KUPPAM ENGINEERING COLLEGE

DESIGN CONCEPTS IN RAFT FOUNDATION FOR HIGH RISE BUILDINGS

DEPARTMENT OF CIVIL ENGINEERING

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RAFT FOUNDATIONS

Also known as Mat foundations

- It is a continuous slab resting on the soil
- Extends over the entire footprint of the building thereby supporting the building and transferring its weight to the ground.
- Best suitable when have a basement floor (High rise structures)

RAFT FOUNDATIONS

When do we need a raft foundation?

- Bearing capacity of the soil is low
- Load to be transferred to the ground is high
- Deep foundation becomes uneconomical
- More number of columns
- The total footing area is greater than 50% of the building area

RAFT FOUNDATION

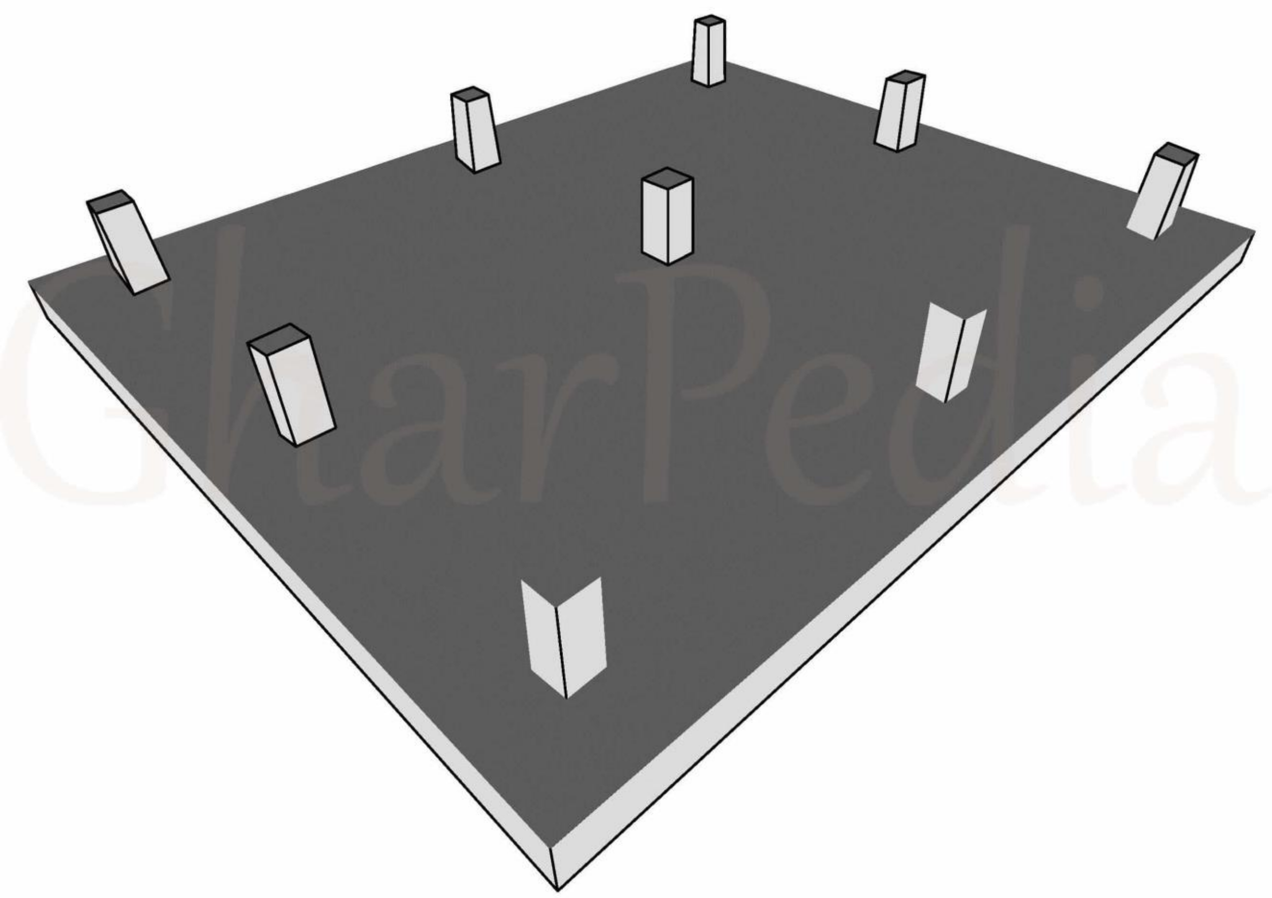
Advantages

- Supports large number of columns
- Helps overcome differential settlement
- Distributes the loads on a wider area thereby not exceeding allowable bearing capacity
- The only shallow foundation to carry heavy loads
- Can carry lateral loads too
- Resists uplift pressure

RAFT FOUNDATIONS TYPES

Flat Slab Type Raft Foundation

- Used when the columns are equally spaced
- Meaning uniform pressure throughout the slab.
- Slab has uniform thickness

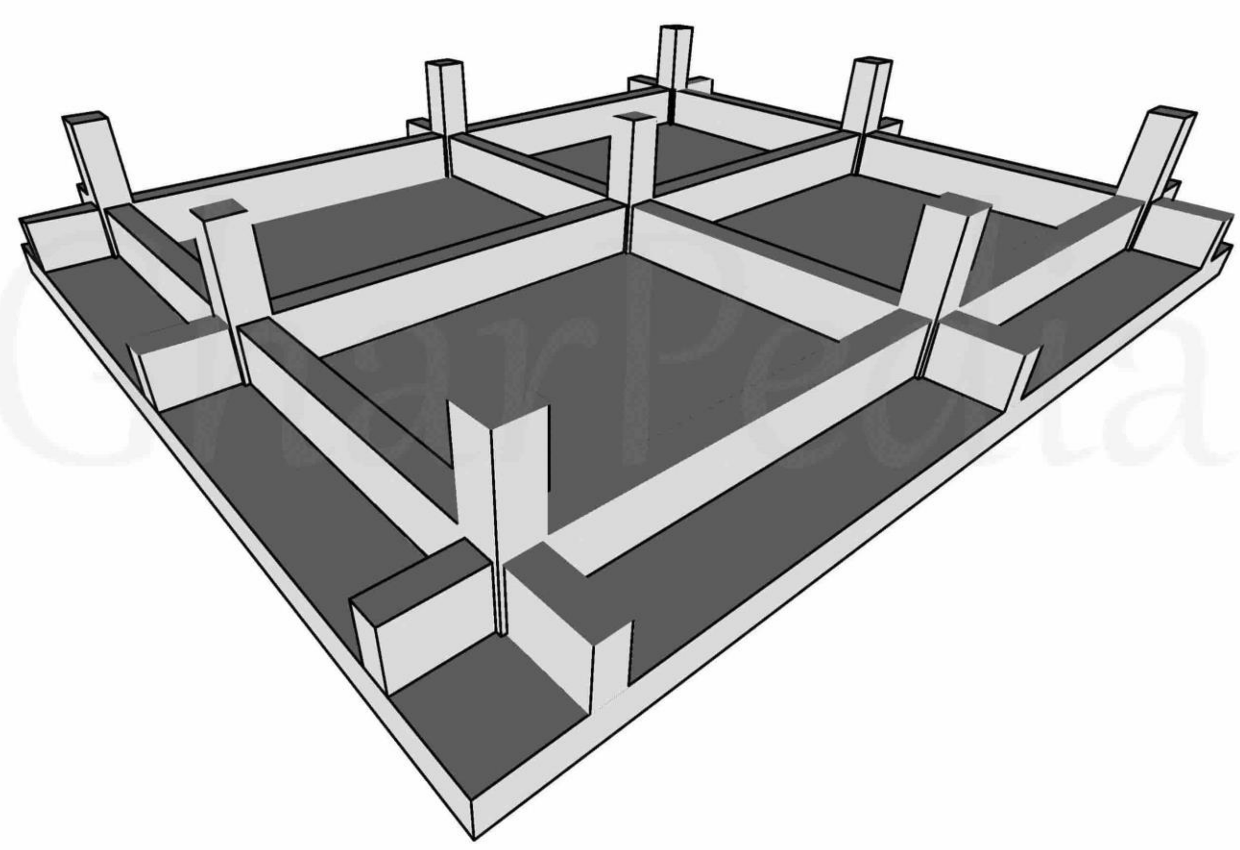


Flat slab type raft foundation

RAFT FOUNDATIONS TYPES

Slab-Beam Type Raft Foundation:

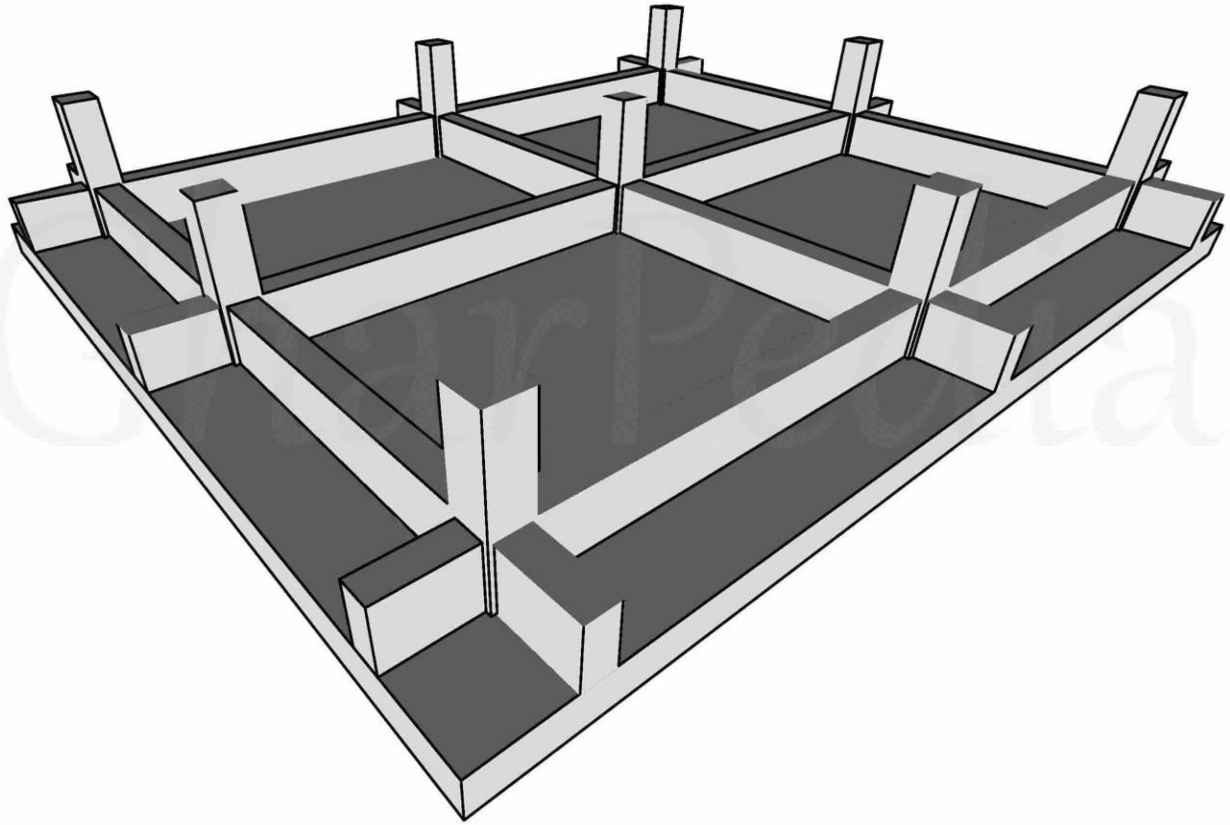
- Used when column loads are unequally distributed .
- To avoid excessive distortion of the structure as a result of variation in the load distribution on the raft. In this type of raft foundation beams are provided with the flat slabs.



Slab-beam type raft foundation

RAFT FOUNDATIONS TYPES

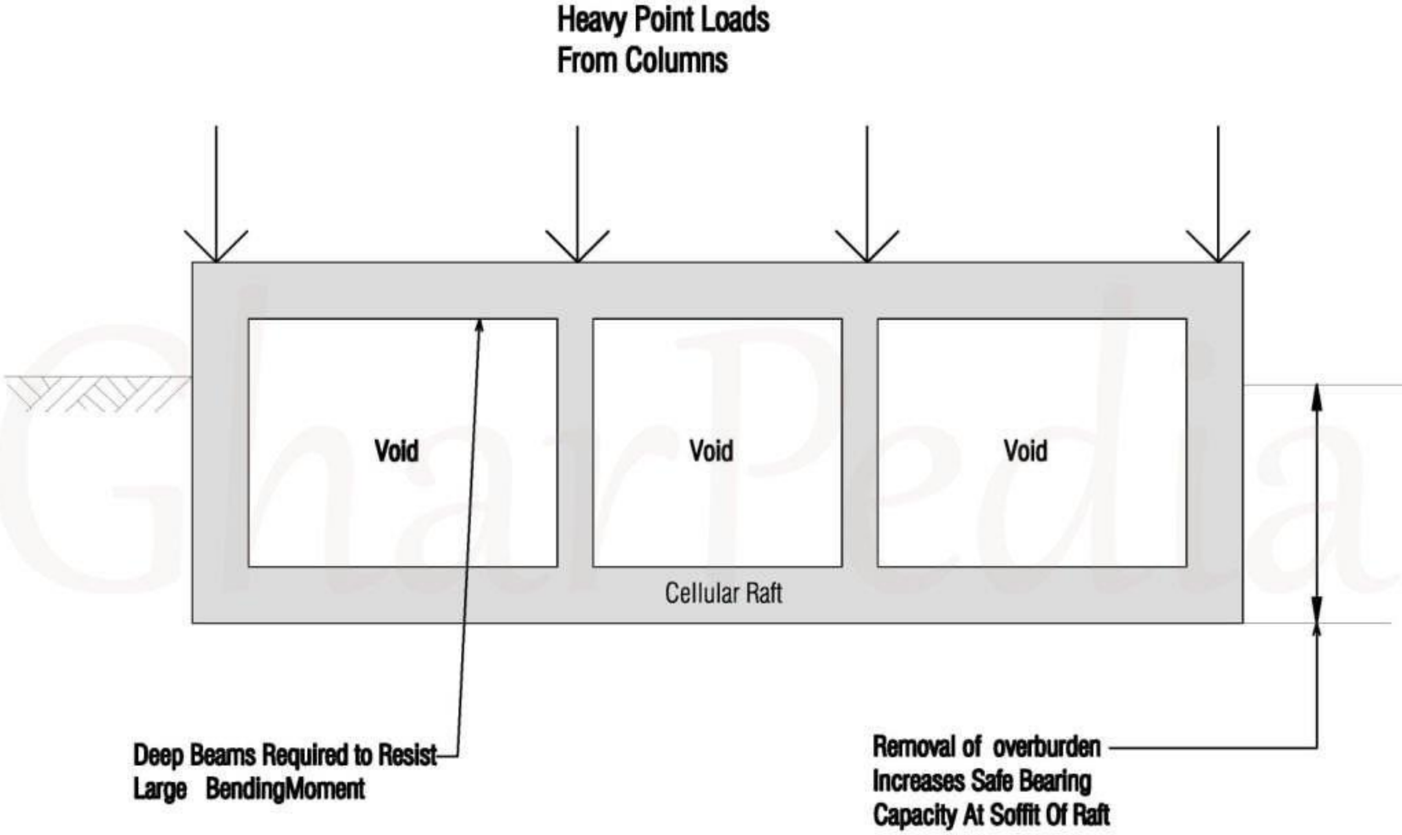
- ***Slab-Beam Type Raft Foundation***:
- The beams add stiffness to the raft foundation.
- The foundation slabs are reinforced with two more steel meshes. One placed on the lower face and another at the upper faces of the raft foundation.
- The raft beams are reinforced with strong stirrups and bars placed at the upper and lower faces.



Slab-beam type raft foundation

RAFT FOUNDATIONS TYPES

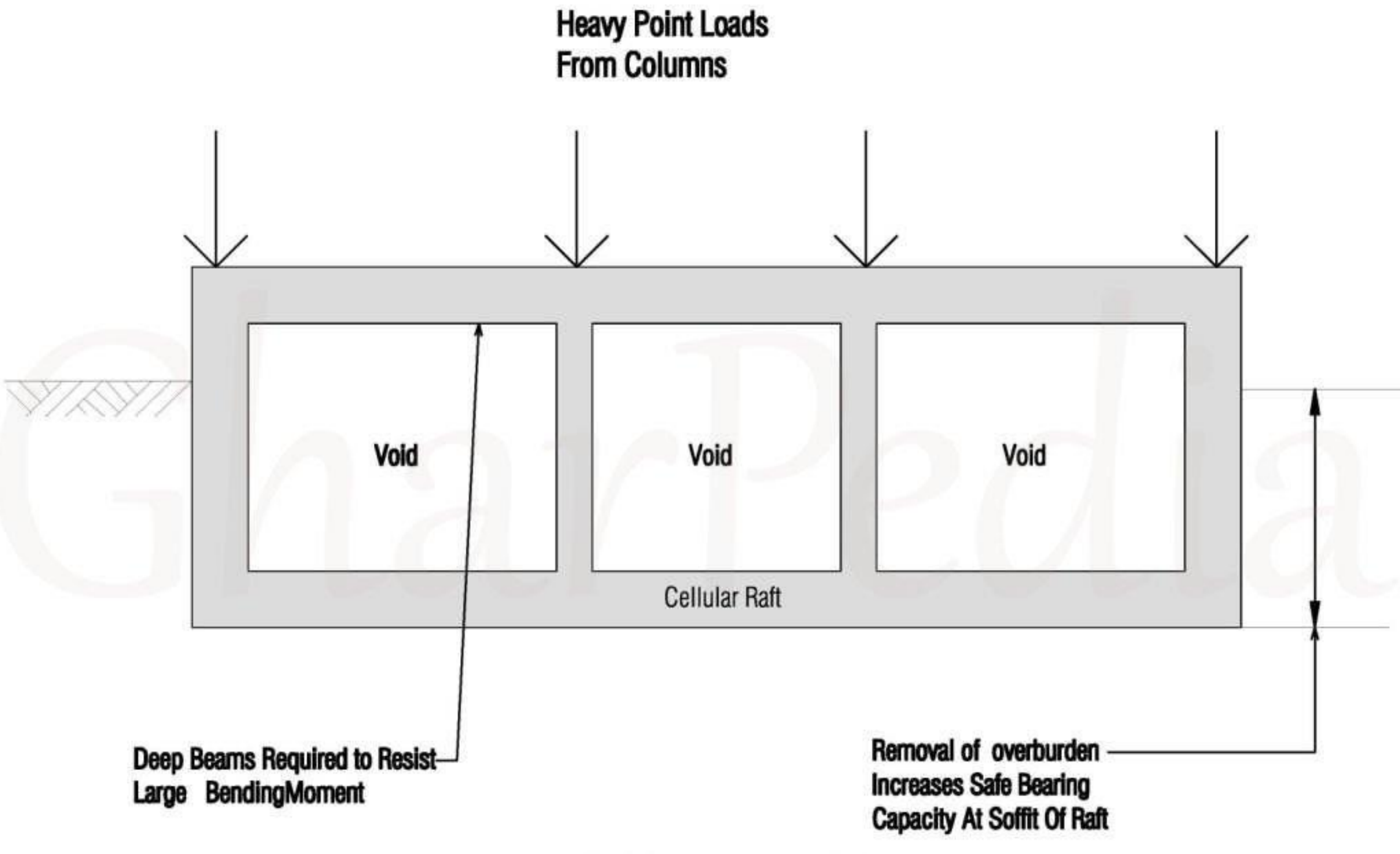
- **Cellular Type Raft Foundation:**
- In case of heavy structures on loose soil or when soil tends for uneven settlement, the thickness required will be more than 1m.
- In such case, cellular raft foundation is more preferable than ordinary raft foundation.



Cellular type raft foundation

RAFT FOUNDATIONS TYPES

- **Cellular Type Raft Foundation:**
- Consists two slabs where a beam is constructed of two slabs in both directions forming hollow cellular raft foundation.
- These foundations are highly rigid and more economical than other foundations in such type of poor soil

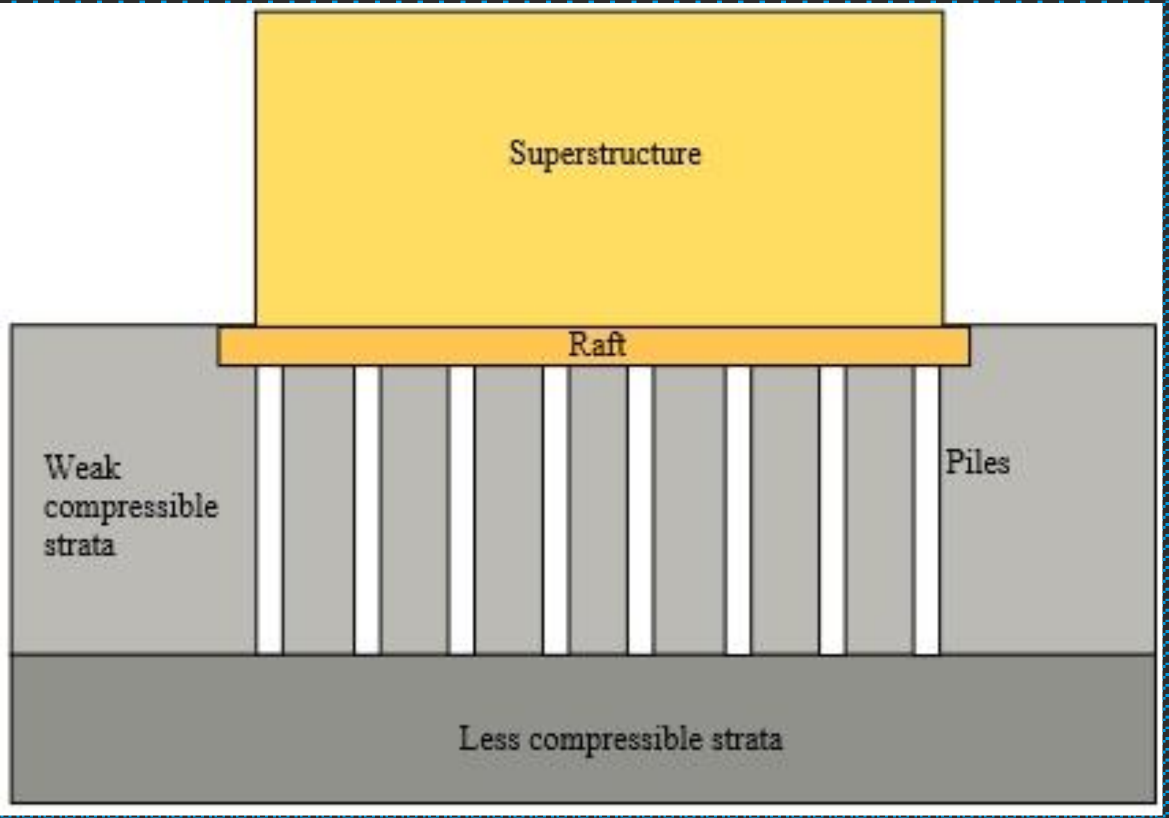


Cellular type raft foundation

RAFT FOUNDATIONS TYPES

Piled Raft foundation

- When the soil so weak that there is an excessive settlement of the raft slab then Raft slab is laid on the piles.
- Load is carried by the raft slab and settlement is resisted by piles



DESIGN OF RAFT SLAB

Two approaches

- Rigid foundation approach
- Flexible foundation approach

Rigid Approach **-** In rigid foundation approach, it is presumed that raft is rigid enough to bridge over non-uniformities of soil structure. Pressure distribution is considered to be either uniform or varying linearly.

(a) Inverted floor system (b) Combined footing approach

- In rigid rafts, differential settlements are comparatively low but bending moment and shear forces to which raft is subjected are considerably high

DESIGN OF RAFT SLAB

Flexible Approach

- In this approach, raft distributes the load in the area immediately surrounding the column depending upon the soil characteristics.
- Differential settlements are comparatively larger but bending moments and shear forces are comparatively low. Two approaches

*(a) Flexible plate supported on elastic foundation, **i.e.,** Hetenyi's Theory*

*(b) Foundation supported on bed of uniformly distributed elastic springs with a spring constant determined using coefficient of sub-grade reaction. Each spring is presumed to behave independently, **i.e.,** Winklers's foundation*

DESIGN OF RAFT SLAB

Pressure distributed under the raft

(1) The nature of the soil below the raft

(2) The nature of the foundation, ***i.e.***, whether rigid, flexible or soft

(3) Rigidity of the super-structure

(4) The quantum of loads and their relative magnitude

(5) Presence of adjoining foundation

(6) Size of raft

(7) Time at which pressure measurements are taken

DESIGN OF RAFT SLAB

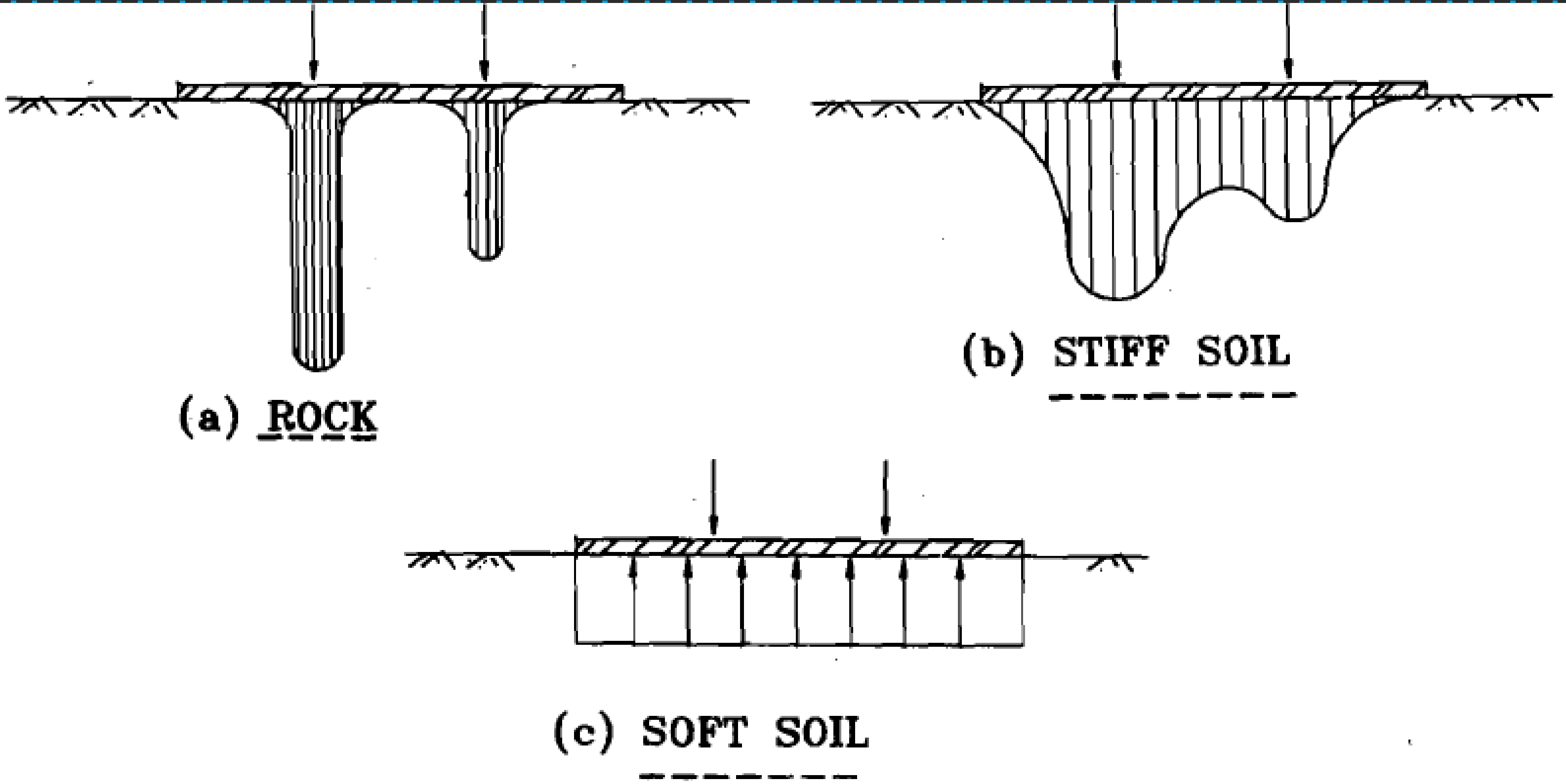


Fig. 5.1 Contact pressure distribution under a raft

DESIGN OF RAFT SLAB

Settlement of Raft Slab

- The total settlement under the raft foundation can be considered to be made up of three components, ***i.e.,***

S = ***Sd+Sc+Ss***

Where,

Sd is the immediate or distortion settlement

Sc the consolidation settlement and

Ss is the secondarycompression settlement

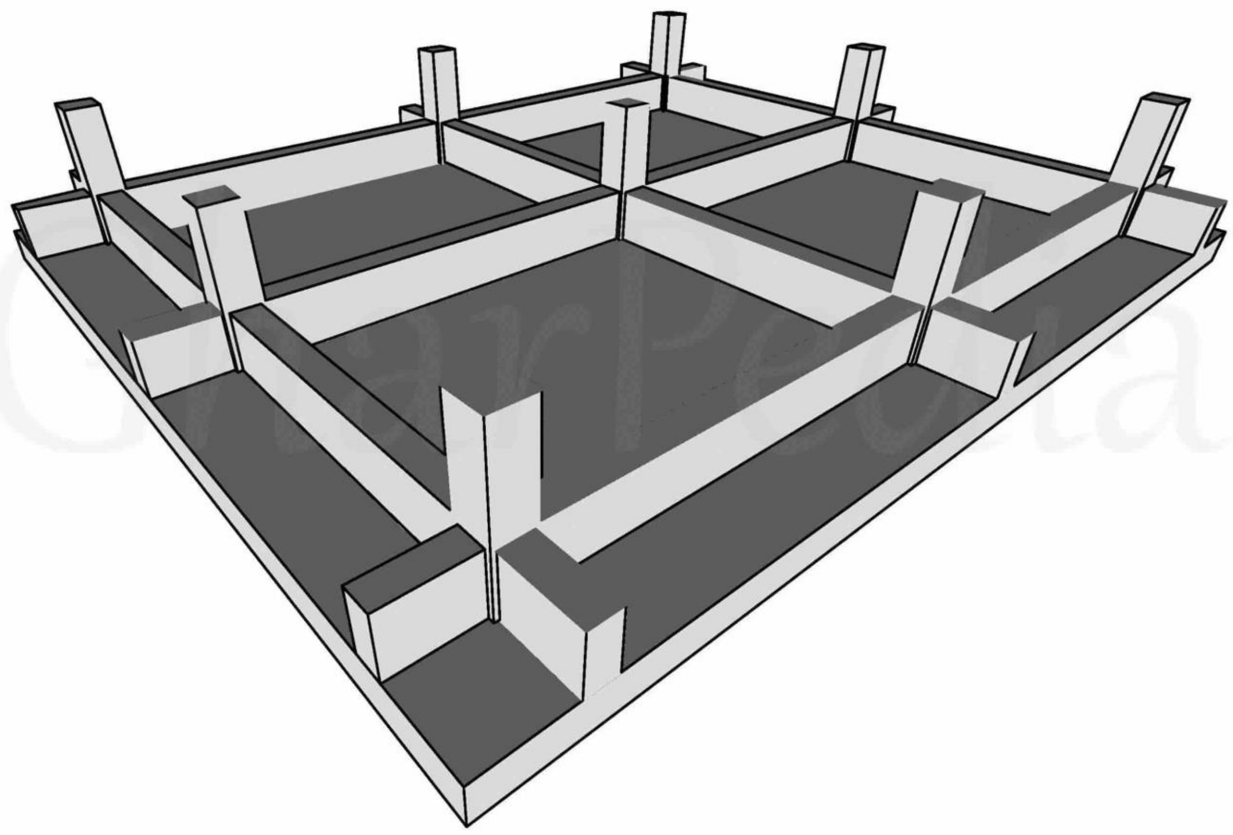
DESIGN OF SLAB-BEAM TYPE RAFT SLAB

Design of Slab-beam type raft slab (Inverted slab)

- The most common approach in Medium rise residential/commercial buildings
- The raft slab is designed as an inverted slab
- The uplift pressure is the loading on the slab, for which BM and SFs are calculated
- The raft beams stiffen the raft slab
- Raft beams are designed as inverted floor beams subjected to uplift pressure

DESIGN OF SLAB-BEAM TYPE RAFT SLAB

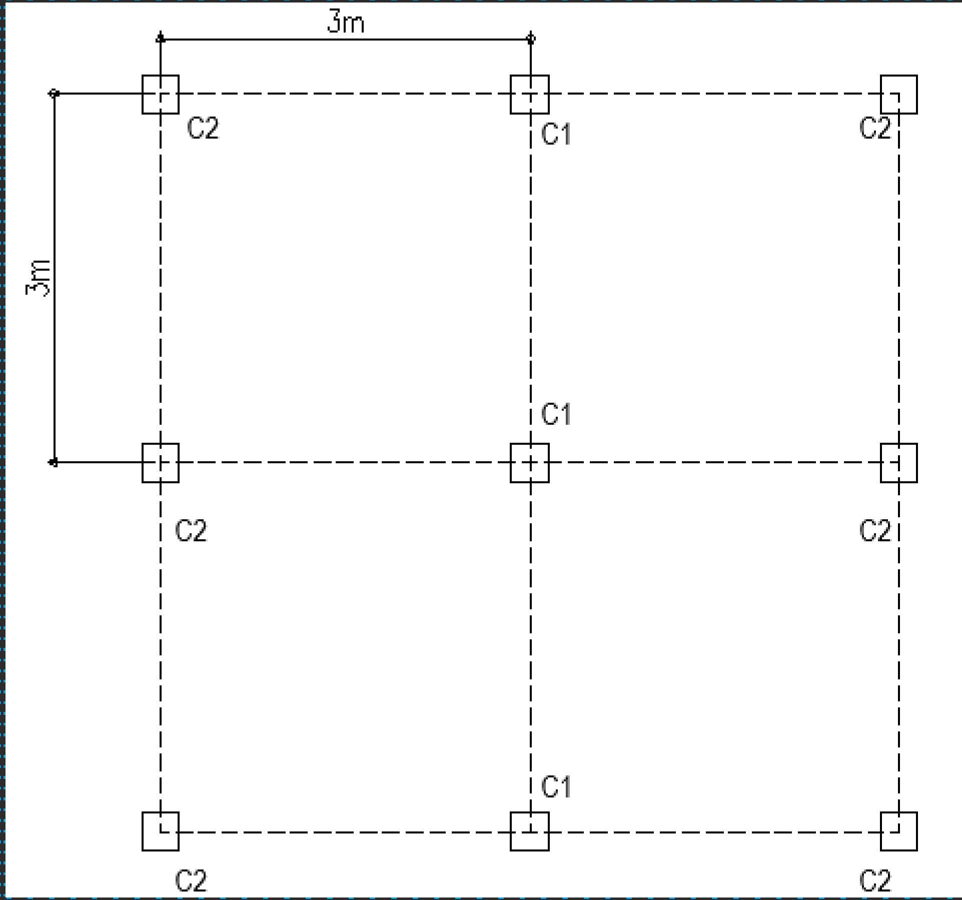
- Area of the slab will be equal to footprint of the building.
- Cantilever portions are not always necessary, depends on the area required



Slab-beam type raft foundation

DESIGN OF SLAB-BEAM TYPE RAFT SLAB

- Example for discussion
- Design a raft footing for the foundation plan shown. Assume SBC 150kN/m²
- C1 – 300x300 – 800 kN
- C2 – 300x300 – 600 kN



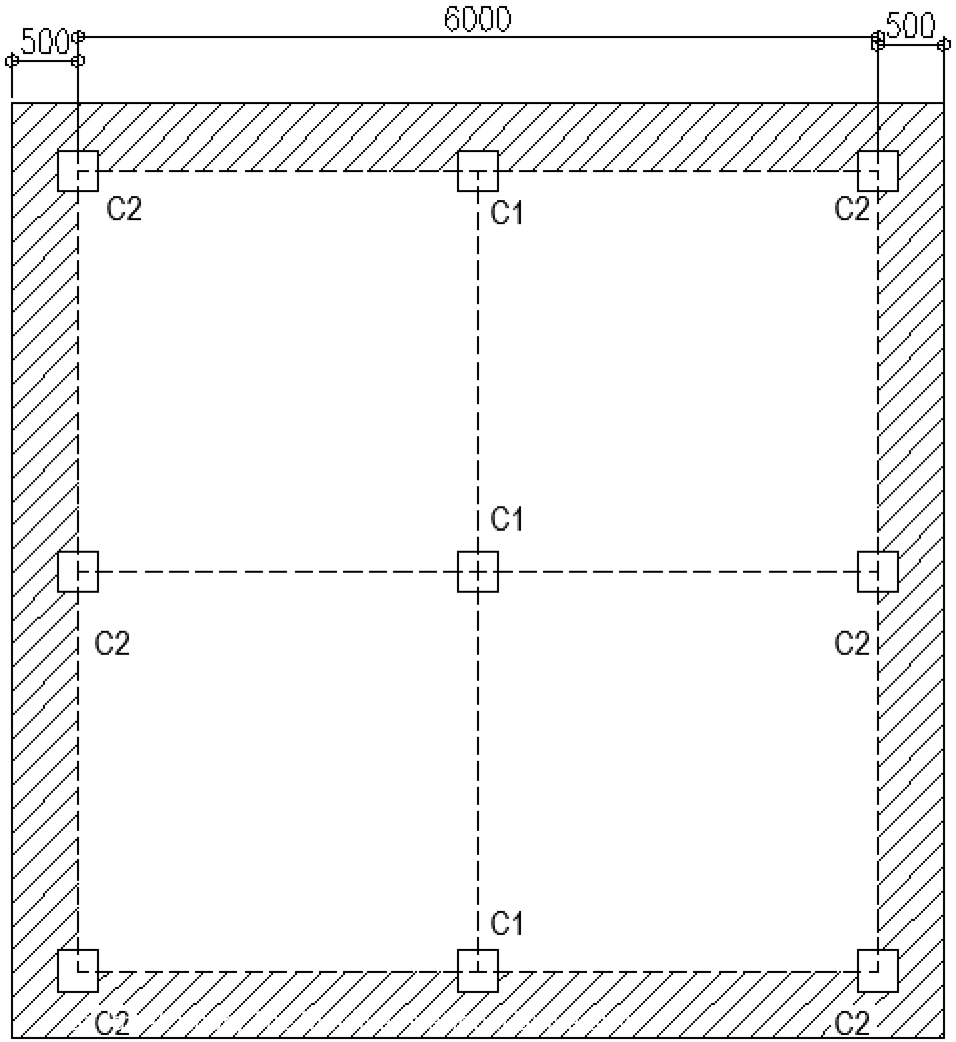
DESIGN OF SLAB-BEAM TYPE RAFT SLAB

Solution : -

- Calculation of column loads
- Load from column C_1 = 3 x 800 = 2400 kN
- Load from column C_2 = 6 x 600 = <u>3600</u> kN
- Total load on Foundation = 6000 kN
- Self weight of Foundation, 10% = 600 kN
- Total load, w = 6600 kN
- Area of footing required, A = 6600/150 = 44 m^2 - SBC = 150kN/ m^2
- Footprint area of the grid = 6.3x6.3 = 39.69 m^2 < Area required.

DESIGN OF SLAB-BEAM TYPE RAFT SLAB

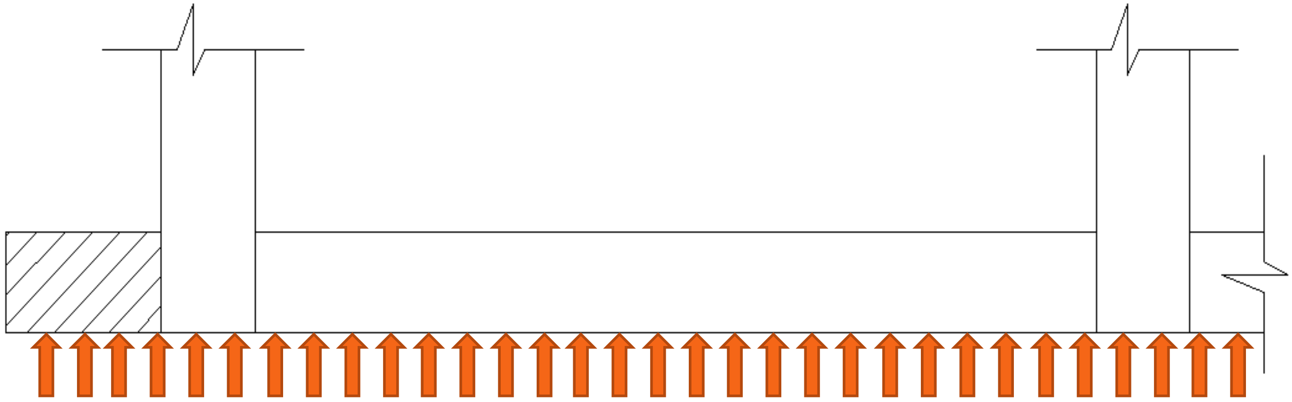
- Adopt a size of 7mx7m = $49m^2$
- Since, the grid cannot be changed, Extend the raft on the edges on all four sides as shown in the figure.
- Now this area would be sufficient.



DESIGN OF SLAB-BEAM TYPE RAFT SLAB

Net upward pressure,

- p = Load of columns/Area provided
- $p = 6000/49 = 122.45\ kN/m^2 < SBC$



- Slab-beam type Raft slab is designed as inverted slab subjected to the Upward pressure $122.45\ kN/m^2$
- The raft slab has interior panels as well as a cantilever portion as shown above.
- Hence we have to design both Interior panel and the cantilever portion.

DESIGN OF SLAB-BEAM TYPE RAFT SLAB

- A) Cantilever Slab

Bending Moment, $M = 1.5 \times wl^2 / 2 = 1.5 \times 122.45 \times 0.35^2 / 2$

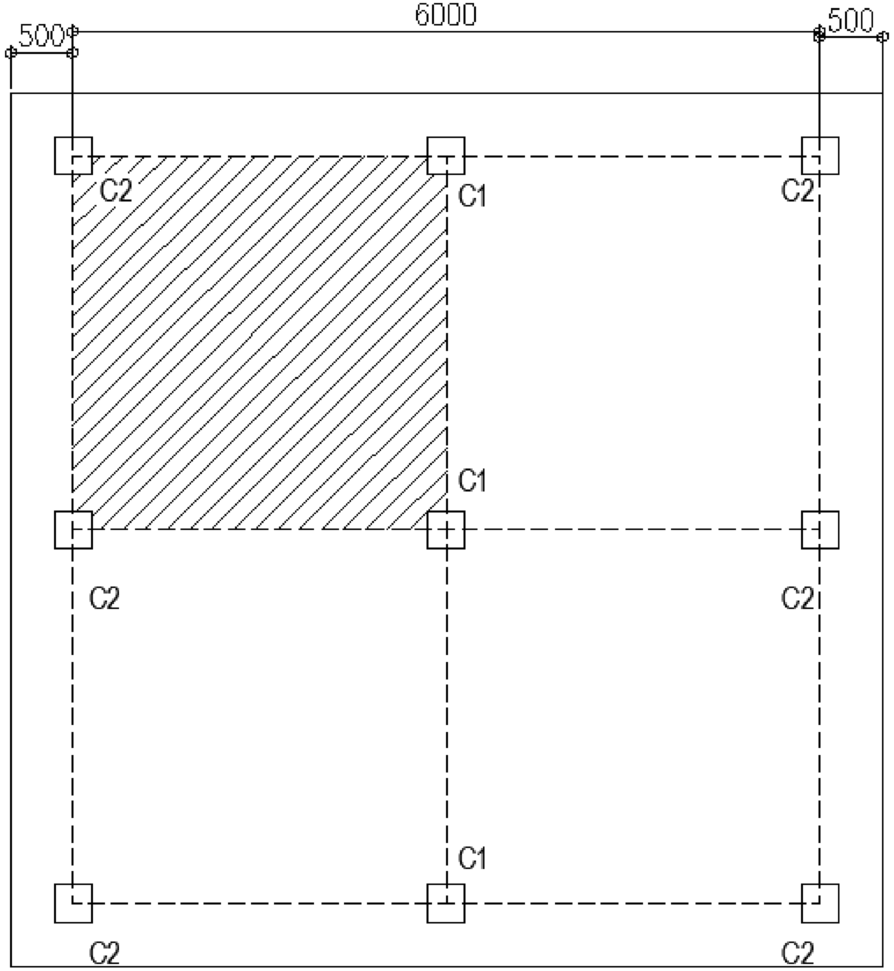
- $M = 11.25$ kN-m

- B) Interior Panel
- $L_y = 3m$, $L_x = 3m$
- $L_y/L_x = 1$
- Referring Table 26, page 91, IS-456,

DESIGN OF SLAB-BEAM TYPE RAFT SLAB

For Interior panels,

- Negative moment coefficients at continuous edge along short span αx = -0.032, along longer span αy = - 0.032
- Positive moment coefficients at midspan along short span αx = -0.032, along longer span αy = - 0.032



DESIGN OF SLAB-BEAM TYPE RAFT SLAB

- Bending Moments are calculated using the following formulae,

$$M_x = \alpha_x \, w \, l_x^2$$
$$M_y = \alpha_y \, w \, l_x^2$$

- Negative bending moment, Mx = My = 0.032 x1.5x 122.45 x 3^2 = 52.89 kN-m (at supports)
- Positive bending moment, Mx = My = 0.024x1.5x122.45x 3^2 = 39.67 kN-m (at Midspan)

DESIGN OF SLAB-BEAM TYPE RAFT SLAB

- Depth required, $M_u = 0.138 f_{ck} bd^2$
- $52.89 \times 10^6 = 0.138 \times 20 \times 1000 d^2$
- $d = 138.43$ mm
- Adopt d = 150mm and a cover of 50mm, D = 200mm

Area of steel required,

For negative moment, $M_u = 0.87 * f_y * A_{st} (d - 0.42 X_{u,max})$

- $52.89 \times 10^6 = 0.87 \times 415 \times A_{st} (150 – 0.42(0.48 \times 150))$

  $A_{st} = 1223.19\ mm^2$

Using 16 dia bars, spacing required = 201x1000/1223.19 = 164.4mm

Place T16 @ 150mm c/c

Area of steel provided, $A_{st} = 1340\ mm^2$

DESIGN OF SLAB-BEAM TYPE RAFT SLAB

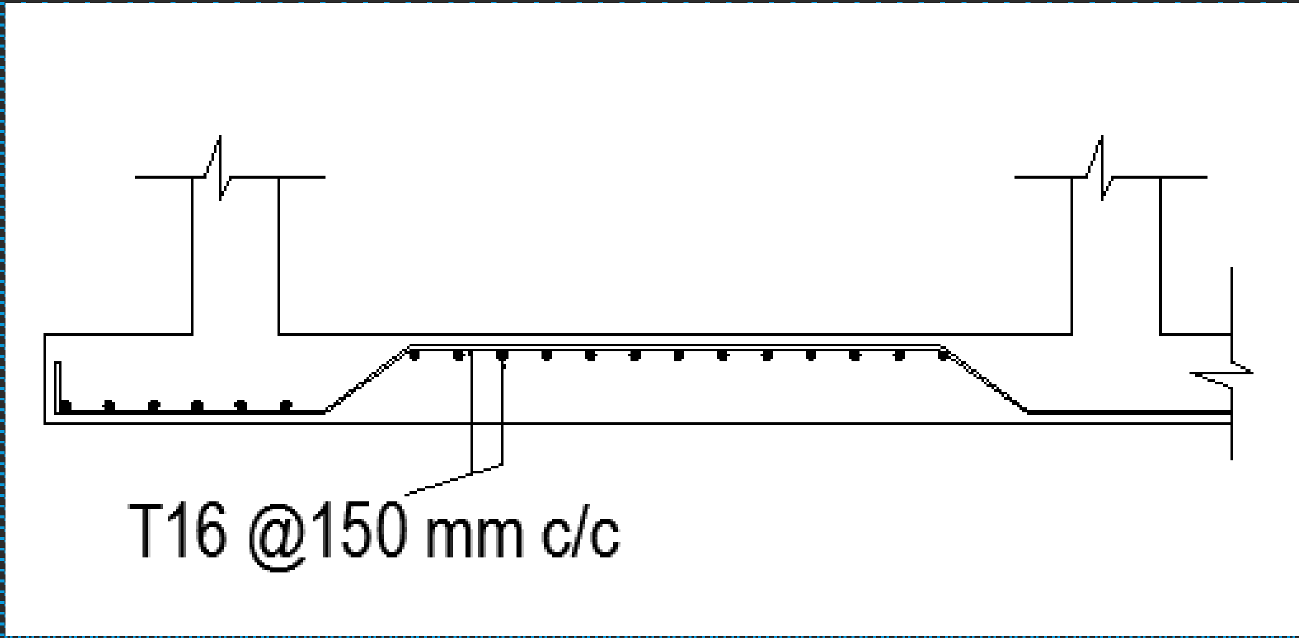
Similarly for positive moment,

Ast = 917.45 mm^2

Using 16 dia bars, spacing required = 201x1000/917.45 = 219.08mm

Place T16 @ 150mm c/c

Area of steel provided, Ast = 1340 mm^2



DESIGN OF SLAB-BEAM TYPE RAFT SLAB

Check for deflection

- Steel stress of service, fs = 0.58 * fy * 1223.19/1340 = 219.72 N/mm^2
- Percentage steel provided is 0.67
- Referring fig.4, IS456, Modification factor is 1.4
- Minimum depth, d min = 3000/26/1.4 = 82 mm
- Allowable s/d ratio = 1.4x26 = 36.4
- Provided s/d ratio = 3000/200 = 15

Hence the section safe in deflection

DESIGN OF SLAB-BEAM TYPE RAFT SLAB

- **Check for Shear**

Shear force, Vu = 122.45 x 3/2 = 183kN

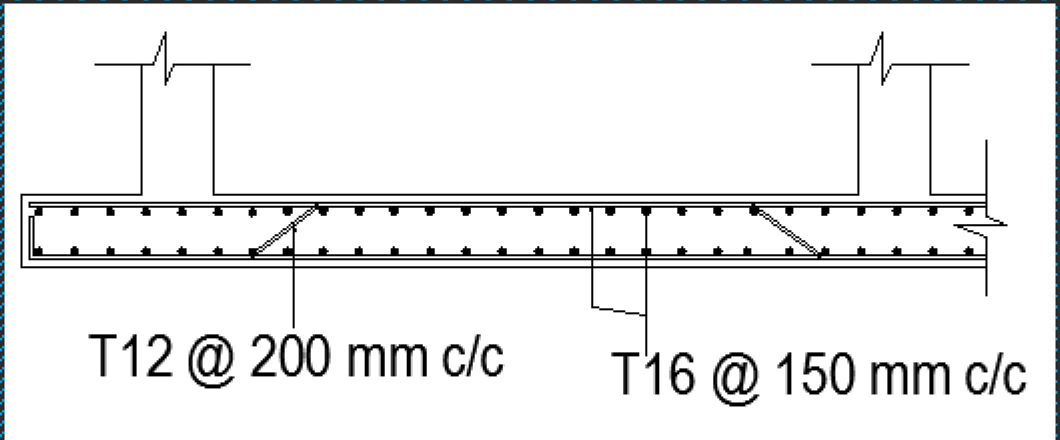
Shear stress, Tv = Vu/bd = 1.22N/mm²

Now, 100Ast/bd = 0.8933, Referring to table 19,

Design shear strength, k*Tc = 1.2 x 0.6 = 0.72 N/mm²

Shear reinforcement is required

Let's provide bent-up bars,



Area of shear reinforcement, for Vus = 1.22 – 0.72 = 0.5 N/mm²

Asv = Vus/(σsv*Sinα) = 0.5x1000x150/(230*sin45) = 461.15 mm2

Provide T12 @ 200mm c/c

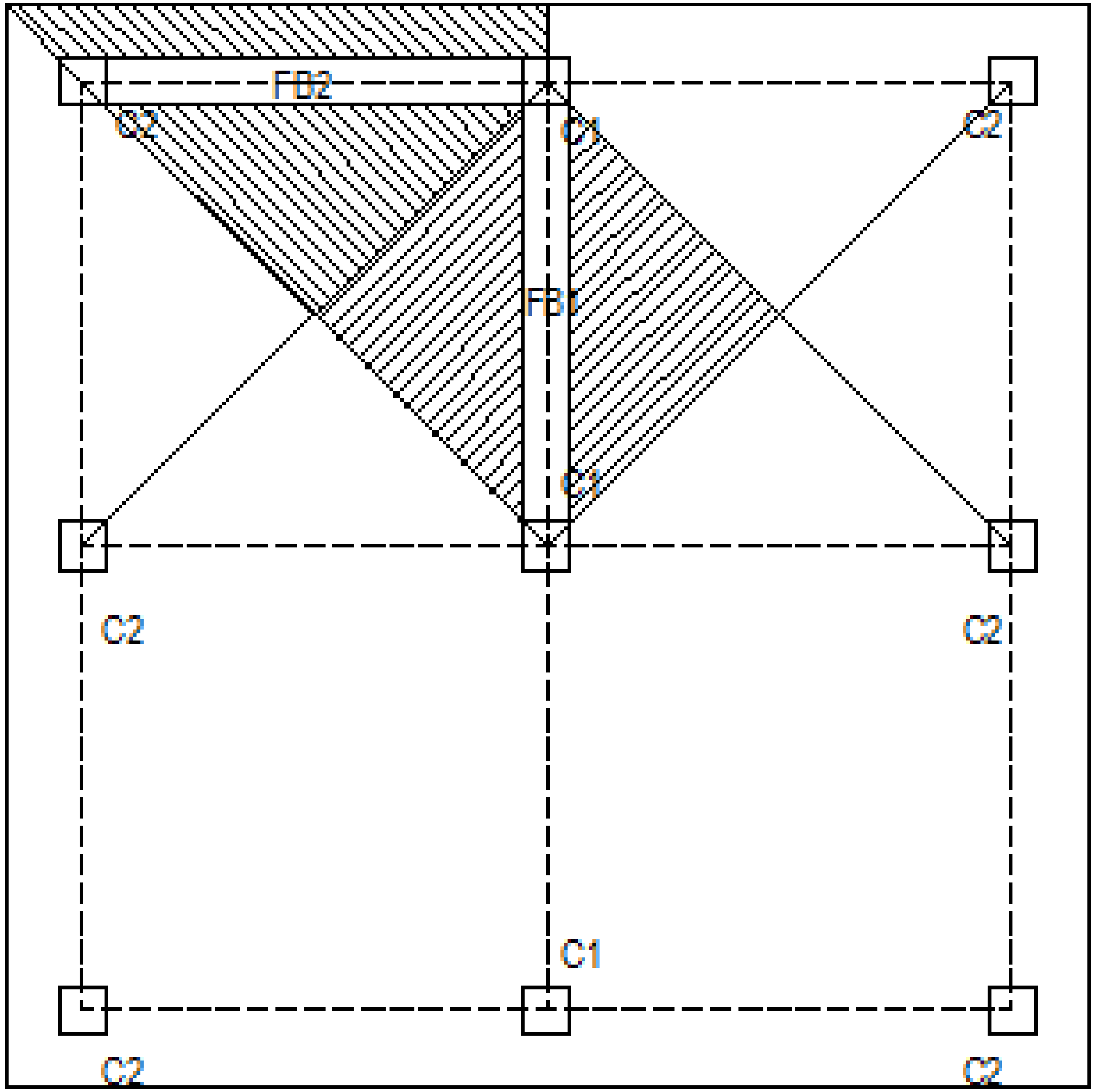
DESIGN OF SLAB-BEAM TYPE RAFT SLAB

Check for cracking

- The steel provided is more than 0.12% of gross area
- Spacing is less than 3d
- Hence the section is safe

DESIGN OF SLAB-BEAM TYPE RAFT SLAB

- **Design of Raft Beams**
- Uplift pressure 122.45 kN/m2
- Load carried by foundation/raft beams is shown in the figure beside.
- FB1 carries the load distributed on two triangles,
- FB2 carries the load distributed on one triangle and a portion of cantilever



DESIGN OF SLAB-BEAM TYPE RAFT SLAB

Design of FB1

- Area of loading = (0.5x3x3)x2 = 9 m^2
- Loading on the beam, w = 122.45x9/3 = 367.35kN/m
- Moment at supports, Mu = $1.5xwl^2 / 10 = 1.5 \times 367.35 \times 3^2 /10$ = 495.92 kN-m (Table-12)
- Moment at mid span, Mu = $1.5xwl^2 / 12 = 1.5 \times 367.35 \times 3^2 /12$ = 413.27 kN-m
- Depth of the beam, d min, Mu = $0.138 f_{ck} b d^2$, assuming b = 400mm
- d min = 670.22 mm,
- Adopt d = 720 mm, cover = 30mm
- Over all depth D = 750mm

DESIGN OF SLAB-BEAM TYPE RAFT SLAB

Design of FB1

Mu lim will be greater than Mu

Beam can be designed as singly reinforced

$$M_u = 0.87 f_y A_{st} d\left(1 - \frac{A_{st} f_y}{bd f_{ck}}\right)$$

Ast reqd = 2322.17 mm^2

- Provide 8-T20
- Ast Provided = 2512mm^2

DESIGN OF SLAB-BEAM TYPE RAFT SLAB

Design of FB1

Check for shear

- Shear Force, Vu = 1.5x367. 35x3x0.6 =991.84kN (Table 13, SF Co-efficient)

τ_v = 661.23x1000/(300x800) = 4.132 N/mm^2

100Ast/bd = 0.872

- τ_c = 0.59 N/mm^2, τ_c max = 2.8 N/mm^2

DESIGN OF SLAB-BEAM TYPE RAFT SLAB

Design of FB1

Section requires shear reinforcement

Vc = 0.59x400x720 = 169.92kN

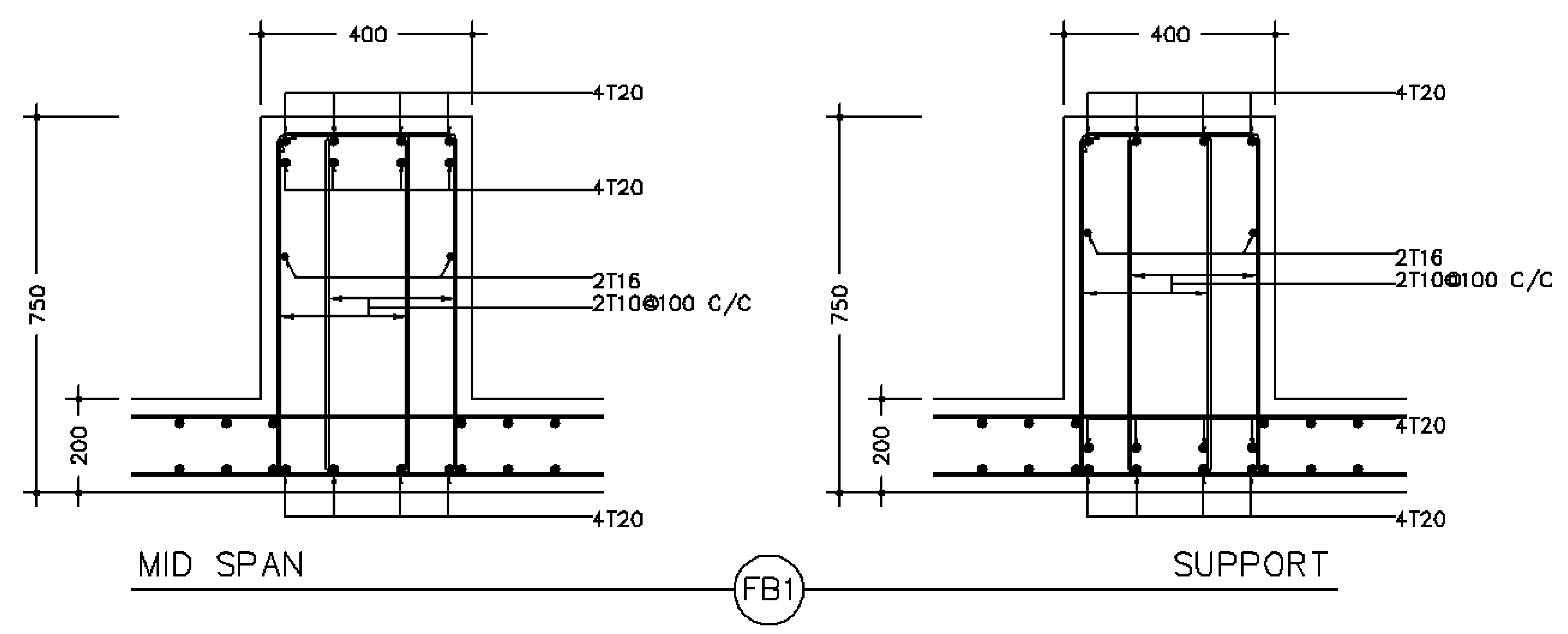
Shear to be resisted, Vus = Vu – Vc = 821.9kN

S = 0.87*fy*As*d/Vus = 0.87x415x4x78.55x800 / 821920 = 110.42mm c/c

- Provide 4-legged stirrups at 100 mm c/c

DESIGN OF SLAB-BEAM TYPE RAFT SLAB

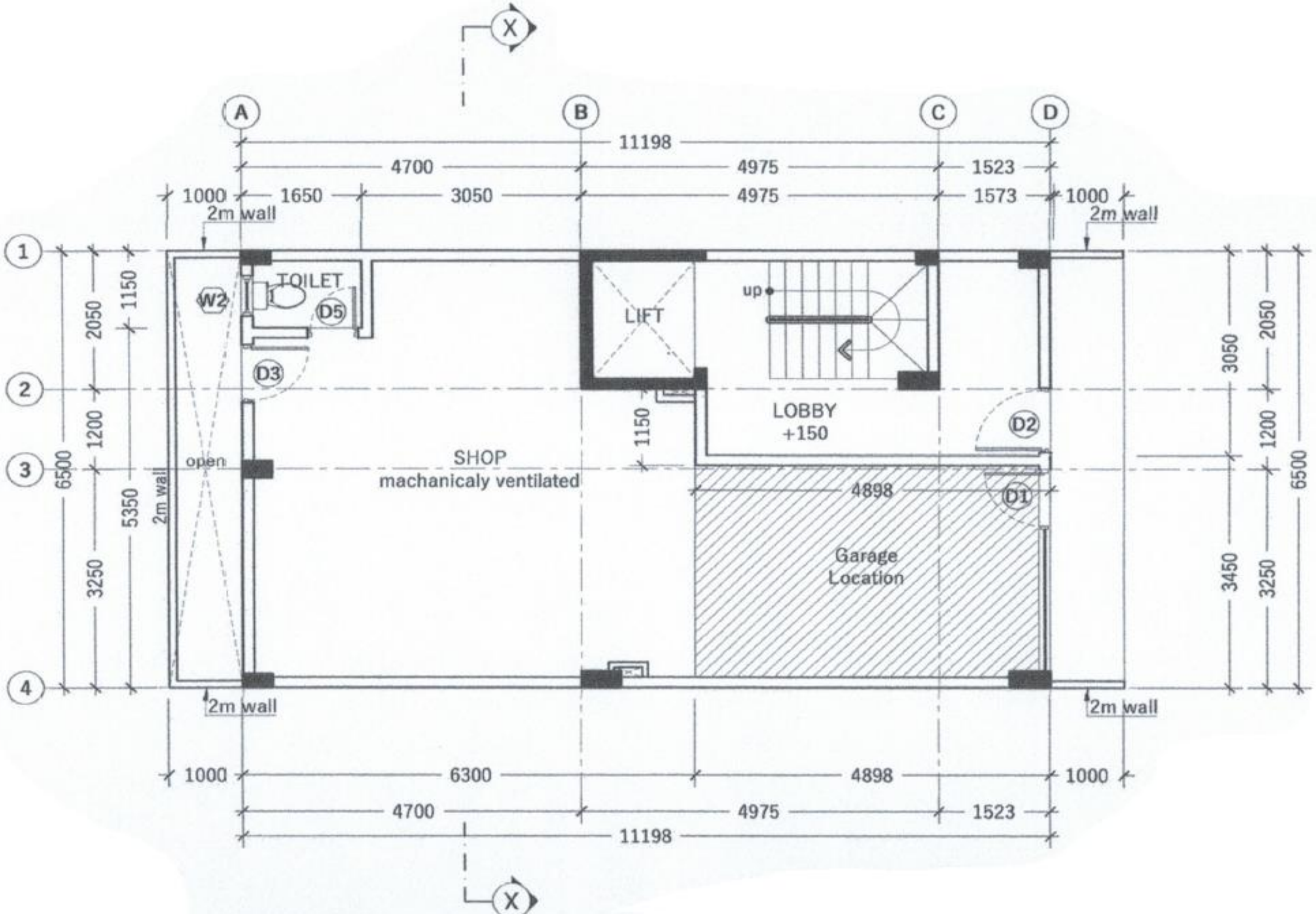
- **Structural details of FB1**



CASE STUDIES

Project -1

- Design of Raft foundation for a 6 floor building



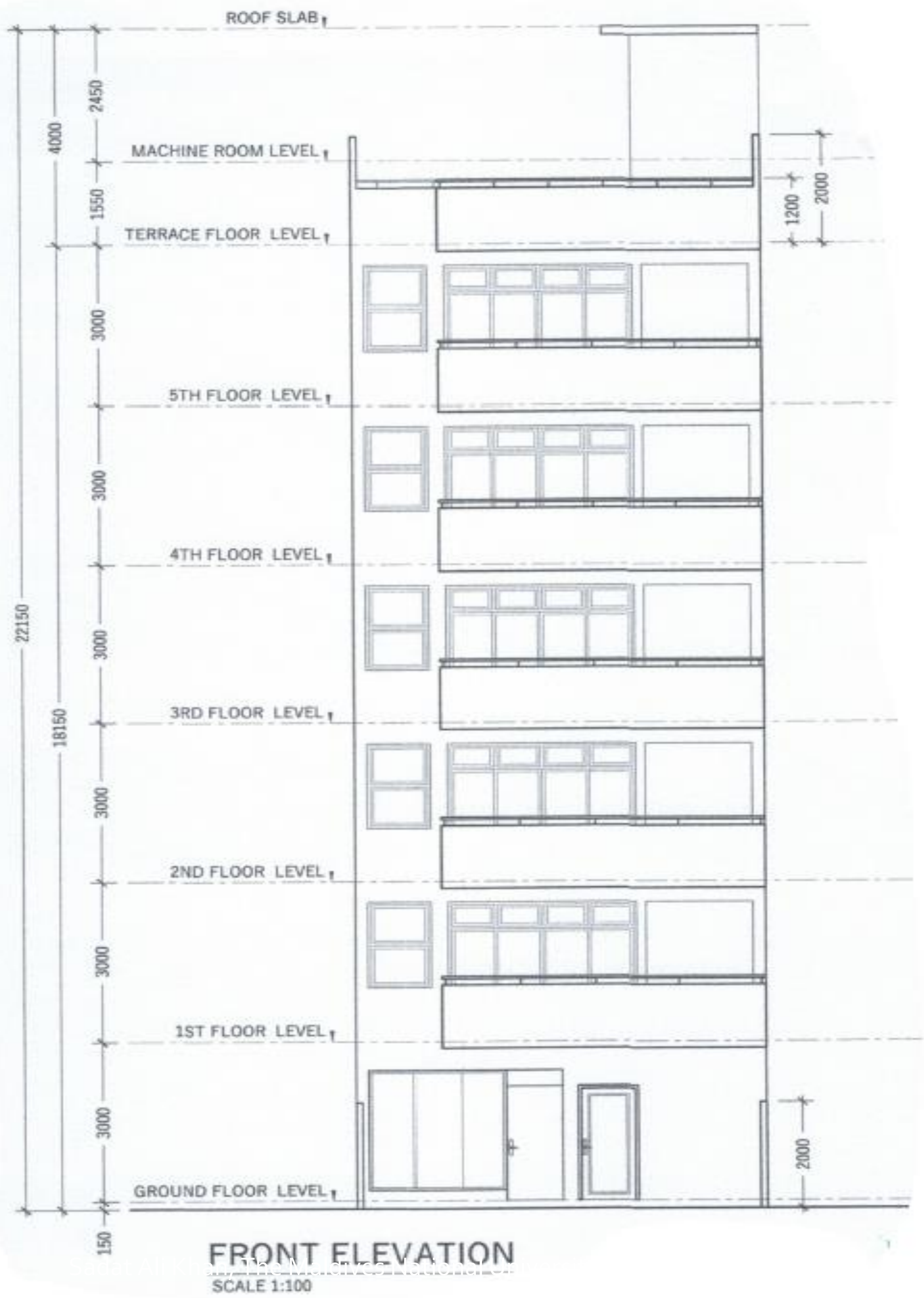
GROUND FLOOR PLAN

SCALE 1:100

CASE STUDIES

Project -1

- Design of Raft foundation for a 6 floor building.



CASE STUDIES

Project -1

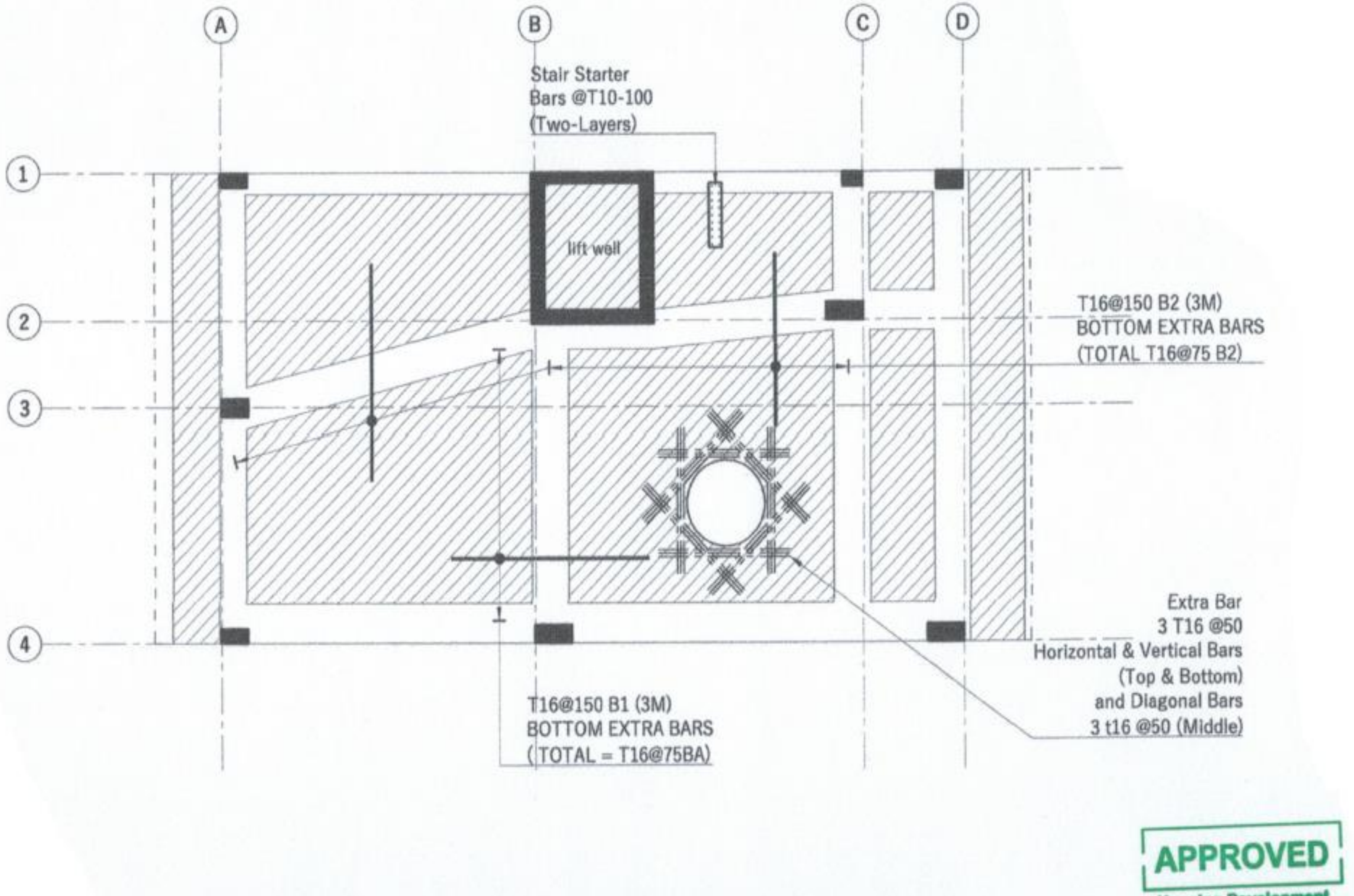
- Details of Raft foundation

NOTES:
RAFT THICKNESS = 500MM
TOP & BOTTOM RFMT: T16 @150 B/W
THROUGHOUT NOT SHOWN

BOTTOM EXTRA BARS PROVIDE AS SHOWN

PARRIED BOTTOM EXTRA BARS AS SHOWN

COVER TO FOUNDATION = 50MM
COVER TO BEAMS = 30-35MM
COVER TO COLUMNS = 40MM
LAPS = 45⌀
(⌀=BAR DIAMETER)
CONCRETE MIX = 1:2:3

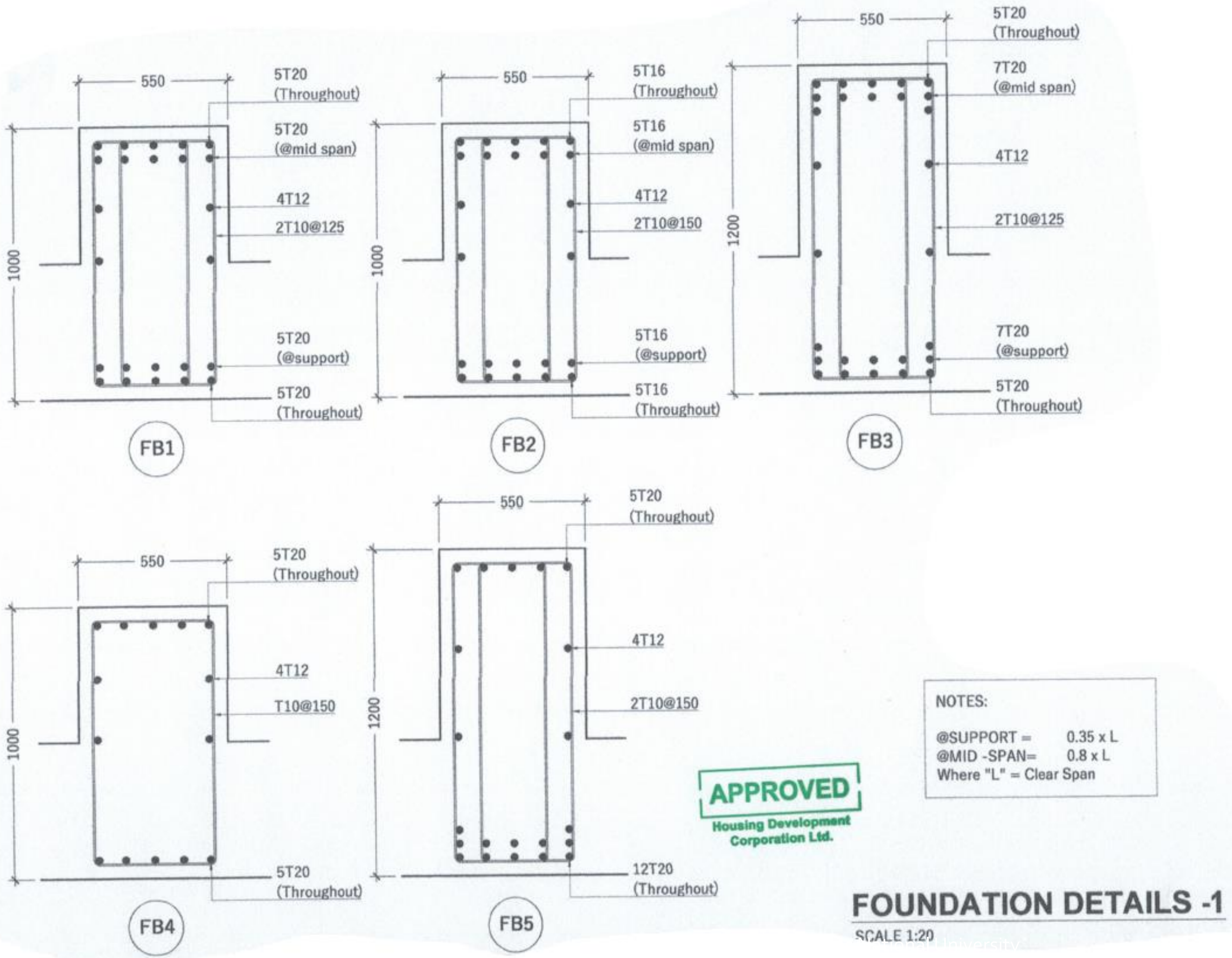


FOUNDATION RAFT REINFORCEMENT PLAN
SCALE 1:100

CASE STUDIES

Project -1

- Design of Raft foundation for a 6 floor building.



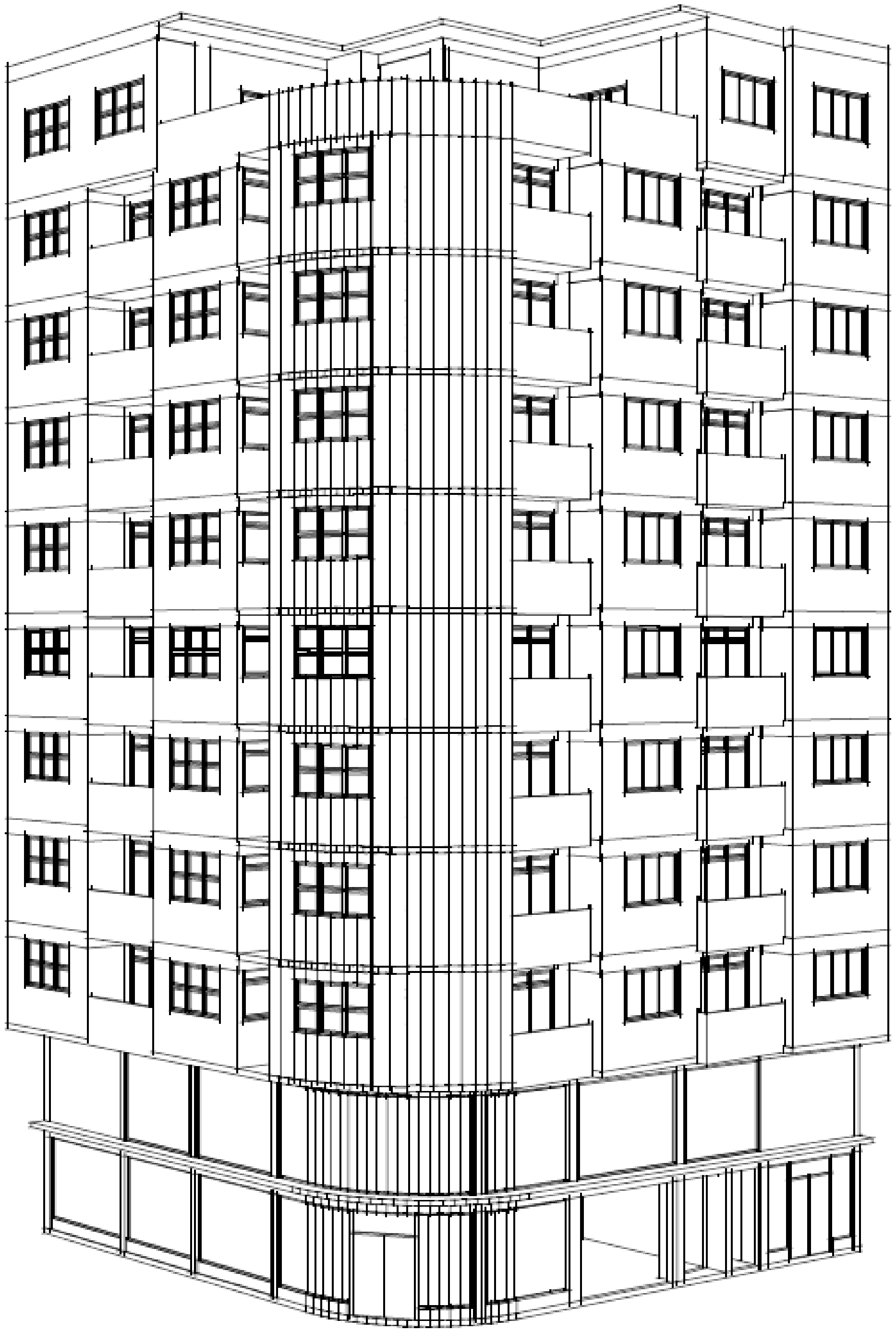
CASE STUDIES


R.C.C


CASE STUDIES

Project-2

- Design of raft foundation for a 11 story Residential Building



Thank you….