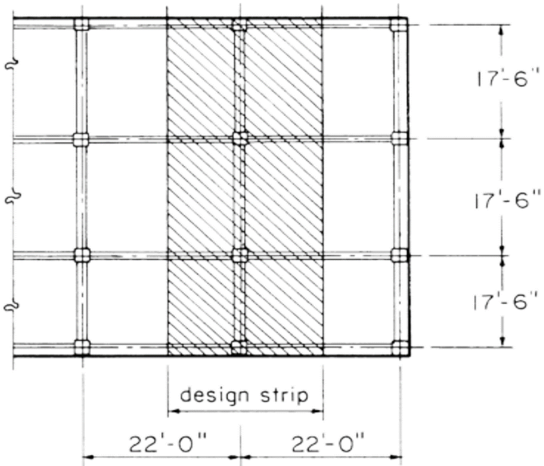
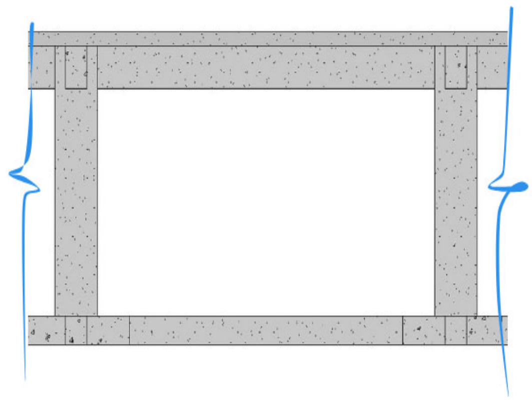
TWO-WAY SLABS (Direct Method)

This Calcolations uses to the design of noneprestressed solid Two-way slabs reinforced for flexture and shear. Calculations are based on ACI-318 2019.





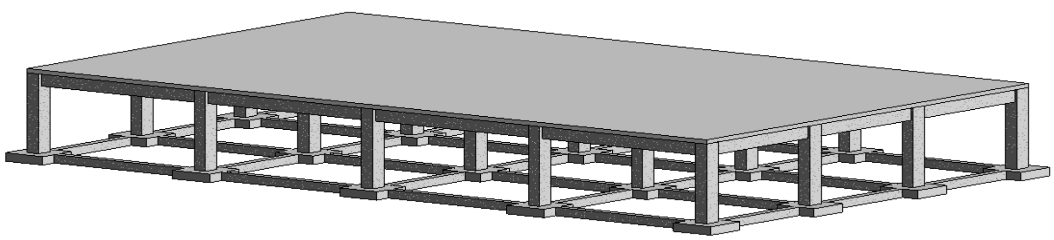


Figure 1-General Geometry

1.Geometry :

L Length = 22
B Length = 17.6 → Two-way Slab
4-Edge Suported

Dimensions of beams or walls:

Peripheral beams:

Cross section depth of beam or wall height h_b =	685.80	mm	27.00	in
Cross section width of beam or wall b_w =	355.60	mm	14.00	in
Cross section depth of beam or wall height h_b =	508.00	mm	20.00	in
Cross section width of beam or wall b_w =	355.60	mm	14.00	in

Dimensions of columns:

Story height H =	3657.6	mm	12.00	ft
Column cross-section depth h_c =	457.20	mm	18.00	in
Column cross section width b_c =	457.20	mm	18.00	in

Floor Dimensions :

l_a =	6705.6	mm	22.00	ft
l_b =	5334.0	mm	17.50	ft

Net Floor Dimensions :

l_{na} =	6248.4	mm	20.50	ft
l_{nb} =	4876.8	mm	16.00	ft

2.Loading :

assume thickness =	152.4	mm	Ξ	6.00	in
DL =	366	kg/m^2		74.9	psf
SDL =	0	kg/m^2		0.0	psf
LL =	488	kg/m^2		100.0	psf

Loading Combinations :

ACIB01 : 1.4D
ACIB02 : 1.2D+1.6L

3.Material Properties :

Specification of reinforced concrete materials :

Concrete :

Normal Weight → λ = 1.00

Weight per Unit Volume :	W =	23.54	KN/m^3			
	W =	149.83	lb/ft^3	≡	2400	kg/m^3
Mass per Unit Volume :	M =	15.278	lb/ft^3	≡	245	kg/m^3
Poisson's Ratio :	U =	0.15	-			
Coefficient of Thermal Expansion :	A =	9.90E-06	1/C°			
Compressive strength of concrete:	f'_c =	28	Mpa			
	f'_c =	4000.00	psi	≡	281.23	kgf/cm^2

Modulus of Elasticity :

$$E_c = 0.043\omega_C^{1.5}\sqrt{f'_c} \longrightarrow$$

E_c =	26550.7	Mpa	≡	270741.9	kgf/cm^2
E_c =	3827626	psi			

$$E_c = 4700\sqrt{f'_c} \longrightarrow$$

E_c =	24682.5	Mpa	≡	251691.2	kgf/cm^2
E_c =	3604997	psi			

19-2-1 ~19.2.4.3

Rebars :

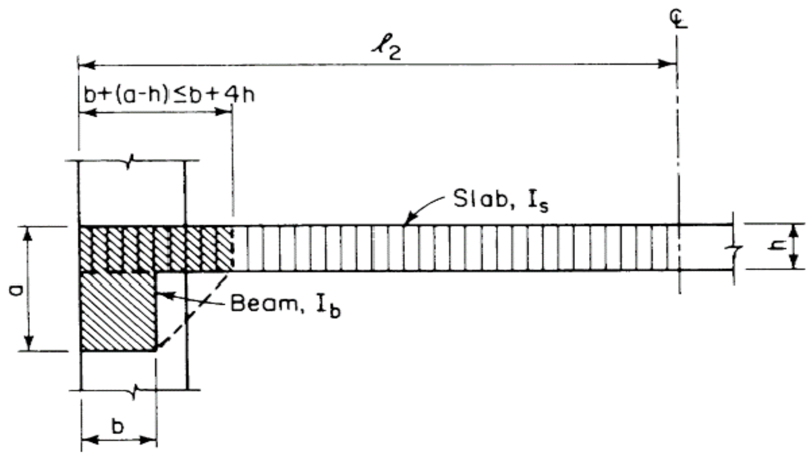
Rebar Specifications :

Modulus of Elasticity : E_s = 200000 Mpa

Category of Longitudinal Rebars:	S400	→		-			
Minimum Tensile Stress		f_u =	600	Mpa	≡	87022.1	psi
Minimum Yield Stress		f_y =	400	Mpa	≡	58014.7	psi
Category of Transverse Rebars:	S340	→		-			
Minimum Tensile Stress		f_u =	500	Mpa			
Minimum Yield Stress		f_y =	340	Mpa			

20.2 - ASTM A370

4.Determination of α_f :



$$\alpha_f = \frac{E_{cb} I_b}{E_{cs} I_s}$$

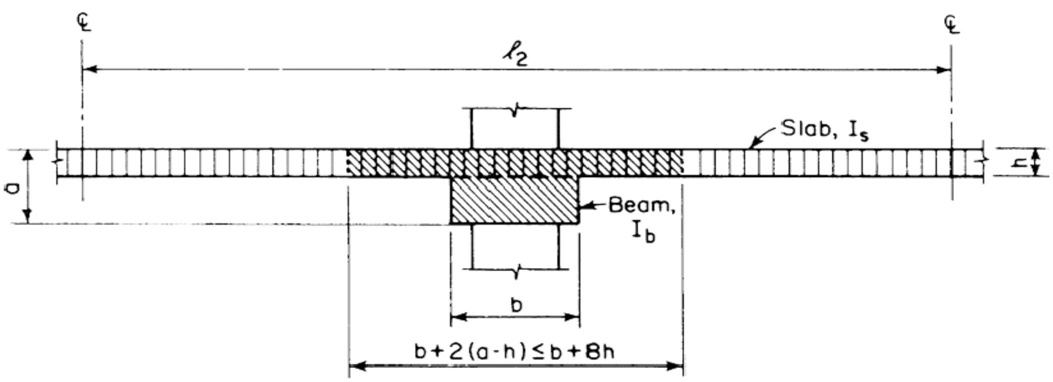
$$l_2 = \frac{l_n}{2} + \frac{COL._b}{2} \longrightarrow$$ l_2 = 141.00 in 3581.4 mm

N-S EDGE BEAMS :
h = t_f = 152.4 mm
b_w = 355.60 mm
h_b = 533.40 mm
⟶ α_f = 13.302

$$l_2 = \frac{l_n}{2} + \frac{COL._b}{2} \longrightarrow$$ l_2 = 114.00 in 2895.6 mm

E-W EDGE BEAMS :
h = t_f = 152.4 mm
b_w = 355.60 mm
h_b = 533.40 mm
⟶ α_f = 16.452

8.10.2.7



$$l_2 = l_n \longrightarrow$$ l_2 = 264.00 in 6705.6 mm

N-S interior BEAMS :
h = t_f = 152.4 mm
b_w = 355.60 mm
h_b = 355.60 mm
⟶ α_f = 3.153

$$l_2 = l_n \longrightarrow$$ l_2 = 210.00 in 5334 mm

E-W interior BEAMS :
h = t_f = 152.4 mm
b_w = 355.60 mm
h_b = 355.60 mm
⟶ α_f = 3.964

5.Determination of slab thickness: :

Minimum slab thickness according to ACI318-19:

$$\alpha_m = \frac{\sum_1^n \alpha_i}{n} \longrightarrow \quad \alpha_m = 9.22 \quad \rightarrow \quad d,e$$

β = 1.28

$$\begin{cases} IF: a:\ \alpha_{fm} \le 0.2 \ \rightarrow 8.3.1.1 \\ IF: b,c : 0.2 \le \alpha_{fm} \le 2.0 \ \rightarrow h = max\left\{\frac{l_n\left(0.8 + \frac{f_y}{200000}\right)}{36 + 5\beta(\alpha_{fm} - 0.2)}, 5.0\right\} \\ IF: d,e : \alpha_{fm} > 2.0 \ \rightarrow h = max\left\{\frac{l_n\left(0.8 + \frac{f_y}{200000}\right)}{36 + 9\beta}, 3.5\right\} \end{cases}$$

8.10.2.7

Deflection Control :

$$\begin{cases} Slabs\ Without\ drop\ panels \ \rightarrow \ h_{s,min} \ge \left\{\frac{1}{c} l_n, 5\ in\right\} \\ Slabs\ With\ drop\ panels \ \rightarrow \ h_{s,min} \ge \left\{\frac{1}{c} l_n, 4\ in\right\} \end{cases}$$

8.3.1.1

Slab Type : Without drop panels

Peripheral beams: With edge beams

$h_{s,min}$ = - mm Ξ - in

$$h = max\left\{\frac{l_n\left(0.8 + \frac{f_y}{200000}\right)}{36 + 5\beta(\alpha_{fm} - 0.2)}, 5.0\right\} \longrightarrow$$

$h_{s,min}$ = - in

$h_{s,min}$ = - mm

$$h = max\left\{\frac{l_n\left(0.8 + \frac{f_y}{200000}\right)}{36 + 9\beta}, 3.5\right\} \longrightarrow$$

$h_{s,min}$ = 5.64 in

$h_{s,min}$ = 143.3 mm

8.3.1.2

$\longrightarrow$ USE : h_s = 152.4 mm Ξ 6.000 in

6.Reinforcement detailing

Provisions for durability of steel reinforcement

Specified concrete cover requirements

Table 20.5.1.3.1—Specified concrete cover for cast-in-place nonprestressed concrete members

Concrete exposure	Member	Reinforcement	Specified cover, in.
Cast against and permanently in contact with ground	All	All	3
Exposed to weather or in contact with ground	All	No. 6 through No. 18 bars	2
		No. 5 bar, W31 or D31 wire, and smaller	1-1/2
Not exposed to weather or in contact with ground	Slabs, joists, and walls	No. 14 and No. 18 bars	1-1/2
		No. 11 bar and smaller	3/4
	Beams, columns, pedestals, and tension ties	Primary reinforcement, stirrups, ties, spirals, and hoops	1-1/2

Concrete exposure : Not exposed to weather or in contact with ground

Slabs, joints and walls

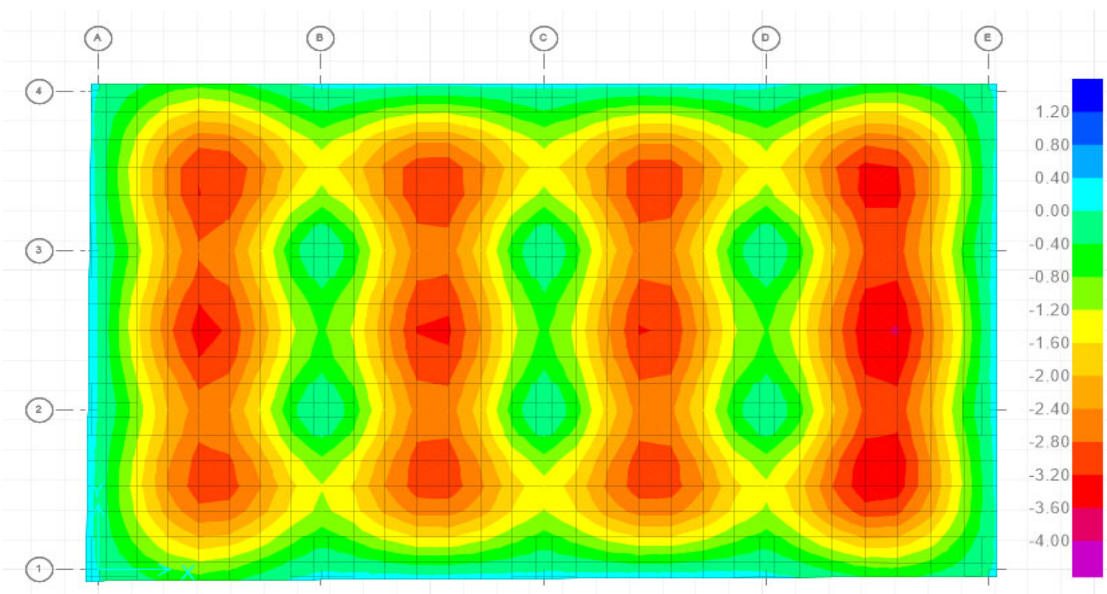
Rebar Size : Ø10

Cover = 0.75 in ≡ 19.05 mm ≈ 20 mm

7.7.1.1. , 20.5.1.3

7.Control the thickness of the slab according to the slab deformation:

Immediate Transformation of the Slab

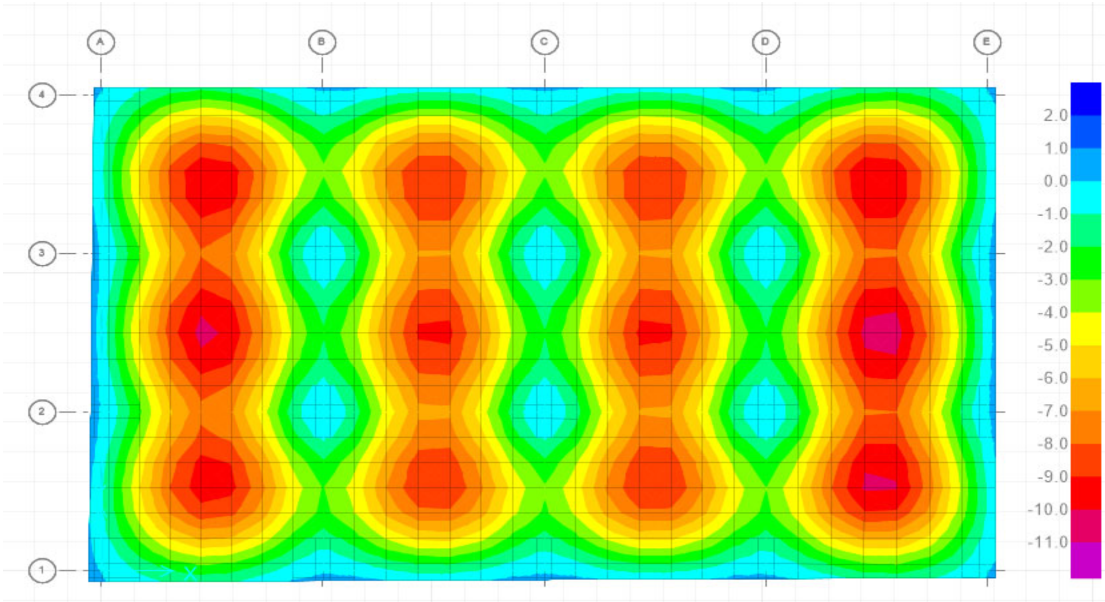


ACI318-14-24.1~2.4.2

$$\Delta_{i,L} \leq \frac{l}{360} \longrightarrow \left\{ \begin{array}{ll} \Delta = 3.63 & \text{mm} \\ \Delta_{i,L} = 18.6 & \text{mm} \end{array} \right\} \rightarrow \text{OK}$$

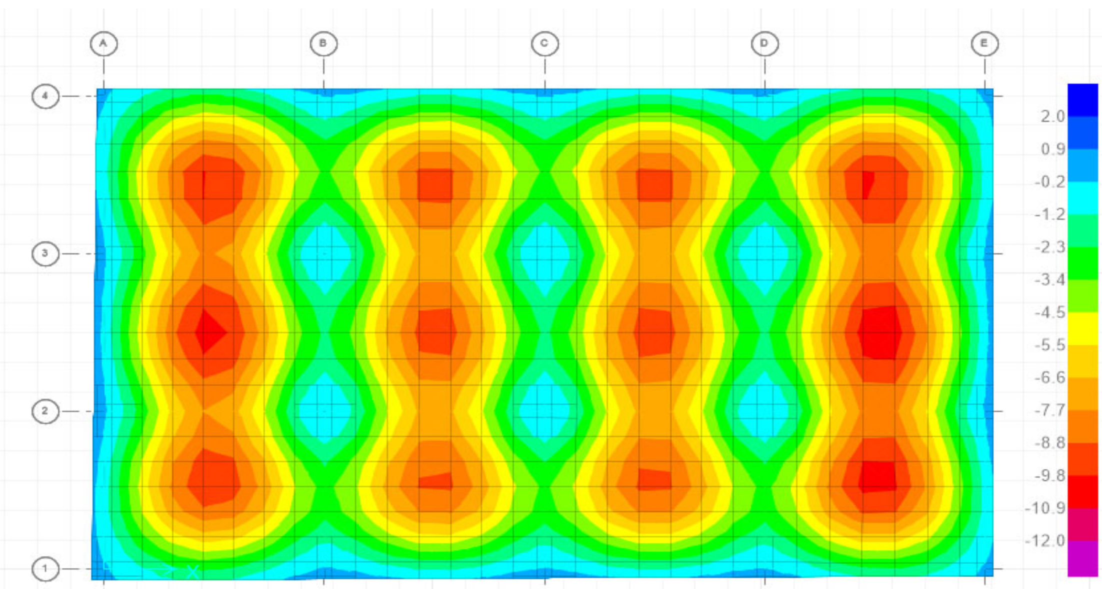
DCR = 0.19

Long-term slab deformation



If there is no harm to the undamaged parts:

$$\Delta_{D+L} \le \frac{l}{240} \longrightarrow \left\{ \begin{array}{ll} \Delta = 10.45 & \text{mm} \\ \Delta_{i,\,D+L} = 27.9 & \text{mm} \end{array} \right\} \rightarrow \text{OK} \qquad \text{DCR} = 0.37$$



If there is no harm to the undamaged parts:

$$\Delta_{D+L} \le \frac{l}{480} \longrightarrow \left\{ \begin{array}{ll} \Delta = 10.45 & \text{mm} \\ \Delta_{i,\,D+L} = 14.0 & \text{mm} \end{array} \right\} \rightarrow \text{OK} \qquad \text{DCR} = 0.75$$

ACI318-14-24.1~2.4.2

8.Controlling the conditions of using direct method 8.10.2

8.10.2.1 There are at least three continuous slab openings in each direction.

8.10.2.2 The distance between the center and center of the successive spans is more than one-third of the larger openings, there is no difference:

l_a = 5.33 m
l_b = 6.71 m
$\longrightarrow \frac{l_a}{l_b} \leq 3 \longrightarrow$ Ok

8.10.2.3 The slab springs are rectangular and the ratio of long span to short span length is less than 2.

l_{nb} = 6.25 m
l_{na} = 6.25 m
$\longrightarrow \frac{l_a}{l_b} \leq 2 \longrightarrow$ Ok

8.10.2.4 Exit from the center of the columns relative to each of the central axes of the successive columns, in fact zeroIt is less than 10% of the length of the opening.

Column eccentricity relative to the main axis of columns
Offset = 457.2 mm
10% l_a = 671 mm
OK

8.10.2.5 All the loads are of gravity type and distributed uniformly over the entire source of the slab.

8.10.2.6 The ratio of live load without coefficient to dead load without coefficient does not exceed 2.

$\frac{LL}{DL} \leq 2 \longrightarrow \frac{LL}{DL} =$ 1.19 $\longrightarrow$ OK

8.10.2.7 For all the slab springs on all four sides are placed on the beam, the relative hardness of the beams in. Two orthogonal directions apply in the following relationship: 8.10.2

Interior Panel :

α_{f1} = 3.153 l_1 = 210.00 in
α_{f2} = 3.964 l_2 = 264.00 in

$0.2 \leq \frac{\alpha_{f1} l_2^2}{\alpha_{f2} l_1^2} \leq 5 \longrightarrow \frac{\alpha_{f1} l_2^2}{\alpha_{f2} l_1^2} =$ 1.257 $\longrightarrow$ OK

Exterior Panel :

α_{f1} = 13.302 l_1 = 114.00 in
α_{f2} = 16.452 l_2 = 141.00 in

$0.2 \leq \frac{\alpha_{f1} l_2^2}{\alpha_{f2} l_1^2} \leq 5 \longrightarrow \frac{\alpha_{f1} l_2^2}{\alpha_{f2} l_1^2} =$ 1.237 $\longrightarrow$ OK

9.Final Loading :

Floor Loading :

Live Load :	LL =	488.24	kg/m^2 ≡	100.0	psf
Flooring and partition load:	SDL =	0.00	kg/m^2 ≡	0.0	psf
Beam's Dead Load :	DL_b =	45.26	kg/m^2 ≡	9.27	psf
Slab's Dead Load :	DL_s =	365.76	kg/m^2 ≡	74.91	psf
Total Dead Load :	DL =	411.02	kg/m^2 ≡	84.18	psf

-

Load Combinations :

Comb 1 : 1.4 DL $\longrightarrow$ L/Area = 575.4 kg/m^2 ≡ 117.86 psf

Comb 2 : 1.2DL+1.6LL $\longrightarrow$ L/Area = 1274.4 kg/m^2 ≡ 261.02 psf

10.Calculation of the moment in the slab 8.10.4

In the north-south direction:

$M_0 = \frac{q_u l_2 l_n^2}{8} \longrightarrow$ M_0 = 183.76 kips.ft 249.14 KN.m

Interior Span:

Positive	$0.35M_0 =$	64.32
Negative	$0.65M_0 =$	119.44

End Span:

Interior negative	$0.70M_0 =$	128.63
Positive	$0.57M_0 =$	104.74
Exterior negative	$0.16M_0 =$	29.40

8.10.4

Distribution of coefficient moment between the column strip and the middle strip:

In the north-south direction: $\alpha_f =$ 3.153

$\frac{l_2}{l_1}$ 1.26

% Negative Factored Moment @ interior Suport Resisted by Column Strip :

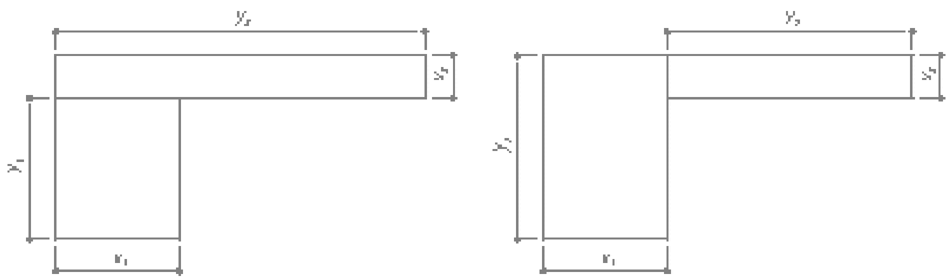
$$= 75 + 30\left(\frac{\alpha_{f1} l_2}{l_1}\right)\left(1 - \frac{l_2}{l_1}\right) = \quad 67.29 \quad \%$$

PCA NOTE 13.6.4

8.10.5

$$I_s = \frac{l_2 h^3}{12} \longrightarrow I_s = 4752.000094 \quad in^4$$

$$C = \sum\left(1 - 0.63\frac{x}{y}\right)\frac{x^3 y}{3}$$



Middle Beams:

$x_1 =$ 14 $x_2 =$ 6

$y_1 =$ 21 $y_2 =$ 35

$C_1 =$ 11140.64 $C_2 =$ 2247.84

C = 13388.48 in⁴

Edge Beams:

$x_1 =$ 14 $x_2 =$ 6

$y_1 =$ 27 $y_2 =$ 21

$C_1 =$ 16628.64 $C_2 =$ 1239.84

C = 17868.48 in⁴

$$\beta_t = \frac{C}{2I_s} \longrightarrow \beta_t = 1.880100973 \quad in^4$$

% Negative Factored Moment @ exterior Suport Resisted by Column Strip :

$$= 100 - 10\beta_t + 12\beta_t\left(\frac{\alpha_{f1} l_2}{l_1}\right)\left(1 - \frac{l_2}{l_1}\right) = \quad 75.40$$

% Positive Factored Moment Resisted by Column Strip :

$$= 60 + 30\left(\frac{\alpha_{f1} l_2}{l_1}\right)\left(1.5 - \frac{l_2}{l_1}\right) = \quad 67.29 \quad \%$$

	Factored Moment	Column Strip Percent	Column Strip Moment	Moment (ft-kips) in Two Half-Middle Strips
End Span:				
Interior negative	128.63	67.29	86.55	42.08
Positive	104.74	67.29	70.48	34.27
Exterior negative	29.40	75.40	22.17	7.23
Interior Span:				
Positive	64.32	67.29	43.27	21.04
Negative	119.44	67.29	80.37	39.07

11.Calculation of Factored moment in columns :

In the north-south directio

Given the same size of the columns on the upper and lower floors and the same openings:

$$M_u = 0.07(q_{uD} + 0.5q_{uL})l_2{l_n}^2 - q'_{uD}l'_2(l'_n)^2$$

$$M_u = 0.07\left(0.5q_{ul}l_2{l_n}^2\right) \longrightarrow$$ M_u = 31.54 Kips.ft Ξ 42.76 KN.m

$$M_{col.} = \frac{M_u}{2} \longrightarrow$$ $M_{col.}$ = 15.77 Kips.ft Ξ 21.38 KN.m

Edge Columns :

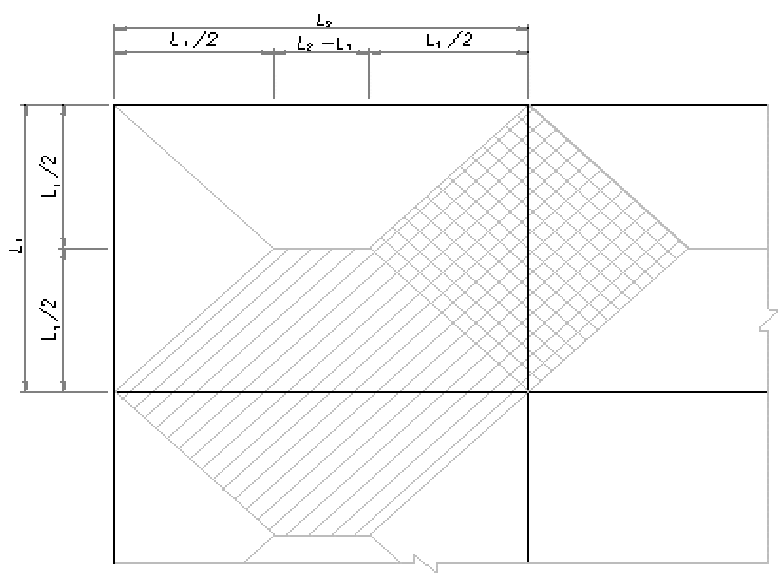
$$M_u = Exterior\ negative \longrightarrow$$ M_u = 29.40 Kips.ft Ξ 39.86 KN.m

$$M_{col.} = \frac{M_u}{2} \longrightarrow$$ $M_{col.}$ = 14.70 Kips.ft Ξ 19.93 KN.m

8.10.7

12.Shear Check :

Final Shear at Beams :



$$V_{u\ N-S} = \frac{q_u{l_1}^2}{4} \longrightarrow$$ $V_{U\ N\text{-}S}$ = 20.0 Kips Ξ 137.79 N/mm^2

$$V_{u\ E-W} = \frac{q_u l_1}{4}(2l_2 - l_1) \longrightarrow$$ $V_{U\ E\text{-}W}$= 30.26 Kips Ξ 208.65 N/mm^2

Shear Check of Beam :

h =	152.4	mm	b =	1000	mm
d =	132	mm	V_u =	138	KN

$V_c = 0.17\lambda\sqrt{f'_c}b_w d$ $\longrightarrow$ V_c = 118.20 KN Ξ 26.57 kips

$\sqrt{f'_c} \le 8.3\ MPa$ $\longrightarrow$ $\sqrt{f'_c} =$ 0.0 $\longrightarrow$ OK

Ø = 0.75

$V_u \le \emptyset\left(V_c + 0.066\sqrt{f'_c}b_w d\right)$ $\longrightarrow$ NOT OK

$\begin{cases} IF:\ V_u < \emptyset V_c \rightarrow N.N. \\ IF:\ V_u \ge \emptyset V_c \rightarrow \text{transverse reinforcement shall be provided} \end{cases}$

$\emptyset V_c =$ 88.7 KN KN Ξ 19.93 kips

$\longrightarrow$ Vu > ØVc , transverse reinforcement shall be provided

$V_s \ge \frac{V_u}{\emptyset} - V_c$ $\longrightarrow$ V_s = 65.52 KN Ξ 14.73 kips

$V_s = \frac{A_v f_{yt} d}{s}$ $\longrightarrow$ $\frac{A_v}{s} =$ 0.001455

Use : 10 @ 100

$\frac{A_v}{s} =$ 1.571 $\longrightarrow$ V_s = 71 KN Ξ 15.90 kips

$V_n = V_c + V_s$ $\longrightarrow$ V_n = 188.9 KN Ξ 42.47 kips

$V_r = \emptyset V_n$ $\longrightarrow$ V_r = 141.7 KN Ξ 31.85 kips

DCR = 0.973

22.5

13.Flextural Design of the Slab :

Column strip width b $= \frac{l_2}{2}$ $\longrightarrow$ b = 105.00 in Ξ 2667 mm

Flextural Design of the Slab (Column strip) : Rebar : Ø12

d =	132	mm	M_u =	42.76	KN.m
f'_c =	28	Mpa	f_y =	400	Mpa

$m = \frac{f_y}{0.85f'_c}$ $\longrightarrow$ m_Φ = 17.06

$R_r = \frac{M_r}{\emptyset b d^2}$ $\longrightarrow$ R_r = 2.71 N/mm^2 393.1 psi

$\rho = \frac{1}{m}\left\{1 - \sqrt{1 - \frac{2mR_r}{f_y}}\right\}$ ρ = 0.0072

$A_s = \rho b d$ $\longrightarrow$ A_s = 956.0 mm^2 Ξ 1.48 in^2

$A_{s,min} = 0.0018bd$ $\longrightarrow$ $A_{s,min}$ = 238.3 mm^2 Ξ 0.37 in^2

$\longrightarrow$ S = 450 mm Ξ 17.7 in

$S_{max} = min\{2h, 18in\}$ $\longrightarrow$ S_{max} = 300 mm Ξ 11.8 in

USE Ø12 @ 300

22.2

$$a = \frac{A_s f_y}{\beta_1 f'_c b} \longrightarrow$$ a = 16.31 mm Ξ 0.64 in

$$c = \frac{a}{\beta_1} \longrightarrow$$ c = 19.19 mm Ξ 0.76 in

$$\varepsilon_s = \varepsilon_t = \varepsilon_{cu}\left(\frac{d_t - c}{c}\right) \longrightarrow$$ ε_t = 0.0206

$$\begin{cases} if:\ \varepsilon_t \le 0.002 \rightarrow \begin{cases} if: spiral \rightarrow \emptyset = 0.7 \\ if: tie \rightarrow \emptyset = 0.65 \end{cases} \\ if: 0.002 \le \varepsilon_t \le 0.005 \rightarrow \begin{cases} if: spiral \rightarrow \emptyset = 0.567 + 66.7\varepsilon_t \\ if: tie \rightarrow \emptyset = 0.483 + 83.3\varepsilon_t \end{cases} \\ if:\ \varepsilon_t \ge 0.005 \rightarrow \emptyset = 0.9 \end{cases} \longrightarrow$$ Ø = 0.900

Flextural Design of the Slab (Middle strip) :

Flextural Design of the Slab (Column strip) : Rebar : Ø12

d = 132 mm M_u = 39.86 KN.m

f'_c = 28 Mpa f_y = 400 Mpa

$$m = \frac{f_y}{0.85 f'_c} \longrightarrow$$ m_Φ = 17.06

$$R_r = \frac{M_r}{\emptyset b d^2} \longrightarrow$$ R_r = 2.53 N/mm^2 366.4 psi

$$\rho = \frac{1}{m}\left\{1 - \sqrt{1 - \frac{2 m R_r}{f_y}}\right\}$$ ρ = 0.0067

A_s $\longrightarrow$ A_s = 887.0 mm^2 Ξ 1.37 in^2

$A_{s,min} = 0.0018bd$ $\longrightarrow$ $A_{s,min}$ = 238.3 mm^2 Ξ 0.37 in^2

$\longrightarrow$ S = 500 mm Ξ 19.7 in

$S_{max} = min\{2h, 18in\}$ $\longrightarrow$ S_{max} = 300 mm Ξ 11.8 in

USE Ø12 @ 300

$$a = \frac{A_s f_y}{\beta_1 f'_c b} \longrightarrow$$ a = 15.13 mm Ξ 0.60 in

$$c = \frac{a}{\beta_1} \longrightarrow$$ c = 17.81 mm Ξ 0.70 in

$$\varepsilon_s = \varepsilon_t = \varepsilon_{cu}\left(\frac{d_t - c}{c}\right) \longrightarrow$$ ε_t = 0.0225

$$\begin{cases} if:\ \varepsilon_t \le 0.002 \rightarrow \begin{cases} if: spiral \rightarrow \emptyset = 0.7 \\ if: tie \rightarrow \emptyset = 0.65 \end{cases} \\ if: 0.002 \le \varepsilon_t \le 0.005 \rightarrow \begin{cases} if: spiral \rightarrow \emptyset = 0.567 + 66.7\varepsilon_t \\ if: tie \rightarrow \emptyset = 0.483 + 83.3\varepsilon_t \end{cases} \\ if:\ \varepsilon_t \ge 0.005 \rightarrow \emptyset = 0.9 \end{cases} \longrightarrow$$ Ø = 0.900

22.2