Analyses and design of flat slab multistory building

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CHAPTER ONE: INTRODUCTION

١,١ Introduction

Since people begin to construct buildings, they utilize numerous conceivable approaches to plan and build high quality and flat slab building. Additionally, they found new basic arrangements and create new building materials in the field of structural engineering. These arrangements help us to save time, money and construction straightforwardness. Architects and structural engineers work as a team to find the best possible solution that will meet the owner's requirements and the fundamental requirements for the building respectively. A selection of the structural system is a part of this process. Structural system is expected to carry all loads acting on the building and transfer them effectively to the foundation.

Flat slab is generally constructed by reinforce concrete slab which supported by concrete column without using beam. Flat slab is characterized as one sided or two-sided support system with shear load of the slab being concentrated on the supporting columns and a square slab called 'drop panels.

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CHAPTER TWO: THE LITERATURE REVIEW

Literature Review

Previous Studies

Flat slab building has been a topic of exchange since numerous decades. A great deal of research work has occurred in this field tending to every single significant issue relating to the modeling, analysis and construction of flat slab structures. The most broadly utilized development material on earth is concrete. Solid foundation includes around 60% of the assembled condition in many created nations. Actually, concrete has shaped civilization from as far back as the old Egypt and the Roman Empires. Today it is essential in the advancement of foundation, industry and housing. Without concrete the manufactured condition environment would fail to accommodate our modern our modern and requesting way of life.

Expository strategy that can consider the stiffness degradation impacts in the section of slat slab upon the lateral drifts utilizing super component for the effective and exact investigation of level flat slab structure. The super components utilized for the effective analysis and the exactness and the effectiveness of the proposed technique were researched through the investigation of model structures. Structural analysis of the flat slab structure having unpredictable plan or slab with openings can be performed and stress circulation of floor slab can be effectively represented to the limited component technique if the stiffness degradation in the slab could be consider legitimately. The stiffness degradation in the flat slab system could be represented by the decreased modulus of elasticity of floor slab. The stress distribution in the slab could be represented approximately by the proposed method. **(Kim and Lee,** 2005**)**

The main role of floors is to help the connected floor loading and distribute the loading to the supporting walls and columns. Depending on the structural framing system adopted, floor structure may likewise add to the lateral load carrying system or in increasingly complex ways.

For certain strength frameworks, the floors may contribute straightforwardly furthermore; form the horizontal elements of moment-resisting stability frames. **(Carl Erik Broms** 1990)

Classification of slabs: In general slabs are classified as follows:

١. One-way slabs.
٢. Two-way slabs.
٣. Flat slabs.
٤. Flat plate slabs.
٥. Waffle slabs.

One-way slabs:

They are slabs which are supported on two opposite sides Slabs are considered as one-way slab when the ratio of length to width of two perpendicular sides of the slab exceed2.

Two-way slabs:

Slabs supported on four sides are considered as two-way slabs when the ratio of length to width of two perpendicular side of the slab equal or less than 2.

Flat Slab

Flat slab is a reinforced concrete slab supported by concrete columns without the utilization of beams. Flat slab is characterized as two way slabs being focused on the supporting columns and a square slab called 'drop panels.

Drop panels play a significant role here as they increase the general limit and toughness of the flooring system underneath the vertical loads accordingly boosting cost viability of the construction.

Flat plate slabs:

Flat plate slabs are those slabs which are constructed without drop panel with or without drop panel.

Waffle slabs

Those are slabs designed with two direction beams.

Methods for analysis of two-way slabs:

- Coefficient method.
- Direct design method.
- Yield line method.
- Equivalent frame method.

In this project direct design method is used for slab design.Which is well explained in the ACI code 2014.

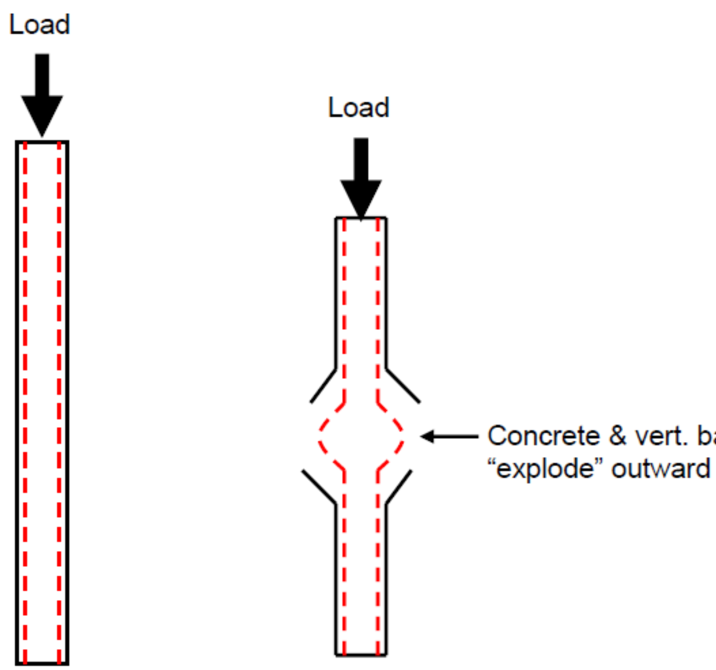
This method has limitations according to ACI-٣١٨ ٢٠١٤ which are:

- There must be three or more spans in each direction.
- Panels should be rectangular and the large span should not be more than twice of the short span.
- Successive span length center to center of supports in each direction shall not be differ by more than 1/3 of the larger span.
- Columns must be near the corners of each panel with an offset from the general column line that should not be more than 10 % of the span.
- Live load should not exceed 3 times the dead load.
- Minimum slab reinforcements based on ACI code 2014 Article 7-12-2-1:
  - 0.0018 b h for fy = 420 Mpa.
  - 0.002 b h for fy = 250, 350 Mpa.

All of the above limitations are satisfied. Chapter three: calculation for slab

Types of Concrete Columns:

There are two types of reinforced concrete columns – tied and spiral –And refer to the type of confining bars used to contain the interior core of Concrete. It has been shown that unconfined concrete core wills carry much less load than a confined core as shown below:



Unconfined core

A confined concrete core will carry substantially more load and will NOT explode outward like the unconfined concrete section will.

Additionally, the ACI dictates that there must be a minimum of 4 vertical bars having a minimum area of 1% of the column cross-sectional area and a maximum of 8% of the columncross-sectional area.

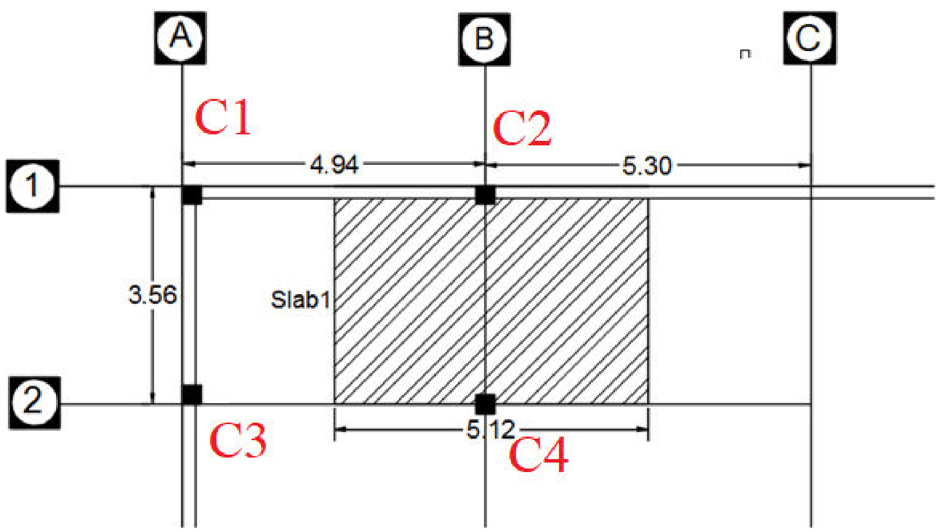
From constructability standpoint, 4% is the upper maximum that can be readily Achieved because of rebar congestion

Design of columns:

Columns are structural members with a ratio of height to least lateral dimension exceed 3 according to ACI code 2014, which carries compressive load.

The columns are 30X 30 cm, the interior columns were designed without moments since the spans are approximately equal, while the corner columns are designed with biaxial moment and the exterior columns are designed with not having axial moment. As well as the compressive loads comes from the slab, beam, and wall self-weight of the columns.

The interaction charts of (Design of concrete) by Nilsson, David were used.



Design of corner column C١ at roof:

check whether it is short or long column

- This building is braced
- for braced column k = 0.5
- Radius of gyration (r) = 0.3 ∗ h (Rectangular section) = 0.3 ∗ 300 = 90

$$(slenderness\ ratio\ )\frac{kl_u}{r} = \frac{0.5 * 3000}{90} = 16.6$$

- $\frac{kl_u}{r} \leq 34 - 12\frac{m1}{m}$ $16.6 \leq 34 - 12\frac{10.3}{16.26} = 26.3$

2

$\therefore$ *short column*

- Area supported by the column= $(\frac{4.94}{2} + 0.15)\ (\frac{3.14}{2} + 0.15) = 2.62 * 1.855 = 4.86\ m^2$
- (Roof) load supported by this column= wu $*$ area = 7 $*$ 4.86 = 34.0 kN
- Height of column = 3 m
- Density of concrete = 24 kN/m^3
- Self weight = $0.3 * 0.3 * 3 * 24 * 1.2 = 7.8\ kN$
- Column $p_u = 34.0 + 7.8 = 42\ kN$
- *moment according to ACI* 2014 *unbalanced on adjacent will cause unbalanced moment.*
- $w_d = 1.2 * 0.16 * 24 = 4.6$ KN/m^2
- $w_l = 1.6 * 1.50 = 2.4$ KN/m^2
- $0.5 w_l = 1.2\ kN/m^2$

$Assume\ \rho_{min} = 0.01bh = 0.01 * 300 * 300 = 900\ mm^2$

$\rightarrow use\ \emptyset 20mm\ : A_b = 314\ mm^2\ \rightarrow no. of\ bars = \frac{900}{314} = 2.80 \approx 3\ bars$

but we can not use odd bars number so, use $4\emptyset 20mm$

ρ= 4*314/300*300= 0.014

for y − direction

- $l_n = 4.94 - 0.3 = 4.64\ m$
- $l_2 = \frac{3.41}{2} + 0.15 = 1.855\ m$
- $m_{uy} = 0.07(4.6 + 1.2) * (4.64)^2 * 1.855 = 16.21\ kN.m$
- $e_x = \frac{m}{p} = \frac{16.21}{42.0} = 0.38\ mm$
- $\frac{e}{h} = \frac{0.38}{0.3} = 1.28$
- $k_n = 0.08 = \frac{p_{uy}}{0.65*28*300^2} \rightarrow p_{uy} = 201.6\ kN$

for x − direction

- $l_n = 3.41 - 0.3 = 3.11\ m$
- $l_2 = \frac{4.94}{2} + 0.15 = 2.62\ m$
- $m_{ux} = 0.07(4.6 + 1.2) * (4.6)^2 * 2.62 = 10.3$ kN.m
- $e_y = \frac{m_x}{p} = \frac{10.3}{42.0} = 0.245mm$
- $\frac{e}{h} = \frac{0.245}{0.3} = 0.8$
- $k_n = 0.16 = \frac{p_{ux}}{0.65*28*300^2} \rightarrow p_{ux} = 262\ kN$

Draw a horizontal line to read k_n from the chart column strength intersection diagram for rectangular section with bars of four faces and

Y =٠,٦٠

- p_0 =?
- $k_n = 1.04 = \frac{p_n}{0.65*28*300^2} = 1700K$

Use Bresler reciprocal equation:

$$\frac{1}{p_n} = \frac{1}{\emptyset p_{nxo}} + \frac{1}{\emptyset p_{nyo}} - \frac{1}{\emptyset p_0}$$

$$\frac{1}{p_n} = \frac{1}{201.6} + \frac{1}{262} - \frac{1}{1700}$$

$$\emptyset p_n = 122.1 > pu = 42\ kN$$

$$\therefore Safe$$

Design of exterior column C٢ at roof:

$$Area\ supported\ by\ the\ column = (\frac{5.3}{2} + \frac{4.94}{2}) * (\frac{3.42}{2} + 0.15) = 5.12 * 1.855 = 9.5\ m^2$$

$$load\ supported\ by\ this\ column = w_u * area = 7 * 9.5 = 66.5\ kN$$

- $hieght\ of\ column = 3\ m$
- $density\ of\ concrete = 24\ \frac{kN}{m^3}$
- $self\ weight = 0.3 * 0.3 * 3 * 24 * 1.2 = 7.8 \approx 8\ kN$
- $column\ load\ p_u = 66.5 + 8 = 74.5\ kN$

Column loading:

- $w_d = 1.2 * 0.16 * 24 = 4.6$ KN/m^2
- $w_l = 1.6 * 1.50 = 2.4$ KN/m^2
- $0.5w_l = 1.2\ KN/m^2$

Design of biaxial column:

1. $assume\ \rho : we\ use\ \emptyset 20\ mm$

   $clear\ cover\ d' = 40mm$

2. $find\ \gamma = \frac{h-2*d^F-2*d_{stirrup} - /2}{h} = \frac{300*2*40-2*10-20/2}{300} = 0.63 \approx 0.6$

3. $\rho = \frac{4*314}{300*300} = 0.014$

for x – direction

- $l_n = 3.41 - 0.3 = 3.11\ m$
- $l = \frac{5.3}{} + \frac{4.94}{} = 5.12\ m$

2 2 2

- $m_{ux} = 0.07\ [\ (4.6 + 1.2) * 3.11^2 * 5.12\ ]\ = 20\ kN.m$
- $e_y = \frac{}{p} = \frac{20}{74.5} = 0.27\ mm$
- $\frac{e}{h} = \frac{0.27}{0.3} = 0.9$
- $k_n = 0.54 = \frac{p_{ux}}{0.65*28*300^2} \rightarrow p_{ux} = 885\ kN$

for y − direction

- $l_n = 5\ m$
- $_2 = \frac{3.41}{2} = 1.705\ m$
- $m_{uy} = 0.07\ \{(\ 4.6 + 1.2\ ) * (\ 5\ )^2 * 1.705 - 4.6 * 4.64^2 * 1.705 = 5.68 \approx 5.7\ kN.m$
- $e_x = \frac{m_y}{p} = \frac{5.7}{74.5} = 0.07\ mm$
- $\frac{e}{h} = \frac{0.07}{0.3} = 0.25$
- $k_n = \frac{p_{uy}}{\emptyset * fc^F * A_g * h} = 0.58 = \frac{p_{uy}}{0.65*28*300^2} \rightarrow p_{uy} = 950.0\ kN$

- **Draw a horizontal line to read k_n from the chart column strength intersection diagram for rectangular section with bars of four faces and □=٠,٦٠:**

- $p_0 = ?$
- $k = 1.04 = \frac{p_n}{0.65*28*300^2} = 1700kN$

Use bresler reciprocal equation:

$$\frac{1}{p_n} = \frac{1}{\emptyset p_{nxo}} + \frac{1}{\emptyset p_{nyo}} - \frac{1}{\emptyset p_0}$$

$$\frac{1}{p_n} = \frac{1}{885} + \frac{1}{950} - \frac{1}{1700}$$

$$\emptyset p_n = 629 > 74.4$$

$$\therefore Safe$$

Design of exterior column C٣ at roof:

$$Area\ supported\ by\ the\ column = (\frac{3.41}{2} + \frac{3.11}{2})\ (\frac{4.94}{2} + 0.15) = 3.26 * 2.62 = 8.5m^2$$

- load supported by this column $= w_u *$ area $= 7 * 8.5 = 59.7$ kN
- $hieght\ of\ column = 3\ m$
- $density\ of\ concrete = 24$
- $self\ weight = 0.3 * 0.3 * 3 * 24 * 1.2 = 7.8\ kN \approx 8$
- $column\ p_u = 59.7 + 8 = 67.7 \approx 68\ kN$
- $moment\ according\ to\ ACI\ 2014\ unbalanced\ on\ adjacent\ panels$
- $will\ cause\ unbalanced\ moment.$

$$m_u = 0.07[(w_d + 0.5w_l)\ l_2^2 - w'\ l_2'(l_n')^2]$$

Column loading:

- $w_d = 1.2 * 0.16 * 24 = 4.6$ KN/m^2
- $w_l = 1.6 * 1.50 = 2.4\ KN/m^2$
- $0.5w_l = 1.2\ KN/m^2$

Design of biaxial column:

1. $assume\ \rho : we\ use\ \emptyset 20\ mm$

   $clear\ cover\ d' = 40\ mm$

2. $find\ \gamma = \frac{h-2*d^F-2*d_{stirrup} - /2}{h} = \frac{300*2*40-2*10- 20/2}{300} = 0.63 \approx\ 0.6$

3. $\rho = \frac{4*314}{300*300} = 0.014$

for x − direction

- $l_n = 3.11\ m$
- $l_2 = \frac{4.94}{2} = 2.74\ m$
- $m_{ux} = 0.07\ [(4.6 + 1.2) * 3.11^2 * \frac{4.94}{2} - 4.6 * 2.81^2 * \frac{4.94}{2}] = 3.41\ kN.m$
- $e_y = \frac{m_x}{p} = \frac{3.41}{68} = 0.05\ mm$
- $\frac{e}{h} = \frac{0.05}{0.3} = 0.16$
- $k_n = 0.74 = \frac{p_{ux}}{0.65*28*300^2} \rightarrow p_{ux} = 1212\ kN$

for y − direction

- $l_n = 4.0.7494 - 0.3 = 4.64\ m$
- $l_2 = \frac{3.41}{2} + \frac{3.11}{2} = 3.26\ m$
- $m_{uy} = 0.07\ [(\ 4.6 + 1.2\ ) * (\ 3.26\ )^2 * 4.64\ )\ ] = 20\ kN.m$
- $e_x = \frac{m_y}{p} = \frac{20}{68} = 0.29\ mm$
- $\frac{e}{h} = \frac{0.29}{0.3} = 0.98$
- $k_n = \frac{p_{uy}}{\emptyset*fc^F*A_g*h} = 0.12 = \frac{p_{uy}}{0.65*28*300^2} \rightarrow p_{uy} = 196.6\ kN$
- $Assume\ \rho_{min} = 0.01bh = 0.01 * 300 * 300 = 900\ mm^2$

$\rightarrow use\ \emptyset 20mm\ : A_b = 314mm^2\ \rightarrow no.of\ bars = \frac{900}{} = 2.80 \approx 3bars\ \rightarrow$

3 $\overline{14}$

because we can not use odd bars nomber

$$so, use\ 4\emptyset 20mm$$

Draw a horizontal line to read $k_n$from the chart column strength intersection diagram for rectangular section with bars of four faces and □=٠,٦٠:

- $p_0 = ?$
- $k = 1.04 = \frac{p_n}{0.65*28*300^2} = 1700kN$

Use Bresler reciprocal equation:

$$\frac{1}{p_n} = \frac{1}{\emptyset p_{nxo}} + \frac{1}{\emptyset p_{nyo}} - \frac{1}{\emptyset p_0}$$

$$\frac{1}{p_n} = \frac{1}{1212} + \frac{1}{196.6} - \frac{1}{1700}$$

$$\emptyset p_n = 188\ kN > P_u = 68\ kN$$

$$\therefore Safe$$

Design of exterior column C٤ at roof:

Area supported by the column $= (\frac{3.42}{2} + \frac{3.11}{2}) * (5.12) = 3.26 * 5.12 = 16.7\ m^2$

load supported by this column $= w_u * area = 7 * 16.7 = 116.8$ kN

- hieght of column = 3 m
- density of concrete = 24 KN/m^2
- self weight $= 0.3 * 0.3 * 3 * 24 * 1.2 = 7.8$ kN ≈ 8 kN
- column load $p_u = 116.8 + 8 = 125$ kN

Column loading:

- $w = 1.2 * 0.16 * 24 = 4.6 \frac{kN}{m^2}$
- $w = 1.6 * 1.50 = 2.4 \frac{kN}{m^2}$
- $0.5w_l = 1.2\ kN/m^2$

Design of biaxial column:

$Assume\ \rho : we\ use\ \emptyset 20\ mm$

$clear\ cover\ d' = 40mm$

1. $find\ \gamma = \frac{h-2*d^F-2*d_{stirrup} - /2}{h} = \frac{300*2*40-2*10-20/2}{300} = 0.63 \approx 0.6$

2. $\rho = \frac{4*314}{300*300} = 0.014$

for x – direction

- $l_n = 3.41 - 0.3 = 3.11\ m$
- $l'_n = 3.11 - 0.3 = 2.81\ m$
- $l_2 = \frac{5.3}{2} + \frac{4.94}{2} = 5.12\ m$
- $m_{ux} = 0.07[\ (4.6 + 1.2) * 3.11^2 * 5.12 - 4.6 * 2.81^2 * 5.12\ ] = 7.0\ KN.m$
- $e_y = \frac{m_x}{p} = \frac{7.0}{125} = 0.056\ mm$
- $\frac{e}{h} = \frac{0.056}{0.3} = 0.18$
- $k_n = 0.64 = \frac{p_{ux}}{0.65*28*300^2} \rightarrow p_{ux} = 1048\ kN$

for y – direction

- $l_n = 5.3 - 0.3 = 5.0\ m$
- $l'_n = 4.94 - 0.3 = 4.64$
- $l_2 = \frac{3.41}{2} + \frac{3.11}{2} = 3.26\ m$
- $m_{uy} = 0.07\ \{\ (4.6 + 1.2) * (\ 5\ )^2 * 3.26 - 4.6 * 4.64^2 * 3.26\ \} = 10.4\ kN.m$
- $e_x = \frac{m_y}{p} = \frac{10.4}{125} = 0.08\ mm$
- $\frac{e}{h} = \frac{0.08}{0.3} = 0.28$

- $k_n = \frac{p_{uy}}{\emptyset * fc^F * A_g * h} = 0.48 = \frac{p_{uy}}{0.65 * 28 * 300^2} \rightarrow p_{uy} = 786\ kN$

- **Draw a horizontal line to read k_n from the chart column strength intersection diagram for rectangular section with bars of four faces and □=٠,٦٠:**

- $k = 1.04 = \frac{p_n}{0.65 * 28 * 300^2} = 1700\ kN$

Use Bresler reciprocal equation:

$$\frac{1}{p_n} = \frac{1}{\emptyset p_{nxo}} + \frac{1}{\emptyset p_{nyo}} - \frac{1}{\emptyset p_0}$$

$$\frac{1}{p_n} = \frac{1}{1048} + \frac{1}{786} - \frac{1}{1700}$$

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$$\emptyset p_n = 613\ kN > 125\ kN$$

$$\therefore Safe$$

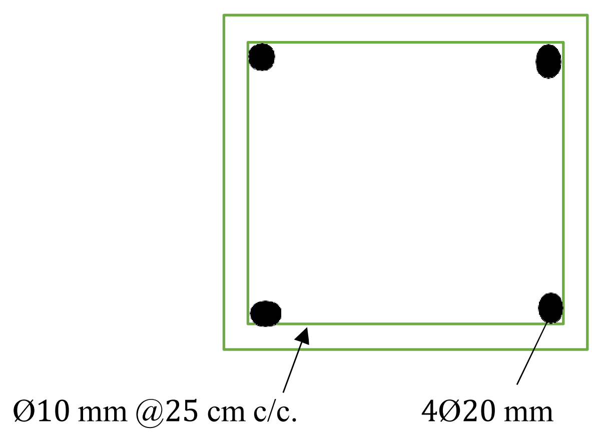
Stirrups: use lesser of:

48 tie dia. = 48 x 10 = 48 cm

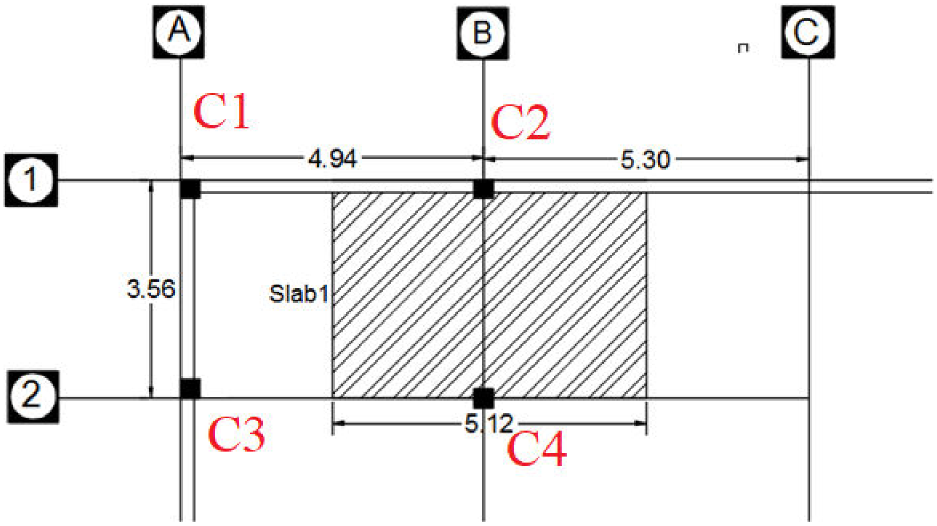
16 dia. Of main bar = 16 x 16 = 25.6

cmLeast dia. Of column = 30 cm

Use Ø10 mm @25 cm c/c.



Design of first floor columns:



Design of Corner column C١ at first floor

$$Area\ supported\ by\ the\ column = \left(\frac{4.94}{2} + 0.15\right)\left(\frac{3.14}{2} + 0.15\right) = 2.62 * 1.855 = 4.86 m^2$$

- (roof) load from upper floor = 42 kN
- (first $floor$) load supported by this column = w_u * area = 10.41 * 4.86 = 50.6 kN
- $hieght\ of\ column = 3\ m$
- $density\ of\ concrete = 24\ KN/m^2$
- $self\ weight = 0.3 * 0.3 * 3 * 24 * 1.2 = 7.8\ kN \approx 8.0\ kN$
- $Wall\ load = 14.4 * \left(\frac{4.94}{2} + \frac{3.14}{2}\right) = 58\ kN$
- $column\ p_u = 42.0 + 50.6 + 8 + 58 = 158.6\ kN$
- $moment\ according\ to\ ACI\ 2014\ unbalanced\ on\ adjacent\ panels$
- $will\ cause\ unbalanced\ moment.$

$$m_u = 0.07\ [(w_d + 0.5 w_l)\ l_2^2 - w'\ l'_2 (l'_n)^2]$$

Column loading:

- $w_d = 1.2 * 0.16 * 24 = 4.6\ KN/m^2$
- $w_l = 1.6 * 2.50 = 4\ KN/m^2$
- $0.5w_l = 2\ kN/m^2$

Design of biaxial column:

1. $assume\ \rho : we\ use\ \emptyset 20\ mm$

   $clear\ cover\ d' = 40mm$

2. $find\ \gamma = \frac{h-2*d^F-2*d_{stirrup}-\ /2}{h} = \frac{300*2*40-2*10-20/2}{300} = 0.63 \approx\ 0.6$

3. $\rho = \frac{4*314}{300*300} = 0.014$

for y − direction

- $l_n = 4.94 - 0.3 = 4.64\ m$
- $_2 = \frac{3.41}{2} + 0.15 = 1.855\ m$
- $m_u = 0.07[(w_d + 0.5w_l)\ l_2^2 - w'\ l'_2(l'_n)^2]$

- $m_{uy} = 0.07 \{ (4.6 + 2) * (4.64)^2 * 1.855 \} = 18.45\ kN.m$

  $m_{uy} = 18.45\ kN.m / 2 = 9.22\ kN.m$

- $e_x = \frac{m_y}{p} = \frac{9.22}{76} = 0.12\ mm$
- $\frac{}{h} = \frac{0.12}{0.3} = 0.4$
- $k_n = \frac{p_{uy}}{0.65*28*300^2} = 0.36 \rightarrow p_{uy} = 589.7\ kN$

for x − direction

- $l_n = 3.41 - 0.3 = 3.11\ m$
- $_2 = \frac{4.94}{2} + 0.15 = 2.62\ m$

$$m_u = 0.07[(w_d + 0.5w_l)\ l_2^2 - w'\ l'_2(l'_n)^2]$$

- $m_{ux} = 0.07\{(4.6 + 2) * (3.11)^2 * 2.62\} = 11.7\ kN.m$

$m_{ux} = 11.7\ kN.m\ /\ 2 = 5.85\ \ kN.m$

- $e_y = \frac{m_x}{p} = \frac{5.85}{76} = 0.077\ mm$
- $\frac{e}{h} = \frac{0.077}{0.3} = 0.26$
- $k_n = \frac{p_{ux}}{0.65*28*300^2} = 0.5 \rightarrow p_{ux} = 819\ kN$

Draw a horizontal line to read k_n from the chart column strength intersection diagram for rectangular section with bars of four faces and □=٠,٦٠:

- $k_n = 1.04 = \frac{p_n}{0.65 * 28 * 300^2} = 1700\ kN$

Use Bresler reciprocal equation:

$$\frac{1}{p_n} = \frac{1}{\emptyset p_{nxo}} + \frac{1}{\emptyset p_{nyo}} - \frac{1}{\emptyset p_0}$$

$$\frac{1}{p_n} = \frac{1}{589.7} + \frac{1}{819} - \frac{1}{1700}$$

$$\emptyset p_n = \quad 429\ kN > pu = 158.6\ kN$$

$$\therefore Safe$$

Design of exterior column C٢ at first floor:

$$Area\ supported\ by\ the\ column = (\frac{5.3}{2} + \frac{4.94}{2}) * (\frac{3.42}{2} + 0.15) = 5.12 * 1.855 = 9.5m^2$$

- $load\ from\ upper\ floor = 74.5\ kN$
- $(first\ floor)\ supported\ by\ this\ column = w_u * area = 10.41 * 9.5 = 99\ kN$
- $hieght\ of\ column = 3\ m$
- $density\ of\ concrete = 24\ kN/m^3$
- $self\ weight = 0.3 * 0.3 * 3 * 24 * 1.2 = 7.8 \approx 8\ kN$
- $Wall\ load = 14.4 * (\frac{4.94}{2} + \frac{5.3}{2}) = 73.7\ kN$
- $column\ load\ p_u = 74.5 + 99 + 8 + 73.7 = 255.2\ kN$

Column loading:

- $w_d = 1.2 * 0.16 * 24 = 4.6\ KN/m^2$
- $w_l = 1.6 * 2.5 = 4\ KN/m^2$
- $0.5w_l = 2\ kN/m^2$

Design of biaxial column:

1. $assume\ \rho : we\ use\ \emptyset 20\ mm$

   $clear\ cover\ d' = 40\ mm$

2. $find\ \gamma = \frac{h-2*d^F-2*d_{stirrup} - \ /2}{h} = \frac{300*2*40-2*10-20/2}{300} = 0.63 \approx\ 0.6$

3. $\rho = \frac{4*314}{300*300} = 0.014$

for x − direction

- $l_n = 3.41 - 0.3 = 3.11\ m$
- $l_2 = \frac{5.3}{2} + \frac{4.94}{2} = 5.12\ m$
- $m_u = 0.07[(w_d + 0.5w_l)\ l_2^2 - w'\ l'_2 (l'_n)^2]$

- $m_{ux} = 0.07[(4.6 + 2) * 3.11^2 * 5.12] = 22.87\ KN.m$

  $m_{ux} = 22.87\ kN.m / 2 = 11.4\ kN.m$

- $e_y = \frac{m_x}{p} = \frac{11.4}{141} = 0.08$
- $\frac{e}{h} = \frac{0.08}{0.3} = 0.27$
- $k_n = \frac{p_{ux}}{0.65*28*300^2} = 0.5 \rightarrow p_{ux} = 819\ kN$

for y − direction

- $l_n = 5.3 - 0.3 - 5\ m$
- $l'_n = 4.94 - 0.3 = 4.64m$
- $_2 = \frac{3.41}{2} = 1.705\ m$
- $m_u = 0.07[(w_d + 0.5w_l)\ \frac{l^2}{2} - w'\ \frac{l'}{2}(l'_n)^2]$
- $m_{uy} = 0.07\{(4.6 + 2) * (5)^2 * 1.705 - 4.6 * 4.64^2 * 1.705\} = 7.87\ kN.m$

$m_{uy} = 7.87\ kN.m /2 = 3.93\ kN.m$

- $e_x = \frac{m_y}{p} = \frac{3.93}{141} = 0.027\ mm$
- $\frac{e}{h} = \frac{0.027}{0.3} = 0.092$
- $_n = \frac{p_{uy}}{\emptyset*fc^F*A_g*h} = \frac{p_{uy}}{0.65*28*300^2} = 0.82 \rightarrow p_{uy} = 1343\ kN$

Draw a horizontal line to read k_n from the chart column strength intersection diagram for rectangular section with bars of four faces and □=٠,٦٠:

- $k_n = 1.04 = \frac{p_n}{0.65*28*300^2} = 1700kN$

Use Bresler reciprocal equation:

$$\frac{1}{p_n} = \frac{1}{\emptyset p_{nxo}} + \frac{1}{\emptyset p_{nyo}} - \frac{1}{\emptyset p_0}$$

$$\frac{1}{p_n} = \frac{1}{1343} + \frac{1}{819} - \frac{1}{1700}$$

$$\emptyset p_n = 762kN \quad > 255.2\ kN$$

$$\therefore Safe$$

Design of exterior column C٣ at first floor:

$$Area\ supported\ by\ the\ column = (\frac{3.41}{2} + \frac{3.11}{2})(\frac{4.94}{2} + 0.15) = 3.26 * 2.62 = 8.5\ m^2$$

- load from upper floor = 68 kN
- (first floor)load supported by this column = w_u ∗ area = 10.41 ∗ 8.5 = 88.5 kN
- $hieght\ of\ column = 3\ m$
- $density\ of\ concrete = 24\ kN/m^3$
- $self\ weight = 0.3 * 0.3 * 3 * 24 * 1.2 = 7.8\ kN \approx 8$
- $Wall\ load = 14.4 * (\frac{3.71}{2} + \frac{3.11}{2}) = 50\ kN$
- $column\ p_u = 68 + 88.5 + 8 + 50 = 214.5\ kN$
- $moment\ according\ to\ ACI\ 2014\ unbalanced\ on\ adjacent\ panels$
- $will\ cause\ unbalanced\ moment.$

$m_u = 0.07[(w_d + 0.5w_l)\ l_2^2 - w'\ l'_2 (l'_n)^2]$

Column loading:

- $w_d = 1.2 * 0.16 * 24 = 4.6\ KN/m^2$
- $w_l = 1.6 * 2.5 = 4\ KN/m^2$
- $0.5w_l = 2\ KN/m^2$

$clear\ cover\ d' = 40\ mm$

$$find\ \gamma = \frac{h - 2 * d' - 2 * d_{stirrup}\ - d_b\ /2}{h} = \frac{300 * 2 * 40 - 2 * 10 - 20/2}{300} = 0.63 \approx 0.6$$

for x − direction

- $l_n = 3.11\ m$
- $_2 = \frac{4.94}{2} = 2.47$
- $m_{ux} = 0.07[\ (\ 4.6 + 2\ ) * 3.11^2 * 2.47 - 4.6 * 2.81^2 * 2.47\ ] = 4.75\ kN.m$

$m_{ux} = 4.75kN.m\ /2 = 2.37kN.m$

- $e_y = \frac{}{p} = \frac{2.37}{127.4} = 18mm < 0.1h = 0.1 * 300 = 30\ mm \qquad neglect\ it$

for y − direction

- $l_n = 4.94 - 0.3 = 4.64\ m$
- $l_2 = \frac{3.41}{2} + \frac{3.11}{2} = 3.26\ m$
- $m_{uy} = 0.07[(\ 4.6 + 1.2\ ) * (\ 3.26\ )^2 * 4.64\ )\ ] = \frac{20}{2} = 10\ kN.m$
- $e_x = \frac{m_y}{p} = \frac{10}{214.5} = 0.04\ m$
- $\frac{e}{h} = \frac{0.04}{0.3} = 0.155$
- $k_n = \frac{p_{uy}}{\emptyset * fc^F * A_g * h} = \frac{214.5 * 1000}{0.65 * 28 * 300^2} = 0.13$

- with intersection e/h=0.155 $\rho = \rho_{min} = 0.01$ Use 4Ø20mm

Design of interior column C٤ at first floor:

$$Area\ supported\ by\ the\ column = (\frac{3.42}{2} + \frac{3.11}{2}) * (5.12) = 3.26 * 5.12 = 16.7\ m^2$$

- $load\ from\ upperfloor = 128\ kN$
- $(first\ floor)\ supported\ by\ this\ column = w_u * area = 10.41 * 16.7 = 174\ kN$
- $hieght\ of\ column = 3\ m$
- $density\ of\ concrete = 24\ kN/m^3$
- $self\ weight = 0.3 * 0.3 * 3 * 24 * 1.2 = 7.8\ kN \approx 8\ kN$
- $Wall\ load = 14.4 * (\ 3.26 + \ 5.12\ ) = 121\ kN$
- $column\ load\ p_u = 128 + 174 + 8 + 121 = 431\ kN$
- $\boldsymbol{interior\ column\ loading}$:
- $w_d = 1.2 * 0.16 * 24 = 4.6 \frac{kN}{m^2}$
- $w_l = 1.6 * 2.50 = 4 \frac{kN}{m^2}$
- $0.5w_l = 2\ kN/m^2$

$clear\ cover\ d' = 40mm$

$$find\ \gamma = \frac{h - 2 * d' - 2 * d_{stirrup} - d_b\ /2}{h} = \frac{300 * 2 * 40 - 2 * 10 - 20/2}{300} = 0.63 \approx 0.6$$

for x − direction

- $l_n = 3.41 - 0.3 = 3.11\ m$
- $l'_n = 3.11 - 0.3 = 2.81\ m$
- $l_2 = \frac{5.3}{2} + \frac{4.94}{2} = 5.12\ m$
- $m_{ux} = 0.07[(4.6 + 2) * 3.11^2 * 5.12 - 4.6 * 2.81^2 * 5.12]\ = 9.86\ KN.m$

$$m_{ux} = 9.86kN.\frac{m}{2} = 4.93\ kN.m$$

- $e_y = \frac{}{p} = \frac{4.93}{241.6} = 0.02m < 0.1h = 0.1 * 0.3 = 0.03\ m \quad so, neglect\ this\ moment$

for y − direction

- $l_n = 5.3 - 0.3 = 5.0\ m$
- $l'_n = 4.94 - 0.3 = 4.64$
- $l_2 = \frac{3.41}{2} + \frac{3.11}{2} = 3.26\ m$
- $m_{uy} = 0.07\ \{(4.6 + 2) * (5)^2 * 3.26 - 4.6 * 4.64^2 * 3.26\} = \frac{15.0}{2} = 7.5\ kN.m$
- $e_x = \frac{m_y}{p} = \frac{7.5}{431} = 0.017m < 0.1 * 0.3 = 0.03\ m$

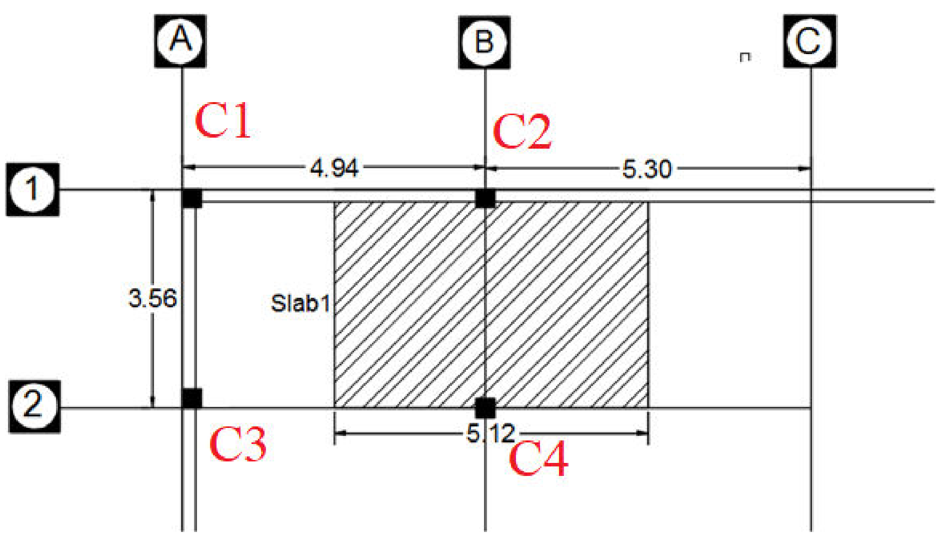
SO, design it as axial compression member without moment

Provide minimum reinforcement 4 Ø20 mm As = 4 * 314 = 1256 mm2

Pu = 0.8 * 0.65 { .85fc (Ag – As) + Asfy } = 1372 kN > 431 kN

$\therefore Safe$

Design of Ground floor columns:

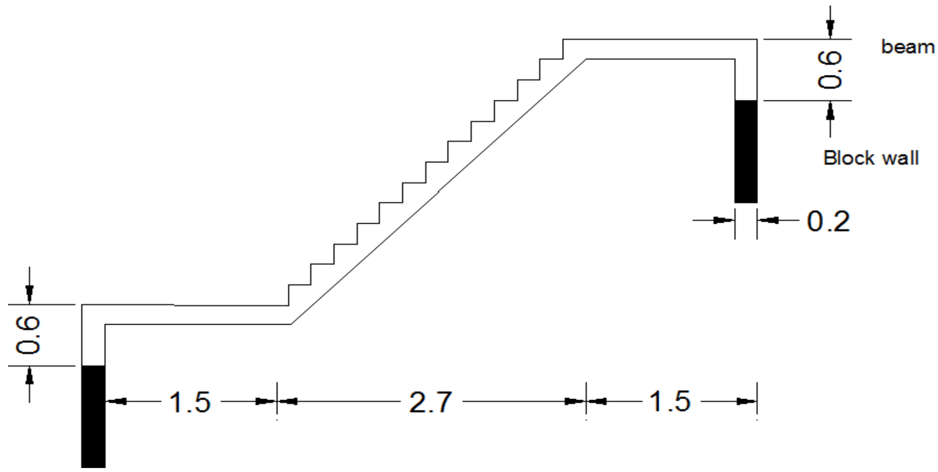


Design of stair cases:

- Stair cases are the way to transfer between levels in the building.
- It is comprised from landing, rise and tread.
- The comfortable dimension of rise and tread is 16 x 30 cm which is supported on two ends and treated as one-way slab covered with mosaic tiles or ceramic tiles or marble.
- The stair case according to the ASCE code should carry 4 kN/m live load.
- It may rest on masonry wall which will consider as hinge or may rest on stiff beams and considered as a rigid support, and the minimum thickness of the slab will be selected from the table below which is taken from ACI- code:

Minimum Suggested Thickness "h" of Concrete Beams & One-Way Slabs				
Member:	End Conditions			
	Simply supported	One end continuous	Both ends continuous	Cantilever
Solid one-way slab	L/20	L/24	L/28	L/10
Beam	L/16	L/18.5	L/21	L/8

- In the stair case of this building, beams will be provided to support the stair case slab at the ends as below:



Structural design:

- 1- $h\ min = \frac{ln}{28}$ Since there are beams at two ends it is considered as two ends continuous:
- $h\ min = \frac{5.7}{28} = 0.2\ m$
- 2- Loadings:
- D.L (slab) = 0.2 * 24 = 4.8 KN / m^2
- D.L (ceramic tiles) = 1 KN / m^2
- D.L (steps) = (0.2 * 0.3 * 0.5 * 24) 3 step / m = 2.16 KN / m
- Width of stair = 1.5 m
- Total dead load / m = (1.2 * 4.8 * 1.5) + (1.2 * 1 * 1.5) +(1.2 * 2.16) = 13 KN / m
- Live load = 1.6 *4 * 1.5 = 9.6 KN / m
- Wu on Stairs = 13 + 9.6 = 22.6 KN / m
- +ve Mu = W L^2/16 = 22.6*5.7^2/16 = 46 KN .m
- -ve Mu=WL^2/14= 53 kN.m
- Using Ø 12 mm as reinforcing bars
- d = 200 – 20 – 6 = 172 mm
- $-ve\ As = \frac{Mu}{0.9 * fy * 0.9 * d} = \frac{53 * 10^6}{0.9 * 420 * 0.9 * 172} = 905\ mm^2/m$
- $+ve\ As = \frac{Mu}{0.9 * fy * 0.9 * d} = \frac{46 * 10^6}{0.9 * 420 * 0.9 * 172} = 785\ mm^2/m$

- As min =0.002 b * h = 0.002 * 1000 * 200 = 400 mm^2

- For negative and positive reinforcement:
- $Number\ of\ bars = \frac{905}{113} = 8\ bars$
- Spacing= 1000/7= 143 mm   Use Φ12 mm @ 14 cm c / c
- Transverse reinforcement = 0.002 * 1000 * 200 = 400 mm^2
- $Number\ of\ bars = \frac{400}{113} = 4\ bars$
- Use Φ12 mm @ 25 cm c / c

- Check for shear force:
- V_d (Applied) = 45.5-(0.172 * 10 KN) = 43.78 KN
- $ØV_c$ = Ø * 0.17 * √fc' * b * d
- $ØV_c$ = 0.75 * 0.17 * √28 * 1000 * 172 /1000 = 116 > 43.78
- Safe for shear.

Design of foundation:

Design of foundation:

The part of a structure that transmits the loads of the structure to the soil safely is called foundation. And the loads of the structure should not be more than the soil bearing capacity, because it will cause failure in the structure.

There are many types of footing such as single column footing, combined footing, mat or raft foundation, wall footing, strip footing, and pile foundation.

Selection of the type of footing that can be used depends on the allowable soil bearing capacity, structural loads, and another important factor which is economy, which type is more economy for your project.

In this project single column footing & combined footing were used.

Conclusion

Based on the results of our study, the following conclusion can be drawn. Generally, from the results of the study, the flat slab system building is less costly in construction because it requires less weight due to non-using beam in the system, therefore it requires less volume of concrete and less cost. These levels of the deflection and displacement are zero because in slabs we do not have them and can be considered as a safe structure, and have no danger to failure in the future, and so on. Form this experience we can say column system is the best for quality of the building, cost and safety. Flat slab is beautiful in architectural point of view but it needs labors that have lots of skill and experience in this type of slab. Flat slab is safer than Beam – Column system. The design of flat slab by Direct Design Method has some restrictions that it should have minimum three spans in each direction

Recommendation

Flat Slabs are considered suitable for most of the construction and need special considerations during implementation in terms of formwork, safety, formwork removal, and concrete casting. Formwork should be designed by specialist engineering team to avoid any difficulties and maintaining safety environment.

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