An-Najah National University
Faculty of Engineering
Civil Engineering Department

Graduation Project
3D Analysis and Design of Al-Amal Hospital

Prepared By:

Ahmad Jaber

Ameen Daraghmeh

Laith Mahmoud

Mosab Saabna

Supervised By:

Dr. Munther Diab

Outline

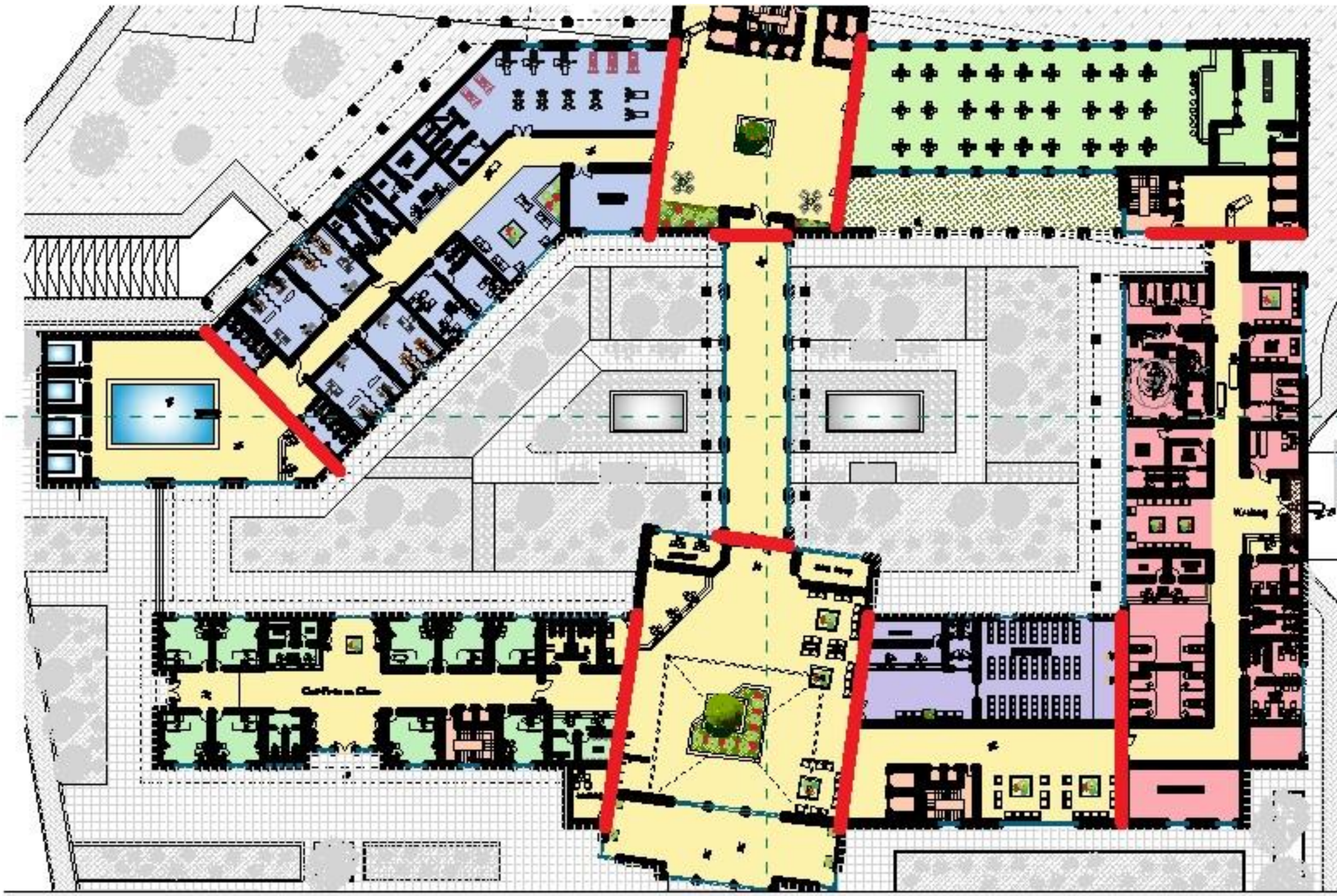
Introduction:

- Al-Amal Hospital is an architectural graduation project that was designed by architectural student in An-Najah National University.

- This hospital is located in Salem village near the city of Nablus.

- Total area of the structure is 11,000 m^2.

The project is separated into many parts by seismic joints as shown below



Methodology:

Design codes :

The codes used in the project are:

1- The American Concrete Institute (ACI) code 2008

2- The International building code (IBC-2009)

3- The Uniform Building Code (UBC-97)

Materials :

Concrete:

Concrete strength for columns and shear walls is fc=35MPa.

Concrete strength for other structural elements is fc=28 MPa.

Steel:

Steel yield strength = f_y = 420 MPa.

Seismic and site properties:

- $Z= 0.2$ (zone 2)
- Soil type B (Rock)
- $I= 1.25$
- $R= 5.5$
- q allowable = 320 kN/m^2

Loads:

Superimposed Dead Load = 5 KN/m^2

Live load = 7 KN/m^2

Slab systems

- *One and two way solid slabs with drop beams*
- *One way ribbed slabs with drop beams*

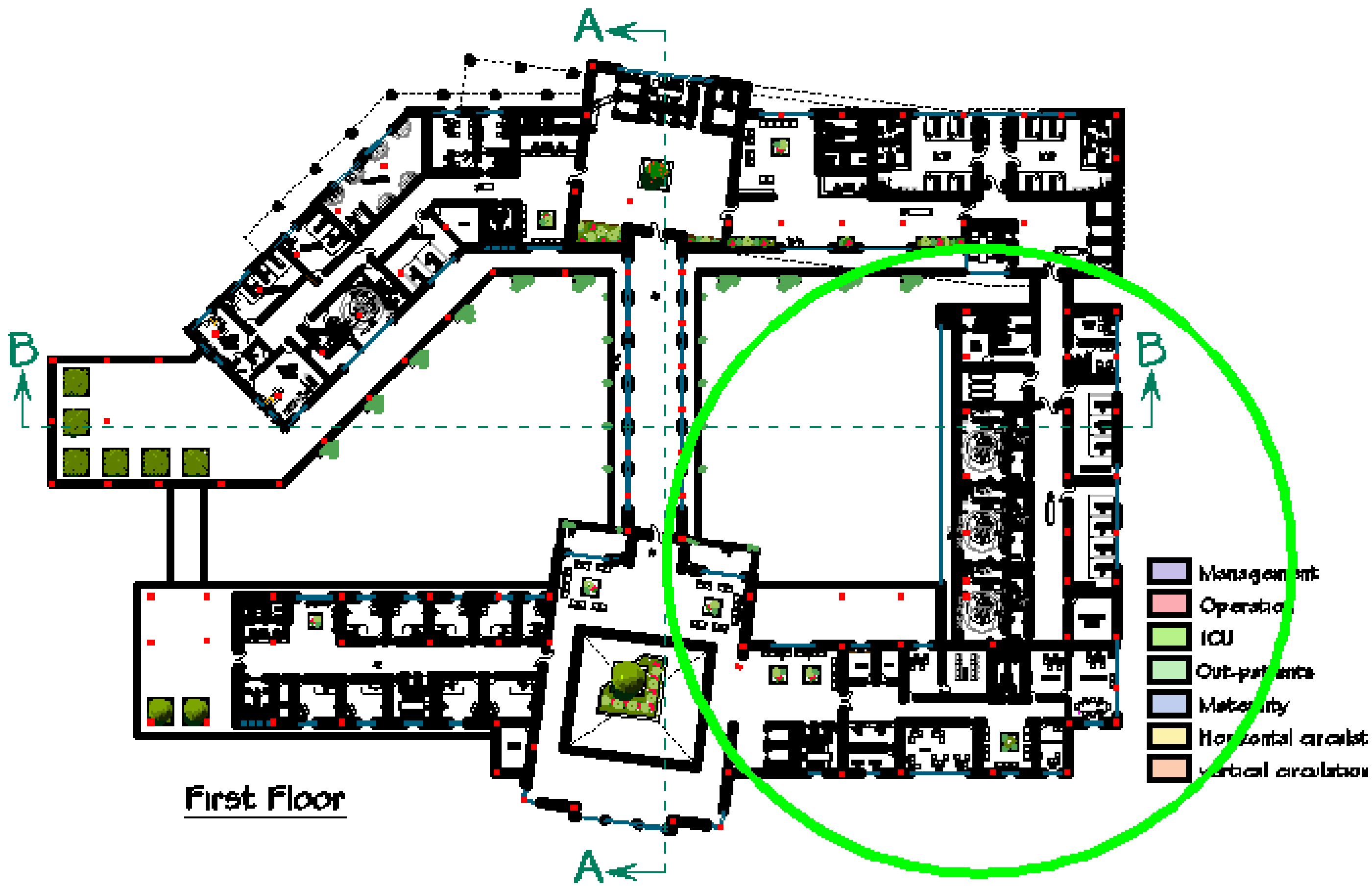
Challenges and problems

- The architect didn’t take any consideration for structural purposes.
- Due to the first issue , the length of spans was relatively long.
- The unsymmetrical shape of the building causes an extra load from lateral forces (earthquackes) due to torsion effect.

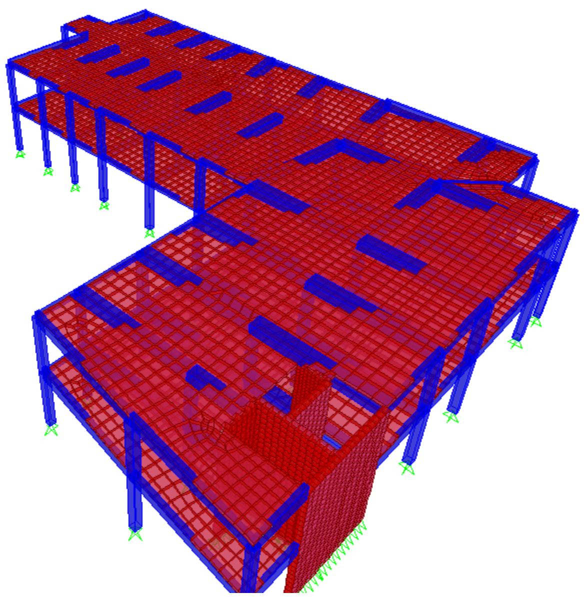
Preliminary dimensions

- Conceptual equations were used to get an approximate dimensions for structural elements

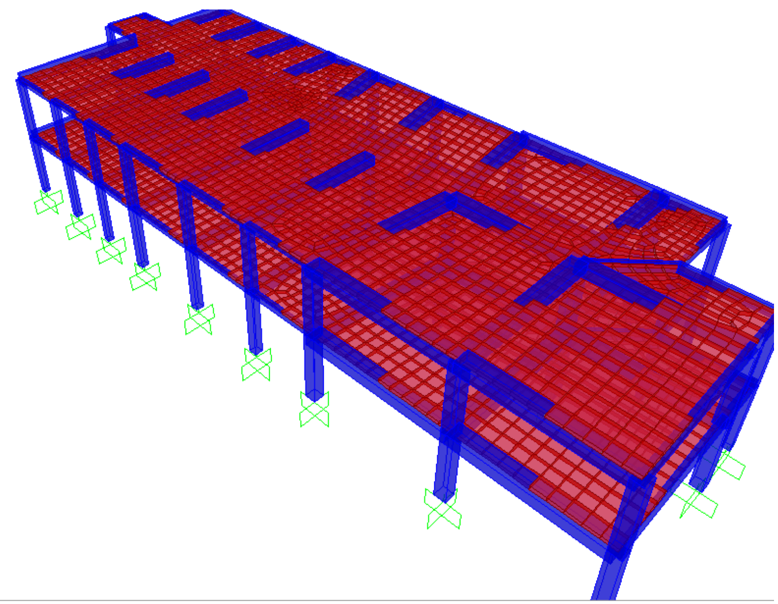
Part 3



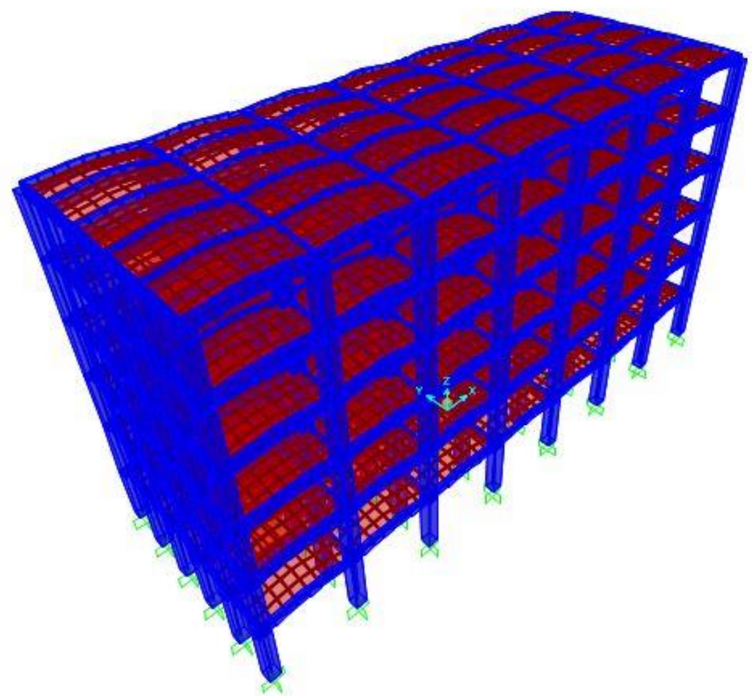
- This part was designed in three ways
  - Without seismic consideration



- With seismic consideration



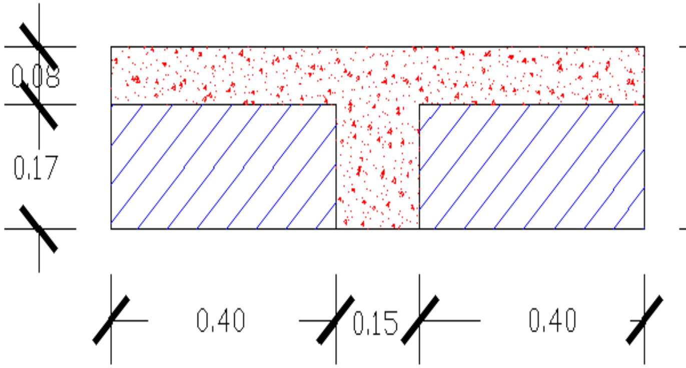
◦ With seismic consideration



Slab thickness

- In this part , two slab systems were used
- Solid slab
  - Based on deflection criteria in ACI, slab thickness was estimated to be 25 cm

- Ribbed slab
- slab thickness is 25 cm



Beams dimensions

- Minimum beams thicknesses were estimated based on deflection criteria and were enlarged to avoid strength failure.

- Beams width can be estimated using a conceptual equation

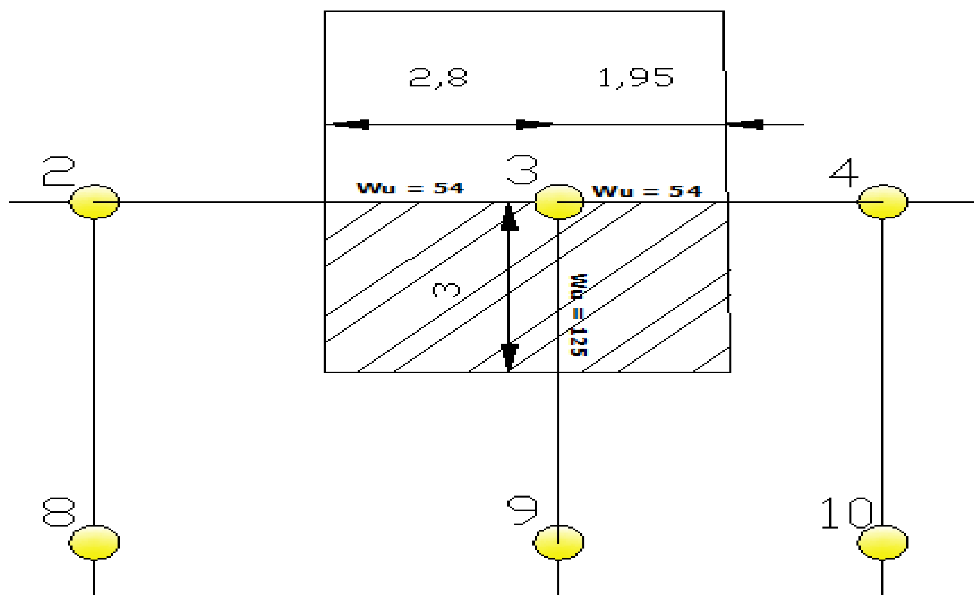
$$M_d = \frac{A_s d}{3}$$

using excel sheets the following results were obtained

						Main Beams					
Beam	Width	Length	Wt slab	Own	Wt Wall	Total Wt/m	Moment	D	B	B new	Discription
3=4	2.50	10.70	61.75	11.20	46.80	119.75	1,113.95	100.00	25.71	30	B6
4=5	2.50	9.40	61.75	11.20	46.80	119.75	859.72	100.00	19.84	30	B6
6=7	4.80	10.70	118.56	11.20	-	129.76	1,207.07	64.00	68.01	70	B1
7=8	4.80	9.90	118.56	11.20	-	129.76	1,033.32	64.00	58.22	70	B1
9=10	4.60	10.30	113.62	11.20	-	124.82	1,075.92	64.00	60.62	70	B1
10=11	4.60	9.80	113.62	11.20	-	124.82	974.00	64.00	54.88	70	B1
12=13	5.70	10.70	140.79	11.20	-	151.99	1,413.86	64.00	79.66	80	B2
13=14	5.50	9.40	135.85	11.20	-	147.05	1,055.71	64.00	59.48	80	B2
15=16	6.50	10.70	160.55	11.20	-	171.75	1,597.67	64.00	90.01	90	B3
16=17	6.50	9.60	160.55	11.20	-	171.75	1,286.06	64.00	72.46	90	B3
18=19	5.90	10.70	145.73	11.20	-	156.93	1,459.81	64.00	82.25	90	B3
19=20	7.10	9.60	175.37	11.20	-	186.57	1,397.04	64.00	78.71	90	B3
25=26	6.30	10.60	174.51	11.20	-	185.71	1,695.39	64.00	95.52	100	B4
26=27	7.50	9.40	207.75	11.20	-	218.95	1,571.90	64.00	88.56	100	B4
21=28	2.50	10.60	65.50	11.20	46.80	123.50	1,313.30	100.00	30.31	30	B6
28=37	2.50	9.80	61.75	11.20	46.80	119.75	934.44	100.00	21.56	30	B6
22=29	4.70	10.40	123.14	11.20	-	134.34	1,611.00	64.00	90.76	90	B3
29=S	4.90	4.50	128.38	11.20	-	139.58	229.65	64.00	12.94	90	B3
23=30	6.00	10.40	157.20	11.20	-	168.40	1,977.00	64.00	111.38	110	B5
30=S	6.00	4.50	157.20	11.20	-	168.40	277.07	64.00	15.61	110	B5
24=31	6.20	10.40	162.44	11.20	-	173.64	2,040.00	64.00	114.93	120	B11
31=38	6.50	9.70	170.30	11.20	-	181.50	1,387.53	64.00	78.17	120	B11
25=32	6.90	10.50	191.13	11.20	-	202.33	2,077.00	64.00	117.02	120	B11
32=39	6.90	9.50	191.13	11.20	-	202.33	1,483.65	64.00	83.59	120	B11

Columns preliminary dimensions

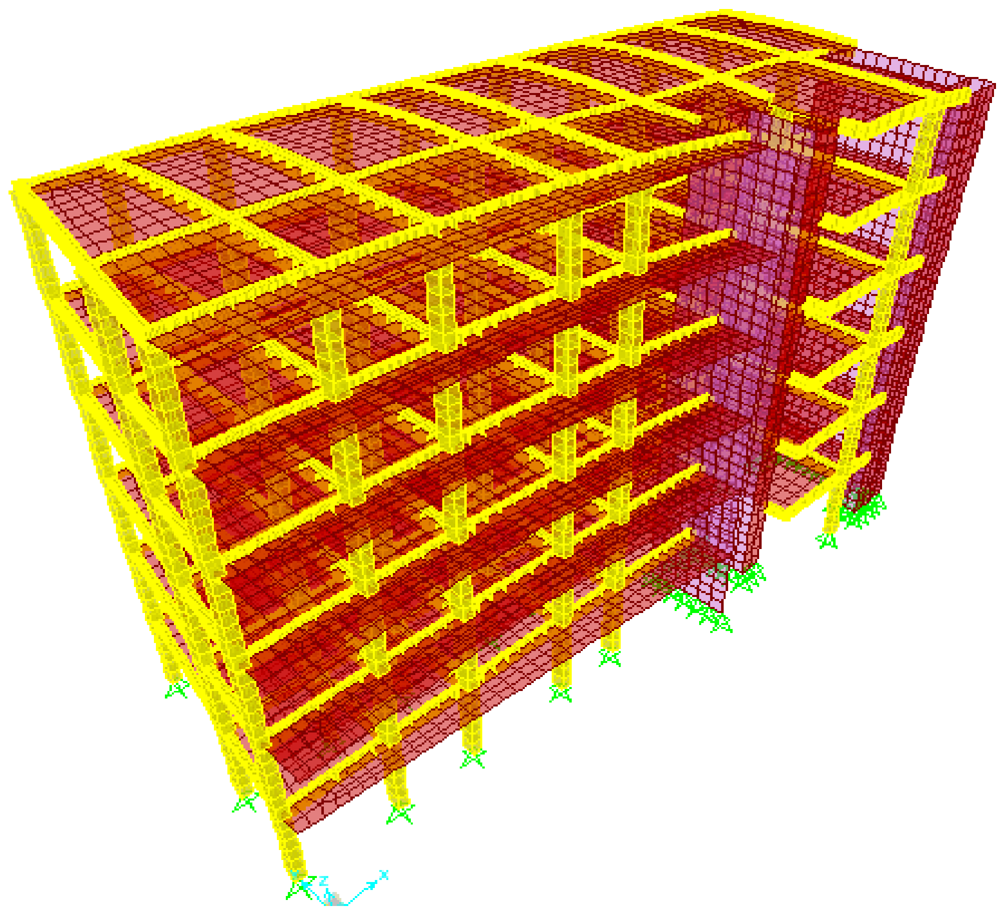
- Pu on each column can be calculated from summation of Wu from each beam connected to the column or by tributary area



Columns results

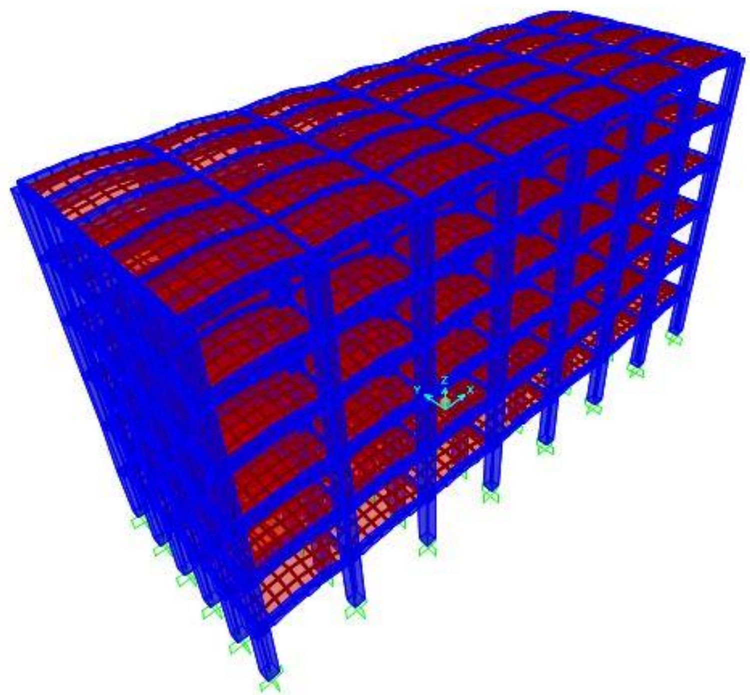
		Column	Total Pu	
		1	148.00	C1
148.00		2	148.00	C1
436.00		3	745.50	C1
466.00		4	1,311.50	C2
700.50		5	700.50	C1
706.00		6	953.50	C1
745.50		7	1,304.00	C2
860.00		8	870.00	C1
867.00		9	891.00	C1
870.00		10	1,250.00	C2
891.00		11	860.00	C1
904.00		12	1,121.00	C2
940.00		13	1,500.00	C2
953.50		14	940.00	C1
973.00		15	1,261.00	C2
1,020.00		16	1,735.00	C3
1,050.00		17	1,127.00	C2
1,121.00		18	1,150.00	C2
1,127.00		19	1,727.00	C3
1,150.00		20	1,280.00	C2
1,197.00		21	867.00	C1
1,217.00		22	973.00	C1
1,250.00		23	1,020.00	C2
1,261.00		24	1,050.00	C2
1,280.00		25	2,282.00	C3
1,294.00		26	2,032.00	C3
1,304.00		27	1,993.00	C3
1,311.50		28	1,470.00	C2
1,407.00		29	1,294.00	C2
1,470.00		30	1,407.00	C2
1,500.00		31	1,922.00	C3
1,612.00		32	3,185.00	C4
1,727.00		33	4,080.00	C5
1,735.00		34	1,612.00	C3
1,922.00		35	1,197.00	C2
1,971.00		36	466.00	C1
1,993.00		37	706.00	C1
2,032.00		38	1,217.00	C2
2,282.00		39	1,971.00	C3
3,185.00		40	904.00	C1
4,080.00		41	436.00	C1

SAP2000 Model

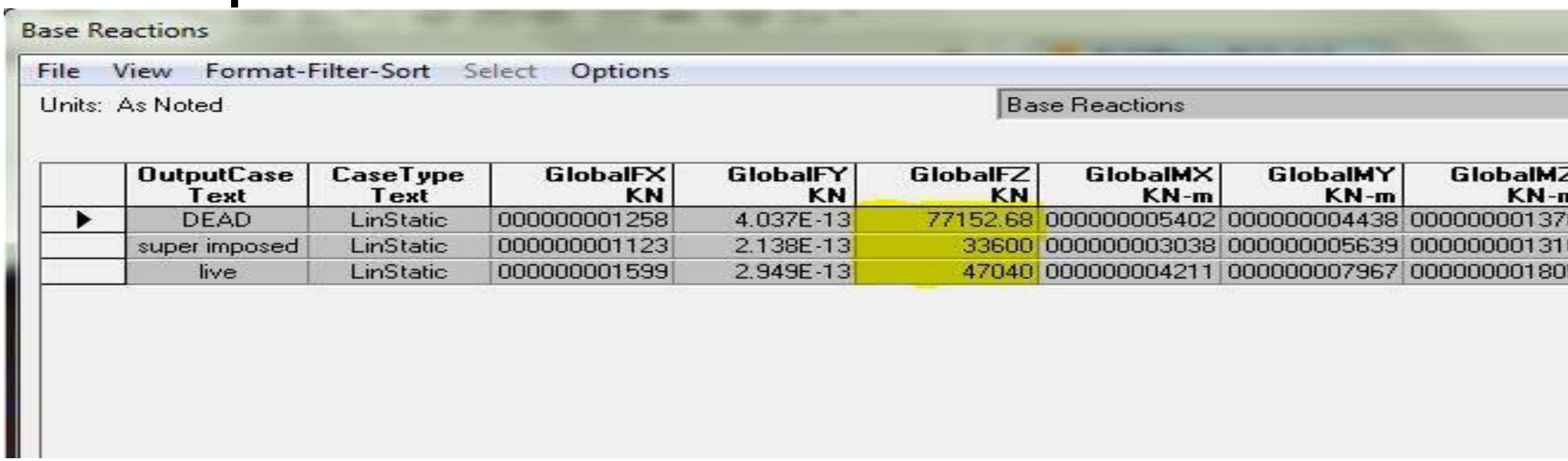


Sap model checks

- Compatibility



- Equilibrium



Base Reactions

File View Format-Filter-Sort Select Options

Units: As Noted

Base Reactions

	OutputCase Text	CaseType Text	GlobalFX KN	GlobalFY KN	GlobalFZ KN	GlobalMX KN-m	GlobalMY KN-m	GlobalMZ KN-m
▶	DEAD	LinStatic	000000001258	4.037E-13	77152.68	000000005402	000000004438	00000000137
	super imposed	LinStatic	000000001123	2.138E-13	33600	000000003038	000000005639	00000000131
	live	LinStatic	000000001599	2.949E-13	47040	000000004211	000000007967	00000000180

load	SAP	Hand cal.	error
Dead	77152.6	77152.7	0.0
Superimposed	33600	33600	0.0
Live	47040	47040	0.0

- Stress-Strain relationship
  - For one span
  - For one beam

Seismic analysis

- Z= 0.2 (zone 2), Soil type B (Rock), I= 1.25, R=5.5

$$For Z = 0.2 \ And \ S_B$$

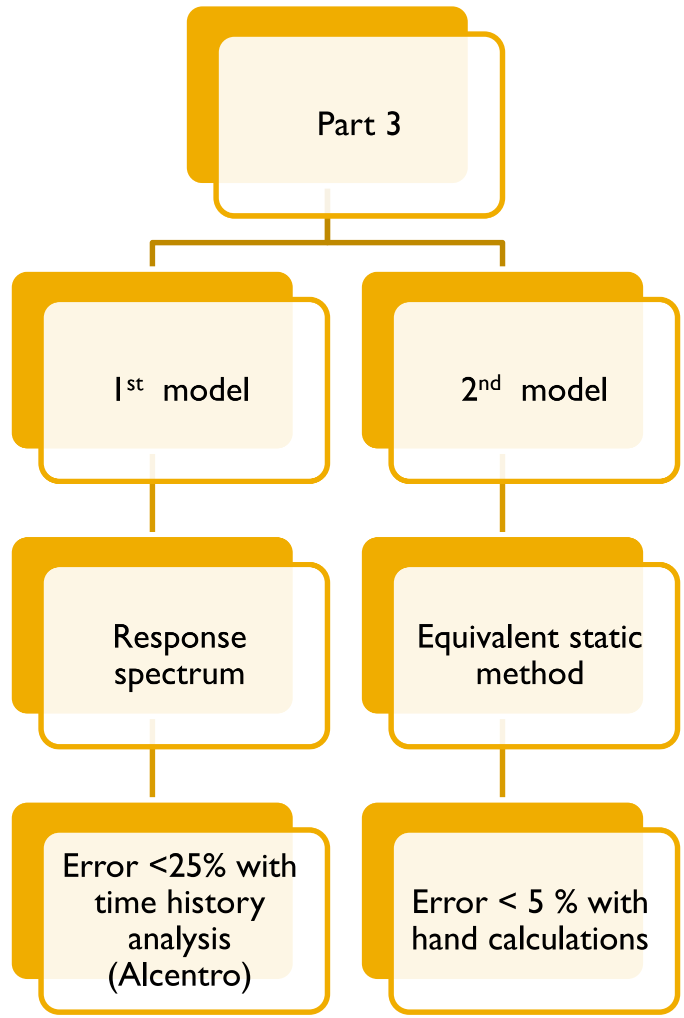
$$C_v = 0.2$$

$$C_a = 0.2$$

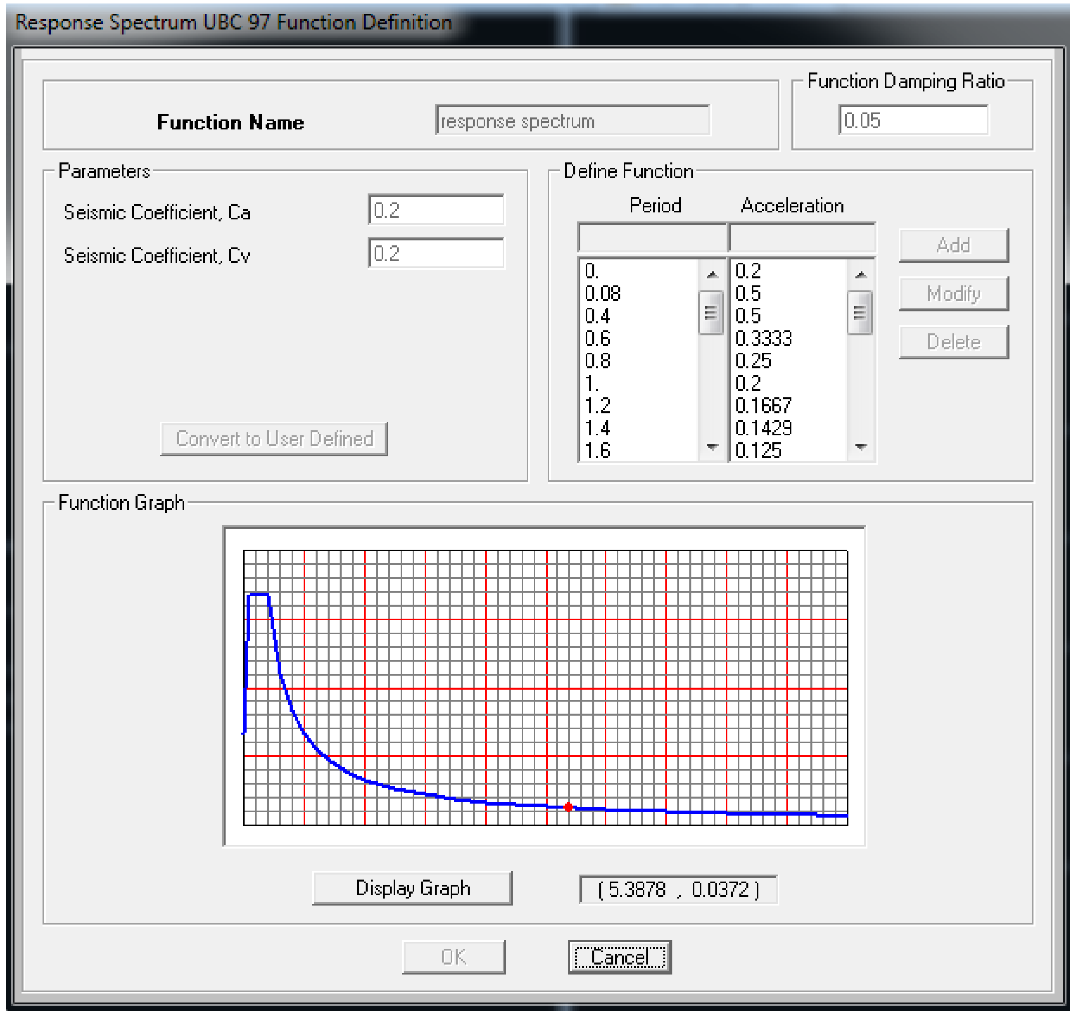
Model :

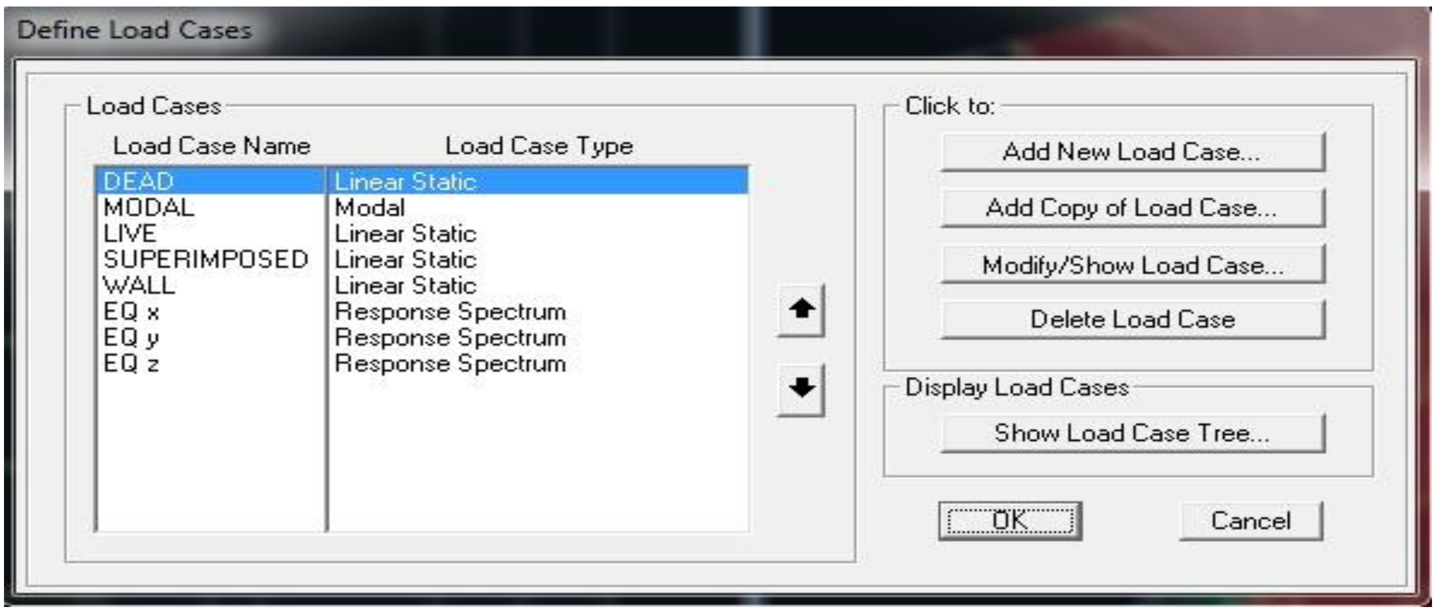
Earthquake :

Checks :



Response spectrum




Define Load Cases
Load Cases
Load Case Name
Load Case Type
DEAD
Linear Static
MODAL
Modal
LIVE
Linear Static
SUPERIMPOSED
Linear Static
WALL
Linear Static
EQ x
Response Spectrum
EQ y
Response Spectrum
EQ z
Response Spectrum
Click to:
Add New Load Case...
Add Copy of Load Case...
Modify/Show Load Case...
Delete Load Case
Display Load Cases
Show Load Case Tree...
OK
Cancel

Equivalent static method

$$C_s = \frac{C_v \times I}{R \times T}$$

$$C_s = \frac{0.2 \times 1.25}{5.5 \times 0.38} = 0.12$$

w = own + superimposed + 0.25 live = 122512.7 kN

$$T = 2\pi \sqrt{\left(\sum_{i=1}^{n} w_i \delta_i^{\,2}\right) \div \left(g \sum_{i=1}^{n} f_i \delta_i\right)} \quad (30\text{-}10)$$

Tx = Ty = 0.38 seconds

$$V = 0.12 \times 122512.7 = 14654.6 \ldots \ldots$$

$$V_{MAX} = \frac{2.5 \times C_a \times I}{R} \times W$$

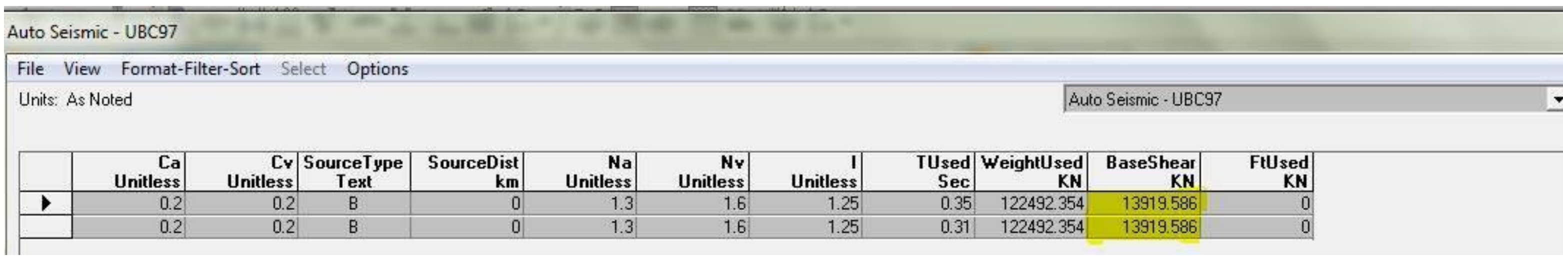
$$V_{MAX} = \frac{2.5 \times 0.2 \times 1.25}{5.5} \times 122512.7 = 13921.9$$

$$V_{MIN} = 0.11 \times C_a \times I \times W$$

$$V_{MIN} = 0.11 \times 0.2 \times 1.25 \times 122512.7 = 3369.1$$

$$V = 13921.9$$

SAP 2000 results



Auto Seismic - UBC97

File View Format-Filter-Sort Select Options

Units: As Noted

Auto Seismic - UBC97

Ca Unitless	Cv Unitless	SourceType Text	SourceDist km	Na Unitless	Nv Unitless	I Unitless	TUsed Sec	WeightUsed KN	BaseShear KN	FtUsed KN
0.2	0.2	B	0	1.3	1.6	1.25	0.35	122492.354	13919.586	0
0.2	0.2	B	0	1.3	1.6	1.25	0.31	122492.354	13919.586	0

V from sap = 13919.5 kN

Error < 5%

Design

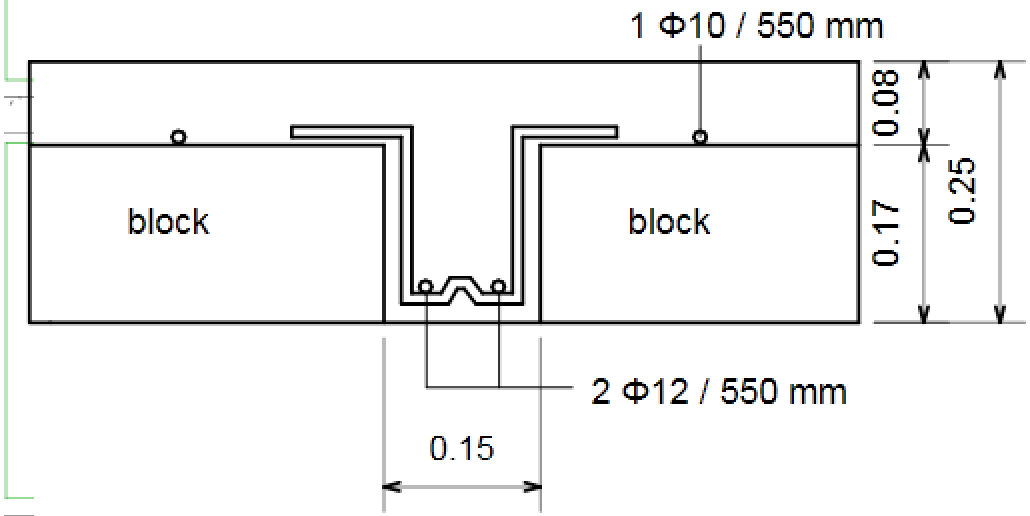
- 1- Slabs design
- 2- Beams design
- 3- Columns design
- 4- Footings design

Slab design

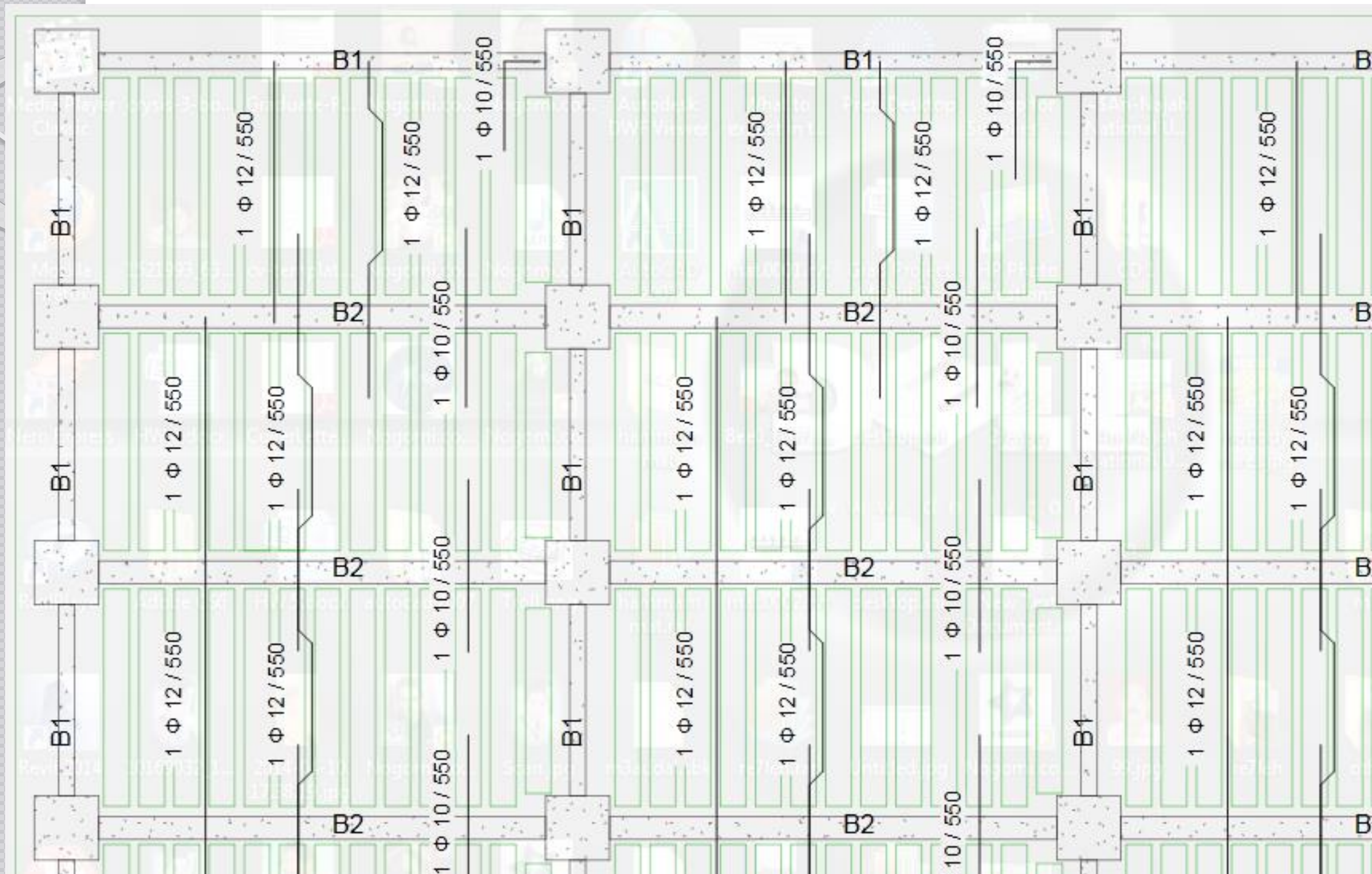
- One way ribbed slab
- Dimensions are the same from preliminary dimensions
- Check shear capacity
- Find max positive and negative moment
- Find ρ
- Find As and compare with minimum As
- Choose a suitable reinforcement & check for spacing

- From SAP we find max M+ , M- for both directions X & Y

- Max +ve moment = 16.5 kN/ rib
- Max –ve moment = 4.4 kN/ rib

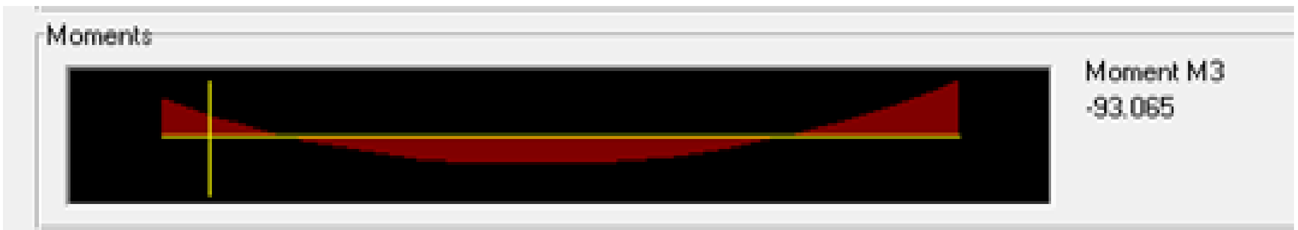


typical cross section in slab


B1
B2
1 Φ 12 / 550
1 Φ 10 / 550

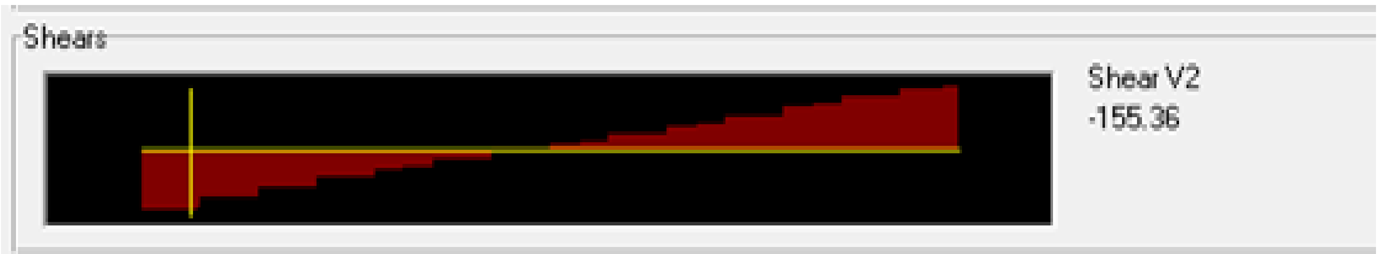
Beams design

- Design for Bending moment



- Take moment from SAP
- Find ρ
- Check for ρ min
- Find area of steel

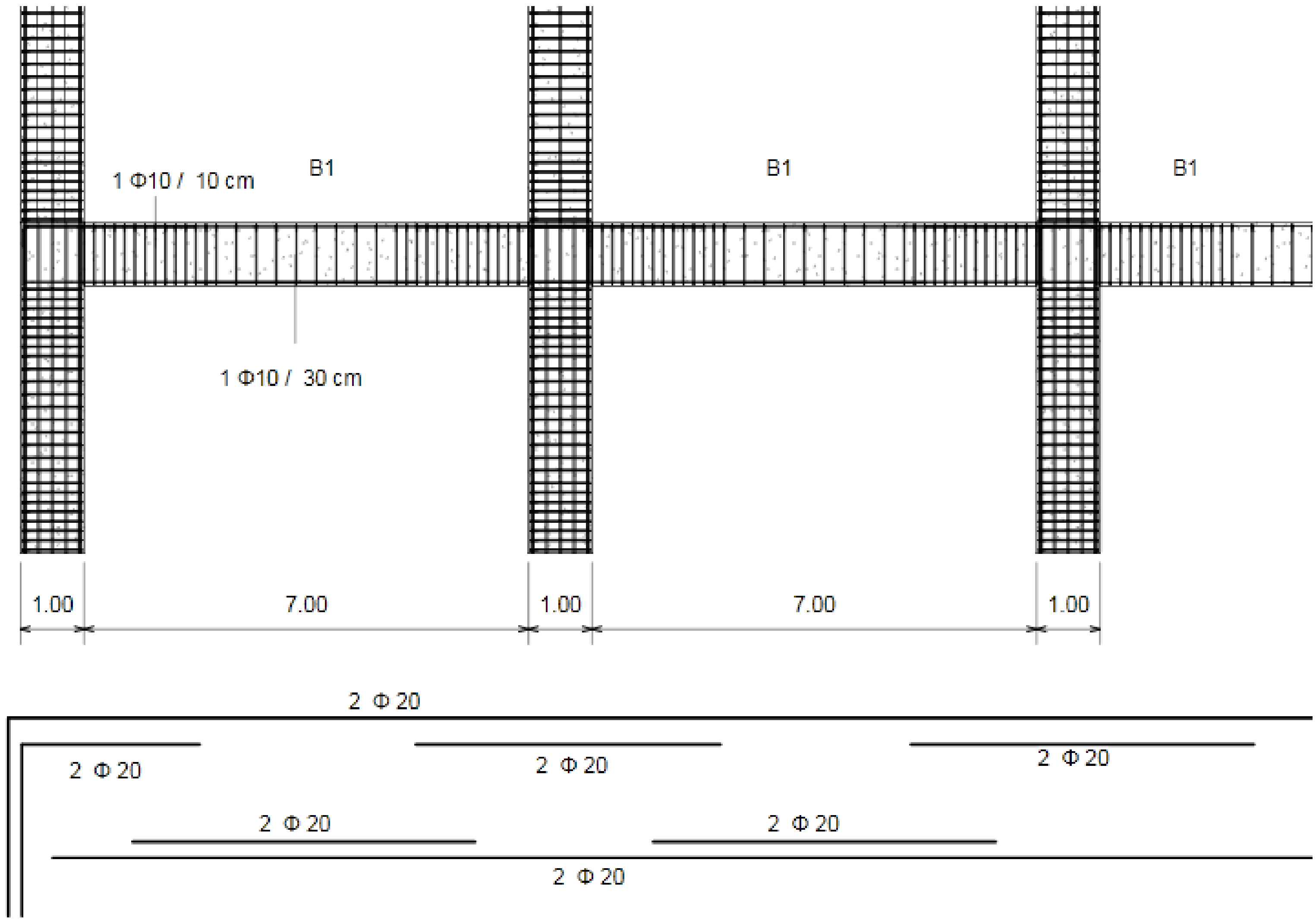
- Design for Shear



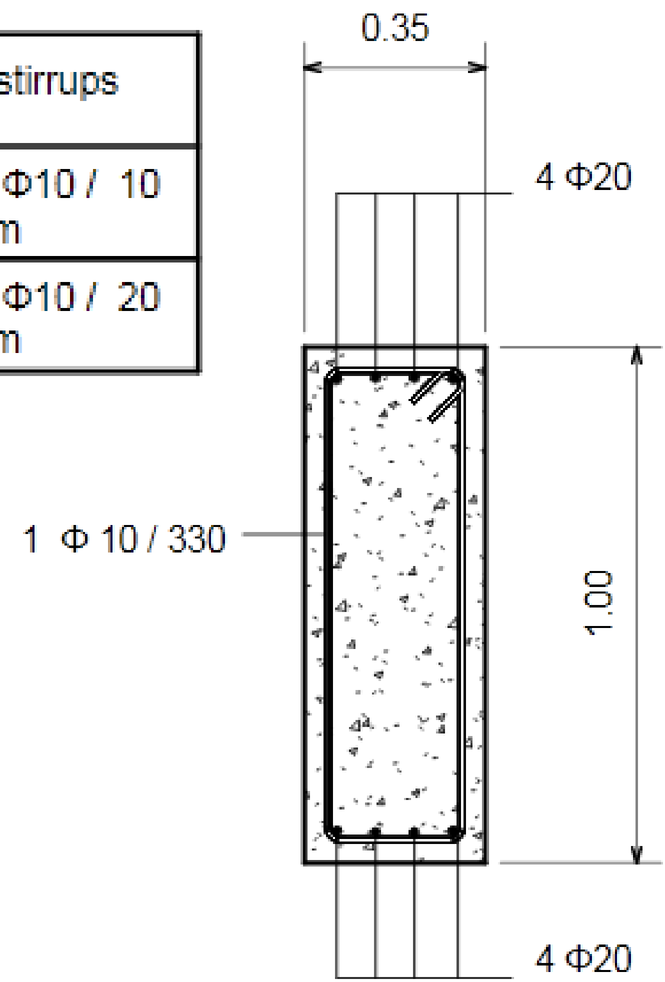
- Take Vu from SAP
- Find Vc and check for need of steel
- Check spacing

SAP results

Beam	Max –ve moment	reinforce ment	Max +ve moment	reinforce ment	Vs = (Vu-0.75Vc)	Shear reinforce ment
main	352	4Φ 20	310	4Φ 20	425	1 Φ 8 / 100 mm
secondary	273	3Φ 20	300	3Φ 20	232	1 Φ 8 / 300 mm


1 Φ10 / 10 cm
B1
B1
B1
1 Φ10 / 30 cm
1.00
7.00
1.00
7.00
1.00
2 Φ 20
2 Φ 20
2 Φ 20
2 Φ 20
2 Φ 20
2 Φ 20
2 Φ 20

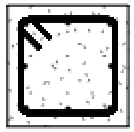
beam	dimensions	top bars	bottom bars	stirrups
B1	35 X 100	4 Φ 20	4 Φ 20	1 Φ10 / 10 cm
B2	25 X 100	3 Φ 20	3 Φ 20	1 Φ10 / 20 cm



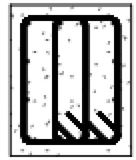
Columns design

- Modify column dimensions in SAP until we have $A_s = 0.01\,A_g$
- Check SAP results using interaction diagrams
- Find As and suitable reinforcement

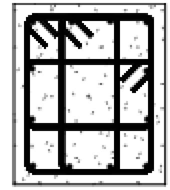
column	dimensions	bars	stirrups
C1	40 X 40	8 Φ 16	1Φ 10
C2	40 X 50	10 Φ 16	2Φ 10
C3	50 X 60	12 Φ 18	3Φ 10
C4	25 X 40	12 Φ 20	1Φ 10
C5	50 X 50	12 Φ 18	3Φ 10
C6	60 X 60	12 Φ 20	3Φ 10
C7	50 X 70	12 Φ 20	3Φ 10
C8	80 X 80	16 Φ 25	2Φ 10
C9	100 X 100	16 Φ 32	2Φ 10
C10	60 X 60	12 Φ 20	3Φ 10
C11	60 X 80	16 Φ 20	3Φ 10
C12	60 X 90	18 Φ 20	3Φ 10



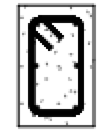
C1



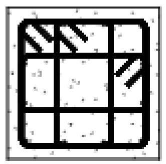
C2



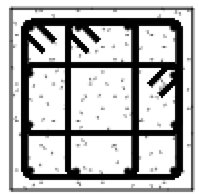
C3



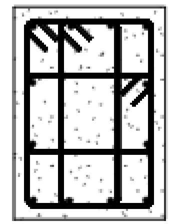
C4



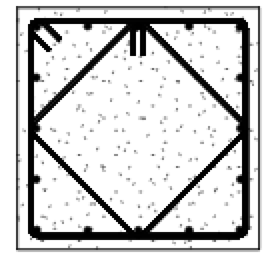
C5



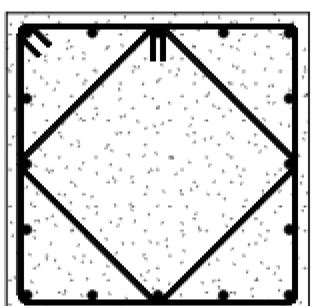
C6



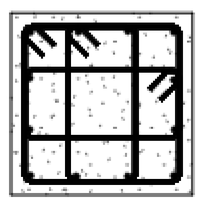
C7



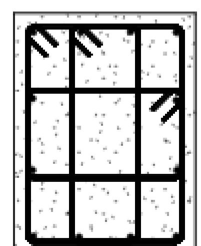
C8



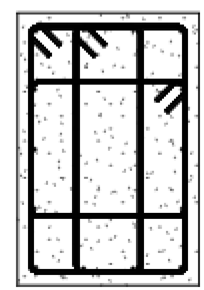
C9



C10



C11



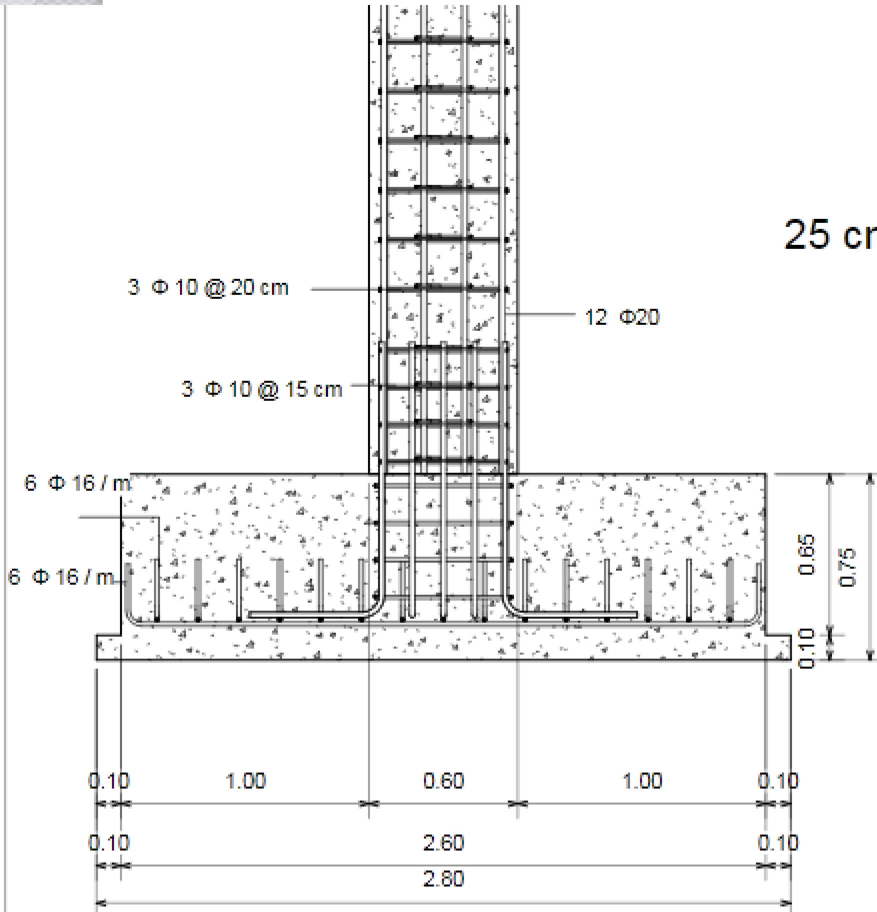
C11

Footings design

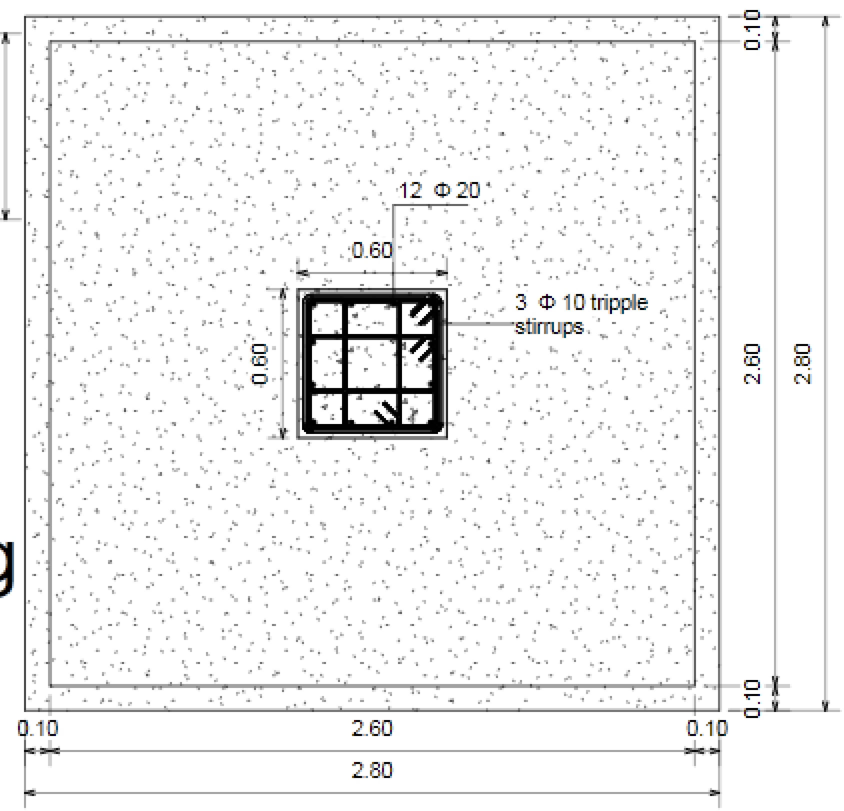
- Choose the largest footing area from the following calculations :
  - A = Axial(LL + DL) / q all
  - A = Axial (LL + DL + EQ env) / 1.3 q all

- Calculate the thickness of the footing based on punching shear and wide beam shear
- Find Moment and As

footing	dimensions	shorter di reinf.	longer di reinf.
F1	1.8X1.8X0.45	5 Φ 16 /m	5 Φ 16 /m
F2	2X2.1X0.5	5 Φ 16 /m	5 Φ 16 /m
F3	2.6X2.7X0.55	7 Φ 16 /m	7 Φ 16 /m
F4	2X2.1X0.5	5 Φ 16 /m	5 Φ 16 /m
F5	2X2X0.5	5 Φ 16 /m	5 Φ 16 /m
F6	2.6X2.6X.65	6 Φ 16 /m	6 Φ 16 /m
F7	3.1X3.3X0.75	8 Φ 16 /m	8 Φ 16 /m
F8	3.4X3.4X0.8	8 Φ 16 /m	8 Φ 16 /m
F9	3.5X3.5X0.85	5 Φ 20 /m	5 Φ 20 /m
F10	3.5X3.5X0.8	7 Φ 18 /m	7 Φ 18 /m
F11	4X4.2X0.95	8 Φ 18 /m	8 Φ 18 /m
F12	4.1X4.4X1	7 Φ 20 /m	7 Φ 20 /m



typical sections in footing



Conclusion and Recommendations

- The EQ mainly affects the design of columns. The effect of it on slab and beams is too small.
- Using drop beams leads to a rigid diaphragm which is easier to predict its behavior in lateral loads
- The architect and the civil should work together in selecting the shape of the structure and the distribution of the structural elements

- Making a symmetrical structure will also make it easier to predict its behave under lateral forces

- Having tie beams with suitable dimensions will let us neglect the moment effect on the footings

Thank you