Kurdistan Region

Salahaddin University-Erbil

College of Engineering

Civil Engineering Department

Analysis by (ETABS) and Design by (Hand Calculation) of Apartment Building

A Project Submitted to the Civil Engineering Department

University of Salahaddin-Erbil

In the Partial Fulfillment of the Requirement for the Degree of Bachelor of Science in Civil Engineering

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Dedication

We dedicate our thanks to our parents and family who paved the way for us to succeed in life helping us with all of our needs, and our supervisor Dr.Hemn Qader Ahmed ,who was with us in every step of the project and was thrilled to teach us everything he knows about our project. We wish to serve our country in constructing buildings in good conscience.

Abstract

The global economy and population will increase the demand for land. In order not to experience a shortage of space due to the increase in population, the government should deal with housing construction. This will allow the government to have more people in the specified area like Civil engineering, architectural engineering, structural engineering, geotechnical engineering, transportation engineering, research engineering, water engineering, environmental engineering, etc. It is a diverse industry that includes many branches and this project focuses on building design, specifically the analysis of high-rise buildings using ETABS, a software tool designed for the analysis and design of high-rise buildings with the use hand calculations for design.

I certify that the engineering project titled **“Analysis by (ETABS) and Design by (Hand Calculation) of Apartment Building"** was done under my supervision at the Civil Engineering Department, College of Engineering - Salahaddin University –Erbil in the partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineering.

Supervisor

Signature:

Name:Dr. Hemn Qader Ahmed

Date: /   /

Chapter One

Introduction

A multi-story building is a structure that's outlined and built to have different levels or floors, regularly three or more, supported by a combination of columns, beams, and other load-bearing components. The plan and development of multi-story buildings include an extent of designing disciplines, mechanical, electrical, and civil engineering. The structural viewpoint of multi-story buildings includes the choice of suitable materials, such as concrete, steel, or wood, and the plan of load-bearing frameworks that can withstand the weight of the building and the loads forced by inhabitants, hardware, and natural components such as wind and seismic tremors. The plan must take under consideration variables such as fire security, availability, and natural supportability.

History

High-rise buildings date back to ancient civilizations, such as the Egyptians, who built high-rise buildings as early as 2600 BC. However, it was not until the 18th and early 19th centuries that the advanced concept of multiple buildings came to fruition. One of the most significant multi-story buildings was the Domestic Protections Building in Chicago, built in 1885 by William Le Noble Jenney. The building was ten stories tall and included a steel structure. This plan permitted for more noteworthy statures and bigger floor regions than already possible with brick work development. Within the early 20th century, multi-story buildings got to be more common in urban regions as cities developed it got to be more costly. The Realm State Building, completed in 1931, was the tallest building within the world at the time and checked a modern time of skyscraper construction. Since then, the plan and development of multi-story buildings have proceeded to advance, with progresses in building and development procedures empowering the development of taller and more complex structures. For illustration, the Burj Khalifa in Dubai, completed in 2010, stands at 828 meters tall and is as of now the tallest building within the world.[1]

Material types of multi-story buildings

Multi-story buildings can be developed employing an assortment of materials, each with its claim interesting preferences and drawbacks. The choice of materials frequently depends on components such as taken a toll, solidness, aesthetics, natural affect, and building codes and regulations.

Concrete: a well-known choice for building high-rise structures due to its quality and strength. Concrete is composed of cement, water, and sand, that are mixed together and poured into molds to create the building's establishment, columns, dividers, and floors. Concrete structures can withstand extreme weather conditions, seismic tremors, and fires.

Figure 1-1 concrete structure

Steel: it is another prevalent material utilized for multi-story building development. It is solid, lightweight, and permits for adaptable plan alternatives. Steel buildings can be raised rapidly and proficiently, and can too be dismantled and reused on the off chance that required. In any case, steel is defenseless to erosion and fire, as written in a report by the National Fire Protection Association.[2]

Figure 1-2 steel structure

Slab types of multi-story building

The construction of multi-story buildings involves various types of slab systems that serve as floors, roofs, and intermediate levels. The selection of slab type depends on factors such as building design, span, load, aesthetics, and cost.

Flat plate slab: Is a simple and economical system in which the slab is supported directly on columns without the use of beams. The slab thickness is uniform throughout the building, and the reinforcement is placed near the bottom of the slab. This system is suitable for low-rise buildings with regular column grids and uniform loads.[3]

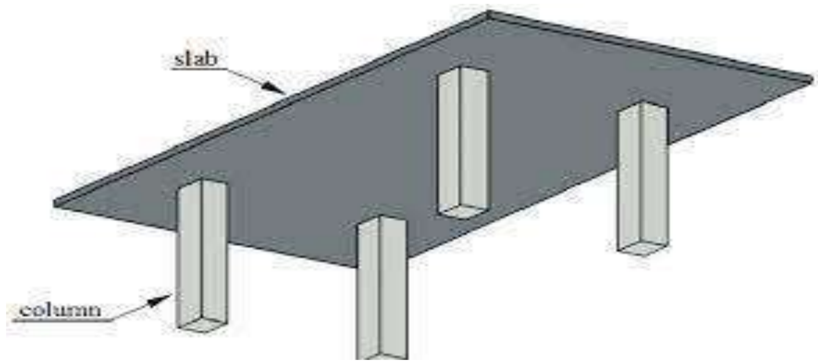


Figure 1-5 Flat plat slabs

Flat slab: Is a variant of the flat plate system in which drop panels or column capitals are used to increase the shear capacity and stiffness of the slab. The reinforcement is placed in the drop panels or capitals, which are thicker than the rest of the slab. This system is suitable for mid-rise and high-rise buildings with irregular column grids and variable loads.[4]

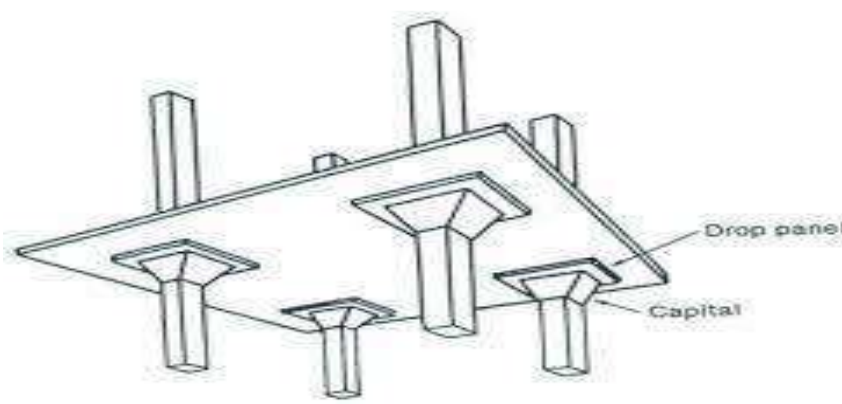


Figure 1-6 Flat slabs

Two-way slab: a slab that is supported by four sides and is designed to resist bending in two directions. The reinforcement is placed near the top and bottom of the slab and the slab thickness varies according to the span and load. This system is suitable for buildings with regular column grids and uniform loads.[5]

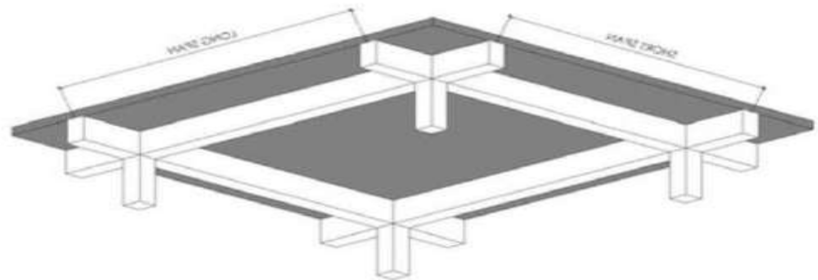


Figure 1-7 Two-way slab

One-way slab: a slab that is supported by two sides and is designed to resist bending in one direction. The reinforcement is placed near the bottom of the slab, and the slab thickness varies according to the span and load. This system is suitable for buildings with regular column grids and uniform loads.[6]

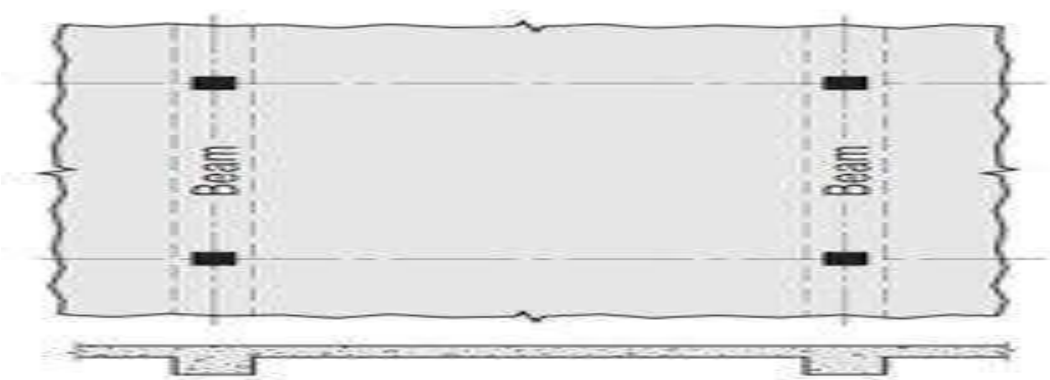


Figure 1-8 one-way slab

Used codes in multi-story building design

The design of a multistory building involves following various codes of practice to ensure safety, durability, and functionality. Here are some of the commonly used codes of practice for designing multistory buildings:

The American Concrete Institute (ACI) has long been a leader in such efforts. As part of its activities, the American Concrete Institute has published building codes and reviews as guidelines for the design and construction of concrete buildings. The ACI Code itself has no status. However, it is generally accepted as the current standard of good practice in the concrete addition field. As such, it has been unified using the International Building Code and similar laws, which are legally recognized as statutory municipal and regional building codes.[7]

Therefore, its provisions are well received by the law. Most concrete and related buildings in the United States are designed according to current ACI codes. It also serves as a document model for many countries, especially Iraq.

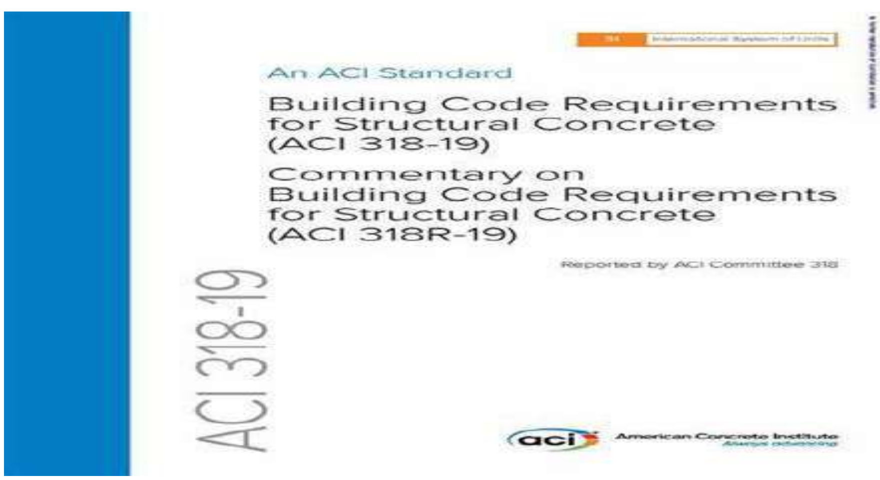


Figure 1-9 ACI code

International Building Code (IBC): It used in the United States and many other countries. It specifies requirements for design, fire protection and accessibility, as well as minimum requirements for design and construction. IBC is constantly evolving to incorporate new technologies and research.

Euro codes: they are European standards for building and construction. It covers topics such as design, fire protection and accessibility.

Indian Standard: The Bureau of Indian Standards (BIS) has standards and codes for building and construction in India. These standards include elements such as design, fire protection and accessibility.

Loads that affect a building

Dead load: refers to the weight of the permanent elements of the building, such as the slabs, columns, and beams. This load is permanent and doesn't change over time .the amount of dead load affects the overall structural stability and the amount of material required for construction.

Live load: it refers to the weight of people, furniture, equipment, and other movable objects within the building. This load can change anytime as it varies overtime. Live load is significant on the design of a multi-story building, as it affects the structural strength and the overall safety of the building.

Wind load: refers to the force that wind exerts on the building. This load can be significant, especially in areas with high wind speeds.

Seismic load: Seismic load refers to the force that an earthquake exerts on the building. This load can be very destructive and can cause significant damage to buildings.[8]

ACI 318-19 §5.3: Load Factors and Combinations

Notation:
D: Dead Load
L: Live Load
L_r: Roof Live Load
S: Snow Load
R: Rain Load
E: Earthquake Load
W: Wind Load

Required strength ***U***
After ACI 318-19 Table 5.3.1: Load Combinations

Load Combination	Equation	Primary Load
$U = 1.4D$	5.3.1a	*D*
$U = 1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$	5.3.1b	*L*
$U = 1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (1.0L \text{ or } 0.5W)$	5.3.1c	L_r or *S* or *R*
$U = 1.2D + 1.0W + 1.0L + 0.5(L_r \text{ or } S \text{ or } R)$	5.3.1d	*W*
$U = 1.2D + 1.0E + 1.0L + 0.2S$	5.3.1e	*E*
$U = 0.9D + 1.0W$	5.3.1f	*W*
$U = 0.9D + 1.0E$	5.3.1g	*E*

Table 1-1 Load combination

Analysis of building using software program (ETABS)

ETABS is an engineering software product that caters to multi-story building analysis and design. Modeling tools and templates, code-based load prescriptions, analysis methods and solution techniques, all coordinate with the grid-like geometry unique to this class of structure. The program can also perform dynamic analysis, including earthquake analysis and response spectrum analysis. One of the advantages of ETABS is its user-friendly interface, which allows for easy input of building data and quick generation of analysis results. The program also provides a wide range of analysis options, including linear and nonlinear static and dynamic analysis, time-history analysis, and pushover analysis.[9]

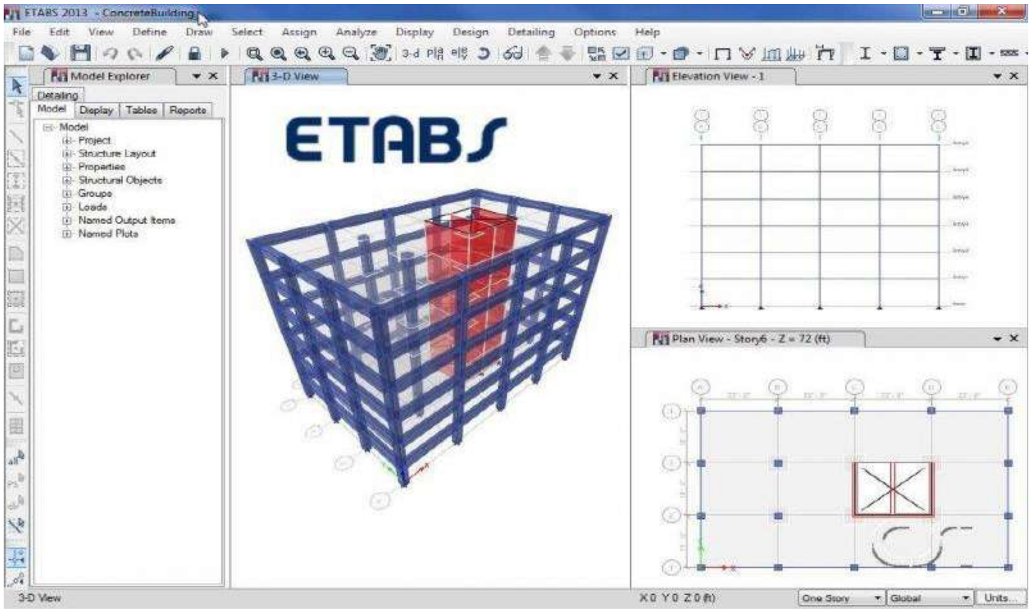


Figure 1-10 ETABS PROGRAM

General components that compose a multi-story building

The components of a building structure are the foundation, floors, walls, beams, columns, roof, stair, etc. These elements serve the purpose of supporting, enclosing and protecting the building structure. Here are some of the general components of a multi-story building:

Superstructure

Shear walls: is a general term for a wall that is designed and constructed to resist racking from forces such as wind using masonry, concrete, cold-formed steel, or wood framing.

Slabs: A concrete slab is a structural feature, usually of constant thickness, that can be used as a floor or a roof.

Beams: A beam is a structural element that supports loads by resisting bending. Beams can be made of steel or reinforced concrete and are typically used to span openings between columns or walls.

Columns: A column is a vertical structural element that supports the weight of the structure above it. Columns can be made of reinforced concrete or steel.

Substructure

Foundation: A foundation is the lowest part of a building that transfers the building's weight to the ground. There are two main types of foundations: shallow foundations and deep foundations.[10]

Figure 1-11 Typical R.C. Frame Building

Chapter Two

Methodology

In order to ensure the utmost satisfaction in our life's work, we have made the decision to undertake the design and analysis of a multistory building for our project.

Analyzing

The analysis for this project was conducted using the ETABS program, with the project model depicted in Figure [2-a].

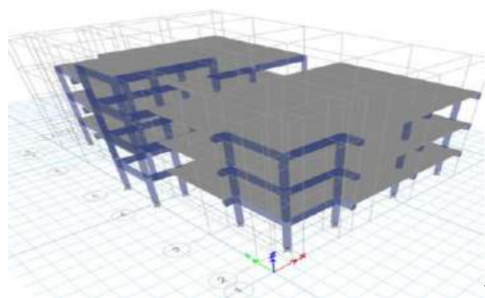


fig (2-a)

Design

In this project, we chose to design the structure through hand calculations, utilizing widely used methods, as follow:

-Slabs: for maximum positive and negative moment ultimate load method used to designing top and bottom bars for each direction.

- Beam: the design is only for longitudinal bar which is main direction for top and bottom by using ultimate load method.

- Column: the design is only for longitudinal bar which is main direction for X&Y direction by using ACI charts (interaction diagram).

- Foundation: using square footing with design width, length and thickness also design total Reinforcement for X&Y direction using ultimate load method.

Chapter Three

Checking slab thickness

SLAB THICKNESS

As shown in figure (3-a), selecting the panel with the longest span lengths (Panel 1).

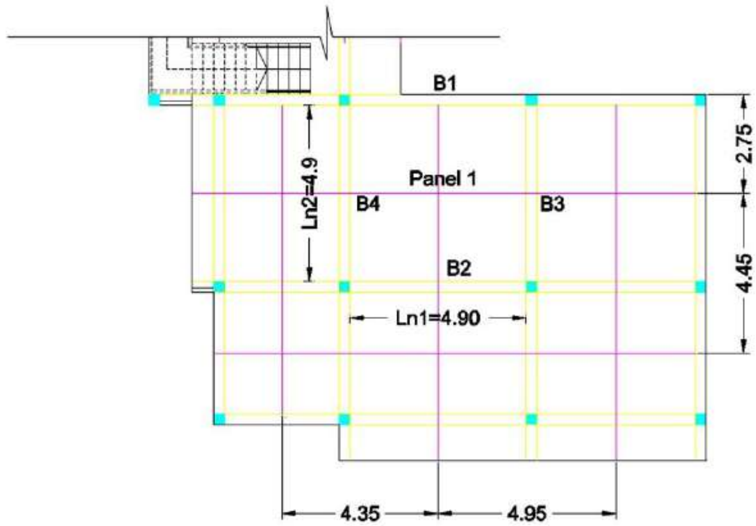


Fig (3-a), plan view of

Referring to the figures (3-b), use the dimentions to determine the moment of inertia for both the beam and slab, utilizing the equations provided.

Assuming slab thickness = 150 mm

$$I_b \; for \; T \; beam = 2 \frac{b \; x \; h^3}{12}$$

$$I_b \; for \; L \; beam = 1.5 \frac{b \; x \; h^3}{12}$$

$$I_s \; for \; Slab = \frac{b \; x \; t^3}{12}$$

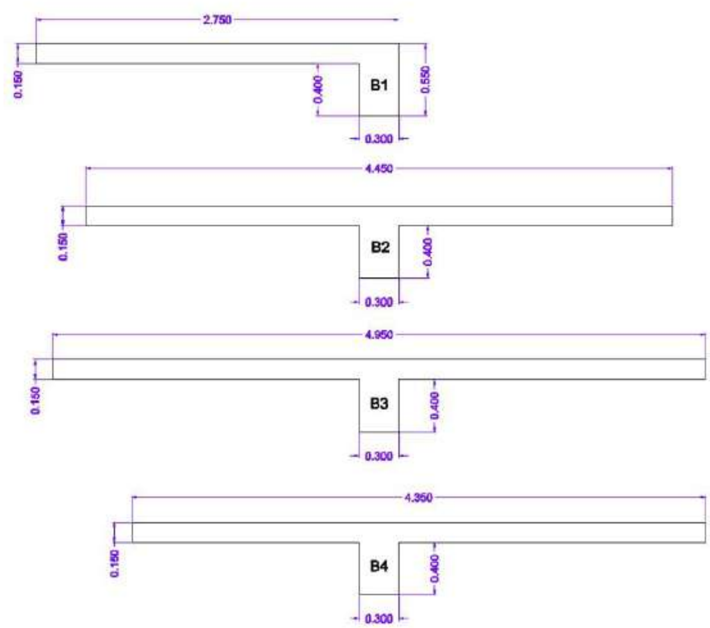


Fig (3-b) , Beam

So that

$I_b\ for\ B1 = 1.5\ \frac{bw \times h^3}{12} = 1.5 \frac{0.3 \times 0.55^3}{12}$ =0.006239

$I_s\ for\ B1 = \frac{be \times h^3}{12} = \frac{0.3 \times 0.55^3}{12}$ =0.000773

$$\alpha f\ B1 = \frac{Ecb \times Ib}{Ecs \times Is} = \frac{Ib}{Is} = \frac{0.006239}{0.000773} = 8.067$$

Same calculations were done for the remaining sections as shown in the table

PANEL 1							
	be	bw	h	t	Ib	Is	αfm
B1	2.75	0.3	0.55	0.15	0.006239	0.000773	8.067
B2	4.45	0.3	0.55	0.15	0.008319	0.001252	6.647
B3	4.95	0.3	0.55	0.15	0.008319	0.001392	5.975
B4	4.35	0.3	0.55	0.15	0.008319	0.001223	6.799

Table (3-1)

Then ;

$$\alpha fm = \frac{8.067 + 6.647 + 5.975 + 6.799}{4} = 6.872$$

$\boldsymbol{\alpha fm = 6.872\ > 2}$

Therefore h_{min} is calculated using table 8.3.1.2 – ACI 318M-19

$$h_{min} = \frac{l_n(0.8 + \frac{f_y}{1400})}{36 + 9\beta} = \frac{4.9(0.8 + \frac{420}{1400})}{36 + 9(1)} = 0.1197\ m \approx 0.120\ m$$

Since 120 *mm* is greater than 90 *mm* , 120 is controled

Using 150 mm as slab thickness is accepted

Checking minimum depth of beam

Using table 9.3.1.1 ACI 318M-19

Table 9.3.1.1—Minimum depth of nonprestressed beams

Support condition	Minimum h[1]
Simply supported	$\ell/16$
One end continuous	$\ell/18.5$
Both ends continuous	$\ell/21$
Cantilever	$\ell/8$

[1]Expressions applicable for normalweight concrete and f_y = 420 MPa. For other cases, minimum h shall be modified in accordance with 9.3.1.1.1 through 9.3.1.1.3, as appropriate.

Table (3-2)

For Cantilever :

Distance = 1150mm

$$550 > \frac{1150}{8} = 143.75$$

For both ends continuous :

Distance = 5200mm

$$550 > \frac{5200}{21} = 247.6$$

Minimum depth for beam is Checked. OK

Load calculation

Material unit weight according to ASCE

•R. Concrete.. (24.0 KN/m^3)

•Gypsum........... (8Psf x 0.0479)/ (0.025)................... (15.3 KN/m^3)

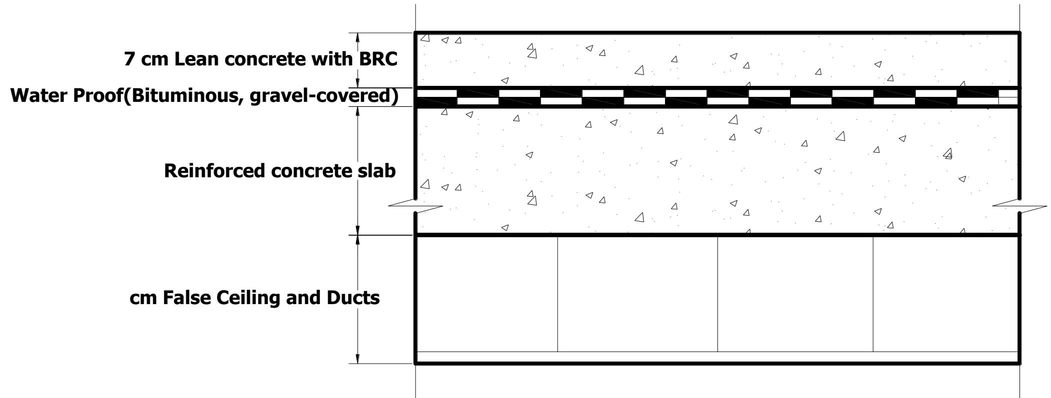
•Mortar.. (20.4 KN/m^3)

•Lean concrete with BRC... (24.0 KN/m^3)

•Tile................... (12Psf x 0.0479) / (0.025)................ (23.0 KN/m^3)

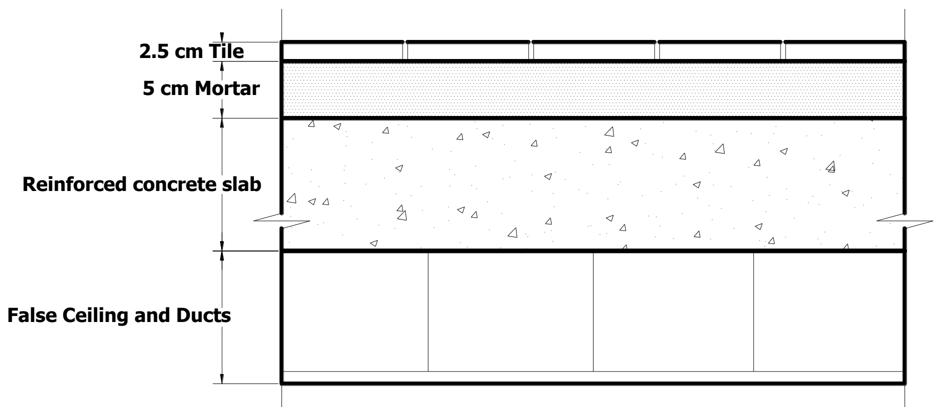
•Water Proof..(0.26 KN/m^2)

•False ceiling & Ducts..............................(0.15+0.19=0.34 KN/m²)



Slab Section For Roof

W_{DL}= (0.07 * 24) + (0.26) + (0.15 * 24) + (0.34) = 5.88 **KN/m²**



Slab Section For Floors

W_{DL}= (0.025*23) + (0.05*20.4) + (0.15 * 24) + 0.34 = **5.535 KN/m²**

$W_{partition}$ = (89.9*5.823)/ (150.22) =**3.48 KN/m²**

Live Load from Nilson 15th Edition

For floor → 100 pfs = 100 * 0.0479 = **4.79 kN/m²**

For roof→ 20 pfs = 20 * 0.0479 = **0.958 kN/m²**

TABLE 1.1
Minimum uniformly distributed live loads in pounds per square foot (psf)

Occupancy or Use	Live Load, psf
Apartments (see Residential)	
Access floor systems	
Office use	50
Computer use	100
Armories and drill rooms[a]	150
Assembly areas and theaters	
Fixed seats (fastened to floor)[a]	60
Lobbies[a]	100
Movable seats[a]	100
Platforms (assembly)[a]	100
Stage floors[a]	150
Balconies and decks[b]	
Catwalks for maintenance access	40
Corridors	
First floor	100
Other floors, same as occupancy served except as indicated	
Dances halls	100
Gymnasiums[a]	100
Reviewing stands, grandstands, and bleachers[a,f]	100
Stadiums and arenas with fixed seats (fastened to floor)[a,f]	60
Residential	
One- and two-family dwellings	
Uninhabitable attics without storage[g]	10
Uninhabitable attics with storage[h]	20
Habitable attics and sleeping areas	30
All other areas except stairs and balconies	40
All other residential occupancies	
Hotels and multifamily houses	
Private rooms and corridors serving them	40
Public rooms and corridors serving them	100
Reviewing stands, grandstands, and bleachers[c]	100
Roofs	
Ordinary flat, pitched, and curved roofs[i]	20
Roofs used for roof gardens	100
Roofs used for assembly purposes	
Roofs used for other occupancies[j]	
Awnings and canopies	
Fabric construction supported by a lightweight rigid skeleton structure	5
Hospitals	
Operating rooms, laboratories	60
Patient rooms	40
Corridors above first floor	80
Hotels (see Residential)	
Libraries	
Reading rooms	60
Stack rooms[a,e]	150
Corridors above first floor	80
Manufacturing	
Light[a]	125
Heavy[a]	250
Office buildings	
File and computer rooms shall be designed for heavier loads based on anticipated occupancy	
Lobbies and first floor corridors	100
Offices	50
All other construction	20
Schools	
Classrooms	40
Corridors above first floor	80
First floor corridors	100
Sidewalks, vehicular driveways, and yards, subject to trucking[a,k]	250
Stairs and exit-ways	100
One- and two-family residences only	40
Storage areas above ceilings	20
Storage warehouses (shall be designed for heavier loads if required for anticipated storage)	
Light[a]	125
Heavy[a]	250
Stores	
Retail	
First floor	100
Upper floors	73
Wholesale, all floors[a]	125
Walkways and elevated platforms (other than exit-ways)	60
Yards and terraces, pedestrians	100

Table (3-3)

Chapter 4

Design reinforcements concrete member

Defining symbol:

Ab: Area of a reinf. bar - mm^2,	**D:** Diameter of a reinforcement bar - m
Asmin: Minimum area of flexural reinf. - mm^2	**R:** Flexural resistance factor
ρ: Reinforcement ratio**,Mu**: Factored load moment - kn.m	**Ø:** Strength reduction factor
b: Cross section width - mm	**d:** Effective depth of beam cross section from the top of the beam to the center of reinforcement layer - mm
fc': Compressive strength of concrete- Mpa	**fy:** Yield strength of steel bars - Mpa
ϵc: Ultimate strain in concrete which is equal to 0.003 according to ACI Code	**ϵt :** Steel strain
As: Reinforcement area - mm^2	**S:** Spacing between adjacent bars mm
n: Number of bars in a single layer	**t:** Thickness of the section - mm
Es=200000 MPa	**P:** Axial load – kn
	e : Eccentricities – mm

Design of slab reinforcement

For all slabs Fy =420Mpa, f’c = 21Mpa, dx=124mm, dy =112mm

Design for one meter b=1000mm, thickness of the slab t=150mm

ϵt=0.003, Es=200000Mpa

ϵy=fy/Es =420/200000=0.0021

β= 0.85 for f’c

As min = 0.0018 x b x t = 0.0018 x 1000x150 =270 mm2 /m

Using Ø12 bar Ab=ЛxD2 /4 = 3.14x122 /4=113mm2

Spacing = Ab/As=113/270=0.419m=419m **use S = 400mm**

S min>2t s>2x150 =300mm

As *min 2* for 300mm = 1000x113/300 =**376.7mm2 ---> control**

for story 1 and 2 -ve moment x- axis= 22.1 kn.m/m

$$R = \frac{Mu}{(0.9 * b * d^2)} = \frac{22.1}{0.9 * 1000 * 124^2} = 1.597$$

$$\rho = \frac{1}{m} * (1 - (1 - 2 * m * R)^{0.5})$$

$$= \frac{1}{23.53} * (1 - \left(1 - \frac{2 * 23.53 * 1.597}{420}\right)^{0.5} = 0.00399$$

$As = \rho bd = 0.00399 * 1000 * 124 = 494.72\ mm^2$/m

$494.72\ mm^2$/m >376.7mm2 use $494.72\ mm^2$/m

$$spacing = \frac{Ab}{As} = \frac{113}{494.72} = 0.228m \quad use\ S = 228mm$$

$$a = \frac{As * fy}{(0.85 * fc' * b)} = \frac{420 * 494.72}{0.85 * 21 * 1000} = 11.64mm$$

$$c = \frac{\alpha}{\beta} = \frac{11.64}{0.85} = 13.69 \text{ mm}$$

$$\in t = \frac{\in cu(d - c)}{c} = \left(0.003 * \frac{(124 - 13.69)}{13.69}\right) = 0.0241$$

$\in$t>$\in$y+0.003 tension control --> **0.0241>0.0051 therefore okay**

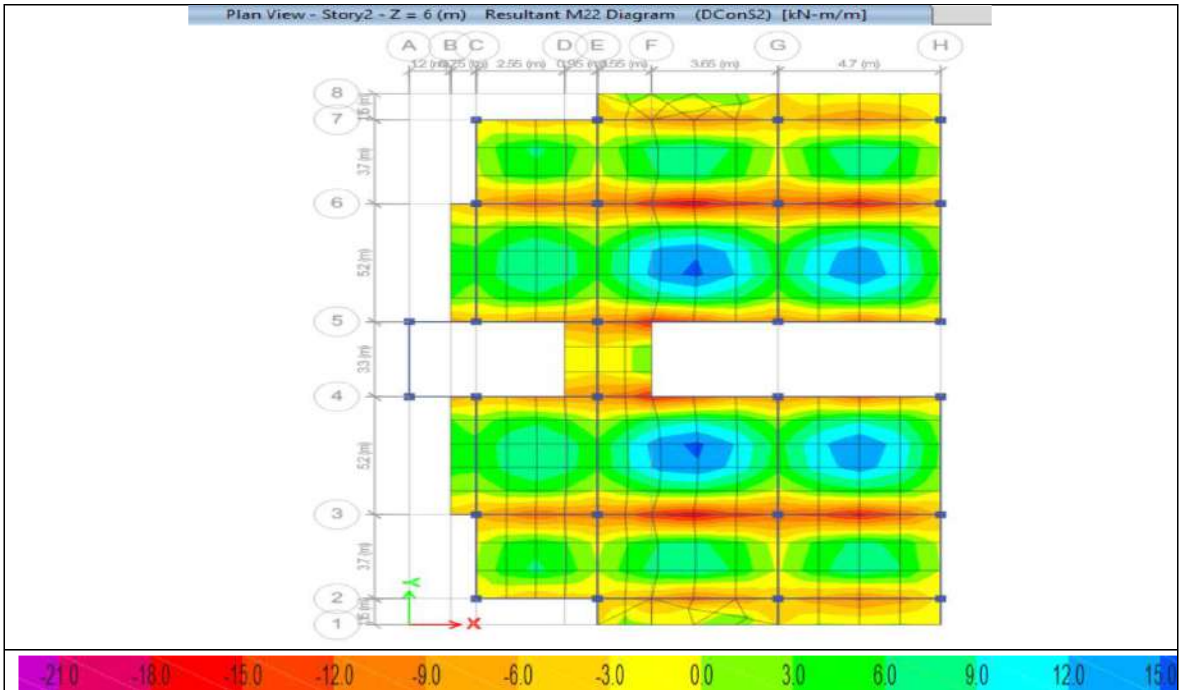


Figure (4-a), Positive and negative X -direction moment of Story 1&

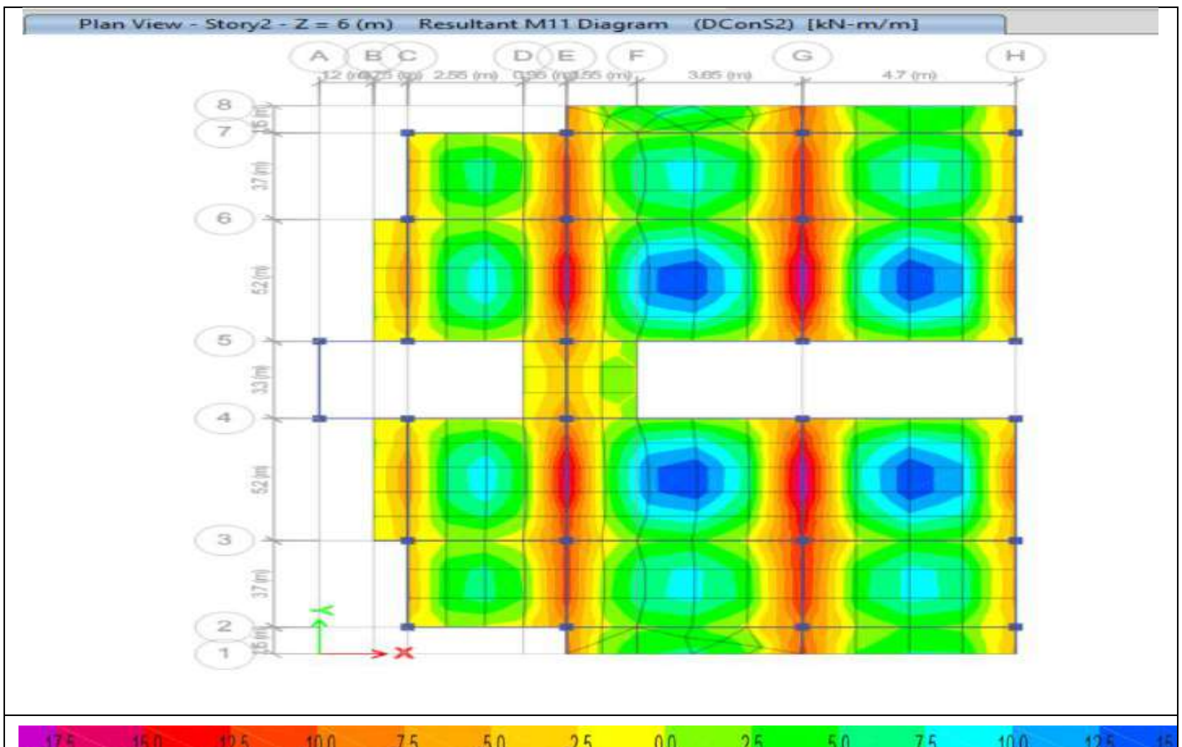


Figure (4 –b) Positive and negative Y, direction moment of Story 1&2

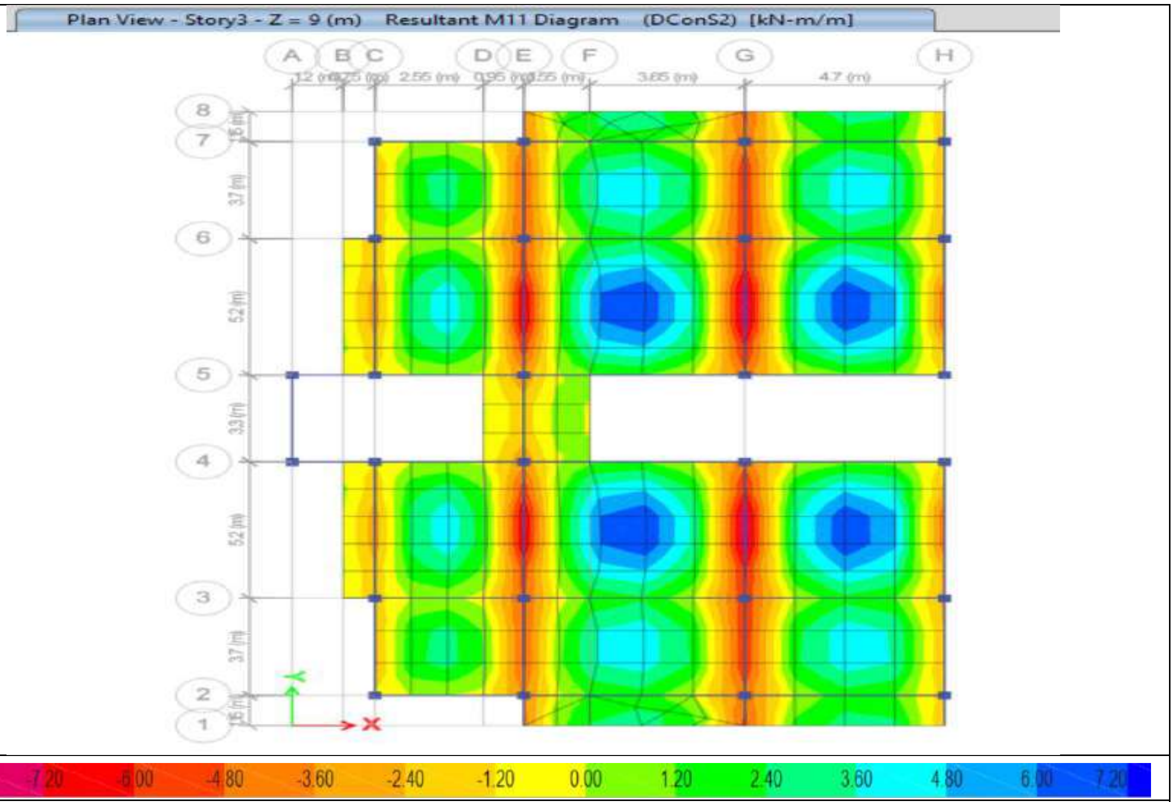


Figure (4-c) Positive and negative y, direction moment of story

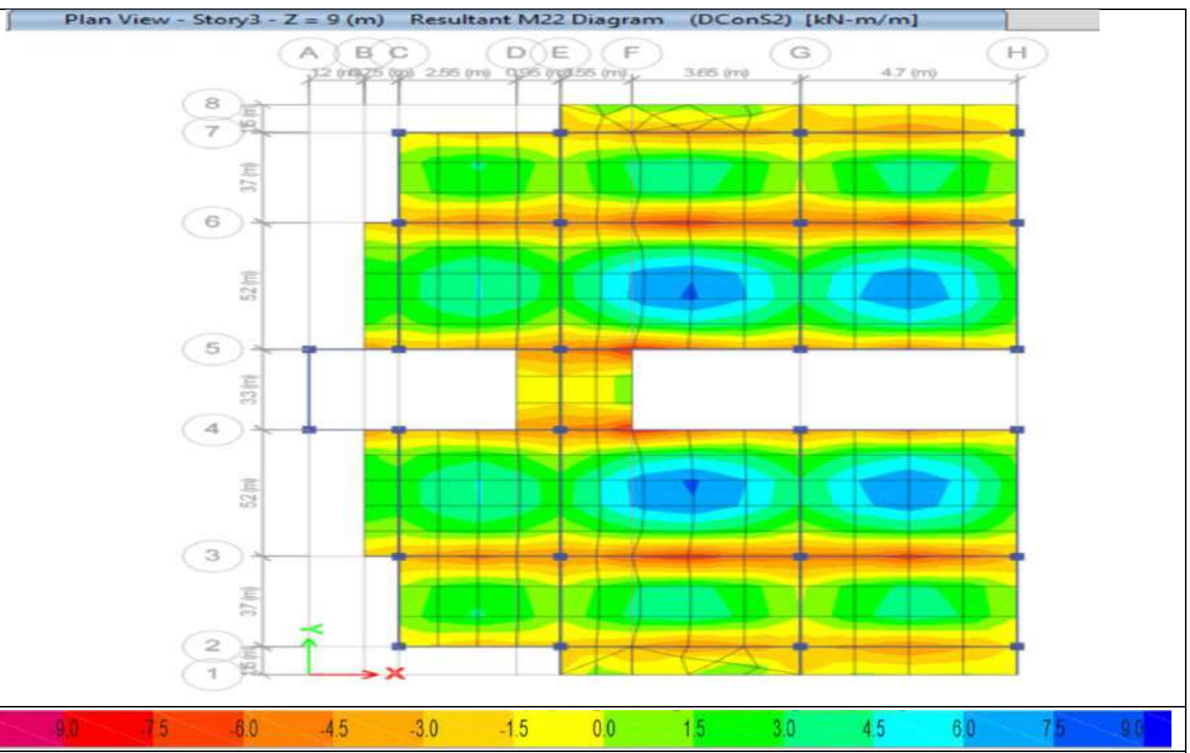


Figure (4-d) Positive and negative X, direction moment of Story

STORY	DIRICTION	Mu (Kn-m/m)	m	R (Mpa)	ρ	As mm2/m (calculated)
1&2	About X-axis	-22.1	23.53	1.6	0.003990	494.72
		15.9	23.53	1.15	0.002830	350.90
3	About X-axis	-11.66	23.53	0.84	0.002056	254.93
		7.76	23.53	0.56	0.001357	168.24
1&2	About Y-axis	-19.88	23.53	1.76	0.004423	228.12
		14.4	23.53	1.28	0.003154	319.89
3	About Y-axis	-8.5	23.53	0.75	0.001832	550.69
		7	23.53	0.62	0.001503	671.34

STORY	DIRICTION	As mm2/m (calculated)	As mm2/m (minimum)	As mm2/m (req.)	Spacing (mm)
1&2	About X-axis	494.72	367.7	494.72	225.0000
		350.90	367.7	367.7	300.0000
3	About X-axis	254.93	367.7	367.7	300.0000
		168.24	367.7	367.7	300.0000
1&2	About Y-axis	228.12	367.7	367.70	300.0000
		319.89	367.7	367.70	300.0000
3	About Y-axis	550.69	367.7	550.69	200.0000
		671.34	367.7	671.34	150.0000

STORY	DIRICTION	As mm2/m (req.)	Spacing (mm)	a (mm)	c (mm)	Єt	TENSION CONTROL
1&2	About X-axis	494.72	225	11.640	13.69	0.0242	O.K.
		367.7	300	8.652	10.18	0.0335	O.K.
3	About X-axis	367.7	300	8.652	10.18	0.0335	O.K.
		367.7	300	8.652	10.18	0.0335	O.K.
1&2	About Y-axis	367.7	300	8.652	10.18	0.0300	O.K.
		367.7	300	8.652	10.18	0.0300	O.K.
3	About Y-axis AXIS	550.69	200	12.957	15.24	0.0190	O.K.
		671.34	150	15.796	18.58	0.0151	O.K.

Table (4-a)

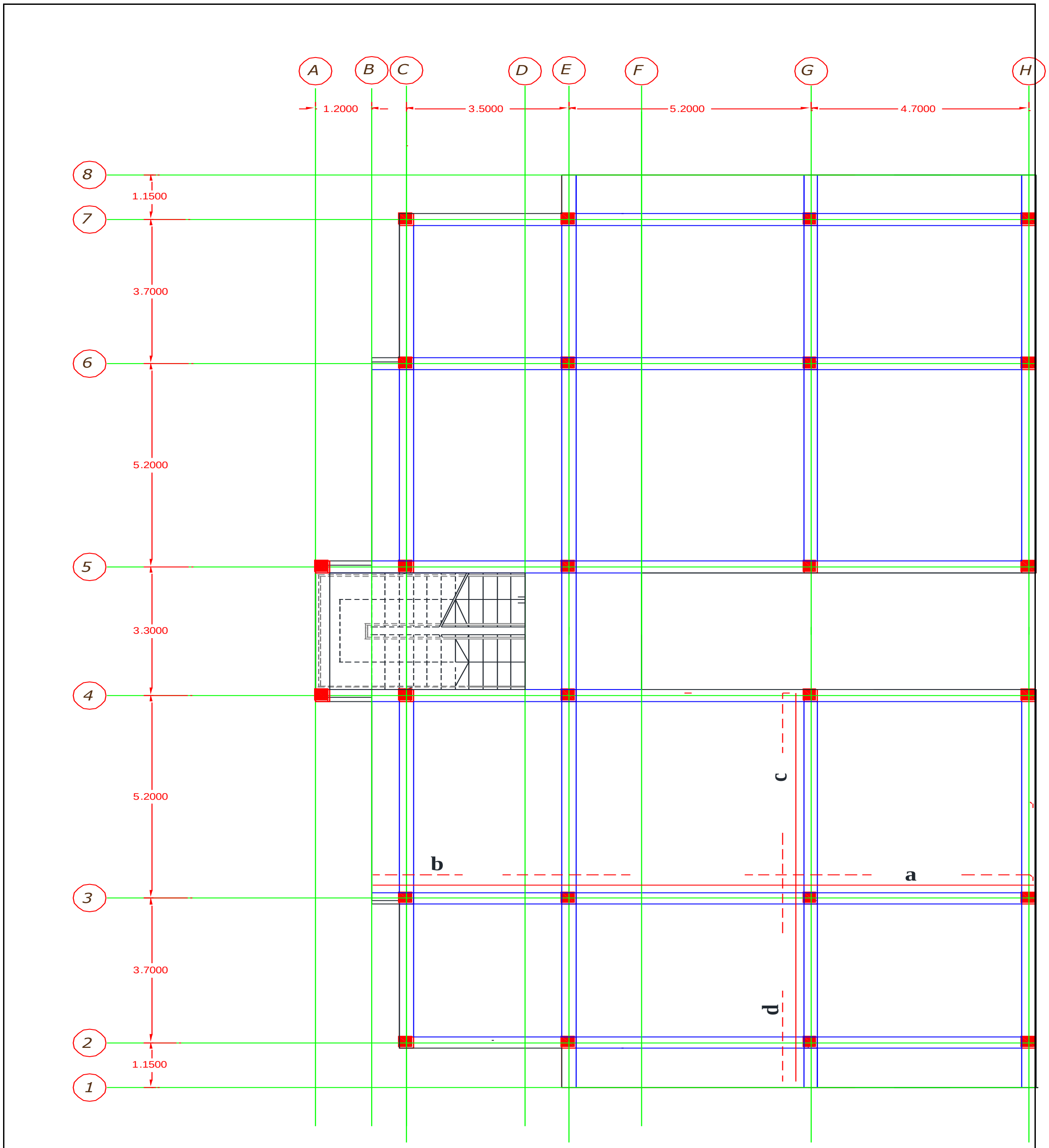


Figure (4- e) 1st And 2nd floor steel reinforcement

A: ϕ 12 @ 300 mm continuous

B: ϕ 12 @ 225 mm Cut bar

C: ϕ 12 @ 300 mm continuous

D: ϕ 12 @ 300 mm cut bar

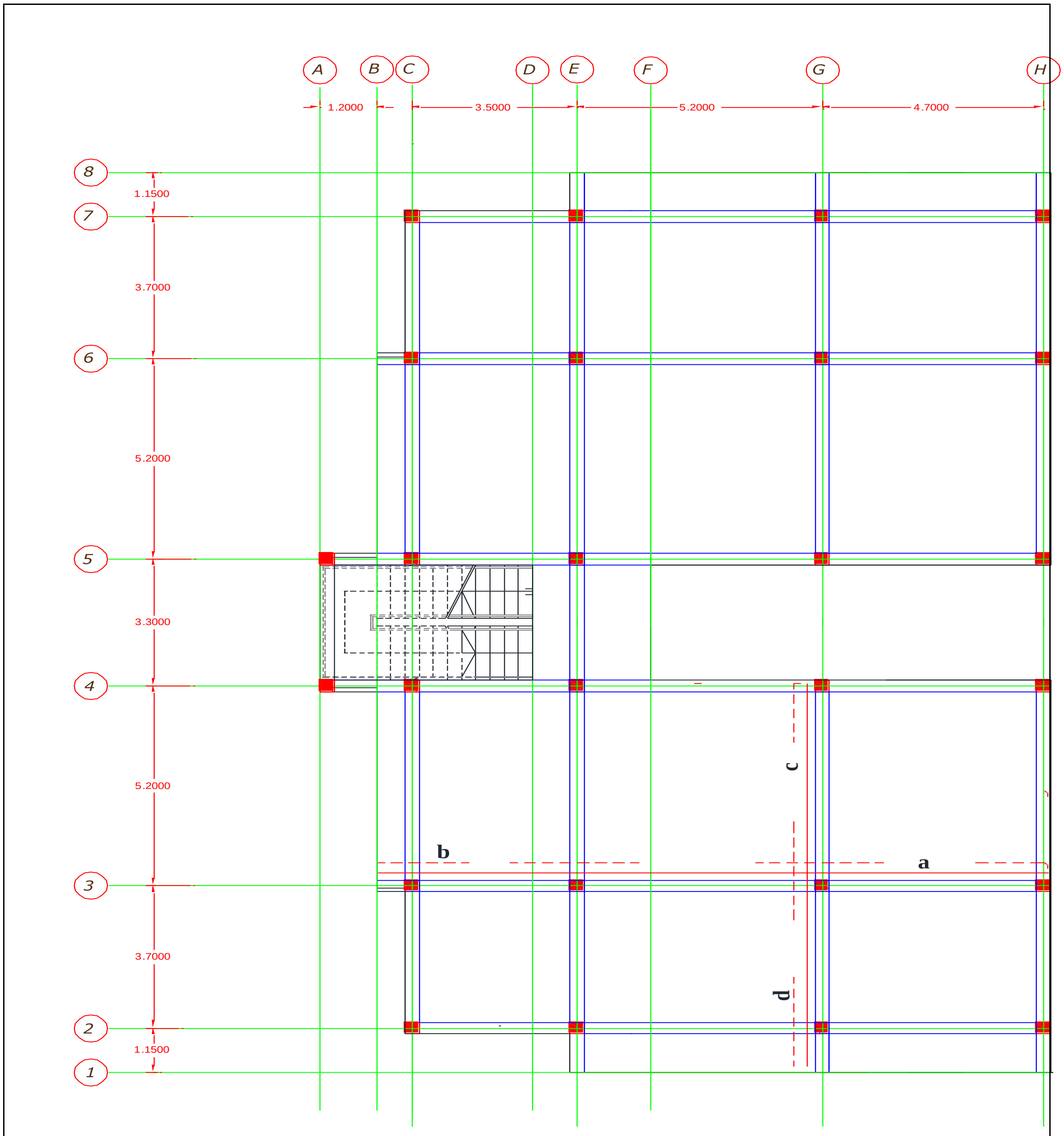


Figure (4-f) 3rd floor steel reinforcement

A: ф 12 @ 300 mm continuous

B: ф 12 @ 300mm Cut bar

C: ф 12 @ 150 mm continuous

D: ф 12 @ 200 mm cut bar

Design of beam reinforcement

For all beam   Fy=420 Mpa, Fc'=21 Mpa, d=492mm

B top interior=1100mm, B top exterior =700mm, b bottom =300mm

ϵt=0.003, Es=200000Mpa ϵy=fy/Es =420/200000=0.0021

β= 0.85 for f'c <28Mpa

$$\rho\ min1 = \frac{\sqrt{fc'}}{4 * fy} = \frac{\sqrt{21}}{4 * 420} = \rho \min 2 = \frac{1.4}{fy} = \frac{1.4}{420} = \mathbf{0.0033} \quad \boldsymbol{control}$$

Using bar $\emptyset$ 16 $\quad \boldsymbol{Ab} = \frac{\boldsymbol{\pi * d^2}}{\mathbf{4}} = \frac{3.14*16^2}{4} = 201\ mm^2$

$$m = \frac{fy}{0.85fc'} = \frac{420}{0.85 * 21} = 23.53$$

For moment diagram

Design of beam G5-G6- ST -1- bottom bar for moment =119.75 kn.m/m

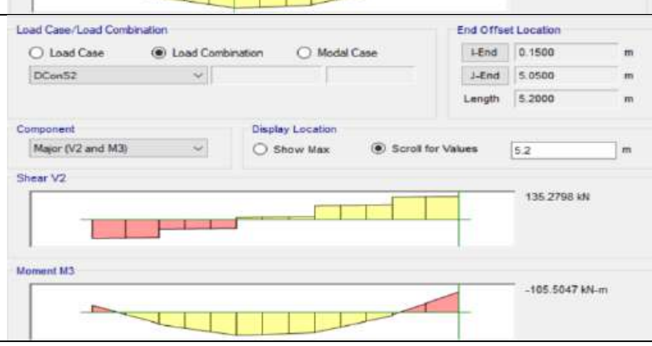


Fig (4-g) Shear and Moment diagram of beam (G5-G6- ST -1-)

$$R = \frac{mu}{0.9 * b * d^2} = \frac{119.75}{0.9 * 1100 * 492} = 0.499$$

$\rho = \left(\frac{1}{m}\right) * \left(1 - \left(1 - \frac{2*m*R}{fy}\right)^{0.5}\right) = \left(\frac{1}{23.53}\right) * \left(1 - \left(\frac{2*23.53*0.499}{420}\right)^{0.5}\right) =$ 0.00121

0.00121<0.0033 use $\rho = 0.0033$

$$As = \rho bd = 0.003 * 300 * 492 = 492\ mm^2$$

$$No.of\ bar = \frac{As}{Ab} = \frac{492}{201} = 2.45\ \boldsymbol{use\ 3\ bars}$$

$a = \frac{as*fy}{(0.85*fc'*b)} = \frac{420*492}{0.85*21*1100}$ =10.52 mm

$$C = \frac{\alpha}{\beta} = \frac{10.52}{0.85} = 12.38mm$$

$$\in t = \frac{\in cu * (d - c)}{c} = \frac{0.003 * (492 - 12.38)}{12.38} = 0.116$$

$\in t > \in y + 0.003\ tension\ control\ \ 0.116 > 0.0051\ tension\ control\ OK$

Design beam G5-G6 Story 1 top bar for moment =105.5 Kn.m/m

$$R = \frac{mu}{0.9 * b * d^2} = \frac{119.75}{0.9 * 300 * 492} = 1.61$$

$\rho = \left(\frac{1}{m}\right) * \left(1 - \left(1 - \frac{2*m*R}{fy}\right)^{0.5}\right) = \left(\frac{1}{23.53}\right) * \left(1 - \left(\frac{2*23.53*1.61}{420}\right)^{0.5}\right) = 0.00403$

0.00403>0.0033 use $\rho = 0.000.00403$

$$As = \rho bd = 0.00403 * 300 * 492 = 595.55\ mm^2$$

$$No.of\ bar = \frac{As}{Ab} = \frac{595.55}{201} = 2.96\ \boldsymbol{use\ 3\ bars}$$

$a = \frac{as*fy}{(0.85*fc'*b)} = \frac{420*595.55}{0.85*21*300}$ =46.7 mm

$$C=\frac{\alpha}{\beta}=\frac{46.7}{0.85}=54.95mm$$

$$\in t=\frac{\in cu*(d-c)}{c}=\frac{0.003*(492-54.95)}{54.95}=0.024386$$

$$\in t>\in y+0.003\ tension\ control\ \ 0.024386 > 0.0051\ tension\ control\ OK$$

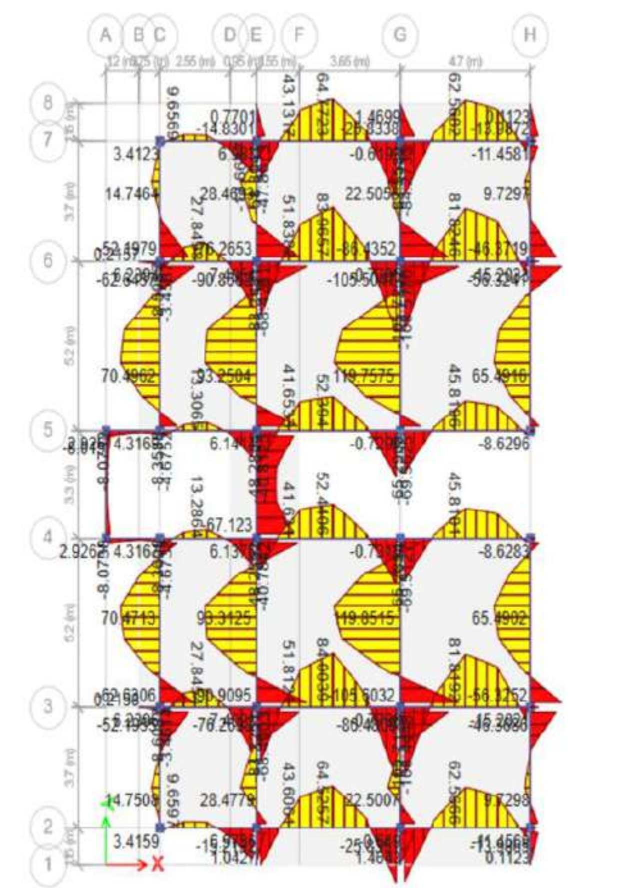
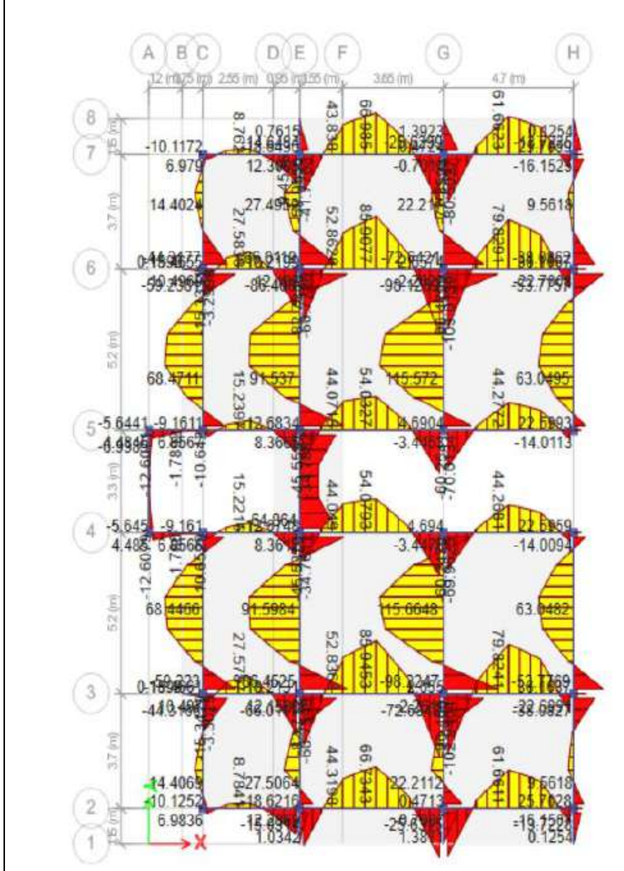
	

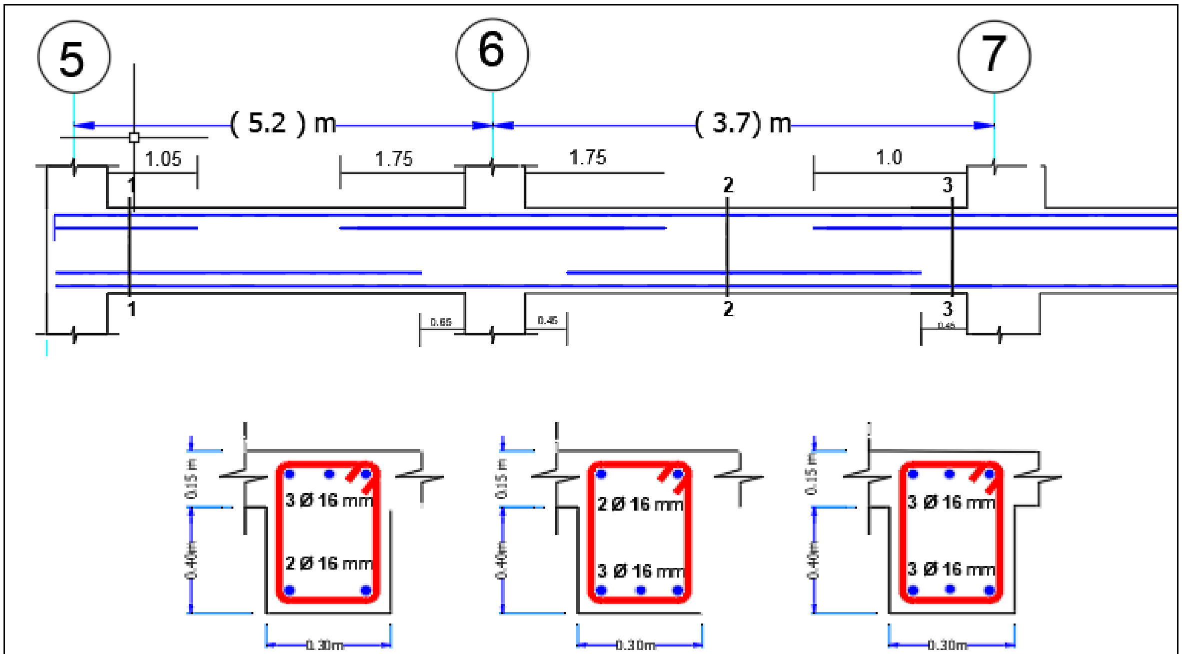
Figure (4-h) Moment of beam in story 1	Figure (4-i) Moment of beam in story 2

Beam	Story	Mu (Kn.m)	R (MPa)	ρ	As calculated (mm^2)	As min. (mm^2)	As used (mm^2)	No. bar
G5-G6	1	119.75	0.4997	0.0012069	178.14	492	492	3
C5-C6	1	-105.5	1.6142	0.0040349	595.55	492	595.55	3
G5-G6	1	70.49	0.2941	0.0007062	104.24	492	492	3
C5-C6	1	-62.65	0.9586	0.0023471	346.44	492	492	3
G5-G6	2	115.57	0.4823	0.0011642	171.83	492	492	3
C5-C6	2	-98.13	1.5014	0.0037394	551.93	492	551.93	3
G5-G6	2	68.47	0.2857	0.0006858	101.23	492	492	3
C5-C6	2	-59.23	0.9062	0.0022155	327.01	492	492	3
G5-G6	3	63.35	0.2644	0.0006341	93.60	492	492	3
C5-C6	3	-39.3	0.6013	0.0014567	215.00	492	492	3
G5-G6	3	37.69	0.1573	0.0003761	55.52	492	492	3
C5-C6	3	-25.65	0.3925	0.0009449	139.47	492	492	3

Table (4-b)

Beam	Story	As used (mm²)	No. bar	a (mm)	c (mm)	Єt	Tension
G5-G6	1	492	3	10.52	12.38	0.1162	O.K
C5-C6	1	595.55	3	46.71	54.95	0.0239	O.K
G5-G6	1	492	3	10.52	12.38	0.1162	O.K
C5-C6	1	492	3	38.59	45.40	0.0295	O.K
G5-G6	2	492	3	10.52	12.38	0.1162	O.K
C5-C6	2	551.93	3	43.29	50.93	0.0260	O.K
G5-G6	2	492	3	10.52	12.38	0.1162	O.K
C5-C6	2	492	3	38.59	45.40	0.0295	O.K
G5-G6	3	492	3	10.52	12.38	0.1162	O.K
C5-C6	3	492	3	38.59	45.40	0.0295	O.K
G5-G6	3	492	3	10.52	12.38	0.1162	O.K
C5-C6	3	492	3	38.59	45.40	0.0295	O.K

Table (4-c)



Section (3-3) Section (2-2) Section (1-1)

Figure (4-j) Steel reinforcement of Beam **(G5-G6**)

Design for column

Design for Column (H-4) story 2-3

Assume all column size is 300x300 mm

Assume ρ= 1.5% use bar diameter Ø16 Ab = 200,

dia stirrup =10 mm cover =40mm

Fy=420Mpa fc'=28 Mpa

Pu=69.25; My;25.58 Mx=21.36

Try (300*300) with 8 ϕ16 mm

$$d' = \frac{db}{2} + Dia\ stirrup + cover = \frac{18}{2} + 10 + 40 = 58mm$$

$$\rho = \frac{1600}{(300 * 300)} = 0.01778$$

$$\gamma = \frac{h - 2d'}{h} = \frac{300 - 2 * 58}{300} = 0.6$$

$$ey = \frac{my}{pu} = \frac{25.58}{69.25} = 0.369 = 369mm$$

$$\frac{e}{h} = \frac{369}{300} = 1.23 > 1 \ldots . not\ ok$$

Try (400*300) mm

Solve for Pny_o (Y-Y)

$$\gamma y = \frac{400 - 2 * 58}{400} = 0.7$$

$$\frac{As}{Ab} = \frac{1800}{200} = 9\ bars\ Use\ 10\ bars$$

$$Ast = 10 * 200 = 2000mm^2$$

$$\rho = \frac{2000}{400 * 300} = 0.017$$

$$\frac{ey}{h} = \frac{369}{400} = 0.923$$

From chart ($\boldsymbol{\gamma = 0.7}$; $\boldsymbol{\rho = 0.017, \frac{ey}{h} = 0.923}$)

Kn for finding $\mathrm{Pny}_{o=}$ 0.14 **(index A)**

$$kn = \frac{\mathrm{Pny}_0}{\mathrm{Fc}' * \mathrm{Ag}} => 0.14 = \frac{\mathrm{Pny}_0}{28 * (300 * 400)} = \mathrm{Pny}_0 -\!\!\rightarrow \mathrm{Pny}_0 = 470.4Kn$$

Kn for finding $p_{o=1.08}$

$$1.08 = \frac{p_o}{28 * (300 * 400)} => p_o = 3629Kn$$

Solve for .. $\boldsymbol{pnx_o}(\boldsymbol{moment\ about}\ \mathbf{0}.(\boldsymbol{X - X}))$

$$\gamma_x = \frac{300 - 2 * 58}{300} = 0.6$$

$$e_x = \frac{21.36}{69.25} = 308mm$$

$$\frac{ex}{h} = \frac{308}{300} = 1.02 \approx 1$$

$\boldsymbol{\rho = 0.017}$; $\boldsymbol{\gamma_x = 0.6}$; $\boldsymbol{\frac{e}{h} = 1}$

Kn for finding pnx_o==0.11 **(index A)**

$$0.11 = \frac{pnx_o}{28 * (300 * 400)} ==> pnx_o = 370\ Kn$$

$$\frac{1}{Pn} = \frac{1}{pn_y} + \frac{1}{pn_x} - \frac{1}{p_o}$$

$$\frac{1}{Pn} = \frac{1}{470.4} + \frac{1}{370} - \frac{1}{3629} = Pn = 219.6\ Kn$$

$$\emptyset Pn = 0.65 * 219.6 = 142.7 > (Pn = 68) \ldots\ldots checks\ and\ OK$$

Column	Dimension (mm)	Direction	Pu (KN)	M (KN.m)	e/h	ρ	As (mm2)	ϒ	Kn (KN)	PN (KN)	Po (KN)	ØPN (KN)
H4; Story 2-3	400x300	X	69.25	21.36	1	0.017	2000	0.6	0.11	370	3629	142.7
		Y		25.58	0.92			0.7	0.14	470.4		
G6; Story 1-2	300x300	X	777.3	2.65	0.011	0.018	1600	0.6	1.04	2620.8	2746.8	1311.525
		Y		24.1	0.10				0.83	2091.6		
G5; Story 1-2	300x300	X	444.83	4.7	0.04	0.018	1600	0.6	1.01	2545.2	2746.8	590.1915
		Y		54.5	0.41				0.37	932.4		

Table (4-d)

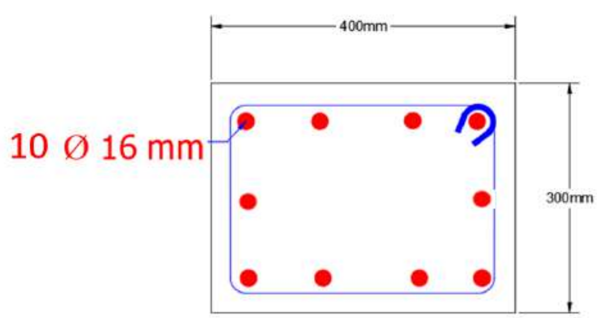


Figure (4-k) reinforcement detail of column

Foundation design

Design a square R.C footing using following data:

F'c=28MPa for both the column and footing

F'y=420MPa for the reinforcement bars

For footing G6; The column size is 30x30cm,

$P_{un\text{-}factored}$=674 KN

$P_{factored}$ = 1313 KN

Net allowable pressure=100 kPa

Finding base dimensions of footing using un-factored =

$$\boldsymbol{A = \frac{LL + DL}{net\ (qall)} = \frac{674}{100} = 6.74\ m^2}$$

$$\boldsymbol{B = (6.74)^{\frac{1}{2}} = 2.6\ m}$$

Calculating the footing thickness by considering shear at the critical section using factored load

$$\text{Applied factored stress} = \frac{1.6 * \text{DL} + 1.2\text{LL}}{\text{area}} = \frac{1313}{2.6 * 2.6} = 194.23 \text{ Kpa}$$

Applied shear force=1313 KN

Resisting shear force=shear resistance of concrete +soil reaction= (allowable shear strength of concrete x area of concrete) + (factored soil pressure x area of critical shear perimeter)

Check for two-way shear:

$$\boldsymbol{Vc} = 0.33\lambda\sqrt{\mathrm{fc}'} = 0.33 * 1 * \sqrt{28} = 1.746\ MPa$$

$$\emptyset Vc = 0.75 * 1.746 = 1.310\ Mpa$$

$1313 = (1310 * 4(0.3 + d) * d) + (194.23 * (0.3 + d)^2) =>$ **d=0.36m**

Check for one-way shear:

$$Vc = \left(\frac{1}{6}\right) * \sqrt{fc'}$$

$$\phi Vc = 0.75 * \left(\frac{1}{6}\right) * \sqrt{28} = 661\ KPa$$

The critical section is at a 0.36m distance from face of column

$$x = \frac{2.6}{2} - \frac{0.3}{2} - 0.36 = 0.79m$$

$$Vu = 2.60 * 0.79 * 194.23 = 398.95\ Kn$$

$$398.95 = 661 * d * 2.6$$

$$d = 0.23 < 0.36$$

$$use\ d = 0.36m$$

Determine the required steel area at the critical section for bending (at the face of column):

Mu $_{\text{applied}}$=The applied BM on 1m of the critic$al = \frac{qfactored * L'^2}{2} =$

$$L' = \frac{2.6 - 0.3}{2} = 1.15\ m$$

$$Mu = \frac{(194.23 * 1.15^2)}{2} = 128.43$$

$$\text{Mu} = 0.9 * \text{As} * 420\left(360 - \frac{420 * As}{1.7 * 28 * 1000}\right)$$

$$As = 966.69\ \frac{mm\text{^}2}{m}$$

Assume using bar size 16mm.

According to ACI 7.7.1 cover=75

$$t = 0.36 + 0.016 + 0.075 = 0.46\,m$$

$$Asmin = 0.0018 * b * t = 828\ \frac{mm^2}{m}$$

$$< 966.69\frac{mm^2}{m}\ \text{m obtained by analysis}$$

$$966.6\frac{mm^2}{m} * 2.6m = 2513.4\,mm\text{^}2$$

Assume using bar No. 16

As of one bar is 201mm2 Max. spacing 3d or 45cm

$$No. of\ bars = \frac{2513.4}{201} = 12.5 \approx 13\ bars$$

$$2.6 - 0.15 - 0.016 = 2.434m$$

$$spacing = \frac{2.434}{12spaces} = 0.203 \approx 0.2 = 20cm$$

Use 13 Ø16

Check column bearing on footing:

$A1 = 0.3 * 0.3 = 0.09\text{m}^2, A2 = 1.74^2 = 3.028m^2$

$$\text{L for A2} = 2 * 0.36 + 2 * 0.36 + 0.3 = 1.74 \text{ m}$$

$$The\ allowable\ bearing\ strength = \varphi(0.85 * fg' * A1) * \sqrt{(\frac{A2}{A1})}$$

$$\sqrt{(\frac{A1}{A2})} = \sqrt{\frac{3.028}{0.09}} = 5.8\ use\ 2$$

$\rightarrow = \mathbf{0.65(0.85 * 28000 * 0.09) * 2 = 2784.6}\boldsymbol{Kn} > \mathbf{194.23 * 6.76 = 1313}\boldsymbol{Kn} \rightarrow \boldsymbol{ok}$

footing	P unfactored KN	P factored	B (m)	d (m)	Thickness (m)	Mu (Kn.m/m)	As used (mm^2)	As total (mm^2)	No. of bar	spacing (mm)
G6 interior	674	1313	2.60	0.36	0.45	128.39	966.69	2509.67	13	200
H3 edge	314	581	1.77	0.2	0.29	50.12	683.57	1211.29	7	260
H5 corner	172	303	1.31	0.1	0.19	18.29	506.5	664.27	4	300

footing	AS total (mm2)	reinforcement	spacing (mm)	Check for column bearing
G6 interior	2509.67	13Ø16mm	200	O.K
H3 edge	1211.29	7Ø16mm	260	O.K
H5 corner	664.27	4Ø16mm	300	O.K

Design of some other footing shown in table (4-e)

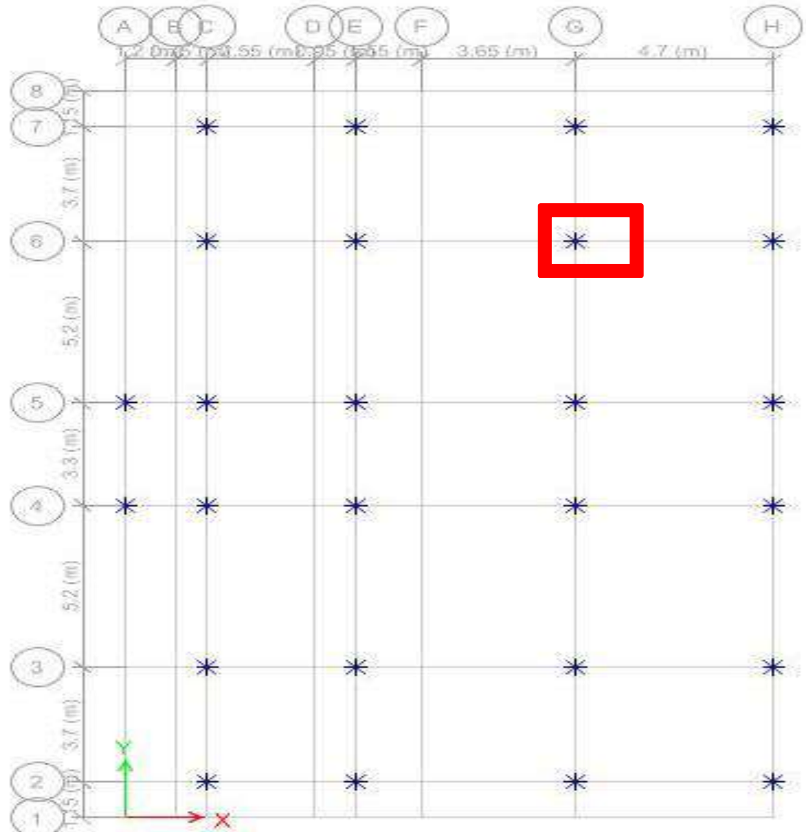


Figure (4-l) Location of interior single footing (G-6)

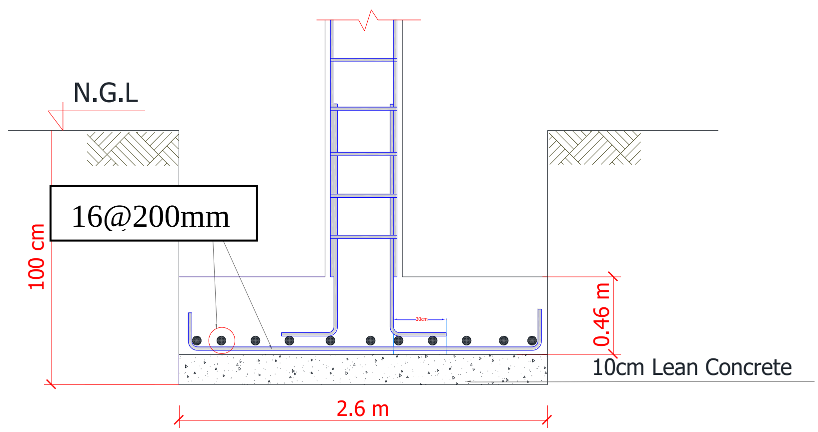


Figure (4-m) Steel reinforcement

Chapter Five

Discussion:

In today's world, multistory buildings have become popular across the globe, serving many purposes and fulfilling various needs. In our research, we specifically focus on one aspect, mainly the utilization of multistory buildings as residential houses.

In the construction of such buildings, the selection, quality, and quantity of materials plays a crucial role in calculation of strength and durability of the structure. Among the primary materials used, concrete, steel, and wood, each possesses distinct specifications and applications. Steel is the strongest material that is capable of handling both tension and compression forces. Wood, on the other hand, offers longevity and resilience against temperature, often lasting for hundreds of years. Concrete, being the most commonly used material, relies on a well-designed mixture to achieve required strength.

Apart from the materials, there are crucial components that play a vital role in ensuring the overall stability of the structure. While some of these components were previously mentioned, this research gives specific emphasis to essential elements including slabs, beams, columns, and foundations. Detailed analysis and design of these components were conducted using specific methodologies, which was explored with great detail in the previous sections.

During the design of a building, it’s important to carefully consider the loads it will experience. The major types of loads that should be taken into account are the dead load, live load, and wind load. These loads play an important role in the design process as they determine the structural integrity of the building and helps preventing potential issues in the future.

To fulfill our project requirements, we have been advised to utilize the ETABS program to analyze the multistory building. This recommendation is based on the program's wide design methodology, robust modeling capabilities, and its ability to handle an extensive range of load cases and intricate specifications directly within the software.

During the design phase, we used hand calculations to determine the critical components of the building these calculations were based on the data and results obtained from the ETABS program. While analyzing with ETABS, some values, such as component dimensions, were assumed based on field experience. However, to ensure accuracy, these assumptions were thoroughly checked during the design of each individual component using popular methods in civil engineering by hand calculations.

In the model, we initially considered a slab thickness of 150mm, after checking it, we found it met the required standards. As for the slab reinforcements, we determined that it is a two-way slab, checked out the minimum reinforcement for the 3rd story of our model, which included Ø12mm bars spaced at 300mm about X-axis. For the negative moment in the first and second stories, we found that Ø12mm bars spaced at 225mmabout X-axis.

As for the beam design, all the beams were 300mm x 550mm. The reinforcement for the beams, the required reinforcement for the beams was determined 3Ø16 bars at the top and 3Ø16 bars at the bottom. Although not all beams met the exact minimum reinforcement criteria, the number of bars specified was in close proximity to the minimum requirement. Therefore, to ensure adequate strength and durability, the provided number of bars for each beam remained the same as the minimum requirement.

In the column design process, we used ACI column strength interaction diagram. Based on the maximum load and moment values obtained from the ETABS program, we selected three columns in different positions: corner column, edge column, and interior column. The design of the edge and interior columns met the design requirements. However, the assumption made for the corner column did not pass the checking stage. So, we decided to increase the column section from 300x300mm to 400x300mm to ensure its adequacy. In the reinforcement all columns checked by 8Ø16mm except the corner columns which according to our calculation 10Ø16mm is adequate.

In the foundation design phase, we used square reinforced concrete (R.C) footings for the existing columns. The design process took into consideration the maximum factored and un-factored loads obtained from the ETABS program. The thicknesses of the footings were thoroughly checked to ensure they met the requirements for two-way shear (punching), and the columns bearing on footing.

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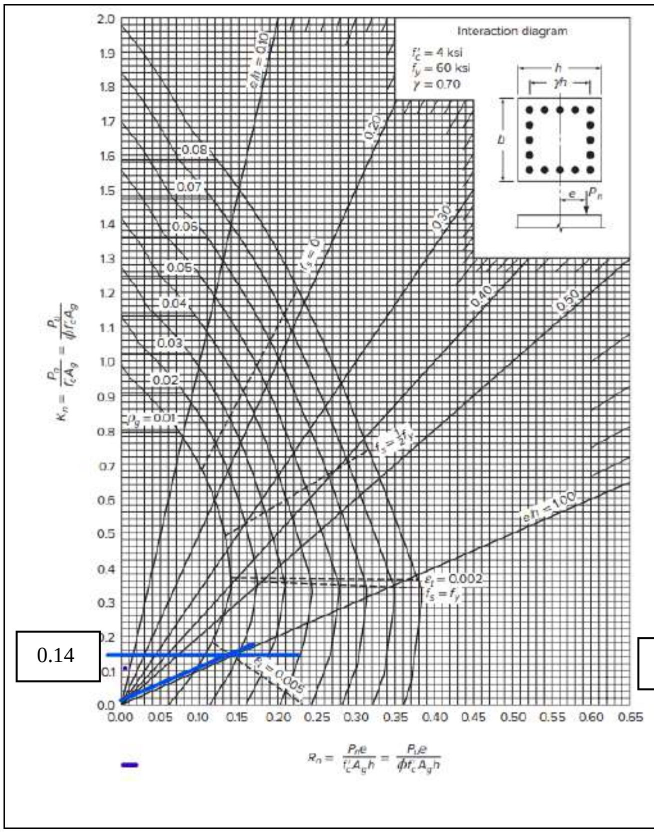
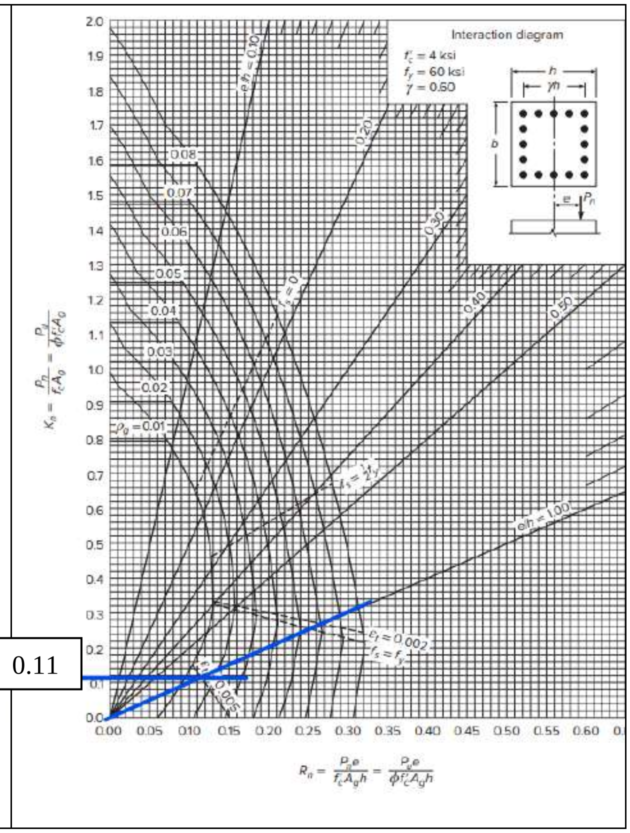
(Appendix A)


Interaction diagram
$f'_c = 4$ ksi
$f_y = 60$ ksi
$\gamma = 0.70$
0.14
$K_n = \frac{P_n}{f'_c A_g} = \frac{P_u}{\phi f'_c A_g}$
$R_n = \frac{P_n e}{f'_c A_g h} = \frac{P_u e}{\phi f'_c A_g h}$
e/h = 1.00
$\rho_g = 0.01$
$f_s = 0$
$\epsilon_t = 0.002$
$\epsilon_t = 0.005$


Interaction diagram
$f'_c = 4$ ksi
$f_y = 60$ ksi
$\gamma = 0.60$
0.11
$K_n = \frac{P_n}{f'_c A_g} = \frac{P_u}{\phi f'_c A_g}$
$R_n = \frac{P_n e}{f'_c A_g h} = \frac{P_u e}{\phi f'_c A_g h}$
e/h = 1.00
$\rho_g = 0.01$
$f_s = 0$
$\epsilon_t = 0.002$