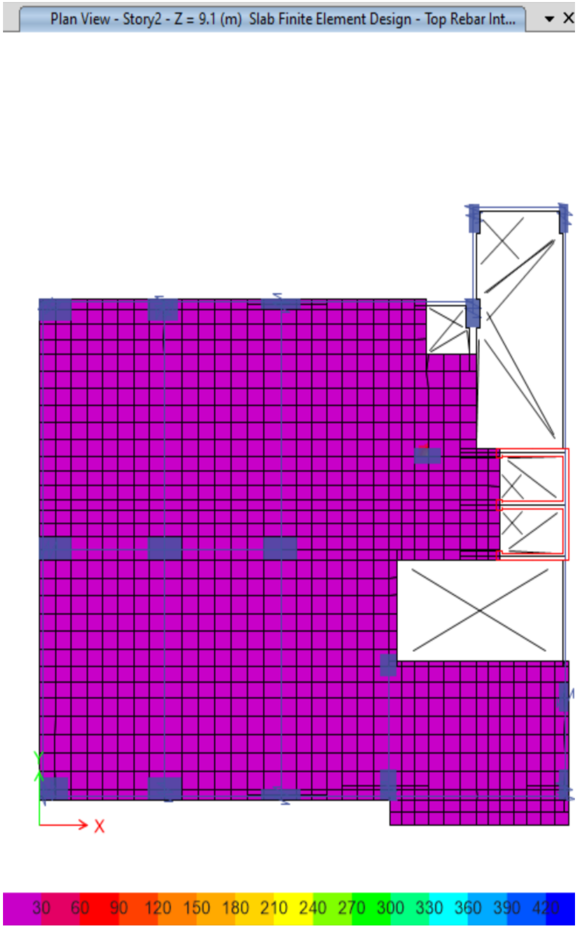


Figure 4-31 Solid slab top rebar direction 2

Figures 4-32 and 4-33 show the bottom reinforcement design for both directions.

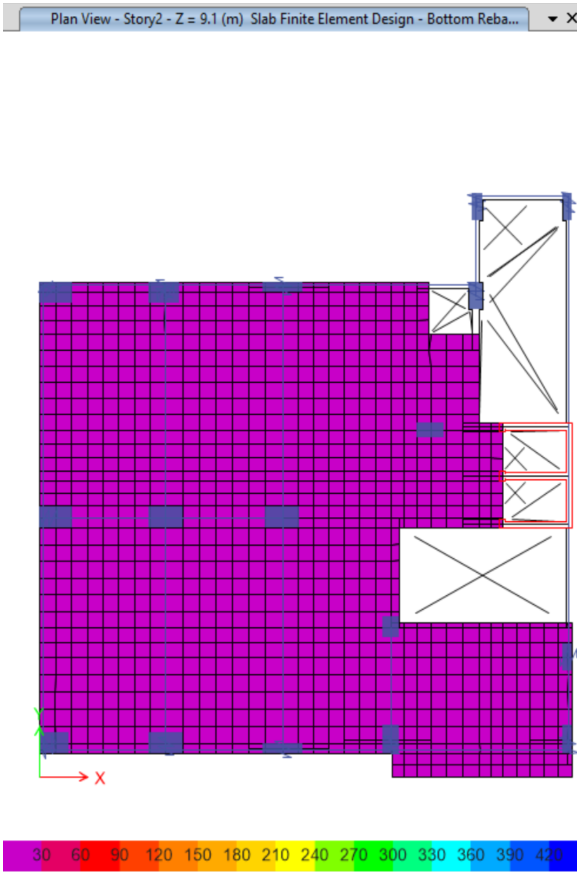


Figure 4-32 Solid slab bottom rebar direction 1

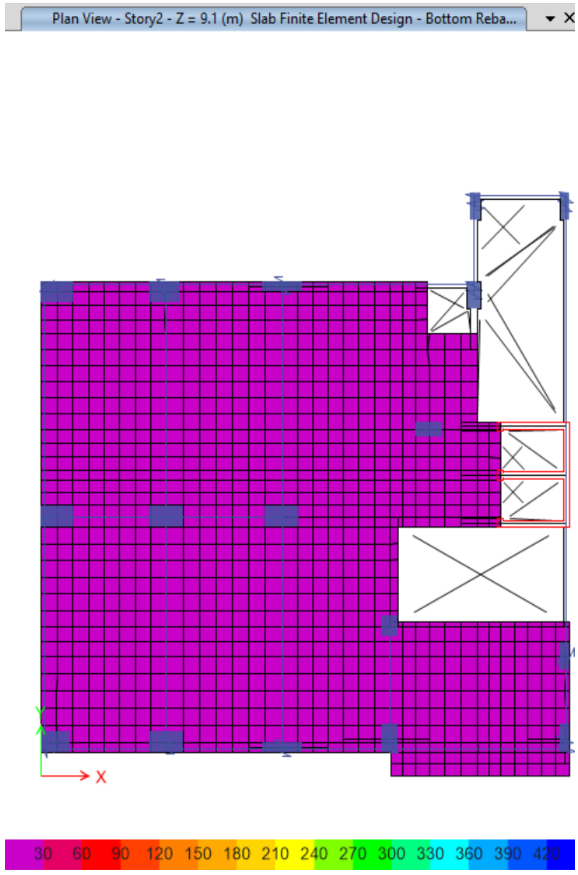


Figure 4-33 Solid slab bottom rebar direction 2

Overall, the reinforcement of the solid slab is 5 Φ10 / m top and bottom both directions.

4.8. Beam design

Beam design will be done by using ETABS and checked by using Excel sheet.

4.8.1. Flat slab moments

The moment diagram of the beams from story 1 to 7 is calculated in ETABS as shown in figures 4-34, 4-35, 4-36, 4-37 and 4-38.

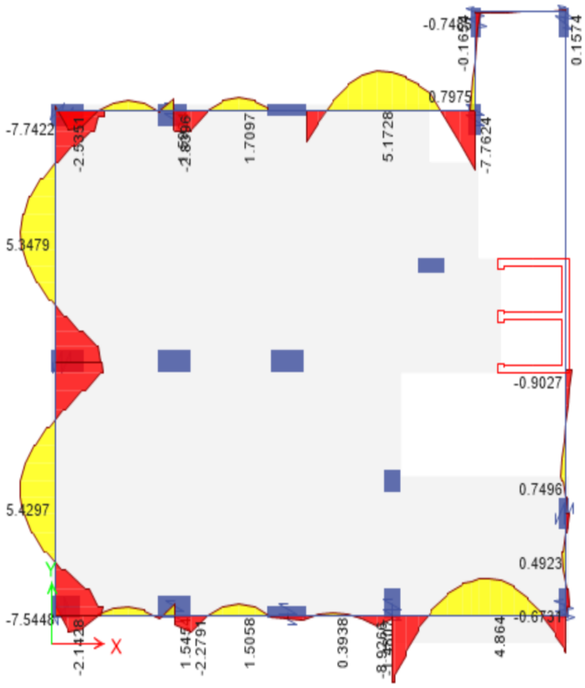


Figure 4-34 Beams moment (story 1)

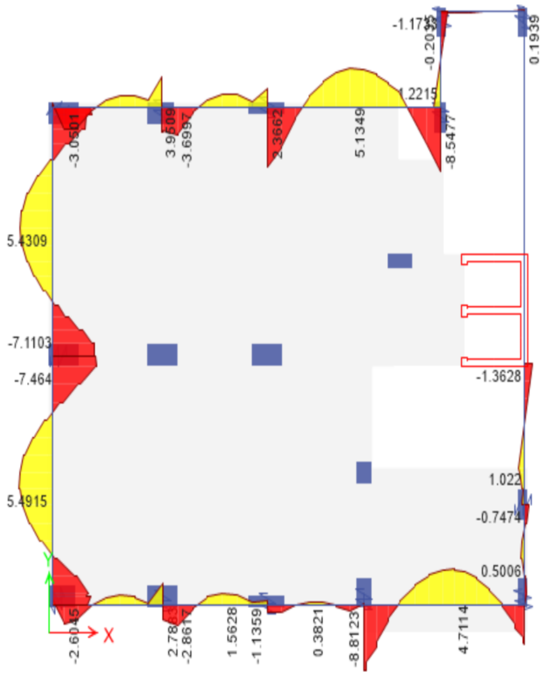


Figure 4-35 Beams moment (story 2)

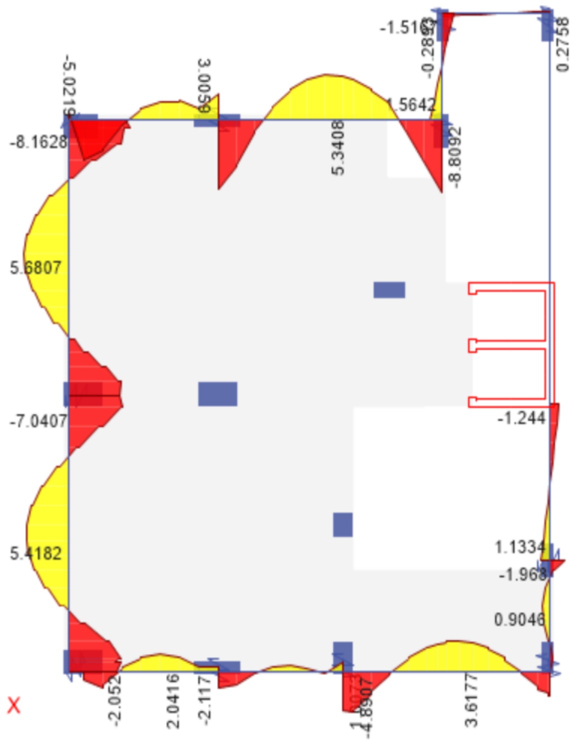


Figure 4-36 Beams moment (story 3 to 5)

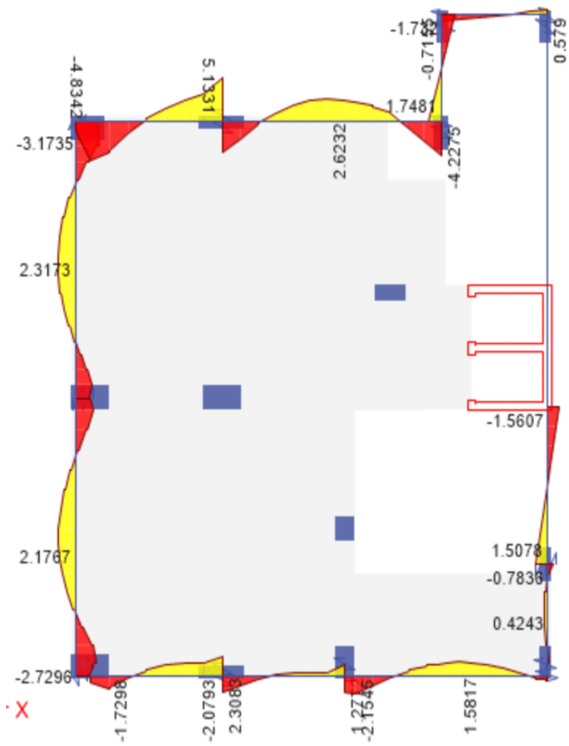


Figure 4-37 Beams moment (story 6)

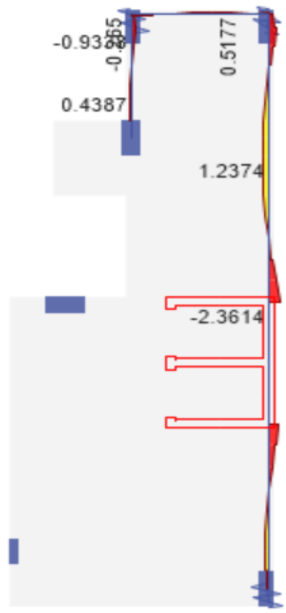


Figure 4-38 Beams moment (story 7)

4.8.2. Solid slab moments

The moment diagram of the beams from story 1 to 7 is calculated in ETABS as shown in figures 4-39, 4-40, 4-41, 4-42 and 4-43.

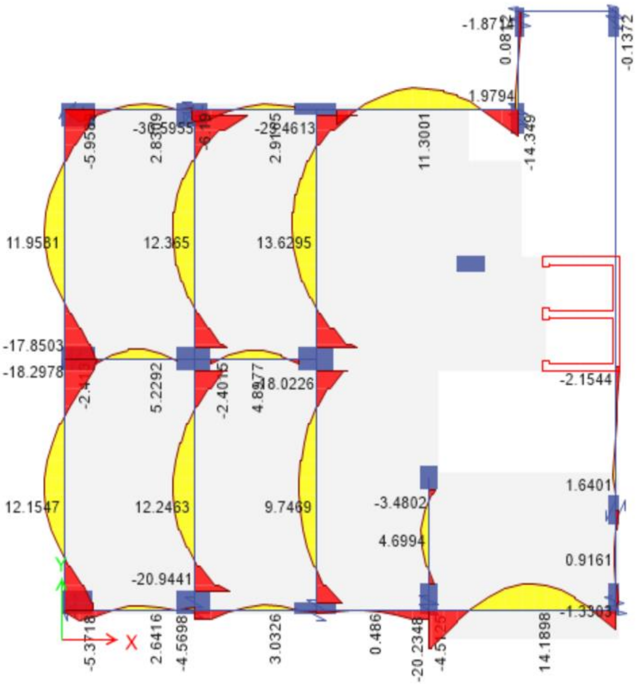


Figure 4-39 Beams moment (story 1)

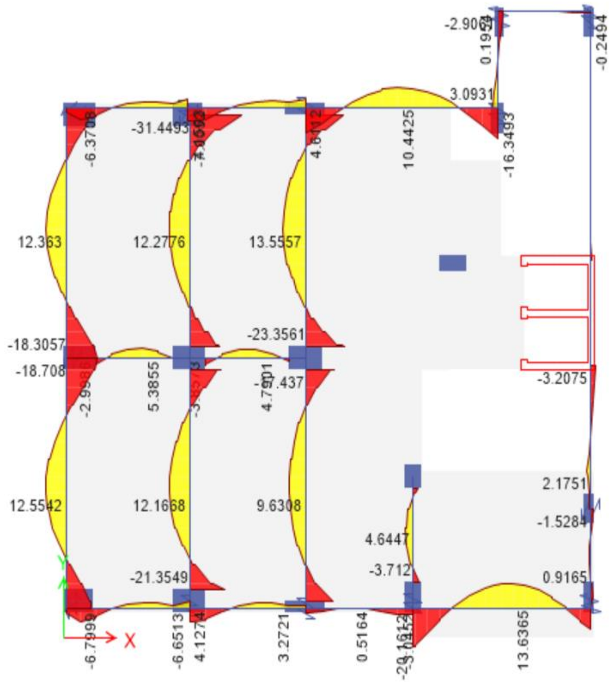


Figure 4-40 Beams moment (story 2)

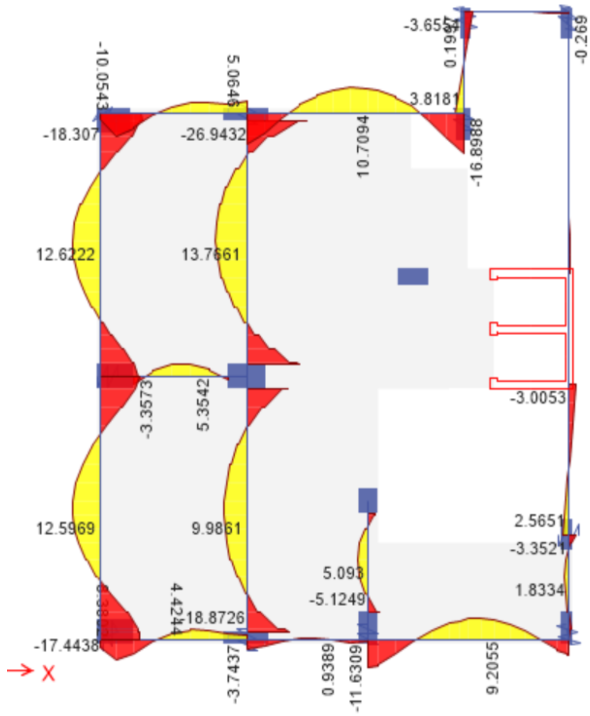


Figure 4-41 Beams moment (story 3 to 5)

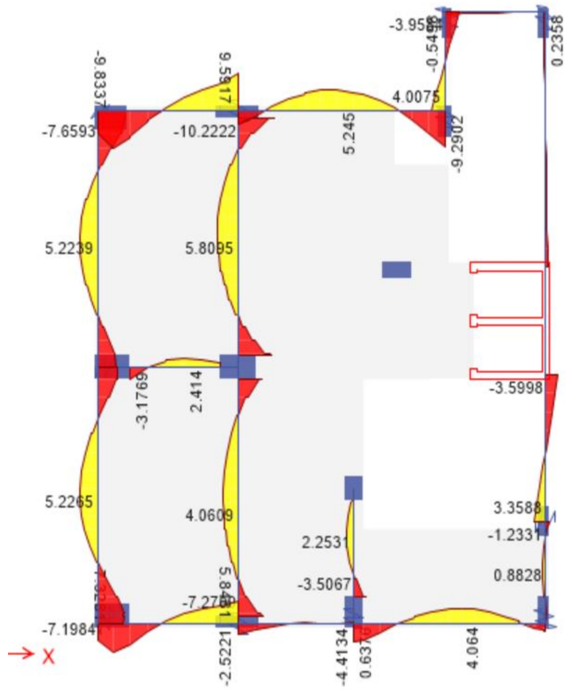


Figure 4-42 Beams moment (story 6)

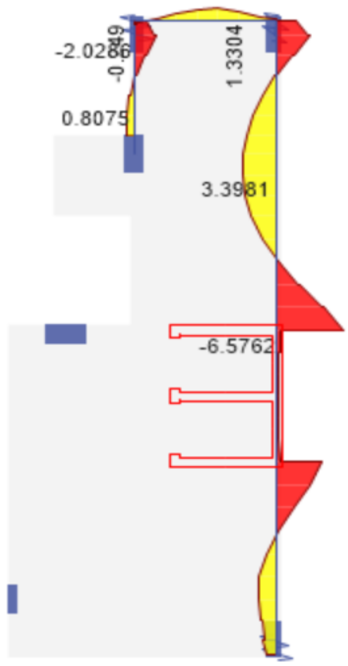


Figure 4-43 Beams moment (story 7)

4.8.3. Beams reinforcement

There are three types of beams, B1 (600 * 300) mm, B2 (600 * 300) mm for flat slab and B3 (400 * 200) mm for solid slab. By taking the maximum moment on B1, B2 and B3 and calculating for reinforcement it was found that all the beams are designed for minimum reinforcement as shown in Table 4-1.

Table 4-1 Beam design

Section #	Mu (KN.m)	Dimensions			Required As (mm^2)	Min As (mm^2)	As (mm^2)	a (mm)	ϕMn (KN.m)	Reinforcement	
		b (mm)	h (mm)	d (mm)						No. Bar	ϕ (mm)
B1	9	300	600	540	44.2	540	540	35.58	106.6	3	16
B2	10	200	600	540	49.1	360	360	35.58	71.06	2	16
B3	28	200	400	340	225.2	226.7	226.7	22.40	28.17	2	16

Beam design equations [5]:

$$A_s = \frac{0.85 \times f_c' \times b \times d}{f_y} \times \left(1 - \sqrt{1 - \frac{4 \times M_u}{0.9 \times 1.7 \times f_c \times b \times d^2}}\right) \quad (4\text{-}2)$$

$$a = \frac{A_s \times f_y}{0.85 \times f'_C \times b} \quad (4\text{-}3)$$

$$\Phi M_n = \times A_s \times f_y \times \left(d - \frac{a}{2}\right) \quad (4\text{-}4)$$

Where Φ here is equal to (0.9).

By designing the beams with etabs also gives the same reinforcement area as shown in figures 4-44 and 4-45.

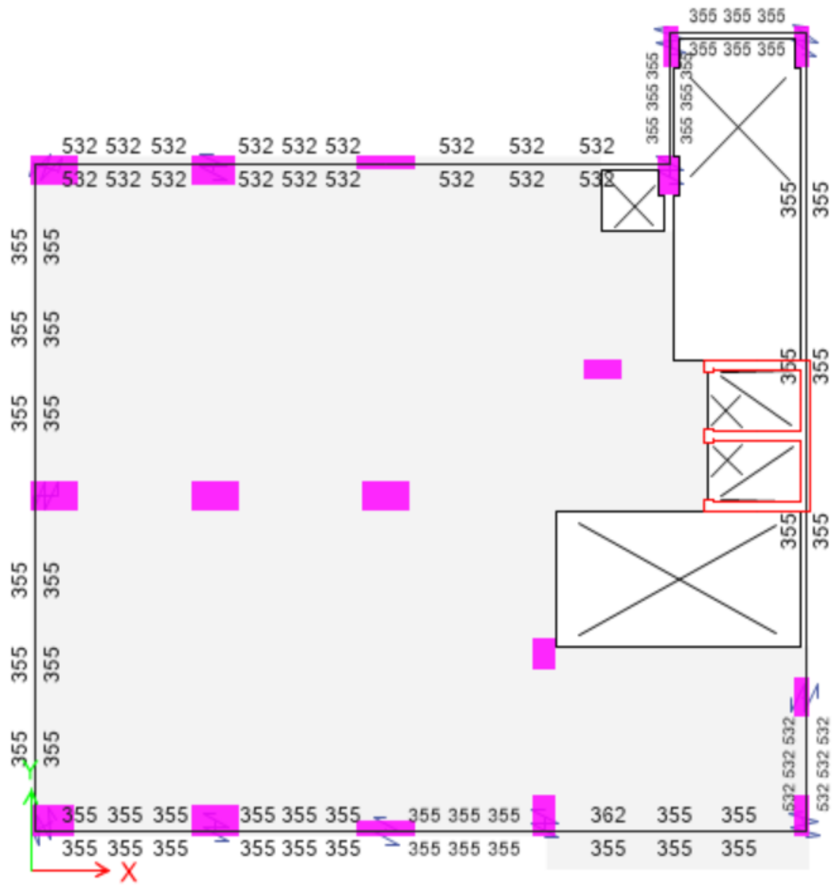


Figure 4-44 Beam longitudinal rebars (flat slab)

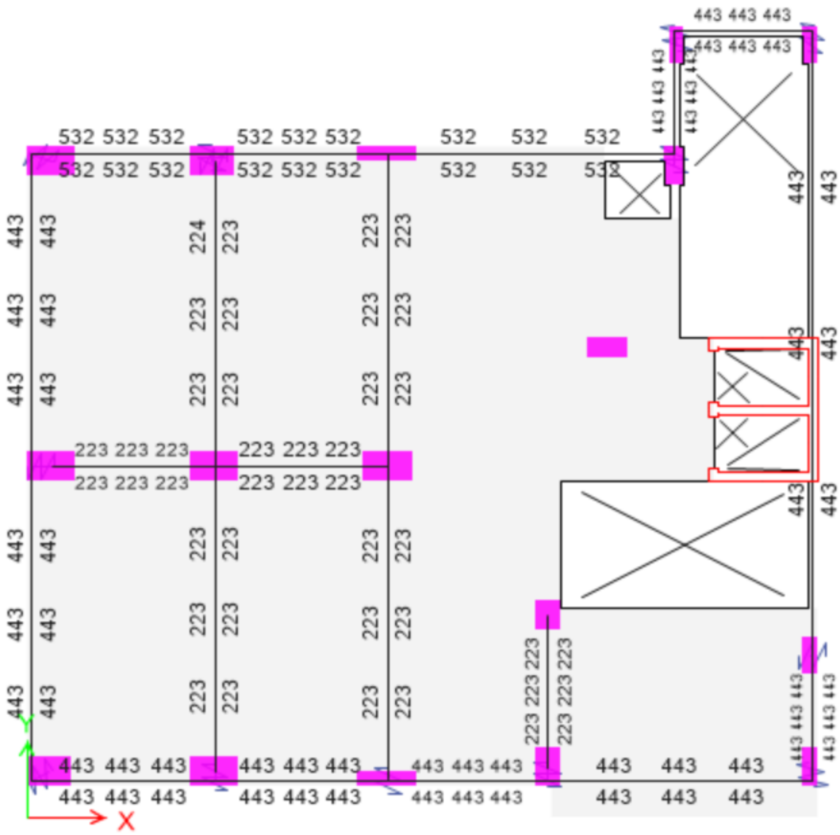


Figure 4-45 Beam longitudinal rebars (solid slab)

4.8.4. Shear reinforcement

It should be noted that the shear reinforcement is not required for B1 and B2 beams in solid slab system as shown in figures 4-46 and 4-47 according to SBC 304 [1] (9.6.3.1 "$A_{v,min}$ shall be provided in all region where $V_u > 0.5 *\varphi V_c$"). However, omitting stirrups in beam can have several potential consequences such as (reducing ductility, cracking, and increasing deflection). Figure 4-48 displays the output obtained from Etabs software concerning the shear force and reinforcement for beam in flat slab system. To determine the spacing of stirrups, an 8mm diameter stirrup shall be considered first, and then check code limitations.

Shear Force and Reinforcement for Shear, V_{u2}

Shear V_{u2} kN	Shear ϕV_c kN	Shear ϕV_s kN	Shear V_p kN	Rebar A_v /s mm²/m
13.4086	47.9753	0	0	0

Figure 4-46 Shear reinforcement of B1beam (Solid)

Shear Force and Reinforcement for Shear, V_{u2}

Shear V_{u2} kN	Shear ϕV_c kN	Shear ϕV_s kN	Shear V_p kN	Rebar A_v /s mm²/m
3.3822	39.9794	0	0	0

Figure 4-47 Shear reinforcement of B2 beam (Solid)

Figure 4-48 Shear reinforcement results from Etabs (Flat)

- Required shear steel area results from Etabs is A_v/s= 250 mm^2/m
- Area of two legs 8mm diameter stirrup is $A_v = 2 * \frac{\pi * 8^2}{4} = 100.5mm^2$
- Required Spacing is $s = \frac{100.5}{250} = 0.402m$

However, according to SBC 304 [1]; maximum spacing of shear reinforcement shall be minimum of (d/2 or 600 mm) so, s=270mm. Therefore, take the transverse reinforcement of all beams for both structural systems as (Φ 8mm @ 25 cm).

4.9. Column design

The loads on the columns are found by using ETABS axial force as shown in Figure 4-49.

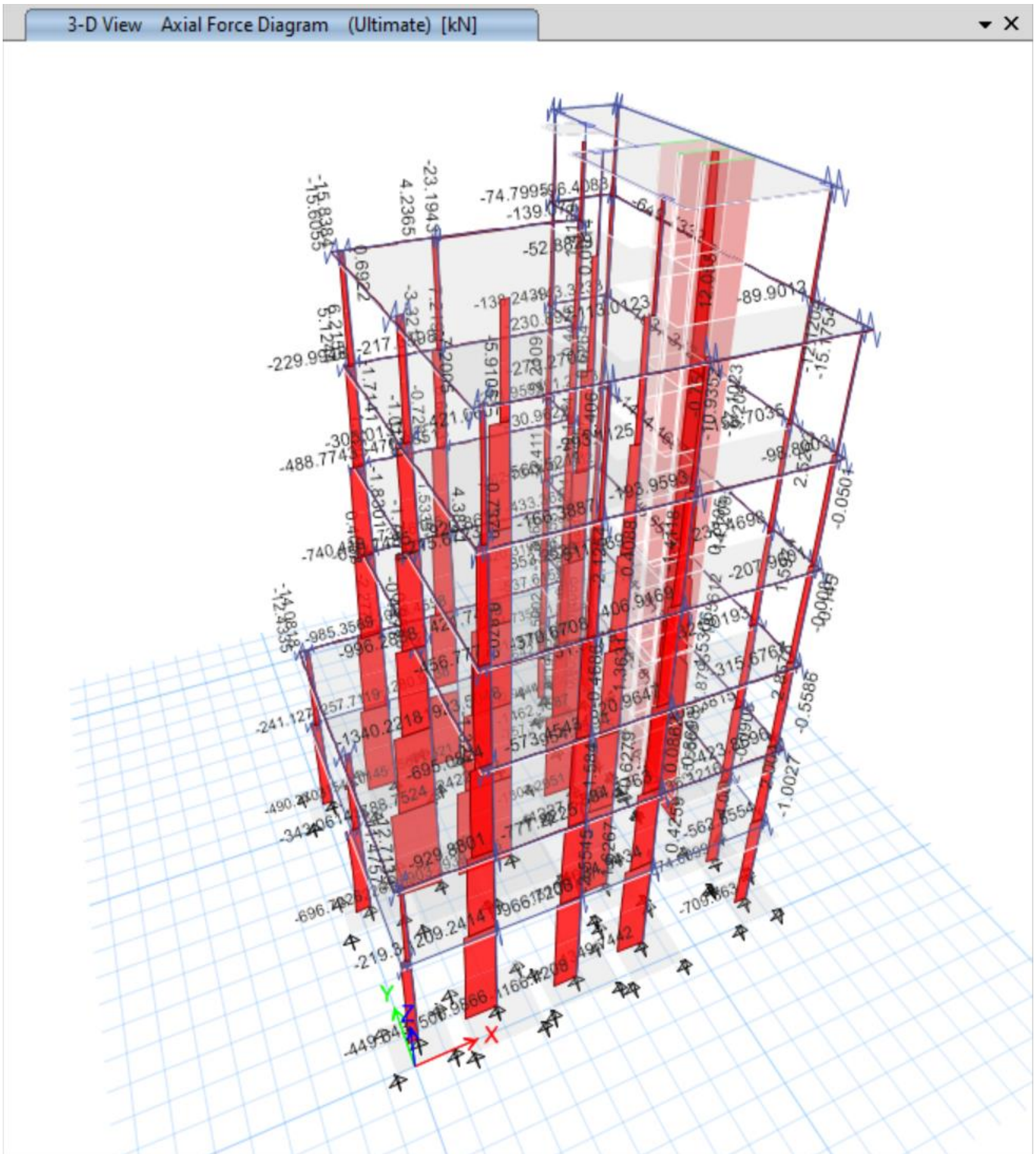


Figure 4-49 Columns axial force

By taking the axial loads on the columns it was found that all the columns are design on the minimum reinforcement as Table 4-2 below shows.

Table 4-2 Column design

Col #	Pu (KN)	Dimensions		Ag (mm^2)	Min As (mm^2)	Required As (mm^2)	As (mm^2)	φPn (KN)	Reinforcement	
		d (mm)	b (mm)						No. Bar	φ (mm)
C1	2300	1000	600	600000	6000	-20882.5	6000	7874.1	24	18
C2	1600	900	600	540000	5400	-21061	5400	7086.69	22	18
C3	1600	1200	300	360000	3600	-11468.5	3600	4724.46	18	16
C4	1500	500	800	400000	4000	-14082.4	4000	5249.4	16	18
C5	1800	800	400	320000	3200	-8372.3	3200	4199.52	16	16
C6	1300	500	600	300000	3000	-9717.87	3000	3937.05	12	18
C7	800	300	800	240000	2400	-12211.2	2400	3149.64	12	16

Where the area steel is found using eq (4-5) [1]:

$$\Phi P_n = 0.8 \times 0.65 \times \left(0.85 \times f'_C \times \left(A_g - A_s\right) + f_y \times A_s\right) \tag{4-5}$$

where $\Phi P_n \geq P_u$

And area steel minimum according to SBC 304 is 1% of the area gross.

4.10. Shear wall design

Shear walls serve as the selected resisting system for lateral forces, including wind and seismic loads. The placement of shear walls on the blueprint as shown in Figure 4-50 was strategically implemented to avoid torsion in the building. This was achieved by ensuring that the center of mass and rigidity were positioned close.

This section of the report presents the design requirements, equations, and final reinforcement area obtained from ETABS software for designing shear walls. The analysis and design process consider factors, such as structural integrity, material properties, and SBC provisions. Additionally, Figure 4-51 shows a flowchart outlined the step-by-step process for the structural design of shear walls.

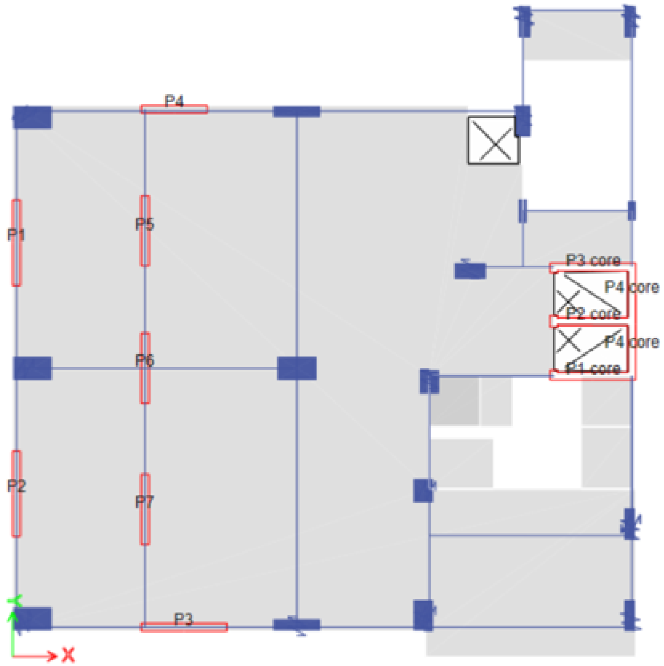


Figure 4-50 The blueprint of the building showing added shear walls

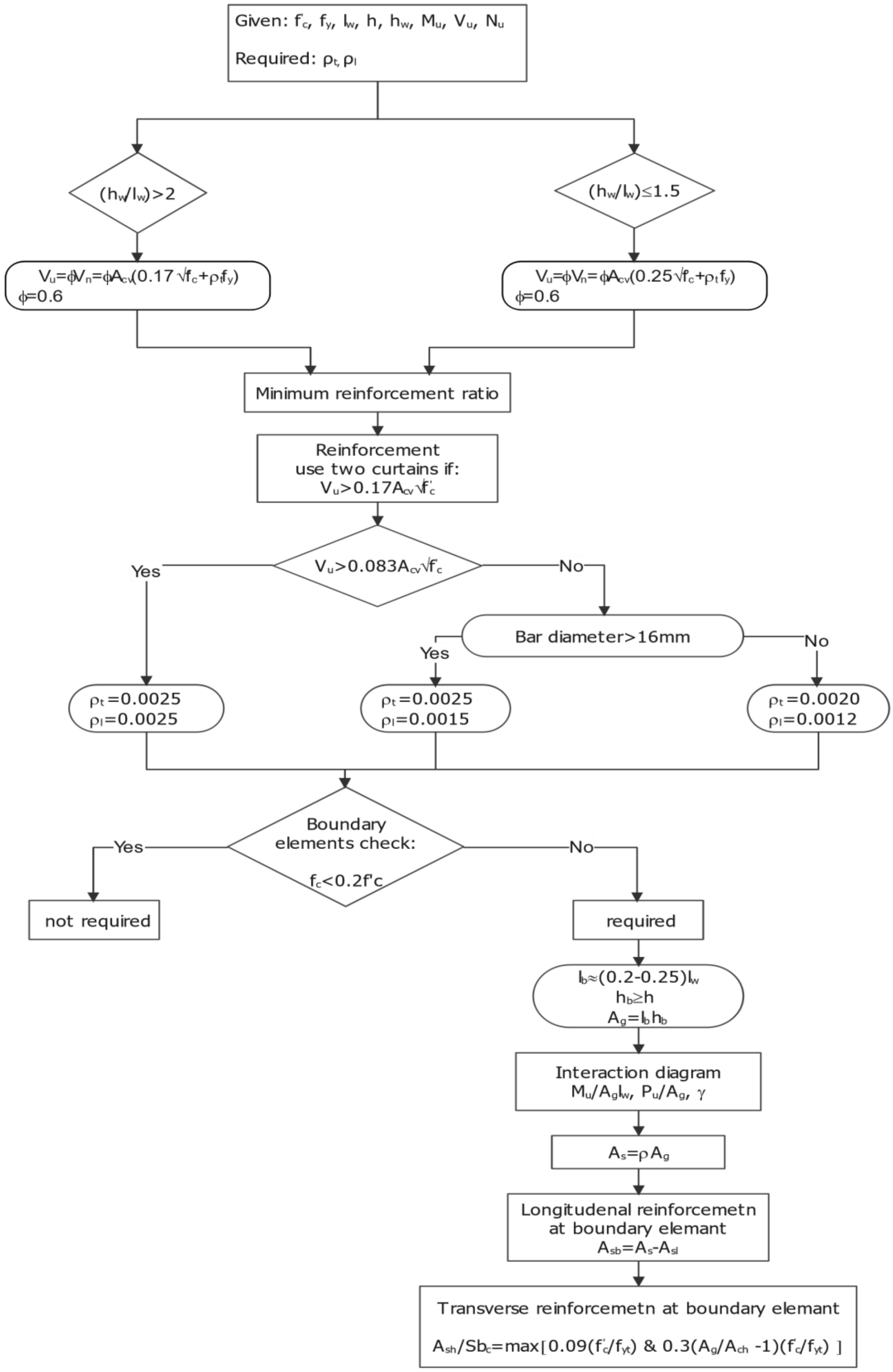


Figure 4-51 The design flowchart for a shear wall

4.10.1. Design requirements and equations

❖ Shear strength [1]:

$$V_C = 0.17 \times \lambda \times \sqrt{f'c} \times h \times d \qquad (4\text{-}6)$$

$$V_S = \frac{V_u}{\phi} - V_C \qquad (4\text{-}7)$$

$$A_v = \frac{V_S \times S}{f_{yt} \times d} \geq A_{v\,\min} = \rho_t \times h \times S \qquad (4\text{-}8)$$

$$V_{S\ \min} = \frac{A_v \times f_{yt} \times d}{S} \qquad (4\text{-}9)$$

$$V_n = V_C + V_S \qquad (4\text{-}10)$$

Where:

V_C: Nominal shear strength provided by concrete (N).

V_S: Nominal shear strength provided by shear reinforcement (N).

Vn: Nominal shear strength (N).

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete.

h: Overall thickness of the member (mm).

d: Distance from extreme compression fiber to centroid of longitudinal tension reinforcement (mm).

V_u: Factored shear force at section (N).

S: Center to center spacing of items (mm).

A_v: Area of shear reinforcement within spacing (mm^2).

f'_C: Specified compressive strength of concrete (MPa).

f_{yt}: Specified yield strength of transverse reinforcement (Mpa).

4.10.2. Reinforcement area

The chosen design approach in ETABS was the Uniform Reinforcing method, which involves the inclusion of reinforcement area in both the longitudinal and transverse directions across the section of the wall, while also ensuring compliance with the necessary boundary element requirements, as shown in figures 4-52, 4-53, 4-54, and 4-55. The reinforcement areas for each wall obtained from ETABS were documented in Table 4-3 further detailed in the Drawings section using Revit software.

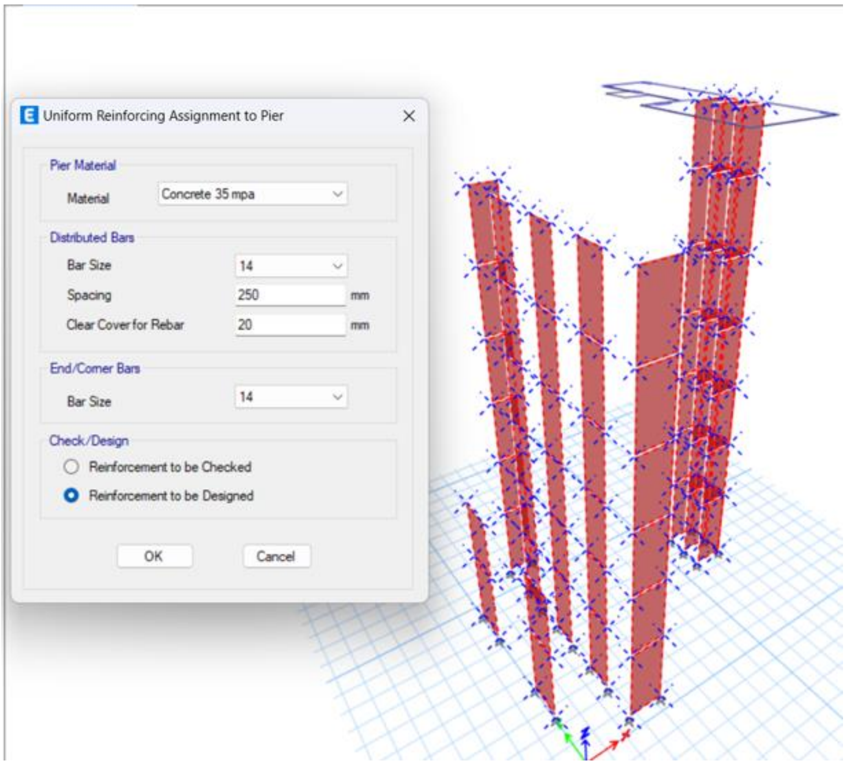


Figure 4-52 Assigning Uniform reinforcing design method

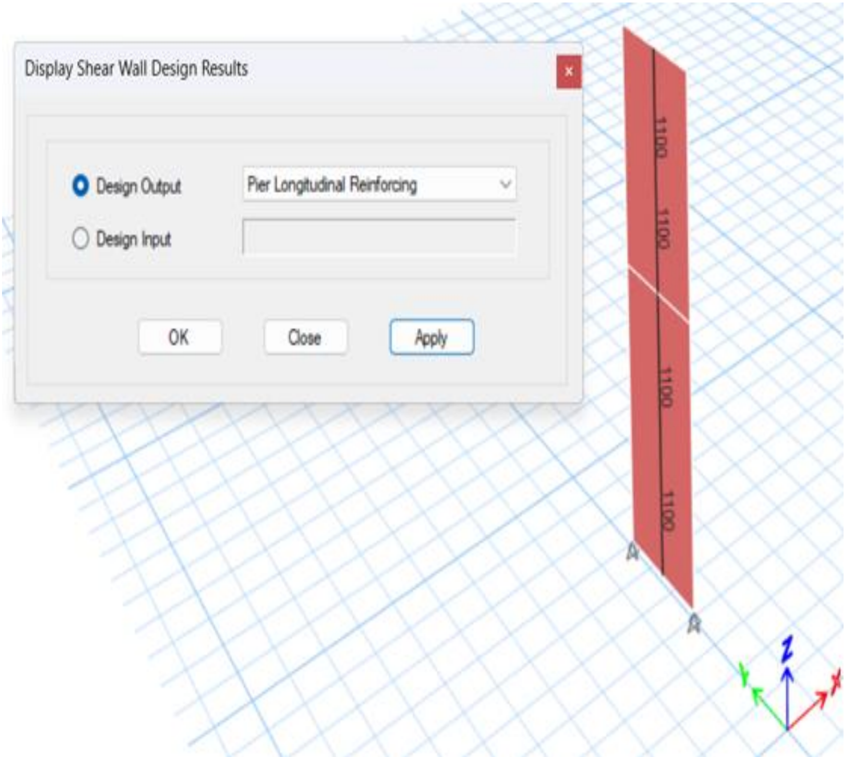


Figure 4-53 Longitudinal reinforcement area for P2 wall in (mm^2)

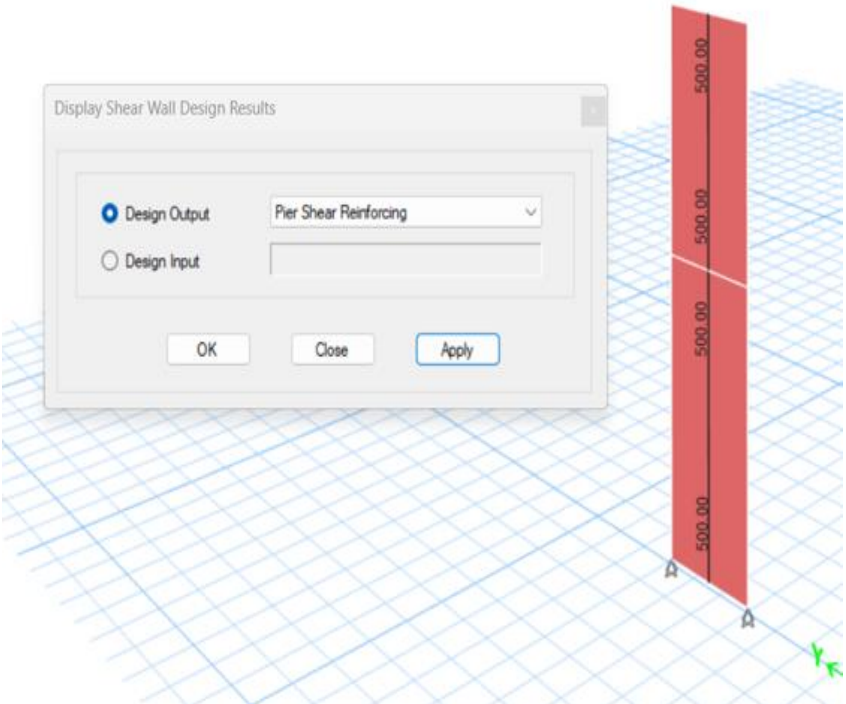


Figure 4-54 Transverse reinforcement area for P2 wall in (mm^2/m)

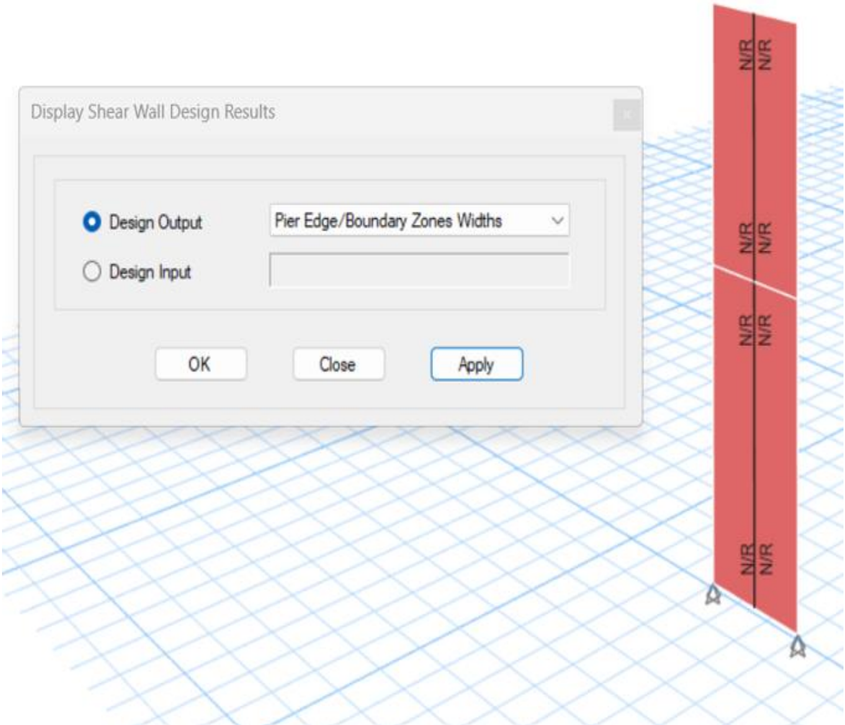


Figure 4-55 Boundary element check for P2 wall

Table 4-3 Longitudinal reinforcement areas obtained from ETABS

Story	Piers Flexural Reinforcement (mm^2)							
	P1	P2	P3	P4	P5	P6	P7	Pcore
1	1100	1100	1100	850	900	900	900	4600
2	1100	1100	1100	850	900	900	900	4600
3			1100	850	900	900	900	4600
4			1100	850	900	900	900	4600
5			1100	850	900	900	900	4600
6			1100	850	900	900	900	4600
7								4600

Table 4-4:Longitudinal Reinforcment Detaling

Piers Sections	Longitudinal Reinforcement (mm^2)	Dimensions (mm)		Detailing	
		Lw	t	Diameter of bar	Spacing (S)
P1-P3	1100	2200	200	Y12	400
P4	850	1700	200	Y12	400
P5-P7	900	1800	200	Y12	400

Table 4-5 Horizontal Reinforcement Detaling

Piers Sections at story no.	Horizontal Reinforcement (mm^2/m)	Dimensions (mm)		Detailing	
		hw	t	Diameter of bar	Spacing (S)
[1]	500	5000	200	Y12	400
[2-6]		4100	200	Y12	400

CHAPTER 5. FOUNDATIONS

5.1. Isolated Footing:

An isolated footing is a type of foundation that is used to support a single column or a small group of columns. It is typically a rectangular or circular slab of concrete that is reinforced with steel bars and placed directly on the soil. The purpose of the footing is to spread the load of the structure over a larger area of soil in order to prevent excessive settlement or bearing capacity failure. The design of an isolated footing involves determining the size and thickness of the footing, as well as the amount and placement of the reinforcing steel. Figure 5-1 below shows a simple isolated footing.

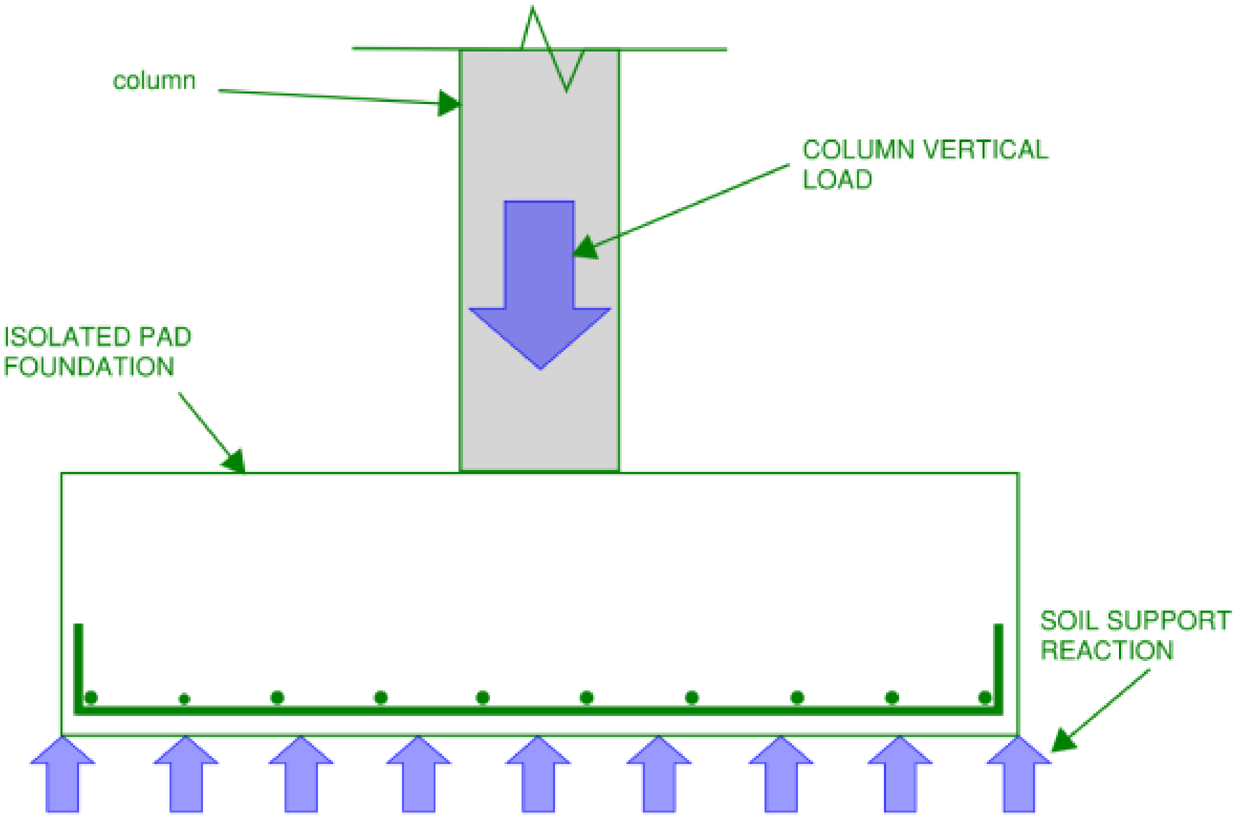


Figure 5-1 Isolated footing

5.1.1. Assumptions

Since there is no geotechnical report available the following assumptions were made:

- ❖ Concrete compressive strength f'_c = 25 Mpa
- ❖ Steel tensile strength f_y = 420 Mpa
- ❖ Soil unit weight γ soil = 15 kN/m3
- ❖ Soil bearing capacity $qall$ = 200 kN/m2
- ❖ Unit weight of concrete γ concrete = 25 kN/m³
- ❖ Distance from the surface to the top of footing Df = 1.2 m
- ❖ Minimum thickness t_{min} = 0.5 m

5.1.2. Formulas

The design of an isolated footing involves several steps including determining the required size and thickness of the footing, calculating the loads that the footing will be subjected to, and selecting the appropriate reinforcing steel [4].

$$A_f = \frac{Q_{Working}}{q_{all\ net}} \tag{5-1}$$

$$q_{\text{all net}} = q_{\text{all}} - \left(\gamma_s \times D_f + \gamma_c \times t_f\right) \tag{5-2}$$

$$q_S = \frac{Q_{ult}}{A_f} \tag{5-3}$$

Where:

A_f: Area of the foundation (m^2).

$Q_{working}$: The load of the column (kN).

$q_{all\ net}$: The net allowable gross soil bearing capacity (kN/m^2).

q_{all}: Soil bearing capacity (kN/m^2).

γ_s: Soil unit weight (kN/m^3).

D_f: Distance from the surface to the top of footing (m)

γ_c: Unit weight of concrete (kN/m^3).

t_f: footing thickness (m).

q_s: The Contact Soil Bearing Capacity (kN/m^2).

Q_{ult}: The ultimate load of the column (kN).

Foundation shear Strength:

❖ For one way shear (Vu ≤ ΦVc):

$$Vu = q_s \times L_f \times X \tag{5-4}$$

$$\Phi V_C = 0.75 \times 0.17 \times \sqrt{f'_c} \times B_f \times d \tag{5-5}$$

Where:

V_u: shear force due to factored load (kN).

ΦV_c: design shear strength of concrete (compressive strength of concrete Φ = 0.75).

X = (B-2d-Culumn width)/2 (m).

L_f: Length of the footing (m).

B_f: Width of the footing (m).

If (Vu ≤ ΦVc) ok continue to two-way shear.

❖ For two-way shear (Vu ≤ ΦVc):

$$V_u = q_S \times \left[\left(B_f \times L_f \right) - \left(\left(b_c + d \right) \times \left(h_c + d \right) \right) \right] \tag{5-6}$$

$$\Phi V_c = 0.75 \times 0.34 \times \sqrt{f'_c} \times b_o \times d \tag{5-7}$$

Where:

b_c: Width of the column (m).

h_c: Height of the column (m).

$b_o = 2\ [(b_c + d) + (h_c + d)]$.

Flexural reinforcement:

❖ **Along the width direction**

$$M_u = q_s \times L_f \times \frac{L'^2}{2} \quad (5\text{-}8)$$

$$a = \frac{A_s \times f_y}{0.85 \times f'_c \times L_f} \quad (5\text{-}9)$$

Where:

L' = (B_f-b_c)/2 (m).

a: The height of the stress block (m).

Let $M_u = \Phi \times A_s \times f_y \times (d - a/2)$, then find A_{s1} and A_{s2}.

$\rho = [A_s / (B \times d)]$, (check $\rho_{min} < \rho < \rho_{max}$) then select A_s

$$n = \frac{A_s}{\pi \times \frac{d_b^2}{4}} \quad (5\text{-}10)$$

Where: $\rho_{min} = 0.0018$ and $p_{max} = 0.75 \times \left(\frac{0.85 \times f'_c}{f_y} \times B_f \times \frac{600}{600 + f_y} \right)$.

❖ **Along the length direction**

$$M_u = q_s \times B_f \times \frac{B'^2}{2} \quad (5\text{-}8)$$

$$a = \frac{A_s \times f_y}{0.85 \times f'_c \times B_f} \quad (5\text{-}9)$$

Where:

B' = (L_f-h_c)/2 (m).

Let $M_u = \Phi \times A_s \times f_y \times (d - a/2)$, then find A_{s1} and $A_{s2.}$

$\rho = [A_s / (B \times d)]$, (check $\rho_{min} < \rho < \rho_{max}$) then select A_s

$$n = \frac{A_s}{\pi \times \frac{d_b^{\ 2}}{4}} \tag{5-10}$$

Check Development Length:

The development length of the reinforcing bars in an isolated footing is an important aspect of the design, as it ensures that the bars are properly anchored in the concrete and can resist the applied loads.

$$L_d = max\left[\left(0.019 \times A_{\mathrm{bar}} \times \frac{f_y}{\sqrt{f'_c}}\right), \left(0.058 \times d_b \times f_y\right)\right] \tag{5-11}$$

$$L_{\mathrm{dav}} = \frac{B}{2} - \frac{b_c}{2} - cc \tag{5-12}$$

Check if $L_{dav} > L_d$ (ok) otherwise increase B.

5.1.3. Design by EXCEL:

The formulas listed in 5.1.2. have been entered into excel to create a model for designing isolated footing. Tables 5-1, 5-2, 5-3, 5-4, 5-5, 5-6 and 5-7 show an example of the designed footing in excel.

Table 5-1 Inputs

Inputs			
q all (kN/m2)	200	**t (m)**	0.5
C x-dir (m)	0.5	**C y-dir (m)**	0.6
cc (m)	0.076	**db (m)**	0.025
Unit weight of concrete(kN/m3)			25

q D.D (kN)	752	**q L.L (kN)**	170.8
Df	1.2	**qu (kN)**	1343.16

Table 5-2 Calculation

Calculation				
Af	5.214	**B x L**	2.1	2.6
d (m)	0.4115	**x (m)**	0.3885	
q all net	177	**Q working (kN)**	922.8	
qs	258	**A dp**	0.00049	

Table 5-3 Check one way shear

Check one way shear					
Vu (kN)	260.23026	**phi Vc**	773.00275	**Vu < phi Vc**	**Ok**

Table 5-4 Check two-way shear

Check Two Way Shear							
bo (m)	3.846	**Vu (kN)**	1285.737	**phi Vc (kN)**	2286.9	**Vu < phi Vc**	**Ok**

Table 5-5 Reinforcement in x-direction

Check Reinforcement (X - Direction)

L'		0.8			
Mu (kN.m)		214.35			
a		7.602		* As	
0	=	3.8009	* As^2 -	155547	* As +	214.35
As equals		40923.67	or	0.00137	
Rho min		0.0018	Rho max	0.0625	
Rho calculated		0.00159	Rho selected	0.0018	
As used			0.00156	m^2	
use			4	Φ 25 in X - direction	

Table 5-6 Reinforcement in y-direction

Check Reinforcement (Y - Direction)						
B'		1				
Mu (kN.m)		270.51				
a		9.412		* As		
0	=	4.705882353	* As^2 -	155547	* As +	270.51
As equals		33053.73	or	0.001734		
Rho min		0.0018	Rho max	0.07738		
Rho calculated		0.00162	Rho selected	0.0018		
As used			0.00192	m^2		
use			4	Φ 25 in Y - direction		

Table 5-7 Development length

Check Ld	
Ld av > Ld	
Ld av	0.924
Ld	0.609
Ok	

5.1.4. AutoCAD Drawings:

After designing the footing by using the excel sheet for the flat slab and the solid slab models, the footings have been drawn by AutoCAD as shown in figures 5-2 and 5-3. Tables 5-8 and 5-9 show the dimension and reinforcement.

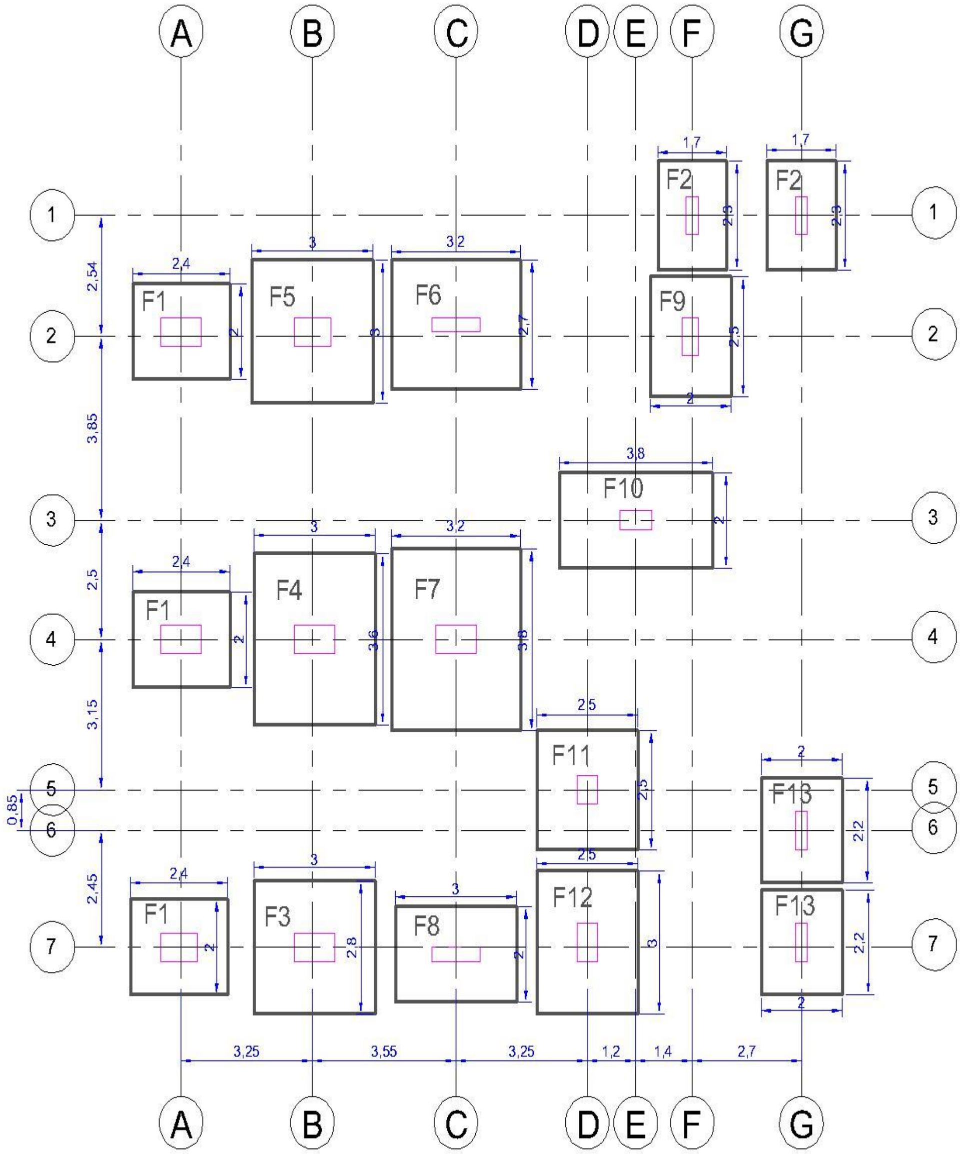


Figure 5-2 Flat slab footings

Table 5-8 Dimension and Reinforcement (flat slab)

Footing	Dimension (mm)			R.C Reinforcement	
	R.C footing			Width	Length
	Width	Length	Depth		
F1	2400	2000	0.5	4 Φ 25	4 Φ 25
F2	1700	2300	0.5	3 Φ 25	4 Φ 25
F3	300	2800	0.5	7 Φ 25	4 Φ 25

F4	3000	3600	0.5	7 Φ 25	12 Φ 25
F5	3000	3000	0.5	7 Φ 25	5 Φ 25
F6	3200	2700	0.6	7 Φ 25	7 Φ 25
F7	3200	3800	0.6	8 Φ 25	11 Φ 25
F8	3000	2000	0.6	5 Φ 25	4 Φ 25
F9	2000	2500	0.5	4 Φ 25	4 Φ 25
F10	3800	2000	0.5	8 Φ 25	5 Φ 25
F11	2500	2500	0.5	5 Φ 25	4 Φ 25
F12	2500	3000	0.5	6 Φ 25	6 Φ 25
F13	2000	2200	0.5	4 Φ 25	4 Φ 25

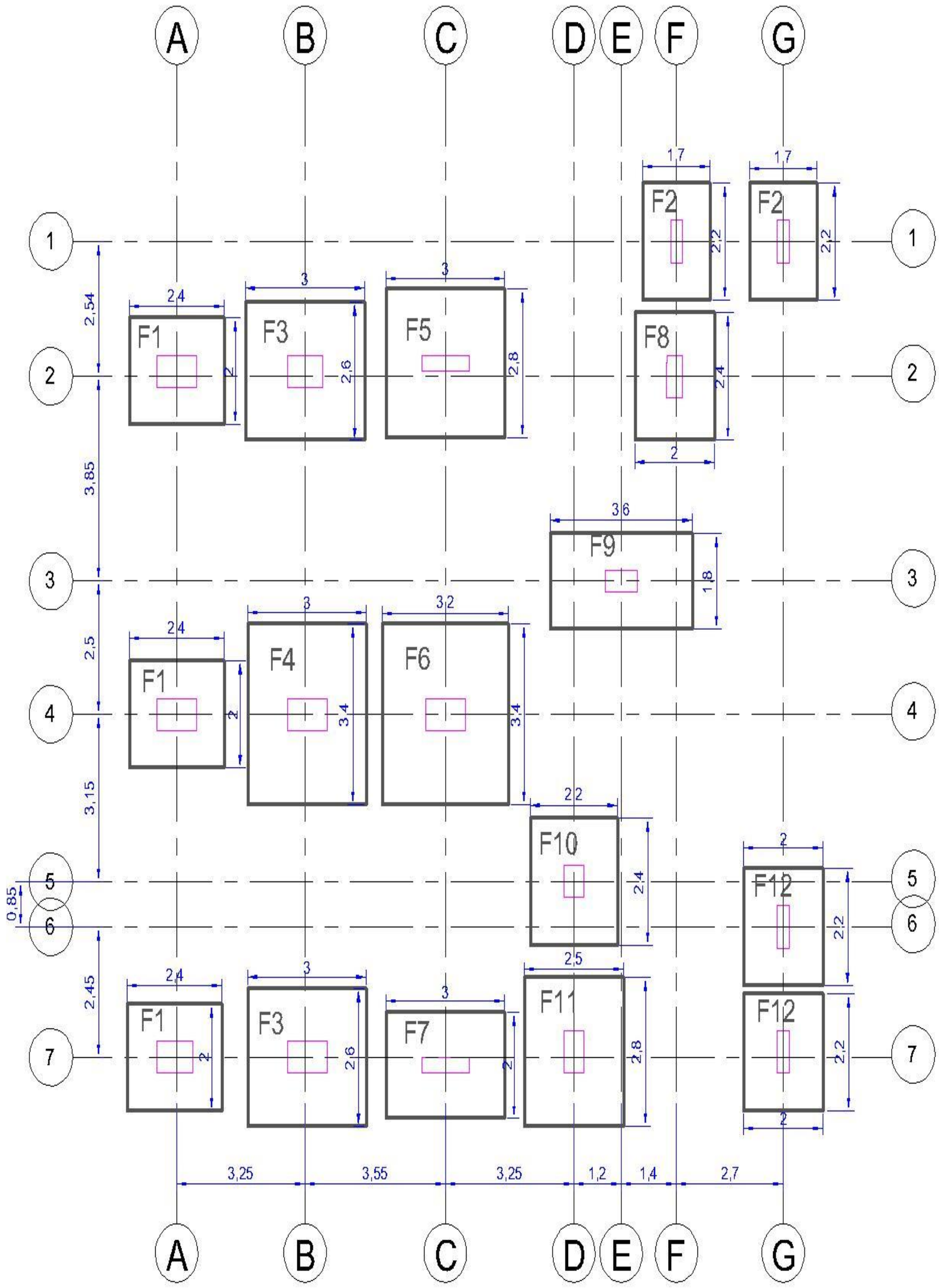


Figure 5-3 Solid slab footings

Table 5-9 Dimension and Reinforcement (solid slab)

Footing	Dimension (mm)			R.C Reinforcement	
	R.C footing			Width	Length
	Width	Length	Depth		
F1	2400	2000	0.5	4 Φ 25	4 Φ 25
F2	1700	2200	0.5	3 Φ 25	4 Φ 25
F3	3000	2600	0.5	5 Φ 25	5 Φ 25
F4	3000	3400	0.5	6 Φ 25	10 Φ 25
F5	3000	2800	0.5	5 Φ 25	8 Φ 25
F6	3200	3400	0.5	7 Φ 25	11 Φ 25
F7	3000	2000	0.5	5 Φ 25	4 Φ 25
F8	2000	2400	0.5	4 Φ 25	4 Φ 25
F9	3600	1800	0.5	6 Φ 25	3 Φ 25
F10	2200	2400	0.5	4 Φ 25	4 Φ 25
F11	2500	2800	0.5	5 Φ 25	5 Φ 25
F12	2000	2200	0.5	4 Φ 25	4 Φ 25

5.2. Strip footing

A strip footing, also known as a continuous footing or a wall footing, is a type of shallow foundation used to distribute the load of a building or structure to the underlying soil. It consists of a continuous strip of concrete or masonry that extends along the length of a load-bearing wall or column. Strip footings are typically wider than the wall they support and are designed to transfer the vertical loads to the soil while also providing stability against lateral movements. Figure 5-4 shows the strip footing.

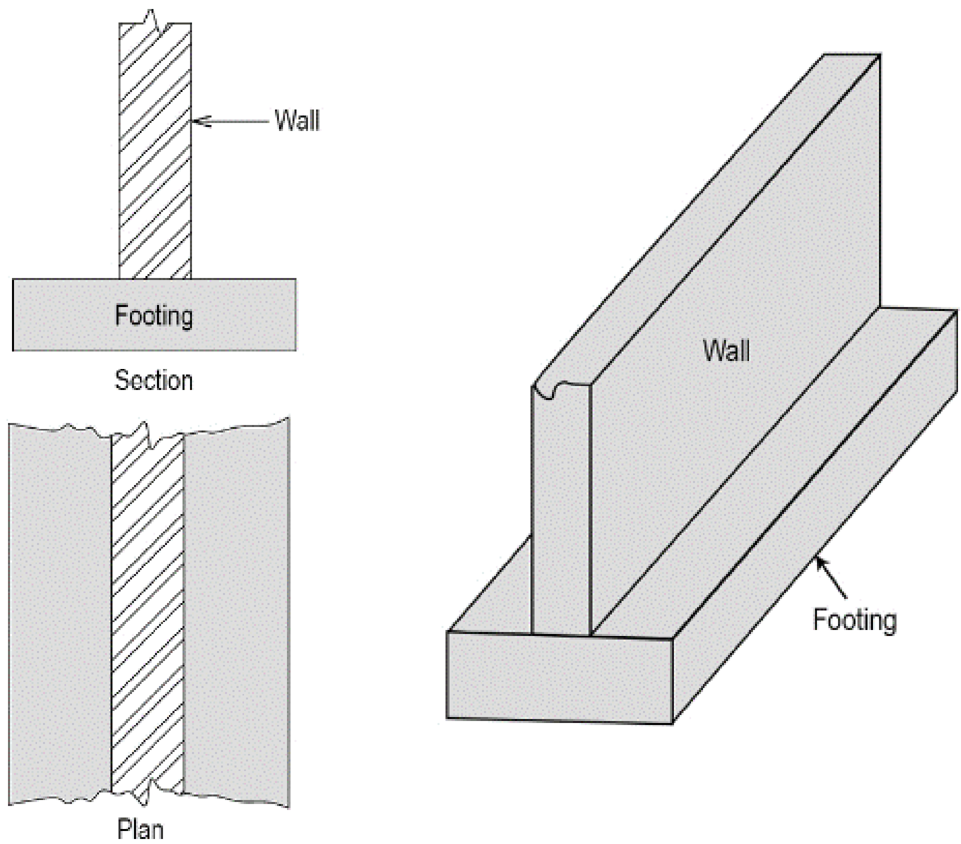


Figure 5-4 Strip footing

5.2.1. Equations and parameters

❖ Preliminary member sizing [5]:

$$q_n = q_a - weight_{footing} - weight_{soil} \quad (5\text{-}13)$$

$$A_{req} = \frac{P_{service}}{q_n} \quad (5\text{-}14)$$

$$q_{nu} = \frac{P_u}{A_{footing}} \quad (5\text{-}15)$$

Where:

q_a, q_n & q_{nu}: are allowable soil pressure, allowable net soil pressure and factored net pressure respectively (kN/m^2).

$P_{service}$: Axial force (N).

P_u: Factored axial force (N).

❖ Shear capacity chech [1][5]:

$$V_u = q_{nu} \times A_{tributary} \quad (5\text{-}16)$$

$$\phi\ V_C = 0.75 \times 0.17 \times \lambda \times \sqrt{f\ '\mathrm{c}} \times b \times d \quad \geq \ V_u \quad (5\text{-}17)$$

Where:

V_C: Nominal shear strength provided by concrete (N).

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete.

b: Overall length of the wall (m).

d: Distance from extreme compression fiber to centroid of longitudinal tension reinforcement (mm).

V_u: Factored shear force at section (N).

$A_{tributary}$: Tributary area for one way shear (m^2).

❖ Flexural reinforcement design [5]:

$$M_u = A_{tributary} \times \frac{L_{tributary}}{2} \tag{5-18}$$

$$A_S = \frac{M_u}{\phi \times f_y \times d} \tag{5-19}$$

$$a = \frac{A_S \times f_y}{0.85 \times f'c \times b} \quad , \quad c = \frac{a}{\beta_1} \tag{5-20}$$

$$\in_t = \left(\frac{0.003}{c}\right) \times d - 0.003 \ \geq \ 0.005 \ \ Tension \ \ control \tag{5-21}$$

$$A_S = \frac{M_u}{\phi \times f_y \times \left(d - \frac{a}{2}\right)} \ \geq \ A_{S\,\min} \tag{5-22}$$

$$A_{S\,\min} = Greator \ \ of \ \left(\frac{0.0018 \times 420}{f_y}, 0.0014\right) \times A_g \tag{5-23}$$

Where:

$A_{tributary}$: Tributary area for flexure (m^2).

$L_{tributary}$: Tributary width for flexure (m).

A_S: Area of the steel reinforcement (mm^2).

a: Depth of equivalent rectangular stress block (mm).

c: Distance from extreme compression fiber to neutral axis (mm).

ε_t: Net tensile strain.

A_g: Gross area of concrete section (m^2).

5.2.2. Design by excel

An excel sheet was established following the above equations to design the strip footings. Figure 5-5 and Figure 5-6 show the excel sheet used for the design of strip footings.

Entry data		
Fc	35	mpa
fy	420	mpa
Soil unit weight	15	kN/m^3
Concrete unit weight	25	kN/m^3
$q_{allowable}$	200	kN/m^2
Wall thcikness	0.2	m
distance from ground to foot base	1.2	m
Foot thickness	0.5	m
Q working	1900	kN
Q factored	2060	kN
Concrete cover	75	mm
Bar size	25	mm
Length	2.2	m

Figure 5-5 Entry data

Results		
q_n	177.000	kN/m^2
$A_{required}$	10.734	m^2
width	4.9	m
q_{nu}	191.095	kN/m^2
d	412.500	mm
Vu	370.246	kN
ΦVc	684.527	oK foot thickness is safe
Mu	1160.852	kN.m
A_s	7836.777	mm^2
a	50.289	mm
β1	0.850	
c	59.164	mm
ε_t	0.018	> 0.005 oK Tension control
A_s	7928.219	mm^2
$A_{s\ min}$	900.000	mm^2
S_{max}	450.000	mm
n	17	bars

Figure 5-6 Results

Table 5-10 shows the reinforcement and dimension for each strip footing associated with the shear walls.

Table 5-10 Reinforcement and dimensions of strip footings

Pier #	**Length**	**Width (m)**	**n**		
P1	2.2	0.9	5	Φ 12	t = 0.3 m
P2	2.2	0.9	5	Φ 12	t = 0.3 m
P3	2.2	2.5	15	Φ 18	t = 0.3 m
P4	1.7	2.4	10	Φ 18	t = 0.3 m
P5	1.8	3	9	Φ 25	t = 0.3 m
P6	1.8	2.5	12	Φ 18	t = 0.3 m
P7	1.8	2.8	15	Φ 18	t = 0.3 m
P1 core	2.2	3.8	10	Φ 25	t = 0.5 m
P2 core	2.2	4.9	17	Φ 25	t = 0.5 m
P3 core	2.2	3.8	9	Φ 25	t = 0.5 m
P4 core	3	2.8	7	Φ 25	t = 0.5 m

CHAPTER 6. CALCULATION OF QUANTITIES

The quantities were quantified and calculated using Revit software, and to ensure model compatibility between Etabs and Revit, the Etabs model was transferred to Revit using the CSIxRevit tool. Figure 6-1 shows the building model in Revit software.

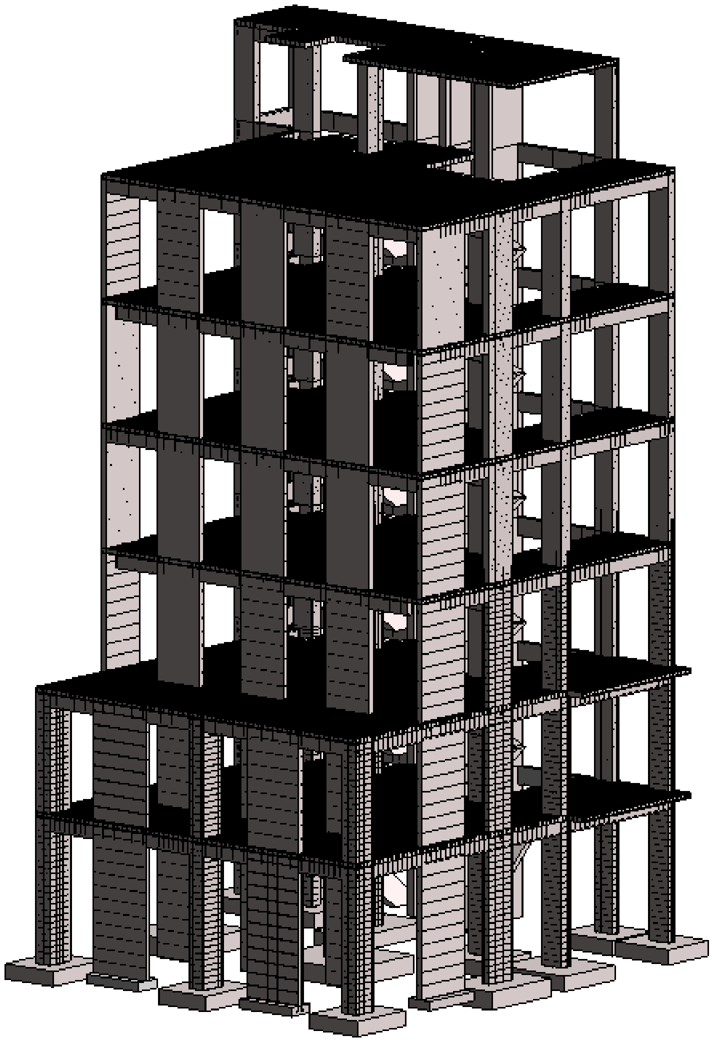


Figure 6-1 Building model in Revit software

6.1. Flat Slab System

6.1.1. Concrete Quantity Schedules

- Table 6-1 shows the calculated concrete volume in (m^3) for the footings of the flat slab system building.

Table 6-1 Concrete quantity for the footings of the building (Flat)

Foundations Concrete Schedule		
Mark	Core Thickness	Volume
F8	0.60 m	3.60 m³
F13	0.50 m	2.20 m³
F12	0.50 m	3.75 m³
F11	0.50 m	3.13 m³
F2	0.50 m	1.96 m³
F2	0.50 m	1.96 m³
F9	0.50 m	2.50 m³
F10	0.50 m	3.80 m³
F6	0.60 m	5.18 m³
F1	0.50 m	2.40 m³
F7	0.60 m	7.30 m³
F4	0.50 m	5.40 m³
F1	0.50 m	2.40 m³
F13	0.50 m	2.20 m³
F1	0.50 m	2.40 m³
F5	0.50 m	4.50 m³
F3	0.50 m	4.20 m³
Total		58.87 m³

- Using Revit software, the concrete quantity for columns, beams, and slabs respectively was calculated separately for each floor as shown in figures 6-2, 6-3 and 6-4.

<Forth Floor Column Schedule>

A	B	C
Mark	Dimension (cm)	Volume
C1	100 X 60	6.98 m³
3		6.98 m³
C2	90 X 60	2.10 m³
1		2.10 m³
C3	120 X 30	2.79 m³
2		2.79 m³
C4	50 X 80	1.55 m³
1		1.55 m³
C5	80 X 40	2.55 m³
2		2.55 m³
C6	50 X 60	1.16 m³
1		1.16 m³
C7	30 X 80	3.87 m³
4		3.87 m³
14		21.01 m³

Figure 6-2 Concrete quantity for fourth floor columns (Flat)

<Forth Floor Beams Schedule>

A	B	C
Mark	Dimension (cm)	Volume
B1	60 X 30	1.11 m³
3		1.11 m³
B2	60 X 20	3.21 m³
8		3.21 m³
11		4.32 m³

Figure 6-3 Concrete quantity for fourth floor beams (Flat)

<Concrete Floor Schedual>

A	B	C	D	E
Type	Level	Core Thickness	Area	Volume
Flat slab	Story7	0.22 m	60.66 m²	13.35 m³
Flat slab	Story1	0.22 m	185.61 m²	40.84 m³
Flat slab	Story2	0.22 m	185.60 m²	40.83 m³
Flat slab	Story3	0.22 m	131.28 m²	28.88 m³
Flat slab	Story6	0.22 m	131.28 m²	28.88 m³
Flat slab	Story5	0.22 m	131.28 m²	28.88 m³
Flat slab	Story4	0.22 m	131.28 m²	28.88 m³
7				210.54 m³

Figure 6-4 Concrete quantity for floors (Flat)

- Table 6-2 shows the calculated concrete volume in (m^3) for each floor of the flat slab system building.

Table 6-2 Concrete quantity schedule for each floor of the building (Flat)

Story#	Volume of concrete (m^3)
Story#1	79.73
Story#2	73.29
Story#3	54.21
Story#4	54.21
Story#5	54.21
Story#6	54.21
Story#7	19.06
Total	388.92

6.1.2. Reinforcement Quantity Schedules

- Reinforcement rebar was placed in all elements of the building using Revit software with considering all properties of the reinforcement rebars such as (standard type, diameter, shape, bend…etc.) as shown in figures 6-5 and 6-6.

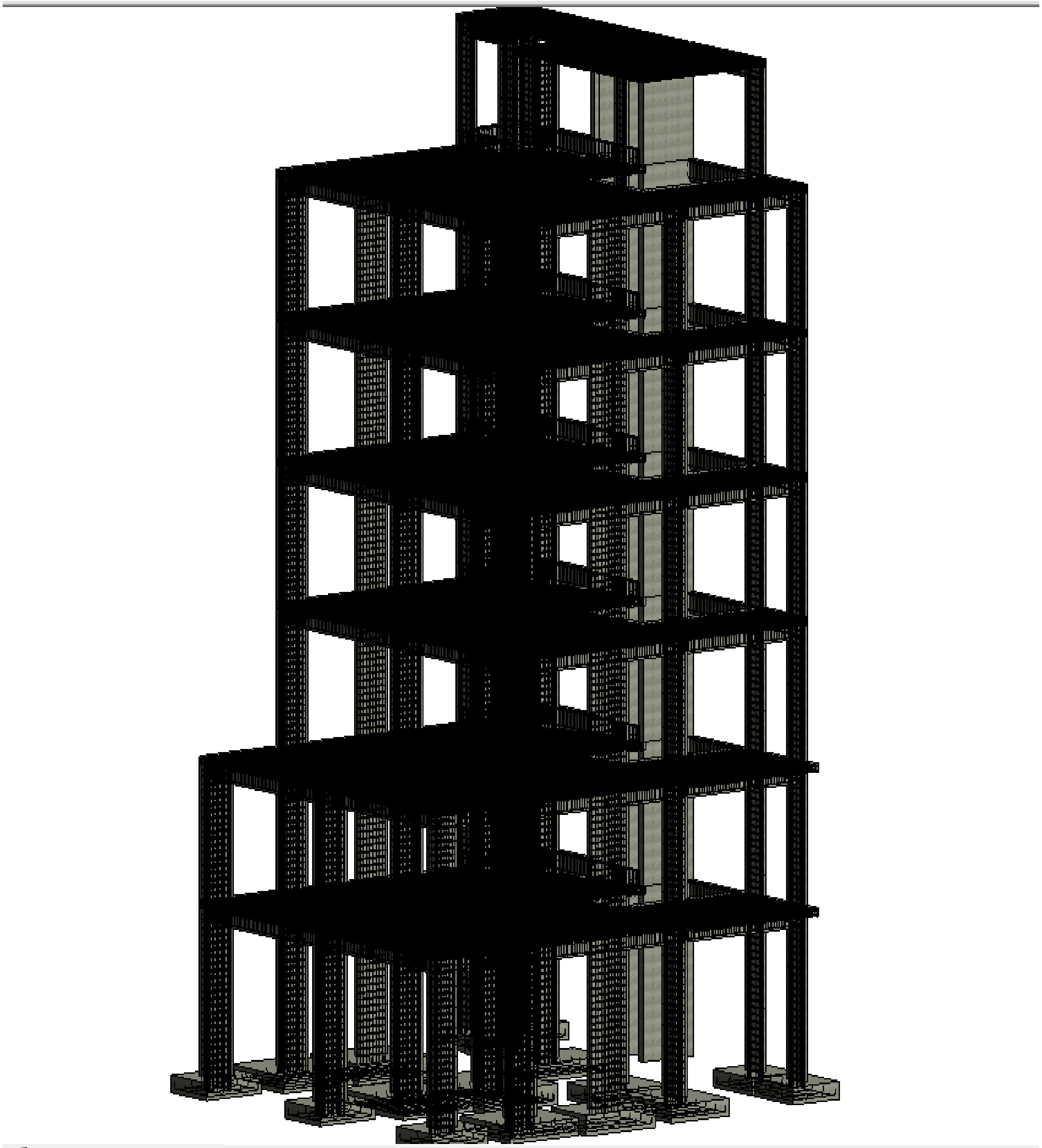


Figure 6-5 3D view of the building visible rebars

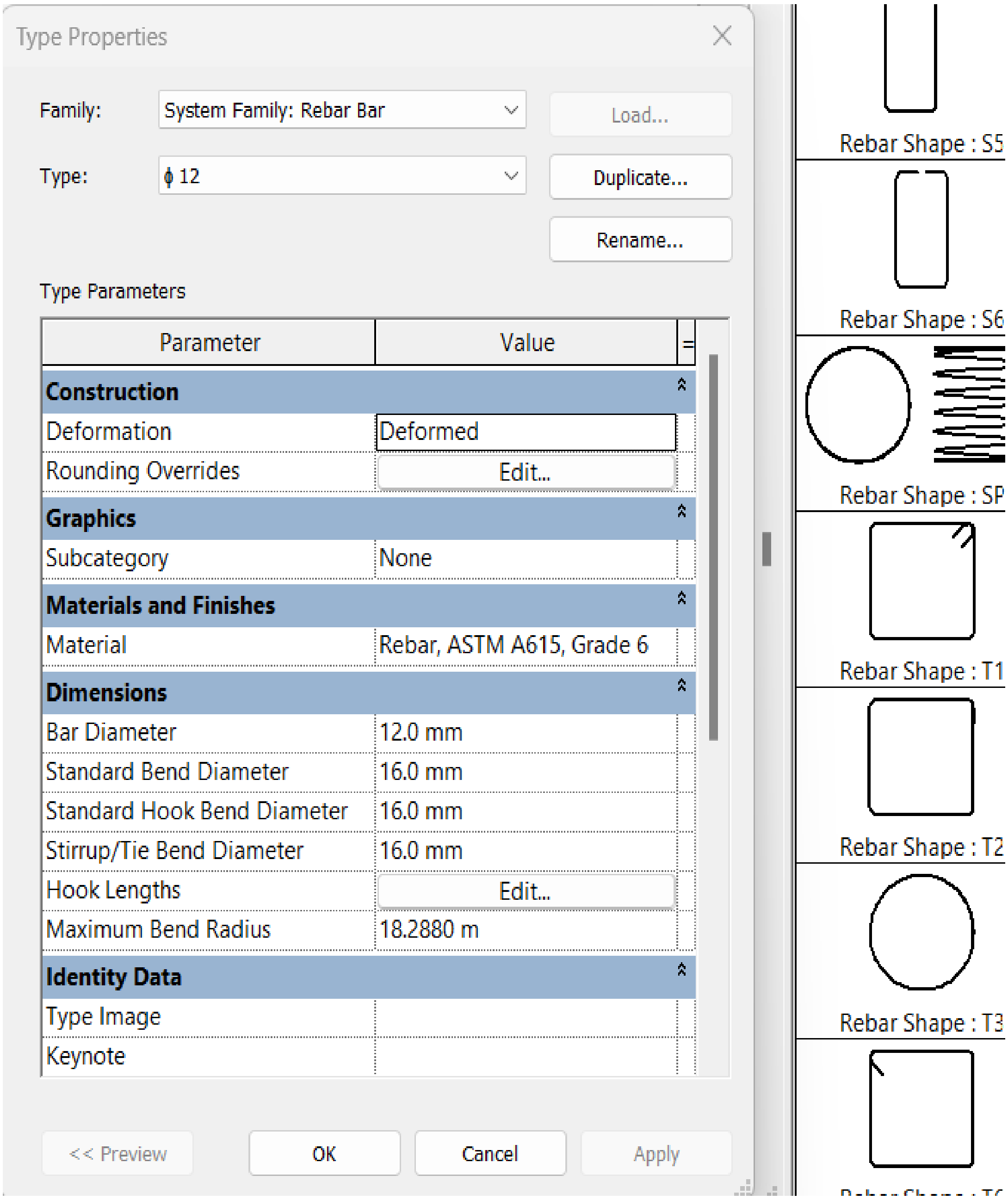


Figure 6-6 Selection of properties of the rebar in Revit software

- Table 6-3 shows the calculated weight in (ton) of the reinforcement rebars for the entire flat slab system building according to the standard diameter placed in the model. However, the weight parameter was added to the Revit by inserting eq (6-1) as shown in Figure 6-7.

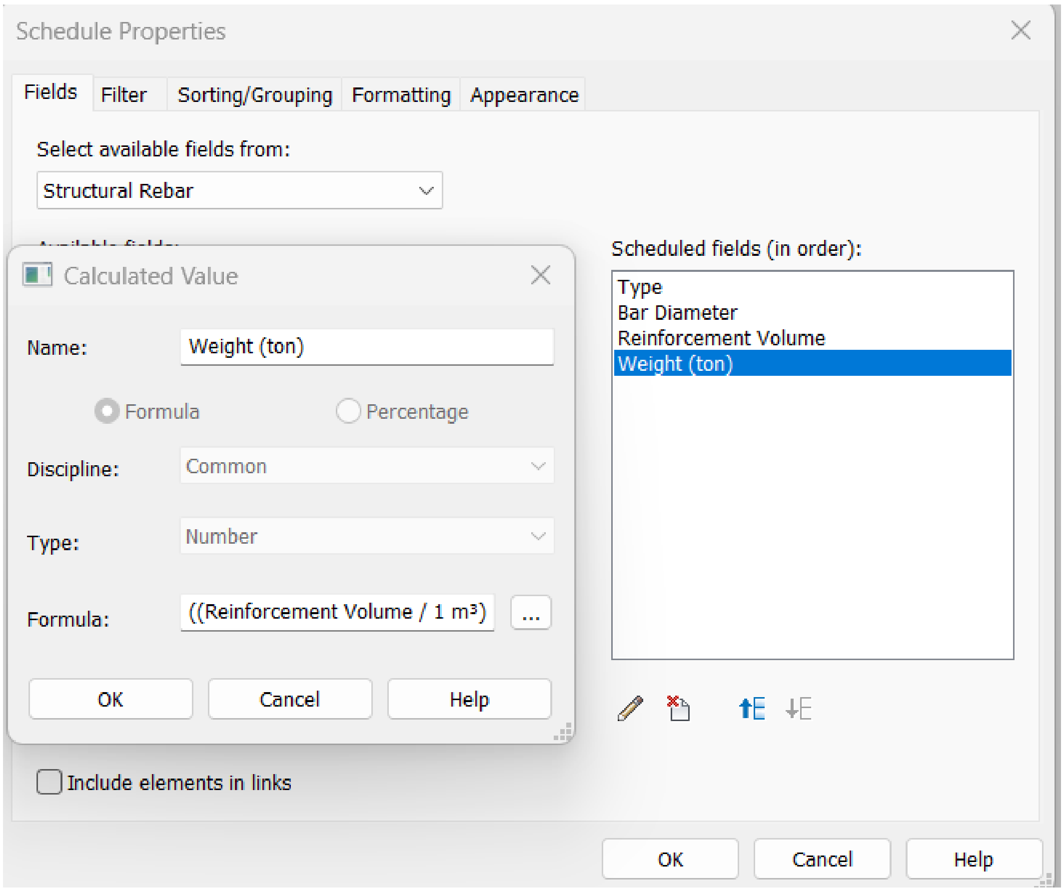


Figure 6-7 Setting weight parameter in Revit software

$$\text{Weight (ton)} = \frac{\text{Reinforcement Volume} \times 7850}{1000} \tag{6-1}$$

In which 7850 is the density of the A615-Grade 60 rebar in (Kg/m^3).

Table 6-3 Reinforcement rebars quantity for the entire building (Flat)

Reinforcement quantity Schedule (Flat)		
Bar Diameter	Reinforcement Volume	Weight (ton)
8 mm	0.085 m^3	0.67
10mm	0.979 m^3	7.68
12 mm	1.497 m^3	11.75
14 mm	2.053 m^3	16.12
16 mm	1.321 m^3	10.37
18 mm	1.220 m^3	9.58
25 mm	0.260 m^3	2.04
Grand total: 1556	7.416 m^3	58.21

- Table 6-4 shows the calculated weight in (ton) of reinforcement rebars required for the footings of the flat slab system building.

Table 6-4 Reinforcement quantity for the footings (Flat)

Foundations Reinforcement quantity Schedule (Flat)				
Host Mark	Bar Diameter	Quantity	Reinforcement Volume	Weight (ton)
F1	25 mm	24	0.028 m^3	0.22
F2	25 mm	14	0.015 m^3	0.12
F3	25 mm	12	0.018 m^3	0.14
F4	25 mm	19	0.032 m^3	0.25
F5	25 mm	14	0.022 m^3	0.17
F6	25 mm	14	0.022 m^3	0.17
F7	25 mm	19	0.035 m^3	0.27
F8	25 mm	9	0.012 m^3	0.09
F9	25 mm	8	0.010 m^3	0.08
F10	25 mm	13	0.019 m^3	0.15
F11	25 mm	9	0.012 m^3	0.09
F12	25 mm	12	0.018 m^3	0.14
F13	25 mm	16	0.018 m^3	0.14
Total		183	0.260 m^3	2.04

- Table 6-5 shows an estimated weight in (ton) of reinforcement rebars for each floor of the flat slab system building according to the different diameters that have been selected and placed in the model in Revit software. The estimated weight of the 12mm and 14mm diameter slab reinforcing rebar is more accurate than other because it is directly calculated from Revit software as shown in Figure 6-8. However, other diameters were estimated based on avilable data.

Table 6-5 Reinforcement rebars quantity for each floor of the building (Flat)

Story#	Weight of Reinforcement rebars (ton)						Total
	φ 8mm	φ 10mm	φ 12mm	φ 14mm	φ 16mm	φ 18mm	
Story#1	0.11	1.2	2.26	3.1	1.65	1.79	10.11
Story#2	0.11	1.2	2.26	3.1	1.65	1.79	10.11
Story#3	0.1	1.1	1.62	2.22	1.57	1.5	8.11
Story#4	0.1	1.1	1.62	2.22	1.57	1.5	8.11
Story#5	0.1	1.1	1.62	2.22	1.57	1.5	8.11
Story#6	0.1	1.1	1.62	2.22	1.57	1.5	8.11
Story#7	0.05	0.88	0.75	1.04	0.79	0	3.51
Total	0.67	7.68	11.75	16.12	10.37	9.58	56.17

<Story#7 Slab Reinforcement Schedule>

A	B	C	D	E	F	G	H
Host Category	Comments	Top/Exterior Major	Top/Exterior Minor	Bottom/Interior Major	Bottom/Interior Minor	Reinforcement Volume	Weight (ton)
Floor	Story#7	ϕ 14 @ 150 mm (T)	ϕ 14 @ 150 mm (T)			0.133 m³	1.04
						0.133 m³	1.04
1						0.133 m³	1.04

Figure 6-8 Reinforcement rebars quantity for a flat slab of story#7 by Revit

6.2. Solid Slab System

6.2.1. Concrete Quantity Schedules

- Table 6-6 shows the calculated concrete volume in (m^3) for the footings of the solid slab system building.

Table 6-6 Concrete quantity for the footings of the building (Solid)

Foundations concrete Schedule		
Mark	Core Thickness	Volume
F1	0.50 m	2.40 m^3
F1	0.50 m	2.40 m^3
F1	0.50 m	2.40 m^3
F2	0.50 m	1.87 m^3
F2	0.50 m	1.87 m^3
F3	0.50 m	3.90 m^3
F3	0.50 m	3.90 m^3
F4	0.50 m	5.10 m^3
F5	0.60 m	5.04 m^3
F6	0.60 m	6.53 m^3
F7	0.60 m	3.60 m^3
F8	0.50 m	2.40 m^3
F9	0.50 m	3.24 m^3
F10	0.50 m	2.64 m^3
F11	0.50 m	3.50 m^3
F12	0.50 m	2.20 m^3
F12	0.50 m	2.20 m^3
Total		55.19 m^3

- Table 6-7 shows the calculated concrete volume in (m^3) for each floor of the solid slab system building.

Table 6-7 Concrete quantity schedule for each floor of the building (solid)

Story#	Volume of concrete (m^3)
Story#1	74.53
Story#2	68.11
Story#3	50.3
Story#4	50.3
Story#5	50.3
Story#6	50.3
Story#7	16.77
Total	360.61

6.2.2. Reinforcement Quantity Schedules

- Table 6-8 shows the calculated weight in (ton) of the reinforcement rebars for the entire solid slab system building according to the standard diameter placed in the model.

Table 6-8 Reinforcement quantity for the entire building (solid)

Rebar Schedule		
Bar Diameter	Reinforcement Volume	Weight (ton)
8 mm	0.12 m^3	0.96
10 mm	2.54 m^3	19.95
14 mm	0.34 m^3	2.67
16 mm	0.98 m^3	7.72
18 mm	1.22 m^3	9.55
25 mm	0.23 m^3	1.77
Total	5.43 m^3	42.62

- Table 6-9 shows the calculated weight in (ton) of reinforcement rebars required for the footings of the solid slab system building.

Table 6-9 Reinforcement quantity for the footings (Solid)

Foundations Reinforcement Schedule				
Host Mark	Bar Diameter	Quantity	Reinforcement Volume	Weight (ton)
F1	25 mm	24	0.03 m³	0.22
F2	25 mm	14	0.01 m³	0.11
F3	25 mm	20	0.03 m³	0.23
F4	25 mm	16	0.03 m³	0.21
F5	25 mm	13	0.02 m³	0.16
F6	25 mm	18	0.03 m³	0.24
F7	25 mm	9	0.01 m³	0.09
F8	25 mm	8	0.01 m³	0.07
F9	25 mm	9	0.01 m³	0.09
F10	25 mm	8	0.01 m³	0.08
F11	25 mm	10	0.01 m³	0.11
F12	25 mm	16	0.02 m³	0.14
Total		165	0.23 m³	1.77

- Table 6-10 shows an estimated weight in (ton) of reinforcement rebars for each floor of the solid slab system building according to the different diameters that have been selected and placed in the model in Revit software.

Table 6-10 Reinforcement quantity for each floor of the building (Solid)

Story#	Weight of Reinforcement (ton)					Total
	φ 8mm	φ 10mm	φ 14mm	φ 16mm	φ 18mm	
Story#1	0.18	3.2	0.54	1.25	1.77	6.94
Story#2	0.18	3.2	0.54	1.25	1.77	6.94
Story#3	0.14	3	0.4	1.1	1.5	6.14
Story#4	0.14	3	0.4	1.1	1.5	6.14
Story#5	0.14	3	0.4	1.1	1.5	6.14
Story#6	0.14	3	0.4	1.1	1.5	6.14
Story#7	0.05	1.55	0	0.82	0	2.42
Total	0.97	19.95	2.68	7.72	9.54	40.86

6.3. The Comparison & Charts

- Table 6-11 shows a comprehensive inventory of the quantities of concrete and steel for both structural systems. After comparing the quantities of materials, it appears that the solid slab system requires less steel and concrete, which means that it is more efficient in terms of sustainability and economically advantageous.

Table 6-11 Comparison table between the two structural systems

Structural System	Volume of Concrete (m^3)	Volume of steel rebars (m^3)	Weight of steel rebars (ton)
Flat Slab System	447.79	7.416	58.21
Solid Slab System	415.8	5.43	42.62

- Figures 6-9 and 6-10 illustrate the ratios of the concrete and steel for the building elements

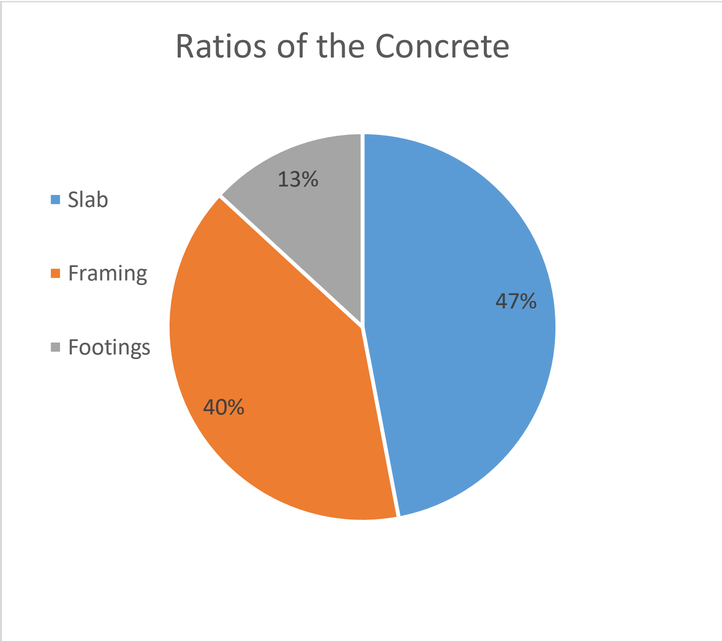


Figure 6-9 Ratios of the concrete in elements of the building

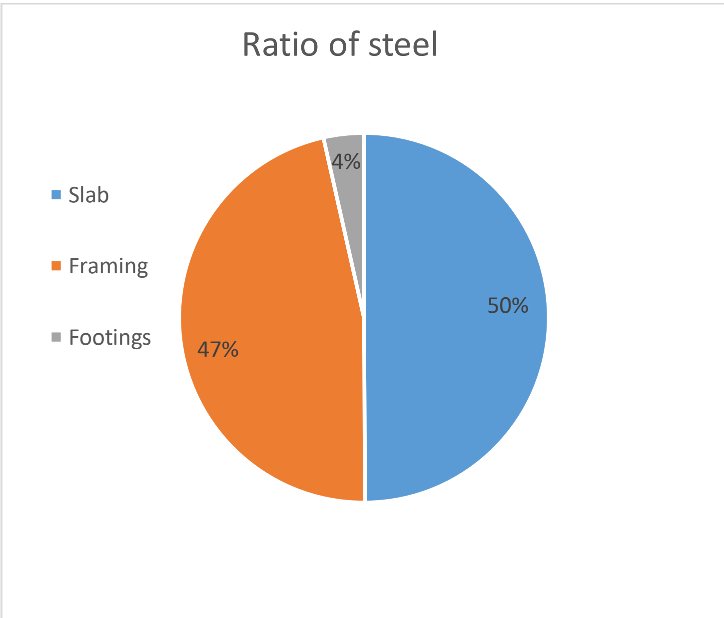


Figure 6-10 Ratios of the steel in elements of the building

CHAPTER 7. DRAWINGS

7.1. General Columns-Axis Layout

- Figure 7-1 displays the general columns axis layout of the building, in which the yellow color represents columns that stops at the level of story#1, the cyan color stops at the level of story#6, and gray the columns that are to the roof of the building.

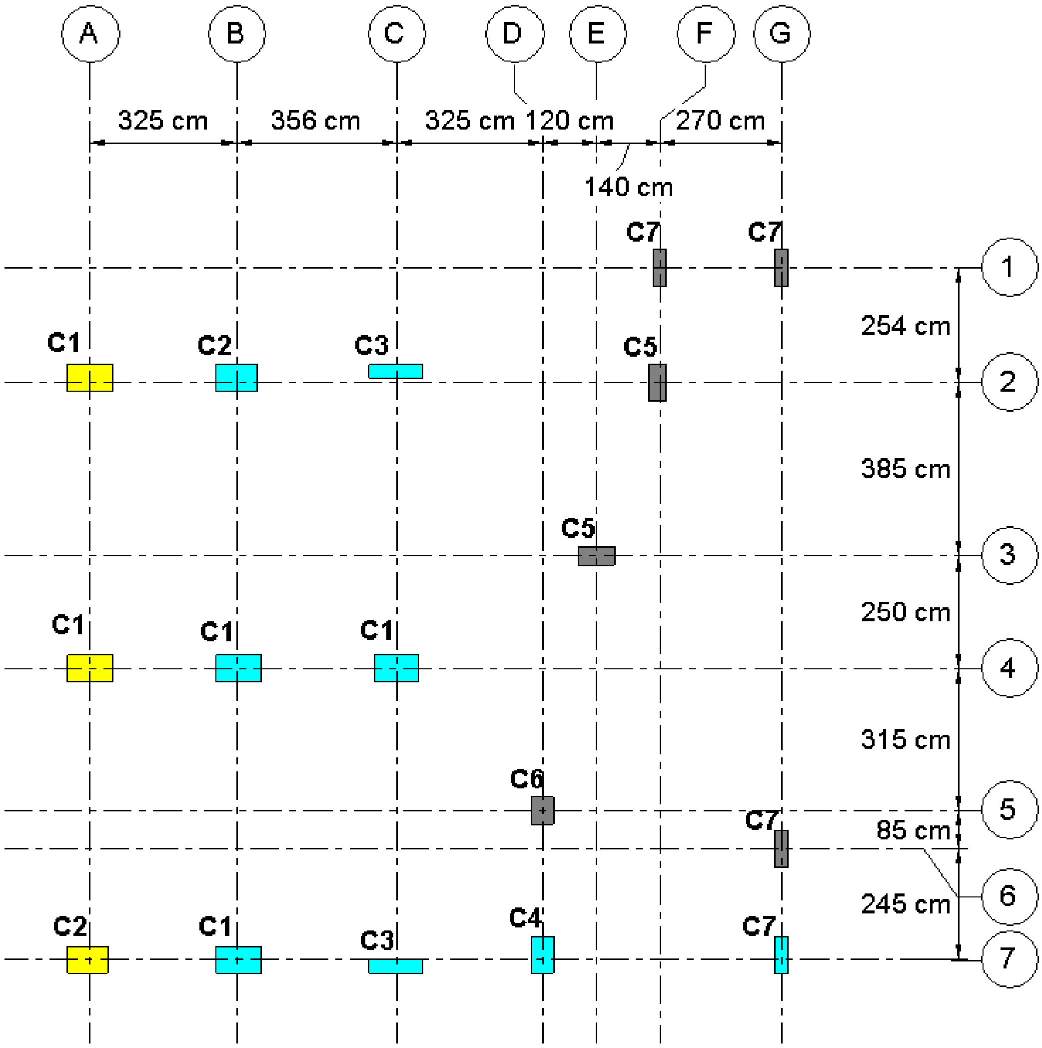


Figure 7-1 General columns-axis layout

7.2. Typical Detail Sectional Elevation

- Isolated concrete footing and column is shown in Figure 7-2

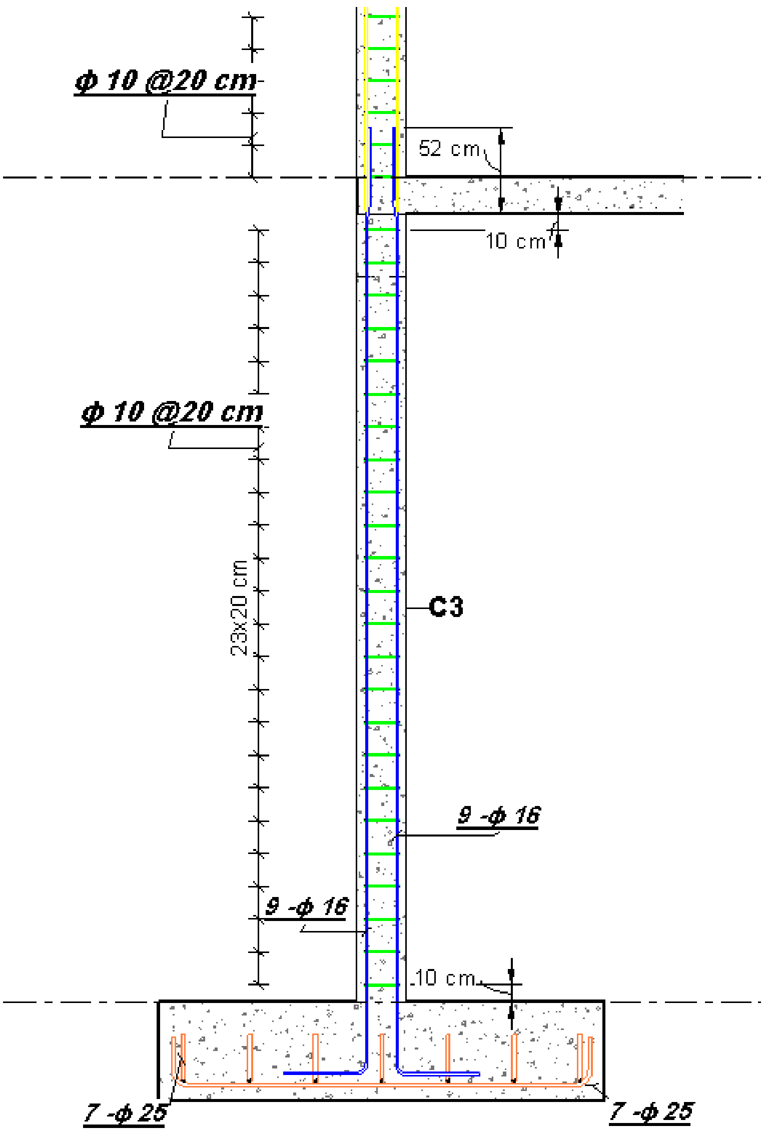


Figure 7-2 Isolated footing and column

- Typical beam detail is shown in Figure 7-3.

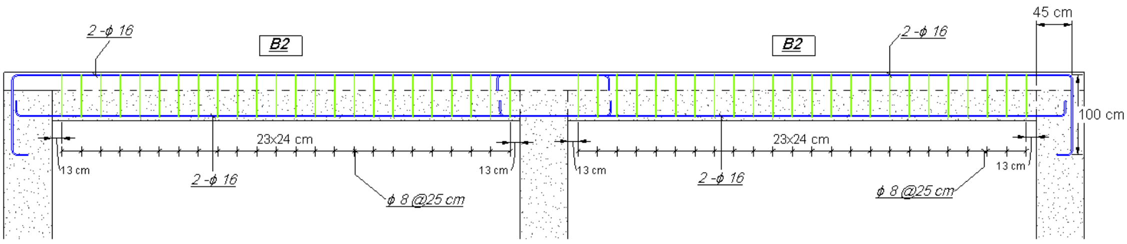


Figure 7-3 Typical beam detail

7.3. Columns Details

Figures 7-4, 7-5, 7-6, 7-7, 7-8, 7-9, 7-10 and 7-11 display the section's detail of the columns. The stirrups were placed according to the SBC 304 criteria to ensure confinement between rebars and to prevent any obstruction that may prevent the concrete mix from passing through column. It should be noted that in the sections C4 and C5, the stirrups were placed in the manner shown in figures 7-7 and 7-8 to avoid placing a two bars tie in the long direction of the section, which prevent more concrete mix from passing through column.

C1

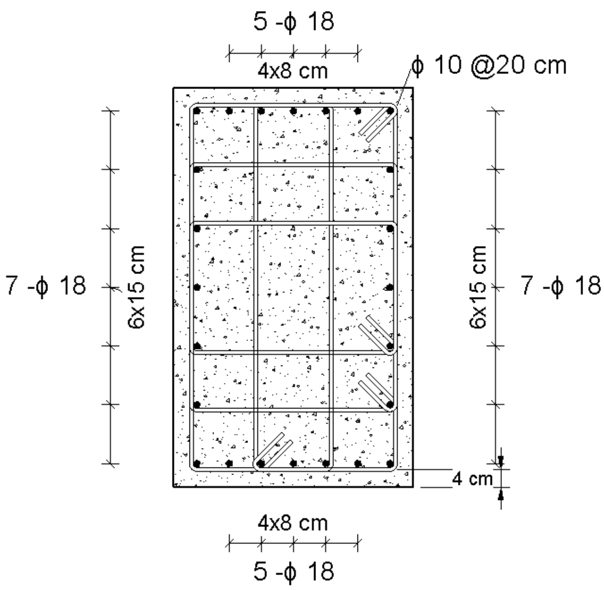


Figure 7-4 C1 Section details

C2

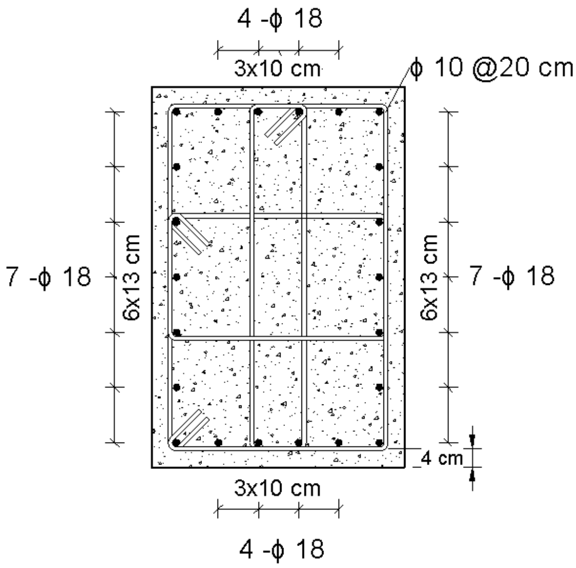


Figure 7-5 C2 Section details

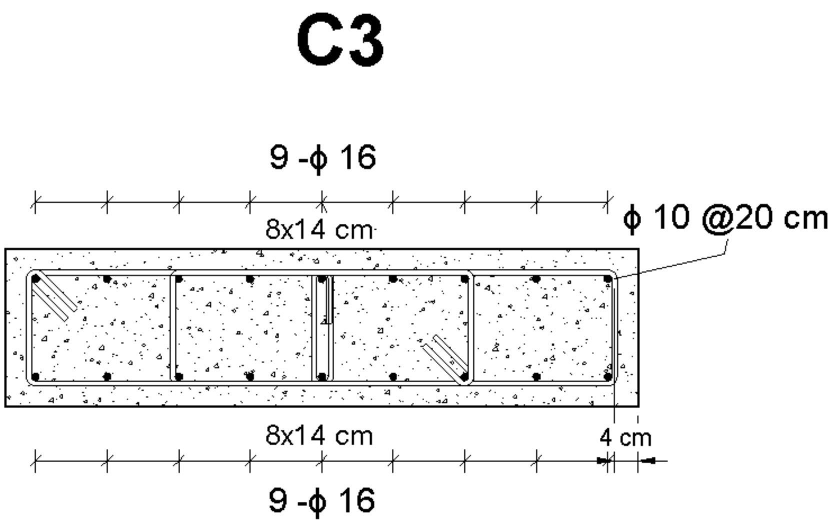


Figure 7-6 C3 Section details

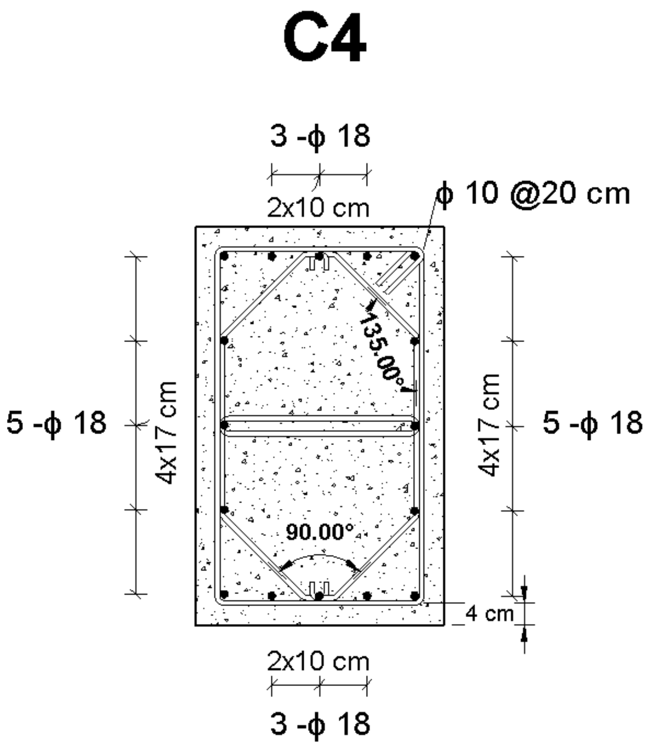


Figure 7-7 C4 section details

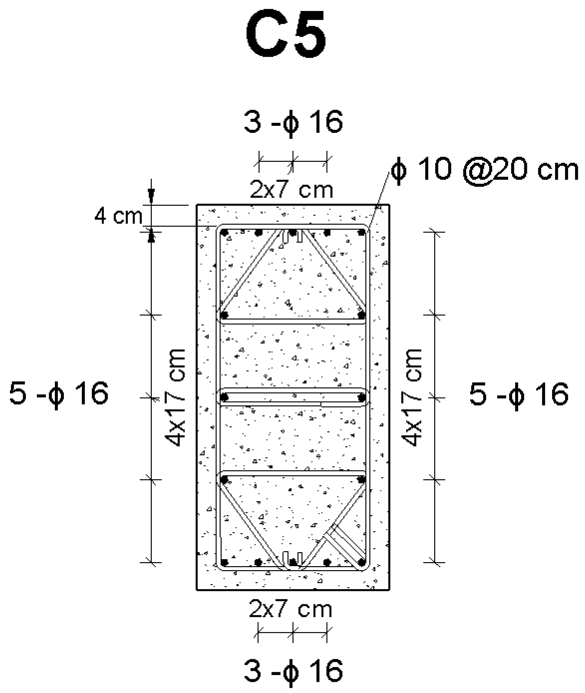


Figure 7-8 C5 Section details

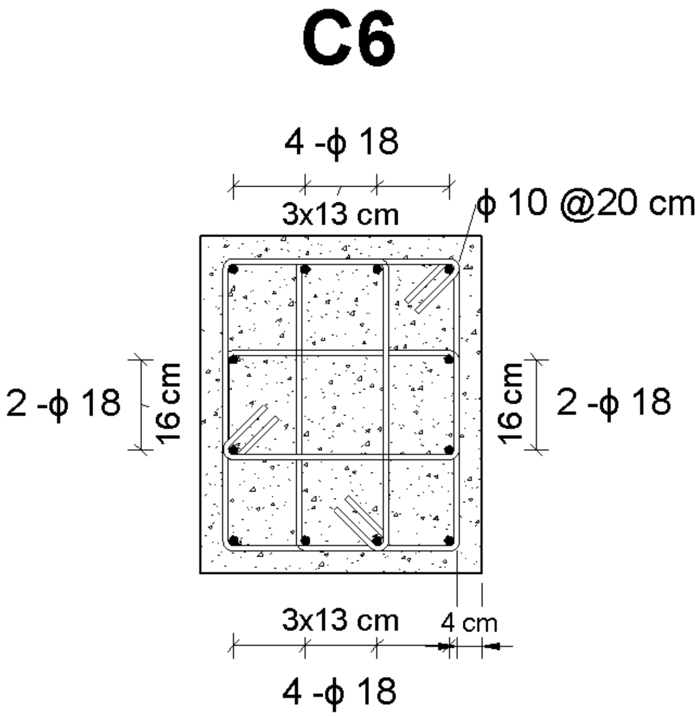


Figure 7-9 C6 section details

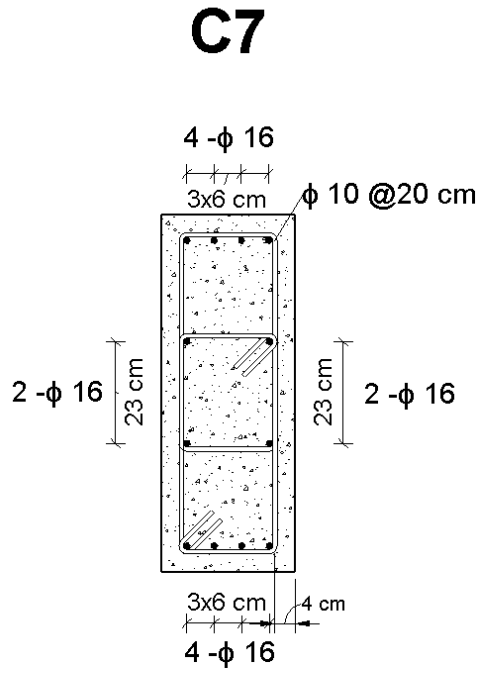


Figure 7-10 C7 section details

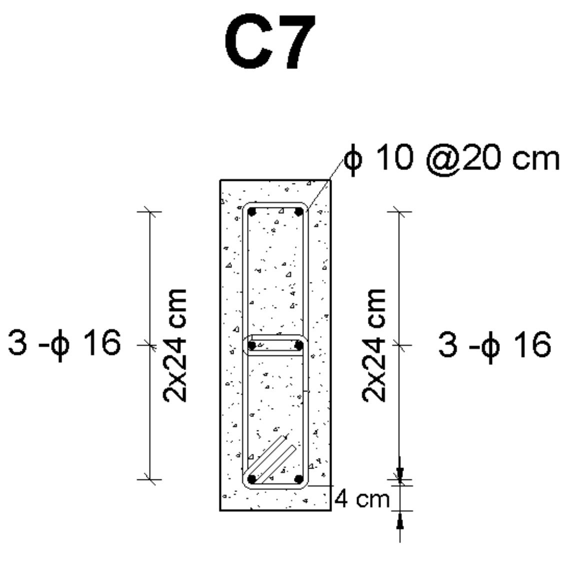


Figure 7-11 C7 section details at level of story#6

7.4. Beams Details of Flat Slab System

- Figure 7-12 displays the beams axis-layout for the flat slab system. While figures 7-13 and 7-14 show beams section detail of B1 and B2 in flat slab system.

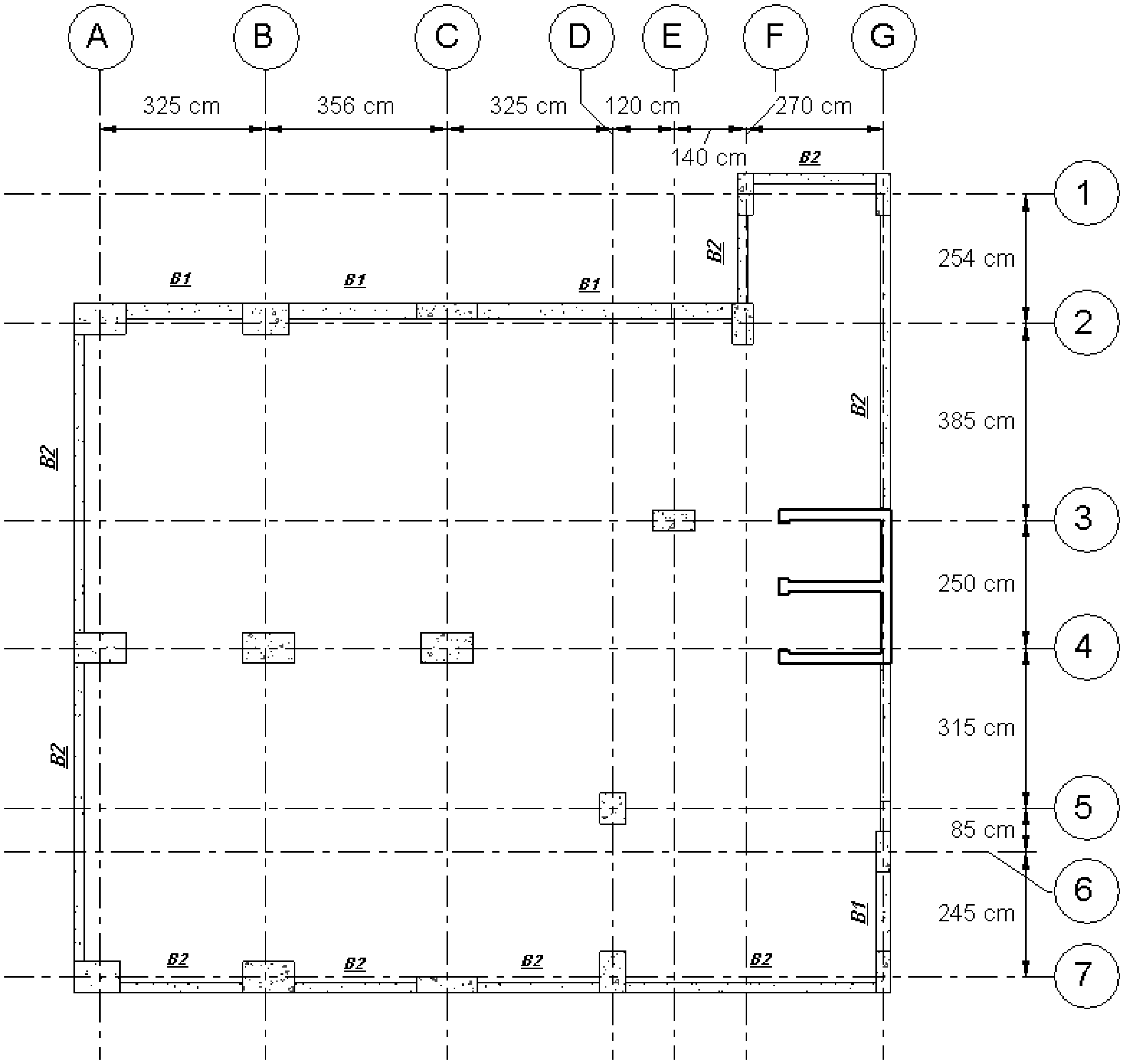


Figure 7-12 Beams-axis layout (Flat)

Beam Mark #	Dimension		Reinforcement					
	Depth (cm)	Width (cm)	Bottom Continous (B)	Top		Stirrups		
				Mid span	@ Support	Size (mm)	Spacing, mm "Ends"	Spacing, mm "Mid"
B1	60	30	3 ϕ 16	3 ϕ 16	3 ϕ 16	8	1 : 130 Rest 250	250
B1	60	20	2 ϕ 16	2 ϕ 16	2 ϕ 16	8	1 : 130 Rest 250	250

Figure 7-13 Beams reinforcement detail (Flat)

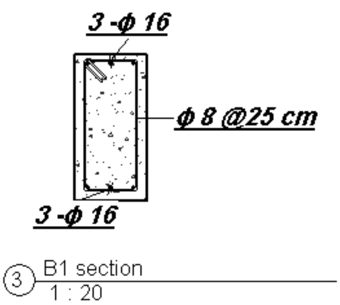
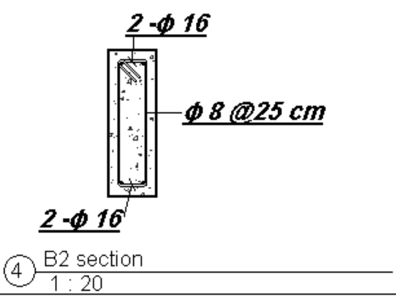
Section Details	
B1	
B2	

Figure 7-14 Beams section details (Flat)

7.5. Beams Details of Solid Slab System

- Figure 7-15 displays the beam's axis layout for the solid slab system. The beams section and reinforcement details of B1, B2, and B3 for the solid slab system is shown in Figures 7-16 and 7-17.

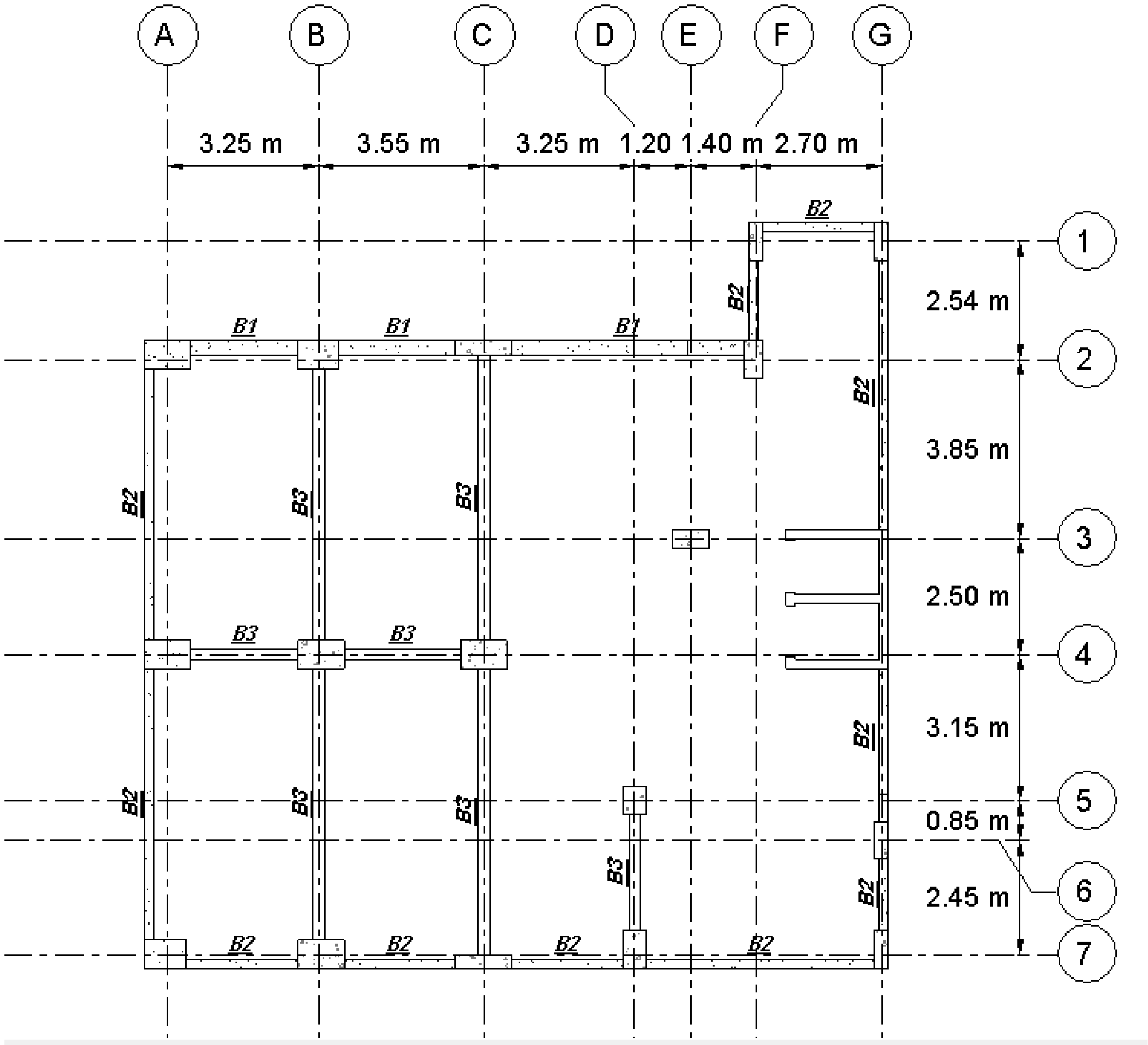


Figure 7-15 Beams-axis layout (Solid)

Beam Mark #	Dimension		Reinforcement					
	Depth (cm)	Width (cm)	Bottom Continous (B)	Top		Stirrups		
				Mid span	@ Support	Size (mm)	Spacing, mm "Ends"	Spacing, mm "Mid"
B1	60	30	3 ϕ 16	3 ϕ 16	3 ϕ 16	8	1 : 130 Rest 250	250
B2	60	20	3 ϕ 14	3 ϕ 14	3 ϕ 14	8	1 : 130 Rest 250	250
B3	40	20	2 ϕ 14	2 ϕ 14	2 ϕ 14	8	1 : 130 Rest 250	250

Figure 7-16 Beams reinforcement details (Solid)

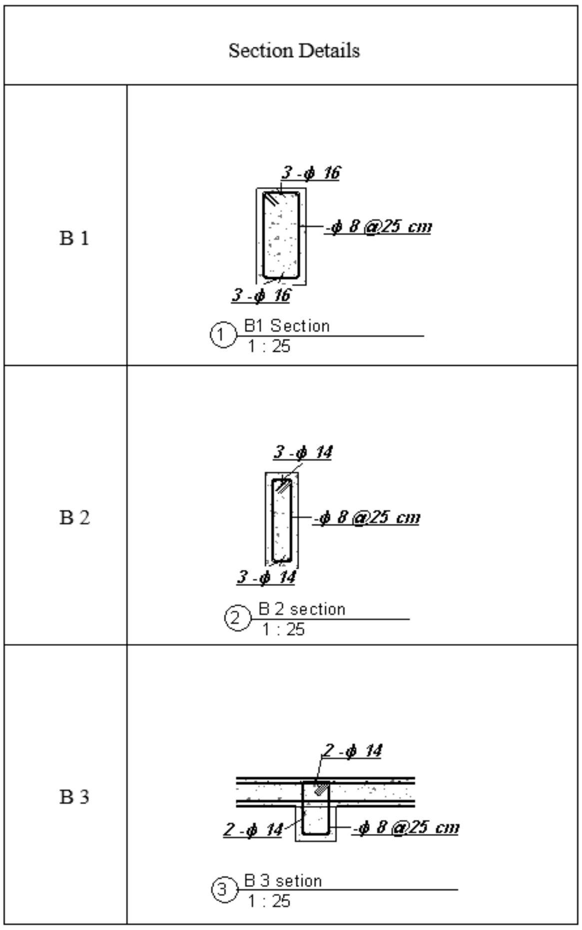


Figure 7-17 Beams section details (Solid)

7.6. Flat Slab Reinforcement Details

- Figure 7-18 displays the flat slab with visible reinforcement rebars that was modeled using Revit software. As detected in the design stage 4.7.1. , for top reinforcement Φ14 is selected and for bottom reinforcement Φ12, and additional top reinforcement Φ16 at (E3 grid). It shall be noted that the additional cover (35mm) is made at the top to place the additional reinforcement as shown in Figure 7-20. Roof slab reinforcement details is shown in Figure 7-19.

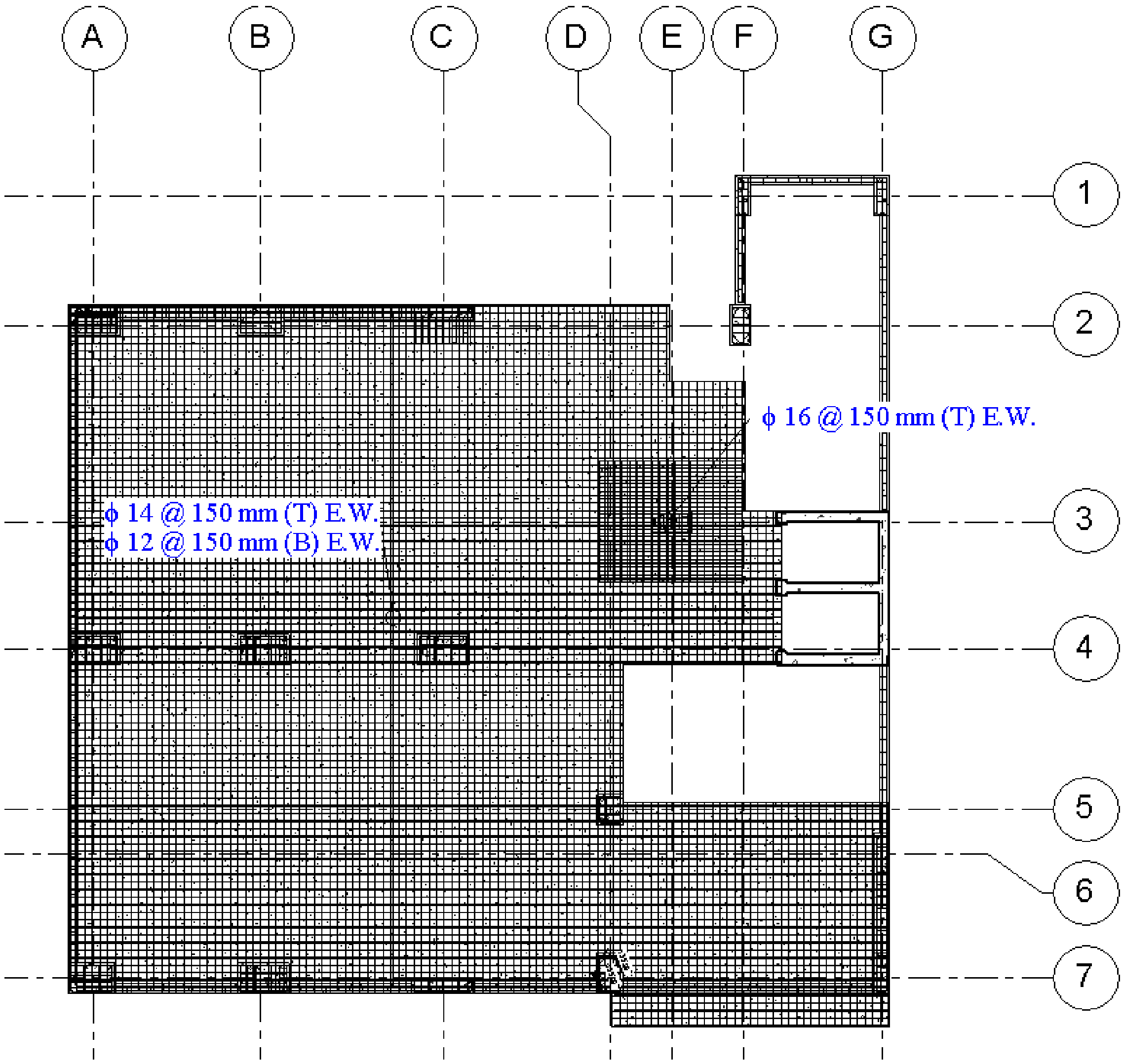


Figure 7-18 Flat slab reinforcement details

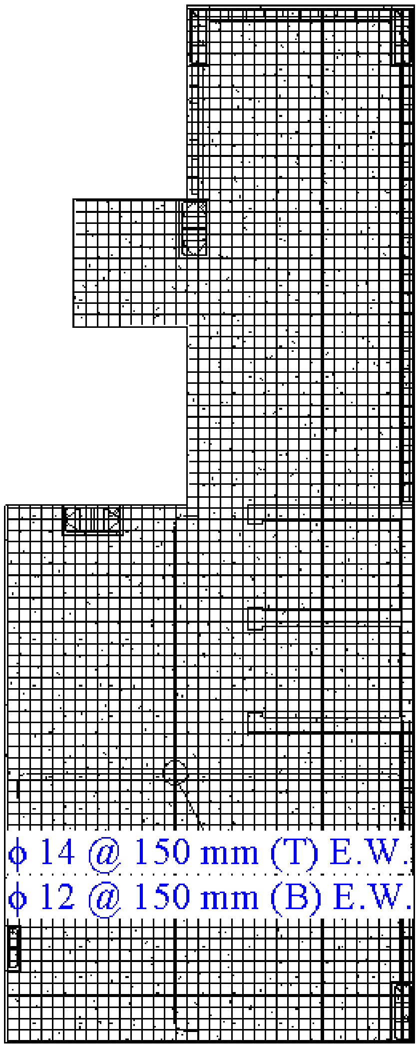


Figure 7-19 Roof slab reinforcement details

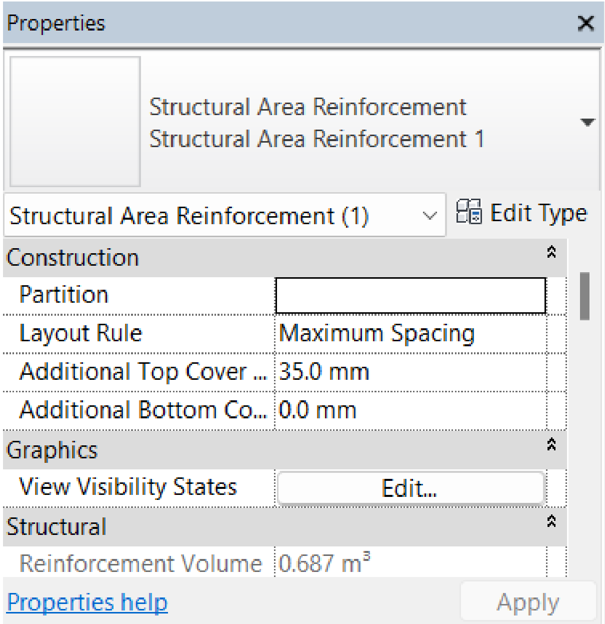


Figure 7-20 Setting slab reinforcement in Revit software

7.7. Solid Slab Reinforcement Details

- Figure 7-21 shows the solid slab reinforcement details, as detected in the design stage 4.7.2. for top and bottom reinforcement $\Phi10$ is selected. Where EW refers to Each Way and EF refers to Each Face. Roof slab reinforcement details for solid slab system is shown in Figure 7-22.

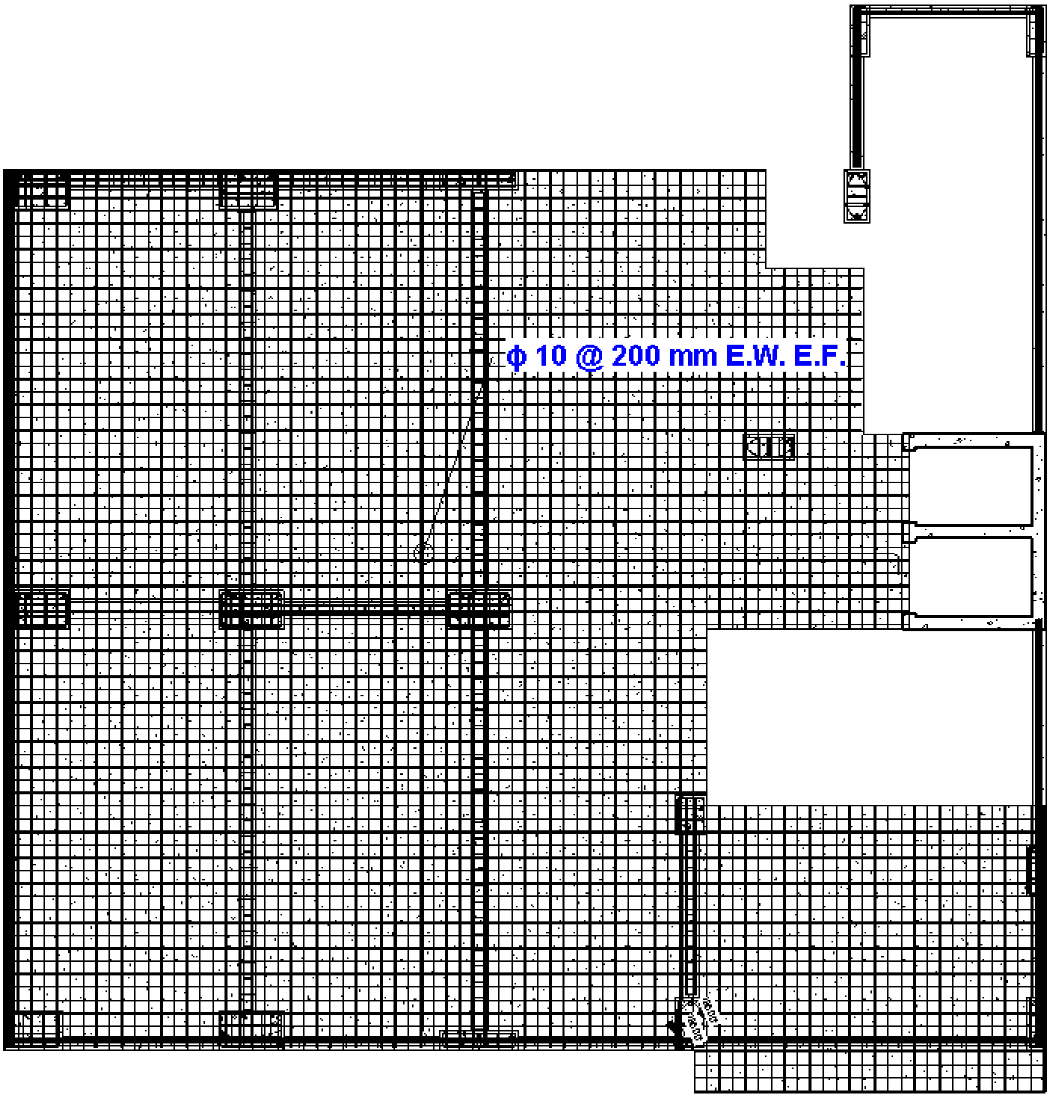


Figure 7-21 Solid slab reinforcement details

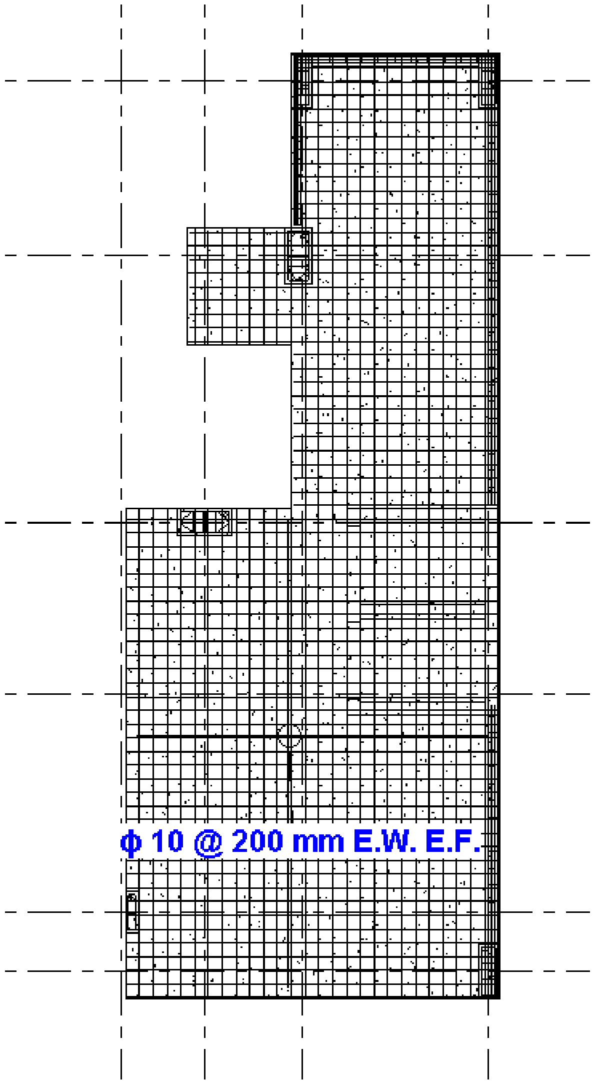


Figure 7-22 Roof slab reinforcement details (Solid)

7.8. Shear Wall Reinforcement Details

Figure 7-23 shows the shear wall sample reinforcement detailing, which include the longitudinal or flexural reinforcement in addition to the horizontal or shear reinforcement.

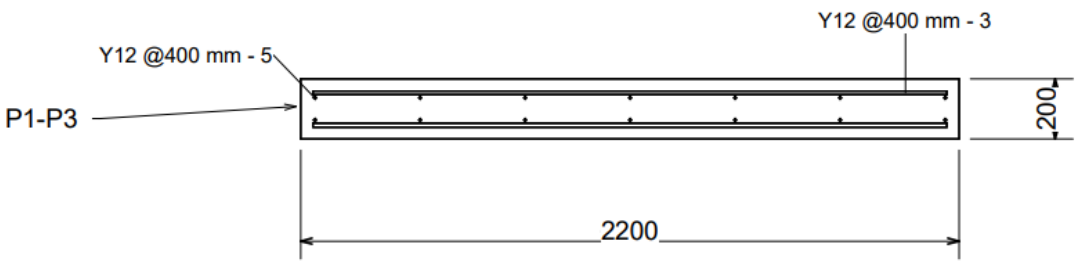


Figure 7-23 Shear wall reinforcement

7.9. Strip Footing Reinforcement Details

Figure 7-24 shows the strip footing reinforcement detailing.

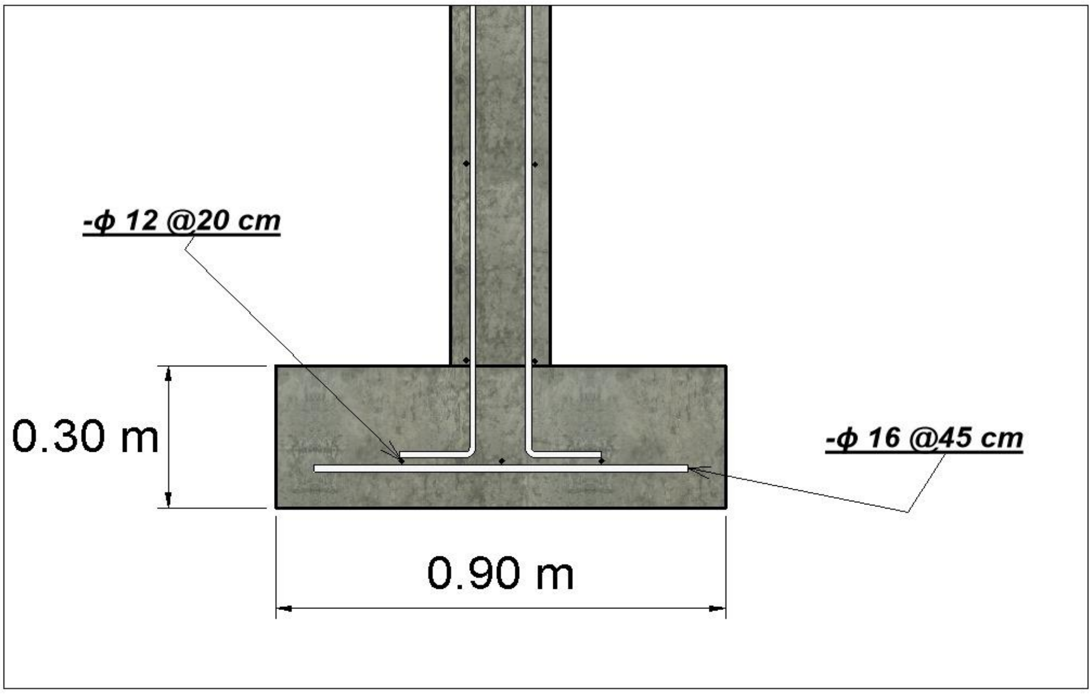


Figure 7-24 Strip footing reinforcement

CHAPTER 8. CONCLUSION

To summarize, in SDP I, the primary focus was on designing the building structure to withstand gravity loads. A comparison was made between the flat slab and solid slab systems in terms of material quantities and structural integrity. The structural elements considered in SDP1 included slabs, beams, columns, and isolated footings for columns. The findings were as follows:

1. The flat slab system required 447.79 m^3 of concrete and 58.21 tons of reinforcement steel.

2. The solid slab system required 415.8 m^3 of concrete and 42.62 tons of reinforcement steel.

Based on these findings, it is evident that the solid slab system is more cost-effective and sufficient.

Moving on to SDP II, wind and seismic loads were manually determined and applied to the building structure using ETABS software. The chosen lateral resisting system was shear walls. The placement of shear walls was carefully done to avoid torsion on the building, resulting in an average eccentricity of 3.7% on the x-axis and 6.7% on the y-axis with respect to the center of mass and rigidity. The design of shear walls was carried out using the Uniform Reinforcing approach in ETABS. The foundations for the walls were manually designed, considering the axial loads from the walls. Finally, all the structural elements were transferred to Revit software for reinforcement and detailed drawings.

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[1] National Committee for the Saudi Building Code, Saudi Building Code Requirements for Concrete Structure (SBC 304). 2018.

[2] National Committee for the Saudi Building Code, Saudi building code requirements for Soil and Foundations (SBC 303). 2018.

[3] A. C. Institute, ACI 318-14 Building Code Requirements for Structural Concrete and Commentary. 2019.

[4] J. E. Bowles, Foundation Analysis and Design. 1997.

[5] J. K. Wight and J. G. MacGregor, Reinforced Concrete: Mechanics and Design. Pearson Higher Ed, 2011.

[6] National Committee for the Saudi Building Code, Saudi building code for Structural Loading and Forces (SBC 301). 2018.

CHAPTER 9. APPENDICES

Appendix A (Maps and Design tables for wind loads)

9.1.1. A-1 Risk category of buildings and other structure

RISK CATEGORY	NATURE OF OCCUPANCY
I	Buildings and other structures that represent a low hazard to human life in the event of failure, including but not limited to: • Agricultural facilities. • Certain temporary facilities. • Minor storage facilities.
II	Buildings and other structures except those listed in Risk Categories I, III and IV.
III	Buildings and other structures that represent a substantial hazard to human life in the event of failure, including but not limited to: • Buildings and other structures whose primary occupancy is public assembly with an occupant load greater than 300. • Buildings and other structures containing Group E occupancies with an occupant load greater than 250. • Buildings and other structures containing educational occupancies for students above the 12th grade with an occupant load greater than 500. • Group I-2 occupancies with an occupant load of 50 or more resident care recipients but not having surgery or emergency treatment facilities. • Group I-3 occupancies. • Any other occupancy with an occupant load greater than 5,000.[a] • Power-generating stations, water treatment facilities for potable water, wastewater treatment facilities and other public utility facilities not included in Risk Category IV. • Buildings and other structures not included in Risk Category IV containing quantities of toxic or explosive materials that: Exceed maximum allowable quantities per control area as given in Table 307.1(1) or 307.1(2) of SBC 201 or per outdoor control area in accordance with the *SBC 801*; and Are sufficient to pose a threat to the public if released.[b]
IV	Buildings and other structures designated as essential facilities, including but not limited to: • Group I-2 occupancies having surgery or emergency treatment facilities. • Fire, rescue, ambulance and police stations and emergency vehicle garages. • Designated earthquake, hurricane or other emergency shelters. • Designated emergency preparedness, communications and operations centers and other facilities required for emergency response. • Power-generating stations and other public utility facilities required as emergency backup facilities for Risk Category IV structures. • Buildings and other structures containing quantities of highly toxic materials that: Exceed maximum allowable quantities per control area as given in Table 307.1(2) of SBC 201 or per outdoor control area in accordance with the *SBC 801*; and Are sufficient to pose a threat to the public if released[b]. • Aviation control towers, air traffic control centers and emergency aircraft hangars. • Buildings and other structures having critical national defense functions. • Water storage facilities and pump structures required to maintain water pressure for fire suppression.

Figure 9-1 Risk category of buildings and other structures

9.1.2. A-2 Ultimate wind speed map for risk category II

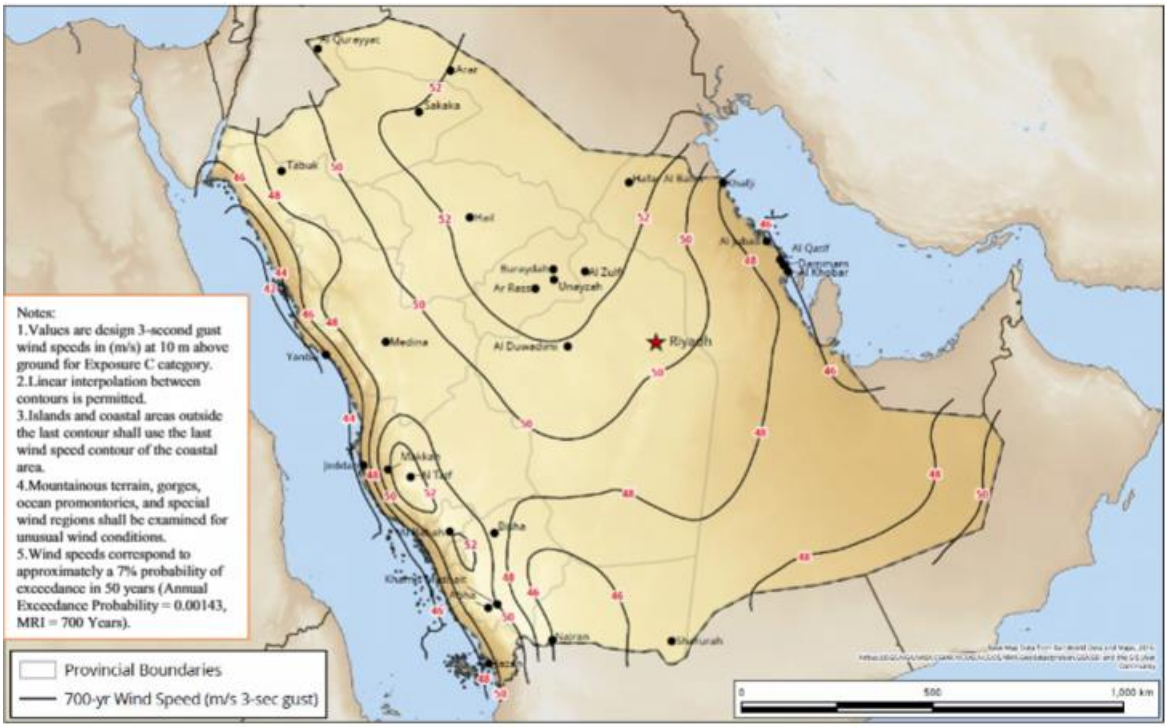


Figure 9-2 Ultimate wind speed category for risk category II

9.1.3. A-3 Wind directionality factor, K_d

Structure Type	Directionality Factor K_d*
Buildings	
Main Wind Force Resisting System	0.85
Components and Cladding	0.85
Arched Roofs	0.85
Chimneys, Tanks, and Similar Structures	
Square	0.90
Hexagonal	0.95
Round	0.95
Solid Freestanding Walls and Solid Freestanding and Attached Signs	0.85
Open Signs and Lattice Framework	0.85
Trussed Towers	
Triangular, square, rectangular	0.85
All other cross sections	0.95

Figure 9-3 Table of wind directionality factor, Kd

9.1.4. A-4 Exposure category

(a) **Surface Roughness B**: Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.

(b) **Surface Roughness C**: Open terrain with scattered obstructions having heights generally less than 10 m. This category includes flat open country and grasslands.

(c) **Surface Roughness D:** Flat, unobstructed areas and water surfaces. This category includes smooth mud flats and salt flats.

26.7.4 Exposure Categories.

26.7.4.1 Exposure B:

(a) For buildings with a mean roof height of less than or equal to 9 m, Exposure B shall apply where the ground surface roughness, as defined by Surface Roughness B, prevails in the upwind direction for a distance greater than 450 m.

(b) For buildings with a mean roof height greater than 9 m, Exposure B shall apply where Surface Roughness B prevails in the upwind direction for a distance greater than 780 m or 20 times the height of the building, whichever is greater.

26.7.4.2 Exposure C:

(a) Exposure C shall apply for all cases where Exposures B or D do not apply.

26.7.4.3 Exposure D:

(a) Exposure D shall apply where the ground surface roughness, as defined by Surface

Figure 9-4 Exposure category section from SBC 301

9.1.5. A-5 Topographic factor, K_{zt}

26.8 —Topographic effects

26.8.1 Wind Speed-Up over Hills, Ridges, and Escarpments. Wind speed-up effects at isolated hills, ridges, and escarpments constituting abrupt changes in the general topography, located in any exposure category, shall be included in the determination of the wind loads when buildings and other site conditions and locations of structures meet all of the following conditions:

1. The hill, ridge, or escarpment is isolated and unobstructed upwind by other similar topographic features of comparable height for 100 times the height of the topographic feature (100*H*) or 3 km, whichever is less. This distance shall be measured horizontally from the point at which the height *H* of the hill, ridge, or escarpment is determined.
2. The hill, ridge, or escarpment protrudes above the height of upwind terrain features within a 3 km radius in any quadrant by a factor of two or more.
3. The structure is located as shown in Figure 26-3 in the upper one-half of a hill or ridge or near the crest of an escarpment.
4. $H/L_h \geq 0.2$.
5. *H* is greater than or equal to 5 m for Exposure C and D and 18 m for Exposure B.

26.8.2 Topographic Factor.

26.8.2.1 The wind speed-up effect shall be included in the calculation of design wind loads by using the factor K_{zt}

$$K_{zt} = (1 + K_1K_2K_3)^2 \qquad \textbf{(26-1)}$$

where K_1, K_2, and K_3 are given in Figure 26-3.

26.8.2.2 If site conditions and locations of buildings and other structures do not meet all the conditions specified in Section 26.8.1 then K_{zt} = 1.0.

Figure 9-5 Topographic factor section from SBC 301

9.1.6. A-6 Gust effect factor, G

26.9 —Gust-effects

26.9.1 Gust-Effect Factor. The gust-effect factor for a rigid building or other structure is permitted to be taken as 0.85.

Figure 9-6 Gust effect factor section from SBC 301

9.1.7. A-7 Enclosure classification

(such as solid freestanding walls and solid freestanding signs, chimneys, tanks, open signs, lattice frameworks, and trussed towers) as specified in CHAPTER 29;

4. Wind Tunnel Procedure for all buildings and all other structures as specified in CHAPTER 31.

26.1.2.2 Components and Cladding. Wind loads on components and cladding on all buildings and other structures shall be designed using one of the following procedures:

1. Analytical Procedures provided in Parts 1 through 6, as appropriate, of CHAPTER 30;

BUILDING, OPEN—A building having each wall at least 80 percent open. This condition is expressed for each wall by the equation $A_o \geq 0.8 A_g$; where, A_o = total area of openings in a wall that receives positive external pressure, in m²; A_g = the gross area of that wall in which A_o is identified, in m².

BUILDING, PARTIALLY ENCLOSED—A building that complies with both of the following conditions:

1. The total area of openings in a wall that receives positive external pressure exceeds the sum of the areas of openings in the

balance of the building envelope (walls and roof) by more than 10 percent.

2. The total area of openings in a wall that receives positive external pressure exceeds 0.4 m² or 1 percent of the area of that wall, whichever is smaller, and the percentage of openings in the balance of the building envelope does not exceed 20 percent.

These conditions are expressed by the following

DIAPHRAGM—Roof, floor, or other membrane or bracing system acting to transfer lateral forces to the vertical Main Wind-Force Resisting System. For analysis under wind loads, diaphragms constructed of untopped steel decks, concrete filled steel decks, and concrete slabs, each having a span-to-depth ratio of two or less, shall be permitted to be idealized as rigid.

Figure 9-7 Enclosure classification definitions

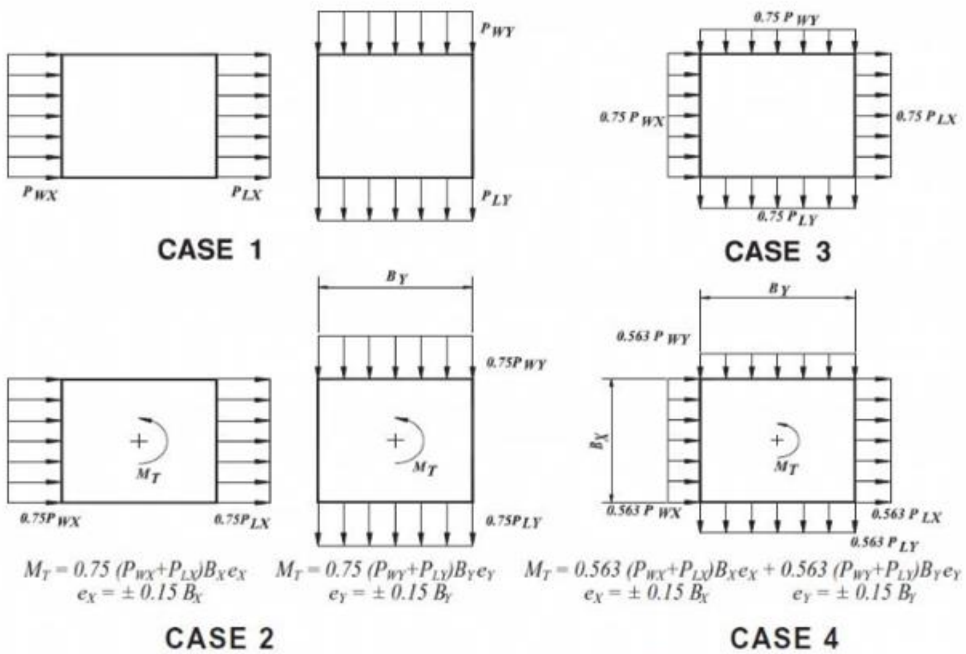
9.1.8. A-8 Internal pressure coefficient, GC_{pi}

Enclosure Classification	Internal Pressure Coefficient (GC_{pi})
Open Buildings	0.00
Partially Enclosed Buildings	+0.55
	- 0.55
Enclosed Buildings	+0.18
	- 0.18

Notes:
1. Plus and minus signs signify pressures acting toward and away from the internal surfaces, respectively.
2. Values of (GC_{pi}) shall be used with q_z or q_h as specified.
3. Two cases shall be considered to determine the critical load requirements for the appropriate condition:
   (i) a positive value of (GC_{pi}) applied to all internal surfaces
   (ii) a negative value of (GC_{pi}) applied to all internal surfaces

Figure 9-8 Table of internal pressure coefficient

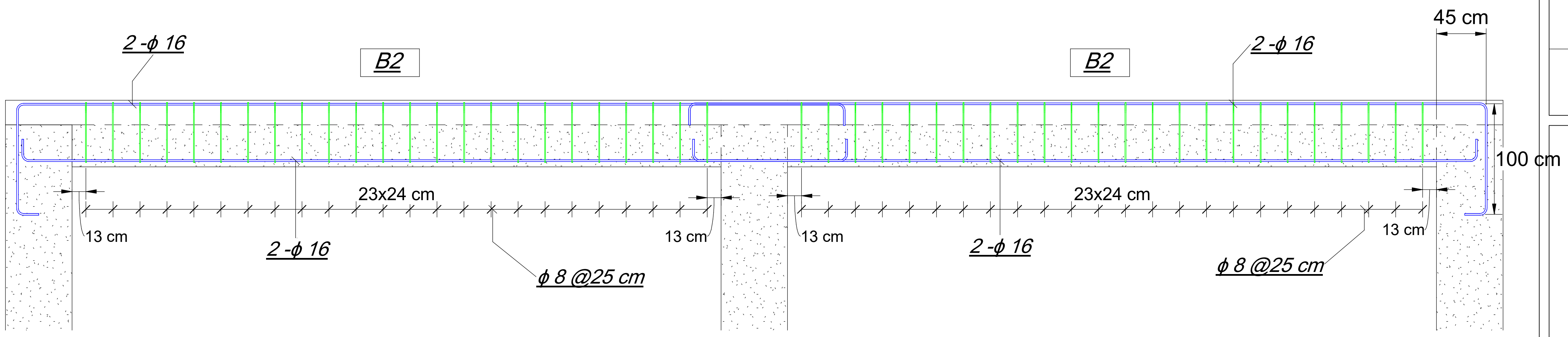
9.1.9. A-9 Design wind load cases



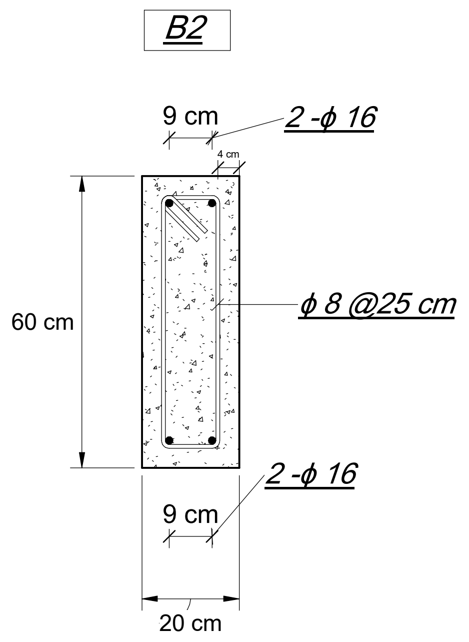
Case 1. Full design wind pressure acting on the projected area perpendicular to each principal axis of the structure, considered separately along each principal axis.
Case 2. Three quarters of the design wind pressure acting on the projected area perpendicular to each principal axis of the structure in conjunction with a torsional moment as shown, considered separately for each principal axis.
Case 3. Wind loading as defined in Case 1, but considered to act simultaneously at 75% of the specified value.
Case 4. Wind loading as defined in Case 2, but considered to act simultaneously at 75% of the specified value.

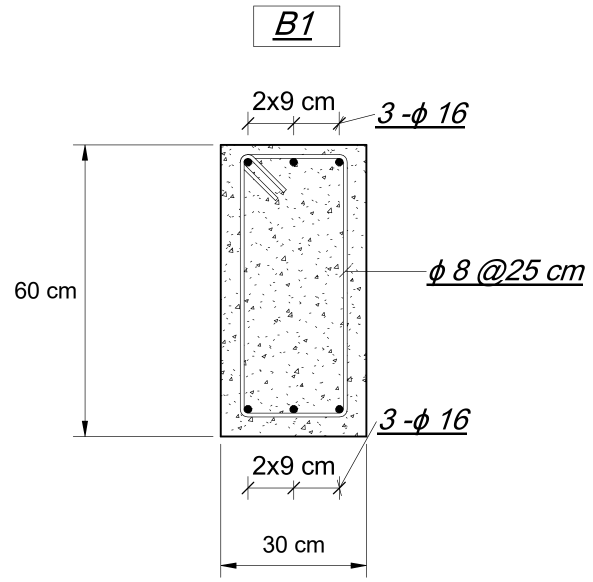
Notes:
1. Design wind pressures for windward and leeward faces shall be determined in accordance with the provisions of Sections 27.4.1 and 27.4.4 as applicable for building of all heights.
2. Diagrams show plan views of building.
3. Notation:
   P_{WX}, P_{WY}: Windward face design pressure acting in the *x*, *y* principal axis, respectively.
   P_{LX}, P_{LY}: Leeward face design pressure acting in the *x*, *y* principal axis, respectively.
   e (e_X, e_Y) : Eccentricity for the *x*, *y* principal axis of the structure, respectively.
   M_T: Torsional moment per unit height acting about a vertical axis of the building.

Figure 9-9 Design wind load cases



Beam Mark #	Dimension		Reinforcement					
	Depth (cm)	Width (cm)	Bottom Continous (B)	Top		Stirrups		
				Mid span	@ Support	Size (mm)	Spacing, mm "Ends"	Spacing, mm "Mid"
B1	60	30	3 ϕ 16	3 ϕ 16	3 ϕ 16	8	1 : 130 Rest 250	250
B1	60	20	2 ϕ 16	2 ϕ 16	2 ϕ 16	8	1 : 130 Rest 250	250





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Flat slab system

Beams

Project number	Project Number
Date	Issue Date
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Sheet#1

Scale As indicated

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Reinforcement Schedule		
Bar Diameter	Reinforcement Volume	Weight (ton)
8 mm	0.088 m³	0.69
10 mm	0.973 m³	7.64
12 mm	1.497 m³	11.75
14 mm	2.053 m³	16.12
16 mm	1.323 m³	10.39
18 mm	1.220 m³	9.57
25 mm	0.277 m³	2.18
Grand total: 1546	7.431 m³	58.33

Concrete Floor Schedual				
Type	Level	Core Thickness	Area	Volume
Flat slab	Story7	22 cm	60.66 m²	13.35 m³
Flat slab	Story1	22 cm	185.61 m²	40.84 m³
Flat slab	Story2	22 cm	185.60 m²	40.83 m³
Flat slab	Story3	22 cm	131.28 m²	28.88 m³
Flat slab	Story6	22 cm	131.28 m²	28.88 m³
Flat slab	Story5	22 cm	131.28 m²	28.88 m³
Flat slab	Story4	22 cm	131.28 m²	28.88 m³
7				210.54 m³

Concrete Beams Schedule		
Mark	Dimension (cm)	Volume
B1	60 X 30	7.23 m³
20		7.23 m³
B2	60 X 20	20.68 m³
54		20.68 m³
74		27.90 m³

Fondation Schedule			
Type	Core Thickness	Area	Volume
Foot 60	60 cm	6.00 m²	3.60 m³
Foot 50	50 cm	4.40 m²	2.20 m³
Foot 50	50 cm	7.50 m²	3.75 m³
Foot 50	50 cm	6.25 m²	3.13 m³
Foot 50	50 cm	3.91 m²	1.96 m³
Foot 50	50 cm	3.91 m²	1.96 m³
Foot 50	50 cm	5.00 m²	2.50 m³
Foot 50	50 cm	7.60 m²	3.80 m³
Foot 60	60 cm	8.64 m²	5.18 m³
Foot 50	50 cm	4.80 m²	2.40 m³
Foot 60	60 cm	12.16 m²	7.30 m³
Foot 50	50 cm	10.80 m²	5.40 m³
Foot 50	50 cm	4.80 m²	2.40 m³
Foot 50	50 cm	4.40 m²	2.20 m³
Foot 50	50 cm	4.80 m²	2.40 m³
Foot 50	50 cm	9.00 m²	4.50 m³
Foot 50	50 cm	8.40 m²	4.20 m³
Grand total: 17			58.87 m³

Concrete Columns Schedule		
Mark	Dimension (cm)	Volume
C1	100 X 60	53.92 m³
22		53.92 m³
C2	90 X 60	17.73 m³
8		17.73 m³
C3	120 X 30	17.41 m³
12		17.41 m³
C4	50 X 80	9.67 m³
6		9.67 m³
C5	80 X 40	17.94 m³
14		17.94 m³
C6	50 X 60	7.25 m³
6		7.25 m³
C7		26.59 m³
28		26.59 m³
96		150.52 m³

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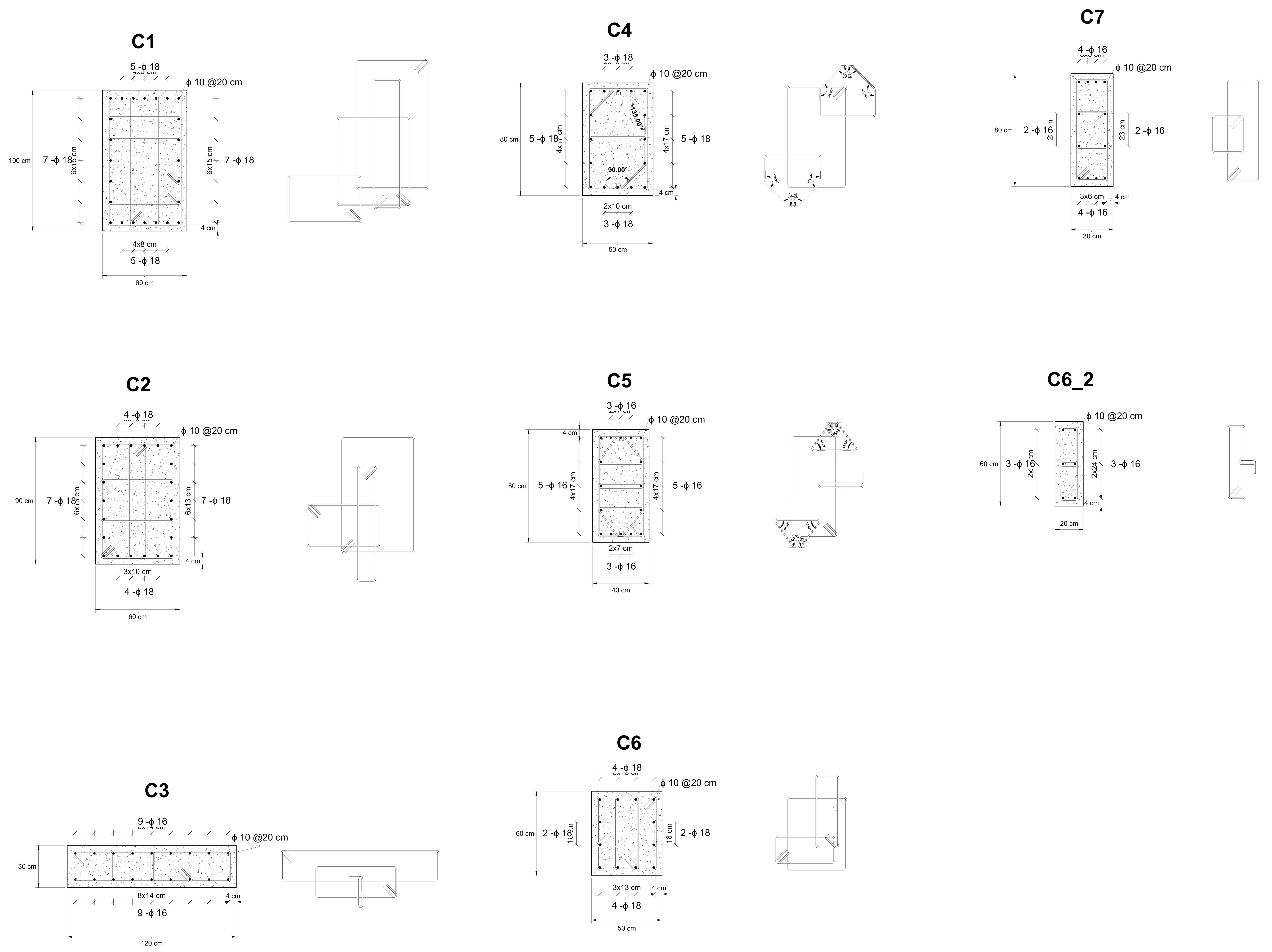

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Flat slab system

Column Patterns

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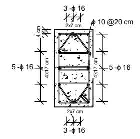
Penthouse floor to roof level	Details					
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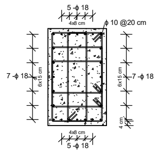
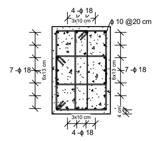
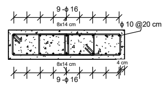
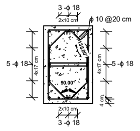
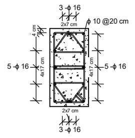
Story#2 floor to Penthouse floor level	Details					
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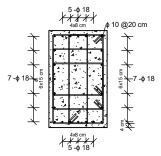
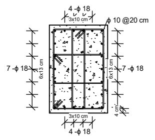
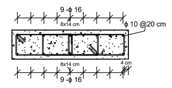
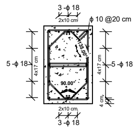
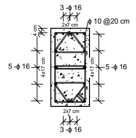
Story#1 floor level to Story #2 floor level	Details					
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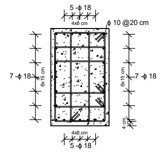
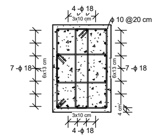
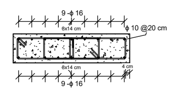
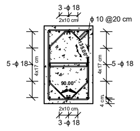
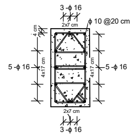
Ground floor to Story #1 floor level	Details					
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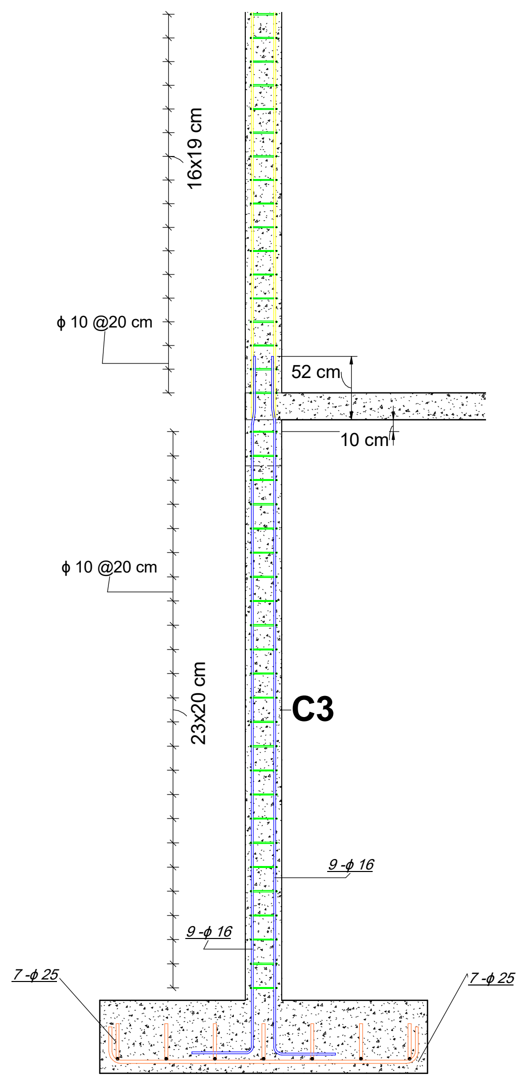

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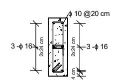
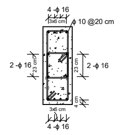
Penthouse floor to roof level	Details		
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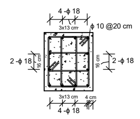
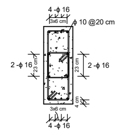
Story#2 floor to Penthouse floor level	Details		
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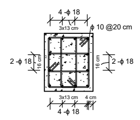
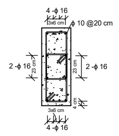
Story#1 floor level to Story #2 floor level	Details		
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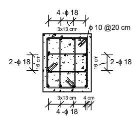
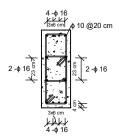
Ground floor to Story #1 floor level	Details		
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	Tie	ϕ 10 @20cm	ϕ 10 @20cm
	Size, cm	60 X 50	80 X 30

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Column Details 2

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Date	Issue Date
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Sheet#5

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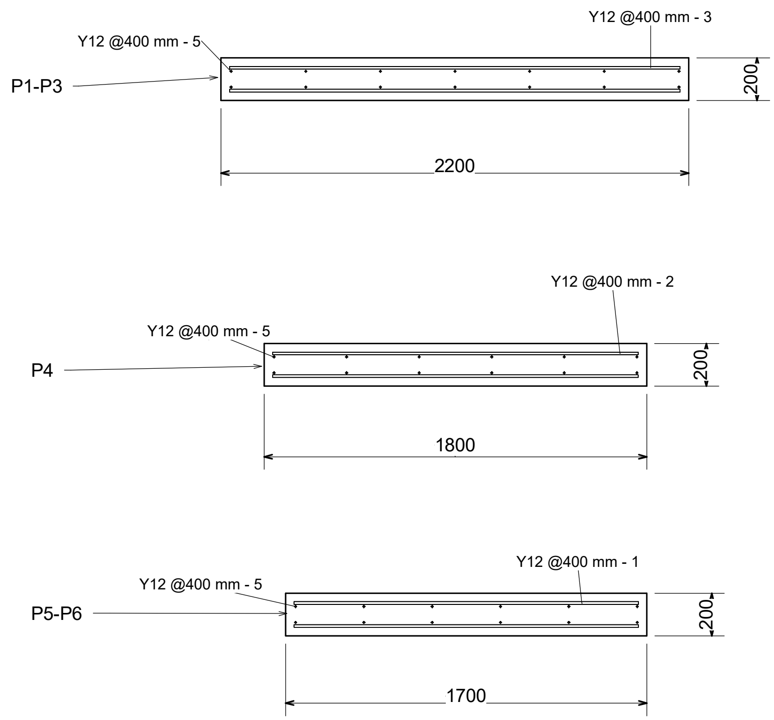

AUTODESK	Senior Design Project	Shear Walls Details	
www.autodesk.com/revit		Project number	Sheet 6
		Date	
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