SHAFIE ABDI IBRAHIM

COMPARATIVE STUDY OF ANALYSIS AND COST OF FLAT SLAB AND TWO-WAY SLAB IN SOMALIA-MOGADISHU

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NEAR EAST UNIVERSITY

INSTITUTE OF GRADUATE STUDIES

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M.Sc.THESIS

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Approval

We certify that we have read the thesis submitted by **Shafie Abdi IBRAHIM** titled "**COMPARATIVE STUDY OF ANALYSIS AND COST OF FLAT SLAB AND TWO-WAY SLAB IN SOMALIA-MOGADISHU**" and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Educational Sciences.

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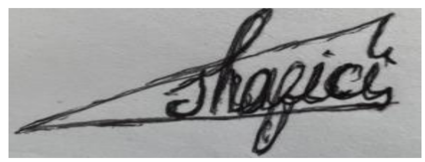
Declaration

I hereby declare that all information, documents, analysis and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of the institute of graduate studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study.

Shafie Abdi IBRAHIM



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Abstract

COMPARATIVE STUDY OF ANALYSIS AND COST OF FLAT SLAB AND TWO-WAY SLAB IN SOMALIA-MOGADISHU

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MA, Department of Civil Engineering, Faculty of Civil and Environmental Engineering, Near East University, Nicosia.

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Rapid population increase has led in a rise in multi-story reinforced concrete (RC) residential buildings, offices, public halls etc. in Somalia. The common practice in construction is to support the slab by beams and beams supported by a column which provides more stiffness. Nowadays flat slabs have been widely used due to their advantages like reducing story height, easier formwork and shorter construction period which are all related to cost. As being flat slabs are vulnerable to punching shear, need more attention. The main goal of this research is to examine the performance and behavior of flat slab and two-way slab structures subjected to gravity loads and conditions and to compare the total cost for structure with flat slab & two-way slab for concrete, steel, formwork. A 8 story residential building having flat slab and two-way slab has been analyzed using ETABS software as per ACI 318-14. The results obtained are bending moment, shear force, deflection, punching shear, quantity of steel, quantity of concrete and quantity of formwork. The result shows that the cost of two-way slab is higher by around 14.2%-%30 as compared to flat slab system. The study concludes, a flat slab structures are the best as compared to two-way slab structures in terms of cost of material.

Keywords: Flat slab, two-way slab, cost, ETABS, Somalia

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List of Abbreviations

ACI 318-14: American Concrete Institute Code no. 318 in the year 2014

ASCE7-16: American Society of Civil Engineers Code no. 7 in the year 2016

AISC 14: American Institute of Steel Construction Year 2014

AISC 360-10: American Institute of Steel Construction No.360 In the year 2010

ETABS: Extended Three-Dimensional Analysis of Building System

IS: Indian Standard

USGS: United State Geological Survey

SEI: Structural Engineering Institute

RC: Reinforced Concrete

SAP: Structural Analysis Program

STAAD pro: Structural Analysis and Design Program

CHAPTER I

Introduction

Background of the study

The idea of the multistory building has changed throughout history, the developed-in metropolitan regions where high population densities and rising land values led to a preference for vertically rising structures over those that spread out horizontally, using up less expensive land space. The growth of the city has been facilitated by the construction of the high-rise structure. In emerging nations like Somalia, the trend of urbanization which began with the industrial revolution is still continuing and people move to urban areas as a result of industrialization where work possibilities are available. Land available for construction to meet this movement is becoming limited in a significant rise in land prices. The multistory structures are the outcome since they give a significant floor space in a relatively little amount of land in metropolitan areas.

An engineering project's estimated cost can be determined using a scientific method before it is actually started. It differs from figuring out the exact cost once the task is finished. Estimation requires talent, expertise, foresight, and good judgment in addition to a thorough understanding of building procedures and material and labor costs. A construction work's estimated cost is the job's projected cost based on the plans and needs. The actual cost of the planned job after completion should not fluctuate by approximate cost estimate for a solid estimate, assuming there are no unexpected or unanticipated situations. Estimation helps establish the project's approximate cost in order to assess its cost viability and to ensure financial resources in the event that the proposal is accepted. a cost estimate seeks to verify the work that will be done; this might occur at the detail, phase, or project level. Until the work is finished, the exact cost will never be known. The necessity of a trustworthy cost estimate stems from the uncertainty itself, and the justification goes beyond contingency and risk allocations. In Somalia, Mogadishu, high rise building of 5 to 12 stories are the present trend.

These buildings are designed to serve the needs of an intended occupancy, whether residential, commercial, or some cases in combination of the two for the structures. During recent years among different slab system, flat slab systems are widely used in Somalia. These reinforced concrete floor systems have many advantages which enhance speeding up the construction, architectural flexibility, easier formwork and use of space. On the other hand slab systems commonly used in Somalia are flat slab and two-way slab structures. As being one of the special forms flat slab structures need further attention.

Problem Statement

The growth of the population put pressure on the limited land area in Somalia Mogadishu.

Comparative study of analysis and cost of flat slab and two-way slab in Somalia has not been studied yet.

A lack of prior information, a lack of a database that included residential building prices, a lack of suitable resources, and a lack of project management afflicted Somalia.

Objective of the Study

The main objectives of this study presented are the following.

To investigate the performance of flat slab &two-way slab structures subjected to gravity loads and conditions.

To study the behavior of two-way slab and flat slab structures for the parameters like bending moment, shear force etc.

To compare the analysis results of both flat slab and two-way slab structures.

To compare quantity of concrete, steel, & formwork material requirement variation for structure.

To compare total cost for structure with flat slab &two-way slab for concrete, steel, formwork.

Research Questions

Which types of slab systems have cost effectiveness for multistory building structures?

How to calculate design parameters of flat slab and two-way slab?

What is the difference in design for a flat slab and two-way slab?

Significance of the Study

The cost and analysis of a flat slab and a two-way slab are compared in this study.

Limitation of the study

The present study examines the residential 8 story. RC building of 3.2m typical story height which focused on behavior of two different types of slab systems as the area of capital city Somalia where earthquake hazard is classified as very low. The study is limited to plot area of 1225 m^2.

Definition of Key Terms

A slab is a plate component that is used in the building of floors and roofs to transmit weights largely by flexure. The cost and analysis of a flat slab and a two-way slab are compared in this study.

Flat slab is two-way reinforced structural system that includes either drop panels or column capitals at columns to resist heavier loads and thus permit longer spans. There are a wide range of flat slabs available in Somalia.

Figure 1

Flat slab

Figure 2

Flat slab with drop panel and column head

Figure 3

Flat slab with column head

Figure 4

Flat slab with drop panel

The rectangular slabs supported on each side and with the ratio of longer to shorter span less than two, which carry the loads by flexure in two perpendicular directions are called two-way slab. The other common names used for two-way slab is conventional slab. For flat slab used in this study is also called as flat plate.

Figure 5

Two-way slab

Advantages and Disadvantages of Flat Slab

The benefits of flat slab include Flexible space layout and simpler reinforcement placement Building height can be reduced. Ease of formwork installation, less construction time. The disadvantage of flat slab include Span length is medium, large spans are not possible, not appropriate for supporting brittle (masonry) partitions, Larger mechanical ducting may be affected by the use of a drop panel , middle strip deflection is critical, Higher slab thickness.

Advantages and Disadvantages of Two-way Slab

The benefits of two-way slab include having relatively deep beams, which resist lateral loads, high break times, and lightweight slabs. The disadvantages of two-way slab include Reinforcement placement is difficult, building height will increase; the formwork installation is difficult, high construction time. A.S.Patil , Ashish Balasaheb Daphal, Shashank Sadanand Gavasane, Shubham Sambhajirao Ghorpade4, Pankaj Dashrath Ekatpure, & Akshay Ashok Nalawade. (2018).

CHAPTER II

Literature Review

Overview

This chapter includes several prior studies and academic research works mostly on comparative study of analysis and cost of the flat slab and two-way slab structures. These papers and works have been reviewed as part of this study.

Abhijit K Sawwalakhe & Prabodh D Pachpor (2021) Investigated the Modern architecture often supports the normal slab with a beam that has a deep beam and a thin slab, which transfers the load to the column. Anywhere that needs a partition barrier; it may be placed thanks to the level surface. Due to its popularity, affordability, and ability to reduce weight and speed up growth. It is safer and cheaper than the traditional slab, which has been in use since its origin. It also offers advantages including greater stiffness and weight carrying capacity. Greater spans require grid slabs, while lesser spans can be achieved with grid beams. Grid slabs are able to carry heavier loads over longer spans and reduce void-related dead load. Both the Grid slab's pricing and vibration resistance are better. The goal of the experiment is to determine which slab type among grid, flat with drop, and standard is the most affordable. A G+5 in this investigation, the characteristics of flat-slab, traditional-slab, and gird-slab commercial multi-story buildings were examined. Storey drift, shear force, and storey displacement were some of the measurements that were made. 18 distinct constructions in total are examined. Using dead load, living load, and seismic load, it has been determined how each structure within India's seismic zone III operates and behaves. A flat slab performs better than a standard or grid slab when the metrics of shear force, bending moment, displacement, and drift are taken into account.

Shital Borkar, Kuldeep Dabheka, IshaKhedikar, & NaliniVaidva (2021). Examined the Selecting appropriate type of building for a specific purpose is essential for architectural engineers since multistory structures are becoming more and more required as the need for space in living arrangements increases. We must erect skyscrapers as high as we can in order to house the most people possible. This research seeks to investigate the earthquakes. Response of flat slab RCC structures for a variety of heights and designs using analysis software such as ETABS. In terms of maximum BM, story shear, base shear, and story drift, it also contrasts flat slab tower policies with those of the more dated conventional 2-way slab systems for several zones, including zones II, III, IV, and V.

Sayli Madavi, Prof. Sushant M.Gajbhiye, & DilipLBudhlan (2020) Studied In our rapidly expanding world, multistory towering structures are constructed. The floors of a structure can be constructed using a variety of slab types. Flat slabs, also known as standard slabs and grid slabs, are often used in construction because they have various advantages over other kinds of slab systems, such as easier formwork, more flexibility, more room, and quicker building schedules. In the current work, classic slab systems, including flat slabs and grid slabs, have been evaluated using the software's Etabs and StaadPro to investigate elements like as the effects of vertical and horizontal forces, displacement, shear force, and bending moment. This study aims to examine the impacts of vertical and horizontal force, flexibility, and slab behavior in various earthquake zones in addition to analyzing the evaluation outcomes of conventional slabs, flat slabs, grid slabs, and flat plates.

Amit A. Sathwane (2012) have been presented a comparative of Grid Slab, Flat Slab with Drop, and Flat Slab without Drop researchers found that Grid Slab was the most cost-effective option. The nexus point across from the Vidhan Bhavan and next to the NMC office was the subject of research to determine which slab would be the most economical. The analyses of flat slabs, flat slabs without drops, and grid slabs were conducted manually, using STAAD PRO V8i, IS 456-2000, and both of these programs. This study found that compared to other slabs considered, a flat slab with a drop is more reasonably priced. And more concrete is needed for a grid slab. The amount of steel needed for a flat slab with a drop is also greater than for a flat slab without a drop.

Imran B. K, Syed Shamoon, Meraz A, Mohammed U, and Mohammed Bilal Shaikh (2019) studied with a flat slab, also known as a beamless slab, rests directly on a column without a beam, transferring the foundation is then loaded before the columns.

Usually offered are column heads or drops For columns. The fundamental benefit of having flat ceilings is that they look better architecturally and are simpler to build, better at distributing light, and need less formwork when there are no beams present. Planning and analyzing the office building in comparison to flat slab and conventional slab utilizing appropriate tools, such as E-tabs, is the primary goal of this project.

Syed Abdul Qavi, Syed Khaleelullh Shah Quadri, & SyedFarruKh Anwar (2018) studied Flat slab and Grid Slab Systems with Conventional Slab Systems, Design and Analysis Grid and flat slabs are replacing traditional slabs in some places., as well as bending moment and shear force, were examined They came to the conclusion that grid slab is the most cost-effective for all spans taken into account in the investigation. Maximum displacement, maximum bending moment, and maximum force are all at their lowest values in grid slabs and at their highest values in flat slabs

Phyoe Hnin ThuHtum, Nyan Phone, & Kyaw Zeyar Win (2018) has been analyzed RC Buildings Flat Slab and Flat Plate, the analysis was completed using the software Etabs. Utilizing SAFE software, flat plates and slabs were created. Buildings with flat plates have an edge over those with flat slabs, according to comparison data. Flat plate buildings have a smaller steel area than flat slab structures because flat plate construction is more affordable.

Sudhir Singh Bhaduria & Nitin Chhugani (2017) has been presented the Evaluation of the Flat and Grid Slab Systems and the Traditional Slab for Seismic Zone III," Systems Using STAAD Pro V8i, slab systems were evaluated for various plan areas or grid sizes for medium soil conditions. The slab system is designed in accordance with IS 456-2000 and IS 1983-2002. In order to choose the most economically advantageous slab, the slab system was designed to allow various grid sizes and column spacing. After receiving the results, they came to the conclusion that the flat slab is the most cost-effective option for each period taken into account. Maximum force, maximum bending moment, and maximum displacement are all found to be at their lowest values in the flat slab system, but they are all found to be at their greatest values in the grid slab system.

The flat slab system uses the least amount of steel and concrete in comparison to the grid slab system.

CHAPTER III

Methodology

Overview

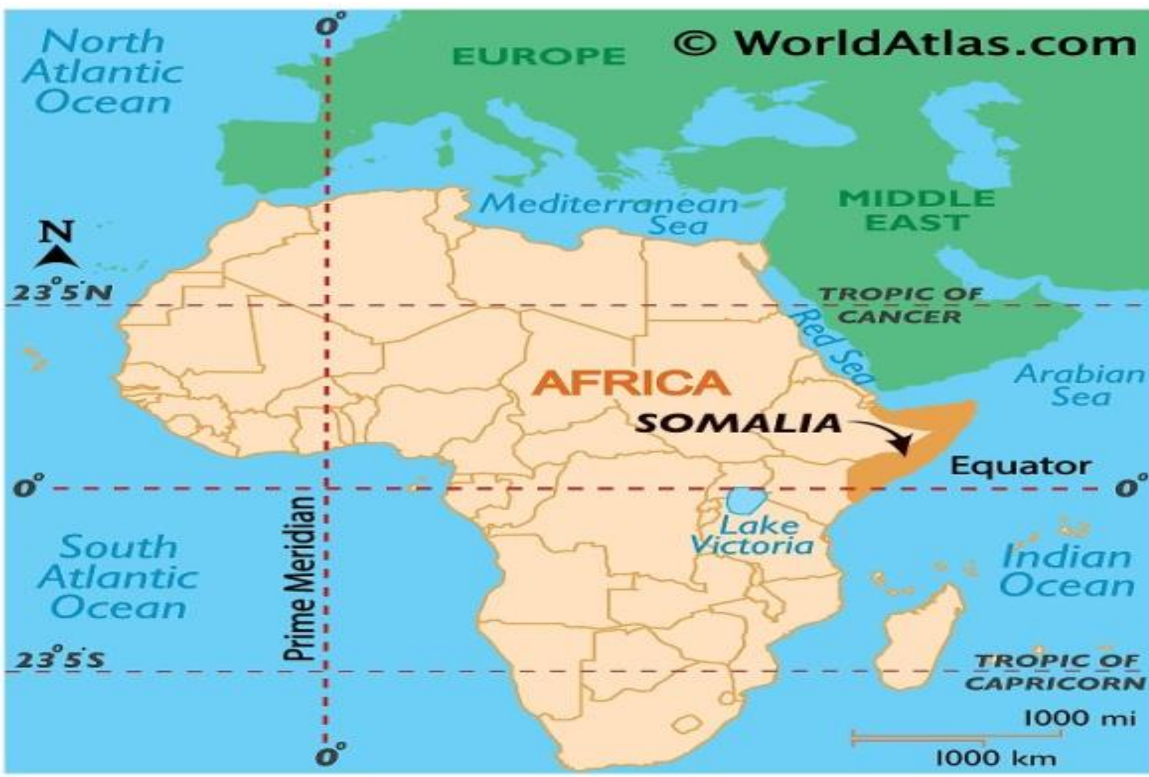
This chapter presents the selected study area and describes the models of the RC framed structures and code that have been adopted in order to define the limitation and variables affecting the outcomes of analysis.

Case Study

Mogadishu, Somalia has been selected as the study area for this thesis. Mogadishu has been the capital and it is the most populous city of Somalia. The location of the building is assumed to be at Mogadishu city as shown in figure 6. In the area of capital city, Mogadishu, earthquake hazard classified as very low.

Figure 6

Shows the location of Somalia in the World



MapWorld Atlas. (2021, February 24). Somalia Maps & Facts.

https://www.worldatlas.com/maps/somalia

The majority of the existing building stock in study area region is low rise and mid-rise RC buildings which are very popular in Somalia.

Figure 7

Shows the location of Mogadishu city in Somalia

Mogadishu - Search /. (2018, September 7). .

https://mobile.twitter.com/hashtag/mogadhishu?src=hash

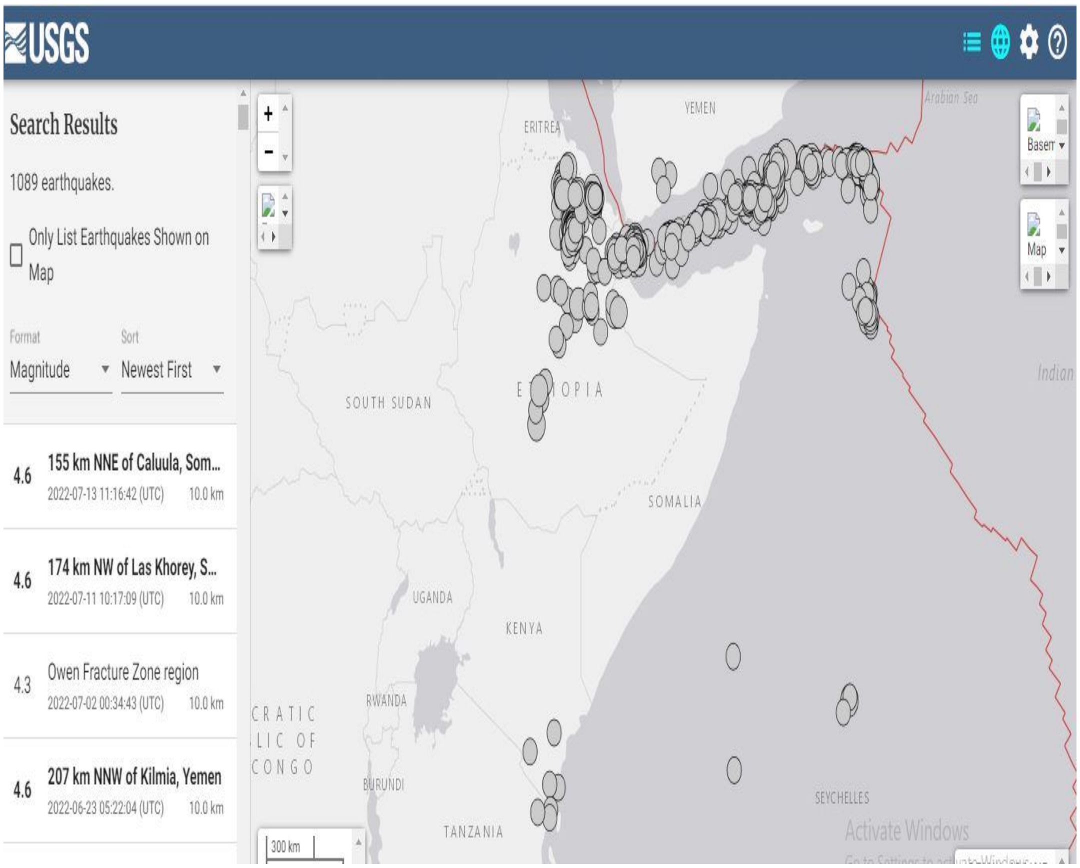
Figure 8

Shows Mogadishu City View

https://twitter.com/independentmi20/status/1453736147352383491

Figure 9

Shows the earthquake is very low in Somalia



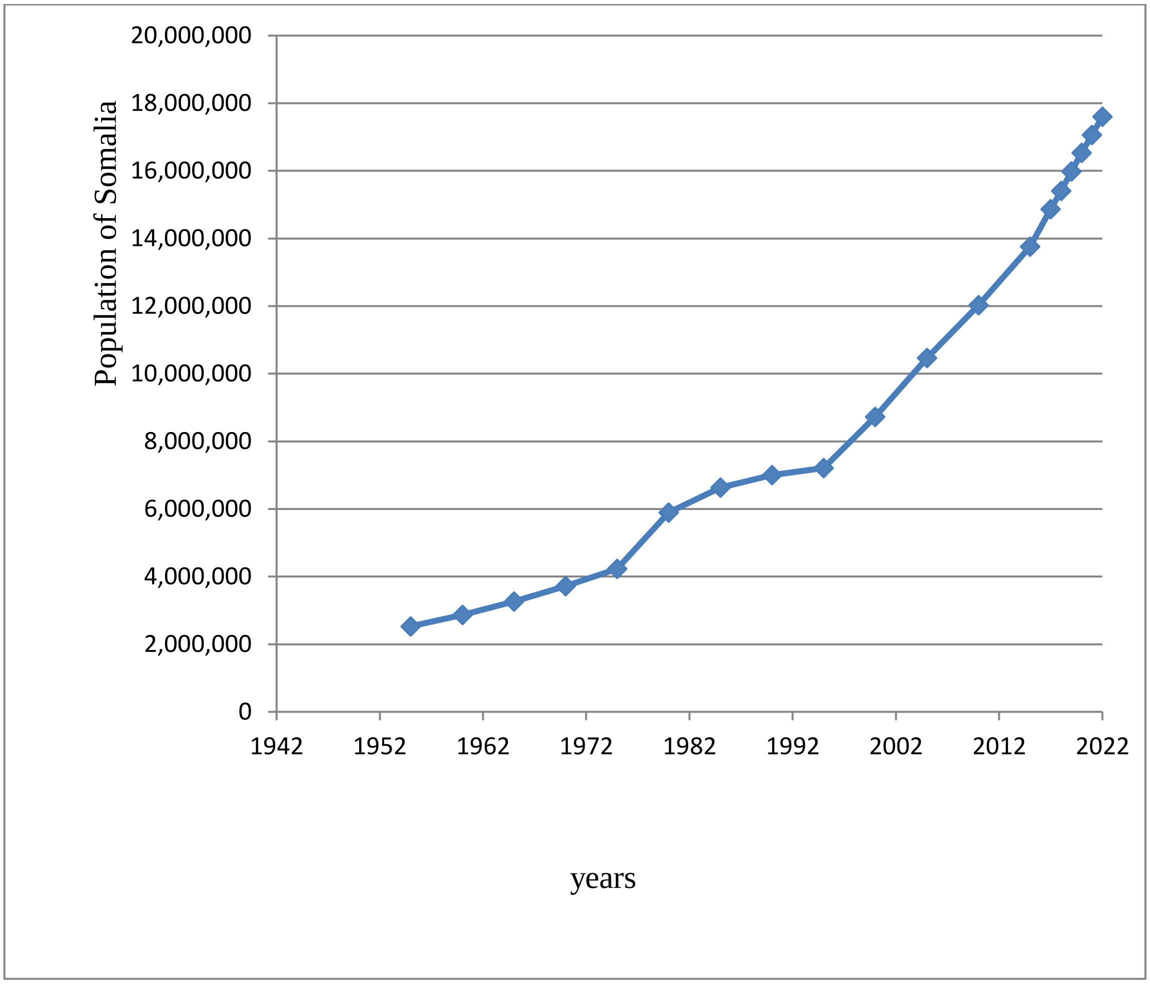
https://earthquake.usgs.gov/earthquakes/map/

The circles represent regions where earthquake has occurred that it's close to for Somalia based on past data analysis.

The population of Somalia is about 16,809,854 and the total land area is 627340 km^2. The current population of the largest city, Mogadishu, is about 2,587,183.

Figure 10

Shows the population of Somalia



https://worldpopulationreview.com/countries/somalia-population

Material Properties

The properties of concrete and steel used in this study is shown in table 1

Table 1

Material Properties

Weight per unit volume of concrete, γ_c	25 kN/m^3
Weight per unit volume of steel, γ_{st}	78.5 kN/m^3
Modulus Elasticity of Steel, E_{st}	200,000MPa
Modulus Elasticity of concrete, E_c	24870 MPa
Compressive strength of concrete, f_c	28 MPa
Yield strength of Steel, f_y	420 MPa

Design Concept

Member Size

Preliminary measurements were made for analysis of the building elements (beams, slabs and columns). Initial slab and beam sizes were calculated, and the estimated sizes of the columns were determined from the axial loads transmitted by the slab and beams as a result of live and dead loads. The appropriate member sizes were agreed the thickness h was computed in compliance with ACI 318-14, which uses the equation in sections 8.3 and 9.3 at table 2 & 3 to specify the minimum thickness of members to regulate deflection**.**

Table 2

Minimum Thickness of Flat Slab Systems According to ACI 318-14

Grade of steel Mpa	**Without Drop Panel**			**With Drop Panel**		
	Exterior		**Interior**	**Exterior**		**Interior**
	Without Edge Beam	**With Edge Beam**		**Without Edge Beam**	**With Edge Beam**	
280	l_n 33	l_n /36	l_n /36	l_n /36	l_n /40	l_n /40
420	l_n /30	l_n /33	l_n /33	l_n 33	l_n /36	l_n /36
520	l_n /28	l_n /31	l_n /31	l_n /31	l_n /34	l_n /34

l_n is the clear span from face to face of the vertical supports in the long direction. The minimum thickness of the flat slabs with drop panel should be ≥ 100 mm. The minimum thickness of the flat slabs without drop panel should be ≥ 125 mm.

Table 3

Minimum Thickness of Two-Way Slab with All Sides a Beam

α_{fm}		Minimum h ,mm	
$\alpha_{fm} \leq 0.2$		8.3.11 applies	(a)
$0.2 < \alpha_{fm} \leq 2.0$	Greater of	$\frac{l_n\left(0.8+\frac{fy}{1400}\right)}{36+9\beta(\alpha_{fm}-0.2)}$	(b)
		125	(c)
$\alpha_{fm} > 2.0$	Greater of	$\frac{l_n\left(0.8+\frac{fy}{1400}\right)}{36+9\beta}$	(d)
		90	(e)

Where α_{fm} is the average value of α_f for all beams on edges of a panel.

l_n is the clear span in the long direction, measured face-to-face of beams (mm).

β is the ratio of clear spans in long to short directions of slab. The calculation details of minimum thickness and punching shear can be seen in Appendices 1 and 2.

Table 4

Minimum Depth of Non- Prestressed Beams

Support condition	Minimum *h*
Simply supported	$l/16$
One end continuous	$l/18.5$
Both ends continuous	$l/21$
Cantilever	$l/8$

Sizing of Columns

The internal column that was the most heavily loaded column in this building layout, had its tributary area calculated as the first stage in calculating the column's size This tributary region was multiplied by to calculate the factored load being transmitted to the column, considering the dead and live loads. The durability of concrete and steel were then used to find the area of concrete required to withstand the estimated force.

To account for the irregularity of the column, appropriate overall strength reduction factors were utilized loads and added an additional layer of safety. The column gross area was calculated, using this equation in accordance with the ACI code;

$$\emptyset Pu = \emptyset r[0.85 fc'(Ag - Ast) + fyAst]$$

Where $\boldsymbol{\emptyset r}$ is the component that reduces strength. For a rectangular cross-section, taken as 0.65 and 0.80

$\emptyset$ Pu is the computed force, Ag is the column's gross area, Ast is the steel's area, taken as 0.002Ag, and fy is the concrete's tensile strength, fc' is Concrete's compressive strength

Loads

Load Patterns

In this study, the loads are dead load and live load. Dead load is the structure self-weights which is automatically calculated by ETABS software. Super dead load is the additional load on the structures; it represents the weight of the finishing materials and partition walls of a building. In this study 2.11 kN/m^2 are taken. Live load is temporary loads on the structures. It depends on types of building. Live load for residential building is taken 2 kN/m^2 and assumed for all floors. The minimum design dead and live load are taken from ASCE/SEI 7-10 and summarized as below.

Table 5

Minimum Design Live Load

Occupancy or Use	Uniform psf (kN/m²)	Conc. lbs (kN)
Grandstands (see stadium and arena bleachers)		
Gymnasiums, main floors, and balconies	100 (4.79) Note (4)	
Handrails, guardrails, and grab bars	See Section 4.4	
Hospitals		
Operating rooms, laboratories	60 (2.87)	1000 (4.45)
Private rooms	40 (1.92)	1000 (4.45)
Wards	40 (1.92)	1000 (4.45)
Corridors above first floor	80 (3.83)	1000 (4.45)
Hotels (see residential)		
Libraries		
Reading rooms	60 (2.87)	1000 (4.45)
Stack rooms	150 (7.18) Note (3)	1000 (4.45)
Corridors above first floor	80 (3.83)	1000 (4.45)
Manufacturing		
Light	125 (6.00)	2000 (8.90)
Heavy	250 (11.97)	3000 (13.40)
Marquees and canopies	75 (3.59)	
Office buildings		
File and computer rooms shall be designed for heavier loads based on anticipated occupancy		
Lobbies and first floor corridors	100 (4.79)	2000 (8.90)
Offices	50 (2.40)	2000 (8.90)
Corridors above first floor	80 (3.83)	2000 (8.90)
Penal institutions		
Cell blocks	40 (1.92)	
Corridors	100 (4.79)	
Residential		
Dwellings (one- and two-family)		
Uninhabitable attics without storage	10 (0.48)	
Uninhabitable attics with storage	20 (0.96)	
Habitable attics and sleeping areas	30 (1.44)	
All other areas except stairs and balconies	40 (1.92)	
Hotels and multifamily houses		
Private rooms and corridors serving them	40 (1.92)	
Public rooms and corridors serving them	100 (4.79)	
Reviewing stands, grandstands, and bleachers	100 (4.79) Note (4)	
Roofs	See Sections 4.3 and 4.9	

Table 6

Minimum Design Dead Load

Component				Load (kN/m^2)
FLOORS AND FLOOR FINISHES				
Asphalt block (51 mm), 13 mm mortar				1.44
Cement finish (25 mm) on stone-concrete fill				1.53
Ceramic or quarry tile (19 mm) on 13 mm mortar bed				0.77
Ceramic or quarry tile (19 mm) on 25 mm mortar bed				1.10
Concrete fill finish (per mm thickness)				0.023
Hardwood flooring, 22 mm				0.19
Linoleum or asphalt tile, 6 mm				0.05
Marble and mortar on stone-concrete fill				1.58
Slate (per mm thickness)				0.028
Solid flat tile on 25 mm mortar base				1.10
Subflooring, 19 mm				0.14
Terrazzo (38 mm) directly on slab				0.91
Terrazzo (25 mm) on stone-concrete fill				1.53
Terrazzo (25 mm), 51 mm stone concrete				1.53
Wood block (76 mm) on mastic, no fill				0.48
Wood block (76 mm) on 13 mm mortar base				0.77
FLOORS, WOOD-JOIST (NO PLASTER)				
DOUBLE WOOD FLOOR				
Joist sizes (mm):	305 mm spacing (kN/m^2)	406 mm spacing (kN/m^2)	610 mm spacing (kN/m^2)	
51 × 152	0.29	0.24	0.24	
51 × 203	0.29	0.29	0.24	
51 × 254	0.34	0.29	0.29	
51 × 305	0.38	0.34	0.29	
FRAME PARTITIONS				
Movable steel partitions				0.19
Wood or steel studs, 13 mm gypsum board each side				0.38
Wood studs, 51 × 102, unplastered				0.19
Wood studs, 51 × 102, plastered one side				0.57
Wood studs, 51 × 102, plastered two sides				0.96
FRAME WALLS				
Exterior stud walls:				
51 mm × 102 mm @ 406 mm, 16 mm gypsum, insulated, 10 mm siding				0.53
51 mm × 152 mm @ 406 mm, 16 mm gypsum, insulated, 10 mm siding				0.57
Exterior stud walls with brick veneer				2.30
Windows, glass, frame and sash				0.38

Component					Load (kN/m^2)
Clay brick wythes:					
102 mm					1.87
203 mm					3.78
305 mm					5.51
406 mm					7.42
Hollow concrete masonry unit wythes:					
Wythe thickness (in mm)	102	152	203	254	305
Density of unit (16.49 kN/m^3)					
No grout	1.05	1.29	1.68	2.01	2.35
1219 mm		1.48	1.92	2.35	2.78
1016 mm grout		1.58	2.06	2.54	3.02
813 mm spacing		1.63	2.15	2.68	3.16
610 mm		1.77	2.35	2.92	3.45
406 mm		2.01	2.68	3.35	4.02
Full grout		2.73	3.69	4.69	5.70
Density of unit (125 pcf):					
No grout	1.25	1.34	1.72	2.11	2.39
1219 mm		1.58	2.11	2.59	2.97
1016 mm grout		1.63	2.15	2.68	3.11
813 mm spacing		1.72	2.25	2.78	3.26
610 mm		1.87	2.44	3.02	3.59
406 mm		2.11	2.78	3.50	4.17
Full grout		2.82	3.88	4.88	5.89
Density of unit (21.21 kN/m^3)					
No grout	1.39	1.68	2.15	2.59	3.02
1219 mm		1.58	2.39	2.92	3.45
1016 mm grout		1.72	2.54	3.11	3.69
813 mm spacing		1.82	2.63	3.26	3.83
610 mm		1.96	2.82	3.50	4.12
406 mm		2.25	3.16	3.93	4.69
Full grout		3.06	4.17	5.27	6.37
Solid concrete masonry unit wythes (incl. concrete brick):					
Wythe thickness (in mm)	102	152	203	254	305
Density of unit (16.49 kN/m^3):	1.53	2.35	3.21	4.02	4.88
Density of unit (19.64 kN/m^3):	1.82	2.82	3.78	4.79	5.79
Density of unit (21.21 kN/m^3):	1.96	3.02	4.12	5.17	6.27

Load Combination

Commonly, a load combination is composed of various loads, such as dead loads and live loads, which are then combined to form a strength design. The load combination is developed in accordance with ASCE 7-10 and the combination is given below,

$$Wu = 1.2Dl + 1.6\,L$$

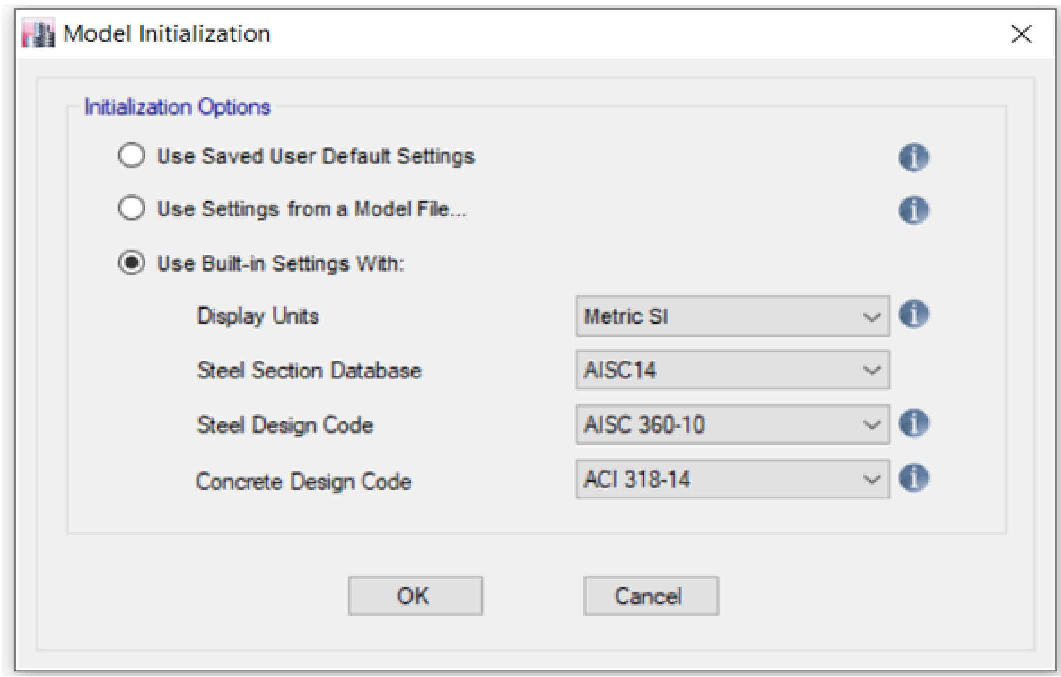
Modeling using ETABS

Model Initialization

For concrete design the required code can be chosen from model initialization.

Figure 11

Determining model initialization

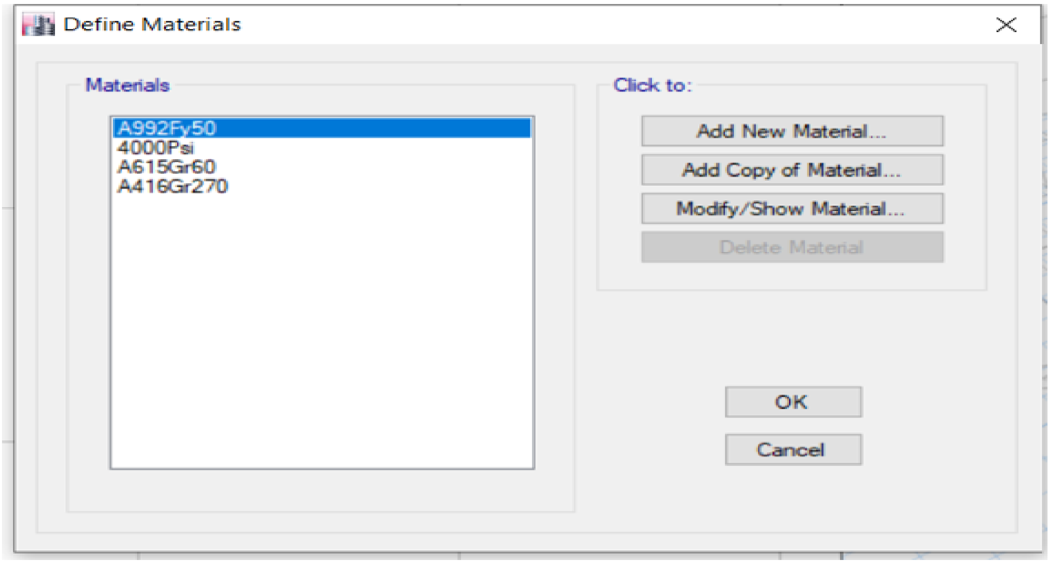


Define Material Properties

The upper material strength limitations for the design of beams, columns, and slabs are enforced by ETABS. If the material qualities are taken into account as being higher than the limits, the upper limits are specified as the input material strengths. The user must make sure that the minimum strength requirements are met.

Figure 12

Material properties in the software

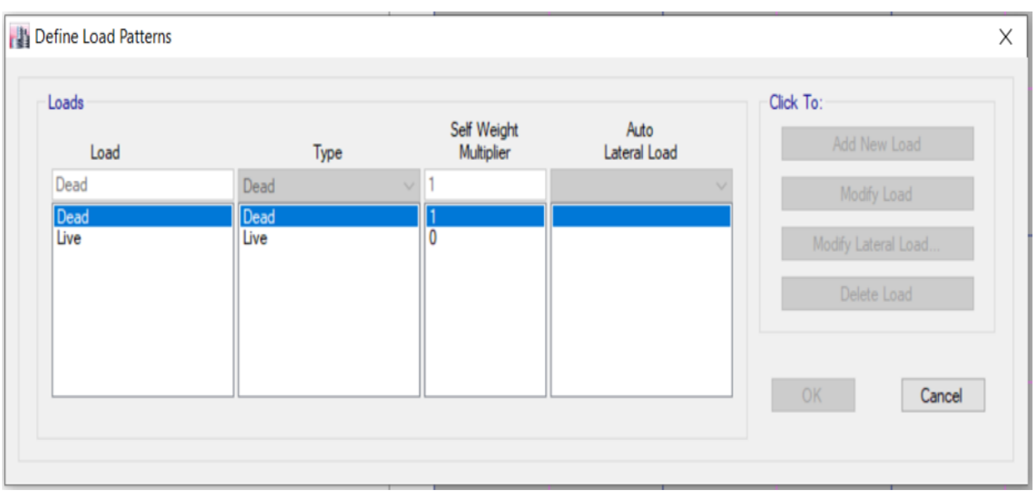


Define Loads Patterns

Typically distinct load patterns would be defined for dead load, live load, and loads that must fluctuate separately, either for design reasons or due to how they are applied to the structure. To automatically produce design load combinations, ETABS employs the type of load pattern.

Figure 13

Load patterns



Description of the Models

In this study, total 18 models were modeled for two-way slab and for flat slab systems. There are three cases in different slab dimensions for the selected building structures. The grid spacing of structure was vary to 5, 6 and 7 meters. 9 were modeled for two-way slab and the other 9 were modeled for flat slab structures. The building height is typically 3.2m and building selected in this study is assumed to be used as residential building. The buildings were modeled by using ETABS by accounting for the linear analysis.

Case: 1

Table 7

Building Parameter Data for Case One _1A

Parameter	**Slab Systems**	
	Two -way Slab	**Flat Slab**
Dimension of the building, length and width	15m*15m	15m*15m
Length of each span x-direction	5m	5m
Length of each span y-direction	5m	5m
No of spans	3Row & 3Column	3Row & 3Column
Story height	3.2m	3.2m
No of story	8	8
Slab thickness	160mm	180mm
Beam size	200mm*310mm	--------
Column size corner	250mm*250mm	200mm*200mm
Column size exterior	300mm*300mm	240mm*240mm
Column size interior	350mm*350mm	330mm*330mm

Figure 14

Floor Plan of 8 Story Flat Slab

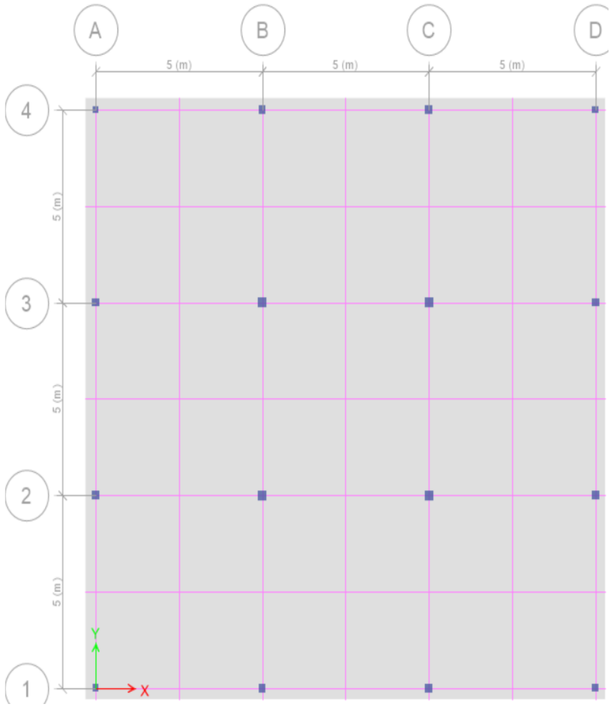


Figure 15

Floor Plan of 8 Story Two-way Slab

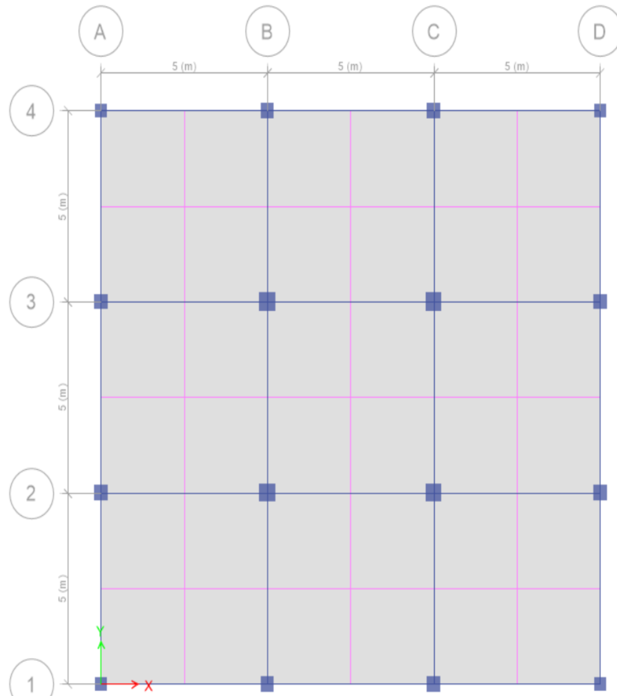


Table 8

Building Parameter Data for Case One _1B

Parameter	**Slab Systems**	
	Two -way Slab	**Flat Slab**
Dimension of the building, length and width	18m*18m	18m*18m
Length of each span x-direction	6m	6m
Length of each span y-direction	6m	6m
No of spans	3Row & 3Column	3Row & 3Column
Story height	3.2m	3.2m
No of story	8	8
Slab thickness	180mm	210mm
Beam size	250mm*360mm	--------
Column size corner	280mm*280mm	230mm*230mm
Column size exterior	330mm*330mm	270mm*270mm
Column size interior	380mm*380mm	360mm*360mm

Figure 16

Floor Plan of 8 Story Flat Slab

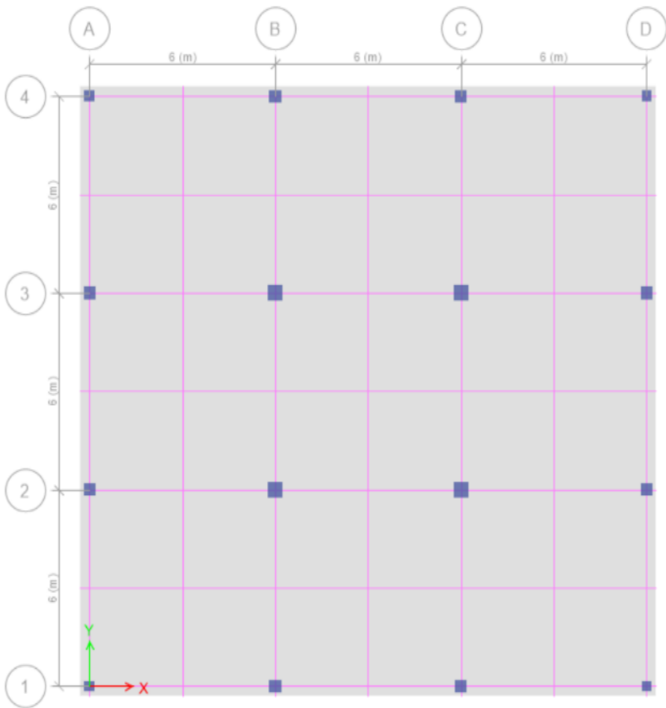


Figure 17

Floor Plan of 8 Story Two-Way Slab

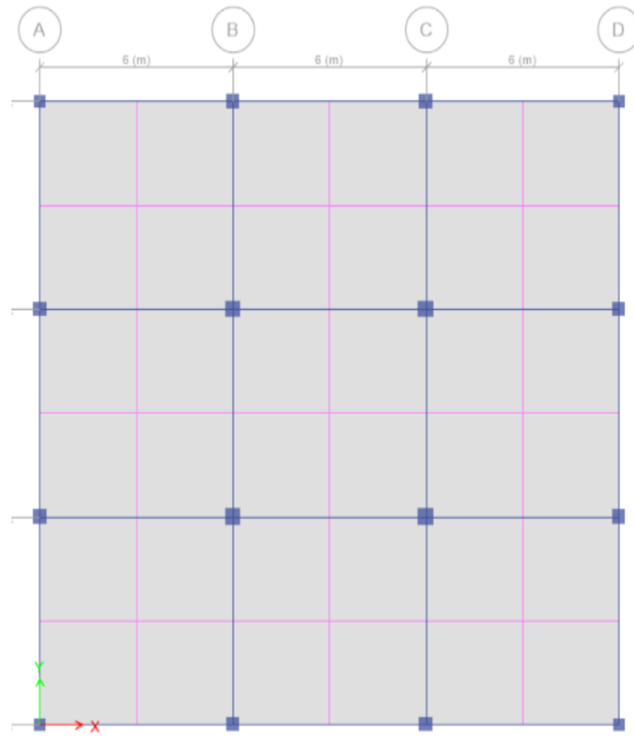


Table 9

Building Parameter Data for Case One _1C

Parameter	**Slab Systems**	
	Two -way Slab	**Flat Slab**
Dimension of the building, length and width	21m*21m	21m*21m
Length of each span x-direction	7m	7m
Length of each span y-direction	7m	7m
No of spans	3Row & 3Column	3Row & 3Column
Story height	3.2m	3.2m
No of story	8	8
Slab thickness	210mm	240mm
Beam size	280mm*420mm	--------
Column size corner	310mm*310mm	260mm*260mm
Column size exterior	360mm*360mm	300mm*300mm
Column size interior	410mm*410mm	390mm*390mm

Figure 18

Floor Plan of 8 Story Flat Slab

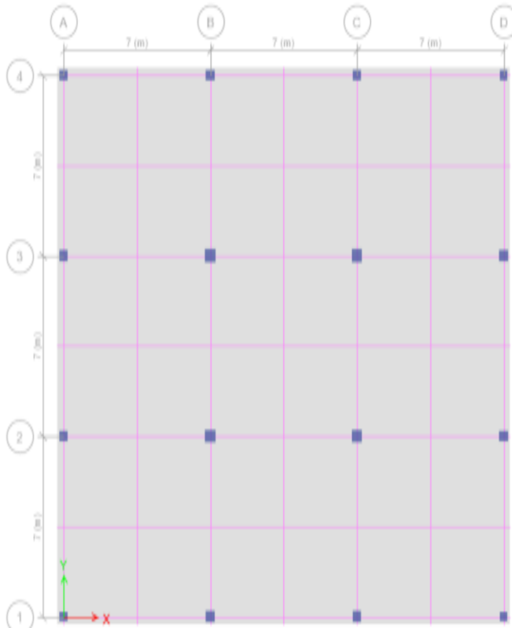


Figure 19

Floor Plan of 8 Story Two-way Slab

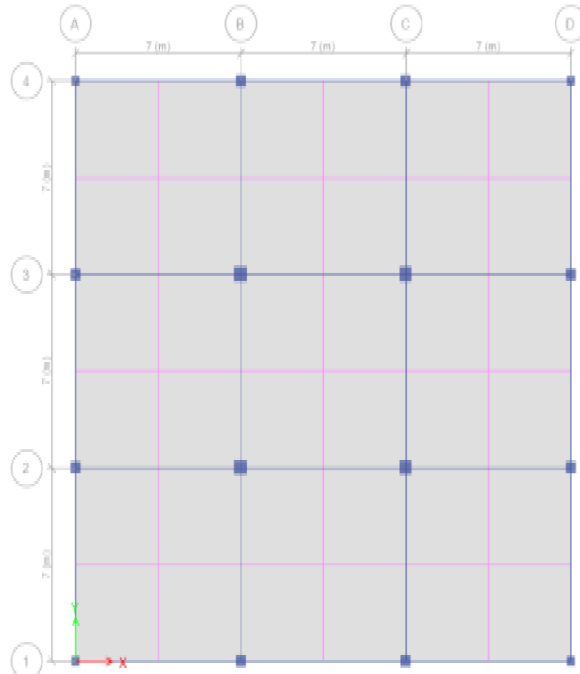


Figure 20

3D model of 8 Story Flat Slab

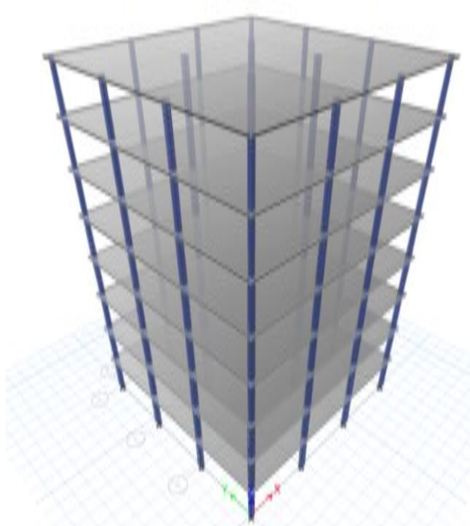
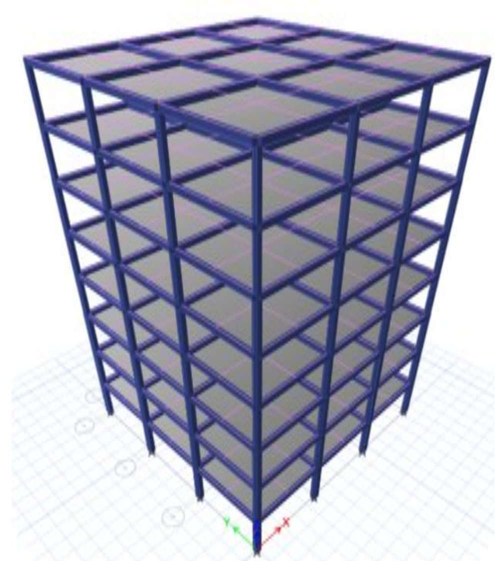


Figure 21

3D Model of 8Story Two-way Slab



Case: 2

Table 10

Building Parameter Data for Case Two _2A

Parameter	**Slab Systems**	
	Two-way Slab	**Flat Slab**
Dimension of the building, length and width	20m*20m	20m*20m
Length of each span x-direction	5m	5m
Length of each span y- direction	5m	5m
No of spans	4Row &4Column	4Row &4Column
Story height	3.2m	3.2m
No of story	8	8
Slab thickness	160mm	180mm
Beam size	200mm*310mm	--------
Column size corner	410mm*410mm	380mm*380mm
Column size exterior	450mm*450mm	420mm*420mm
Column size interior	530mm*530mm	500mm*500mm

Figure 22

Floor Plan of 8 Story Flat Slab

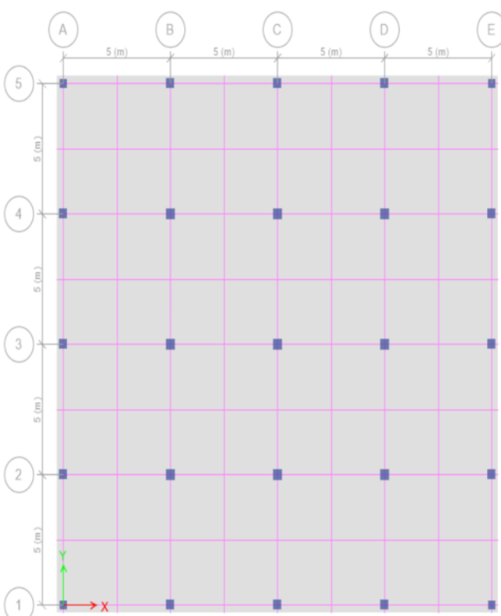


Figure 23

Floor Plan of 8 Story Two-way Slab

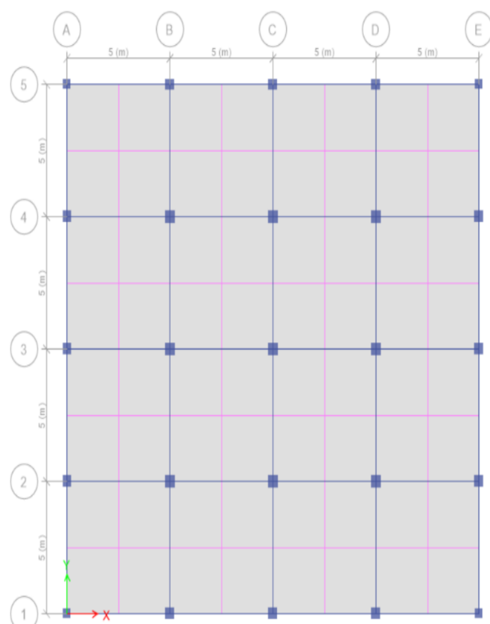


Table 11

Building Parameter Data for Case Two _2B

Parameter	Slab Systems	
	Two -way Slab	**Flat Slab**
Dimension of the building length and width	24m*24m	24mx24m
Length of each span x-direction	6m	6m
Length of each span y-direction	6m	6m
No of Spans	4Row &4Column	4Row &4Column
Story Height	3.2m	3.2m
No of Story	8	8
Slab Thickness	180mm	210mm
Beam size	350mm*450mm	--------
Column size corner	430mm*430mm	400mm*400mm
Column size exterior	470mm*470mm	440mm*440mm
Column size interior	550mm*550mm	520mm*520mm

Figure 24

Floor Plan of 8 Story Flat Slab

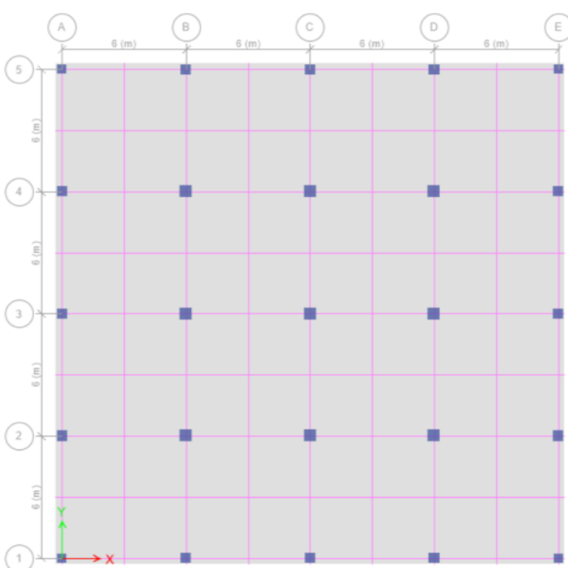


Figure 25

Floor Plan of 8 Story Two-way Slab

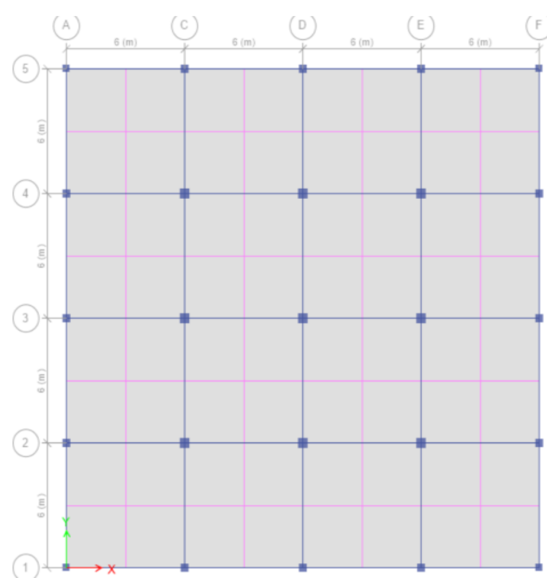


Table 12

Building Parameter Data for Case Two _2C

Parameter	**Slab Systems**	
	Two-way Slab	**Flat Slab**
Dimension of the building, length and width	28m*28m	28mx28m
Length of each span x-direction	7m	7m
Length of each span y-direction	7m	7m
No of spans	4Row & 4Column	4Row & 4Column
Story height	3.2m	3.2m
No of story	8	8
Slab thickness	210mm	240mm
Beam size	390mm*490mm	--------
Column size corner	460mm*460mm	430mm*430mm
Column size exterior	500mm*500mm	470mm*470mm
Column size interior	580mm*580mm	550mm*550mm

Figure 26

Floor Plan of 8 Story Flat Slab

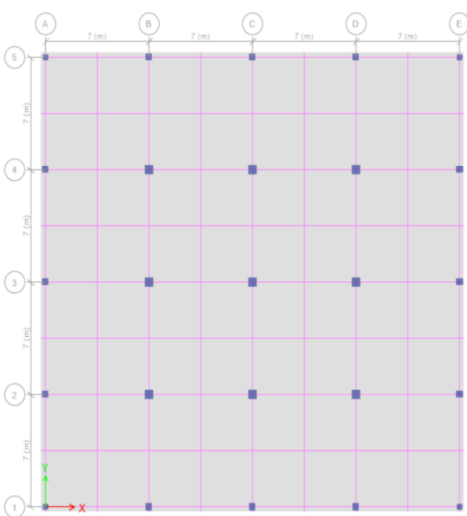


Figure 27

Floor Plan of 8 Story Two-way Slab

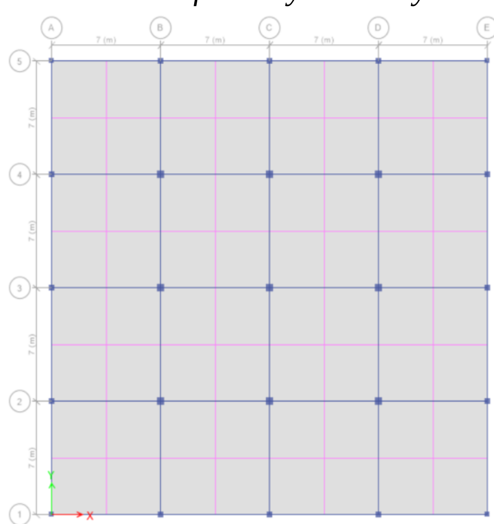


Figure 28

3D model of 8 Story Flat Slab

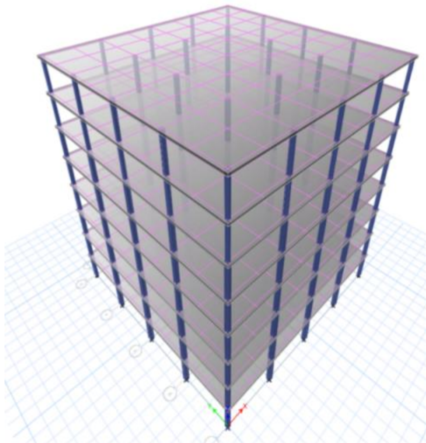
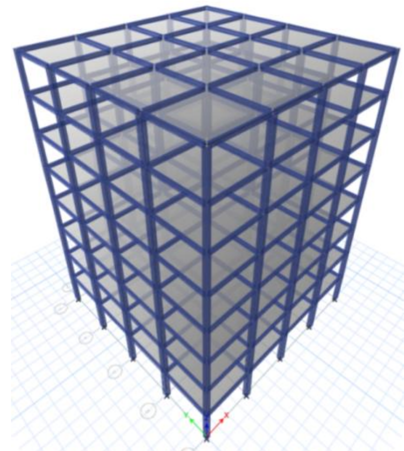


Figure 29

3D model of 8 Story Two-way Slab



Case: 3

Table 13

Building Parameter Data for Case Three_3A

Parameter	**Slab Systems**	
	Two-way Slab	**Flat Slab**
Dimension of the building, length and width	25m*25m	25m*25m
Length of each span x-direction	5m	5m
Length of each span y-direction	5m	5m
No of spans	5Row & 5Column	5Row & 5Column
Story height	3.2m	3.2m
No of story	8	8
Slab thickness	160mm	180mm
Beam size	200mm*310mm	--------
Column size corner	460mm*460mm	400mm*400mm
Column size exterior	500mm*500mm	440mm*440mm
Column size interior	570mm*570mm	520mm*520mm

Figure 30

Floor Plan of 8 Story Flat Slab

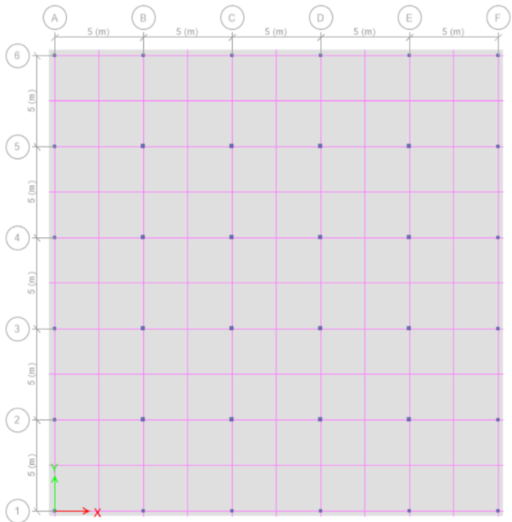


Figure 31

Floor Plan of 8 Story Two-way Slab

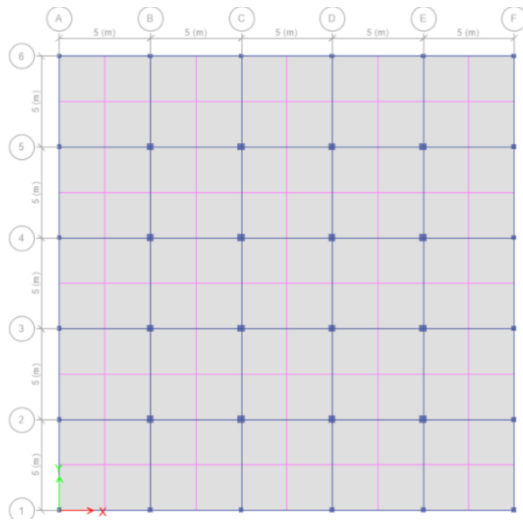


Table 14

Building Parameter Data for Case Three_3B

Parameter	**Slab Systems**	
	Two-way Slab	**Flat Slab**
Dimension of the building, length and width	30m*30m	30mx30m
Length of each span x-direction	6m	6m
Length of each span y-direction	6m	6m
No of spans	5Row & 5Column	5Row & 5Column
Story height	3.2m	3.2m
No of story	8	8
Slab thickness	180mm	210mm
Beam size	350mm*450mm	--------
Column size corner	470mm*470mm	410mm*410mm
Column size exterior	510mm*510mm	450mm*450mm
Column size interior	590mm*590mm	530mm*530mm

Figure 32

Floor Plan of 8 Story Flat Slab

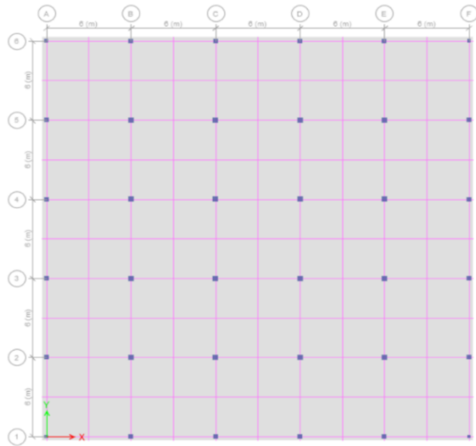


Figure 33

Floor Plan of 8 Story Two-way Slab

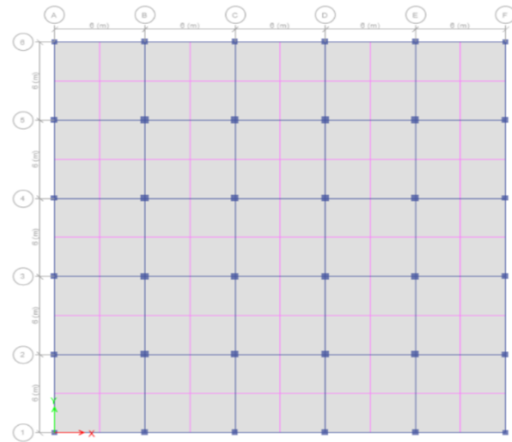


Table 15

Building Parameter Data for Case Three_3C

Parameter	**Slab Systems**	
	Two-way Slab	**Flat Slab**
Dimension of the building, length and width	35m*35m	35mx35m
Length of each span x-direction	7m	7m
Length of each span y-direction	7m	7m
No of spans	5Row & 5Column	5Row & 5Column
Story height	3.2m	3.2m
No of story	8	8
Slab thickness	210mm	240mm
Beam size	390mm*490mm	--------
Column size corner	500mm*500mm	440mm*440mm
Column size exterior	540mm*540mm	480mm*480mm
Column size interior	620mm*620mm	560mm*560mm

Figure 34

Floor Plan of 8 Story Flat Slab

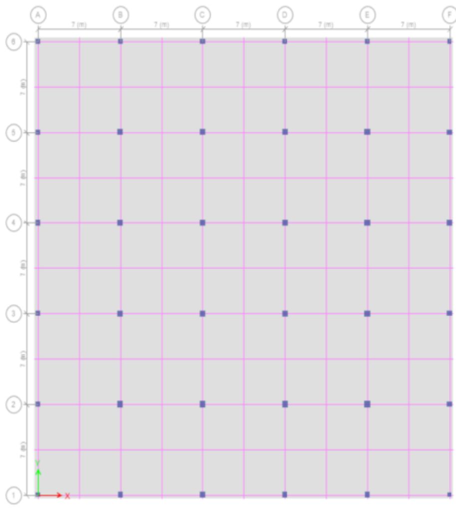


Figure 35

Floor Plan of 8 Story Two-way Slab

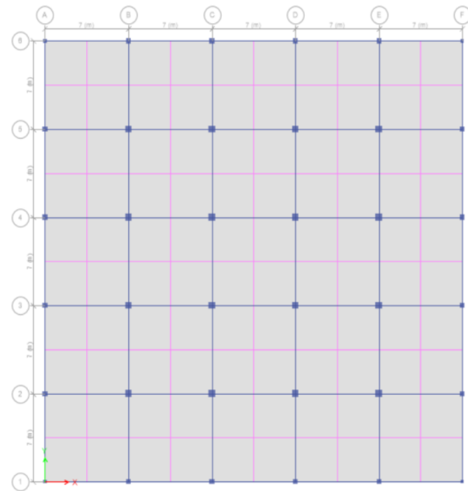


Figure 36

3D model of 8 Story Flat Slab

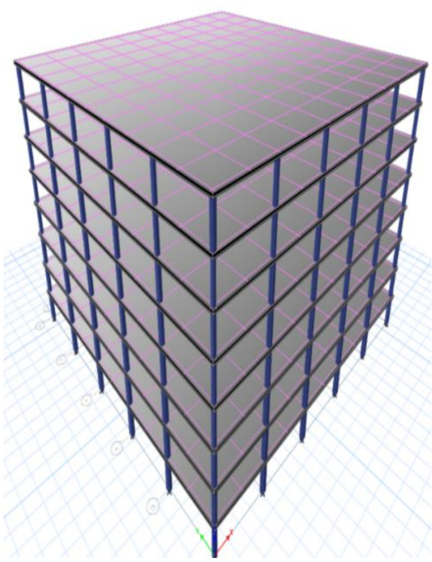
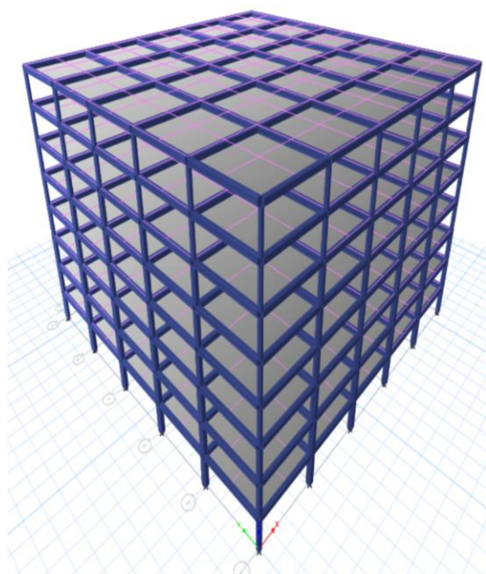


Figure 37

3D model of 8 Story Two-way Slab

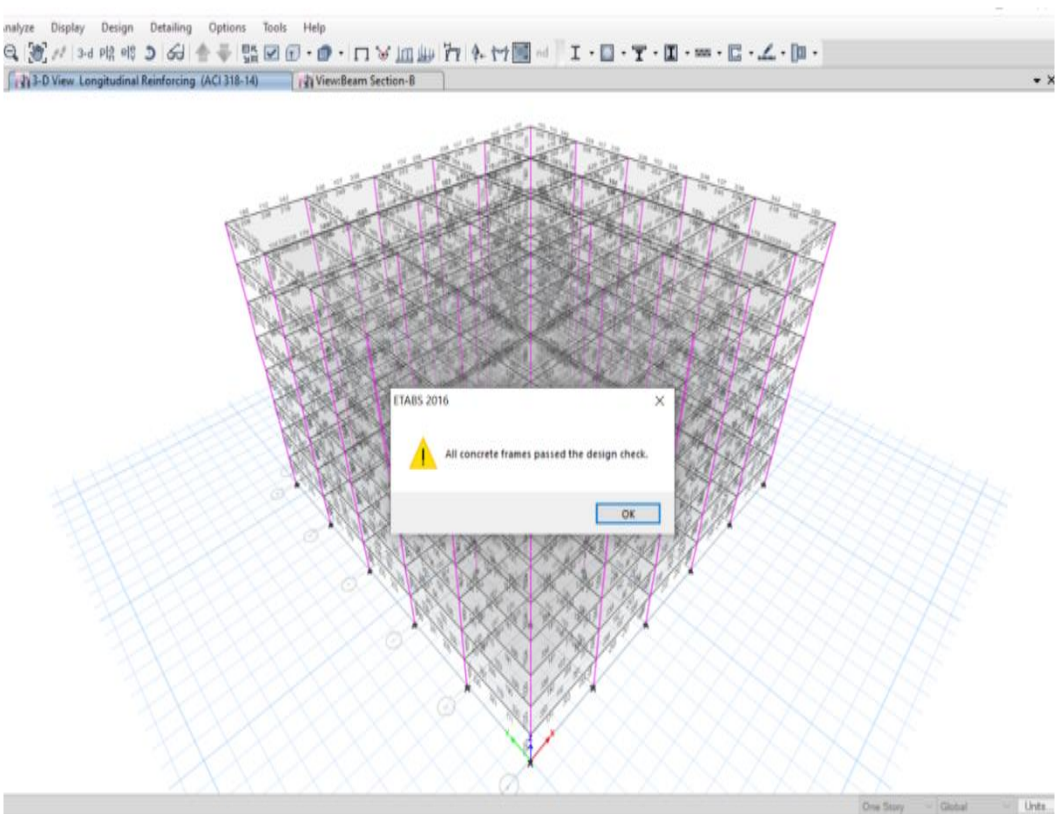


Models in ETABS

ETABS work in two steps. First it runs the analysis to get the forces in each members, then it performs the design to size the members.

Figure 38

3D Two-way Slab Modeling Result



CHAPTER IV

Result & Discussion

Overview

In this chapter, the results are obtained by using ETABS software program as per ACI. The factors considered in this study are namely, slab type, length of span in x and y directions, story height, slab thickness and column sizes. The results include bending moment, shearing force, punching shear force and deflection. Based on the internal forces, required areas of reinforcement have been determined. The weight of the reinforcement steel, quantity of concrete and area of formwork have been obtained. Market rates have been used to compute the total cost of steel and concrete used in both flat slab and two-way slab systems. The rate of steel and concrete is considered 950$ per tonne, 135$ per m^3 respectively. The rate of formwork is 25$ m^2 .Table 19-24 shows the variation in quantity of steel, quantity of concrete, quantity of formwork and total cost of slab between two-way slab and flat slab framed structure.

Table 16

Analysis Result for Case 1

Parameter	Slab Systems					
	Two way Slab			Flat Slab		
Plot Size	15m*15m	18m*18m	21m*21m	15m*15m	18m*18m	21m*21m
Span (m)	5	6	7	5	6	7
Slab Thickness (mm)	160	180	210	180	210	240
Bending Moment (kN-m)	15.9	39.5	41.7	29.9	60.1	98.9
Shear Force (kN)	26.7	47.1	53.2	67.2	93.4	149.2
Punching Shear (kN)	-------	-------	------	0.627	0.704	0.73
Deflection (mm)	2.532	3.741	5.420	3.036	4.334	6.086

In table 16 all plot sizes the flat slab has a greater bending moment, shear force and deflection with respect to two-way slab. Plot sizes (21m*21m) flat slab has greater punching shear with respect to other flat slab plot sizes.

Table 17

Analysis Result for Case 2

Parameter	Slab Systems					
	Two way Slab			Flat Slab		
Plot Size	20m*20m	24m*24m	28m*28m	20m*20m	24m*24m	28m*28m
Span (m)	5	6	7	5	6	7
Slab Thickness (mm)	160	180	210	180	210	240
Bending Moment (kN-m)	16.4	64.6	86.2	42.9	89.1	90.2
Shear Force (kN)	26.8	86.4	90.2	93.1	99.9	150.9
Punching Shear (kN)	-------	-------	------	0.66	0.76	0.82
Deflection (mm)	1.975	3.565	5.163	3.529	4.287	6.066

In table 17 all plot sizes the flat slab has a greater bending moment, shear force and deflection with respect to two-way slab. Plot sizes (28m*28m) flat slab has greater punching shear with respect to other flat slab plot sizes.

Table 18

Analysis Result for Case 3

Parameter	Slab Systems					
	Two way Slab			Flat Slab		
Plot Size	25m*25m	30m*30m	35m*35m	25m*25m	30m*30m	35m*35m
Span (m)	5	6	7	5	6	7
Slab Thickness (mm)	160	180	210	180	210	240
Bending Moment (kN-m)	38.1	66.8	92	52.6	94.3	149.7
Shear Force (kN)	41.6	90.4	93.3	96.8	156.2	160.5
Punching Shear (kN)	-------	------	------	0.74	0.84	0.99
Deflection (mm)	1.927	2.230	3.427	3.874	5.045	5.719

In table 18 all plot sizes the flat slab has a greater bending moment, shear force and deflection with respect to two-way slab. Plot sizes (35m*35m) flat slab has greater punching shear with respect to other flat slab plot sizes.

Table 19

Quantity of Steel, Concrete and Formwork for Slab Systems in Case 1

Parameter	Slab Systems					
	Two way Slab			Flat Slab		
Plot Size	15m*15m	18m*18m	21m*21m	15m*15m	18m*18m	21m*21m
Span (m)	5	6	7	5	6	7
Slabs Thickness (mm)	160	180	210	180	210	240
Steel (tonne)	4.0	6.3	10.3	3.2	5.3	8.3
Concrete (m^3)	43.44	70	112	40	68	106
Formwork (m^2)	299.4	412.2	582.2	225	324	441

In table 19 the quantity of concrete for flat slab is 3% - 8% less than two-way slab, the quantity of steel for flat slab is 16% - 20% less than two-way slab and the quantity of formwork for flat slab is 21% - 25% less than two-way slab.

Table 20

Quantity of Steel, Concrete and Formwork for Slab Systems in Case 2

Parameter	Slab Systems					
	Two way Slab			Flat Slab		
Plot Size	20m*20m	24m*24m	28m*28m	20m*20m	24m*24m	28m*28m
Span (m)	5	6	7	5	6	7
Slab Thickness (mm)	160	180	210	180	210	240
Steel (tonne)	6.9	14.1	21.3	5.6	9.4	14.7
Concrete (m^3)	76.4	130	218	72	104	188
Formwork (m^2)	524	792	1059	400	576	784

In table 20 the quantity of concrete for flat slab is 6% - 20% less than two-way slab, the quantity of steel for flat slab is 18% - 33% less than two-way slab and the quantity of formwork for flat slab is 24% - 27% less than two-way slab.

Table 21

Quantity of Steel, Concrete and Formwork for Slab Systems in Case 3

Parameter	Slab Systems					
	Two-way Slab			Flat Slab		
Plot Size	25m*25m	30m*30m	35m*35m	25m*25m	30m*30m	35m*35m
Span (m)	5	6	7	5	6	7
Slab Thickness (mm)	160	180	210	180	210	240
Steel (tonne)	10.7	20.2	27.9	8.8	14.8	23.1
Concrete (m^3)	119	219	337.2	113	189	294
Formwork (m^2)	811	1149	1636.4	625	900	1225

In table 21 the quantity of concrete for flat slab is 5% - 14% higher than two-way slab, the quantity of steel for flat slab is 18% - 27% higher than two-way slab and the quantity of formwork for flat slab is 22% - 25% less than two-way slab.

Table 22

Total Cost for Different Types of Slabs in Case 1

Plot Size	Span	Description	Unit	Unit price ($)	Quantity		Total ($)	
					Two-way Slab	Flat Slab	Two-way Slab	Flat Slab
15m*15m	5m	Steel	tonne	950	4.0	3.2	3800	3040
		Concrete	m^3	135	43.44	40	5864	5400
		Formwork	m^2	25	299.4	225	7485	5625
18m*18m	6m	Steel	tonne	950	6.3	5.3	5985	5035
		Concrete	m^3	135	70	68	9450	9180
		Formwork	m^2	25	412.2	324	10300	8100
21m*21m	7m	Steel	tonne	950	10.3	8.3	9785	7885
		Concrete	m^3	135	112	106	15120	14310
		Formwork	m^2	25	582.2	441	14555	11025
15m*15m	5m	Total Cost for Slab system					17149	14065
18m*18m	6m	Total Cost for Slab system					25735	22315
21m*21m	7m	Total Cost for Slab system					39460	33220

In table 22 total cost for slab system plot size (15m*15m) of flat slab 19.7% less than total cost for Slab system plot size (15m*15m) of two-way slab. Total cost for slab system plot size (18m*18m) of flat slab 14.2% less than total cost for Slab system plot size (18m*18m) of two-way slab. Total cost for slab system plot size (21m*21m) of flat slab 17.2% less than total cost for slab system plot size (21m*21m) of two-way slab.

Table 23

Total Cost for Different Types of Slabs in Case 2

Plot Size	Span	Description	Unit	Unit price ($)	Quantity		Total ($)	
					Two-way Slab	Flat Slab	Two-way Slab	Flat Slab
20m*20m	5m	Steel	tonne	950	6.9	5.6	6555	5320
		Concrete	m^3	135	76.4	72	10314	9720
		Formwork	m^2	25	524	400	13100	10000
24m*24m	6m	Steel	tonne	950	14.1	9.4	13395	8930
		Concrete	m^3	135	130	104	17550	14040
		Formwork	m^2	25	792	576	19800	14400
28m*28m	7m	Steel	tonne	950	21.3	14.7	20235	13965
		Concrete	m^3	135	218	188	29430	25380
		Formwork	m^2	25	1059	784	26475	19600
20m*20m	5m	Total Cost for Slab system					29969	25040
24m*24m	6m	Total Cost for Slab system					50745	37370
28m*28m	7m	Total Cost for Slab system					76140	58945

In table 23 total cost for slab system plot size (20m*20m) of flat slab 18 % less than total cost for slab system plot size (20m*20m) of two-way slab. Total cost for slab system plot size (24m*24m) of flat slab 30 % less than total Cost for Slab system plot size (24m*24m) of two-way slab. Total Cost for Slab system plot size (28m*28m) of flat slab 25.5% less than total cost for slab system plot size (28m*28m) of two-way slab..

Table 24

Total Cost for Different Types of Slabs in Case 3

Plot Size	Span	Description	Unit	Unit price ($)	Quantity		Total ($)	
					Two-way Slab	Flat Slab	Two-way Slab	Flat Slab
25m*25m	5m	Steel	tonne	950	10.7	8.8	10165	8360
		Concrete	m^3	135	119	113	16065	15255
		Formwork	m^2	25	811	625	20275	15625
30m*30m	6m	Steel	tonne	950	20.2	14.8	19190	14060
		Concrete	m^3	135	219	189	29565	25515
		Formwork	m^2	25	1149	900	28725	22500
35m*35m	7m	Steel	tonne	950	27.9	23.1	26505	21945
		Concrete	m^3	135	337.2	294	45522	39690
		Formwork	m^2	25	1636.4	1225	40910	30625
25m*25m	5m	Total Cost for Slab system					46505	37675
30m*30m	6m	Total Cost for Slab system					77480	62075
35m*35m	7m	Total Cost for Slab system					112937	92260

In table 24 total cost for slab system plot size (25m*25m) of flat slab 20.9% less than total cost for Slab system plot size (25m*25m) of two-way slab. Total cost for slab system plot size (30m*30m) of flat slab 22% less than total cost for slab system plot size (30m*30m) of two-way slab. Total cost for slab system plot size (35m*35m) of flat slab 20.2% less than total cost for slab system plot size (35m*35m) of two-way slab.

The total cost for slab systems flat slab structure is less by around 14.2%-30% as compared two-way slab structure. So that flat slab is more economical as compared two-way slab in terms of cost material.

CHAPTER V

Conclusion and Recommendation

Overview

The comparative study of flat slab and two-way slab system is presented in this study. The grid spacing of structure was vary to 5, 6 and 7 meters. 9 were modeled for two-way slab and the other 9 were modeled for flat slab structures. The building selected in this study is assumed to be used as residential building. The buildings were modeled by using ETABS by accounting for the linear analysis.

The results of the analysis lead to the following conclusions:

- When compared to a two-way slab, a flat slab has a higher bending moment, shear force, and deflection.
- Punching shear value is within the permissible limit. Therefore, the depth of slab is sufficient for flat slab systems.
- The punching shear failure is not critical in all our cases of flat slab but if punching shear becomes critical, it will be considered drop panel, shear reinforcement, increasing section of slab and column.
- As the grid spacing increases, all parameters like bending moment, shearing force and deflection increases.
- Flat slab system is more economical than that of two-way slab system. The cost of that slab system is reduced by %14.2 & %30 compared to two-way slab.
- For high rise buildings, flat slab structures are preferable than two-way slabs as architectural view. In addition to giving the architect greater formwork flexibility, flexural reinforcement insertion ease, concrete casting simplicity, and

open space for water, air, and other piping, flat slab designs enhance the visual perspective.

Future Recommendation

- Comparison of flat slab and two-way slab systems can be studied for different seismic zones.
- The most vulnerable part of slab column joint in flat slab systems can be studied.
- Comparative study of analysis of flat slab and two-way slab can be studied using different code and software programs.

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APPENDICES

Appendix A

Calculation of Preliminary Design

A. Calculating Slab Thickness of flat slab:

Case 1

Span Length 5m

L = 5m, Fy = 420MPa, Fc =28MPa,

Ln=4.6m

$H_{slab} = \frac{Ln}{33}$ Fromtable8.3.1.1

$H_{slab} = \frac{4.6}{33}$ =140mm

For edge

L=5m, Fy=420MPa, Fc=28MPa,

Ln=4.6m

$H_{slab} = \frac{4.6}{30}$ =153mm from table8.3.1.1

But I decide slab thickness 180

Case 2

Span Length 6m:

L = 6m, Fy = 420MPa, Fc = 28MPa, Ln=5.6m

$H_{slab} = \frac{Ln}{33}$ Fromtable8.3.1.1

$H_{slab} = \frac{5.6}{33}$=170$mm$

For edge

L=5.6m, Fy=420MPa, Fc=28MPa,

$H_{slab} = \frac{5.6}{30}$=186$mm$ from table8.3.1.1

But I decide slab thickness 210mm

Case 3

Span length 7m.

L = 7m, Fy = 420MPa, Fc = 28MPa, Ln=6.6m

$H_{slab} = \frac{Ln}{33}$ Fromtable8.3.1.1

$H_{slab} = \frac{6.6}{33}$=200$mm$

For edge

L=6.6m, Fy=420MPa, Fc=28MPa,

$H_{slab} = \frac{6.6}{30}$=220mm from table 8.3.1.1

But I decide slab thickness 240mm

B. Calculating Slab Thickness of two-way slab

Case 1

L=5m, Fy=420MPa, Fc=28MPa,

Design of beam Section:

Minimum depth of beam according to ACI-14-19 Table 9.3.1.1 is:

H=L/18.5= 5000mm/18.5 = 270.27mm ≈275mm

H=b (1.5)=275/1.5, b=183.3mm

Beam section = (183.3mm*275mm)

But I decide = (200mm*310mm) for safety

For depth of Slab with beam we assume depth of slab is 200mm that is required for determining the moment of inertia of the slab that required in the (α_f) equation for determining the slab thickness.

$$\alpha f = \frac{E_{cb} I_b}{E_{cs} I_s}$$

I_{beam} (for edge)= $(bh^3/12)*1.5$

$=200*310^3/12*1.5=7.4*10^8 mm^4$

I_{beam} (interior)= $(bh^3/12)*2=200*310^3/12*2=9.93*10^8 mm^4$

$I_{slab}= b_s*h^3/12$

I_{slab}(edge)= $5000*200^3/12=33.3*10^8 mm^4$

I_{slab}(interior)=$5000*200^3/12=33.3*10^8 mm^4$

α_{f1}(edge)=$7.4*10^8 mm^4/33.3*10^8 mm^4=0.22$

$\alpha_{f(interior)}$=$9.93*10^8 mm^4/33.3*10^8 mm^4=0.298$

$\alpha_{f(total)}$=(0.22+0.298)/2=0.26 $\leq\alpha_f\leq2$ so use table8.3.1.1:

H_{slab}=152mm≤ assumed (200mm)

But I decide for safety 160mm

Case 2

Span length 6m

L=6m, Fy=420MPa, Fc=28MPa,

Design of beam Section:

Minimum depth of beam according to ACI-14-19 Table 9.3.1.1 is:

H=L/18.5= 6000mm/18.5 = 324mm ≈330mm

H=b (1.5)=330/1.5, b=220mm
Beam section = (220mm*330mm)
But I decide = (250mm*360mm) for safety

For depth of Slab with beam we assume depth of slab is 200mm that is required for determining the moment of inertia of the slab that required in the (α_f) equation for determining the slab thickness

$$\alpha f = \frac{E_{cb} I_b}{E_{cS} I_S}$$

I_{beam}(for edge)=(bh^3/12)*1.5

=250*36 0^3/12*1.5=14.58*$10^8$$mm^4$

I_{beam}(interior)=(bh^3/12)*2=250*360^3/12*2=19.44*$10^8$$mm^4$

I_{slab}=b_s*h^3/12

I_{slab}(edge)= 6000*200^3/12=40*$10^8$$mm^4$

I_{slab}(interior)=6000*200^3/12=40*$10^8$$mm^4$

α_{f1}(edge)=14.58*$10^8$$mm^4$/40*$10^8$$mm^4$=0.36

$\alpha_{f(}$interior$_{)}$=19.44*$10^8$$mm^4$/40*$10^8$$mm^4$=0.486

$\alpha_{f(total)}$=(0.365+0.486)/2=0.423
≤α_f≤2sousetable8.3.1.1:

H_{slab}=163mm≤ assumed (200mm)

But I decide for safety 180mm

Case 2

Span length 7m.

Design of beam section if L = 7m

H=L/18.5=7000mm/18.5=378m≈380mm

H=b(1.5)=380/1.5,b=253mm≈260mm

Beam section = (260mm*380mm)

I decide for safety (280mm*420mm)

For depth of Slab with beam we assume depth of slab is 200mm that is required for determining the moment of inertia of the slab that required in the (α_f) equation for determining the slab thickness.

$$\alpha f = \frac{E_{cb} I_b}{E_{cS} I_S}$$

I_{beam}(for edge)=$(bh^3/12)*1.5$

$=280*420^3/12*1.5=25.9*10^8 mm^4$

I_{beam}(interior)=$(bh^3/12)*2$

$=280*420^3/12*2=34.5*10^8 mm^4$

$I_{slab}=b_s*h_s^3/12$

I_{slab}(edge)$=7000*200^3/12=46.60*10^8 mm^4$

I_{slab}(interior)$=7000*200^3/12=46.60*10^8 mm^4$$\alpha_{f1}$(edge)$=25.9*10^8 mm^4/46.60*10^8 mm^4=0.555$

$\alpha_{f(total)}=34.5*10^8 mm^4/46.60*10^8 mm^4= 0.74$

$\alpha_{f(total)}$=(0.555+*0.74)/4=0.65 ≤α_f≤2 so use table8.3.1.1:

H_{slab}=189mm≤ assumed (200mm).
But I decide for safety 210mm

C. Checking for punching shear

Nominal shear strength of concrete:

For flat slabs V_C =nominal shear strength of concreteV_C shall be smallest of the following:

$$V_C = \left(2 + \frac{4}{\beta_C}\right)\sqrt{f_c}\, b_0 d$$

$$V_C = \left(\frac{\alpha_s}{b_0} + 2\right)\sqrt{f_c}\, b_0 d$$

$$V_C = 4\sqrt{f_c}\, b_0 d$$

Where β_C is the ratio of long side to short side of the column, concentrated load or reaction area and where α_s 40 for interior columns, α_s 30 for edge columns, α_s 20 for corner columns.

Case One_1A

Slab dimension = (15m*15m)

Slab thickness = 180mm

d=155mm

Column dimension = (330mm*330mm)

Density of concrete = 25$\frac{kN}{m^3}$

Dead load on the slab = (self load of slab + finish load + wall partion load)

DL= ((25*0.18) + (1.58)+(0.53))

Live load on the slab =1.92$\frac{kN}{m^2}$

Design load on the slab = (1.2DL+1.6LL)

Design load on the slab = (1.2*6.61+1.6*1.92) =11$\frac{kN}{m^2}$

V_U = [11(5m*5m) - (0.485*0.485)]=272KN =61148 lb

$\sqrt{f_c}b_0d = \sqrt{2800}$ x$(76.8)(6.1)$=24661 lb

$V_C = \left(2 + \frac{4}{\beta_C}\right)\sqrt{f_c}b_0d$

$V_C = \left(2 + \frac{4}{1}\right)$ x 24661=147963 lb

$V_C = \left(\frac{\alpha_s}{b_0} + 2\right)\sqrt{f_c}b_0d$

$V_C = \left(\frac{40x6.1}{76.4} + 2\right)x24661$ =128082 lb

$V_C = 4\sqrt{f_c}b_0d$

$V_C = 4x24661 = 98644$ lb

$V_C > V_U$ = 98644 lb >61148 Punching Shear is Safe

Case One_2A

Slab dimension = (18m*18m)

Slab thickness =210mm

d=185mm

Column dimension = (360mm*360mm)

Density of concrete = 25$\frac{kN}{m^3}$

Dead load on the slab = (self load of slab + finish load + wall partion load)

DL= ((25*0.21) + (1.58) + (0.53))

Live load on the slab =1.92$\frac{kN}{m^2}$

Design load on the slab = (1.2DL+1.6LL)

Design load on the slab = (1.2*7.36+1.6*1.92) =12$\frac{kN}{m^2}$

V_U = [12(6m*6m) - (0.545*0.545)] =428KN =96218 lb

$$\sqrt{f_c} b_0 d = \sqrt{2800} x(86)(7.3) = 33220$$

$$V_C = \left(2 + \frac{4}{\beta_C}\right)\sqrt{f_c} b_0 d$$

$$V_C = \left(2 + \frac{4}{1}\right) \text{ x } 33220 = 199320 \text{ lb}$$

$$V_C = \left(\frac{\alpha_s}{b_0} + 2\right)\sqrt{f_c} b_0 d$$

$$V_C = \left(\frac{40x7.3}{86} + 2\right) x33220 = 179233 \text{ lb}$$

$$V_C = 4\sqrt{f_c} b_0 d$$

$$V_C = 4x33220 = 132880 \text{ lb}$$

$V_C > V_U$ = 132880 lb >96218 Punching Shear is Safe

Case One_3A

Slab dimension = (21m*21m)

Slab thickness = 240mm

d=214mm

Column dimension = (390mm*390mm)

Density of concrete = $25\frac{kN}{m^3}$

Dead load on the slab =self load of slab + finish load + wall partion load

DL= ((25*0.24) + (1.58)+(0.53))

Live load on the slab =$1.92\frac{kN}{m^2}$

Design load on the slab = (1.2DL+1.6LL)

Design load on the slab = (1.2*7.87+1.6*1.92) =$13\frac{kN}{m^2}$

V_U = [13(7m*7m) - (0.604*0.604)] =632KN =142079 lb

$\sqrt{f_c} b_0 d = \sqrt{2800}x(4 \times 95)(8.4)$=42226 lb

$$V_C = \left(2 + \frac{4}{\beta_C}\right)\sqrt{f_c} b_0 d$$

$V_C = \left(2 + \frac{4}{1}\right)$ x42226=253357 lb

$$V_C = \left(\frac{\alpha_s}{b_0} + 2\right)\sqrt{f_c} b_0 d$$

$V_C = \left(\frac{40x8.4}{95} + 2\right)$x42226 =233798.6 lb

$$V_C = 4\sqrt{f_c} b_0 d$$

V_C = 4x42226 = 168904 lb

$V_C > V_U$ = 168904 lb >142079 lb Punching Shear is Safe.

Appendix B

ETAB Modeling Result

A. Deflection Results of Flat Slab

Case 1

Figure 39

Deflection Result Case 1A

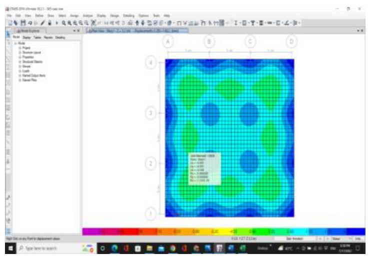


Figure 40

Deflection Result Case 1B

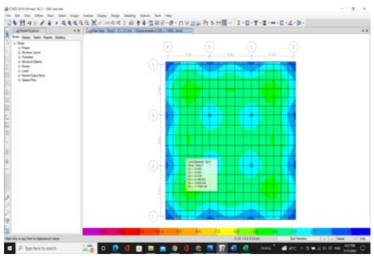
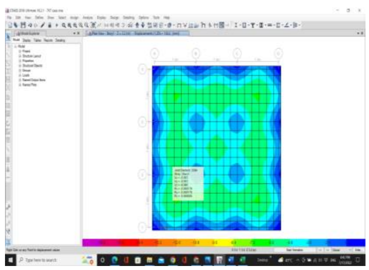


Figure 41

Deflection Result Case 1C



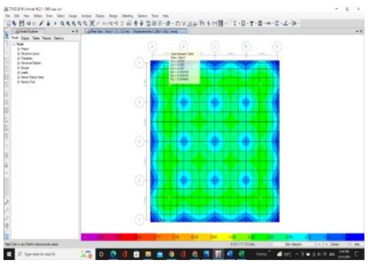
Case2

Figure 42

Deflection Result Case 2A

Figure 43

Deflection Result Case 2B



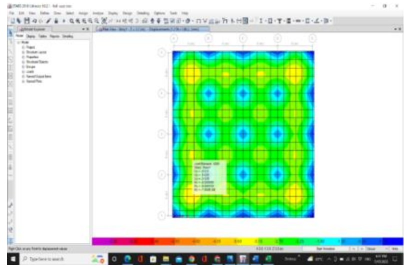
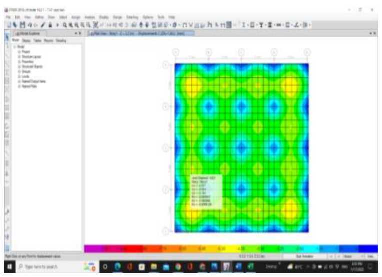


Figure 44

Deflection Result Case 2C



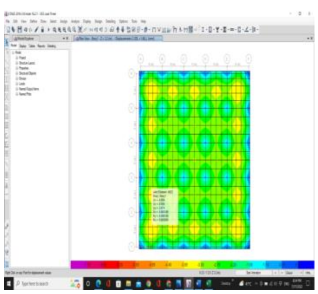
CASE3

Figure 45

Deflection Result Case 3A

Figure 46

Deflection Result Case 3B



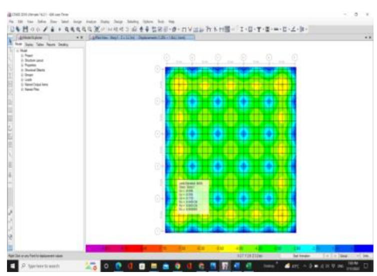
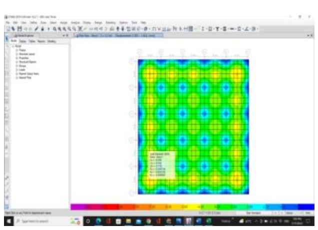


Figure 47

Deflection Result Case 3C



B. Deflection Results of Two-Way Slab

Case 1

Figure 48

Deflection Result Case 1A

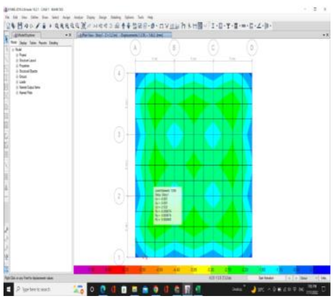


Figure 49

Deflection Result Case 1B

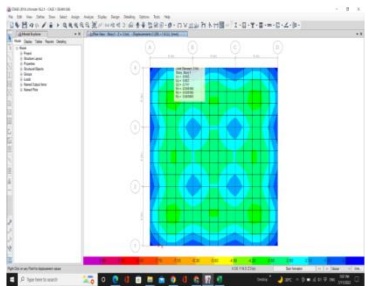
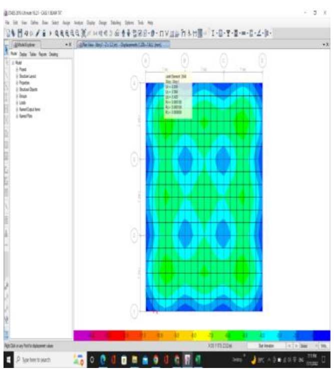


Figure 50

Deflection Result Case 1C



Case 2

Figure 51

Deflection Result Case 2A

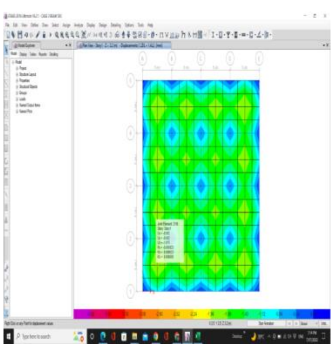


Figure 52

Deflection Result Case 2B

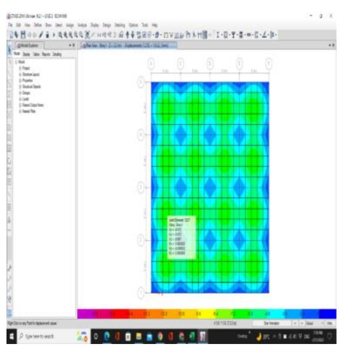
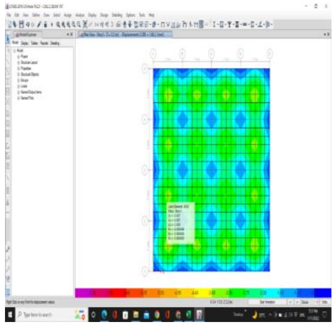


Figure 53

Deflection Result Case 2C



Case3

Figure 54

Deflection Result Case 3A

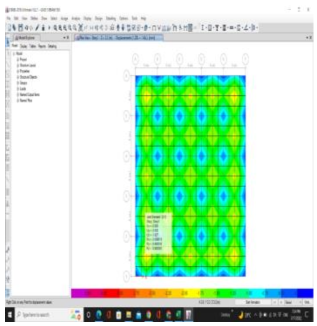


Figure 55

Deflection Result Case 3B

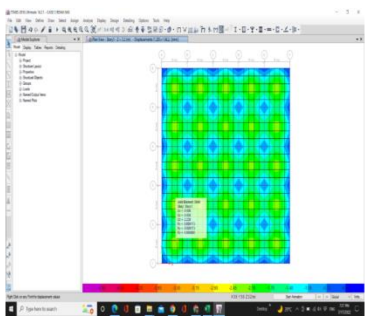
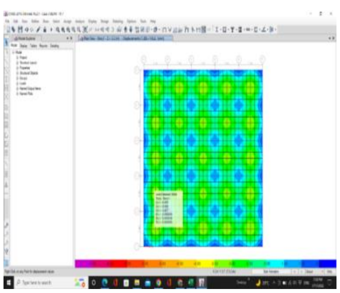


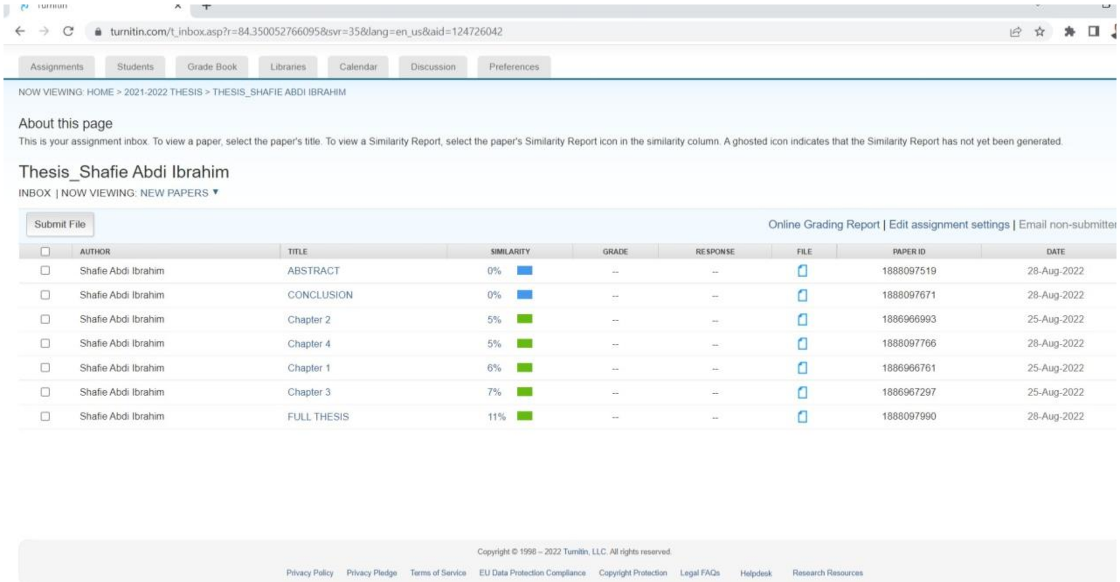
Figure 56

Deflection Result Case 3C



Appendix C

Turnitin Similarity Report



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Student name: Shafie Abdi Ibrahim

Thesis supervisor: Assoc.Prof.Dr. Rifat Reşatoğlu

Appendix D

Ethical Certificate

08.09.2022

ETHICS LETTER

TO GRADUATE SCHOOL OF APPLIED SCIENCES

REFERENCE: SHAFIE ABDI IBRAHIM (20206893)

The aforementioned candidate is one of the Master's students in the field of Civil Engineering.

He is working on a thesis under my supervision, entitled "COMPARATIVE STUDY OF ANALYSIS AND COST OF THE FLAT SLAB AND TWO-WAY SLAB IN SOMALIA-MOGADISHU". The work is based on modeling flat slab and two-way slab systems.

The building type selected in this study is assumed to be used as a residential building. The residential buildings were modeled by using software program called ETABS v16.

Sincerely yours,

Assoc. Prof. Dr. Rifat RESATOGLU

(Supervisor)

Civil Engineering Department,

Faculty of Civil and Environmental Engineering