Chapter One

" General Description "

1.1 Introduction:

- Because of increasing rate of population and many other factors, the constructions sector all over the world is developed rapidly to serve the demand for housing.
- Along with this development came the evolution of new techniques for designing and analyzing different structures, and computer software used to facilitate this process
- This graduation project is to fulfill the requirement of the bachelor degree of science in civil engineering in civil engineering department at Al – Isra private University.

1.2 Objective

- This project is to analysis and design a multi-story commercial building, which will be the objective of this graduation project to make sure that most of the design courses are understood in term of applying all the needed equation given in the well-known codes to all structural elements of the building.

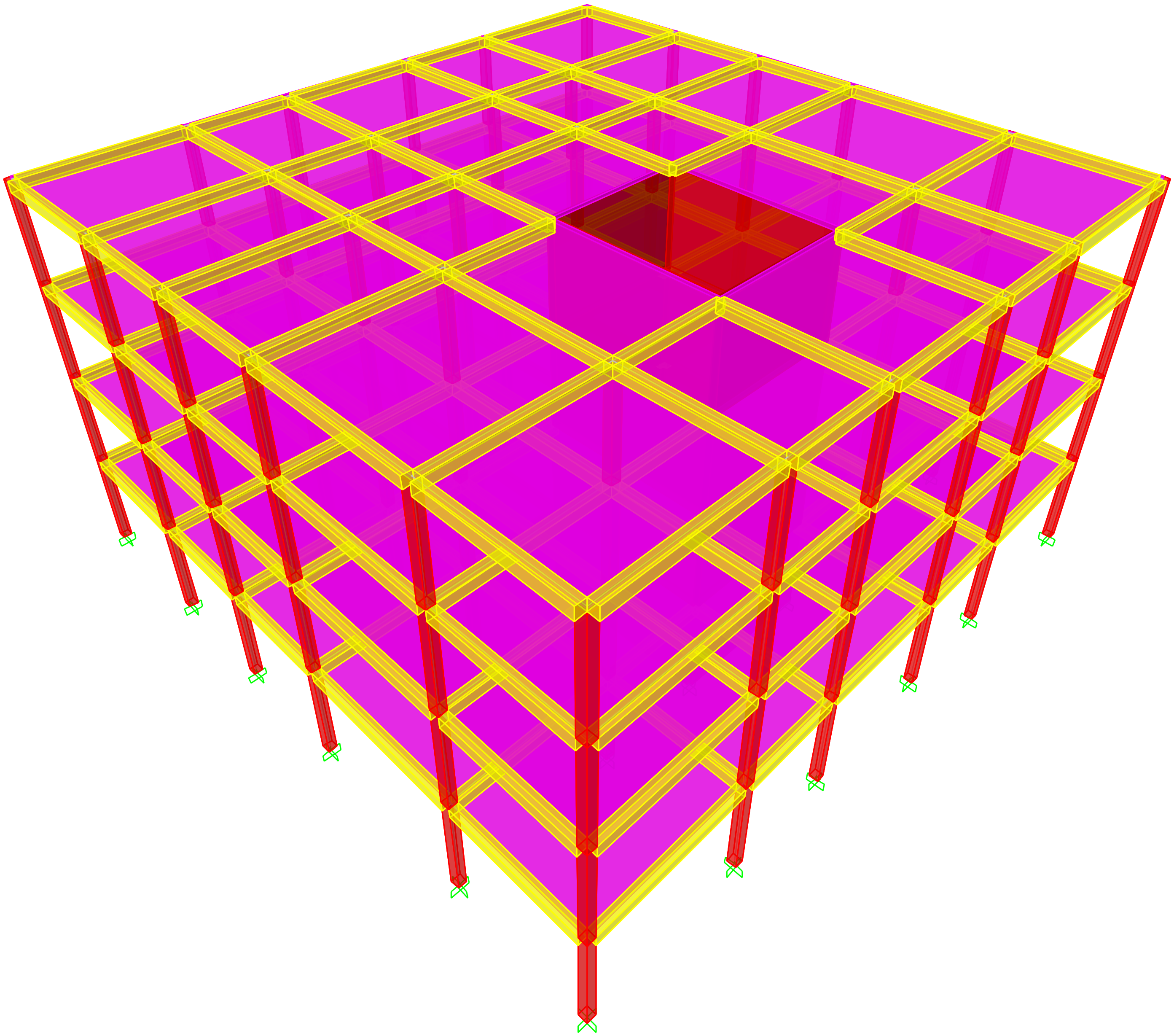
1.3 Project Description:

- The project is a multi-story commercial reinforced concrete building which is located inside Amman city.
- The building consist of (4) floors, the area of each floor is (424.36), total area of the building (1697.44 m^2).

☛ Tow-way solid slab will be used for each floor.

- The building is subjected to **gravity loads** (dead load & live load), in addition to lateral loads **(wind load)**

☛ **Building in 3D View**



1.4 Codes of practices :

- Design and detailing is according to the American concrete institute requirements, the load act on the building from simple gravity load and wind load of the various building element is used from Jordanian loads and forces code **JBC (2/90).**
- The dead & live load factors according to **ACI-code (318M-05)**

1.5 Computer program :

- The following software will be used during this project:
  - ☛ ETABS 9 version (9.5).
  - ☛ PROKON (Version 4.5)
  - ☛ AUTO CAD 2007
  - ☛ Microsoft office 2007

1.6 Methodology :

- The following are the main structural elements that should be analyzed and designed in the building:

1- Analysis and design of slabs.

2- Analysis and design of beams & column as a frames.

3- Analysis and design of footing.

4- Analysis and design of stair.

Chapter Tow

"Material Properties"

2.1Introduction

- To be able to analyze and design reinforced concrete structures the engineer should know the material it's made of and understand their properties, and performances.

- The usual materials used for construction of the main structural component are:
  1-Concrete
  2-Steel reinforcements

- Combination of both steel and concrete called "reinforced concrete" is widely used because of the combined ability of both materials to resist both compressive and tensile stresses, and for other properties of concrete like high durability.

2.2 Concrete

- Concrete is mixture of cement (usually Portland cement) fine, coarse aggregate and water.
  Concrete is reinforced to give extra tensile strength; without reinforcement, many building would not have been possible.
  Reinforced concrete can encompass much type of structure and components, including slabs, walls, beams, column, foundations, frames and more.

2.2.1 <u>Compressive strength</u> (fc')

- ✓ Concrete strength depends on many factors such as :
  1- Material used on it like cement, coarse aggregate, fine aggregate, and water.
  2- Mixing.
  3- Placing compaction
  4- Curing (play a large role on the resulting strength and modulus of elasticity for concrete.

- ✓ Concrete has relatively high compressive strength(fc'), but significantly lower tensile strength (about 10% of the compressive strength)
- ✓ Usually the compressive strength measured after 28 days by testing sample (cubes or cylinders) by subjected them to axial load until failure and recording the stress at failure as (fc') in MPa
- ✓ The strength of concrete at 7 days can be estimated to be 70-80% of the 28 days (fc').

- ✓ The compressive strength of concrete that will be used in casting the main element of the building is **fc' = 25 MPa**

2.2.2 Type of concrete will be used :

1- normal weight concrete (NWC)
   Density, approximately 24 KN/m^3

2- light weight concrete (LWC)
   Density, between (14.5 -19) KN/m^3

3- heavy weight concrete (HWC)
   Density, between (32- 48) KN/m^3

✓ Good uniform concrete:

1- controlled quality of material
2- controlled proportioning
3- controlled handling, placing, and curing

2.3 Reinforced concrete steel :

✓ Reinforced concrete was designed on the principle that steel and concrete act together in resisting forces. Concrete is strong on COMPRESSION but weak in TENSION. The tensile strength is generally rated 10% of compressive strength, for this reason concrete works well for column and posts that are compression member.

✓ When it used in tension member, such as beams, girders, foundation walls, or floor, concrete must be reinforced to attain the necessary tension strength.

- ✓ Reinforced steel is manufactured in Jordan of tow forms, plain bars and deformed bars with minimum yield strength of 276 MPa for mild steel and 420 MPa for high tensile strength steel

  - ✓ Grade 60 (high tensile strength) steel with yield stress of 420 MPa (i.e **Fy = 420 MPa**) will be used.

2.4 Soil properties :

- Bearing capacity of soil will to be considered as:

$$q_{all}=2\ Kg/cm^2\ (200\ KN/m^2)$$

2.5 Material Densities:

- According to the Jordanian codes of loads and forces (JBC 2/90), table (4) …The following densities will be used:

  - ✓ Density of reinforced concrete = 24 KN/m^3
  - ✓ Density of block = 14.5 KN/m^3
  - ✓ Density of plaster = 22 KN/m^3
  - ✓ Density of tile+mortar = 22 KN/m^3
  - ✓ Density of plaster = 22KN/m^3
  - ✓ Density of fill = 18.1KN/m^3

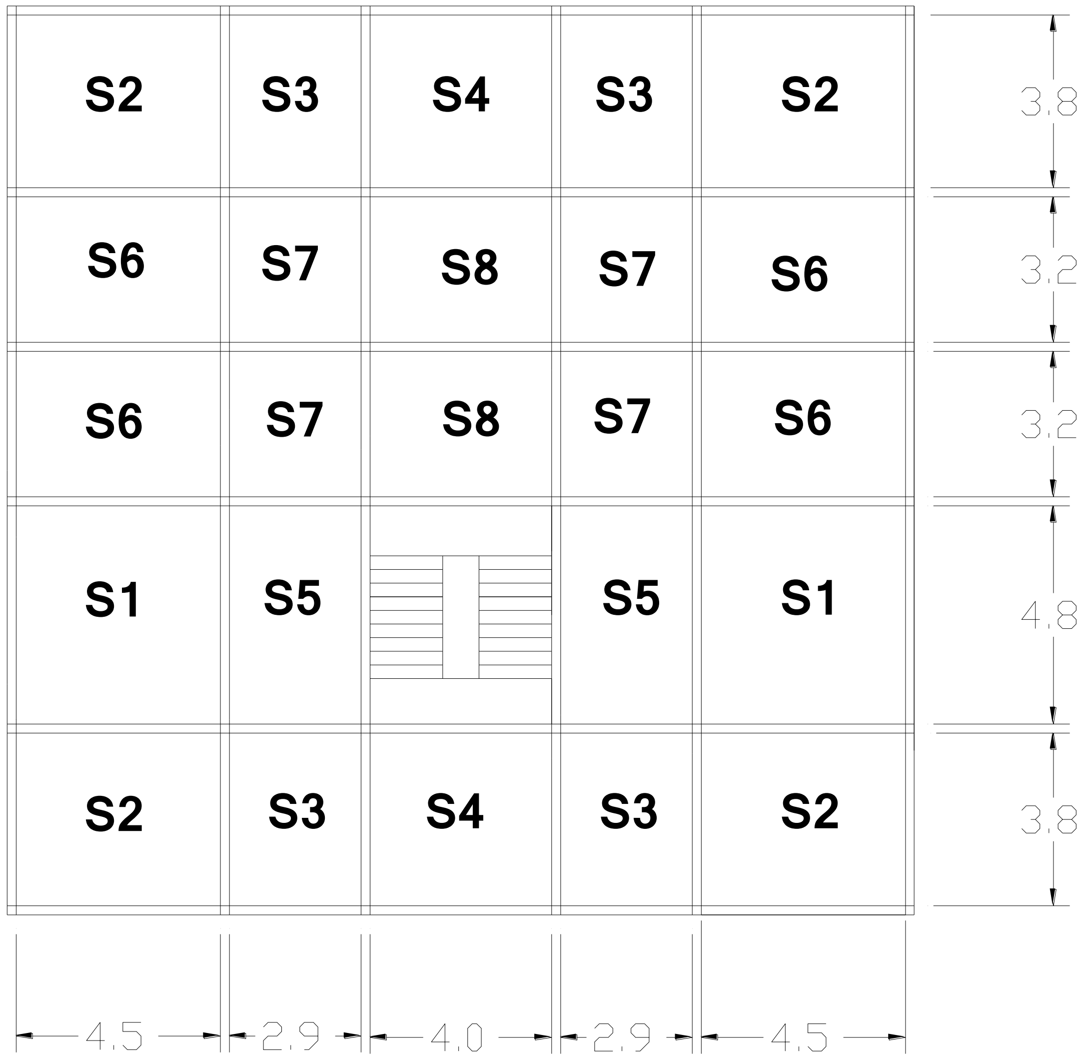
2.6 Dead load parameters design:

- The following parameters will be used in calculations of the dead load of the solid slabs according to (JBC 2/90):

  - ✓ Plaster thickness on walls (each face) = 25mm
  - ✓ Plaster thickness of ceiling = 20mm
  - ✓ Partition load of plaster reduction factor = 0.33
  - ✓ High of partition = 3.0 m
  - ✓ Total thickness of tiles and mortar = 50 mm
  - ✓ Thickness of fill = 100 mm

Chapter Three

" Loads, Requirements, and Design Criteria"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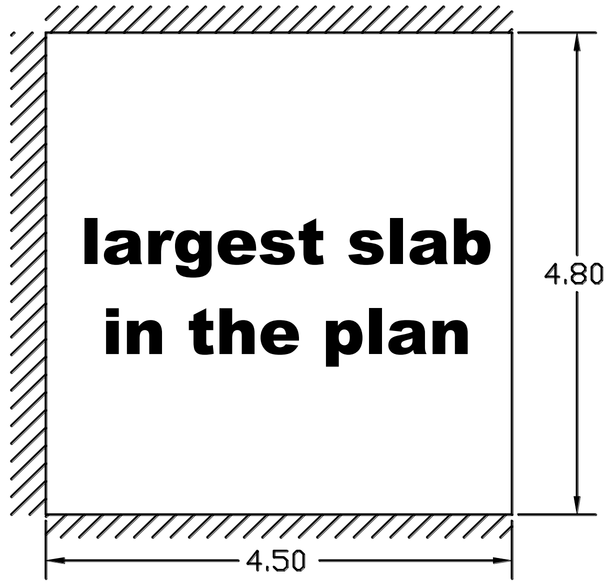
Plan view

3.1 slab thickness



- Determination of thickness according to largest slab:
    - Taking largest slab :
      Length= 4.8 m
      Width = 4.5 m

❖ (L_b/L_a) = (4.8/4.5) = 1.07 < 2.0 …… **the slab is tow way**

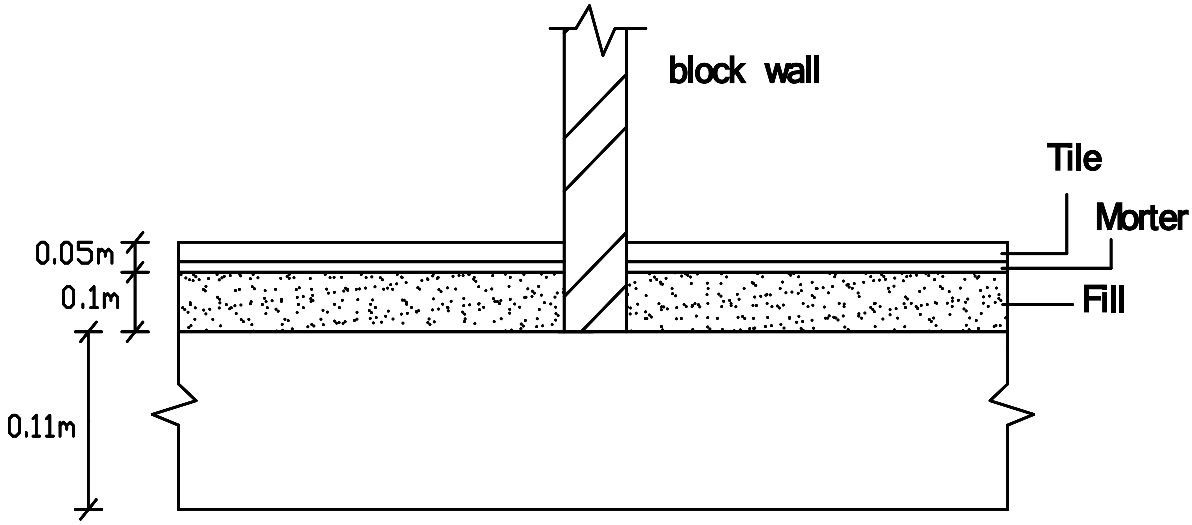
✓ $\mathbf{h_{min}}$ = max of :

- ✓ Parameter/180
- ✓ 90

✓ $\mathbf{h_{min}}$ = parameter/180 = 2*(4.8+4.5)/180 ≈ 110mm

☛ use thickness of slab (h) = **110 mm** (controlled for all slab)

3.2 Dead load:



Slab Section

- ✓ Dead load calculation:

- ✓ Partition (100mm thickness) = 0.1 × 3.0 × 14.5 × 0.33 =1.436KN/m^2
- ✓ fill = 0.1 × 18.1 = 1.81 KN/m^2
- ✓ tiles and mortar = 0.05 × 22 =1.1 KN/m^2
- ✓ plaster on ceiling = 0.02 × 22 = 0.5 KN/m^2
- ✓ partition plaster = 0.05×3.0×22=3.3 KN/m^2
- ✓ Reinforced concrete slab = 0.11 × 24 = 2.64 KN/m^2

☛ $\sum$ D.L = 10.786 KN/m^2

3.3 Live load:

- According to Jordanian building code (JBC 2/90), Live load could be considered as follow:

  - L.L = 4 KN/m^2 (for stair)
  - L.L = 4 KN/m^2 (for commercial building)

3.4 Wind load:

- According to (JBC 2/90), wind load could be calculated as follows:

- The design wind speed is $\mathbf{V_z}$ is:

$$V_z = V \times S_1 \times S_2 \times S_3$$

- Where :

  - **V** : Basic wind speed = 35 m/s (126 Km/hr)
    (JBC 2/90, sec. 4/5/3, part B)

  - $\mathbf{S_1}$: Ground topographic coefficient (JBC 2/90 , Table 13)

  - $\mathbf{S_2}$: Ground roughness coefficient (JBC 2/90 , Table 14), which depend on :

    1- ground classification
    2- type of building
    3- height of building

  - $\mathbf{S_3}$:statistical coefficient (JBC 2/90, Table 15), which depend on The expected life of the building.

✓ **Calculate the value of V_z are shown in the following table :**

Elevation (m)	S_1	S_2	S_3	V(m/s)	V_z(m/s)	q(N/m^2)
3	1.0	0.6	1	35	21.00	270.33
6	1.0	0.668	1	35	23.38	335.08
9	1.0	0.722	1	35	25.27	391.445
12	1.0	0.776	1	35	27.16	452.189

✓ **Horizontal wind pressure:**

$$P = C_f \times q$$

❖ Where:

- ✓ C_f : force Coefficient
- ✓ **q** : Dynamic pressure = $0.613\ V_z^2$
- ✓ **P** : Horizontal wind pressure

- ✓ **Building dimension:**

- ✓ Wind usually calculated as parallel to the smallest dimension of the building so it will be more critical in design.

Where:

  - ✓ L = largest horizontal length of the building = 20.6m
  - ✓ W = smallest horizontal length of the building = 20.6m
  - ✓ B =building length perpendicular to the wind direction= 20.6m
  - ✓ D = building length parallel to the wind direction = 20.6m
  - ✓ H =building height = 12m

L/W = 20.6/20.6=1

B/D = 20.6/20.6 = 1

H/B = 12/20.6 = 0.583

- ✓ **C_f From JBC (Table 20) = 0.9083**

The value of the wind forces on the building is calculated as:

$$F = P \times A$$

❖ Where :

- ✓ **F** : wind force
- ✓ **P** : horizontal wind pressure
- ✓ **A** : exposed area

- The calculated value of **(F)** is tabulated below:

H (m)	C_f	q(N/m^2)	A(m^2)	F(KN)
3	0.9083	270.33	7.2	1.77
6	0.9083	335.08	7.2	2.2
9	0.9083	391.445	7.2	2.56
12	0.9083	452.189	3.6	1.48

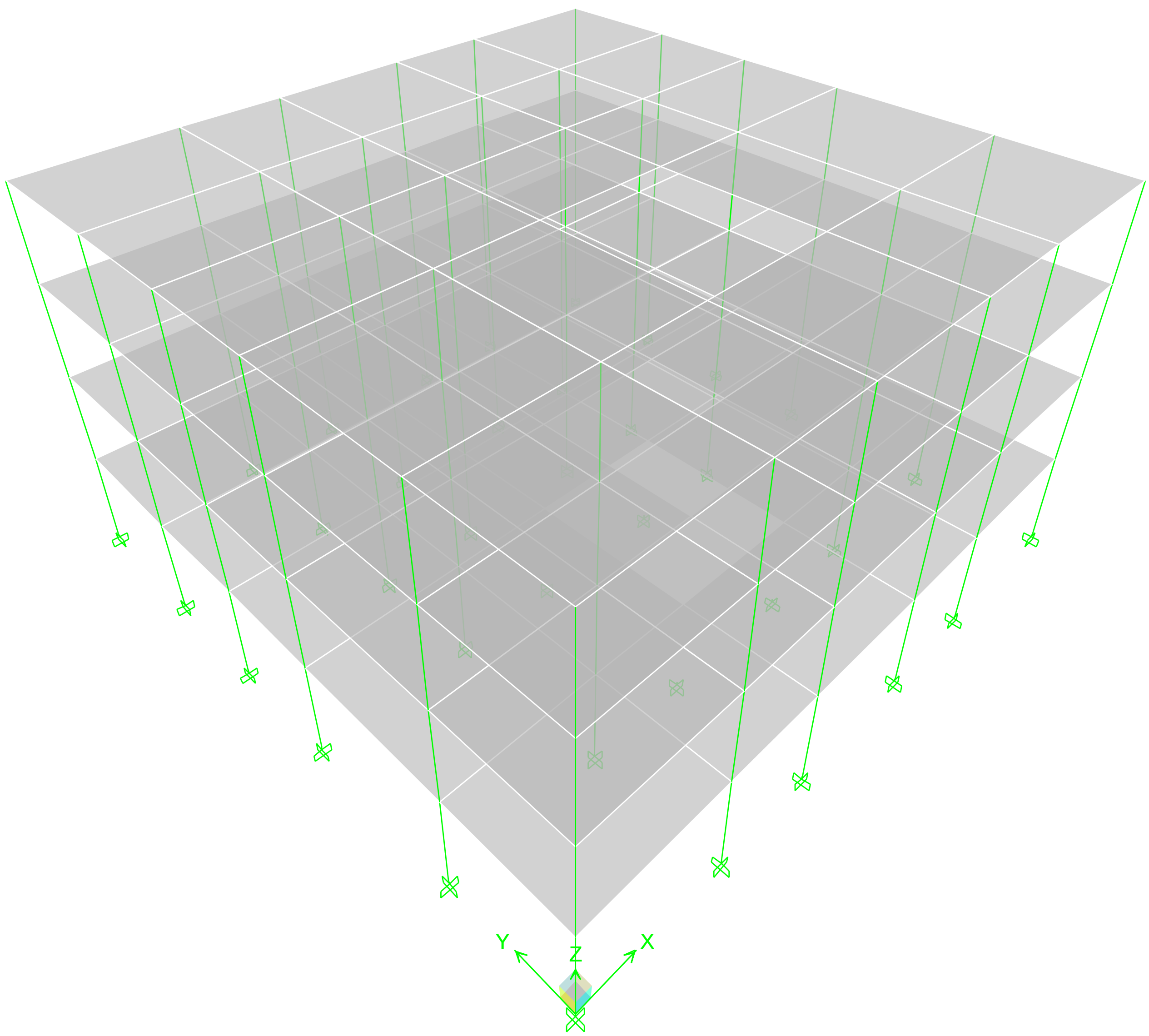
Chapter Four

"Analysis and Design Of Slab"

SECTION 1

"Analysis of slab and moment calculation"

<u>Slabs In 3-D View</u>



- ***Calculation of Factored load :-***

$W_u = 1.2\ W_D + 1.6\ W_L$

$W_u = (1.2 * 10.786) + (1.6 * 4) = 19.34\ KN/m^2$

- ***Determination of thickness according to largest slab:***

  - ✓ *Taking largest slab :*

    Length= 4.8 m

    Width = 4.5 m

- ❖ $(L_b/L_a) = (4.8/4.5) = 1.07 < 2.0$ …… **the slab is tow way solid slab**

✓ $\mathbf{h_{min}}$ = ma* of :

  - ✓ Parameter/180
  - ✓ 90

✓ $\mathbf{h_{min}}$ = parameter/180 = 2*(4.8+4.5)/180 ≈ 110mm

☛ use thickness of slab (h) = **110 mm** (controlled for all slab)

5.1.1 Effective depth of slabs :

Bars used are d_b = 12 mm Reinforcement

- **For short direction :**

$d_s = t - \text{concrete cover} - \frac{db}{2}$

= 110 – 20 – 6 = 84 mm

- **For Long direction :**

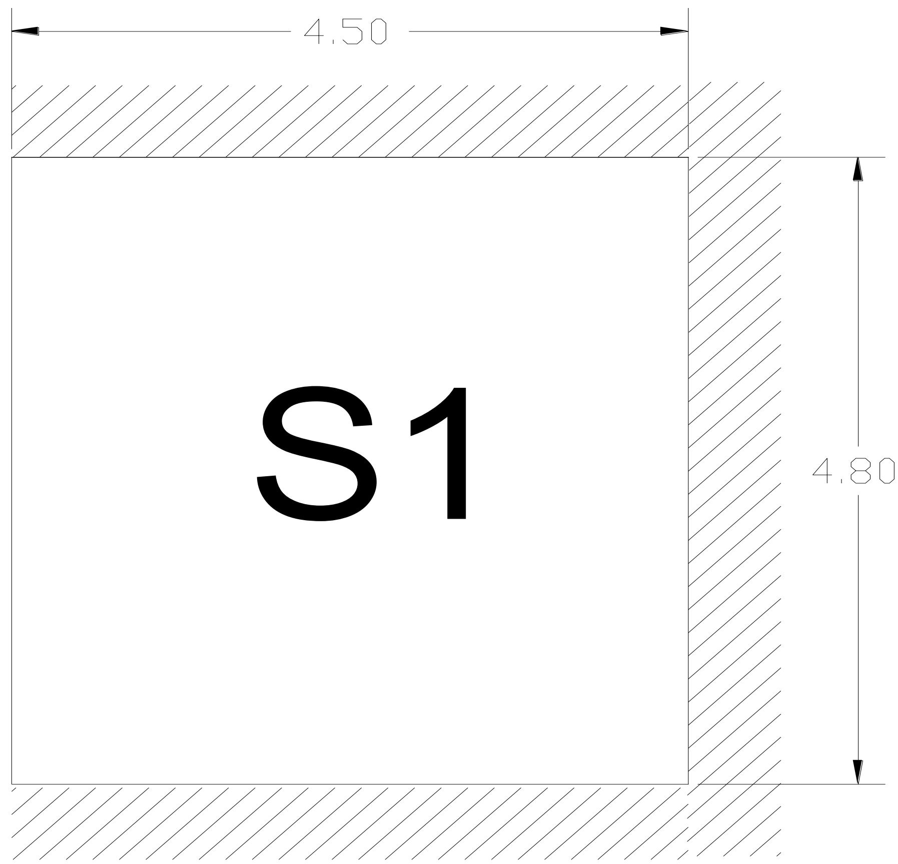
$d_s = t - \text{concrete cover} - db - \frac{db}{2}$

= 110 – 20 – 12 - 6 = 72 mm

5.1.2 Average effective depth :

$\frac{d\ long + d\ short}{2} = \frac{84+72}{2} = 78\ mm$

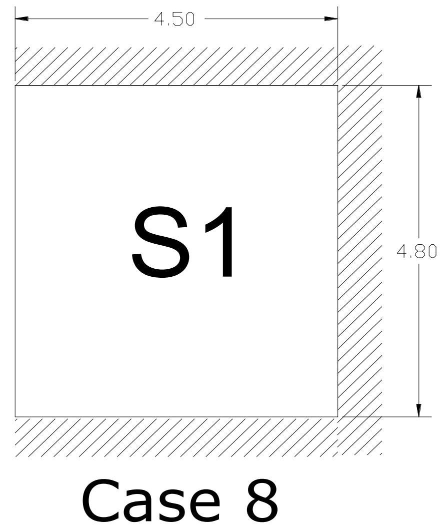
Dimension of slab 1



Case 8

5.1.3 Calculation of moment :

- ***Using Coefficient Method***



☒ **For S-1**

La = 4.5 m , Lb = 4.8 m

m = $\frac{La}{Lb}$ = $\frac{4.5}{4.8}$ = 0.95 > 0.5

∴ **Two way solid slab → Case (8)**

- ***Coefficient of positive moment and negative moment :***

- C_a (neg.) = 0.038
- C_a $^+$(D.L) = 0.022
- C_a^+ (L.L) = 0.031
- C_b (neg.) = 0.056
- C_b $^+$(D.L) = 0.021
- C_b^+ (L.L) = 0.027

☒ **Moment at Middle Strip**

- ***Negative moment at continuous edge :***

Ma neg. = Ca (neg.) * Wu * $(La)^2$

Ma neg. = 0.038 * 19.34 * $(4.5)^2$ = 14.88 *KN.m*

Mb neg. = Cb (neg.) * Wu * $(Lb)^2$

Mb neg. = 0.056 * 19.34 * $(4.8)^2$ = 24.95 *KN.m*

☛ ***Positive Moment :***

- ***Short Direction :***

Ma^+ (DL) = Ca (DL) * Wu (DL) * $(La)^2$

Ma^+ (DL) = 0.022 * (12.943) * $(4.5)^2$ = 5.766 *KN.m*

Ma^+ (LL) = Ca (LL) * Wu (LL) * $(La)^2$

Ma^+ (LL) = 0.031 * (6.4) * $(4.5)^2$ = 4.0176 *KN.m*

Ma^+ (total) = 5.766 + 4.0176 = 9.784 *KN.m*

- ***Long Direction :***

Mb^+ (D.L) = Cb (DL) * Wu (DL) * $(Lb)^2$

Mb^+ (D.L) = 0.021 * (12.943) * $(4.8)^2$ = 6.262 *KN.m*

Mb^+ (L.L) = Cb (LL) * Wu (LL) * $(Lb)^2$

Mb^+ (L.L) = 0.027 * (6.4) * $(4.8)^2$ = 3.981 *KN.m*

Mb_{+} (total) = 6.262 + 3.981 = 10.243 *KN.m*

☛ ***Negative moment at discontinuous edge :***

Ma (neg.) = $\frac{1}{3}$ * (Middle strip positive moment)

Ma (neg.) = $\frac{1}{3}$ * 9.784 = 3.261 *KN.m*

☒ **Moment at Column strip:**

☛ ***Negative moment at continues edge :***

Ma (neg.) = $\frac{2}{3}$ * ($Ma^-_{cont.}$ Middle strip)

Ma (neg.) = $\frac{2}{3}$ * 14.88 = 9.92 *KN.m*

Mb (neg.) = $\frac{2}{3}$ * ($Mb^-_{cont.}$ Middle strip)

Mb (neg.) = $\frac{2}{3}$ * 24.98 = 16.63 *KN.m*

- ***Positive Moment:***

$Ma^{+} = \frac{2}{3} * (Ma^{+}_{tot.} \text{ Middle strip})$

$Ma^{+} = \frac{2}{3} * 9.784 = 6.522$ *KN.m*

$Mb^{+} = \frac{2}{3} * (Mb^{+}_{tot.} \text{ Middle strip})$

$Mb^{+} = \frac{2}{3} * 10.243 = 6.828$ *KN.m*

- ***Negative moment at discontinues edge:***

$Ma \text{ (neg.)} = \frac{1}{3} * (Ma^{-}_{dis.} \text{ Middle strip})$

$Ma \text{ (neg.)} = \frac{1}{3} * 3.261 = 1.087$ *KN.m*

☒ **Check for shear :**

- **use Table – 4**

✓ Wa = 0.38
✓ Wb = 0.62

- Wu a = Wa * Wu = 0.38 * 19.34 = 7.349 *KN/m*
- Wu b = Wb * Wu = 0.62 * 19.34 = 11.990 *KN/m*

- ***Short Direction :***

$Vu \ @ \ d = Wu\ a * \frac{La}{2} - Wu\ a * d$

$Vu \ @ \ d = 7.349 * \frac{4.5}{2} - 7.349 * 0.084 = 15.917$ *KN*

- ***<u>Long Direction :</u>***

Vu @ d =Wu b * $\frac{Lb}{2}$ - Wu b * d

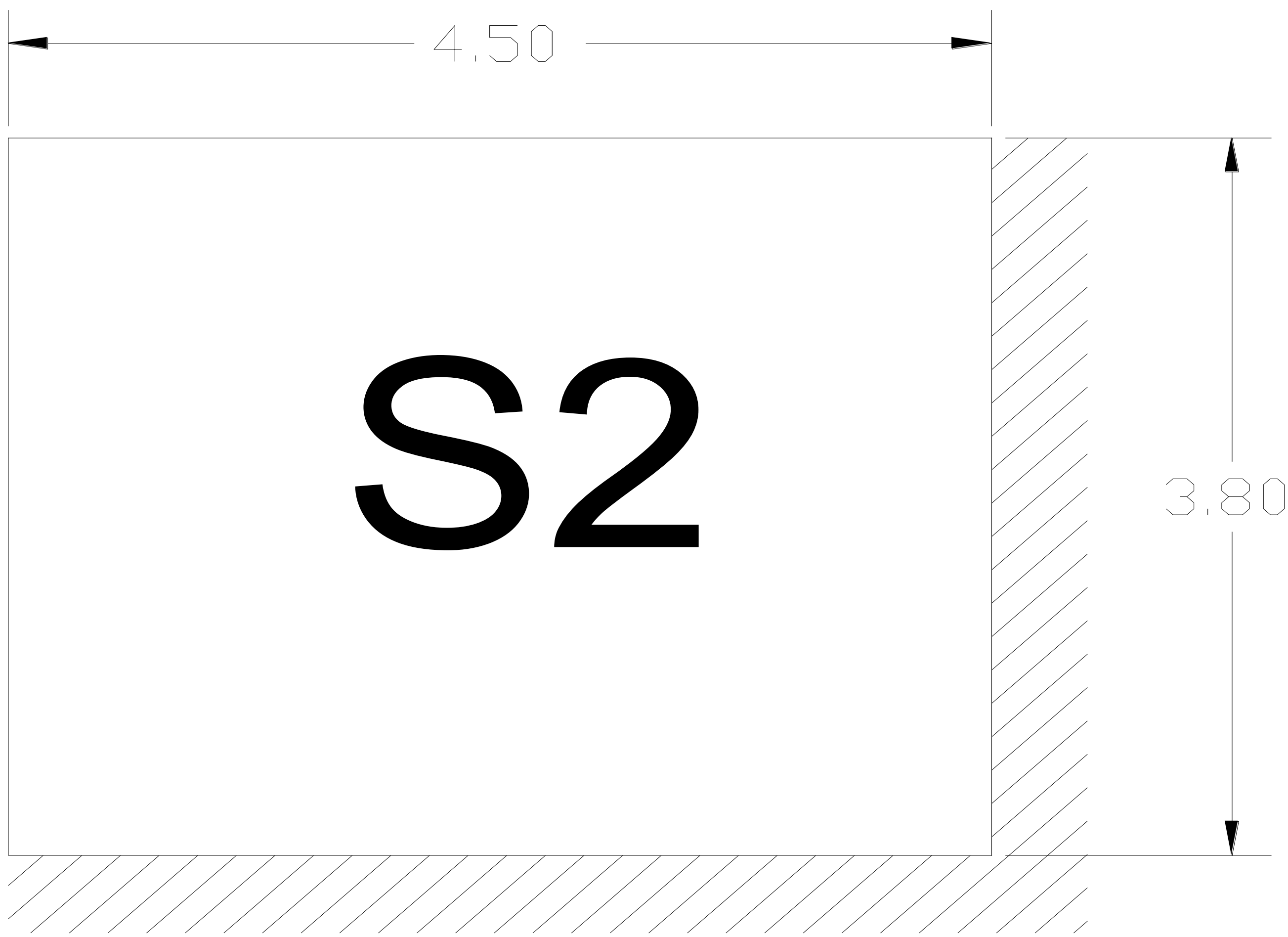
Vu @ d =11.990 * $\frac{4.8}{2}$ - 11.990 * 0.072 = 27.912 *KN*

ØVc = 0.75 * 0.17 * $\sqrt{25}$ *10^3 * 1.0 * 0.072 = 45.9 *KN*

Vu < ØVc → O.K

- **<u>No shear reinforcement is required</u>**

Dimension of slab 2

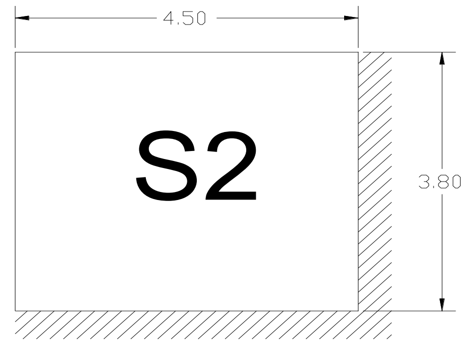


Case 4

5.1.4 *For S- 2*

La = 3.8 m

Lb = 4.5 m



m = $\frac{La}{Lb}$ = $\frac{3.8}{4.5}$ = 0.85 > 0.5

∴ **Two way solid slab → Case (4)**

- ***Coefficient of positive moment and negative moment :***

  - Ca (neg.) = 0.066
  - Ca^{+}(DL) = 0.036
  - Ca^{+} (LL) = 0.043
  - Cb (neg.) = 0.034
  - Cb^{+}(DL) = 0.019
  - Cb^{+} (LL) = 0.023

☒ **Moment at Middle Strip**

- ***Negative moment at continuous edge :***

Ma neg. = Ca (neg.) * Wu * $(La)^2$

Ma neg. = 0.066 * 19.34 * $(3.8)^2$ = 18.431 *KN.m*

Mb neg. = Cb (neg.) * Wu * $(Lb)^2$

Mb neg. = 0.034 * 19.34 * $(4.5)^2$ = 13.315 *KN.m*

- ***Positive Moment:***

- ***Short Direction :***

Ma^{+} (DL) = Ca (DL) * Wu (DL) * $(La)^2$

Ma^{+} (DL) = 0.036 * (12.943) * $(3.8)^2$ = 6.728 *KN.m*

Ma^{+} (LL) = Ca (LL) * Wu (LL) * $(La)^2$

Ma^{+} (LL) = 0.043 * (6.4) * $(3.8)^2$ = 3.973 *KN.m*

Ma^{+} (total) = 10.701 *KN.m*

- ***Long Direction :***

Mb^+ (DL) = Cb (DL) * Wu (DL) * $(Lb)^2$

Mb^+ (DL) = 0.019 * (12.943) * $(4.5)^2$ = 4.979 *KN.M*

Mb^+ (LL) = Cb (LL) * Wu (LL) * $(Lb)^2$

Mb^+ (LL) = 0.023 * (6.4) * $(4.5)^2$ = 2.980 *KN.m*

Mb^+ (total) = 7.959 *KN.m*

☛ ***Negative moment at discontinuous edge :***

Ma (neg.) = $\frac{1}{3}$ * (Middle strip positive moment)

Ma (neg.) = $\frac{1}{3}$ * 10.701 = 3.567 *KN.m*

Mb (neg.) = $\frac{1}{3}$ * (Middle strip positive moment)

Mb (neg.) = $\frac{1}{3}$ * 7.959 = 2.653 *KN.m*

☒ **Moment at Column strip**

☛ ***Negative moment at continues edge :***

Ma (neg.) = $\frac{2}{3}$ * ($Ma^-_{cont.}$ Middle strip)

Ma (neg.) = $\frac{2}{3}$ * 18.43 = 12.286 *KN.m*

Mb (neg.) = $\frac{2}{3}$ * ($Mb^-_{cont.}$ Middle strip)

Mb (neg.) = $\frac{2}{3}$ * 13.315 = 8.876 *KN.m*

- ***Positive Moment:***

$Ma^{+} = \frac{2}{3} * (Ma^{+}_{tot.}$ Middle strip)

$Ma^{+} = \frac{2}{3} * 10.701 = 7.134$ *KN.m*

$Mb^{+} = \frac{2}{3} * (Mb^{+}_{tot.}$ Middle strip)

$Mb^{+} = \frac{2}{3} * 7.959 = 5.306$ *KN.m*

- ***Negative moment at discontinues:***

Ma (neg.) = $\frac{1}{3} * (Ma^{-}_{dis.}$ Middle strip)

Ma (neg.) = $\frac{1}{3} * 3.567 = 1.189$ *KN.m*

Mb (neg.) = $\frac{1}{3} * (Mb^{-}_{dis.}$ Middle strip)

Mb (neg.) = $\frac{1}{3} * 3.935 = 1.311$ *KN.m*

☒ **Check for shear :**

use Table – 4

✓ Wa = 0.66
✓ Wb = 0.34

Wu a = Wa * Wu = 0.66 * 19.34 = 12.764 *KN/m*

Wu b = Wb * Wu = 0.34 * 19.34 = 6.575 *KN/m*

- ***Short Direction :***

Vu @ d =Wu a * $\frac{La}{2}$ - Wu a * d

Vu @ d = 12.764* $\frac{3.8}{2}$ - 12.764* 0.084 = 23.179 *KN*

- ***Long Direction :***

Vu @ d =Wu b * $\frac{Lb}{2}$ - Wu b * d

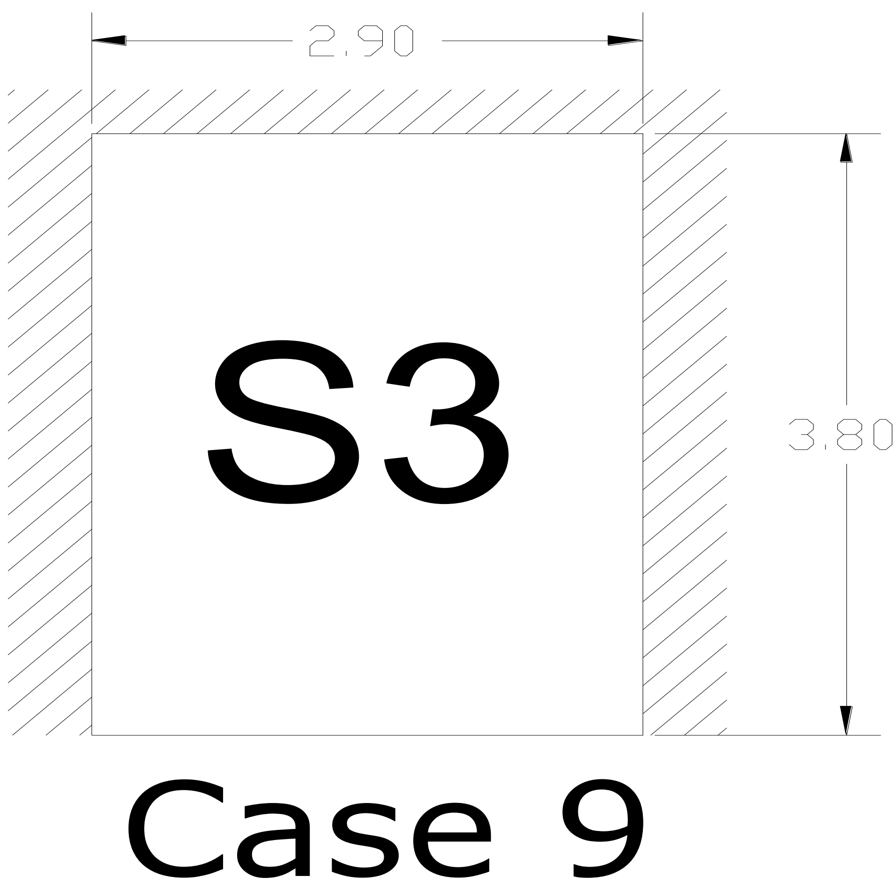
Vu @ d = 6.575* $\frac{4.5}{2}$ - 6.575 * 0.072 = 14.320 *KN*

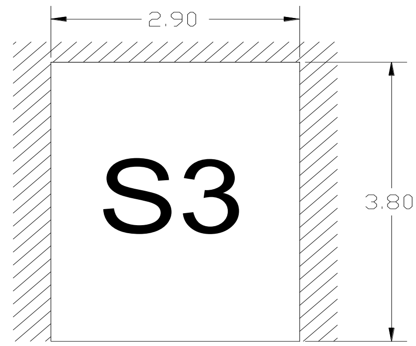
ØVc = 0.75 * 0.17 * $\sqrt{25}$ *10^3 * 1.0 * 0.084 = 53.55 *KN*

Vu < ØVc → Ok ,

☛ **No shear reinforcement is required**

Dimension of slab 3





5.1.5 *For S- 3*

- La = 2.9 m
- Lb = 3.8 m

m = $\frac{La}{Lb}$ = $\frac{2.9}{3.8}$ = 0.8 > 0.5

∴ Two way solid slab

→ Case(9)

- ***Coefficient of positive moment and negative moment :***
  - ✓ Ca (neg.) = 0.075
  - ✓ Ca $^{+}$(DL) = 0.029
  - ✓ Ca^{+} (LL) = 0.042
  - ✓ Cb (neg.) = 0.017
  - ✓ Cb $^{+}$(DL) = 0.010
  - ✓ Cb^{+} (LL) = 0.017

☒ **Moment at Middle Strip**

☛ ***Negative moment at continuous edge :***

Ma neg. = Ca (neg.) * Wu * $(La)^2$

Ma neg. = 0.075 * 19.34 * $(2.9)^2$ = 12.198 *KN.m*

Mb neg. = Cb (neg.) * Wu * $(Lb)^2$

Mb neg. = 0.017 * 19.34 * $(3.8)^2$ = 4.747 *KN.m*

☛ ***Positive Moment:***

- ***Short Direction :***

Ma^{+} (DL) = Ca (DL) * Wu (DL) * $(La)^2$

Ma^{+} (DL) = 0.029 * (12.943) * $(2.9)^2$ = 3.156 *KN.m*

Ma^{+} (LL) = Ca (LL) * Wu (LL) * $(La)^2$

Ma^{+} (LL) = 0.042 * (6.4) * $(3.8)^2$ = 3.881 *KN.m*

Ma^{+} (total) = 7.502 *KN.m*

- ***Long Direction :***

Mb^+ (DL) = Cb (DL) * Wu (DL) * $(Lb)^2$

Mb^+ (DL) = 0.010 * (12.943) * $(3.8)^2$ = 1.868 *KN.m*

Mb^+ (LL) = Cb (LL) * Wu (LL) * $(Lb)^2$

Mb^+ (LL) = 0.017 * (6.4) * $(3.8)^2$ = 1.571 *KN.m*

Mb^+ (total) = 3.439 *KN.m*

☛ ***Negative moment at discontinuous edge :***

Mb (neg.) = $\frac{1}{3}$ * (Middle strip positive moment)

Mb (neg.) = $\frac{1}{3}$ * 3.439 = 1.146 *KN.m*

☒ **Moment at Column strip:**

☛ ***Negative moment at continues edge :***

Ma (neg.) = $\frac{2}{3}$ * ($Ma^-_{cont.}$ Middle strip)

Ma (neg.) = $\frac{2}{3}$ * 12.198 = 8.132 *KN.m*

Mb (neg.) = $\frac{2}{3}$ * ($Mb^-_{cont.}$ Middle strip)

Mb (neg.) = $\frac{2}{3}$ * 4.747 = 3.164 *KN.m*

☛ ***Positive Moment:***

Ma^+ = $\frac{2}{3}$ * ($Ma^+_{tot.}$ Middle strip)

Ma^+ = $\frac{2}{3}$ * 7.502 = 5.001*KN.m*

Mb^+ = $\frac{2}{3}$ * ($Mb^+_{tot.}$ Middle strip)

Mb^+ = $\frac{2}{3}$ * 3.439 = 2.292 *KN.m*

☛ ***Negative moment at discontinues edge:***

Mb (neg.) = $\frac{1}{3}$ * (Mb$^{-}_{dis.}$ Middle strip)

Mb (neg.) = $\frac{1}{3}$ * 1.146 = 0.382 *KN.m*

☒ **Check for shear** :

☛ **use Table – 4**

- ✓ Wa = 0.83
- ✓ Wb = 0.17

Wu a = Wa * Wu = 0.83 * 19.34 = 16.052 *KN/m*

Wu b = Wb * Wu = 0.17 * 19.34 = 3.287 *KN/m*

- ***Short Direction :***

Vu @ d =Wu a * $\frac{La}{2}$ - Wu a * d

Vu @ d =16.052 * $\frac{2.9}{2}$ - 16.052 * 0.084 = 21.927 *KN*

- ***Long Direction :***

Vu @ d =Wu b * $\frac{Lb}{2}$ - Wu b * d

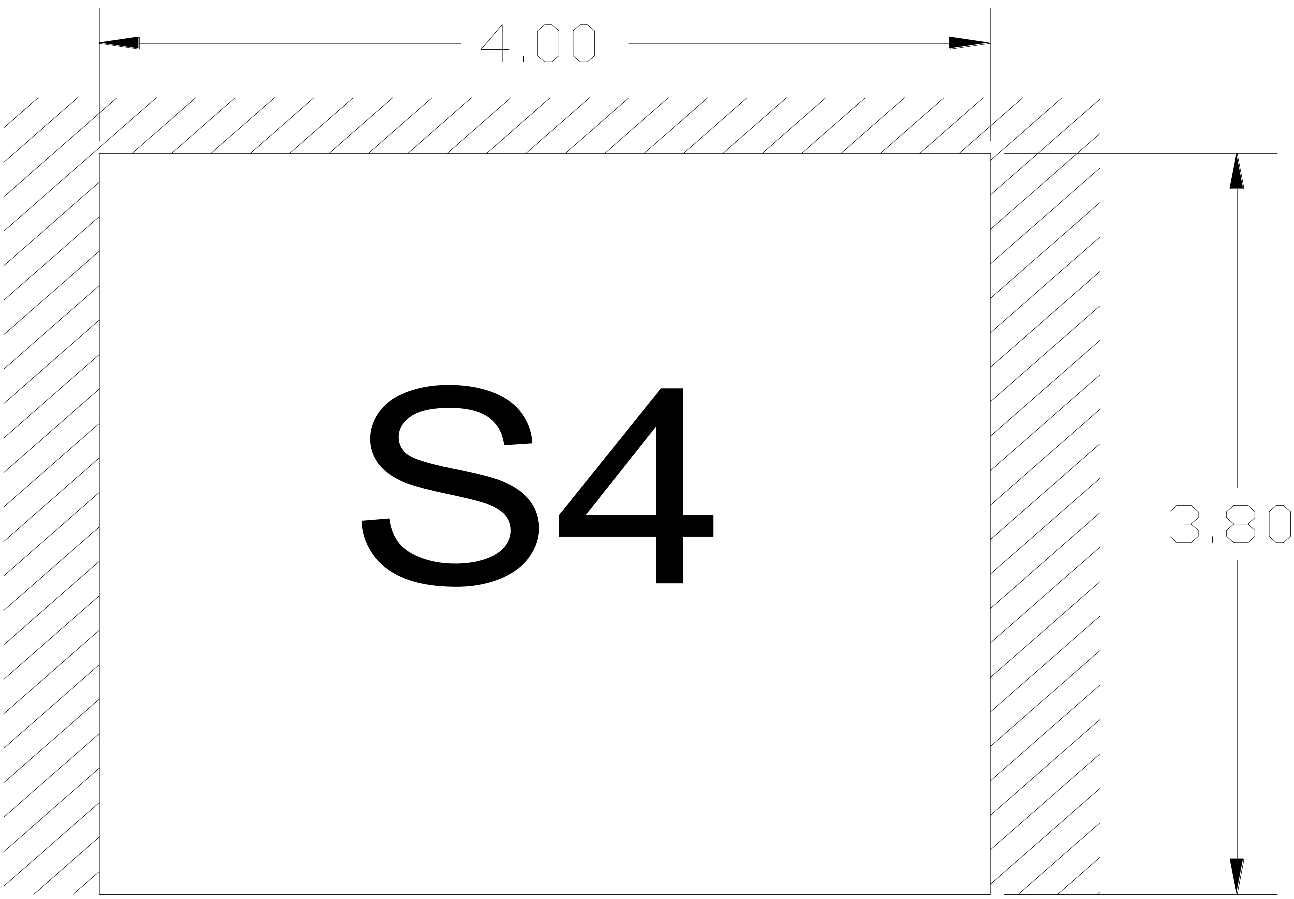
Vu @ d = 3.287 * $\frac{3.8}{2}$ - 3.287 * 0.072 = 6.008 *KN*

ØVc = 0.75 * 0.17 * $\sqrt{25}$ *10^3 * 1.0 * 0.084 = 53.55 *KN*

Vu < ØVc → Ok ,

☛ **No shear reinforcement is required**

Dimension of slab 4



Case 8

5.1.6 *For S- 4*

La = 3.8 m

Lb = 4 m

m = $\frac{La}{Lb}$ = $\frac{3.8}{4}$ = 0.95 > 0.5

∴ Two way solid slab

→ Case (8)

- ***Coefficient of positive moment and negative moment :***

✓ Ca (neg.) = 0.038

✓ Ca $^{+}$(DL) = 0.022

✓ Ca^{+} (LL) = 0.031

✓ Cb (neg.) = 0.056

✓ Cb $^{+}$(DL) = 0.021

✓ Cb^{+} (LL) = 0.027

✓

☒ **Moment at Middle Strip**

☛ ***Negative moment at continuous edge :***

Ma neg. = Ca (neg.) * Wu * $(La)^2$

Ma neg. = 0.038 * 19.34 * $(3.8)^2$ = 10.612 *KN.m*

Mb neg. = Cb (neg.) * Wu * $(Lb)^2$

Mb neg. 0.056 * 19.34 * $(4)^2$ = 17.328 *KN.m*

☛ ***Positive Moment***

- ***Short Direction :***

Ma^{+} (DL) = Ca (DL) * Wu (DL) * $(La)^2$

Ma^{+} (DL) = 0.022 * (12.943) * $(3.8)^2$ 4.111 *KN.m*

Ma^{+} (LL) = Ca (LL) * Wu (LL) * $(La)^2$

Ma^{+} (LL) = 0.031 * (6.4) * $(3.8)^2$ = 2.864 *KN.m*

Ma^{+} (total) = 6.975 *KN.m*

- ***Long Direction :***

Mb^+ (DL) = Cb (DL) * Wu (DL) * $(Lb)^2$

Mb^+ (DL) = 0.021 * (12.943) * $(4)^2$ = 4.348 *KN.m*

Mb^+ (LL) = Cb (LL) * Wu (LL) * $(Lb)^2$

Mb^+ (LL) = 0.027 * (6.4) * $(4)^2$ = 2.764 *KN.m*

Mb^+ (total) = 5.112 *KN.m*

☛ ***Negative moment at discontinuous edge :***

Ma (neg.) = $\frac{1}{3}$ * (Middle strip positive moment)

Ma (neg.) = $\frac{1}{3}$ * 6.975 = 2.325 *KN.m*

☒ ***Moment at Column strip :***

☛ ***Negative moment @ continues edge :***

Ma (neg.) = $\frac{2}{3}$ * ($Ma^-_{cont.}$ Middle strip)

Ma (neg.) = $\frac{2}{3}$ * 10.612 = 7.074 *KN.m*

Mb (neg.) = $\frac{2}{3}$ * ($Mb^-_{cont.}$ Middle strip)

Mb (neg.) = $\frac{2}{3}$ * 17.328 = 11.552 *KN.m*

☛ ***Positive Moment for Column strip :***

Ma^+ = $\frac{2}{3}$ * ($Ma^+_{tot.}$ Middle strip)

Ma^+ = $\frac{2}{3}$ * 6.975 = 4.65 *KN.m*

Mb^+ = $\frac{2}{3}$ * ($Mb^+_{tot.}$ Middle strip)

Mb^+ = $\frac{2}{3}$ * 5.112 = 3.408 *KN.m*

- ***Negative moment at discontinues edge :***

Ma (neg.) = $\frac{1}{3}$ * (Ma$^{-}_{dis.}$ Middle strip)

Ma (neg.) = $\frac{1}{3}$ * 2.325 = 0.775 *KN.m*

☒ **Check for shear :**

use Table – 4

- ✓ W_a = 0.38
- ✓ W_b = 0.62

Wu(a) = Wa * Wu = 0.38 * 19.34 = 7.349 *KN/m*

Wu (b) = Wb * Wu = 0.62 * 19.34 = 11.99 *KN/m*

- ***Short Direction :***

Vu @ d =Wu a * $\frac{La}{2}$ - Wu a * d

Vu @ d =7.349* $\frac{3.8}{2}$ - 7.349 * 0.084 = 13.345 *KN*

- ***Long Direction :***

Vu @ d =Wu b * $\frac{Lb}{2}$ - Wu b * d

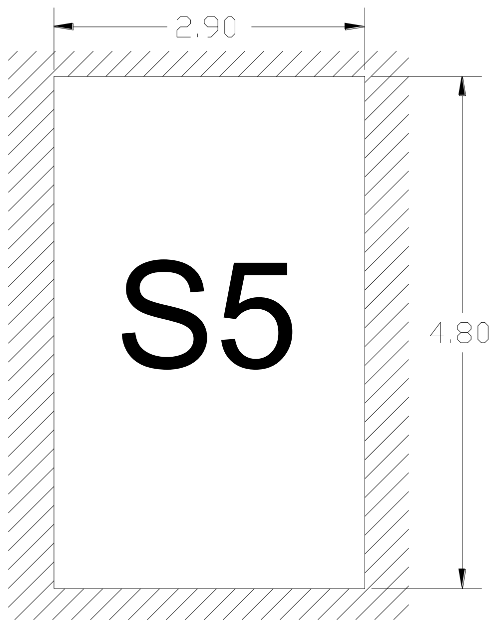
Vu @ d = 11.99 * $\frac{4}{2}$ - 11.99 * 0.072 = 23.116 *KN*

ØVc = 0.75 * 0.17 * $\sqrt{25}$ *10^{3} * 1.0 * 0.084 = 53.55 *KN*

Vu < ØVc → Ok

- **No shear reinforcement is required**

Dimension of slab 5

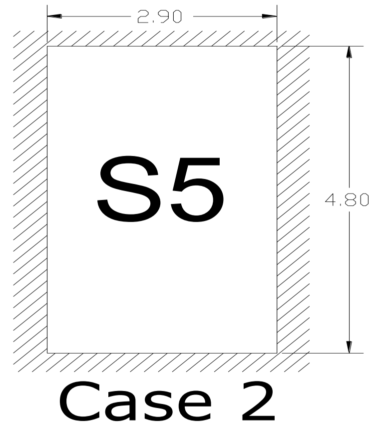


Case 2

5.1.7 *For S- 5*

La = 2.9 m

Lb = 4.8 m



m = $\frac{La}{Lb}$ = $\frac{2.9}{4.8}$ = 0.6 > 0.5

∴ **Two way solid slab → Case (2)**

- ***Coefficient of positive moment and negative moment :***
  - ✓ Ca (neg.) = 0.081
  - ✓ Ca $^{+}$(DL) = 0.034
  - ✓ Ca^{+} (LL) = 0.058
  - ✓ Cb (neg.) = 0.010
  - ✓ Cb $^{+}$(DL) = 0.004
  - ✓ Cb^{+} (LL) = 0.007

- **Moment at Middle Strip**

☛ ***Negative moment at continuous edge :***

Ma neg. = Ca (neg.) * Wu * $(La)^2$

Ma neg. = 0.081 * 19.34 * $(2.9)^2$ = 13.175 *KN.m*

Mb neg. = Cb (neg.) * Wu * $(Lb)^2$

Mb neg. = 0.010 * 19.34 * $(4.8)^2$ = 4.456 *KN.m*

☛ ***Positive Moment :***

- ***Short Direction :***

Ma^{+} (DL) = Ca (DL) * Wu (DL) * $(La)^2$

Ma^{+} (DL) = 0.034 * (12.943) * $(2.9)^2$ = 3.700*KN.m*

Ma^{+} (LL) = Ca (LL) * Wu (LL) * $(La)^2$

Ma^{+} (LL) = 0.058 * (6.4) * $(2.9)^2$ = 3.122 *KN.m*

Ma^{+} (total) = 3.700 + 3.1 = 6.80 KN.m

- ***Long Direction :***

Mb^+ (DL) = Cb (DL) * Wu (DL) * $(Lb)^2$

Mb^+ (DL) = 0.004 * (12.943) * $(4.8)^2$ = 1.193 *KN.m*

Mb^+ (LL) = Cb (LL) * Wu (LL) * $(Lb)^2$

Mb^+ (LL) = 0.007 * (6.4) * $(4.8)^2$ = 1.0321 *KN.m*

Mb^+ (total) = 2.225 *KN.m*

- ***Moment at Column strip :***

☛ ***Negative moment at continues edge :***

Ma (neg.) = $\frac{2}{3}$ * ($Ma^-_{cont.}$ Middle strip)

Ma (neg.) = $\frac{2}{3}$ * 13.175 = 8.783 *KN.m*

Mb (neg.) = $\frac{2}{3}$ * ($Mb^-_{cont.}$ Middle strip)

Mb (neg.) = $\frac{2}{3}$ * 4.456 = 2.971*KN.m*

☛ ***Positive Moment :***

$Ma^+ = \frac{2}{3}$ * ($Ma^+_{tot.}$ Middle strip)

$Ma^+ = \frac{2}{3}$ * 6.80 = 4.549 *KN.m*

$Mb^+ = \frac{2}{3}$ * ($Mb^+_{tot.}$ Middle strip)

$Mb^+ = \frac{2}{3}$ * 2.225 = 1.483 *KN.m*

☒ **Check for shear :**

use Table – 4 get Wa = 0.89, Wb = 0.11

Wu a = Wa * Wu = 0.89 * 19.34 = 17.213 *KN/m*

Wu b = Wb * Wu = 0.11 * 19.34 = 2.127 *KN/m*

- ***Short Direction :***

Vu @ d =Wu a * $\frac{La}{2}$ - Wu a * d

Vu @ d =17.213 * $\frac{2.9}{2}$ - 17.213 * 0.084 = 23.5 *KN*

- ***Long Direction :***

Vu @ d =Wu b * $\frac{Lb}{2}$ - Wu b * d

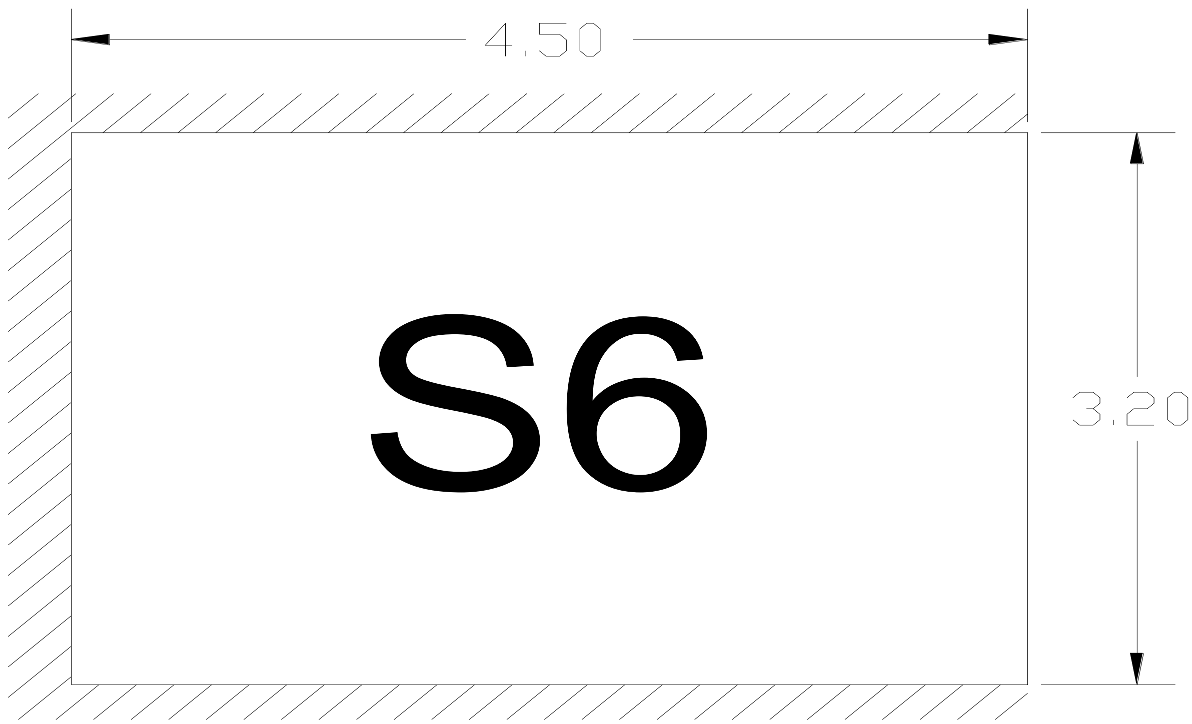
Vu @ d = 2.127 * $\frac{4.8}{2}$ - 2.127 * 0.072 = 4.95 *KN*

ØVc = 0.75 * 0.17 * $\sqrt{25}$ *10^3 * 1.0 * 0.084 = 53.55 *KN*

Vu < ØVc → Ok

☛ **No shear reinforcement is required**

Dimension of slab 6

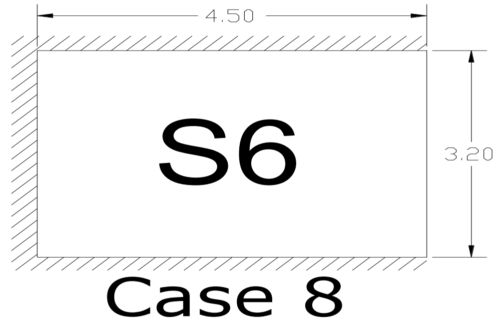


Case 8

5.1.8 *Slab 6*

La = 3.2 m

Lb = 4.5 m



m = $\frac{La}{Lb}$ = $\frac{3.2}{4.5}$ = 0.71 > 0.5

∴ Two way solid slab → Case (8)

- ***Coefficient of positive moment and negative moment :***

  - ✓ Ca (neg.) = 0.068
  - ✓ Ca $^{+}$(DL) = 0.04
  - ✓ Ca^{+} (LL) = 0.054
  - ✓ Cb (neg.) = 0.029
  - ✓ Cb $^{+}$(DL) = 0.011
  - ✓ Cb^{+} (LL) = 0.014
  - ✓

- ***Moment at Middle Strip***

☛ ***Negative moment at continuous edge :***

Ma neg. = Ca (neg.) * Wu * $(La)^2$

Ma neg. = 0.068 * 19.34 * $(3.2)^2$ = 13.467 *KN.m*

Mb neg. = Cb (neg.) * Wu * $(Lb)^2$

Mb neg. = 0.029 * 19.34 * $(4.5)^2$ = 11.357 *KN.m*

☛ ***Positive Moment :***

- ***Short Direction :***

Ma^{+} (DL) = Ca (DL) * Wu (DL) * $(La)^2$

Ma^{+} (DL) = 0.04 * (12.943) * $(3.2)^2$ = 5.301 *KN.m*

Ma^{+} (LL) = Ca (LL) * Wu (LL) * $(La)^2$

Ma^{+} (LL) = 0.054 * (6.4) * $(3.2)^2$ = 3.539 *KN.m*

Ma^{+} (total) = 8.84 *KN.m*

- ***Long Direction :***

Mb^+ (DL) = Cb (DL) * Wu (DL) * $(Lb)^2$

Mb^+ (DL) = 0.011 * (12.943) * $(4.5)^2$ = 2.883 *KN.m*

Mb^+ (LL) = Cb (LL) * Wu (LL) * $(Lb)^2$

Mb^+ (LL) = 0.014 * (6.4) * $(4.5)^2$ = 1.814 *KN.m*

Mb^+ (total) = 4.697 *KN.m*

☛ ***Negative moment at discontinuous edge :***

Mb (neg.) = $\frac{1}{3}$ * (Middle strip positive moment)

Mb (neg.) = $\frac{1}{3}$ * 4.647 = 1.567 *KN.m*

☒ ***Moment at Column strip***

☛ ***Negative moment at continues edge :***

Ma (neg.) = $\frac{2}{3}$ * ($Ma^-_{cont.}$ Middle strip)

Ma (neg.) = $\frac{2}{3}$ * 13.467 = 8.978 *KN.m*

Mb (neg.) = $\frac{2}{3}$ * ($Mb^-_{cont.}$ Middle strip)

Mb (neg.) = $\frac{2}{3}$ * 11.357 = 7.571 *KN.m*

☛ ***Positive Moment:***

Ma^+ = $\frac{2}{3}$ * ($Ma^+_{tot.}$ Middle strip)

Ma^+ = $\frac{2}{3}$ * 8.48 = 5.653 *KN.m*

Mb^+ = $\frac{2}{3}$ * ($Mb^+_{tot.}$ Middle strip)

Mb^+ = $\frac{2}{3}$ * 4.697 = 3.131 *KN.m*

☛ ***Negative moment at discontinues edge:***

Mb (neg.) = $\frac{1}{3}$ * ($Mb^{-}_{dis.}$ Middle strip)

Mb (neg.) = $\frac{1}{3}$ * 1.567 = 0.522 *KN.m*

➢ **Check for shear :**

use Table 4

- ✓ Wa = 0.68
- ✓ Wb = 0.32

Wu a = Wa * Wu = 0.68 * 19.34 = 13.151 *KN/m*

Wu b = Wb * Wu = 0.32 * 19.34 = 6.188 *KN/m*

- ***Short Direction :***

Vu @ d =Wu a * $\frac{La}{2}$ - Wu a * d

Vu @ d =13.151 * $\frac{3.2}{2}$ - 13.151 * 0.084 = 19.937 *KN*

- ***Long Direction :***

Vu @ d =Wu b * $\frac{Lb}{2}$ - Wu b * d

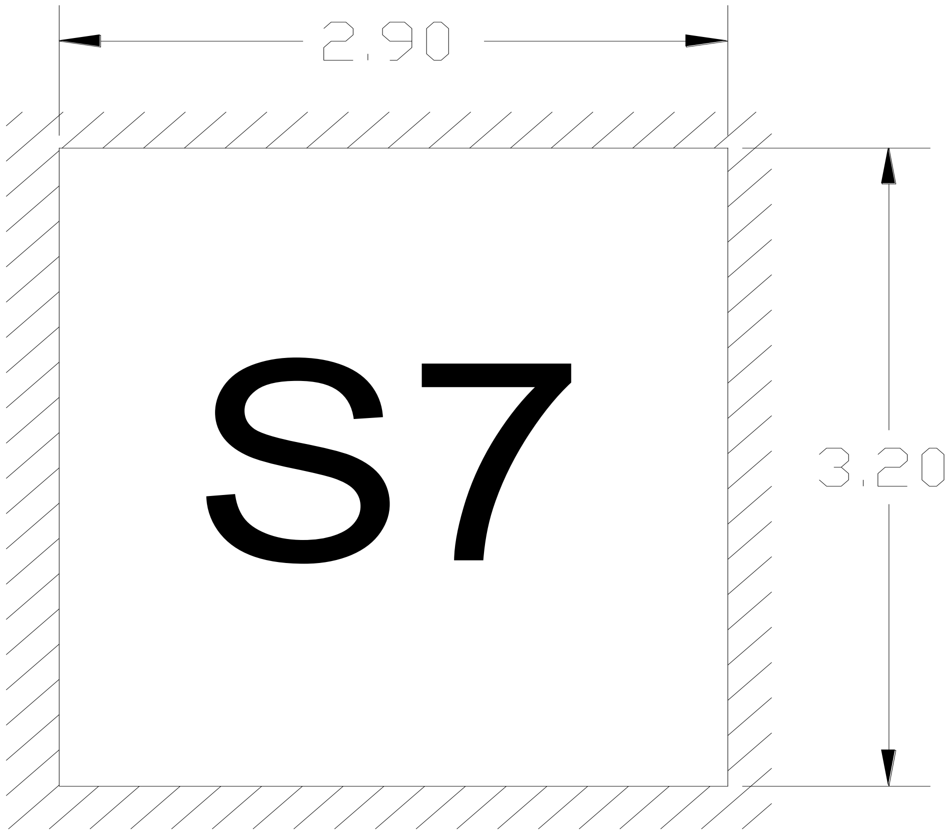
Vu @ d = 6.188 * $\frac{4.5}{2}$ - 6.188 * 0.072 = 13.479 *KN*

ØVc = 0.75 * 0.17 * $\sqrt{25}$ *10^3 * 1.0 * 0.084 = 53.55 *KN*

Vu < ØVc → Ok ,

☛ **No shear reinforcement is required**

Dimension of slab 7



Case 2

5.1.9 ***Slab 7***

La = 2.9 m

Lb = 3.2 m

$m = \frac{La}{Lb} = \frac{2.9}{3.2} = 0.9 > 0.5$

∴ Two way solid slab → Case (2)

- ***Coefficient of positive moment and negative moment*** **:**

  - ✓ Ca (neg.) = 0.055
  - ✓ Ca^{+}(DL) = 0.022
  - ✓ Ca^{+} (LL) = 0.034
  - ✓ Cb (neg.) = 0.037
  - ✓ Cb^{+}(DL) = 0.014
  - ✓ Cb^{+} (LL) = 0.022

- **Moment at Middle Strip**

☛ ***Negative moment at continuous edge :***

Ma neg. = Ca (neg.) * Wu * $(La)^2$

Ma neg. = 0.055 * 19.34 * $(2.9)^2$ = 8.945 *KN.m*

Mb neg. = Cb (neg.) * Wu * $(Lb)^2$

Mb neg. = 0.037 * 19.34 * $(3.2)^2$ = 7.327 *KN.m*

☛ ***Positive Moment :***

- ***Short Direction :***

Ma^{+} (DL) = Ca (DL) * Wu (DL) * $(La)^2$

Ma^{+} (DL) = 0.022 * (12.943) * $(2.9)^2$ = 2.394 *KN.m*

Ma^{+} (LL) = Ca (LL) * Wu (LL) * $(La)^2$

Ma^{+} (LL) = 0.034 * (6.4) * $(2.9)^2$ = 1.830 *KN.m*

Ma^{+} (total) = 4.224 *KN.m*

- ***Long Direction :***

Mb^+ (DL) = Cb (DL) * Wu (DL) * $(Lb)^2$

Mb^+ (DL) = 0.014 * (12.943) * $(3.2)^2$ = 1.855 *KN.m*

Mb^+ (LL) = Cb (LL) * Wu (LL) * $(Lb)^2$

Mb^+ (LL) = 0.022 * (6.4) * $(3.2)^2$ = 1.441 *KN.m*

Mb^+ (total) = 3.296 *KN.m*

☒ **Moment at Column strip:**

☛ ***Negative moment @ continues edge :***

Ma (neg.) = $\frac{2}{3}$ * ($Ma^-_{cont.}$ Middle strip)

Ma (neg.) = $\frac{2}{3}$ * 8.945 = 5.963 *KN.m*

Mb (neg.) = $\frac{2}{3}$ * ($Mb^-_{cont.}$ Middle strip)

Mb (neg.) = $\frac{2}{3}$ * 7.327 = 4.884 *KN.m*

☛ ***Positive Moment for Column strip :***

$Ma^+ = \frac{2}{3}$ * ($Ma^+_{tot.}$ Middle strip)

$Ma^+ = \frac{2}{3}$ * 4.224 = 2.816 *KN.m*

$Mb^+ = \frac{2}{3}$ * ($Mb^+_{tot.}$ Middle strip)

$Mb^+ = \frac{2}{3}$ * 3.296 = 2.197 *KN.m*

☒ **Check for shear** :

use Table – 4

- ✓ Wa = 0.60
- ✓ Wb = 0.40

Wu a = Wa * Wu = 0.60 * 19.34 = 11.604 *KN/m*

Wu b = Wb * Wu = 0.40 * 19.34 = 7.736 *KN/m*

- ***Short Direction :***

Vu @ d =Wu a * $\frac{L}{2}$ - Wu a * d

Vu @ d =11.604 * $\frac{2.9}{2}$ - 11.604 * 0.084 = 15.851 *KN*

- ***Long Direction :***

Vu @ d =Wu b * $\frac{L}{2}$ - Wu b * d

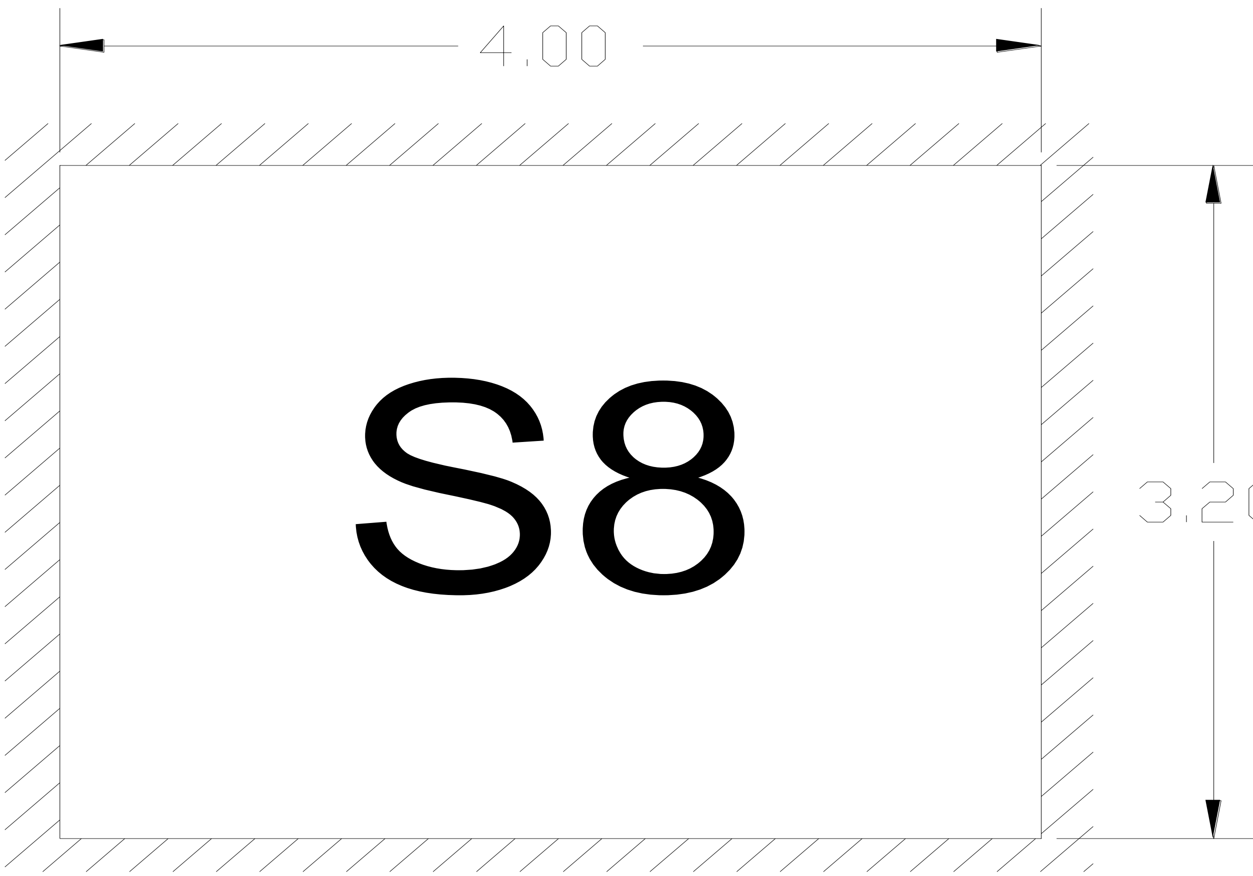
Vu @ d = 7.736 * $\frac{3.2}{2}$ - 7.736 * 0.072 = 11.820 *KN*

ØVc = 0.75 * 0.17 * $\sqrt{25}$ *10^3 * 1.0 * 0.084 = 53.55 *KN*

Vu < ØVc → Ok

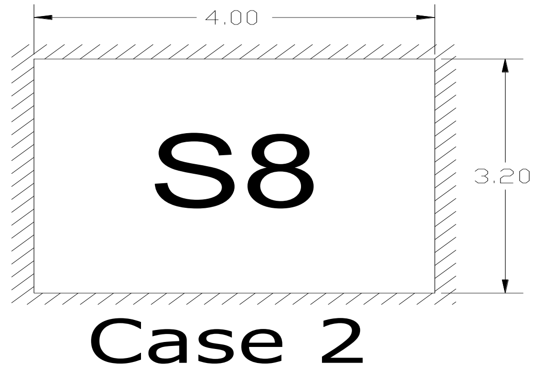
☛ **No shear reinforcement is required**

Dimension of slab 8



Case 2

5.1.10 *Slab 8*



La = 3.2 m

Lb = 4 m

m = $\frac{La}{Lb}$ = $\frac{3.2}{4.0}$ = 0.8 > 0.5

∴ Two way solid slab → Case (9)

- ***Coefficient of positive moment and negative moment :***

  - ✓ Ca (neg.) = 0.075
  - ✓ Ca $^{+}$(DL) = 0.029
  - ✓ Ca^{+} (LL) = 0.042
  - ✓ Cb (neg.) = 0.017
  - ✓ Cb $^{+}$(DL) = 0.010
  - ✓ Cb^{+} (LL) = 0.017

- **Moment at Middle Strip**

☛ ***Negative moment at continuous edge :***

Ma neg. = Ca (neg.) * Wu * $(La)^2$

Ma neg. = 0.075 * 19.34 * $(3.2)^2$ = 14.853 *KN.m*

Mb neg. = Cb (neg.) * Wu * $(Lb)^2$

Mb neg. = 0.017 * 19.34 * $(4)^2$ = 5.260 *KN.m*

☛ ***Positive Moment:***

- ***Short Direction :***

Ma^+ (DL) = Ca (DL) * Wu (DL) * $(La)^2$

Ma^+ (DL) = 0.029 * (12.943) * $(3.2)^2$ = 3.843 *KN.m*

Ma^+ (LL) = Ca (LL) * Wu (LL) * $(La)^2$

Ma^+ (LL) = 0.042 * (6.4) * $(3.2)^2$ = 2.752 *KN.m*

Ma^+ (total) = 6.595 *KN.m*

- ***Long Direction*** :

Mb^+ (DL) = Cb (DL) * Wu (DL) * $(Lb)^2$

Mb^+ (DL) = 0.010 * (12.943) * $(4)^2$ = 2.070 *KN.m*

Mb^+ (LL) = Cb (LL) * Wu (LL) * $(Lb)^2$

Mb^+ (LL) = 0.017 * (6.4) * $(4)^2$ = 1.740 *KN.m*

Mb^+ (total) = 3.81 *KN.m*

☒ ***Moment at Column strip:***

☛ ***Negative moment @ continues edge :***

Ma (neg.) = $\frac{2}{3}$ * ($Ma^-_{cont.}$ Middle strip)

Ma (neg.) = $\frac{2}{3}$ * 14.853 = 9.902 *KN.m*

Mb (neg.) = $\frac{2}{3}$ * ($Mb^-_{cont.}$ Middle strip)

Mb (neg.) = $\frac{2}{3}$ * 5.260 = 3.506 *KN.m*

☛ ***Positive Moment for Column strip :***

Ma^+ = $\frac{2}{3}$ * ($Ma^+_{tot.}$ Middle strip)

Ma^+ = $\frac{2}{3}$ * 6.595 = 4.396 *KN.m*

Mb^+ = $\frac{2}{3}$ * ($Mb^+_{tot.}$ Middle strip)

Mb^+ = $\frac{2}{3}$ * 3.81 = 2.54 *KN.m*

☒ **<u>Check for shear :</u>**

use Table – 4

Wa = 0.83

Wb = 0.17

Wu a = Wa * Wu = 0.83 * 19.34 = 16.068 *KN/m*

Wu b = Wb * Wu = 0.17 * 19.34 = 3.291 *KN/m*

- ***Short Direction :***

Vu @ d =Wu a * $\frac{La}{2}$ - Wu a * d

Vu @ d =16.068 * $\frac{3.2}{2}$ - 16.068 * 0.084 = 24.359 *KN*

- ***Long Direction :***

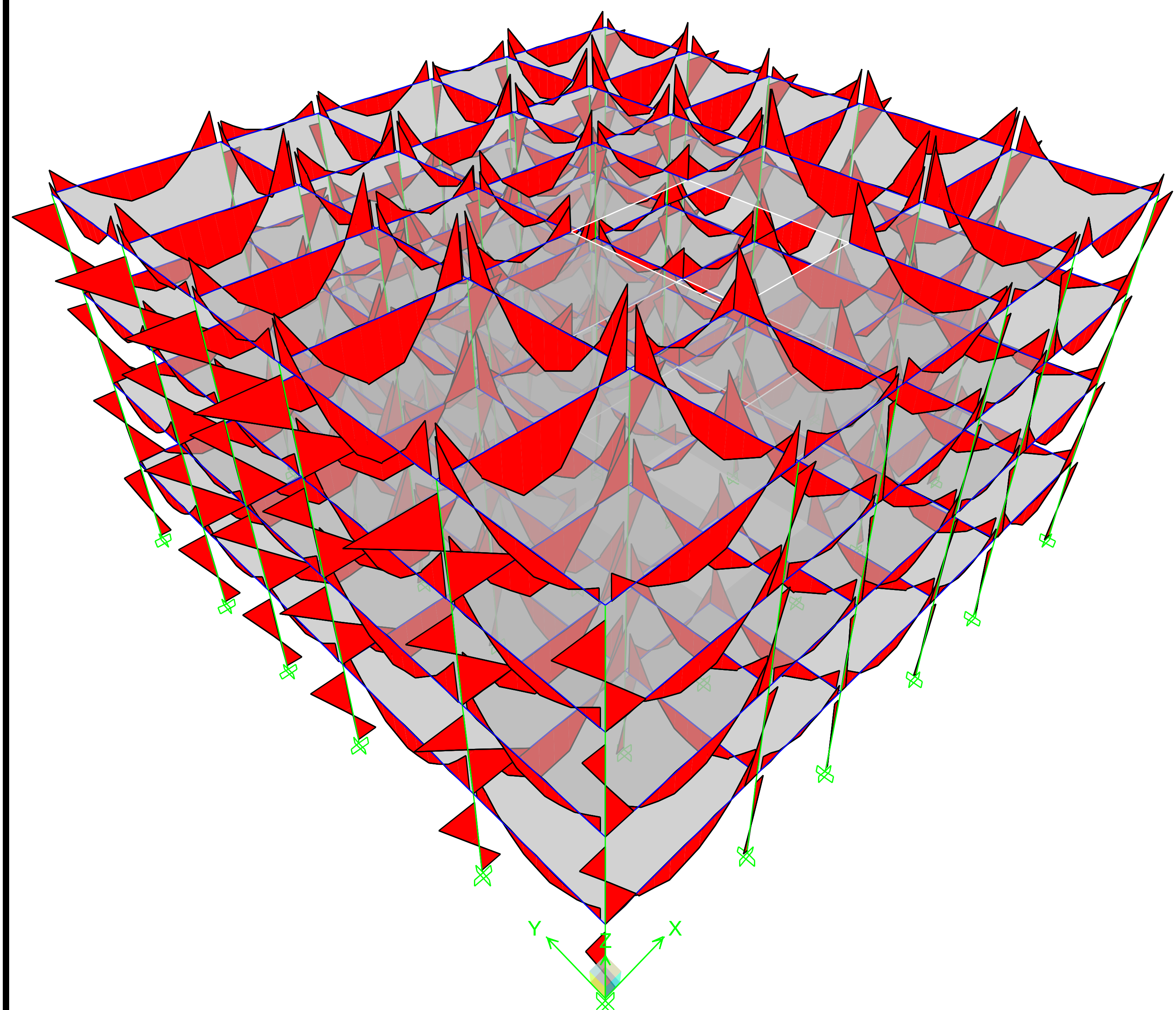
Vu @ d =Wu b * $\frac{Lb}{2}$ - Wu b * d

Vu @ d = 3.291 * $\frac{4}{2}$ - 3.291 * 0.072 = 6.34 *KN*

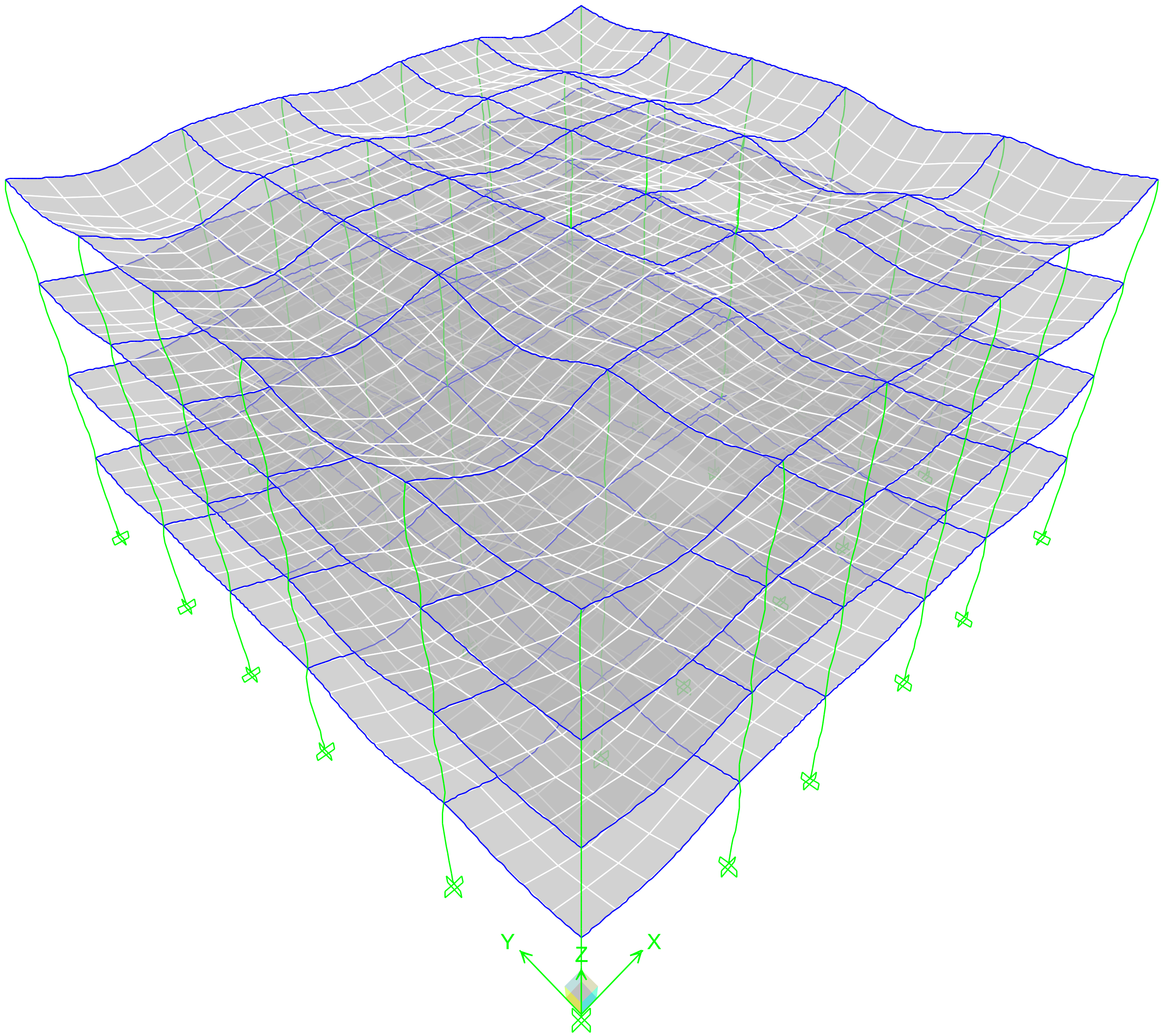
ØVc = 0.75 * 0.17 * $\sqrt{25}$ *10^3 * 1.0 * 0.084 = 53.55 *KN*

☛ **Vu < ØVc → Ok**
No shear reinforcement is required

Moment in 3-D



Deformed shape in slabs due to dead & live load (3-D view)

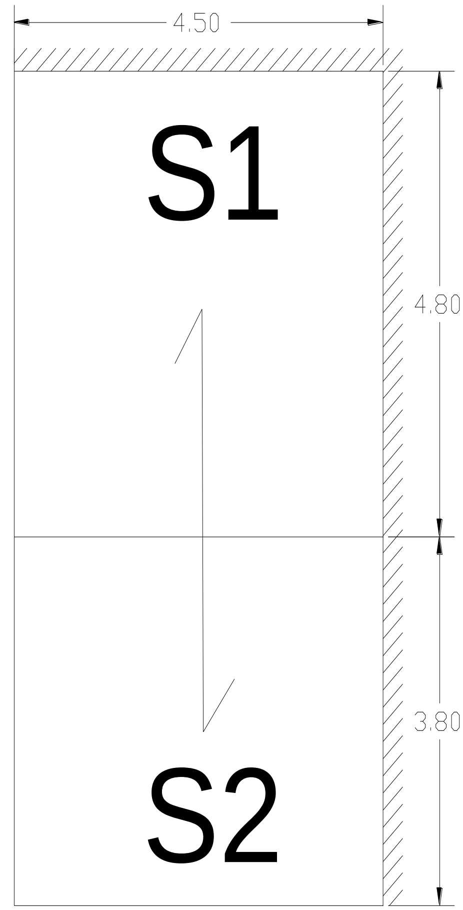


Section 2

" Moment Redistribution"

5.2 Moment Redistribution

5.2.1 Between S1 & s2



M_{b1}^- = 24.95 KN.m

M_{a2}^- = 18.431 KN.m

M_{a2}^- / M_{b1}^- = 18.431/24.95 = 0.738 < 0.80

☛ **Need moment Redistribution**

K1 = $\frac{4EI}{L}$

K2 = $\frac{3EI}{L}$

☛ $K1^-$ = k1 / (k1 + k2)

= (4/4.8) /((4/4.8) + (3/3.8)) = 0.513

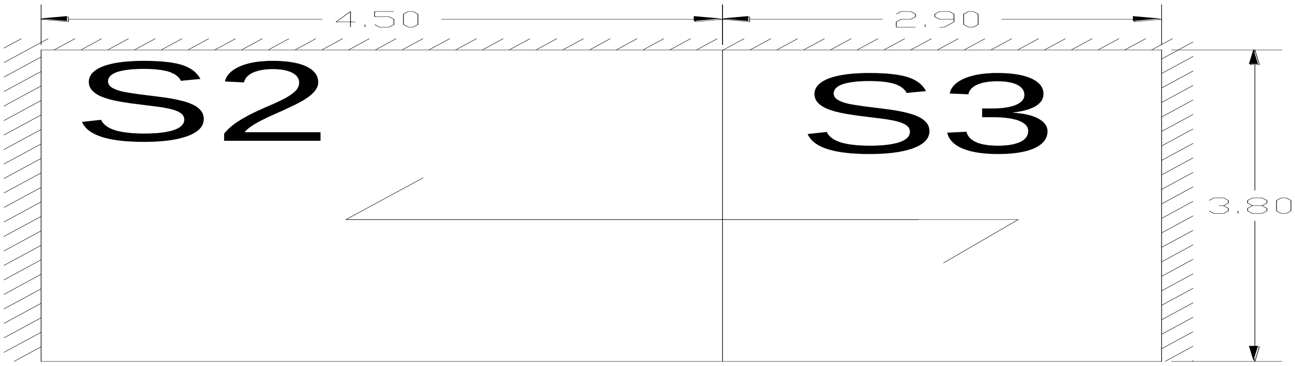
☛ $K2^-$ = k2 / (k1 + k2)

= (3/3.8) /((4/4.8) + (3/3.8)) = 0.487

☛ $\Delta M = M_{b1}^- - M_{a2}^-$ = 24.95 – 18.431 = 6.519

M_{final} = M_{a2}^- + (ΔM * K2) = 18.431 + (0.487*6.519) = **21.605 KN.m**

5.2.2 Between S2 & S3



M_{b2}^{-} = 13.315 KN.m

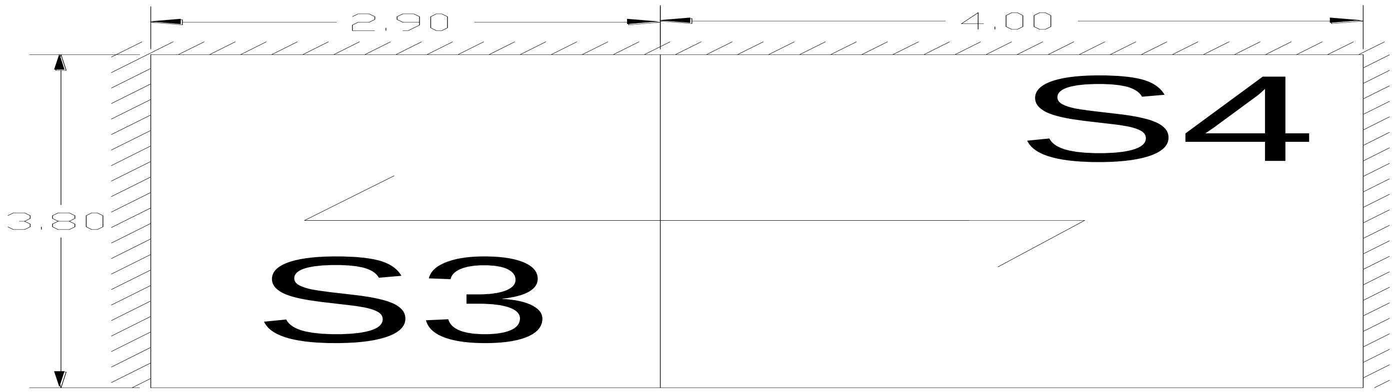
- ✓ **M_{a3}^{-} = 12.198 KN.m**

M_{a3}^{-} / M_{b2}^{-} = 12.198 / 13.315 = 0.916 > 0.8

☛ **No moment Redistribution**

- ✓ **Use M_{b2}^{-} = 13.315 KN.m**

5.2.3 Between S3 & S4



M_{b4}^{-} = 17.328 KN.m

- ✓ **M_{a3}^{-} = 12.189 KN.m**

M_{a3}^{-} / M_{b4}^{-} = 12.189/17.328 = 0.703 < 0.80

☛ **Need moment Redistribution**

K3 = $\frac{4EI}{L}$

K4 = $\frac{4EI}{L}$

☛ $K3^{-}$ = k3 / (k3 + k4)

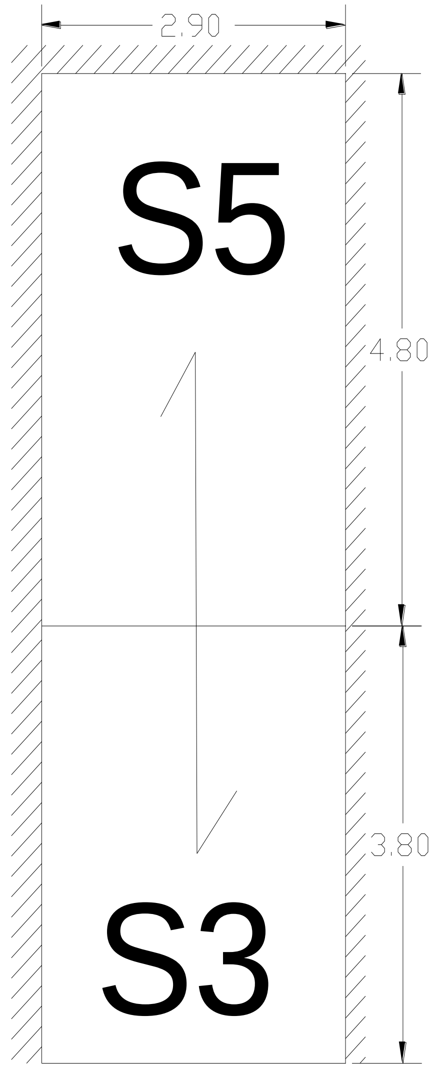
= (4/2.9) /((4/2.9) + (4/4)) = 0.58

☛ $K4^{-}$ = 1 – k3 = 1 – 0.58 = 0.42

☛ ΔM = M_{b4}^{-} - M_{a3}^{-} = 17.328 – 12.189 = 5.139

✓ M_{final} = M_{a3}^{-} + (ΔM * K3) = 12.189 + (0.58*5.139) = **15.169 KN.m**

5.2.4 Between S3 & S5



M_{b3}^{-} = 4.747 KN.m

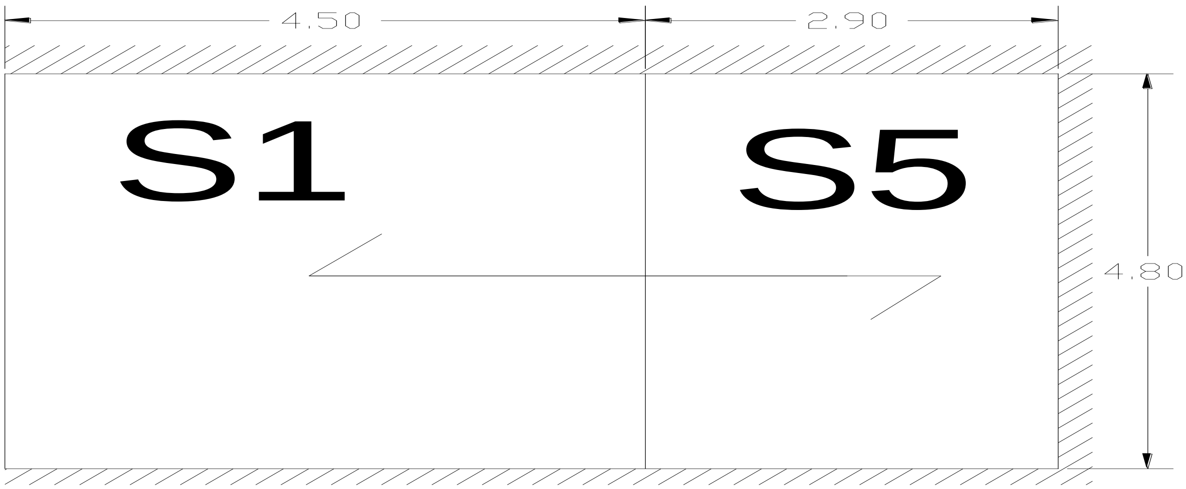
- ✓ M_{b5}^{-} = 4.456 KN.m

M_{b5}^{-} / M_{b3}^{-} = 4.456 / 4.747 = 0.938 > 0.8

☛ **No moment Redistribution**

Use M_{b3}^{-} = 4.747 KN.m

5.2.5 Between S1 & S5



- ✓ M_{a1}^{-} = 14.88 KN.m
- ✓ M_{a5}^{-} = 13.175 KN.m

M_{a5}^{-} / M_{a1}^{-} = 13.175 / 14.88 = 0.885 > 0.8

☛ **No moment Redistribution**

Use M_{b2}^{-} = 14.88 KN.m

5.2.6 Values of moment in Table:

Slab	Case	Middle Strip					
		Short Direction			Long Direction		
		$M^-_{cont.}$	M^+	$M^-_{dis.}$	$M^-_{cont.}$	M^+	$M^-_{dis.}$
S1	Case 8	14.88	9.784	3.261	24.95	10.243	--------
S2	Case 4	**21.605**	10.701	3.567	13.315	7.959	2.653
S3	Case 9	**15.169**	7.502	--------	4.747	3.439	1.146
S4	Case 8	10.612	6.975	2.325	17.328	5.112	--------
S5	Case 2	13.175	6.8	--------	4.456	2.225	--------
S6	Case 8	13.467	8.84	--------	11.357	4.697	1.567
S7	Case 2	8.945	4.224	--------	7.327	3.296	--------
S8	Case 9	14.853	6.595	--------	5.260	3.81	--------

Slab	Case	Column Strip					
		Short Direction			Long Direction		
		$M^-_{cont.}$	M^+	$M^-_{dis.}$	$M^-_{cont.}$	M^+	$M^-_{dis.}$
S1	Case 8	9.92	6.522	1.087	16.63	6.828	--------
S2	Case 4	12.286	7.134	1.189	8.876	5.306	1.311
S3	Case 9	8.132	5.001	--------	3.164	2.292	0.382
S4	Case 8	7.074	4.65	0.775	11.552	3.408	--------
S5	Case 2	8.783	4.549	--------	2.971	1.483	--------
S6	Case 8	8.978	5.653	--------	7.571	3.131	0.522
S7	Case 2	5.963	2.816	--------	4.884	2.197	--------
S8	Case 9	9.902	4.396	--------	3.506	2.54	--------

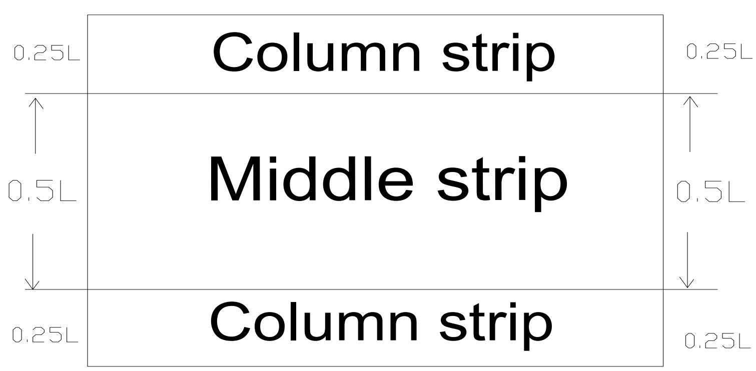
- **M : (KN/m)**

Section 3

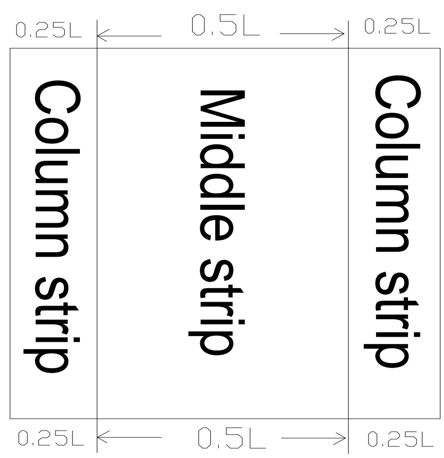
" Design Reinforcement of Slabs "

5.2 <u>*The slab panels in both directions are divided into:*</u>

1- **Two column strip (C.S)**
2- **One middle strip (M.S)**

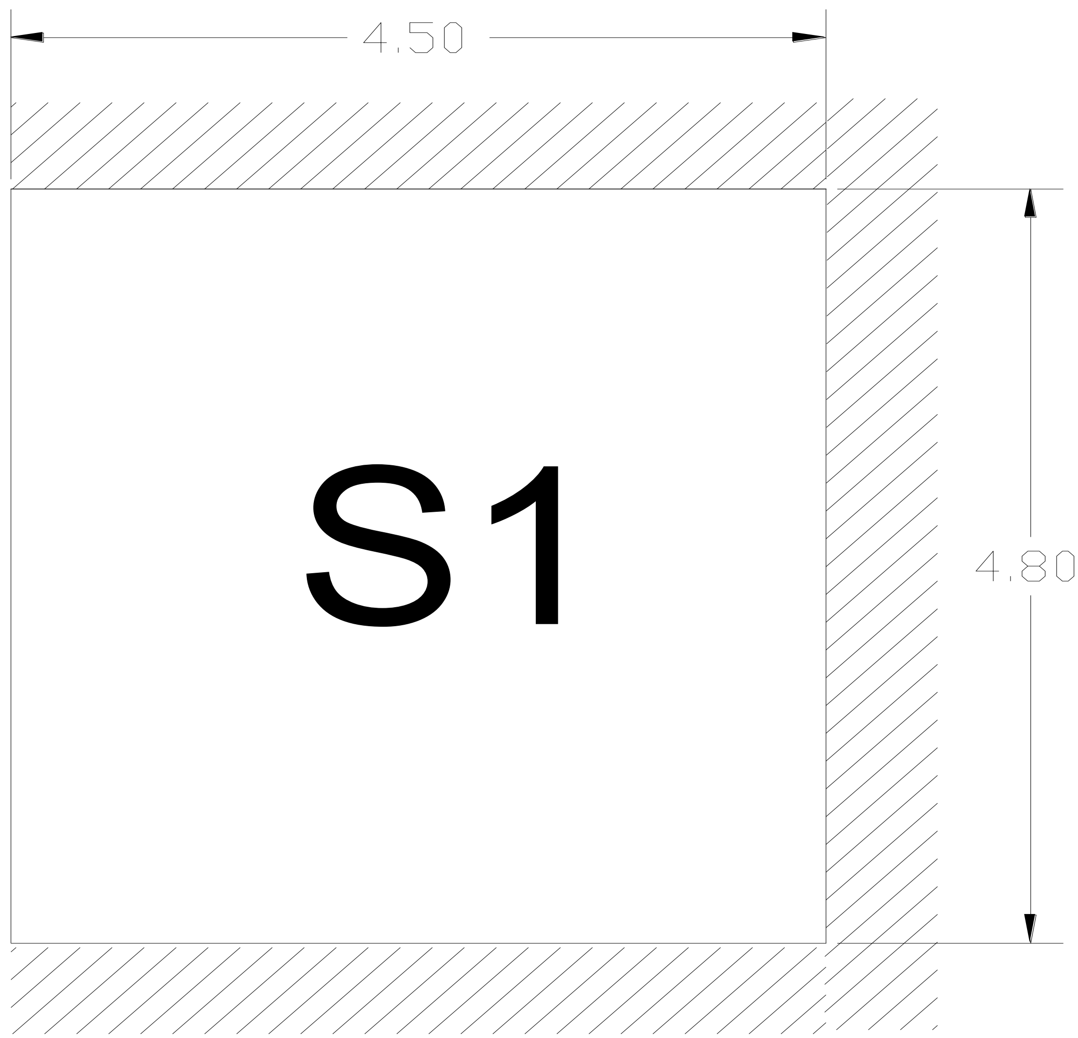


Short direction



Long direction

Dimension of slab 1



Case 8

5.3.1 Reinforcement of Slab 1

- ✓ **Short Direction**
- ❖ **Middle Strip :**

☒ **Negative moment @ continuous edge :**

$Ma^- = 14.88$ KN.m

$$R = \frac{Mu}{\emptyset * f'c * b * d^2} = \frac{14.88}{0.9 * 1000 * 25 * 0.084^2} = 0.0937$$

Using R – ω Table : $\omega = 0.1$

$$\rho = \frac{\omega * f'c}{Fy} = \frac{0.1 * 25}{420} = 0.00595 > \rho_{min} = 0.0018 \quad \text{... O.K}$$

$As_{req.} = \rho * b * d_{short} = 0.00595 * 1000 * 84 = 499.8\ mm^2$

$As_{min} = \rho_{min} * b * t = 0.0018 * 1000 * 110 = 198\ mm^2$

$As_{req.} > As_{min}$ → ... O.K

$$S_{ma*} = \text{min of} \begin{cases} 2t = 2 * 110 = 220\ mm\ (control) \\ 500\ mm \end{cases}$$

☛ Use Ø 12 @ 220 c/c → As = 514 mm^2

☒ **Positive Moment :**

$Ma^+ = 9.784$ KN-m

$$R = \frac{Mu}{\emptyset * f'c * b * d^2} = \frac{9.784}{0.9 * 1000 * 25 * 0.084^2} = 0.0616$$

Using R – ω Table : $\omega = 0.064$

$$\rho = \frac{\omega * f'c}{Fy} = \frac{0.064 * 25}{420} = 0.00381 > \rho_{min} = 0.0018 \quad \text{... O.K}$$

$As_{req.} = \rho * b * d_{short} = 0.00381 * 1000 * 84 = 320\ mm^2$

$As_{req.} > As_{min}$ → … O.K

☛ Use Ø10 @ 220 mm c/c → $As = 357\ mm^2$

☒ **Negative moment @ discontinuous edge :**

$As_{req.} = \frac{320}{3} = 106.6$ → use $As = 198\ mm^2$

☛ Use Ø10 @ 220 mm c/c → $As = 357\ mm^2$

❖ **Column Strip :**

☒ **Negative moment @ continuous edge :**

$M^{-}_{cont.} = 9.92$ KN-m

$As_{req.} = \frac{2}{3} * (499.8) = 333.2\ mm^2$

$As_{req.} > As_{min}$ → … O.K

☛ Use Ø 10 @ 220 mm c/c → $As = 357\ mm^2$

☒ **Positive Moment :**

$As_{req.} = \frac{2}{3} * (320) = 213.33\ mm^2$

$As_{req.} < As_{min}$ → … O.K

☛ Use Ø10 @ 220 mm c/c → $As = 357\ mm^2$

☒ ***Negative moment @ discontinuous edge :***

As $_{req.}$ = $\frac{2}{3}$ * (106.3) = 70.8 mm^2

As $_{req.}$ < As $_{min}$ → … O.K

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

- ✓ **Long Direction**
- ❖ **Middle strip :**

☒ **Negative moment @ continuous edge :**

Mb$^-$ = 24.95 KN-m

$$R = \frac{Mu}{\emptyset * f'c * b * d^2} = \frac{24.95}{0.9 * 1000 * 25 * 0.072^2} = 0.213$$

Using R – ω Table: $\omega = 0.251$

$$\rho = \frac{\omega * f'c}{Fy} = \frac{25 * 0.251}{420} = 0.0149 > \rho_{min} \text{ … O.K}$$

As $_{req.}$ = ρ * b * d $_{short}$ = 0.0149 * 1000 * 72 = 1072 mm^2

As $_{req.}$ > As $_{min}$ → … O.K

☛ Use Ø 14 @ 140 → As = 1100 mm^2

☒ **Positive Moment :**

Mb $^{+}$ = 10.243 KN-m

R = $\frac{Mu}{\emptyset * f'c * b * d^2}$ = $\frac{10.243}{0.9 * 1000 * 25 * 0.072^2}$ = 0.0878

Using R – ω Table : $\omega = 0.093$

$\rho = \frac{\omega * f'c}{Fy}$ = $\frac{0.093 * 25}{420}$ = 0.00553 > ρ = 0.0018

$As_{req.}$ = ρ * b * d_{short} = 0.00553 * 1000 * 72 = 398.16 mm^2

$As_{req.}$ > As_{min} → … O.K

☛ Use Ø 10 @ 190 mm c/c → As = 413 mm^2

❖ **Column Strip :**

☒ **Negative moment @ continuous edge :**

$As_{req.} = \frac{2}{3} * (1073) = 715.3\ mm^2$

$As_{req.}$ > As_{min} → … O.K

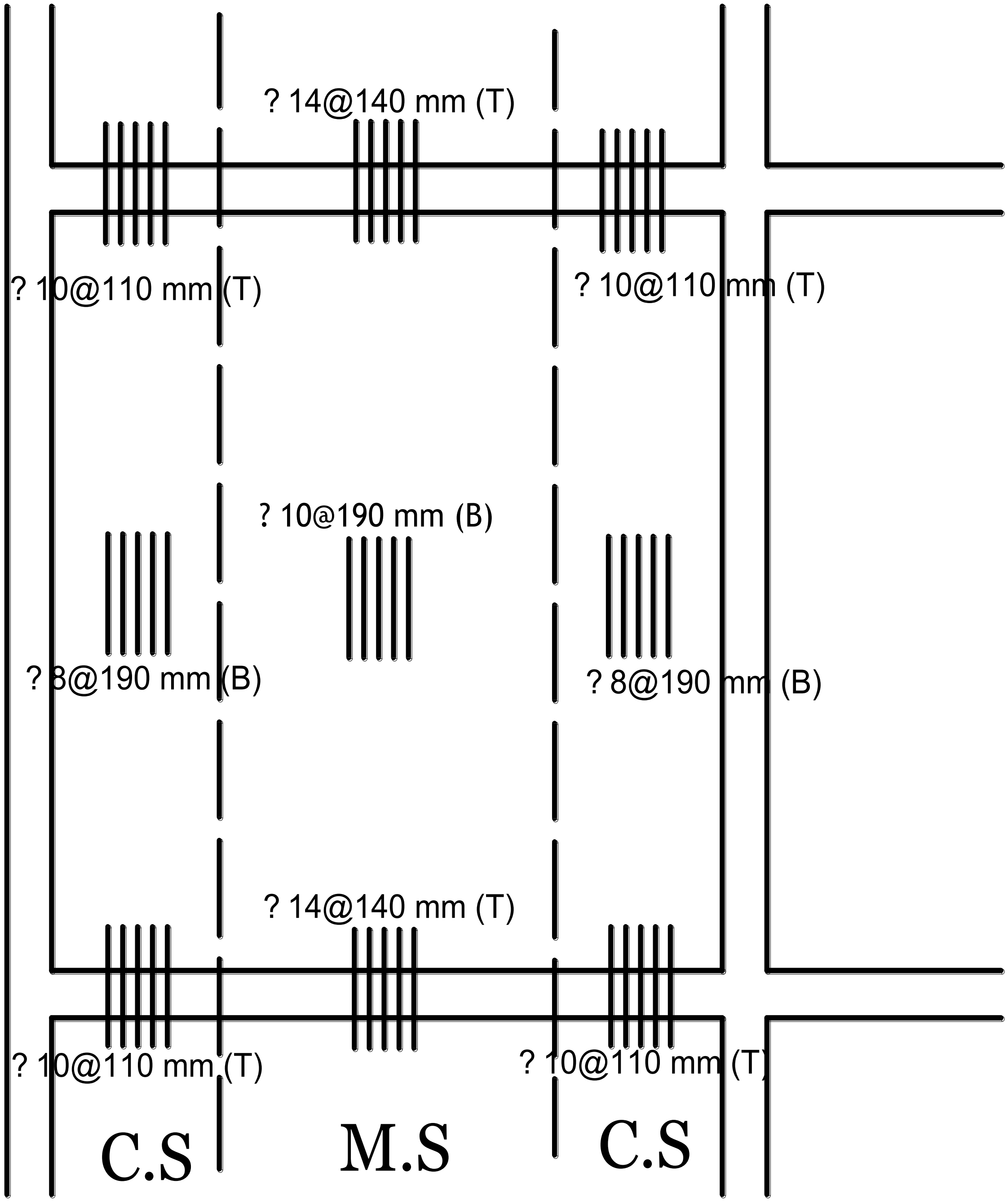
☛ Use Ø 10 @ 110 mm c/c → As = 714 mm^2

☒ **Positive Moment :**

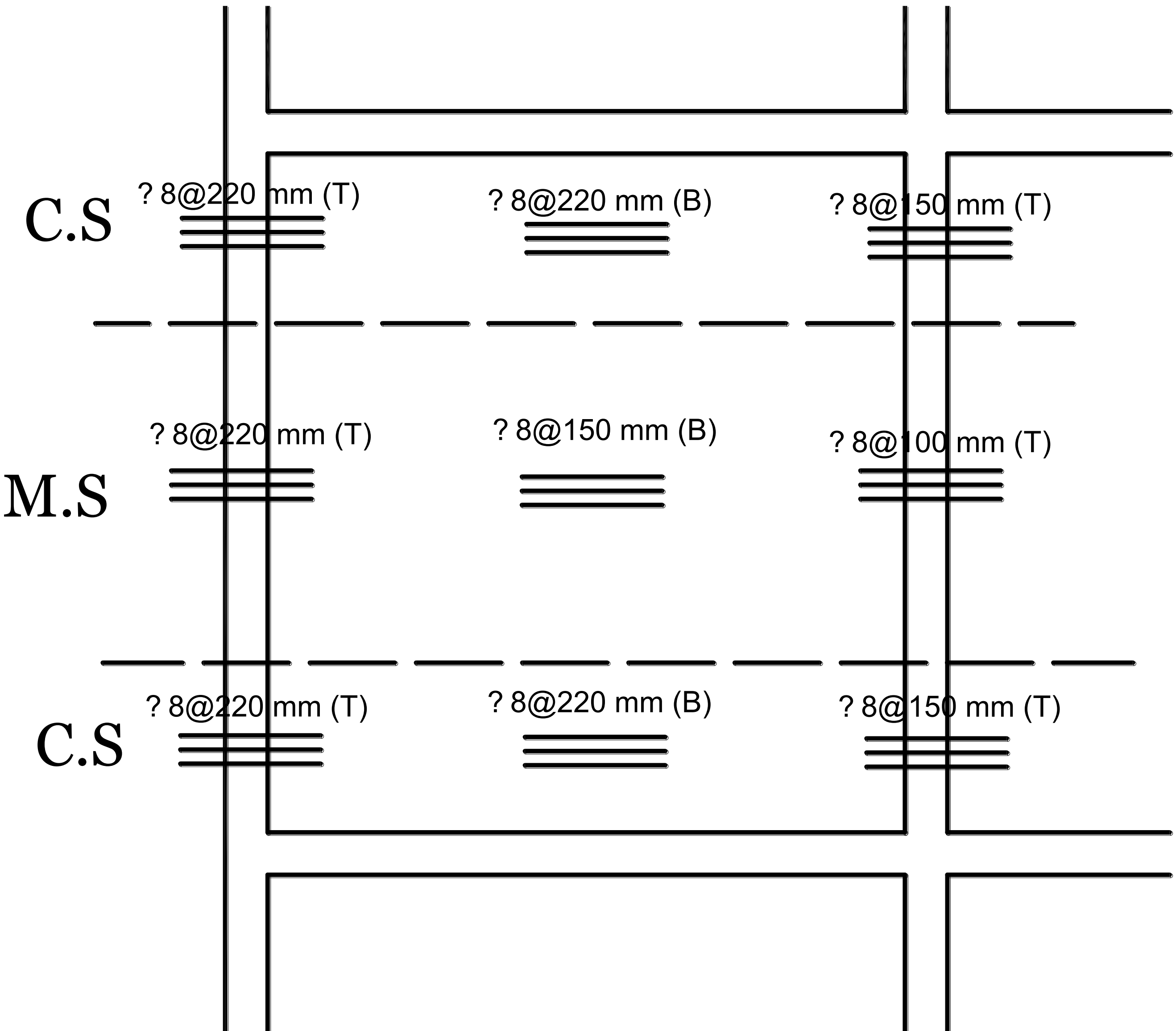
$As_{req.} = \frac{2}{3} * (398) = 265\ mm^2$

$As_{req.}$ > As_{min} → … O.K

☛ Use Ø10 @ 220 mm c/c → As = 357 mm^2



Reinorcement for
Long Direction



Reinorcement for
Short Direction

Dimension of slab 2

Case 4

5.3.2 Reinforcement of Slab 2

- ✓ **Short Direction**
- ❖ **Middle Strip :**
- ☒ **Negative moment @ continuous edge :**

$Ma^- = 21.605$ KN.m

R = $\frac{Mu}{\emptyset * f'c * b * d^2} = \frac{21.605}{0.9 * 1000 * 25 * 0.084^2}$ = 0.136

Using R – ω Table : $\omega = 0.149$

$\rho = \frac{\omega * f\prime c}{Fy} = \frac{0.149 * 25}{420}$ = 0.00886 > ρ_{min}= 0.0018 ... O.K

$As_{req.}$ = $\rho * b * d_{short}$ = 0.00886 * 1000 * 84 = 744.24 mm^2

$As_{req.} > As_{min}$ → ... O.K

☛ Use Ø 12 @ 150 → As = 754 mm^2

- ☒ **Positive Moment :**

$Ma^+ = 10.701$ KN-m

R = $\frac{Mu}{\emptyset * f'c * b * d^2} = \frac{10.701}{0.9 * 1000 * 25 * 0.084^2}$ = 0.0674

Using R – ω Table : $\omega = 0.07$

$\rho = \frac{\omega * f\prime c}{Fy} = \frac{0.07 * 25}{420}$ = 0.00416 > ρ_{min}= 0.0018 ... O.K

$As_{req.}$ = $\rho * b * d_{short}$ = 0.00416 * 1000 * 84 = 350mm^2

$As_{req.} > As_{min}$ → ... O.K

☛ Use Ø 10 @ 220 mm c/c → As = 357 mm^2

☒ **Negative moment @ discontinuous edge :**

As $_{req.}$ = $\frac{350}{3}$ = 116 < As $_{min}$ → use As = 198 mm^2

☛ Use Ø10 @ 220 mm c/c → As = 357 mm^2

❖ **Column Strip :**

☒ **Negative moment @ continuous edge :**

As $_{req.}$ = $\frac{2}{3}$ * (744) = 496 mm^2

As $_{req.}$ > As $_{min}$ → ... O.K

☛ Use Ø10 @ 150 mm c/c → As = 524 mm^2

☒ **Positive Moment :**

As $_{req.}$ = $\frac{2}{3}$ * (350) = 233 mm^2

As $_{req.}$ > As $_{min}$ → ... O.K

☛ Use Ø 10 @ 220 mm c/c → As = 357 mm^2

☒ **Negative moment @ discontinuous edge :**

As $_{req.}$ = $\frac{2}{3}$ * (116) = 77 mm^2

As $_{req.}$ < As $_{min}$ → ... O.K

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

☛ **Long Direction**

❖ **Middle Strip :**

☒ **Negative moment @ continuous edge :**

Mb^{-} = 13.315 KN-m

R = $\frac{Mu}{\emptyset * f'c * b * d^2}$ = $\frac{13.315}{0.9 * 1000 * 25 * 0.072^2}$ = 0.114

Using R – ω Table : $\omega = 0.123$

$\rho = \frac{\omega * f'c}{Fy}$ = $\frac{0.123 * 25}{420}$ = 0.00732 > ρ_{min}= 0.0018 … O.K

$As_{req.}$ = ρ * b * d_{short} = 0.00732 * 1000 * 72 = 527 mm^2

$As_{req.}$ > As_{min} → … O.K

☛ Use Ø 12 @ 210 → As = 539 mm^2

☒ **Positive Moment :**

Mb^{+} = 7.959 KN-m

R = $\frac{Mu}{\emptyset * f'c * b * d^2}$ = $\frac{7.959}{0.9 * 1000 * 25 * 0.072^2}$ = 0.068

Using R – ω Table : $\omega = 0.072$

$\rho = \frac{\omega * f'c}{Fy}$ = $\frac{0.072 * 25}{420}$ = 0.00428 > ρ_{min}= 0.0018 … O.K

$As_{req.}$ = ρ * b * d_{short} = 0.00428 * 1000 * 72 = 308 mm^2

$As_{req.}$ > As_{min} → … O.K

☛ Use Ø 10 @ 250 mm c/c → As = 314 mm^2

☒ **Negative moment @ discontinuous edge :**

As $_{req.}$ = $\frac{462}{3}$ = 154 < As $_{min}$ → use As = 198 mm^2

☛ Use Ø10 @ 220 mm c/c → As = 357 mm^2

❖ **Column Strip :**

☒ **Negative moment @ continuous edge :**

As $_{req.}$ = $\frac{2}{3}$ * (527) = 351 mm^2

As $_{req.}$ > As $_{min}$ → … O.K

☛ Use Ø 10 @ 220 mm c/c → As = 357 mm^2

☒ **Positive Moment :**

As $_{req.}$ = $\frac{2}{3}$ * (462) = 308 mm^2

As $_{req.}$ > As $_{min}$ → … O.K

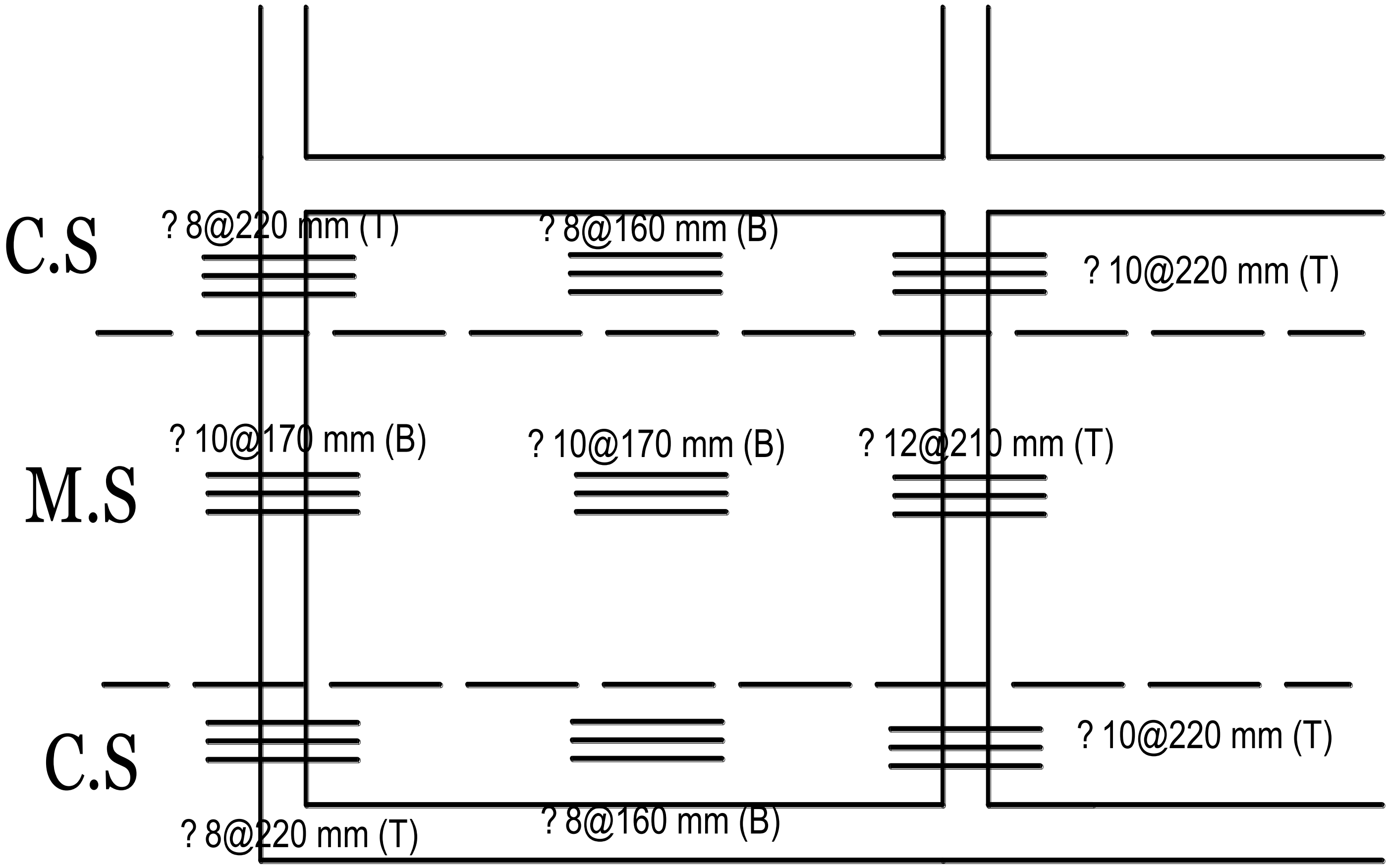
☛ Use Ø 10 @ 220 mm c/c → As = 357 mm^2

☒ **Negative moment @ discontinuous edge :**

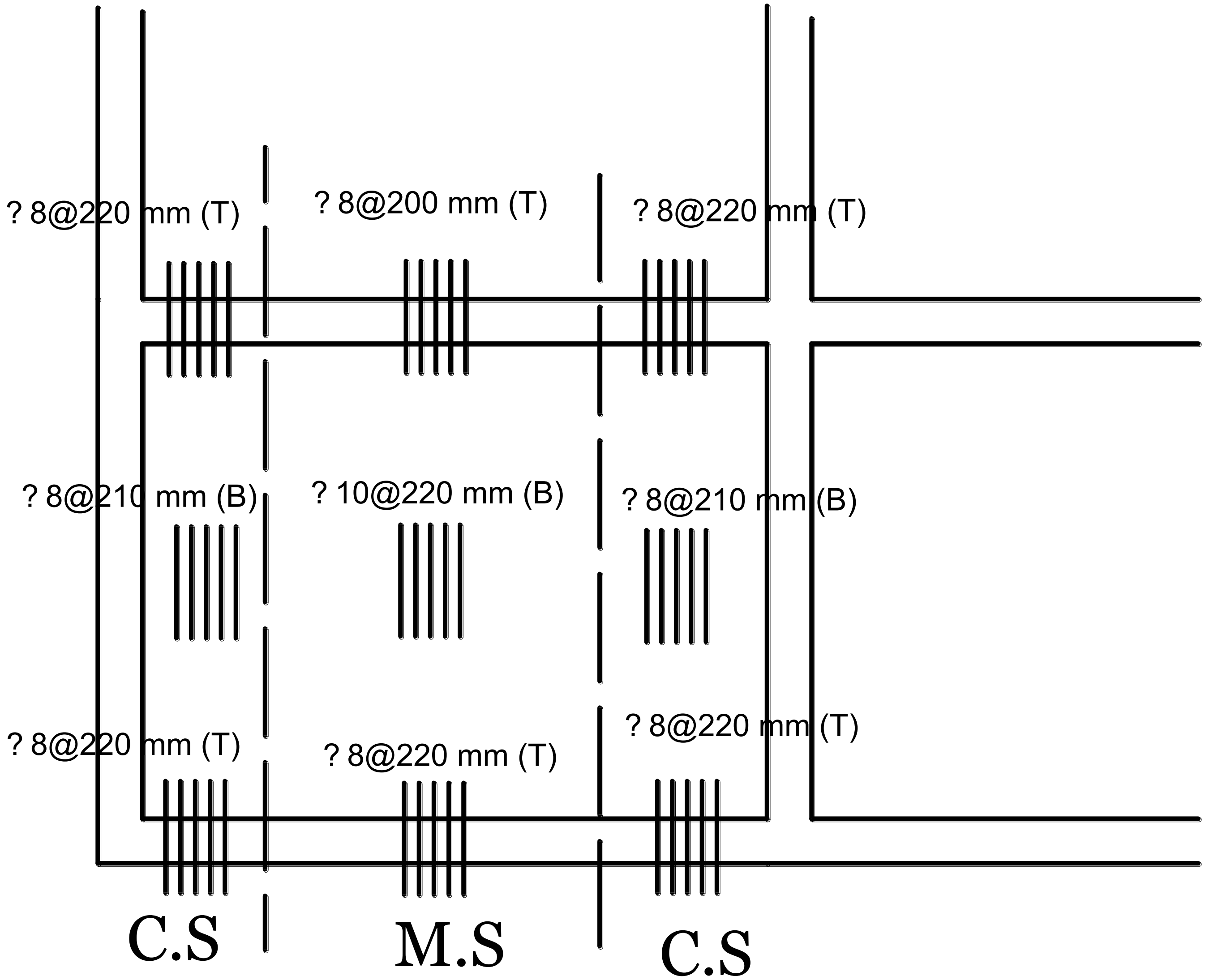
As $_{req.}$ = $\frac{2}{3}$ * (154) = 102 mm^2

As $_{req.}$ < As $_{min}$ → … O.K

☛ Use Ø10 @ 220 mm c/c → As = 357 mm^2

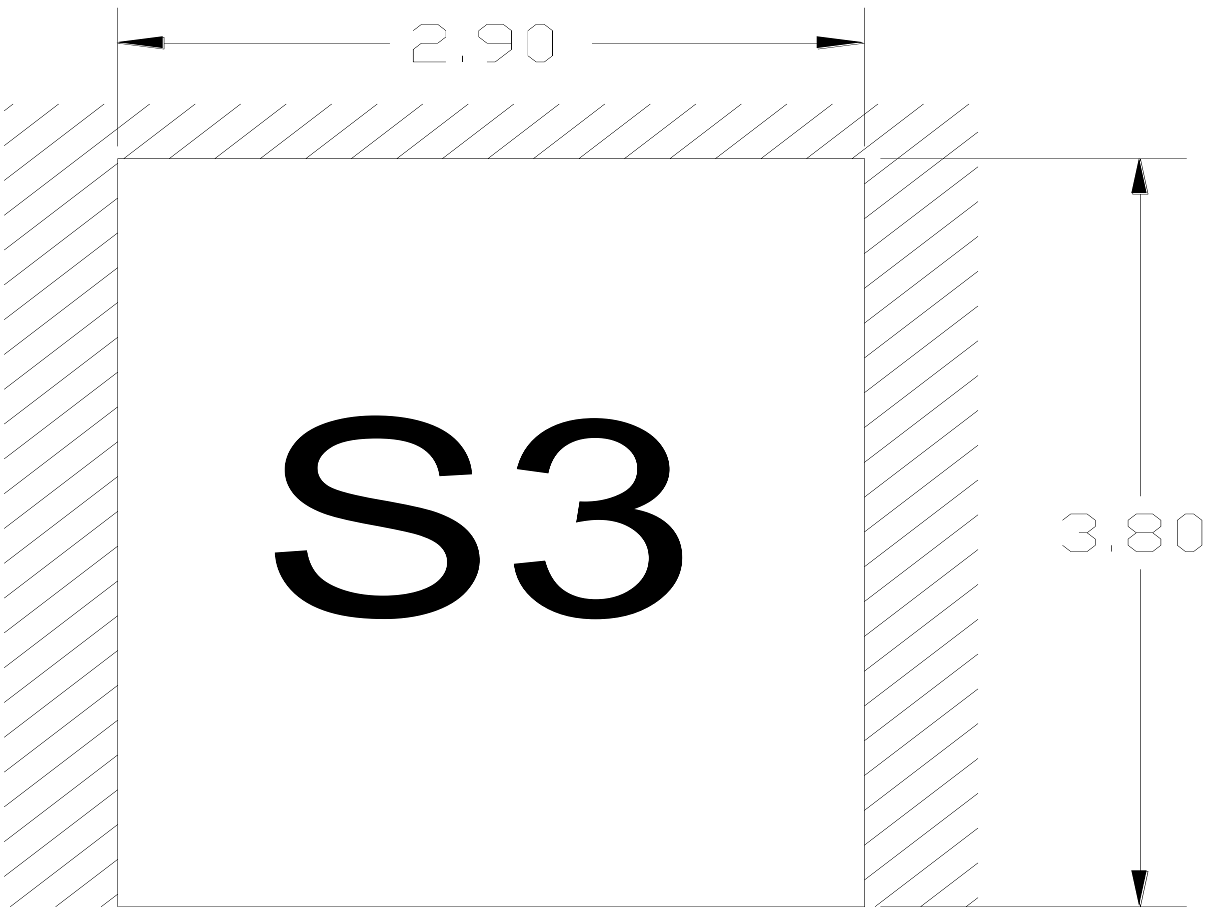


Reinorcement for
Long Direction



Reinorcement for
Short Direction

Dimension of slab 3



Case 9

5.3.3 Reinforcement of Slab 3

- ✓ **Short Direction**
- ❖ **Middle Strip :**
- ☒ **Negative moment @ continuous edge :**

$Ma^- = 15.169$ KN.m

R = $\frac{Mu}{\emptyset * f'c * b * d^2} = \frac{15.169}{0.9 * 1000 * 25 * 0.084^2}$ = 0.0955

Using R – ω Table : $\omega = 0.102$

$\rho = \frac{\omega * f\prime c}{Fy} = \frac{0.102 * 25}{420}$ = 0.00607 > ρ_{min}= 0.0018 … O.K

$As_{req.} = \rho * b * d_{short}$ = 0.00607 * 1000 * 84 = 509 mm^2

$As_{req.} > As_{min}$ → … O.K

☛ Use Ø 12 @ 200 mm → As = 574 mm^2

- ☒ **Positive Moment :**

$Ma^+ = 7.502$ KN-m

R = $\frac{Mu}{\emptyset * f'c * b * d^2} = \frac{7.502}{0.9 * 1000 * 25 * 0.084^2}$ = 0.0472

Using R – ω Table : $\omega = 0.049$

$\rho = \frac{\omega * f\prime c}{Fy} = \frac{0.049 * 25}{420}$ = 0.00291 > ρ_{min}= 0.0018 … O.K

$As_{req.} = \rho * b * d_{short}$ = 0.00291 * 1000 * 84 = 244mm^2

$As_{req.} > As_{min}$ → … O.K

☛ Use Ø 10 @ 220 mm c/c → As = 357 mm^2

❖ **Column Strip :**

☒ **Negative moment @ continuous edge :**

As $_{req.}$ = $\frac{2}{3}$ * (509) = 339 mm^2

As $_{req.}$ < As $_{min}$ → … O.K

☛ Use Ø 10 @ 220 mm c/c → As = 357 mm^2

☒ **Positive Moment :**

As $_{req.}$ = $\frac{2}{3}$ * (244) = 162 mm^2

As $_{req.}$ < As $_{min}$ → … O.K

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

☛ **Long Direction**

❖ **Middle Strip :**

☒ **Negative moment @ continuous edge :**

Mb$^-$ = 4.747 KN-m

R = $\frac{Mu}{\emptyset * f'c * b * d^2}$ = $\frac{4.747}{0.9 * 1000 * 25 * 0.072^2}$ = 0.0406

Using R – ω Table : $\omega = 0.042$

$\rho = \frac{\omega * f'c}{Fy}$ = $\frac{0.042 * 25}{420}$ = 0.0025 > ρ_{min}= 0.0018 … O.K

As $_{req.}$ = ρ * b * d $_{short}$ = 0.0025* 1000 * 72 = 180 mm^2

As $_{req.}$ < As $_{min}$ → … O.K

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

☒ **<u>Positive Moment :</u>**

Mb^{+} = 3.439 KN-m

R = $\frac{Mu}{\emptyset * f'c * b * d^2}$ = $\frac{3.439}{0.9 * 1000 * 25 * 0.072^2}$ = 0.0294

Using R – ω Table : $\omega = 0.03$

$\rho = \frac{\omega * f'c}{Fy}$ = $\frac{0.03 * 25}{420}$ = 0.00178 < ρ_{min}= 0.0018 … O.K

ρ_{min} = 0.0018

$As_{req.}$ = ρ * b * d_{short} = 0.0018* 1000 * 72 = 129 mm^2

$As_{req.}$ < As_{min} → … O.K

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

☒ **<u>Negative moment @ discontinuous edge :</u>**

$As_{req.}$ = $\frac{129}{3}$ = 43 < As_{min} → use As = 198 mm^2

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

❖ **<u>Column Strip :</u>**

☒ **<u>Negative moment @ continuous edge :</u>**

$As_{req.}$ = $\frac{2}{3}$ * (180) = 120 mm^2

$As_{req.}$ < As_{min} → … O.K

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

☒ **Positive Moment :**

$As_{req.} = \frac{2}{3} * (129) = 86\ mm^2$

$As_{req.} < As_{min}$ → … O.K

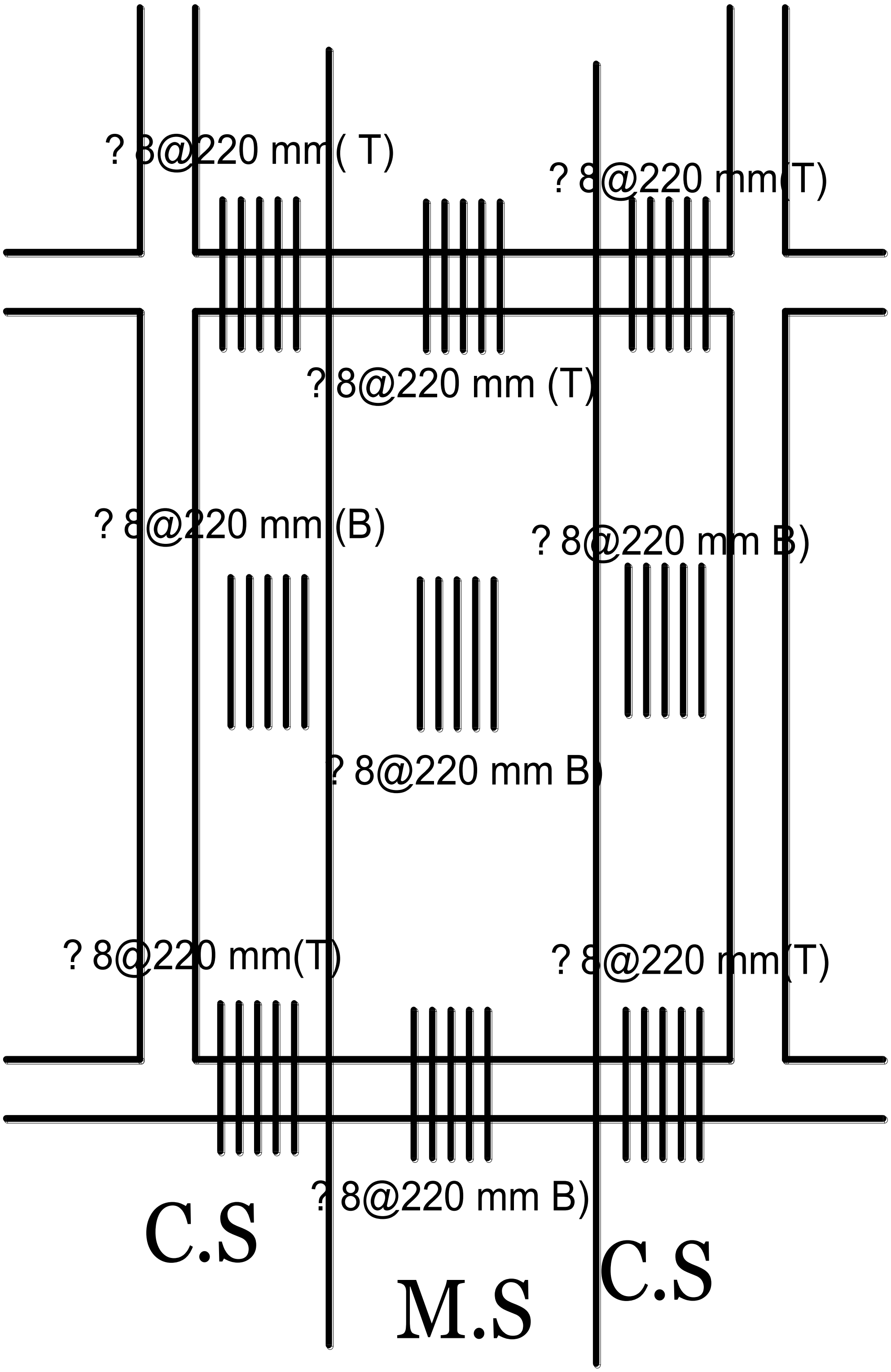
☛ Use $As = 198\ mm^2$ → Use Ø10 @ 220 mm c/c → $As = 357\ mm^2$

☒ **Negative moment @ discontinuous edge :**

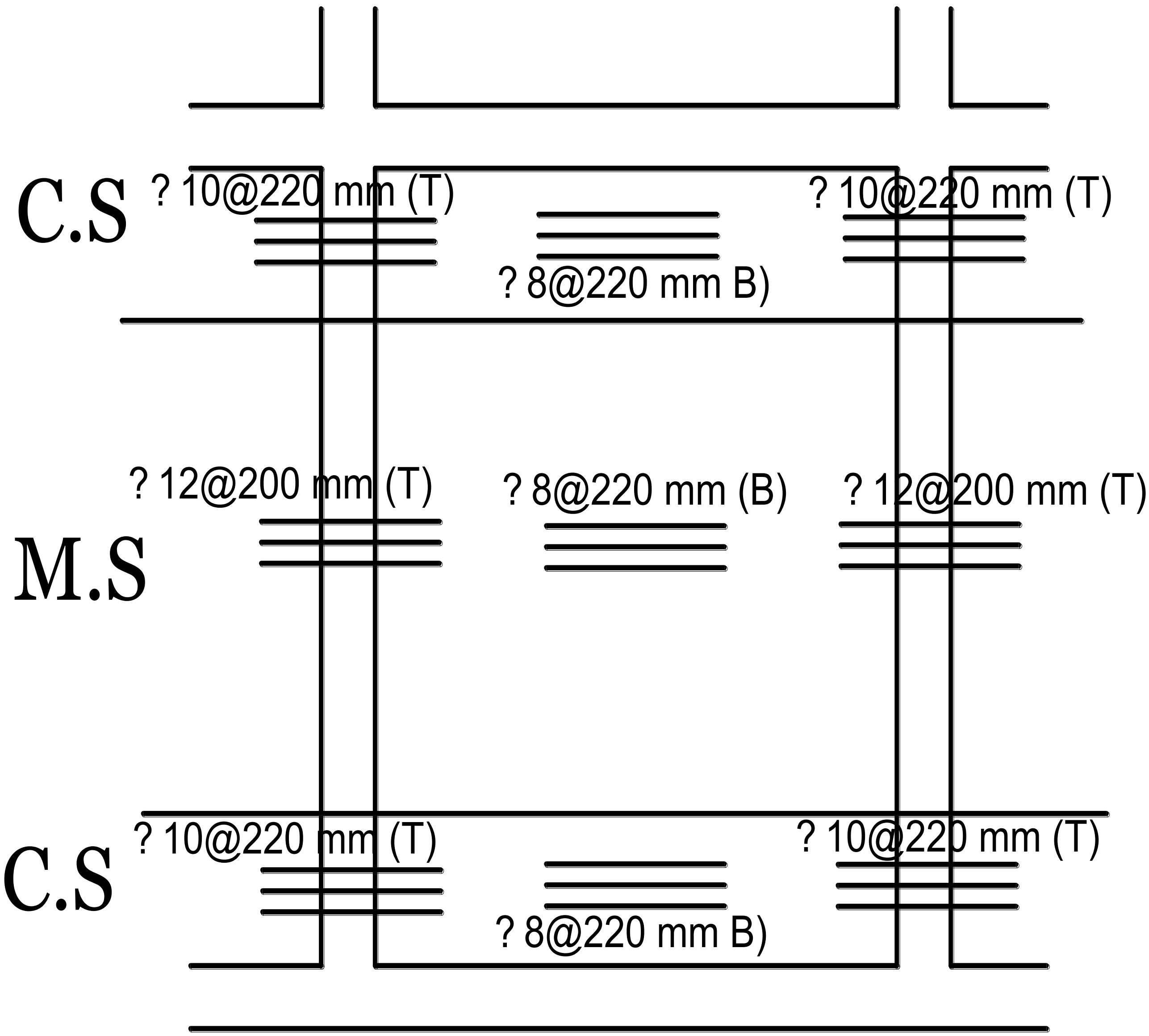
$As_{req.} = \frac{2}{3} * (43) = 28\ mm^2$

$As_{req.} < As_{min}$ → … O.K

☛ Use $As = 198\ mm^2$ → Use Ø10 @ 220 mm c/c → $As = 357\ mm^2$

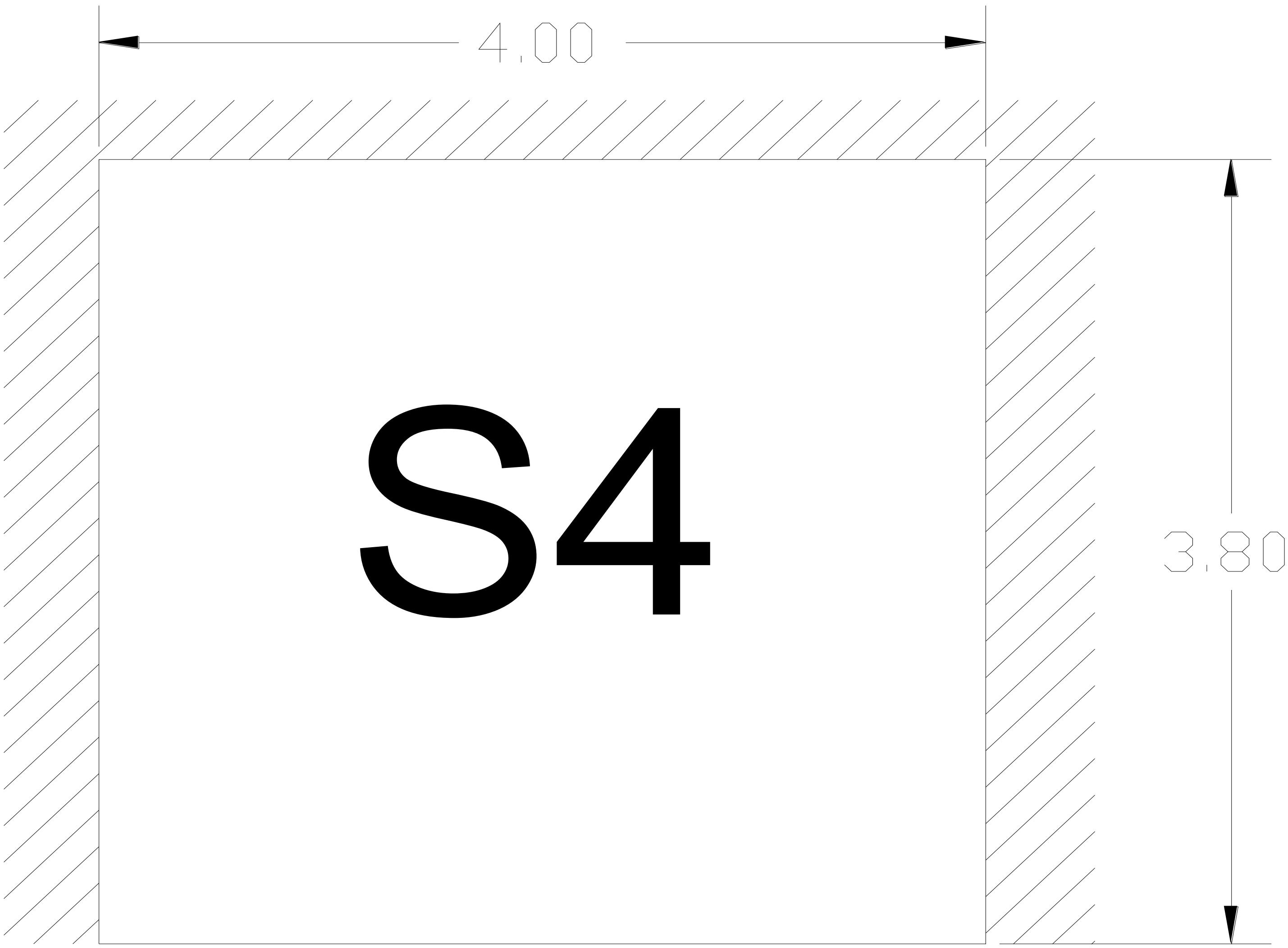


Reinorcement for
Long Direction



Reinorcement for
Short Direction

Dimension of slab 4



Case 8

5.3.4 Reinforcement of Slab 4

- ☛ **Long Direction**
- ❖ **Middle Strip :**
- ☒ **Negative moment @ continuous edge :**

Ma^- = 10.612 KN.m

R = $\frac{Mu}{\emptyset * f'c * b * d^2}$ = $\frac{10.612}{0.9 * 1000 * 25 * 0.084^2}$ = 0.0668

Using R – ω Table : $\omega = 0.069$

$\rho = \frac{\omega * f'c}{Fy}$ = $\frac{0.069 * 25}{420}$ = 0.00410 > ρ_{min}= 0.0018 … O.K

$As_{req.}$ = $\rho * b * d_{short}$ = 0.00410 * 1000 * 84 = 344 mm^2

$As_{req.}$ > As_{min} → … O.K

☛ Use Ø 10 @ 220 → As = 357 mm^2

☒ **Positive Moment :**

Ma^+ = 6.975 KN-m

R = $\frac{Mu}{\emptyset * f'c * b * d^2}$ = $\frac{6.975}{0.9 * 1000 * 25 * 0.084^2}$ = 0.0439

Using R – ω Table : $\omega = 0.045$

$\rho = \frac{\omega * f'c}{Fy}$ = $\frac{0.045 * 25}{420}$ = 0.00267 > ρ_{min} = 0.0018 … O.K

$As_{req.}$ = $\rho * b * d_{short}$ = 0.00267 * 1000 * 84 = 224 mm^2

$As_{req.}$ > As_{min} → … O.K

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

- **Column Strip :**
- ☒ **Negative moment @ continuous edge :**

As $_{req.}$ = $\frac{2}{3}$ * (344) = 229 mm^2

As $_{req.}$ > As $_{min}$ → … O.K

- ☛ Use Ø 10 @ 220 mm c/c → As = 357 mm^2

- ☒ **Positive Moment :**

As $_{req.}$ = $\frac{2}{3}$ * (224) = 149 mm^2

As $_{req.}$ < As $_{min}$ → … O.K

- ☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

Long Direction

- **Middle strip :**

- ☒ **Negative moment @ continuous edge :**

Mb^{-} = 17.328 KN-m

R = $\frac{Mu}{\emptyset * f'c * b * d^2}$ = $\frac{17.328}{0.9 * 1000 * 25 * 0.072^2}$ = 0.148

Using R – ω Table : $\omega = 0.164$

$\rho = \frac{\omega * f'c}{Fy}$ = $\frac{0.164 * 25}{420}$ = 0.00976 > ρ $_{min}$= 0.0018 … O.K

As $_{req.}$ = ρ * b * d $_{short}$ = 0.00976 * 1000 * 72 =703 mm^2

As $_{req.}$ > As $_{min}$ → … O.K

- ☛ Use Ø 12 @ 160 → As = 707 mm^2

☒ **Positive Moment :**

Mb^+ = 5.112 KN-m

R = $\frac{Mu}{\emptyset * f'c * b * d^2}$ = $\frac{5.112}{0.9 * 1000 * 25 * 0.072^2}$ = 0.0438

Using R – ω Table : $\omega = 0.045$

$\rho = \frac{\omega * f\prime c}{Fy}$ = $\frac{0.045 * 25}{420}$ = 0.00267 > ρ_{min}= 0.0018 … O.K

$As_{req.}$ = ρ * b * d_{short} = 0.00267 * 1000 * 72 = 192 mm^2

$As_{req.}$ < As_{min} → … O.K

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

☒ **Negative moment @ discontinuous edge :**

$As_{req.}$ = $\frac{129}{3}$ = 43 < As_{min} → use As = 198 mm^2

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

❖ **Column Strip :**

☒ **Negative moment @ continuous edge :**

$As_{req.}$ = $\frac{2}{3}$ * (703) = 468 mm^2

$As_{req.}$ > As_{min} → … O.K

☛ Use Ø 12 @ 240 mm c/c → As = 471 mm^2

☒ **Positive Moment :**

$As_{req.}$ = $\frac{2}{3}$ * (192) =128 mm^2

$As_{req.}$ < As_{min} → … O.K

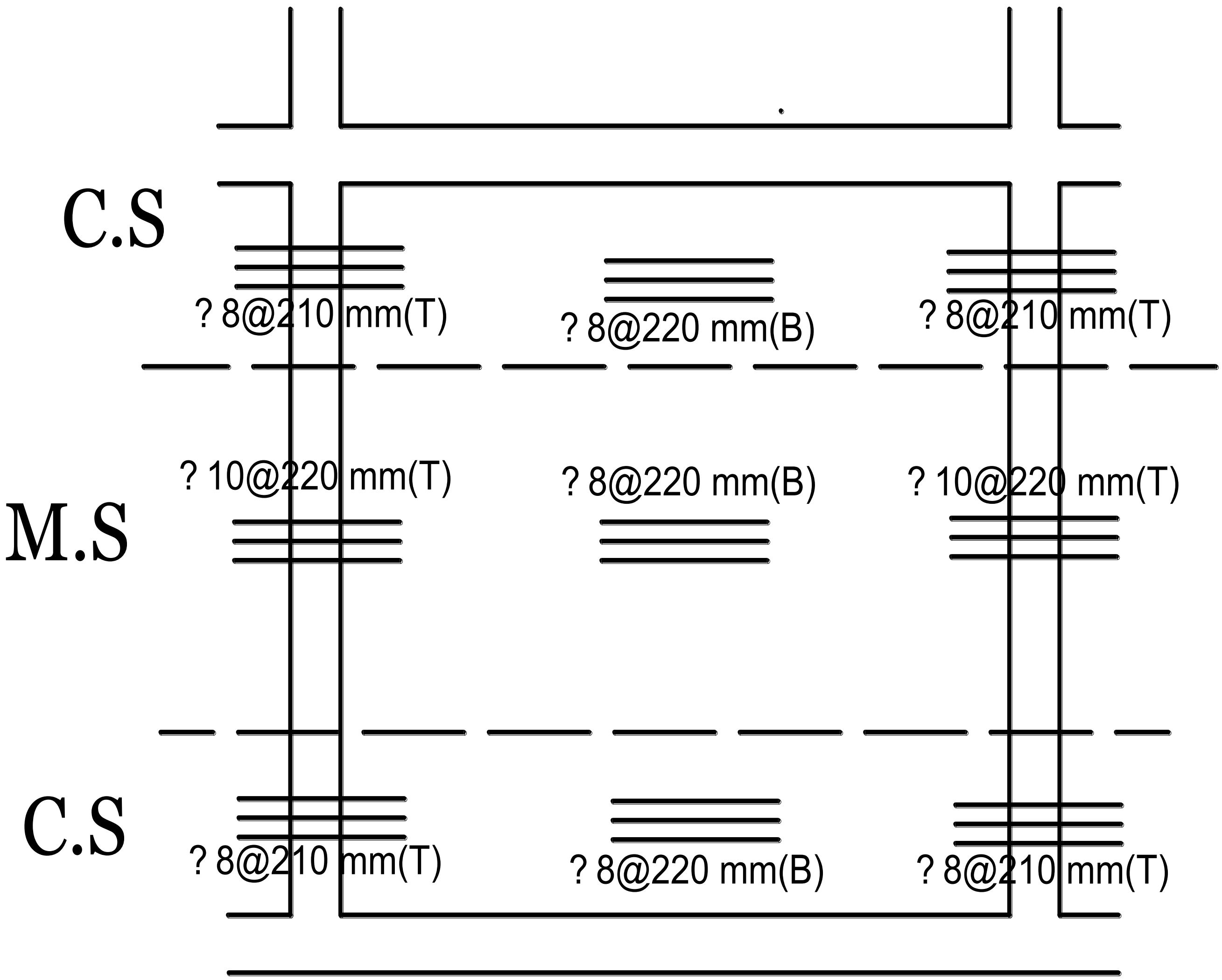
☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

Negative moment @ discontinuous edge :

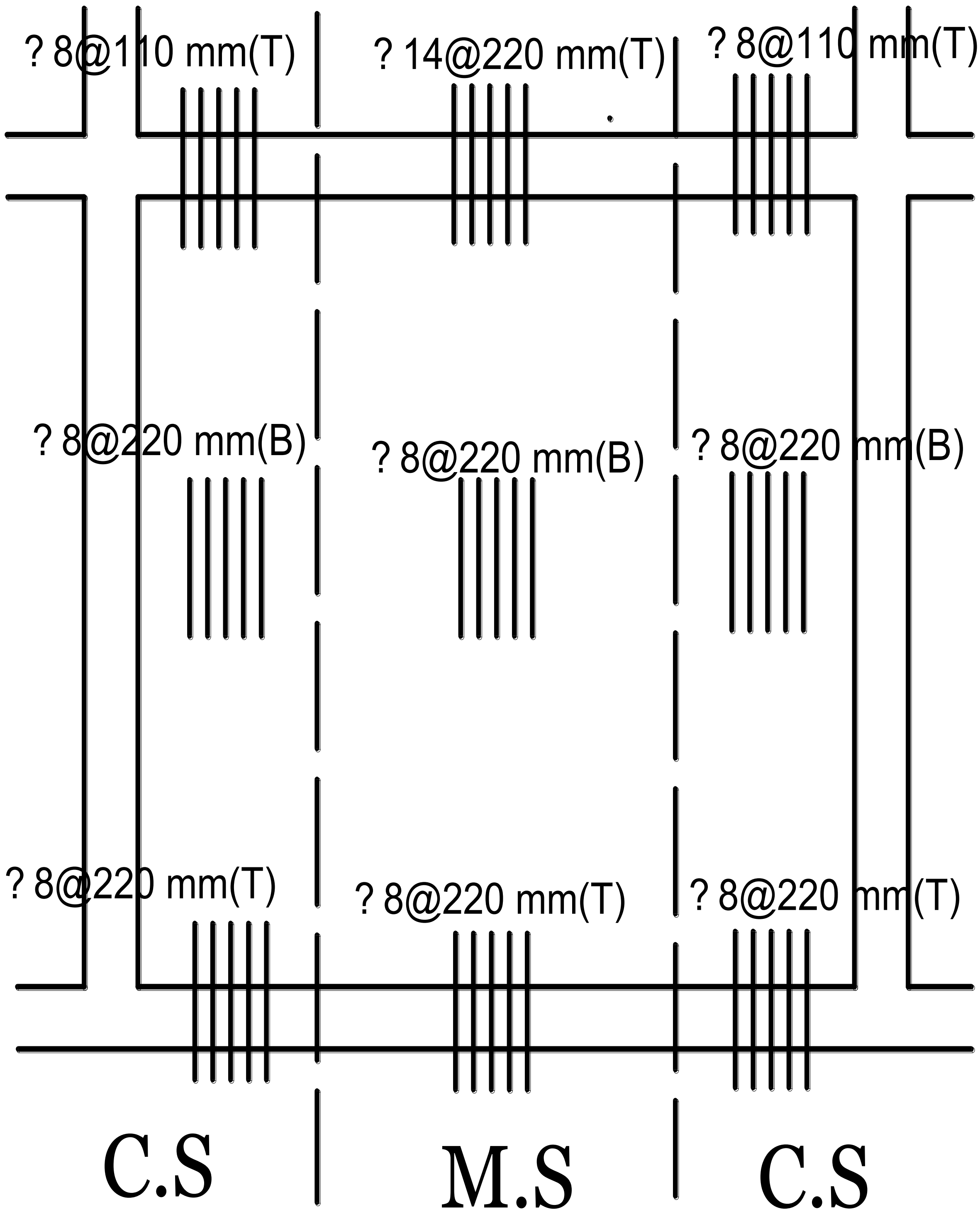
As $_{req.}$ = $\frac{2}{3}$ * (43) = 28 mm^2

As $_{req.}$ < As $_{min}$ → … O.K

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

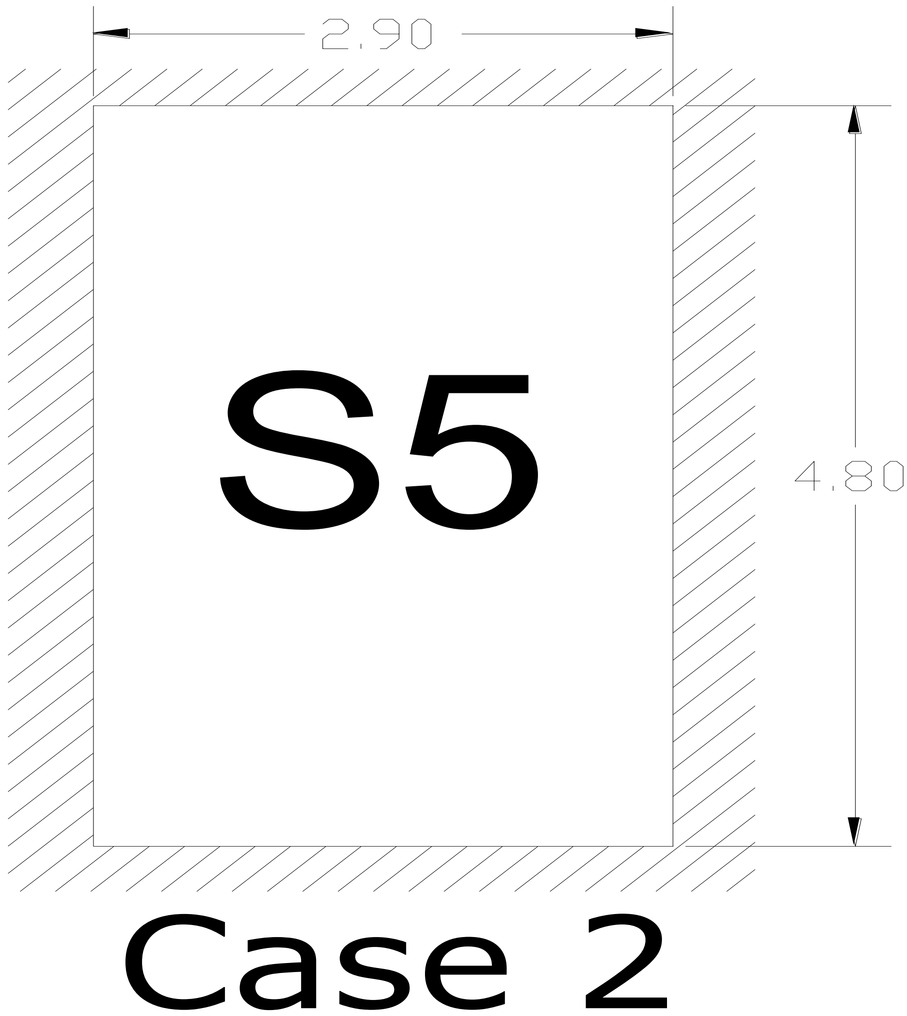


Reinorcement for
Long Direction



Reinorcement for
Short Direction

Dimension of slab 5



5.3.5 Reinforcement of Slab 5

- ✓ **Short Direction**
- ❖ **Middle Strip :**
- ☒ **Negative moment @ continuous edge :**

$Ma^- = 13.175$ KN.m

R = $\frac{Mu}{\emptyset * f'c * b * d^2} = \frac{13.175}{0.9 * 1000 * 25 * 0.084^2}$ = 0.0829

Using R – ω Table : $\omega = 0.087$

$\rho = \frac{\omega * f'c}{Fy} = \frac{0.087 * 25}{420}$ = 0.00517 > ρ_{min}= 0.0018 … O.K

$As_{req.}$ = $\rho * b * d_{short}$ = 0.00517 * 1000 * 84 = 434 mm^2

$As_{req.} > As_{min}$ → … O.K

- ☛ Use Ø 10 @ 180 → As = 436 mm^2

- ☒ **Positive Moment :**

$Ma^+ = 6.8$ KN-m

R = $\frac{Mu}{\emptyset * f'c * b * d^2} = \frac{6.8}{0.9 * 1000 * 25 * 0.084^2}$ = 0.0429

Using R – ω Table : $\omega = 0.044$

$As_{req.}$ = $\rho * b * d_{short}$ = 0.00261* 1000 * 84 = 219 mm^2

$As_{req.} > As_{min}$ → … O.K

- ☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

- ❖ **Column Strip :**
- ☒ **Negative moment @ continuous edge :**

As $_{req.}$ = $\frac{2}{3}$ * (434) = 289 mm^2

As $_{req.}$ > As $_{min}$ → … O.K

☛ Use Ø 10 @ 220 mm c/c → As = 357 mm^2

- ☒ **Positive Moment :**

As $_{req.}$ = $\frac{2}{3}$ * (219) = 146 mm^2

As $_{req.}$ < As $_{min}$ → … O.K

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

- ☛ **Long Direction**
- ❖ **Middle strip :**
- ☒ **Negative moment @ continuous edge :**

Mb^- = 4.456 KN-m

$$R = \frac{Mu}{\emptyset * f'c * b * d^2} = \frac{4.456}{0.9 * 1000 * 25 * 0.072^2} = 0.0382$$

Using R – ω Table : $\omega = 0.039$

$$\rho = \frac{\omega * f'c}{Fy} = \frac{0.039 * 25}{420} = 0.00232 > \rho_{min} = 0.0018 \text{ ... O.K}$$

As $_{req.}$ = ρ * b * d $_{short}$ = 0.00232 * 1000 * 72 = 167 mm^2

As $_{req.}$ < As $_{min}$ → … O.K

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

☒ **Positive Moment :**

Mb^{+} = 2.225 KN-m

R = $\frac{Mu}{\emptyset * f'c * b * d^2}$ = $\frac{2.225}{0.9 * 1000 * 25 * 0.072^2}$ = 0.0190

Using R – ω Table : $\omega = 0.02$

$\rho = \frac{\omega * f'c}{Fy}$ = $\frac{0.02 * 25}{420}$ = 0.00119 < ρ_{min}= 0.0018 ... O.K

ρ_{min} = 0.0018

$As_{req.}$ = ρ * b * d_{short} = 0.0018* 1000 * 72 = 129 mm^2

$As_{req.}$ < As_{min} → ... O.K

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

❖ **Column Strip :**

☒ **Negative moment @ continuous edge :**

$As_{req.} = \frac{2}{3}$ * (167) = 111 mm^2

$As_{req.}$ < As_{min} → ... O.K

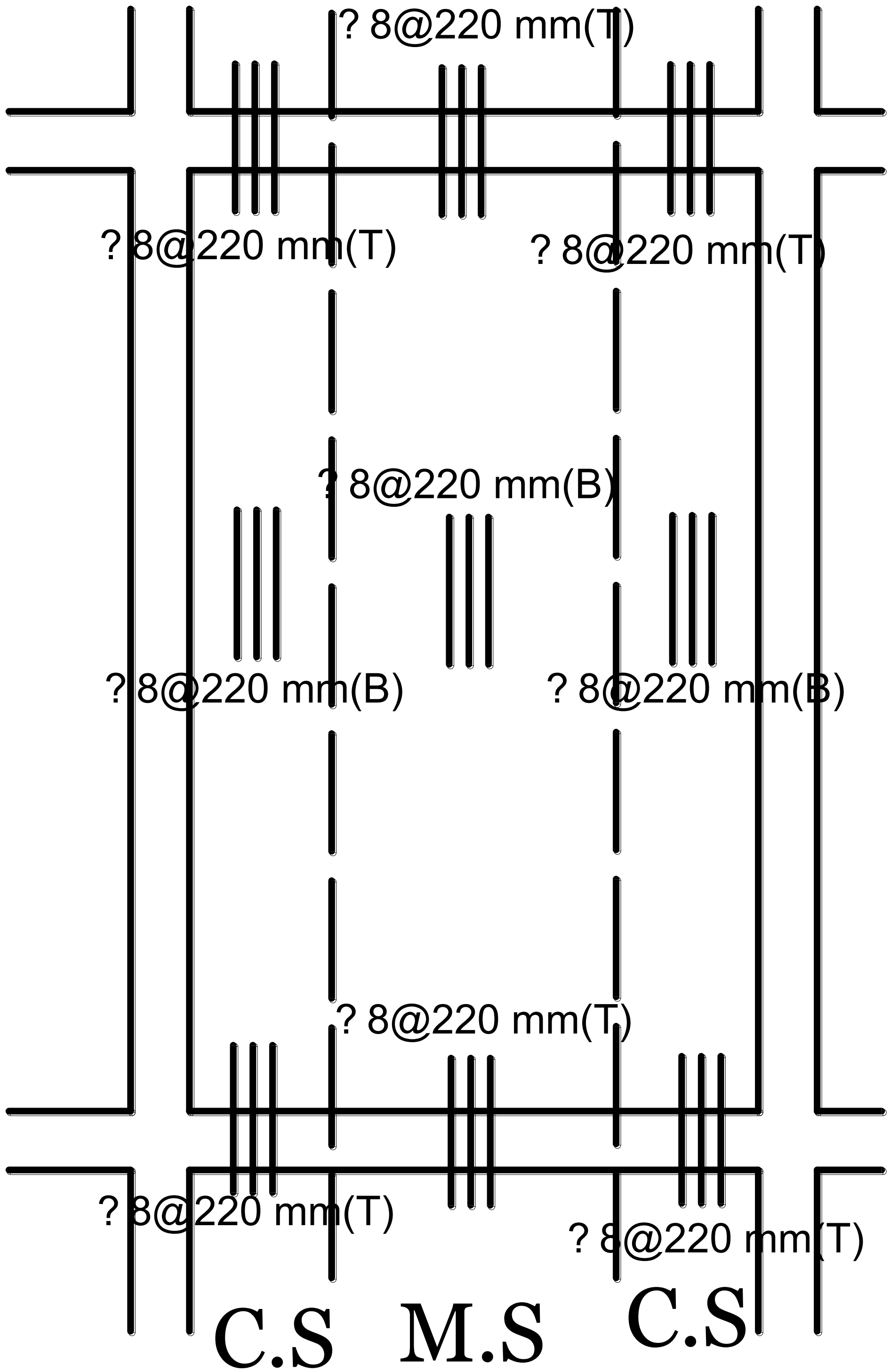
☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2

☒ **Positive Moment :**

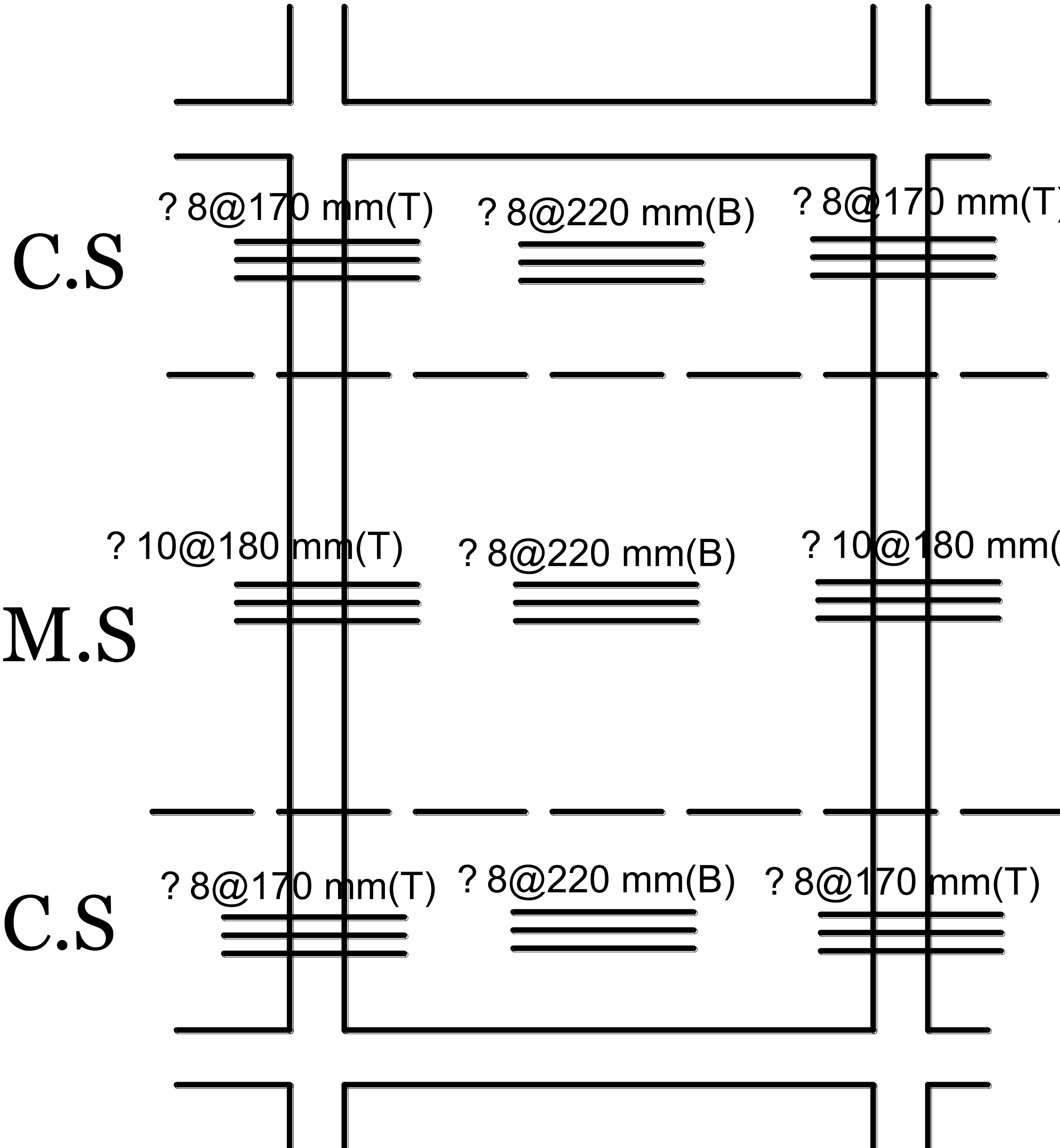
$As_{req.} = \frac{2}{3}$ * (129) = 86 mm^2

$As_{req.}$ < As_{min} → ... O.K

☛ Use As = 198 mm^2 → Use Ø10 @ 220 mm c/c → As = 357 mm^2



Reinorcement for
Long Direction



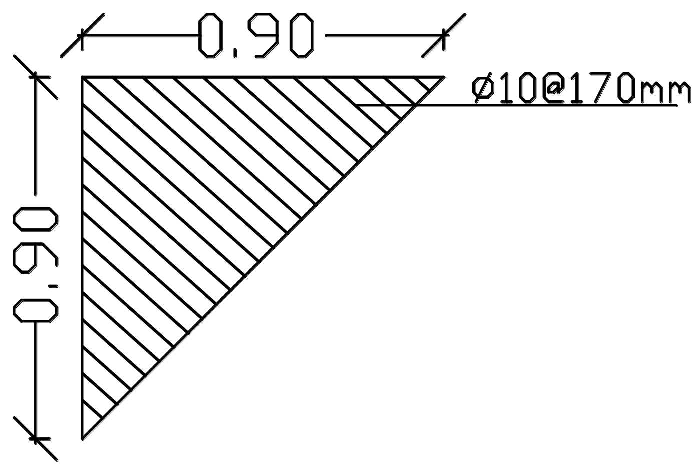
Reinorcement for
Short Direction

☛ Reinforcement for exterior corner for torsional moment

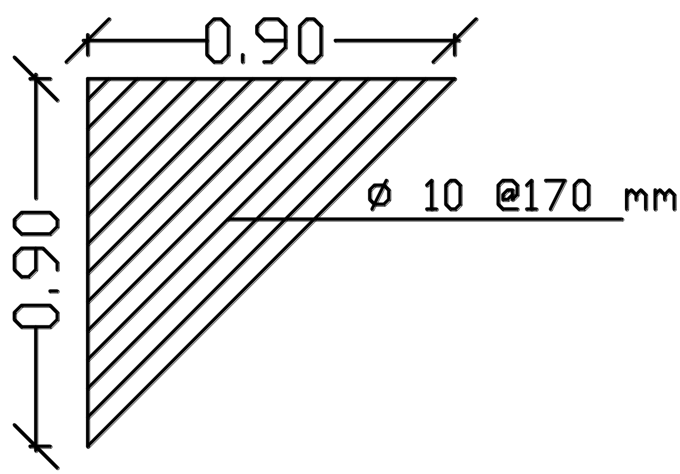
Use Max. Positive M^{+} max Reinforcement in panel shown :

→ Use Ø10 @ 170 mm ***(TOP)***

→ Use Ø10 @ 170 mm ***(BOTT.)***



TOP Reinforcement



BOTTOM Reinforcement

5.3.6 Reinforcement Tables for slabs :

For Slab 1

Direction	Strip	Moment	R	*ω*	*ρ*	As	Bar size and Spacing mm
Short Direction d = 84 mm	Middle Strip	$M^{-}_{cont.}$ = 14.88	0.0937	0.1	0.00595	514	Ø 12 @ 220
		M^{+} = 9.784	0.0616	0.064	0.00381	357	Ø10 @ 220
		$M^{-}_{dis.}$ = 3.261	-----	------	-------	357	Ø10 @ 220
	Column Strip	$M^{-}_{cont.}$ = 9.92	-----	------	-------	357	Ø10 @ 220
		M^{+} = 6.522	-----	------	-------	357	Ø10 @ 220
		$M^{-}_{dis.}$ =3.306	-----	------	-------	357	Ø10 @ 220
Long Direction d = 72 mm	Middle Strip	$M^{-}_{cont.}$ = 24.95	0.213	0.251	0.0149	1100	Ø 14 @ 140
		M^{+} = 10.243	0.0878	0.093	0.00553	413	Ø 10 @ 190
		$M^{-}_{dis.}$ = 3.414	-----	------	-------	-----	------
	Column Strip	$M^{-}_{cont.}$ = 16.63	-----	------	-------	714	Ø 10 @ 110
		M^{+} = 6.828	-----	------	-------	357	Ø10 @ 220
		$M^{-}_{dis.}$ = 2.276	-----	------	-------	-----	------

For Slab 2

Direction	Strip	Moment	R	*ω*	*ρ*	As	Bar size and Spacing mm
Short Direction d = 84 mm	Middle Strip	$M^{-}_{cont.}$ = 21.605	0.136	0.149	0.00886	754	Ø12@ 150
		M^{+} = 10.701	0.0674	0.07	0.00416	357	Ø10 @ 220
		$M^{-}_{dis.}$ = 3.567	-----	------	-------	357	Ø10 @ 220
	Column Strip	$M^{-}_{cont.}$ = 14.403	-----	------	-------	524	Ø10 @ 150
		M^{+} = 7.134	-----	------	-------	357	Ø10 @ 220
		$M^{-}_{dis.}$ = 3.567	-----	------	-------	357	Ø10 @ 220
Long Direction d = 72 mm	Middle Strip	$M^{-}_{cont.}$ = 13.315	0.114	0.123	0.00732	539	Ø 12 @ 210
		M^{+} = 11.807	0.101	0.108	0.00642	462	Ø 10 @ 170
		$M^{-}_{dis.}$ = 2.653	-----	------	-------	357	Ø10 @ 220
	Column Strip	$M^{-}_{cont.}$ = 8.876	-----	------	-------	357	Ø10 @ 220
		M^{+} = 5.306	-----	------	-------	357	Ø10 @ 220
		$M^{-}_{dis.}$ = 2.653	-----	------	-------	357	Ø10 @ 220

For Slab 3

Direction	Strip	Moment	R	ω	ρ	As	Bar size and Spacing mm
Short Direction d = 84 mm	Middle Strip	$M^{-}_{cont.}$ = 15.169	0.0955	0.102	0.00607	574	Ø 12 @ 200
		M^{+} = 7.502	0.0472	0.049	0.00291	357	Ø10 @ 220
		$M^{-}_{dis.}$ = 2.500	-----	------	-------	-----	------
	Column Strip	$M^{-}_{cont.}$ = 10.112	-----	------	-------	357	Ø10 @ 220
		M^{+} = 5.001	-----	------	-------	357	Ø10 @ 220
		$M^{-}_{dis.}$ = 2.500	-----	------	-------	-----	------
Long Direction d = 72 mm	Middle Strip	$M^{-}_{cont.}$ = 4.747	0.0406	0.042	0.0025	357	Ø10 @ 220
		M^{+} = 3.439	0.0294	0.03	0.00178	357	Ø10 @ 220
		$M^{-}_{dis.}$ = 1.582	-----	------	-------	357	Ø10 @ 220
	Column Strip	$M^{-}_{cont.}$ = 3.164	-----	------	-------	357	Ø10 @ 220
		M^{+} = 2.292	-----	------	-------	357	Ø10 @ 220
		$M^{-}_{dis.}$ = 1.146	-----	------	-------	357	Ø10 @ 220

For Slab 4

Direction	Strip	Moment	R	ω	ρ	As	Bar size and Spacing mm
Short Direction d = 84 mm	Middle Strip	$M^{-}_{cont.}$ = 10.612	0.0668	0.069	0.00410	357	Ø10 @ 220
		M^{+} = 6.975	0.0439	0.045	0.00267	357	Ø10 @ 220
		$M^{-}_{dis.}$ = 2.325	-----	------	-------	-----	------
	Column Strip	$M^{-}_{cont.}$ = 7.074	-----	------	-------	357	Ø10 @ 220
		M^{+} = 4.65	-----	------	-------	357	Ø10 @ 220
		$M^{-}_{dis.}$ = 2.325	-----	------	-------	-----	------
Long Direction d = 72 mm	Middle Strip	$M^{-}_{cont.}$ = 17.328	0.148	0.164	0.00927	707	Ø 12 @ 160
		M^{+} = 5.112	0.0438	0.045	0.00267	357	Ø10 @ 220
		$M^{-}_{dis.}$ = 1.704	-----	------	-------	357	Ø10 @ 220
	Column Strip	$M^{-}_{cont.}$ = 11.552	-----	------	-------	471	Ø 12 @ 240
		M^{+} = 3.408	-----	------	-------	357	Ø10 @ 220
		$M^{-}_{dis.}$ = 1.704	-----	------	-------	357	Ø10 @ 220

For Slab 5

Direction	Strip	Moment	R	ω	ρ	As	Bar size and Spacing mm
Short Direction d = 84 mm	Middle Strip	$M^{-}_{cont.} = 13.175$	0.0829	0.087	0.00517	436	Ø 10 @ 180
		$M^{+} = 6.8$	0.0429	0.044	0.00261	357	Ø10 @ 220
		$M^{-}_{dis.} = 2.274$	-----	------	-------	-----	------
	Column Strip	$M^{-}_{cont.} = 8.783$	-----	------	-------	357	Ø10 @ 220
		$M^{+} = 4.548$	-----	------	-------	357	Ø10 @ 220
		$M^{-}_{dis.} = 2.274$	-----	------	-------	-----	------
Long Direction d = 72 mm	Middle Strip	$M^{-}_{cont.} = 4.456$	0.0382	0.039	0.00232	357	Ø10 @ 220
		$M^{+} = 2.225$	0.0190	0.02	0.00119	357	Ø10 @ 220
		$M^{-}_{dis.} = 1.485$	-----	------	-------	------	-------
	Column Strip	$M^{-}_{cont.} = 2.970$	-----	------	-------	357	Ø10 @ 220
		$M^{+} = 1.483$	-----	------	-------	357	Ø10 @ 220
		$M^{-}_{dis.} = 1.485$	-----	------	-------	------	-------

Chapter Five

"Load transfer from slab to beam"

- ***4- Load transfer from slab to beam on frame – 2 :***

❖ ***4.1 Load on B20 :***

1- ***From slab (2) in short direction :***

$\frac{Lb}{La} = \frac{3.8}{4.5}$ = 0.85

Wu $_{(tot.)}$ = La * Lb * Wu

= 3.8 * 4.5 * 19.34 = 330.7 KN/M

❖ ***Load in short direction from S2 :***

$\frac{Wu*Wa}{2*Lb} = \frac{330.7*0.66}{2*4.5}$ = 24.25 KN/m

2-***Load from Slab 6 in short direction :***

$\frac{Lb}{La} = \frac{3.2}{4.5}$ = 0.71

Wa = 0.68

= 3.2 * 4.5 * 19.34 = 278.5 KN/M

$\frac{Wu*Wa}{2*Lb} = \frac{278.5*0.68}{2*4.5}$ = 21 KN/m

☛ Total Load On B20 = 21 + 24.25 + (0.35 * 0.2 * 25) = **47** KN/m

- ***4.2 Load on B39 :***

1- *From slab (3) in long direction :*

$\frac{Lb}{La} = \frac{2.9}{3.8}$ = 0.8

Wb = 0.17

= 2.9 * 3.8 * 19.34 = 213.13 KN/M

$\frac{Wu*Wb}{2*La} = \frac{213.13 *0.17}{2*2.9}$ = 6.25 KN/m

2-***Load from Slab 7 in short direction :***

$\frac{Lb}{La} = \frac{2.9}{3.2}$ = 0.9

Wb = 0.4

= 2.9 * 3.2 * 19.34 = 179.5 KN/M

$\frac{Wu*Wb}{2*Lb} = \frac{179.5 *0.4}{2*2.9}$ = 12.38 KN/m

☛ Total Load On B39 = 12.38 + 6.25 + (0.35 * 0.2 * 25) = **20.38** KN/m

- ***<u>4.3 Load on B16 :</u>***

1- <u>From slab (4) in short direction :</u>

$\frac{Lb}{La} = \frac{3.8}{4}$ = 0.95

Wa = 0.38

= 3.8 * 4 * 19.34 = 294 KN/M

$\frac{Wu*Wa}{2*La}$ = $\frac{294 *0.38}{2*4}$ = 14 KN/m

<u>2-Load from Slab 8 in short direction :</u>

$\frac{Lb}{La} = \frac{3.2}{4}$ = 0.8

Wa = 0.83

= 3.2 * 4 * 19.34 = 247.6 KN/M

$\frac{Wu*Wa}{2*La}$ = $\frac{247.6 *0.83}{2*4}$ = 25.7 KN/m

☛ Total Load On B16 = 25.7 + 14 + (0.35 * 0.2 * 25) = **<u>41.45</u>** KN/m

- ***4.4 Load on B15 :***

Same as B 39

2- From slab (3) in long direction :

$\frac{Lb}{La} = \frac{2.9}{3.8}$ = 0.8

Wb = 0.17

= 2.9 * 3.8 * 19.34 = 213.13 KN/M

$\frac{Wu*Wb}{2*La} = \frac{213.13 *0.17}{2*2.9}$ = 6.25 KN/m

2-***Load from Slab 7 in short direction :***

$\frac{Lb}{La} = \frac{2.9}{3.2}$ = 0.9

Wb = 0.4

= 2.9 * 3.2 * 19.34 = 179.5 KN/M

$\frac{Wu*Wb}{2*Lb} = \frac{179.5 *0.4}{2*2.9}$ = 12.38 KN/m

☛ Total Load On B39 = 12.38 + 6.25 + (0.35 * 0.2 * 25) = **20.38** KN/m

- ***4.5 Load on B42 :***

1- From slab (2) in short direction :

$\frac{Lb}{La} = \frac{3.8}{4.5}$ = 0.85

Wu $_{(tot.)}$ = La * Lb * Wu

= 3.8 * 4.5 * 19.34 = 330.7 KN/M

❖ ***Load in short direction from S2 :***

$\frac{Wu*Wa}{2*Lb} = \frac{330.7*0.66}{2*4.5}$ = 24.25 KN/m

2-Load from Slab 6 in short direction :

$\frac{Lb}{La} = \frac{3.2}{4.5}$ = 0.71

Wa = 0.68

= 3.2 * 4.5 * 19.34 = 278.5 KN/M

$\frac{Wu*Wa}{2*Lb} = \frac{278.5*0.68}{2*4.5}$ = 21 KN/m

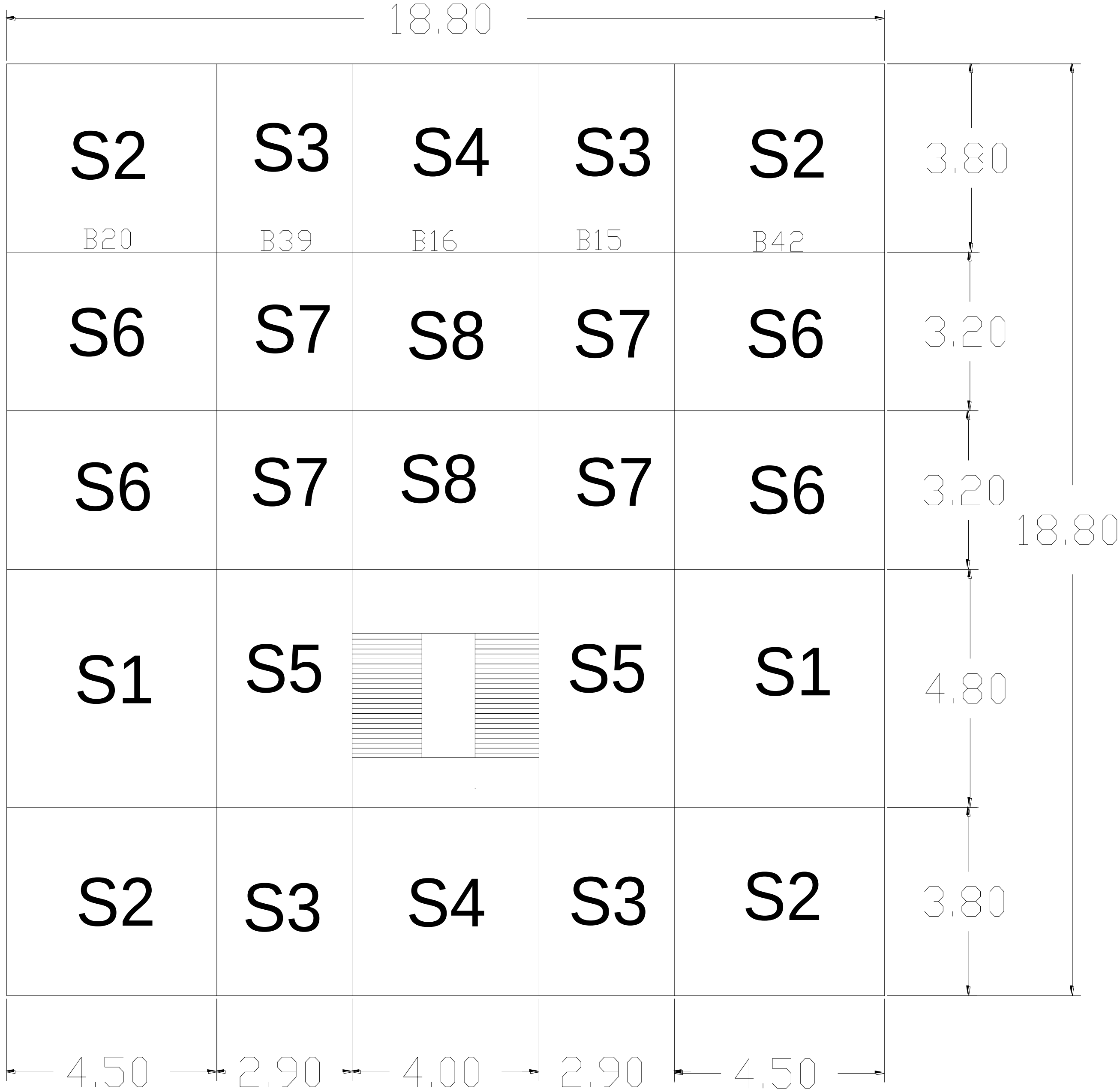
☛ Total Load On B42 = 21 + 24.25 + (0.35 * 0.2 * 25) = 47 KN/m

- ***4.6 Table***

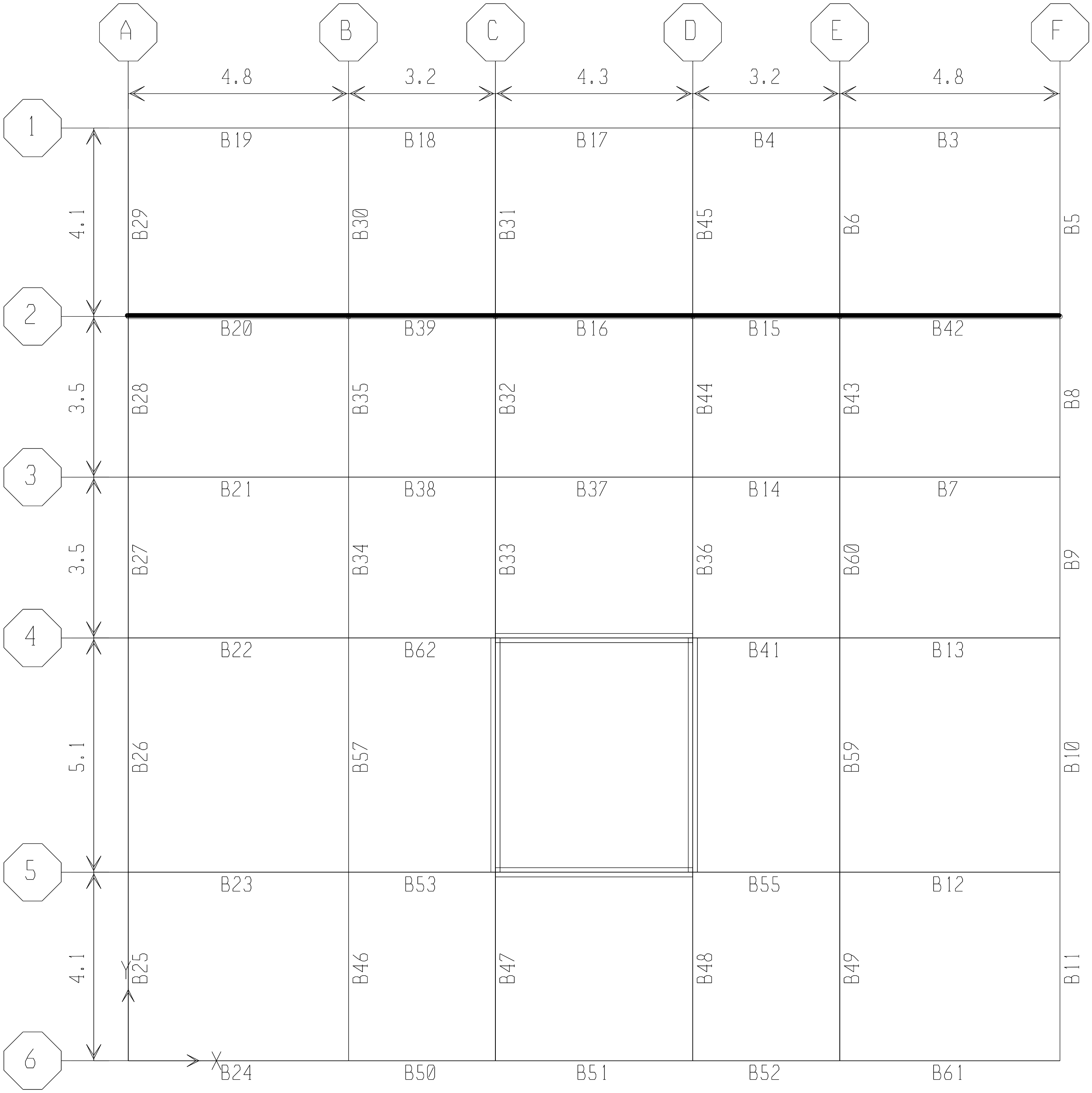
beam	Load (KN/m)
B 20	47
B 39	20.38
B 16	41.45
B 15	20.38
B 42	47

Chapter Six

"Design of Beams"


18.80
S2
S3
S4
S3
S2
B20
B39
B16
B15
B42
S6
S7
S8
S7
S6
S6
S7
S8
S7
S6
S1
S5
S5
S1
S2
S3
S4
S3
S2
3.80
3.20
3.20
4.80
3.80
18.80
4.50
2.90
4.00
2.90
4.50

Plan View


A
B
C
D
E
F
4.8
3.2
4.3
3.2
4.8
1
2
3
4
5
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3.5
3.5
5.1
4.1
B19
B18
B17
B4
B3
B29
B30
B31
B45
B6
B5
B20
B39
B16
B15
B42
B28
B35
B32
B44
B43
B8
B21
B38
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B14
B7
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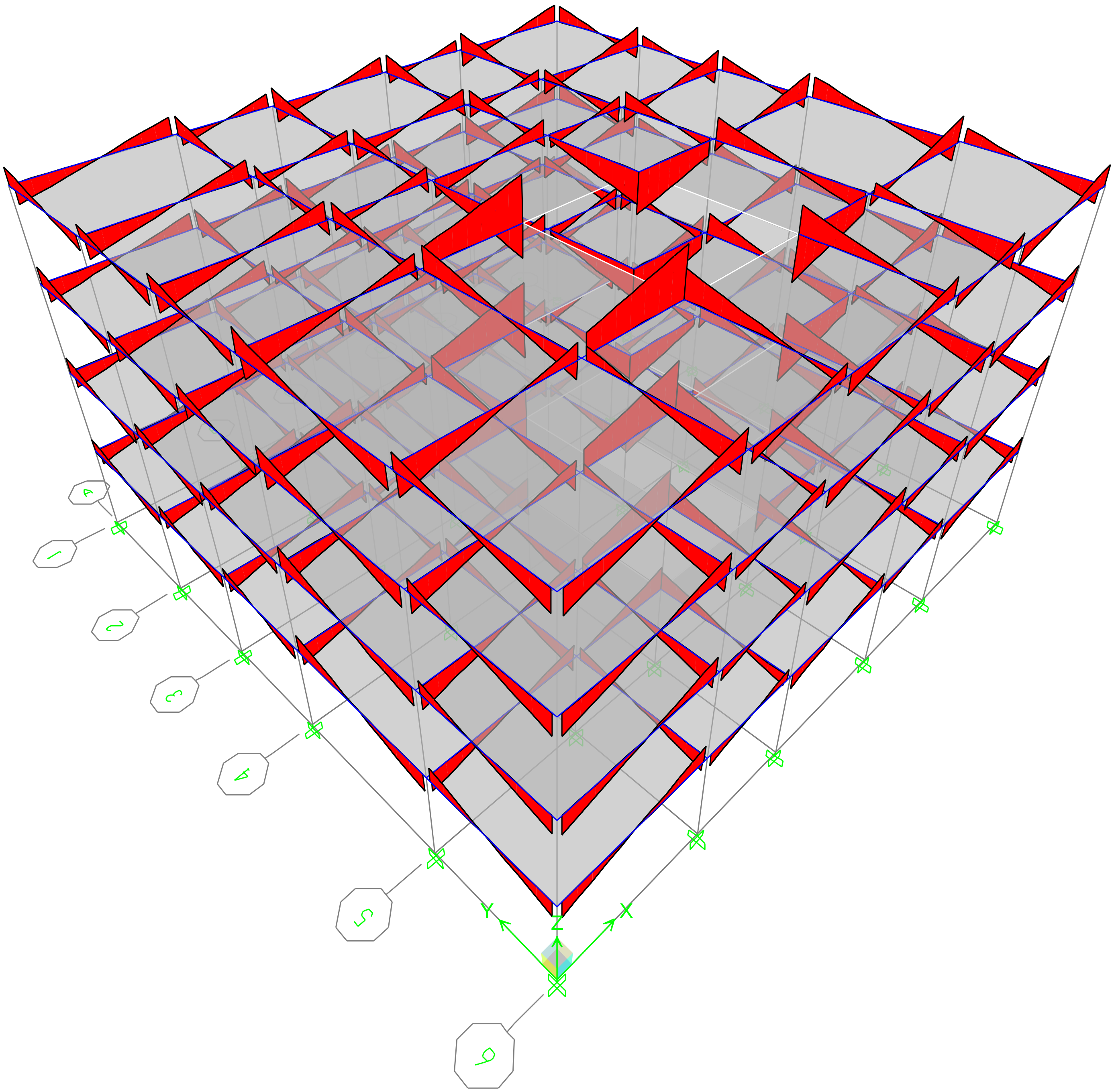
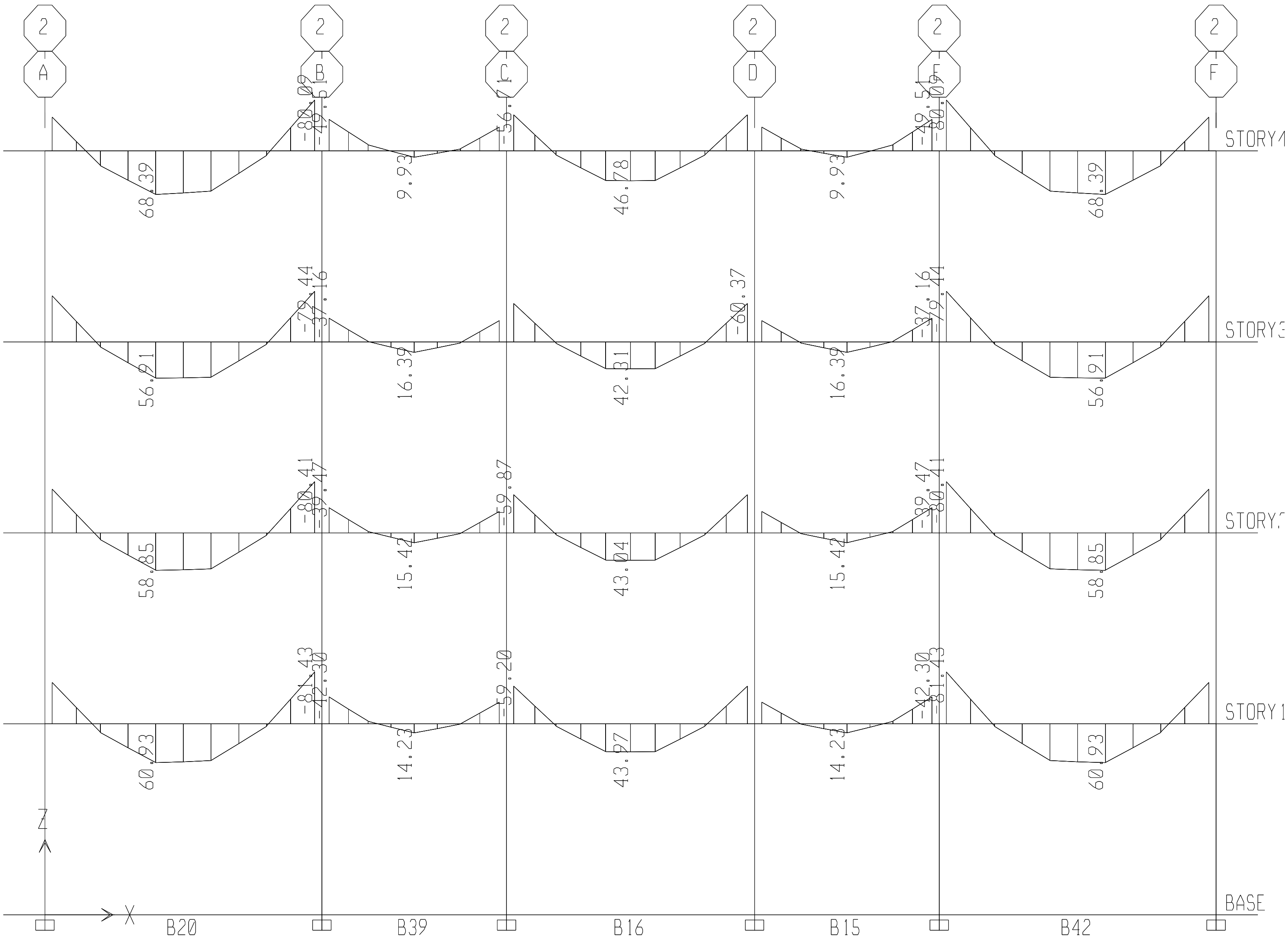
B34
B33
B36
B60
B9
B22
B62
B41
B13
B26
B57
B59
B10
B23
B53
B55
B12
B25
B46
B47
B48
B49
B11
Y
X
B24
B50
B51
B52
B61

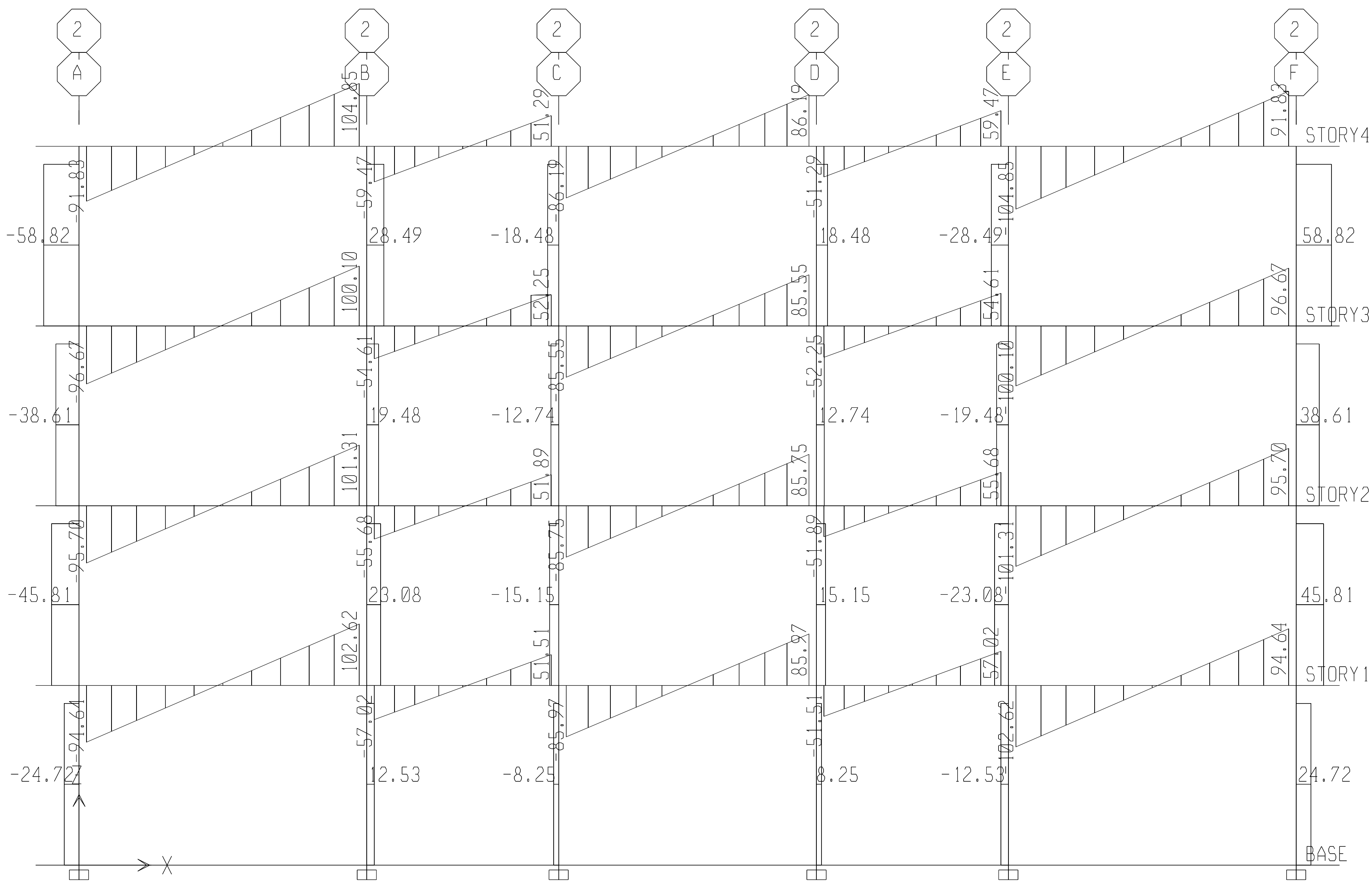
Shear force on beams (3-D) view



Analysis of frame 2
Moment Diagram



Analysis of frame 2
Shear Force Diagram



6.1 Design of Beam (B-20 & 42) :

☒ ***Design of Flexure from analysis of frame B :-***

❖ **Maximum negative moment** = 80.094 KN-m

$\rho_b = 0.85 * 0.85 * \frac{f'c}{Fy} * \frac{600}{600+Fy}$

$\rho_b = 0.85 * 0.85 * \frac{25}{420} * \frac{600}{600+420} = 0.0252$

$\rho_{max} = 0.75 * \rho_b = 0.75 * 0.0252 = 0.019$

$\rho_{min} = \frac{1.4}{Fy} = \frac{1.4}{420} = 0.0033$

h = 350 mm

b = 200 mm

❖ **Assume ∅ 25 mm longitudinal reinforcement**

d = h – (concrete cover + ds + 0.5 db)

d = 350 – (40 + 10 + 12.5) = 297.5 mm

$R = \frac{Mu}{\emptyset * f'c * b * d^2} = \frac{80.094}{0.9 * 1000 * 25 * 0.2 * 0.2975^2} = 0.201$

Using R – ω Table : $\omega = 0.233$

$\rho = \frac{\omega * f'c}{Fy} = \frac{0.233 * 25}{420} = 0.01387$ → 0.0033 < 0.01387 …O.K

$As_{req.} = \rho * b * d = 0.01387 * 200 * 297.5 = 826\ mm^2$

☛ Use 2 ∅ 25 mm → As = 982 mm^2

As > $As_{req.}$ … O.K

Check for b_{min} = (2 * concrete cover) + (2 * ds) + (n * db) + (n-1 * max of $\begin{cases}25\\db\end{cases}$)

b_{min} = (2 * 40) + (2 * 10) + (2 * 25) + (1 * 25) = 175 < b = 200 … O.K

- **Maximum positive moment** Mu^+ = 68.391 KN.m

b = 200 mm

h = 350 mm

d = 297.5 mm

- ***Check for T – beam action***

$$Bf = \min of \begin{cases} \frac{L}{4} = \frac{4.8}{4} = 1200\ mm \\ bw + 16 * t\ slab = 200 + (16 * 110) = 1960\ mm \\ bw + clear\ span\ of\ beam = 200 + 3800 = 4000\ mm \end{cases}$$

Choose bf = 1200 mm

Assume a = h_f = 110 mm

$\emptyset Mn = \emptyset * 0.85 * f'c * bf * hf * (d - \frac{hf}{2})$

$\emptyset Mn = 0.9 * 0.85 * 25x10^3 * 1.2 * 0.11 * (0.2975 - \frac{0.11}{2})$ = 612.2 KN-m

→ $\emptyset Mn$ > Mu^+ → T- beam section with rectangular action

a < hf …… Rectangular action

$$R = \frac{Mu}{\emptyset * f'c * b * d^2} = \frac{68.391}{0.9 * 1000 * 25 * 0.2 * 0.2975^2} = 0.1717$$

Using R – ω Table : $\omega = 0.194$

$$\rho = \frac{\omega * f'c}{Fy} = \frac{0.194 * 25}{420} = 0.0115$$ → 0.0033 < 0.0115 …O.K

$As_{req.} = \rho * b * d = 0.0115 * 200 * 297.5 = 684\ mm^2$

- Use 2 Ø 25 mm
- (As = 982 > As_{req} = 684) ok

- ***Check for shear***

Vu@ d = 0 → Vu = 91.83

Vu@ d = 4.8 →Vu = 104.85

Vc = 0.17 * $\sqrt{f'c}$ * bw * d

Vc = 0.17 * $\sqrt{25}$ x 10^3* 0.2 * 0.2975 = 50.575 KN

$\emptyset\ Vc$ = 0.75 * 50.575 = 37.9 KN

$\frac{\emptyset\ Vc}{2}$ = $\frac{37.9}{2}$ = 18.95 KN

Vu = 104.85 > 18.95 → **Consider shear**

Vu > $\emptyset\ Vc$

Vs = $\frac{Vu}{\emptyset} - Vc$ = $\frac{104.85}{0.75} - 50.575$ = 89.225KN

Check Vs ≤ 2/3 * $\sqrt{f'c}$ * bw * d

= 0.66 * $\sqrt{25}$ x10^3* 0.2 * 0.2975 = 196.35

Vs = 89.225 < 196.35 …. O.K

S max = min of $\begin{cases} \frac{d}{2} = 148.75\ mm \\ 600\ mm \\ \frac{3\ Av\ Fy}{bw} = \frac{3*157*420}{200} = 989\ mm \end{cases}$

S max = 148.75 mm

S req. = $\frac{Av\ Fy\ d}{Vs}$ = $\frac{157*420*290}{121.3*10^3}$ = 158 mm c/c

☛ Use Ø 10 @ 148 $mm\ c/c$

Section @ S = S max = 148 mm

Vs = $\frac{Av\ Fy\ d}{S\ max}$ = $\frac{157*420*297.5*10^{-3}}{148}$ = 132.5KN

$Vu = \emptyset\, Vn = \emptyset\, [\, Vs + Vc\,]$

= 0.75 [132.5+ 50.575] = 137.3 KN > Vu

Spacing of stirrups for full beam is equal S = S_{max} = 148 mm

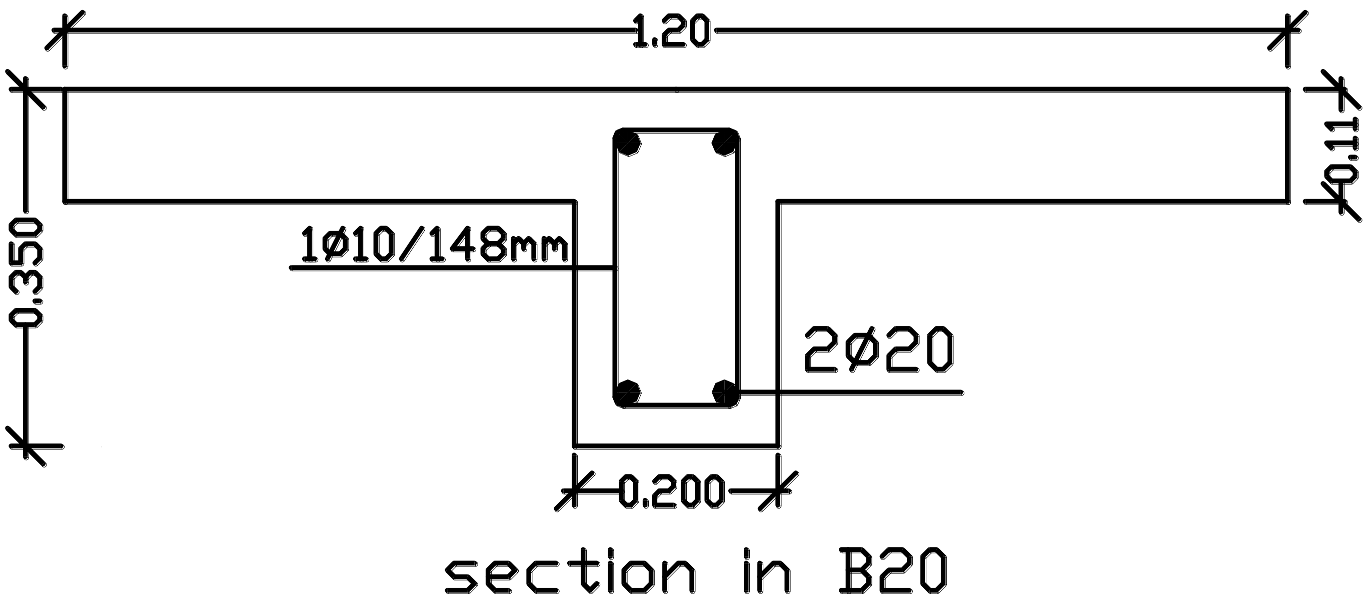
❖ **<u>Section where No shear reinforcement are required :</u>**

$Vu = \frac{\emptyset\, Vc}{2} = \frac{37.9}{2} = 18.95$ KN

104.85/2.8 = 18.95/x

X= 0.506 m From mid center of span

Distance from support = 2.4 – 0.506 = 1.894 m



6.2 Design of Beam (B-16) :

- ☒ **Design of Flexure from analysis of frame B :-**
- ❖ **Maximum negative moment** = 56.715 KN-m

h = 350 mm

b = 200 mm

- ❖ **Assume Ø 20 mm longitudinal reinforcement**

d = h – (concrete cover + ds + 0.5 db)

d = 350 – (40 + 10 + 10) = 290 mm

$R = \frac{Mu}{\emptyset * f'c * b * d^2} = \frac{56.715}{0.9 * 1000 * 25 * 0.2 * 0.29^2} = 0.149$

Using R – ω Table : $\omega = 0.166$

$\rho = \frac{\omega * f'c}{Fy} = \frac{0.166 * 25}{420} = 0.00988$ → 0.0033 < 0.00988 ...O.K

$As_{req.} = \rho * b * d = 0.00988 * 200 * 290 = 573\ mm^2$

☛ Use 2 Ø 20 mm → $As = 628\ mm^2$

$As > As_{req.}$ ... O.K

Check for b_{min} = (2 * concrete cover) + (2 * ds) + (n * db) + (n-1 * max of $\begin{cases} 25 \\ db \end{cases}$)

b_{min} = (2 * 40) + (2 * 10) + (2 * 20) + (1 * 25) = 165mm < b = 200mm ... O.K

❖ ***Maximum positive moment*** Mu^+ = 46.783 KN.m

b = 200 mm

h = 350 mm

d = 290 mm

❖ ***Check for T – beam action***

$$Bf = \min of \begin{cases} \frac{L}{4} = \frac{4.3}{4} = 1075\ mm \\ bw + 16\ * t\ slab = 200 + (16 * 110) = 1960\ mm \\ bw + clear\ span\ of\ beam = 200 + 4100 = 4300\ mm \end{cases}$$

Choose bf = 1075 mm

Assume a = h_f = 110 mm

$\emptyset\ Mn = \emptyset * 0.85 * f'c * bf * hf * (d - \frac{hf}{2})$

$\emptyset\ Mn = 0.9 * 0.85 * 25x10^3 * 1.075 * 0.11 * (0.290 - \frac{0.11}{2})$ = 531 KN-m

→ $\emptyset\ Mn >$ Mu^+ → T- beam section with rectangular action

a < hf …… Rectangular action

$$R = \frac{Mu}{\emptyset * f'c * b * d^2} = \frac{46.783}{0.9 * 1000 * 25 * 0.2 * 0.29^2} = 0.1236$$

Using R – ω Table : $\omega = 0.134$

$$\rho = \frac{\omega * f'c}{Fy} = \frac{0.134 * 25}{420} = 0.00797$$ → 0.0033 < 0.00797 …O.K

$As_{req.} = \rho * b * d = 0.00797 * 200 * 290 = 462\ mm^2$

☛ Use2 Ø 20 mm → As = 628 mm^2

- ***Check for shear***

Vu@ L = 0 → Vu = 86.19

Vu@ L = 3.2 →Vu = 86.19

Vc = 0.17 * $\sqrt{f'c}$ * bw * d

Vc = 0.17 * $\sqrt{25}$ x 10^3* 0.2 * 0.290 = 49.3 KN

$\emptyset\ Vc$ = 0.75 * 49.3 = 36.975 KN

$\frac{\emptyset\ Vc}{2}$ = $\frac{36.975}{2}$ = 18.48 KN

Vu = 86.19 > 18.48 → Consider shear

Vu > $\emptyset\ Vc$ → Case (2)

Vs = $\frac{Vu}{\emptyset} - Vc$ = $\frac{86.19}{0.75} - 49.3$ = 65.62 KN

Check Vs ≤ 2/3 * $\sqrt{f'c}$ * bw * d

= 0.66 * $\sqrt{25}$ x10^3* 0.2 * 0.29 = 191

Vs = 65.62 < 191 …. O.K

S max = min of $\begin{cases} \frac{d}{2} = 145\ mm \\ 600\ mm \\ \frac{3\ Av\ Fy}{bw} = \frac{3*157*420}{200} = 989\ mm \end{cases}$

S max = 145 mm

S req. = $\frac{Av\ Fy\ d}{Vs}$ = $\frac{157*420*290}{65.62*10^3}$ = 291 mm c/c

- Use Ø 10 @ 140 $mm\ c/c$

Section @ S = S max = 140 mm

Vs = $\frac{Av\ Fy\ d}{S\ max}$ = $\frac{157*420*290*10^{-3}}{145}$ = 131.88 KN

Vu = Ø Vn = Ø [$Vs + Vc$]

= 0.75 [131.88 + 49.3] = 135.885 KN > 86.19 KN

Spacing of stirrups for full beam is equal S = S_{max} = 145 mm

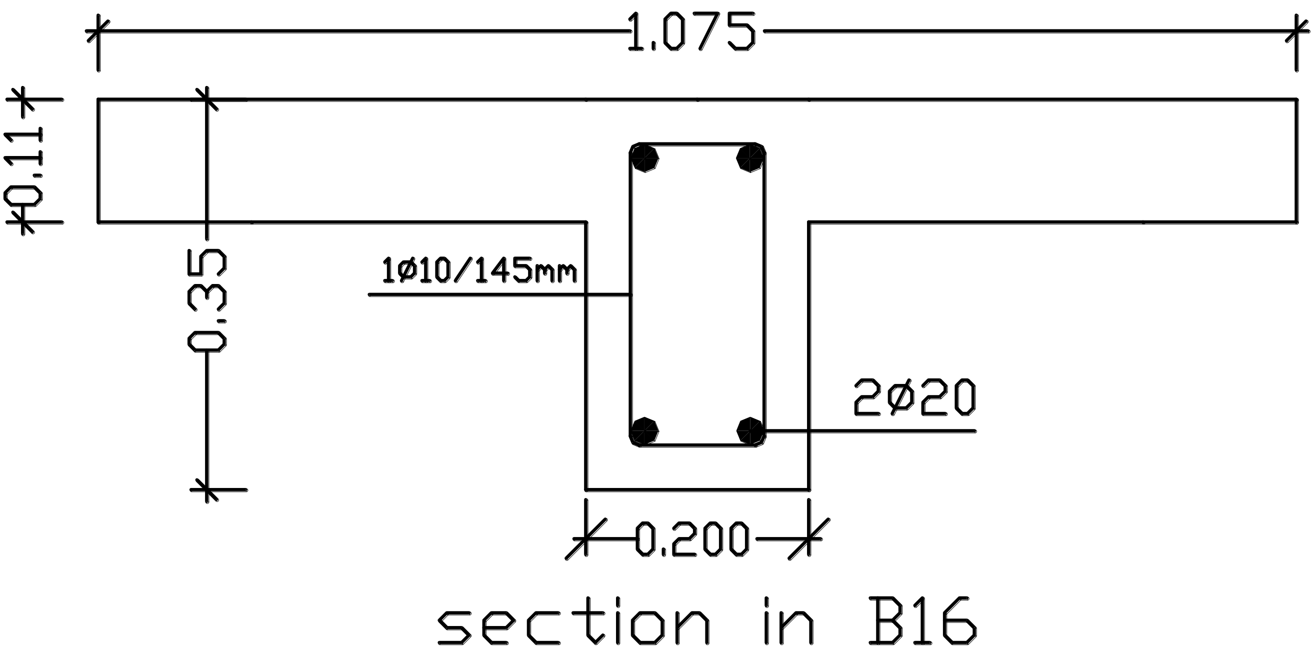
- **Section where No shear reinforcement are required :**

Vu = $\frac{Ø\ Vc}{2} = \frac{36.975}{2}$ = 18.48 KN

86.19/2.15 =18.48 /x

X= 0.460 m From mid center of span

Distance from support = 2.15 – 0.460 =1.69 m



6.3 Design of Beam (B-39 & 15) :

- ☒ ***Design of Flexure from analysis of frame B :-***
- ❖ ***Maximum negative moment*** = 49.517 KN-m

h = 350 mm

b = 200 mm

- ❖ **Assume ∅ 20 mm longitudinal reinforcement**

d = h – (concrete cover + ds + 0.5 db)

d = 350 – (40 + 10 + 10) = 290 mm

$$R = \frac{Mu}{\emptyset * f'c * b * d^2} = \frac{49.517}{0.9 * 1000 * 25 * 0.2 * 0.29^2} = 0.1308$$

Using R – ω Table : $\omega = 0.113$

$$\rho = \frac{\omega * f'c}{Fy} = \frac{0.113 * 25}{420} = 0.00672 \rightarrow 0.0033 < 0.00672 \text{ ...O.K}$$

$As_{req.} = \rho * b * d = 0.00672 * 200 * 290 = 390 \text{ mm}^2$

- ☛ Use 2 Ø 16 mm → As = 402 mm^2

As > $As_{req.}$ ... O.K

Check for b_{min} = (2 * concrete cover) + (2 * ds) + (n * db) + (n-1 * max of $\begin{cases} 25 \\ db \end{cases}$)

b_{min} = (2 * 40) + (2 * 10) + (2 * 16) + (1 * 25) = 157 < b = 200 ... O.K

❖ ***Maximum positive moment*** Mu^+ = 9.932 KN.m

b = 200 mm

h = 350 mm

d = 290 mm

❖ ***Check for T – beam action***

Bf = min of $\begin{cases} \frac{L}{4} = \frac{3.2}{4} = 800\ mm \\ bw + 16 * t\ slab = 200 + (16 * 110) = 1960\ mm \\ bw + clear\ span\ of\ beam = 200 + 4100 = 4300\ mm \end{cases}$

Choose bf = 800 mm

Assume a = h_f = 110 mm

$\emptyset Mn = \emptyset * 0.85 * f'c * bf * hf * (d - \frac{hf}{2})$

$\emptyset Mn = 0.9 * 0.85 * 25x10^3 * 0.8 * 0.11 * (0.29 - \frac{0.11}{2})$ = 395 KN-m

→ $\emptyset Mn >$ Mu^+ → T- beam section with rectangular action

a < hf …… Rectangular action

R = $\frac{Mu}{\emptyset * f'c * b * d^2} = \frac{9.932}{0.9 * 1000 * 25 * 0.2 * 0.29^2}$ = 0.0262

Using R – ω Table : $\omega = 0.027$

$\rho = \frac{\omega * f'c}{Fy} = \frac{0.027 * 25}{420}$ = 0.00160 → 0.0033 > 0.00160 …O.K

$As_{req.} = \rho * b * d$ = 0.0033 * 200 * 290 = 191 mm^2

☛ Use 2 Ø 12 mm → As = 226 mm^2

❖ ***Check for shear***

Vu@ L = 0 → Vu = 51.29

Vu@ L = 3.2 →Vu = 59.47

Vc = 0.17 * $\sqrt{f'c}$ * bw * d

Vc = 0.17 * $\sqrt{25}$ x 10^3* 0.2 * 0.29 = 49.3 KN

$\emptyset\ Vc$ = 0.75 * 49.3 = 36.975 KN

$\frac{\emptyset\ Vc}{2}$ = $\frac{36.975}{2}$ = 18.48 KN

Vu = 59.47 > 18.48 → Consider shear

Vu > $\emptyset\ Vc$ → Case (2)

Vs = $\frac{Vu}{\emptyset} - Vc$ = $\frac{59.47}{0.75} - 49.3$ = 29.9 KN

Check Vs ≤ 2/3 * $\sqrt{f'c}$ * bw * d

= 0.66 * $\sqrt{25}$ x10^3* 0.2 * 0.29 = 191.4

Vs = 29.9 < 191.4 …. O.K

S max = min of $\begin{cases} \frac{d}{2} = 145\ mm \\ 600\ mm \\ \frac{3\ Av\ Fy}{bw} = \frac{3*157*420}{200} = 989\ mm \end{cases}$

S max =145 mm

S req. = $\frac{Av\ Fy\ d}{Vs}$ = $\frac{157*420*290}{29.9*10^3}$ = 639 mm c/c

☛ Use Ø 10 @ $140\ mm\ c/c$

Section @ S = S max = 140 mm

Vs = $\frac{Av\ Fy\ d}{S\ max}$ = $\frac{157*420*290*10^{-3}}{145}$ = 131.88 KN

Vu = Ø Vn = Ø [$Vs + Vc$]

= 0.75 [131.88 + 49.3] = 135.88 KN > 59.47 KN

Spacing of stirrups for full beam is equal S = S_{max} = 145 mm

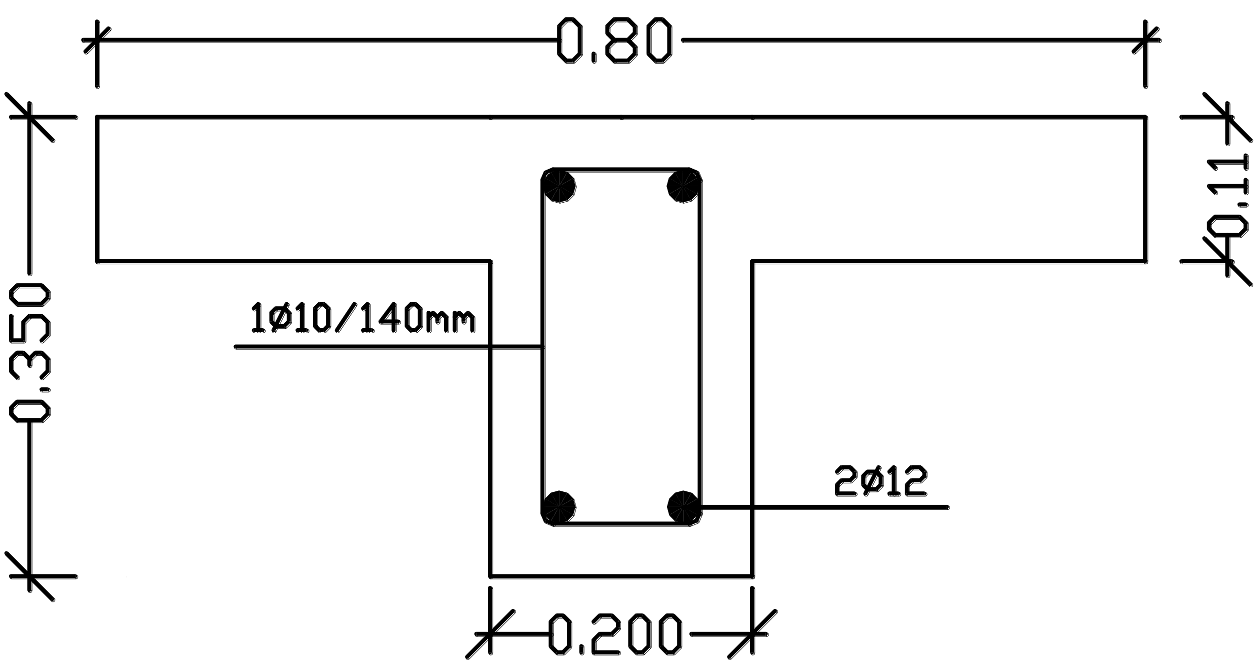
❖ **<u>Section where No shear reinforcement are required :</u>**

Vu = $\frac{\emptyset\, Vc}{2}$ = $\frac{36.975}{2}$ = 18.48 KN

59.47/1.6 =18.48/x

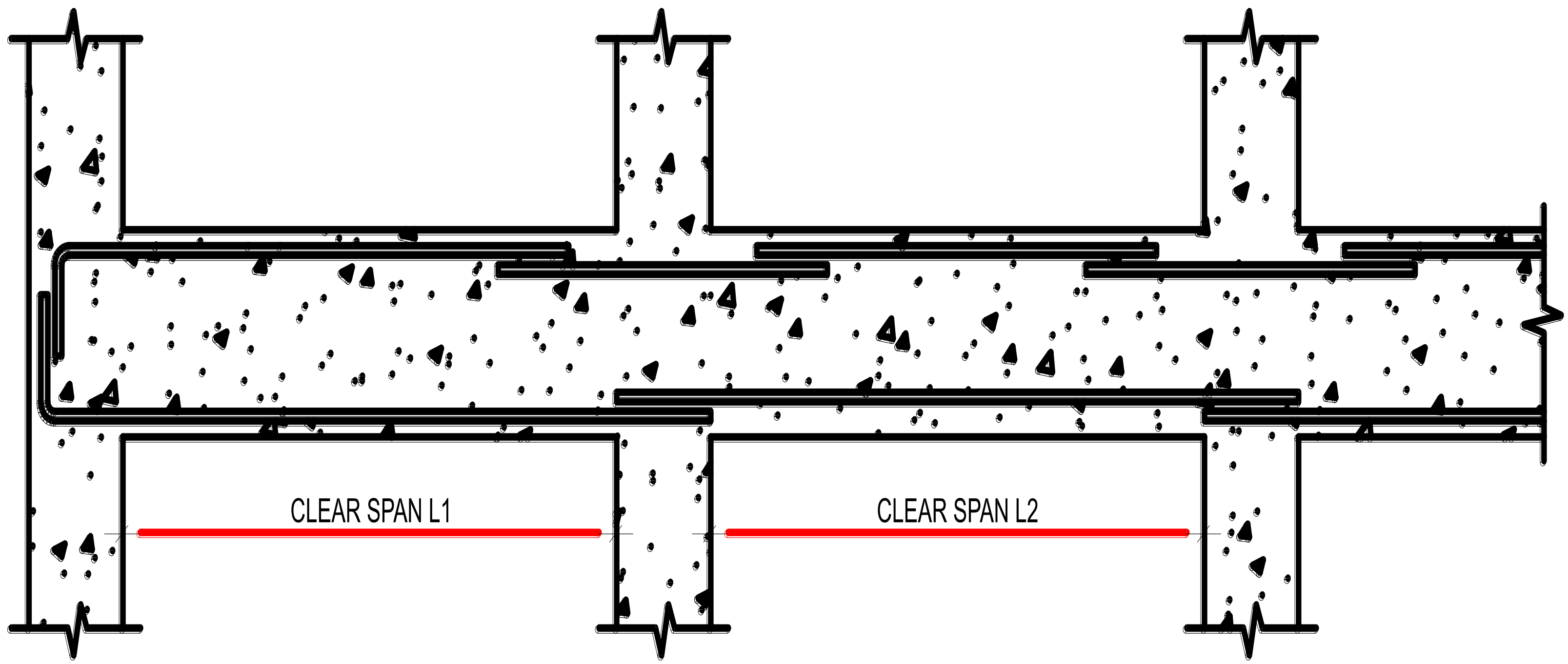
X= 0.497 m From mid center of span

► Distance from support = 1.6 – 0.497 =1.103 m



section in B39 & 15

Reinforcement Placement Rules For Beams

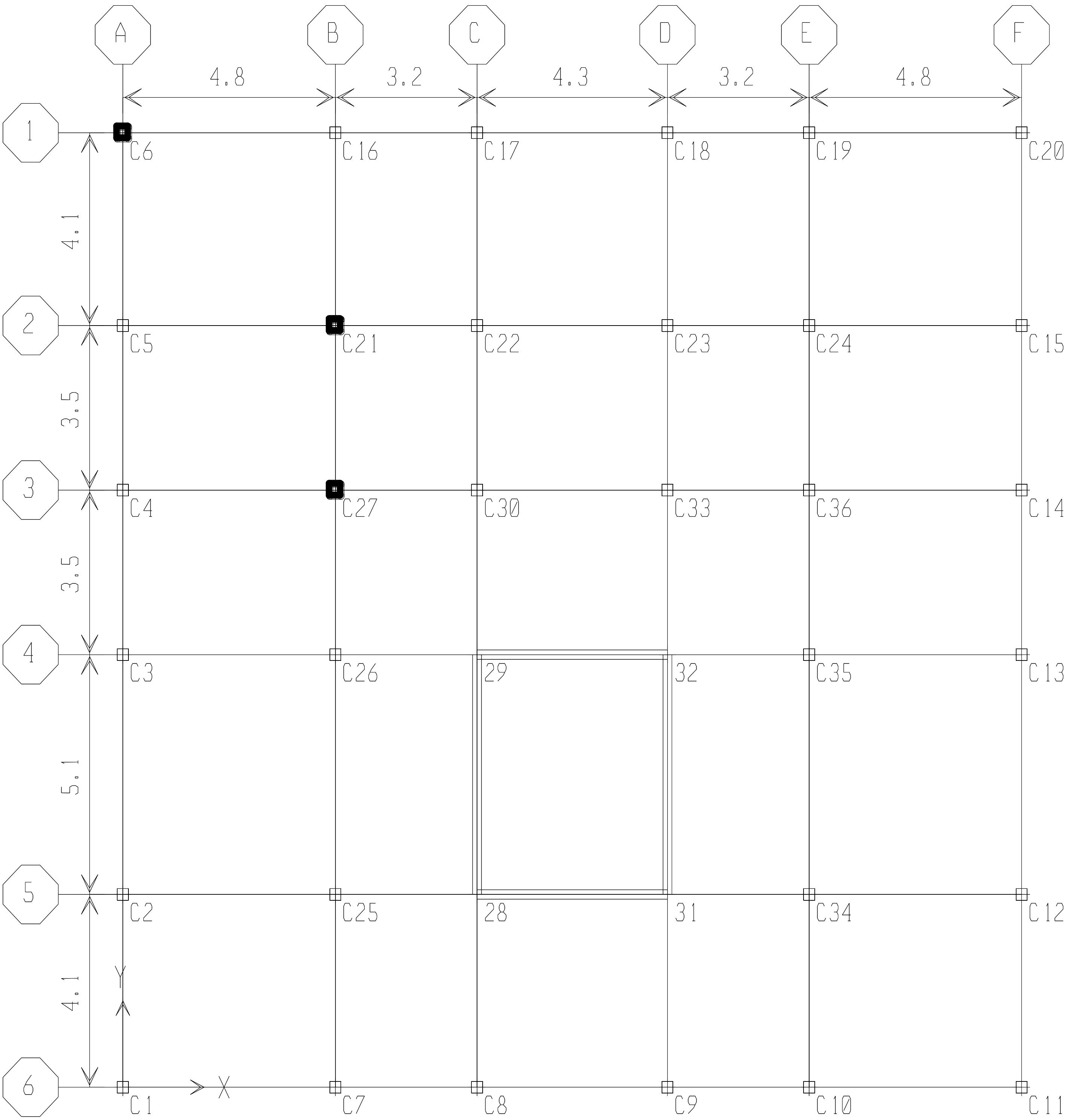


WHERE "L" IS THE LARGER OF THE ADJACENT SPANS

Chapter Seven

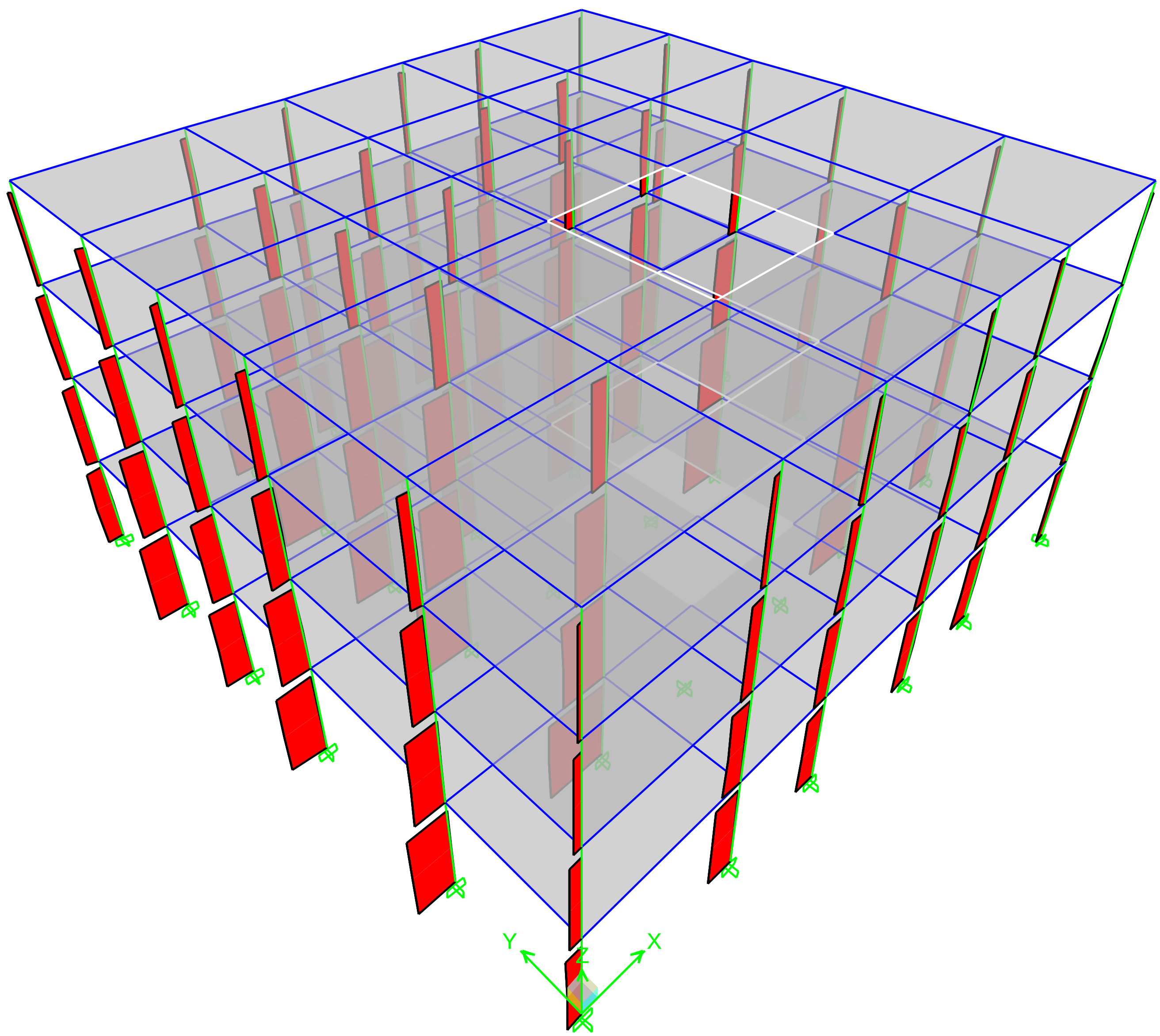
Design Of Column

- **Plan view**

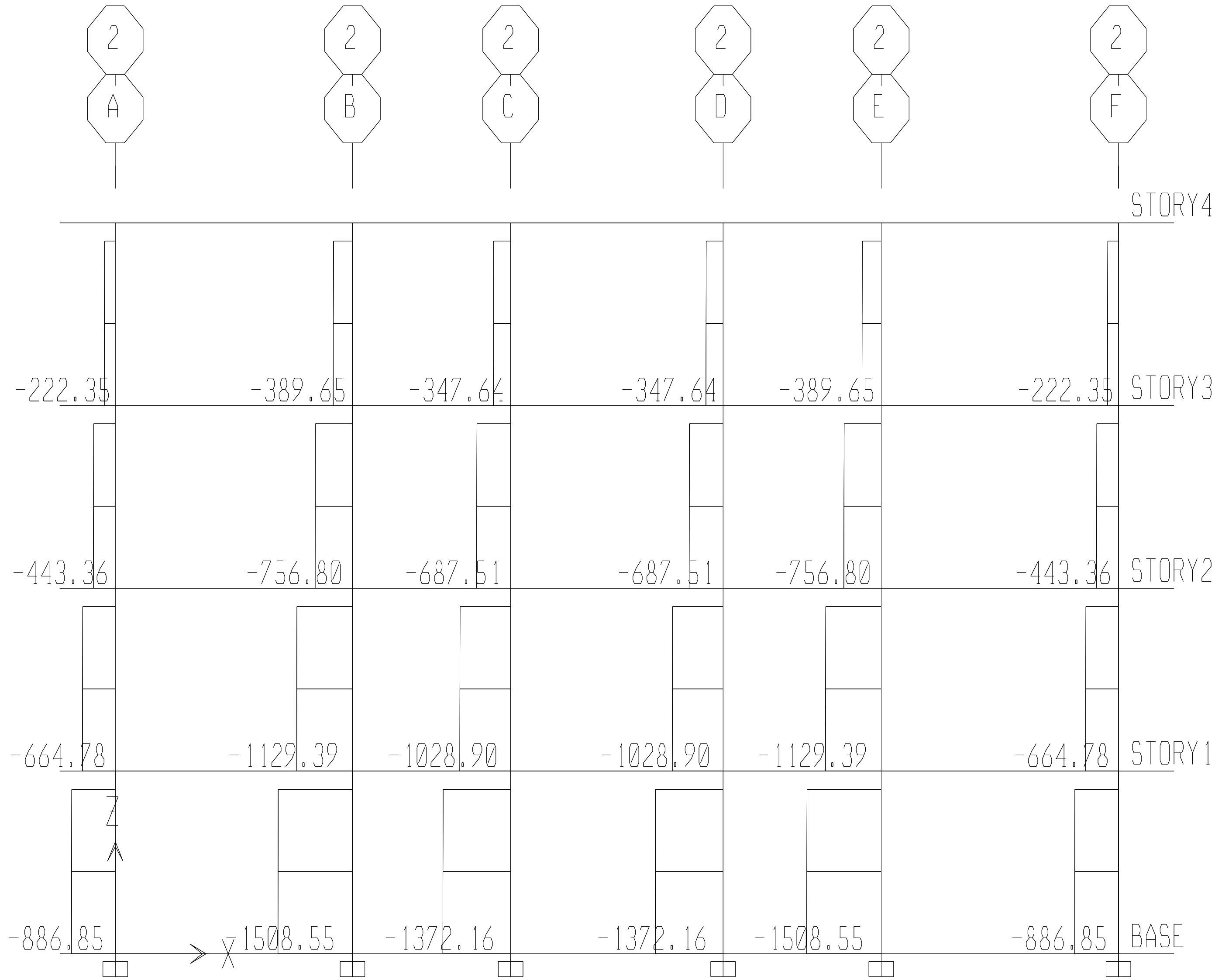


A
B
C
D
E
F
4.8
3.2
4.3
3.2
4.8
1
2
3
4
5
6
4.1
3.5
3.5
5.1
4.1
C6
C16
C17
C18
C19
C20
C5
C21
C22
C23
C24
C15
C4
C27
C30
C33
C36
C14
C3
C26
29
32
C35
C13
C2
C25
28
31
C34
C12
C1
C7
C8
C9
C10
C11
Y
X

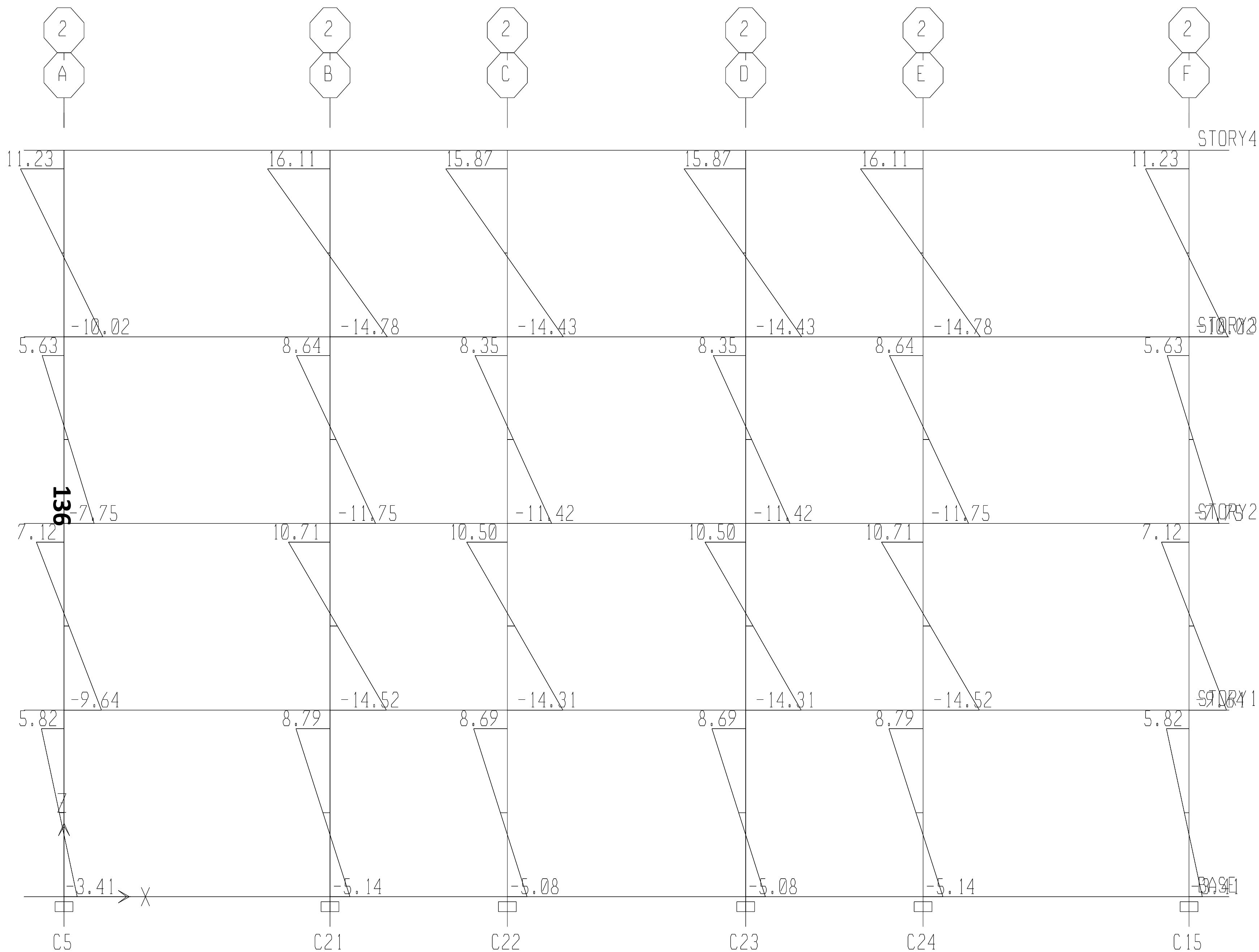
Axial Force on column (3-D view)



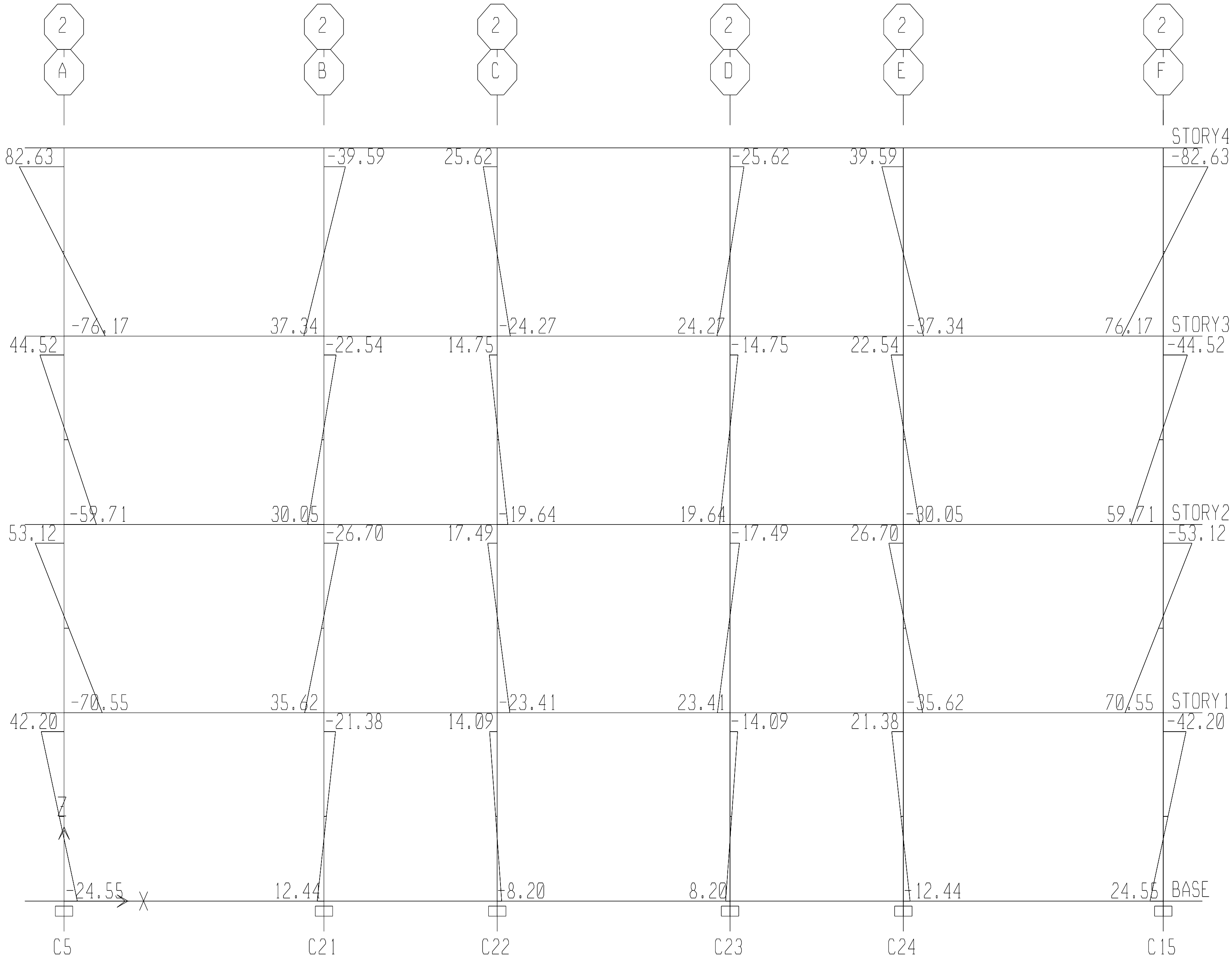
Analysis of frame 2
axial force



axial force diagram



Mux Values on Col. 21



Muy Values on Col.C21

7.1 Design of Column :

7.1.1 (2-B) → C21 (Story 4)

Muy	Mux	Load	Column	Story
37.338	-14.776	UDL	C21	**STORY4**
-1.125	0.666	UDL	C21	**STORY4**
-39.588	16.108	UDL	C21	**STORY4**

Mux = 16.11 KN-m

Muy = 39.59 KN-m

Pu = 461.26 KN

Ag = 0.25 * 0.3 = 0.075 mm^2

$\emptyset\ Mn'x$ = Mux + Muy * $\frac{b}{h}$

= 16.11 + 39.59 * $\frac{250}{300}$ = 49 KN-m

$\frac{\emptyset Pu}{Ag} = \frac{461.26*10^{-3}}{0.075*6.895}$ = 0.892 Ksi

$e_y = \frac{\emptyset\ Mn'x}{Pu} = \frac{49}{461.26}$ = 0.106

$\frac{ey}{hx} = \frac{0.106}{0.25}$ = 0.424

$\frac{\emptyset Pu}{Ag} * \frac{ey}{hx}$ = 0.892 * 0.424 = 0.378

$\gamma_x = \frac{h-\ 2\ (concrete\ cover+ds+0.5\ db\ )}{h}$

Concrete cover = 30 , d_s = 10 , d_b = Ø16

$\gamma_x = \frac{250-(2*48)}{250}$ = 0.616

Use (I.D) charts with $\gamma_x = 0.6$

Get $\rho_g = 0.018$

As = $\rho_g * b * h$

$= 0.018 * 250 * 300 = 1350\ mm^2$

- **Use 8 Ø 16 mm → As = 1690 mm²**

As = $1690\ mm^2 > Ad = 1350\ mm^2$ → → → O.K

- **<u>Check for column capacity :</u>**
- **<u>Find Px</u>**

Mux = 16.11

$e_y = \frac{Mux}{Pu} = \frac{16.11}{461.26} = 0.0348$

$\frac{ey}{hx} = \frac{0.0348}{0.25} = 0.139$

Use (I.D) with $\gamma_x = 0.6$ → $\frac{e}{h} = 0.139$ & $\rho_g = 0.018$

Get → $\frac{\emptyset Pu\ x}{Ag} = 1.2$ Ksi

$Pu_x = \frac{1.2*Ag}{\emptyset} = \frac{1.2*0.075}{0.65} = 0.138 * 6.895 = 0.953$ MN

- **<u>Find Pu_y</u>**

$\gamma_y = \frac{300-96}{300} = 0.68 = 0.7$

$\rho_g = 0.018$

$e_x = \frac{Mu\ y}{Pu} = \frac{39.59}{461.26} = 0.085$

$\frac{ex}{hy} = \frac{0.085}{0.3} = 0.283$

$\frac{\emptyset Pu\ y}{Ag} = 2.25$

$Pu_y = \left(\frac{2.25 * Ag}{\emptyset}\right) * 6.895$

$= \left(\frac{2.25 * 0.075}{0.65}\right) * 6.895 = 1.8$ MN

$b_o = As * Fy + 0.85 * f'c\ (Ag - As_{(tot)})$

$b_o = 1609*10^{-6} * 420 + 0.85 * 25\ (0.075 - 1609*10^{-6}) = 2.24$ MN

$\frac{1}{Pn} = \frac{1}{Pn\ x} + \frac{1}{Pn\ y} - \frac{1}{bo}$

$= \frac{1}{0.953} + \frac{1}{1.8} - \frac{1}{2.24} = 1.158$

➔ Pu = 0.86

$Pu = 0.86 * 10^3 = 860 * 0.65 = 559 > Pu$

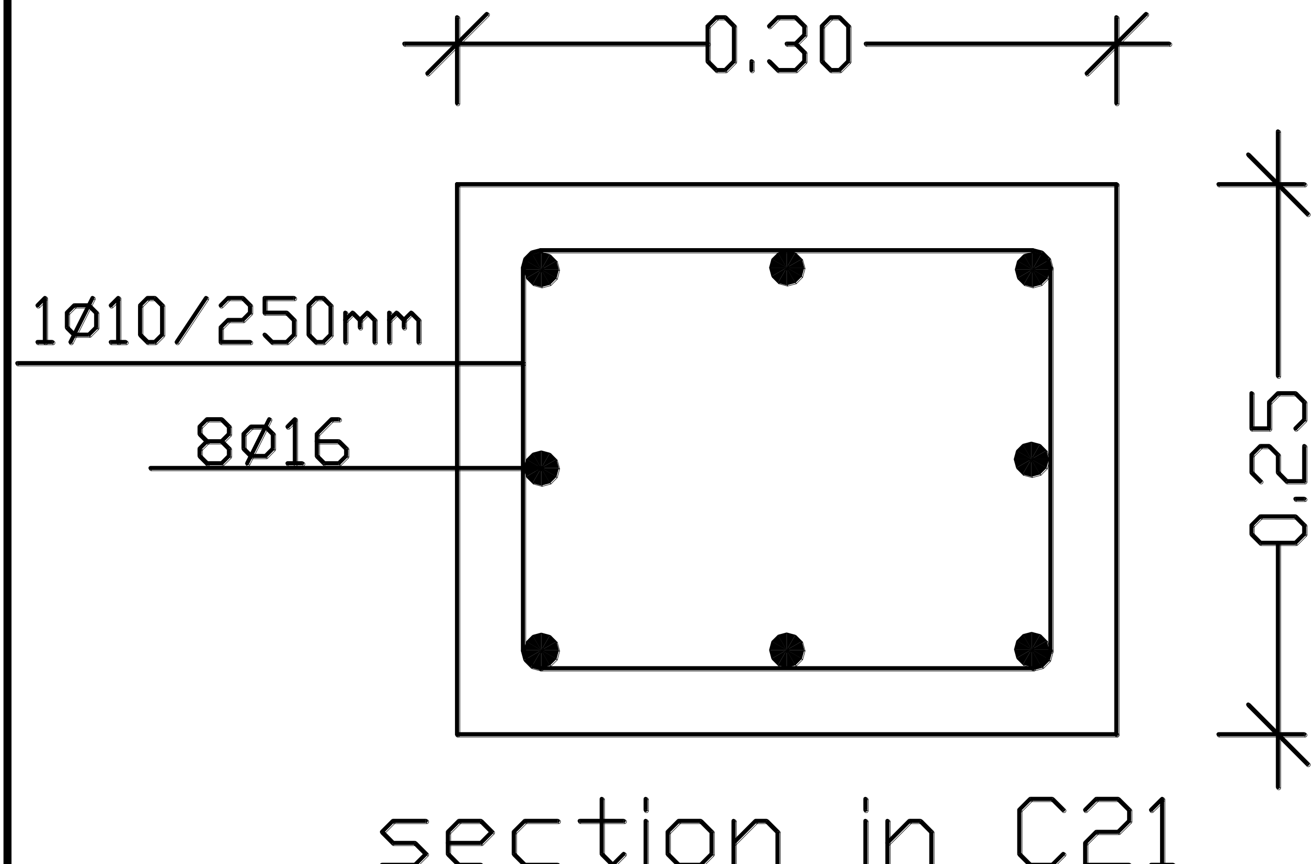
Pu = 559 > Pu = 461.26 → → → O.K

❖ **<u>Design of ties :</u>**

Use minimum shear reinforcement

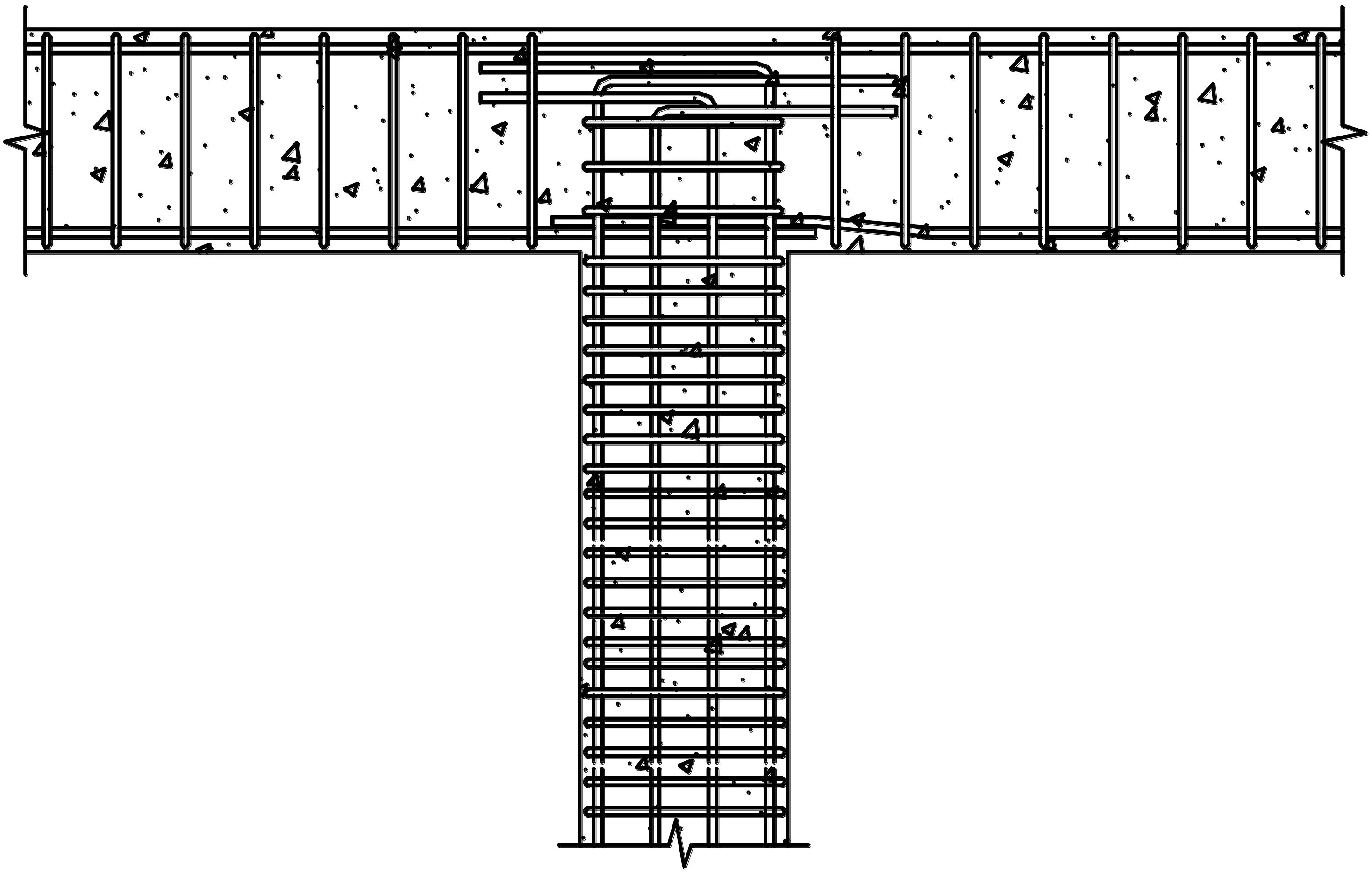
$$S = S\ max = \min \text{ of } \begin{cases} least\ diminsion\ of\ cross\ section\ of\ col. = 250mm(control\ ) \\ 48\ dt = 48\ (10) = 480mm \\ 16\ db = 16\ (\ 16) = 256\ mm \end{cases}$$

☛ Use Ø 10 @ 250 mm c/c



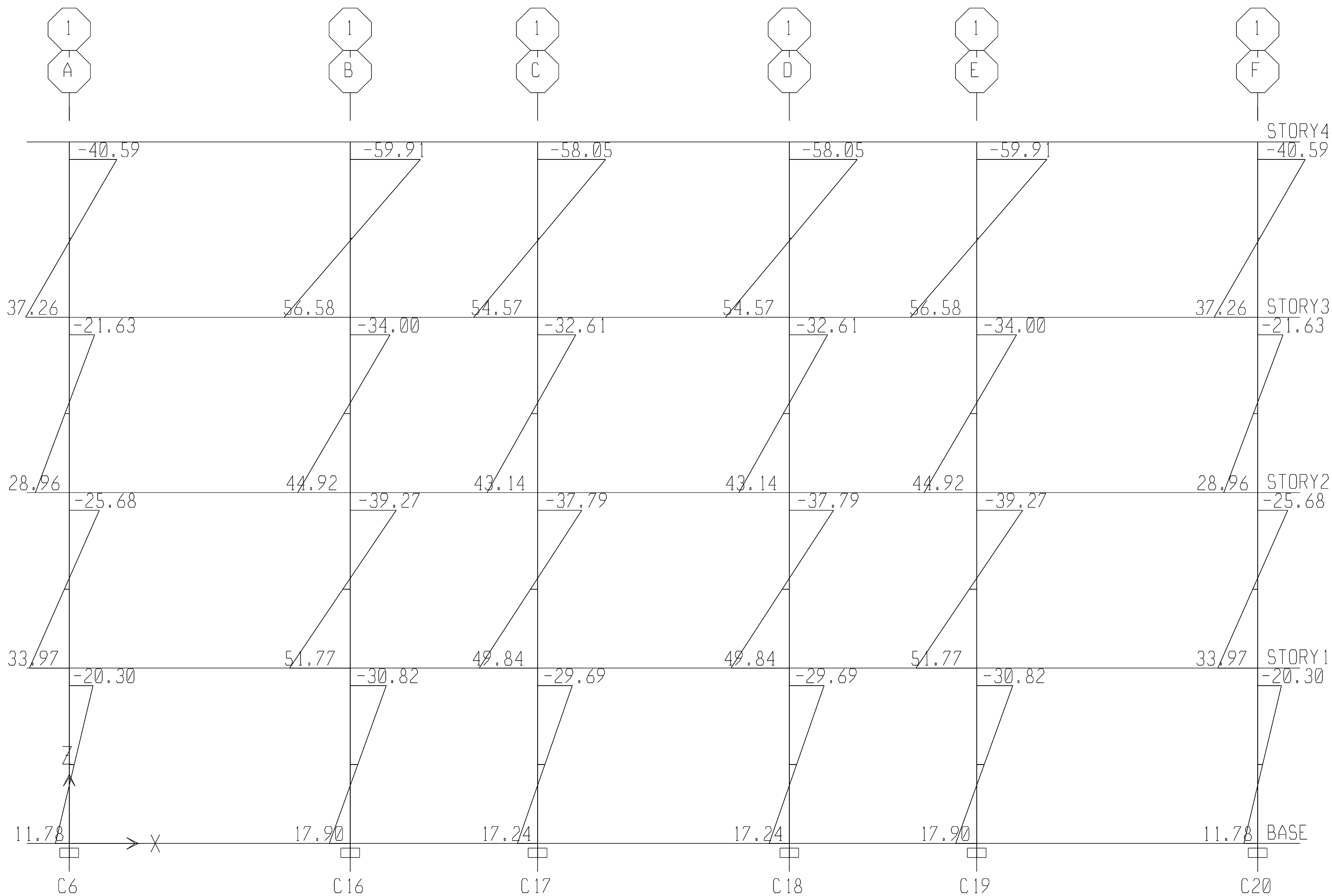
0.30
0.25
1Ø10/250mm
8Ø16
section in C21

- **Beam Column Joint Details**

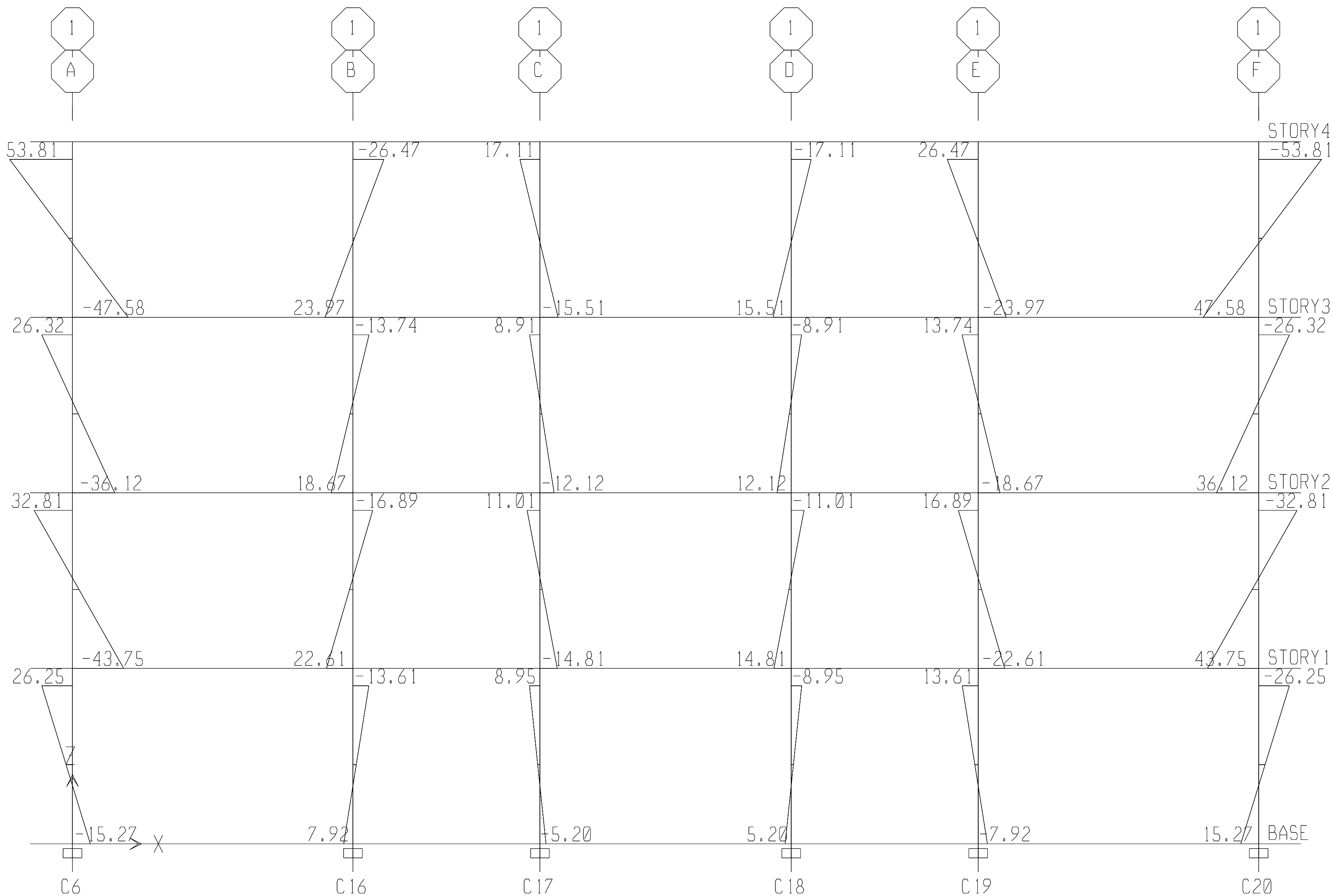


Interior beam – column joint details (END COLUMN)

Analysis of Frame 1



Mux Values on Col.C6



Muy Values on Col.C6

7.1.2 (1-A) → C6 (story 4)

M3	M2	Load	Column	Story
-47.584	37.264	UDL	C6	**STORY4**
3.114	-1.662	UDL	C6	**STORY4**
53.812	-40.588	UDL	C6	**STORY4**

Mux = 40.6 KN-m

Muy = 53.81 KN-m

Pu = 112.6 KN

Ag = 0.3 * 0.35 = 0.105 mm^2

$\emptyset\ Mn'x$ = Mux + Muy * $\frac{b}{h}$

= 40.6 + 53.81 * $\frac{300}{350}$ = 86.72 KN-m

$\frac{\emptyset Pu}{Ag}$ = 0.1555 Ksi

e_y = $\frac{\emptyset\ Mn'x}{Pu}$ = 0.770

$\frac{ey}{hx}$ = 2.6

$\frac{\emptyset Pu}{Ag} * \frac{ey}{hx}$ = 2.6 * 0.1555 = 0.378 Ksi

$\gamma_x = \frac{h - 2\ (concrete\ cover + ds + 0.5\ db\ )}{h}$

Concrete cover = 30 , d_s = 10 , d_b = Ø16

$\gamma_x = \frac{350-(2*48)}{350} = 0.68$

Use (I.D) charts with $\gamma_x = 0.75$

Get $\rho_g = 0.019$ → $\frac{\emptyset Pu}{Ag} = 0.1555$

As = ρ_g * b * h

= 0.019 * 300 * 350 = 1995 mm^2

☛ Use 12 Ø 16 mm → As = 2412 mm^2

- **Check for column capacity :**
  - **<u>Find Px</u>**

Mux = 40.6

$e_y = \frac{Mux}{Pu} = \frac{40.6}{112.6} = 0.360$

$\frac{ey}{hx} = \frac{0.360}{0.3} = 1.2$

Use (I.D) with $\gamma_x = 0.75$ → $\frac{e}{h} = 1.2$ & $\rho_g = 0.018$

Get → $\frac{\emptyset Pu\ x}{Ag} = 0.4$ Ksi

$Pu_x = \frac{0.4*Ag}{\emptyset} = \frac{0.4*0.105}{0.65} * 6.895 = 0.4456$ MN

☛ **<u>Find Pu_y</u>**

$\gamma_y = \frac{300-96}{300} = 0.68 = 0.7$

$\rho_g = 0.019$

$e_x = \frac{Mu\ y}{Pu} = \frac{53.81}{112.6} = 0.478$

$\frac{ex}{hy} = \frac{0.478}{0.35}$ = 1.365

$\frac{\emptyset Pu\ y}{Ag}$ = 0.27

$Pu_y = \left(\frac{0.27 * Ag}{\emptyset}\right) * 6.895$

$= \left(\frac{0.27 * 0.105}{0.65}\right) * 6.895$ = 0.289 MN

$b_o = As * Fy + 0.85 * f'c\ (Ag - As_{(tot)})$

$b_o = 2011*10^{-6} * 420 + 0.85 * 25\ (0.105 - 2011*10^{-6}) = 0.867$ MN

$\frac{1}{Pn} = \frac{1}{Pn\ x} + \frac{1}{Pn\ y} - \frac{1}{bo}$

$= \frac{1}{0.4456} + \frac{1}{0.289} - \frac{1}{0.867}$ = 4.544 MN

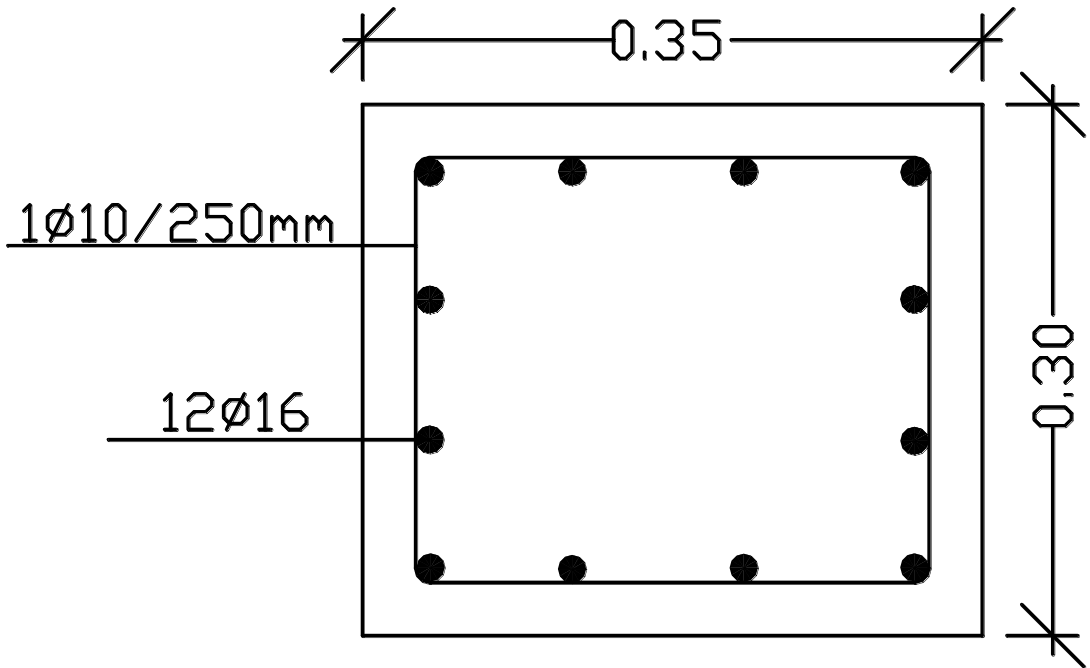
➔ Pu = 0.86

Pu = 0.22 *10^3 = 220 > Pu = 112.6 O.k

☛ **<u>Design of ties :</u>**

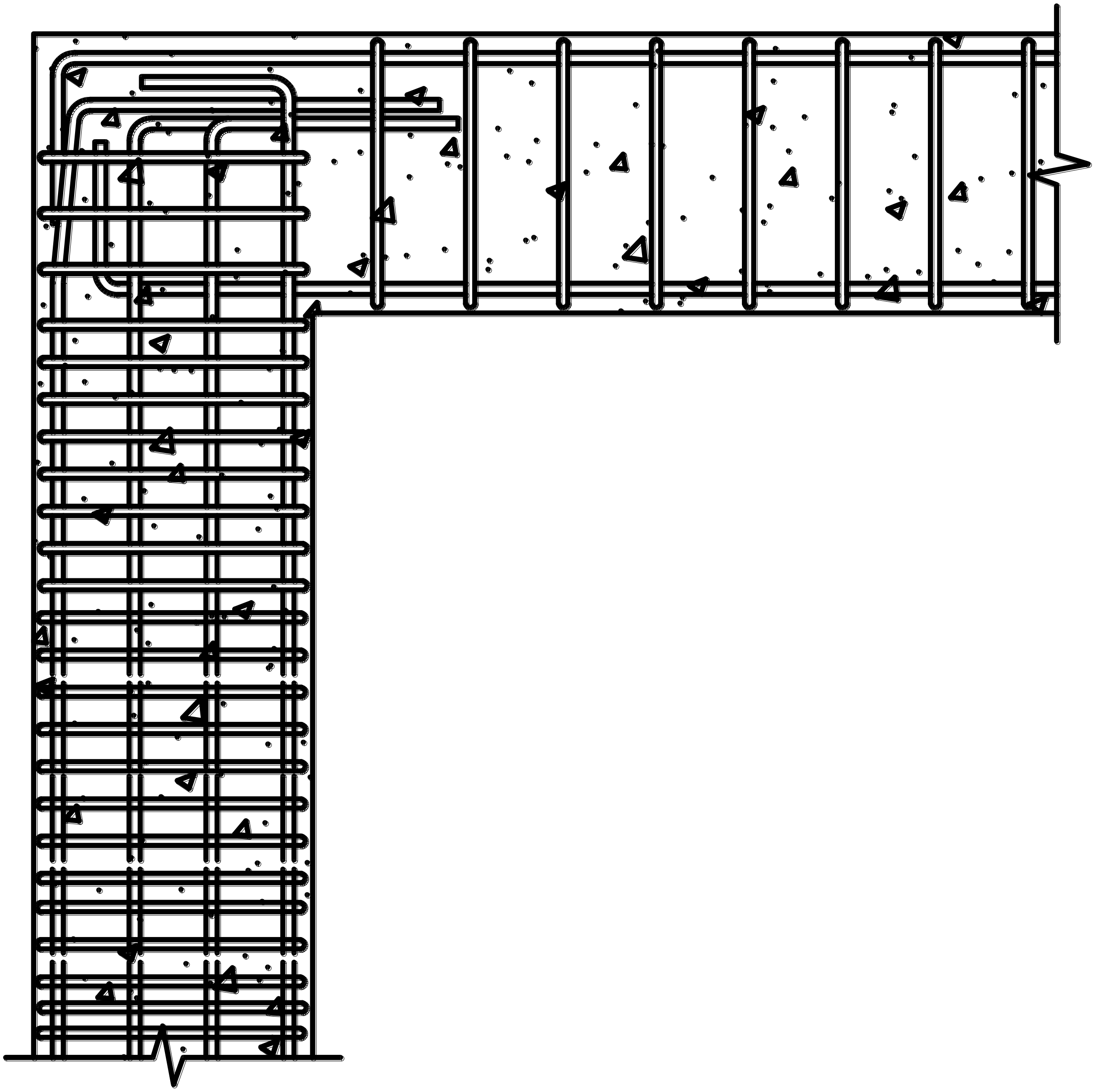
$$S = S\ max = \min of \begin{cases} least\ diminsion\ of\ cross\ section\ of\ col. = 300\ mm \\ 48\ dt = 48\ (10) = 480 mm \\ 16\ db = 16\ (16) = 256\ mm\ (control) \end{cases}$$

☛ Use Ø 10 @ 256 mm c/c



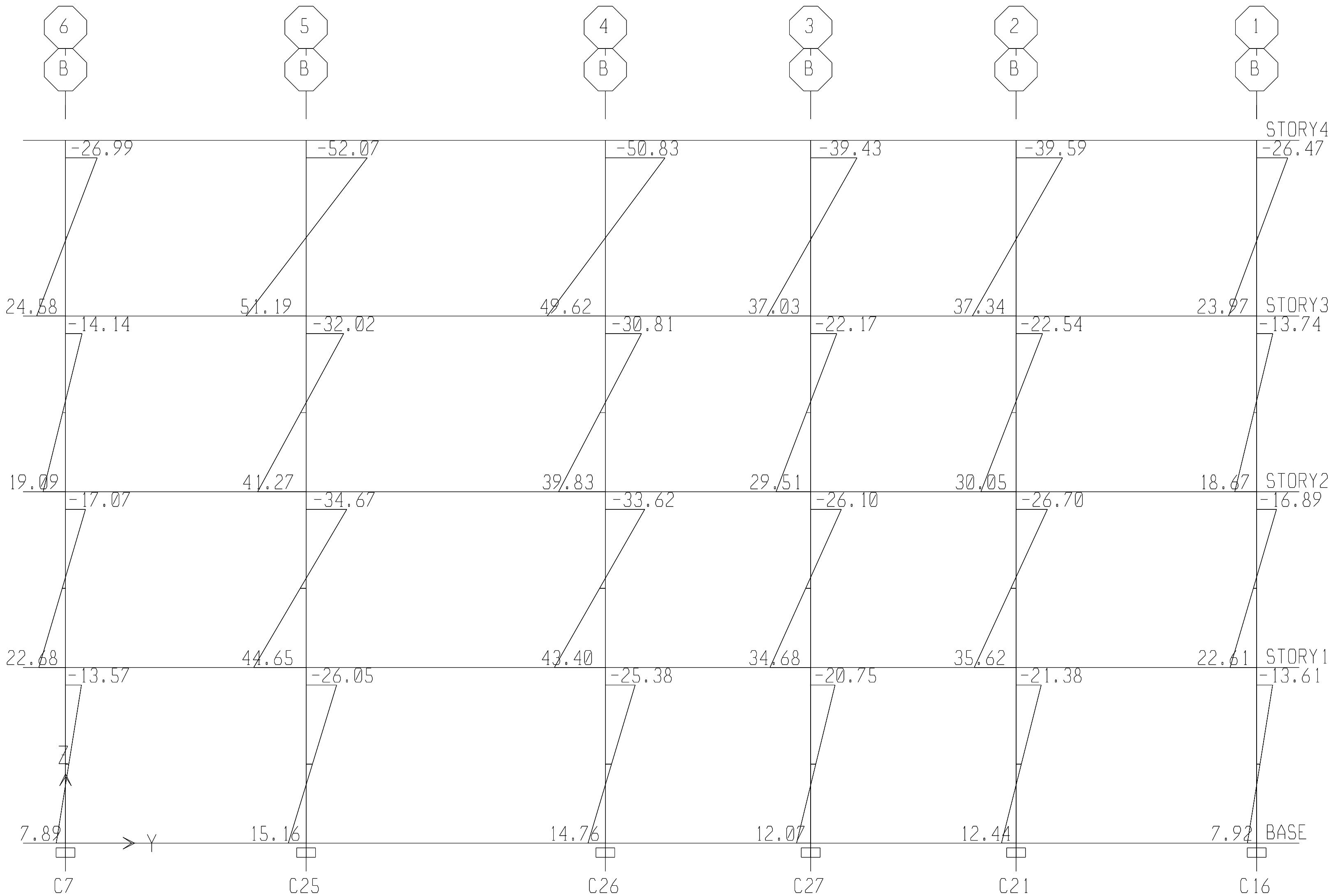
section in C6

Beam – column details



Interior beam – column joint details (END COLUMN)

Analysis of frame B



Moment on col. C27

7.1.3 Design of Column in story 3 Col.27 (3B):

Mu	Load	Column	Story
29.506	UDL	C27	**STORY3**
3.667	UDL	C27	**STORY3**
-22.172	UDL	C27	**STORY3**

Mu1 = 22.17 Kn-m

Mu2 = 29.51 Kn-m

e = $\frac{Mu}{Pu}$ = $\frac{29.51}{659.54}$ = 0.045

Assume e < $\frac{h}{2}$

Ag = $\frac{Pu}{0.6*f'c}$ = $\frac{659.54}{0.6*25*10^3}$ = 0.0439

Try b = 0.2 * H = 0.25 = 0.05 > 0.0439 m^2….O.K

Check the slenderness Ratio :

$I_{col.}$ = 0.7 Ig = 0.7 * $\frac{200*(250)^3}{12}$ = 182.3*10^6 mm^4

I_{beam} = 0.35 Ig = 0.7 * $\frac{300*(300)^3}{12}$ = 236*10^6 mm^4

$\varphi_A = \varphi_B = \frac{\sum\left(\frac{EI}{L}\right) col.}{\sum\left(\frac{EI}{L}\right) beam}$

$= \frac{2\ (\frac{182.3*10^6}{3})}{\left(\frac{236*10^6}{3.5}\right)*2}$ = 0.9

K = 0.77

r = 0.3 h = 0.3 * 250 = 75 mm

$\frac{K*Lu}{r}$ = $\frac{0.77*2700}{75}$ = 27.72 mm

34 – 12 ($\frac{M1}{M2}$) = 34 – 12 ($\frac{22.17}{29.57}$) = 24.98

$\frac{K*Lu}{r}$ = 27.72 > 34 – 12 ($\frac{M1}{M2}$) = 34 – 12 ($\frac{22.17}{29.57}$) = 24.98

☛ **The column will be design as short column**

$\frac{\emptyset\ Pn}{Ag}$ = $\frac{Pn}{Ag}$ = $\frac{659.54*10^{-3}}{6.895*0.05}$ = 1.9 Ksi

$\frac{\emptyset\ Mu}{Ag*h}$ = $\frac{29.51*10^{-3}}{6.895*0.05*0.25}$ = 0.342 Ksi

Assume Ø 12 for main bars and Ø 10 for stirrups.

γ = $\frac{250-2(40+10+6)}{250}$ = $\frac{25-112}{250}$ = 0.55 = 0.6

Use I.D with γ = 0.6

$\frac{\emptyset\ Mu}{Ag*h}$ = 0.3 Ksi

$\frac{\emptyset\ Pn}{Ag}$ = 1.9 Ksi

Get ρ_g = 0.011

As = ρ_g * b * h = 0.011 * 200 * 250 = 550 mm^2

☛ **<u>Use 8 Ø 12 mm</u>**

As = 904 mm^2 > As req. = 550 mm^2

Check for column width

b $_{min}$ = (2*concrete cover + 2d$_s$ + $(\frac{n}{2})$ d$_b$ + 3 * min of $\begin{cases} 1.5\ db \\ 25\ mm \end{cases}$

= (2*40) + (2*10) + (3*12) + (3*18) = 190 mm < b = 200 mm → → O.K

☛ ***Check for Ø :***

Pu > 0.1 f'c Ag

659.54 > 0.1 * 25 * 0.05 * 10^3 = 125

Ø = 0.7 O.K

Check Ø Pu$_{(max)}$ = Ø * 0.8 (0.85 * f'c * (Ag – As$_{(tot)}$) + As$_{(tot)}$ * Fy)

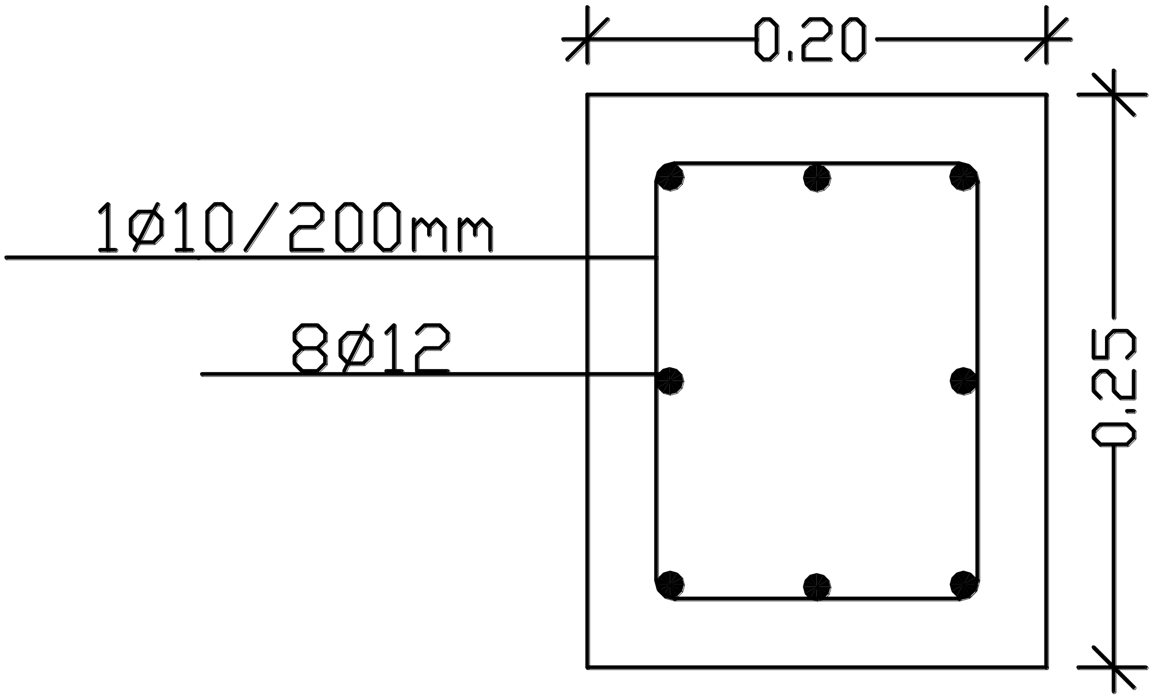
= 0.7 * 0.8 (0.85 * 25 * (0.05 – 679*10^{-6}) * 679*10^6 * 420) * 10^3

= 746.6 Kn > Pu = 659.54 KN → O.K

☛ ***Design of Ties :***

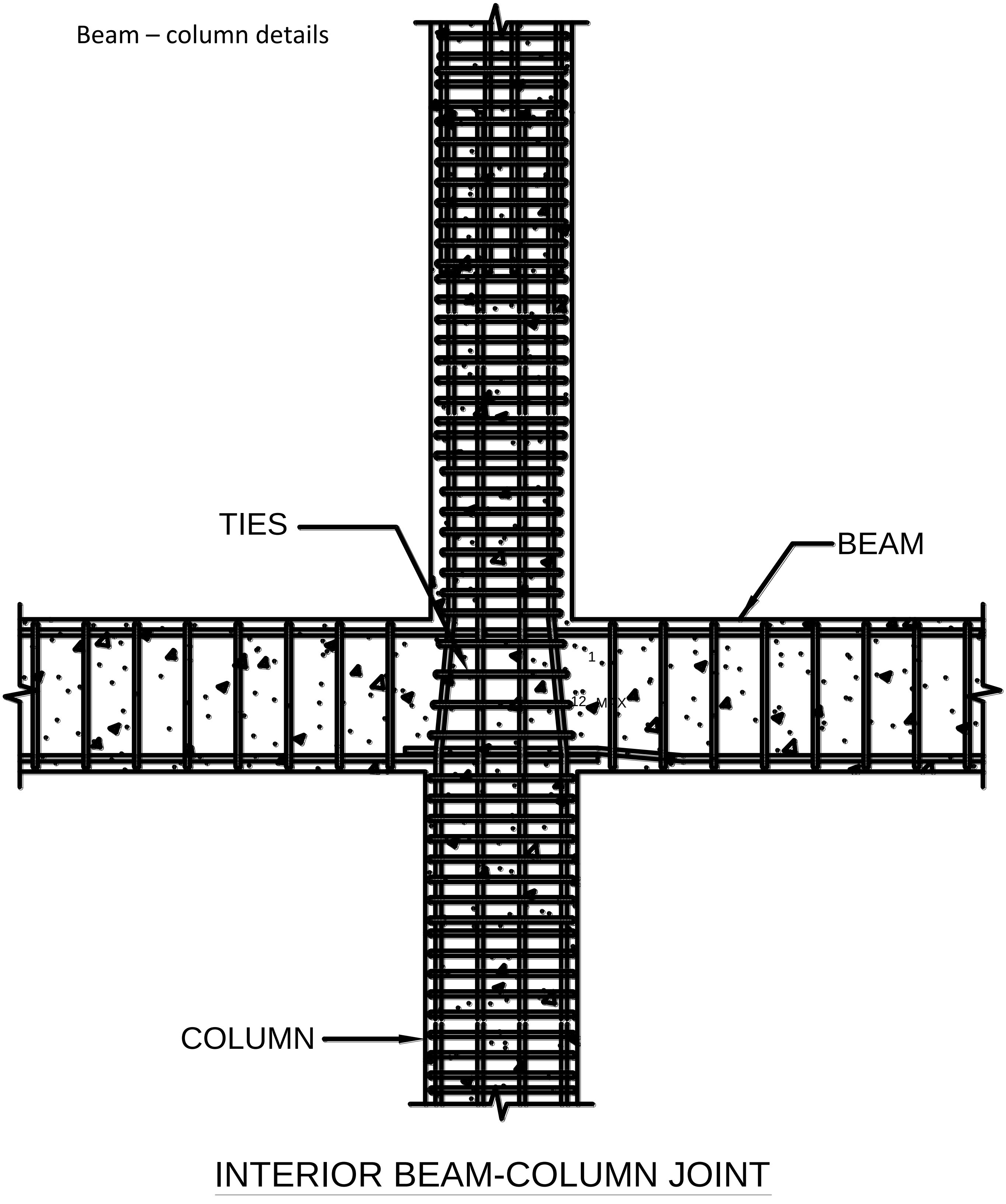
S= S max = min of $\begin{cases} least\ diminsion\ of\ cross\ section\ of\ col. = 200mm\ (\ control\ ) \\ 48\ dt = 48\ (10) = 480mm \\ 16\ db = 16\ (\ 16) = 256\ mm \end{cases}$

☛ Use Ø 10 @ 200 mm c/c



section in C27

Beam – column details



INTERIOR BEAM-COLUMN JOINT

Chapter Eight

" Design Of Stair Case"

8.1 Design of Stair Case :

WL = 4 KN-m^2

Thickness of finishing = 0.04 m

$\gamma_{\text{finishing}}$ = 20 KN/m^3

L = 5.1 m

$T_{waist})_{min} = \frac{L}{24} = \frac{3}{24}$ = 0.125 (Say 13 cm)

Try Rise = 150 mm , Trade with = 300 mm

No. of steps = $\frac{3000}{300}$ = 10 steps

r = $\sqrt{3^2 + 1.5^2}$ = 3.354

weight of wait / m horizontal = $\frac{t*r*1.0*\gamma c}{3}$

= $\frac{0.13*3.354*1*25}{3}$ = 3.6335

Weight of finish :

= $\frac{(0.15+0.3)(1)(0.04)(20)*10}{3}$ = 1.2

Weight of steps = $\frac{0.15*0.3}{2}$ * 1 * 25 * 10 * 0.333 = 1.875

$\sum D.L$ = 1.875 + 1.2 + 3.6335 = 6.7085 KN/m^2

Slab weight = 0.13 * 25 = 3.25 KN/ m^2

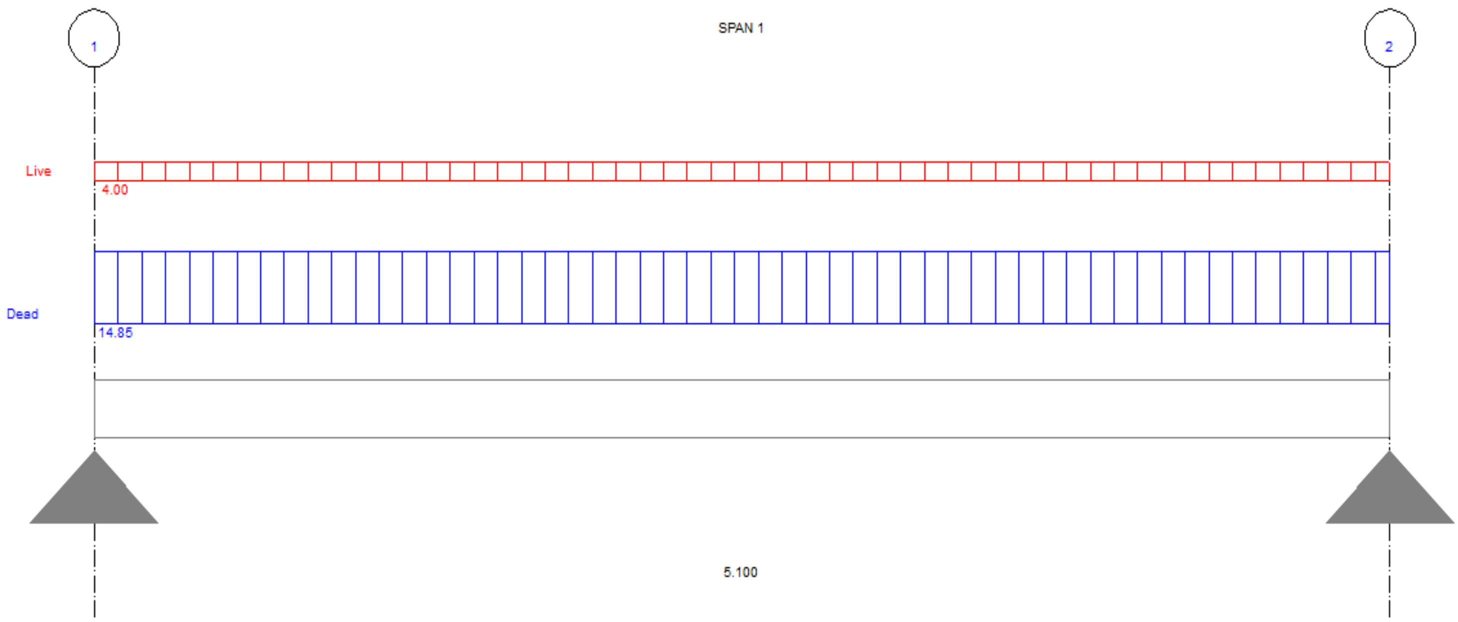
Finish weight = 0.04 * 20 = 0.8 KN/m^2

$\sum D.L$ = 4.05 KN/m^2

Wu1 = (1.2 * 6.7085) + (1.7 * 4) = 14.8502

Wu2 = (1.2*4.05) + (1.7*4) = 11.66

For Wu1 :



For Wu2 :

Mu = Mu1 + Mu2

Mu1 = $\frac{Wu*L^2}{8}$ = $\frac{11.66*5.1^2}{8}$ = 37.909

Wu = Wu1 – Wu2

Wu = 14.8502 – 11.66 = 3.1902

R = 3.1902 * 3 = 4.7853

Mu2 = (4.7852 * 2.55) – ($\frac{3.1402*1.5}{2}$) = 9.809 KN/m^2

Mu = 37.909 + 9.809 = 47.718

D = 130 – 20 – 8 = 102 mm

R = $\frac{47.718*10^{-3}}{0.9*25*1*0.102^2}$ = 0.2038

Use R – W table

$\omega = 0.237$

$\rho = \frac{\omega * f'c}{Fy}$ = $\frac{0.237*25}{420}$ = 0.0141 > ρ_{min} = 0.0018 → O.K

As = ρ * b * d = 0.0141 * 1000 * 102 = 1438 mm^2

- ☛ Use Ø16 @ $130\ mm\ c/c$ → As = 1547 mm^2

❖ ***Temperature Reinforcement***

As = ρ_{min} * b * t

= 0.0018 * 1000 * 130 = 234 mm^2

- ☛ Use Ø8 @ $210\ mm\ c/c$ → As = 239 mm^2

Or Use Ø10 @ $300\ mm\ c/c$ → As = 262 mm^2

As > As $_{req.}$ → O.K

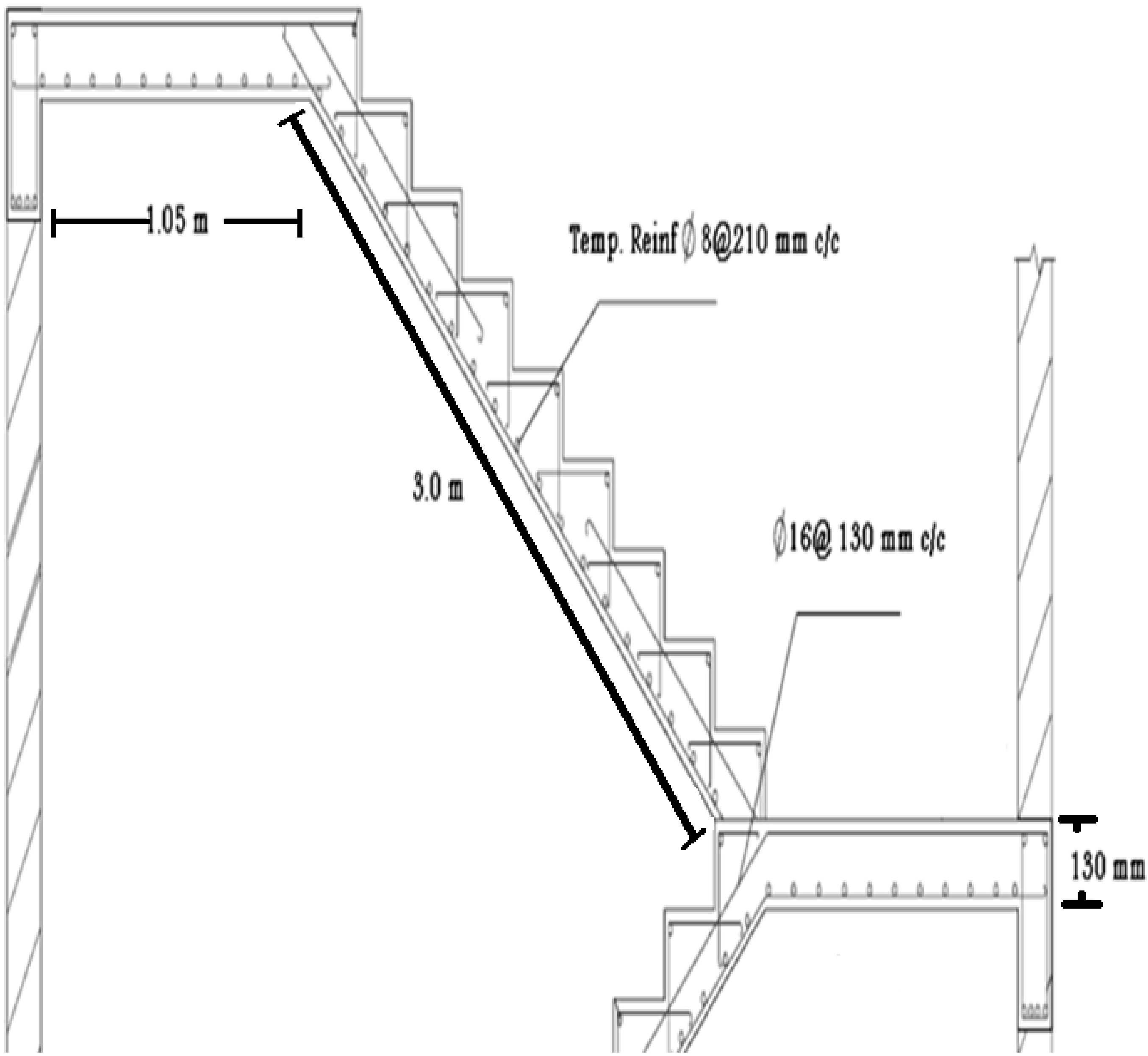
- ***Check for shear***

Vu@d = $\frac{Wu2*L}{2}$ – Wu * d

= $\frac{11.66 * 5.1}{2}$ – 3.1902 * 0.102 = 34.193 KN

Ø Vc = 0.8 * 0.17 * 5 * 1000 * 1 * 0.102 = 69.36

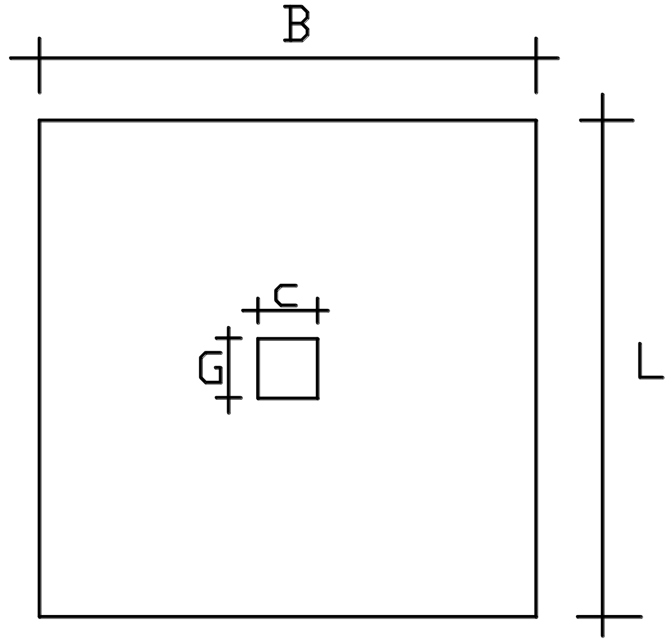
Vu@d = 34.193 < Ø Vc = 69.36 → → O.K


1.05 m
Temp. Reinf Ø 8@210 mm c/c
3.0 m
Ø16@ 130 mm c/c
130 mm

Chapter Nine

"Design Of Footing"

9.1 <u>Design of footing in frame B (2B) :</u>



Ps = 1040.66 KN

Pu = 1508.55 KN

Df = 1 m

q all = 200 Kn/m^2

γ_s = 18 Kn/m^3

Size of footing = 0.3 * 0.3

Assume footing thickness equal (t) = 700 mm

Reinforcement bars = Ø 25

$q_{net} = q_{all} - [\,(t*\gamma_c) + (\,(Df\text{-}t) * \gamma_s)$

= 200 – [(0.7*24) + (0.4*18)] = 176 KN/m^2

A req. = $\frac{Ps}{q\ net} = \frac{1040.66}{176}$ = 5.912 m^2

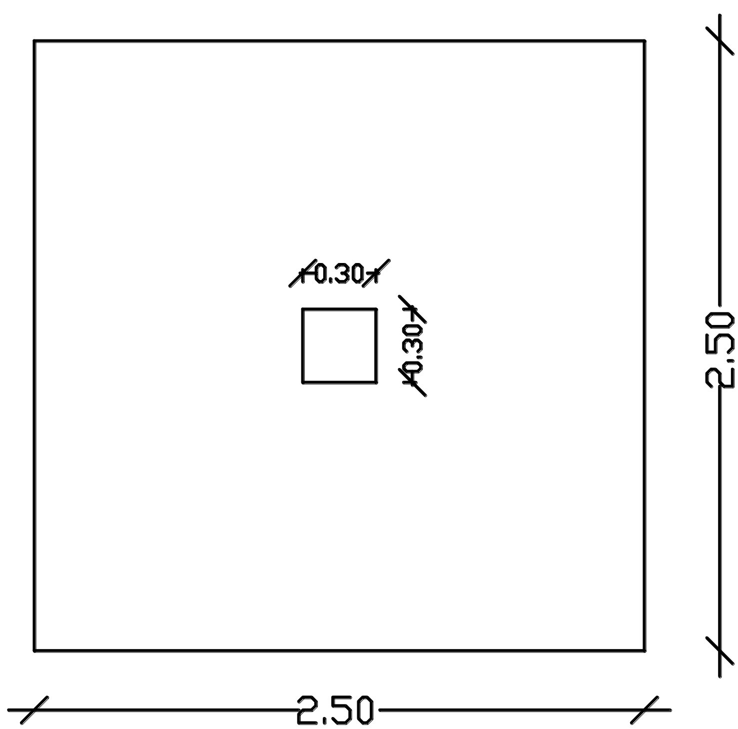
Use L = 2.5 m & B = 2.5 m

Area = 2.5m * 2.5m = 6.25 m

$q_u = \frac{Pu}{A} = \frac{1508.55}{6.25}$ = 241.368

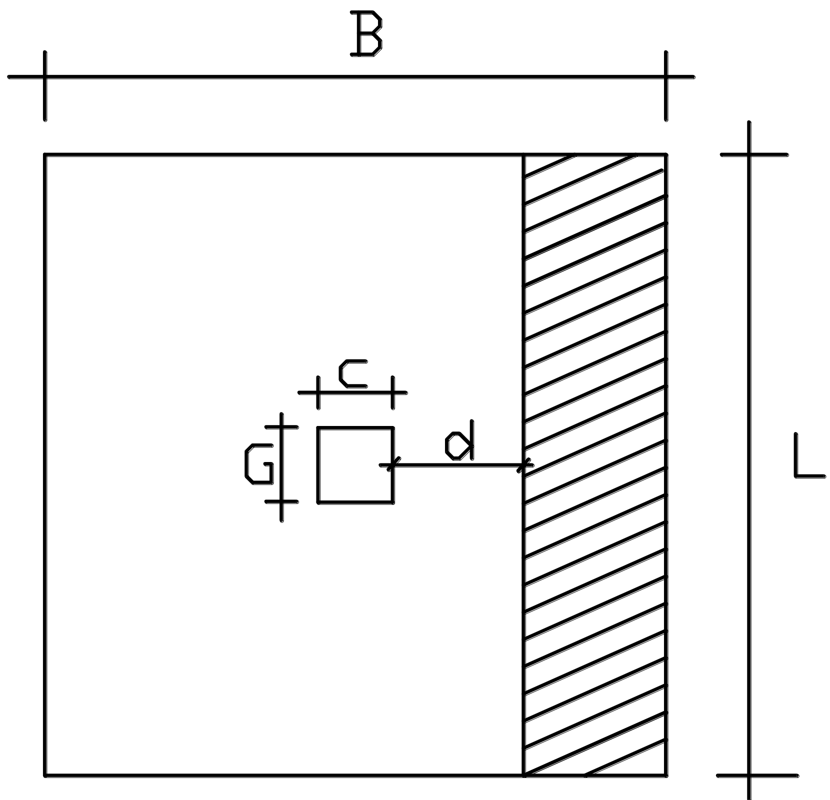
d = t – (concrete cover + d_b)

= 700 – (70 + 25) = 605 mm



❖ ***Check for shear :***

1- Beam shear :



Area of Beam shear

Vu@ d = q_u * B * ($\frac{B-C}{2}$ – d)

= 241.368 * 2.5 * ($\frac{2.5-0.3}{2}$ – 0.605) = 298.692 KN

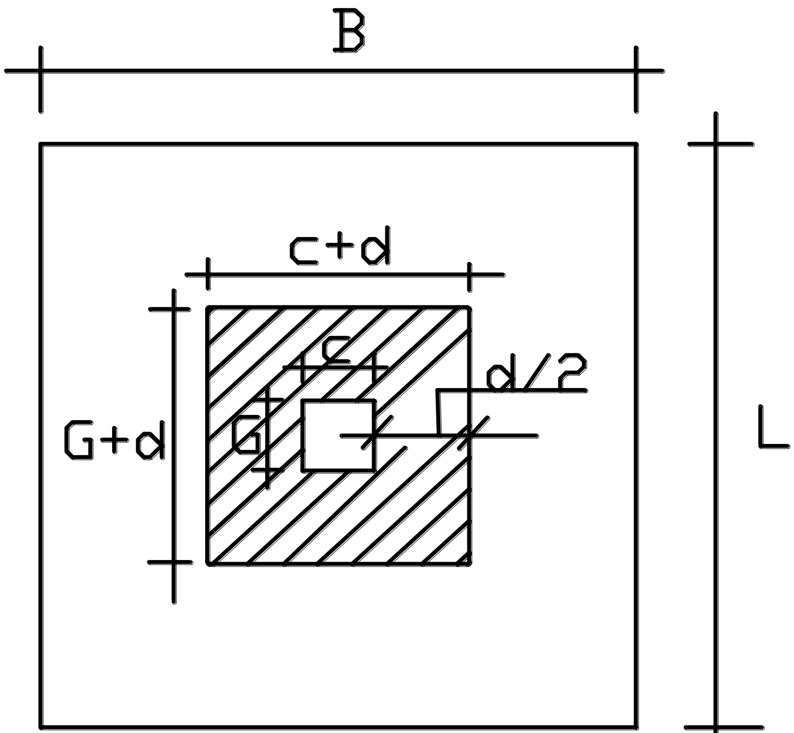
Vn = $\frac{Vu\ @\ d}{\emptyset}$ = $\frac{298.692}{0.85}$ = 351.402 KN

Vc = 0.17 * $\sqrt{F'c}$ * b * d

= 0.17 * $\sqrt{25}$ *2.5 * 0.605*10^3 = 1285.625

Ø Vc = 0.85 * 1285.625 = 1092.78 > Vu@d = 298.692 → O.K

2- Check Punching shear :



Area of punching shear

$Vu = Pu - [(c+d) (G+d) q_u]$

$= 1508.55 - [(0.3 + 0.605) * (0.3 + 0.605) * 241.368]$

$= 1310.86$ KN

$b_o = 2 * (0.805 + 0.805) = 3.22$ m

$\beta_c = 0.3 / 0.3 = 1.00$

$\alpha_s = 40$ (Interior column)

Find $\emptyset Vc$

1- $\emptyset\, Vc = \frac{(\emptyset * \sqrt{f'c} * b * d)}{3}$

$= \frac{0.85 * 5 * 10^3 * 3.22 * 0.605}{3}$ = 2759.80 KN

2- $\emptyset\, Vc = \emptyset * \left[1 + \frac{2}{\beta c}\right] * \left[\frac{\sqrt{f'c}\ \ * bo * d}{6}\ \right]$

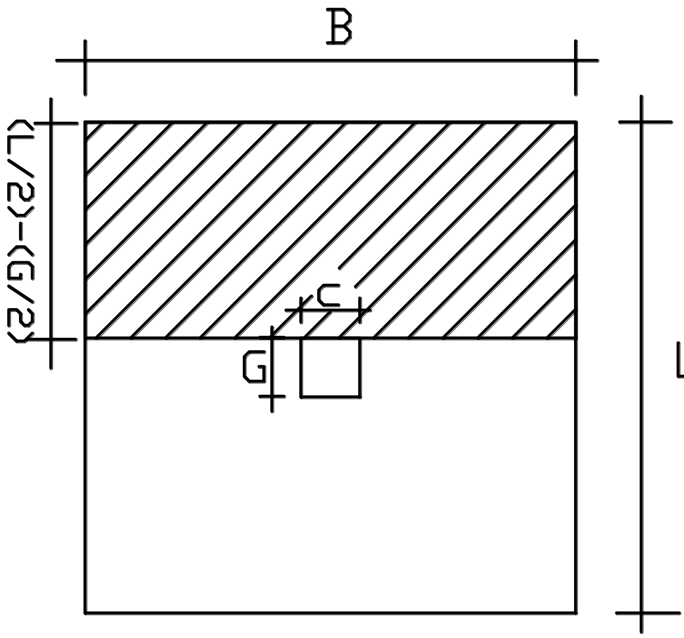
$= 0.85 * 10^3 * \left[1 + \frac{2}{1}\right] * \left[\frac{5\ \ * 3.22 * 0.605}{6}\ \right]$ = 4139.7 KN

3- $\emptyset\, Vc = \emptyset\ \ * \left[2 + \frac{\alpha\, s * d}{bo}\right]\ * \left[\frac{\sqrt{f'c}\ \ * bo * d}{2}\ \right]$

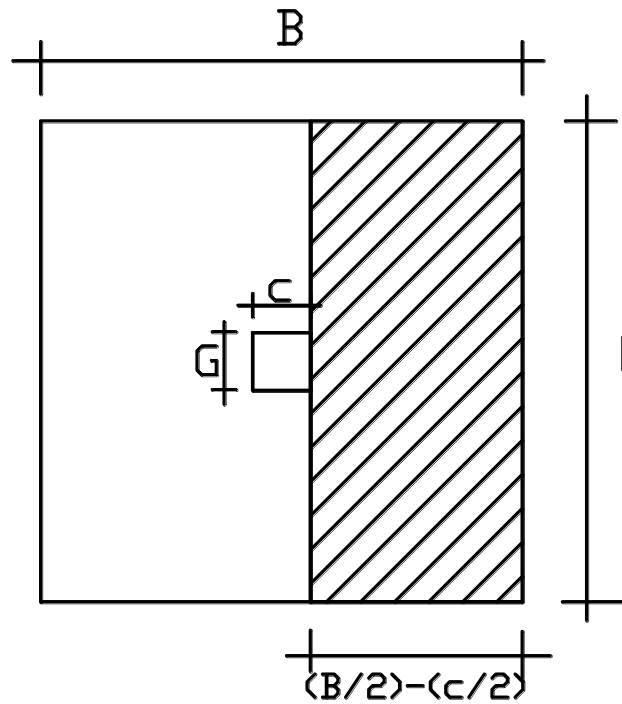
$= 0.85 * 10^3\ \ * \left[2 + \frac{40 * 0.605}{3.22}\right]\ * \left[\frac{5\ \ * 3.22 * 0.605}{12}\ \right]$ = 6565.258 KN

➔ $\emptyset\, Vc$ = 2739.80 > Vu = 1310.86 → → → O.K

3- Flexure Reinforcement :



Flexural Reinforcement



Flexural Reinforcement

$$Mu = q_u * [\, L * (\frac{B}{2} - \frac{C}{2}\,] * [\frac{\left(\frac{B}{2}\right) - \left(\frac{C}{2}\right)}{2}]$$

$$= 241.368 * [\, 2.5 * 1.1 \,] * [\frac{1.1}{2}] = 365.069 \text{ Kn-m}$$

$$R = \frac{Mu}{\emptyset * f'c * b * d^2} = \frac{365.069 * 10^{-3}}{0.9 * 25 * 2.5 * 0.605^2} = 0.0177$$

Using R – ω Table : $\omega = 0.018$

$$\rho = \frac{\omega * f'c}{Fy} = \frac{0.018 * 25}{420} = 0.00107 < \rho_{min} = \frac{1.4}{420} = 0.0033 \text{ ... O.K}$$

➔ Use $\rho_{min} = 0.0033$

As = 0.0033 * 2500 * 605 = 4991 mm^2

Use 11 Ø 25 mm → As = 5401 mm^2

$$S = \frac{2500-((2*70)+(2*12.5))}{8} = 292 \text{ mm c/c}$$

S max = min of $\begin{cases} 3t = 3*700 = 2100 \\ 500 \end{cases}$

Use Smax = 500 mm

S < S max → O.K

4- ***Check for development length :***

- ✓ ***Reinforcement in compression***

$$L_d = \frac{0.24*fy*db}{\sqrt{f'c}} \geq 0.043\ d_b * fy$$

$$= \frac{0.24*420*25}{5} \geq 0.043 * 25 * 420$$

➔ 504 > 415.5 → O.K

- ✓ ***Reinforcement in tension in foot :***

$$L_d = \frac{(Fy*\varphi A*\varphi t*\varepsilon)}{1.4*\sqrt{f'c}} * db$$

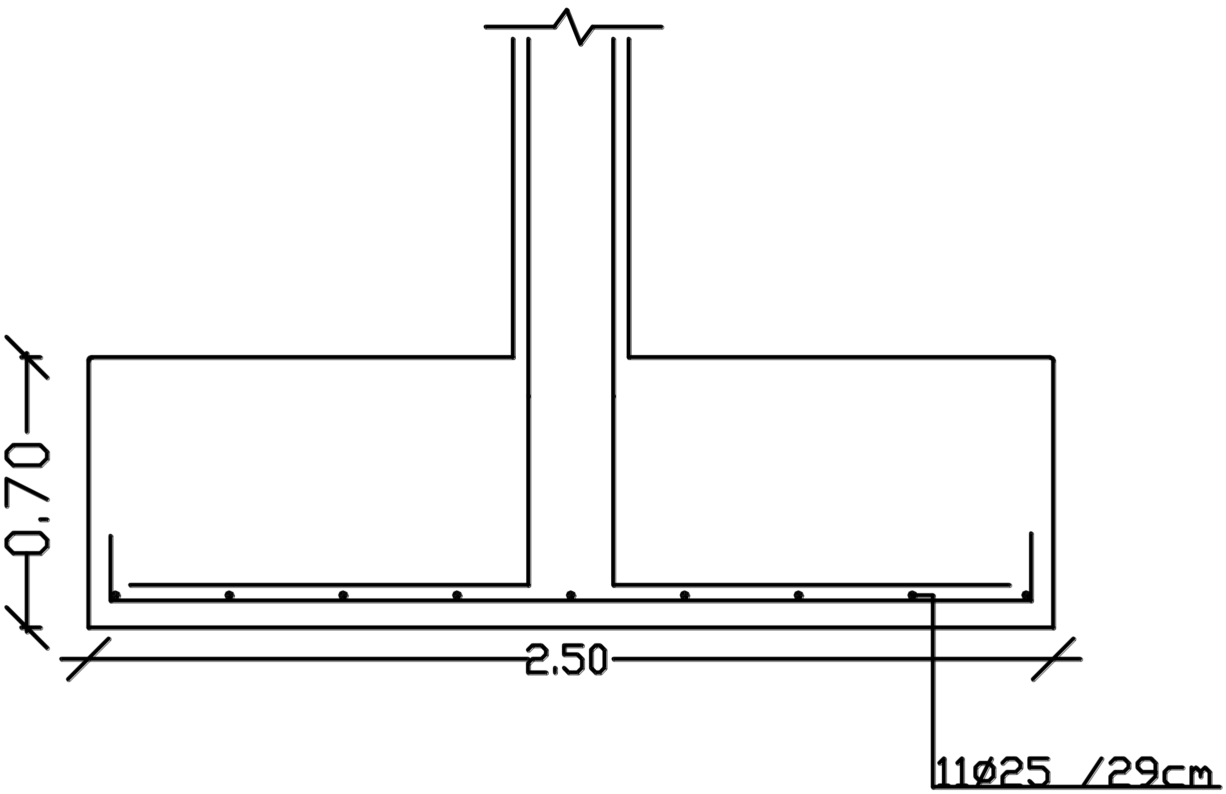
$$= \frac{(420*1*1*1)}{1.4*\sqrt{25}} * 25 = 1500 \text{ mm}$$

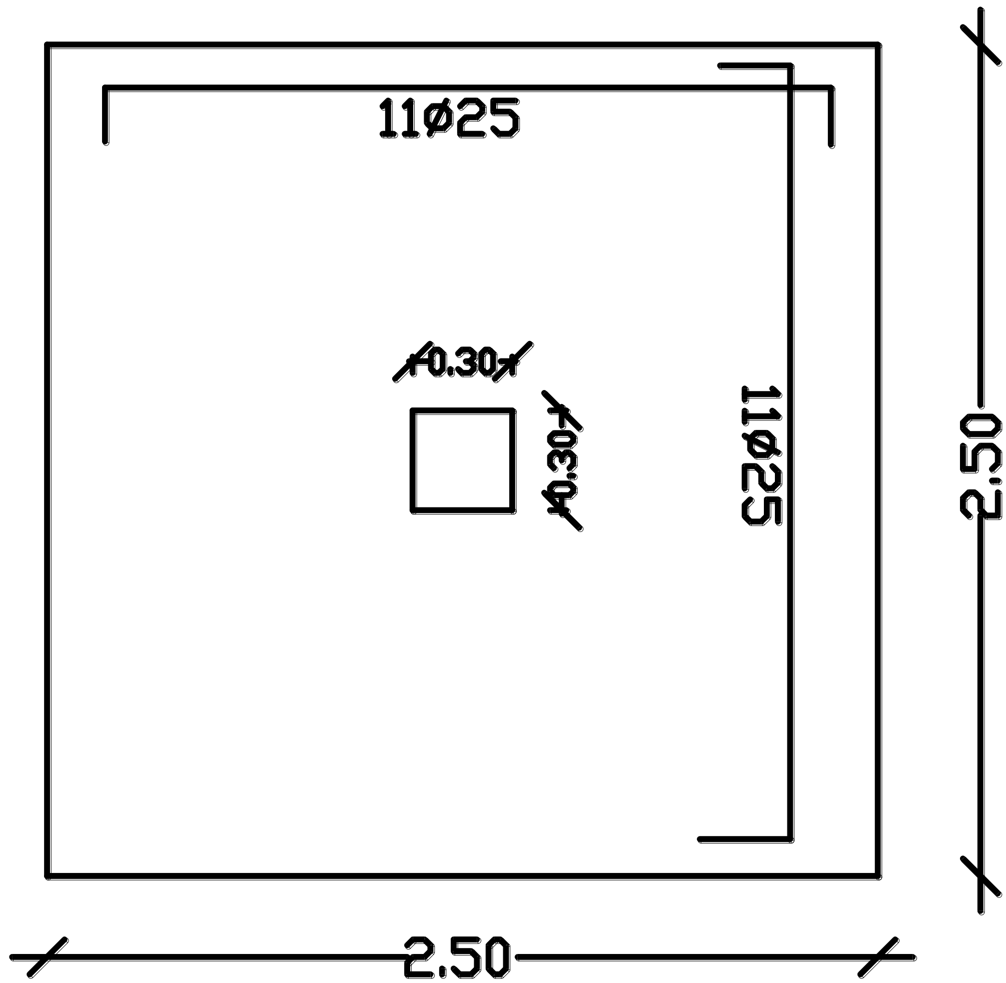
$$L_{available} = \frac{b}{2} - \frac{Column\ dimension}{2} = \frac{2500}{2} - \frac{300}{2} = 1100 \text{ mm}$$

L_d = 1500 > $L_{available}$ = 1100 → → use hook

$$L_{dh} = \frac{0.24*\varphi e*\lambda*Fy}{\sqrt{f'c}} * d_b * \text{factor} \geq \text{max of} \begin{cases} 8\ db = 8\ (25\ ) = 200mm\ (control) \\ 150\ mm \end{cases}$$

$$L_{dh} = \frac{0.24*1*1*420}{\sqrt{25}} *25 * 0.7 = 352.8 > 200\ mm$$ O.K


0.70
2.50
11Ø25 /29cm


11Ø25
0.30
0.30
11Ø25
2.50
2.50

APPENDEX

"B"

Analysis Output

Beams Analysis

M3	M2	T	V3	V2	P	Loc	Load	Beam	Story
-37.416	0	-1.925	0	-51.28	0	0.125	UDL	B15	**STORY4**
-20.258	0	-1.925	0	-50.4	0	0.463	UDL	B15	**STORY4**
-3.398	0	-1.925	0	-49.51	0	0.8	UDL	B15	**STORY4**
-3.035	0	-0.704	0	-17.26	0	0.8	UDL	B15	**STORY4**
3.658	0	-0.704	0	-16.21	0	1.2	UDL	B15	**STORY4**
9.932	0	-0.704	0	-15.16	0	1.6	UDL	B15	**STORY4**
9.9	0	0.509	0	23.25	0	1.6	UDL	B15	**STORY4**
0.389	0	0.509	0	24.3	0	2	UDL	B15	**STORY4**
-9.541	0	0.509	0	25.35	0	2.4	UDL	B15	**STORY4**
-9.971	0	1.891	0	57.69	0	2.4	UDL	B15	**STORY4**
-29.591	0	1.891	0	58.58	0	2.738	UDL	B15	**STORY4**
-49.511	0	1.891	0	59.46	0	3.075	UDL	B15	**STORY4**
-26.27	0	-1.35	0	-36.22	0	0.125	UDLWX	B15	**STORY4**
-14.175	0	-1.35	0	-35.46	0	0.463	UDLWX	B15	**STORY4**
-2.335	0	-1.35	0	-34.7	0	0.8	UDLWX	B15	**STORY4**
-2.082	0	-0.493	0	-12.25	0	0.8	UDLWX	B15	**STORY4**
2.636	0	-0.493	0	-11.35	0	1.2	UDLWX	B15	**STORY4**
6.995	0	-0.493	0	-10.45	0	1.6	UDLWX	B15	**STORY4**
6.972	0	0.356	0	16.22	0	1.6	UDLWX	B15	**STORY4**
0.305	0	0.356	0	17.12	0	2	UDLWX	B15	**STORY4**
-6.723	0	0.356	0	18.02	0	2.4	UDLWX	B15	**STORY4**
-7.023	0	1.326	0	40.55	0	2.4	UDLWX	B15	**STORY4**
-20.836	0	1.326	0	41.31	0	2.738	UDLWX	B15	**STORY4**
-34.905	0	1.326	0	42.07	0	3.075	UDLWX	B15	**STORY4**
-56.708	0	-2.569	0	-86.18	0	0.125	UDL	B16	**STORY4**
-25.214	0	-2.569	0	-85.22	0	0.493	UDL	B16	**STORY4**
5.926	0	-2.569	0	-84.25	0	0.86	UDL	B16	**STORY4**
6.478	0	-1.294	0	-47.51	0	0.86	UDL	B16	**STORY4**
26.667	0	-1.294	0	-46.39	0	1.29	UDL	B16	**STORY4**
46.37	0	-1.294	0	-45.26	0	1.72	UDL	B16	**STORY4**
46.534	0	0	0	-1.13	0	1.72	UDL	B16	**STORY4**
46.777	0	0	0	0	0	2.15	UDL	B16	**STORY4**
46.534	0	0	0	1.13	0	2.58	UDL	B16	**STORY4**
46.37	0	1.294	0	45.26	0	2.58	UDL	B16	**STORY4**
26.667	0	1.294	0	46.39	0	3.01	UDL	B16	**STORY4**
6.478	0	1.294	0	47.51	0	3.44	UDL	B16	**STORY4**

5.926	0	2.569	0	84.25	0	3.44	UDL	B16	**STORY4**
-25.214	0	2.569	0	85.22	0	3.808	UDL	B16	**STORY4**
-56.708	0	2.569	0	86.18	0	4.175	UDL	B16	**STORY4**
-39.815	0	-1.795	0	-60.71	0	0.125	UDLWX	B16	**STORY4**
-17.656	0	-1.795	0	-59.89	0	0.493	UDLWX	B16	**STORY4**
4.2	0	-1.795	0	-59.06	0	0.86	UDLWX	B16	**STORY4**
4.586	0	-0.903	0	-33.48	0	0.86	UDLWX	B16	**STORY4**
18.775	0	-0.903	0	-32.51	0	1.29	UDLWX	B16	**STORY4**
32.548	0	-0.903	0	-31.55	0	1.72	UDLWX	B16	**STORY4**
32.663	0	-0.001	0	-0.94	0	1.72	UDLWX	B16	**STORY4**
32.858	0	-0.001	0	0.03	0	2.15	UDLWX	B16	**STORY4**
32.637	0	-0.001	0	1	0	2.58	UDLWX	B16	**STORY4**
32.522	0	0.902	0	31.61	0	2.58	UDLWX	B16	**STORY4**
18.723	0	0.902	0	32.58	0	3.01	UDLWX	B16	**STORY4**
4.507	0	0.902	0	33.54	0	3.44	UDLWX	B16	**STORY4**
4.121	0	1.795	0	59.13	0	3.44	UDLWX	B16	**STORY4**
-17.761	0	1.795	0	59.96	0	3.808	UDLWX	B16	**STORY4**
-39.947	0	1.795	0	60.78	0	4.175	UDLWX	B16	**STORY4**
-53.01	0	-3.295	0	-91.83	0	0.125	UDL	B20	**STORY4**
-14.901	0	-3.295	0	-90.73	0	0.543	UDL	B20	**STORY4**
22.751	0	-3.295	0	-89.63	0	0.96	UDL	B20	**STORY4**
23.248	0	-2.442	0	-48.16	0	0.96	UDL	B20	**STORY4**
46.064	0	-2.442	0	-46.9	0	1.44	UDL	B20	**STORY4**
68.275	0	-2.442	0	-45.64	0	1.92	UDL	B20	**STORY4**
68.388	0	-1.299	0	4.24	0	1.92	UDL	B20	**STORY4**
66.049	0	-1.299	0	5.5	0	2.4	UDL	B20	**STORY4**
63.105	0	-1.299	0	6.76	0	2.88	UDL	B20	**STORY4**
62.909	0	0.1	0	56.84	0	2.88	UDL	B20	**STORY4**
35.323	0	0.1	0	58.1	0	3.36	UDL	B20	**STORY4**
7.132	0	0.1	0	59.36	0	3.84	UDL	B20	**STORY4**
6.535	0	1.612	0	102.65	0	3.84	UDL	B20	**STORY4**
-36.549	0	1.612	0	103.75	0	4.258	UDL	B20	**STORY4**
-80.092	0	1.612	0	104.84	0	4.675	UDL	B20	**STORY4**
-37.2	0	-2.294	0	-64.68	0	0.125	UDLWX	B20	**STORY4**
-10.392	0	-2.294	0	-63.74	0	0.543	UDLWX	B20	**STORY4**
16.024	0	-2.294	0	-62.8	0	0.96	UDLWX	B20	**STORY4**
16.371	0	-1.696	0	-33.94	0	0.96	UDLWX	B20	**STORY4**
32.402	0	-1.696	0	-32.86	0	1.44	UDLWX	B20	**STORY4**
47.914	0	-1.696	0	-31.78	0	1.92	UDLWX	B20	**STORY4**

47.993	0	-0.902	0	2.81	0	1.92	UDLWX	B20	**STORY4**
46.383	0	-0.902	0	3.89	0	2.4	UDLWX	B20	**STORY4**
44.254	0	-0.902	0	4.97	0	2.88	UDLWX	B20	**STORY4**
44.116	0	0.07	0	39.7	0	2.88	UDLWX	B20	**STORY4**
24.8	0	0.07	0	40.78	0	3.36	UDLWX	B20	**STORY4**
4.966	0	0.07	0	41.86	0	3.84	UDLWX	B20	**STORY4**
4.549	0	1.126	0	72	0	3.84	UDLWX	B20	**STORY4**
-25.707	0	1.126	0	72.94	0	4.258	UDLWX	B20	**STORY4**
-56.355	0	1.126	0	73.88	0	4.675	UDLWX	B20	**STORY4**
-49.511	0	-1.891	0	-59.46	0	0.125	UDL	B39	**STORY4**
-29.591	0	-1.891	0	-58.58	0	0.463	UDL	B39	**STORY4**
-9.971	0	-1.891	0	-57.69	0	0.8	UDL	B39	**STORY4**
-9.541	0	-0.509	0	-25.35	0	0.8	UDL	B39	**STORY4**
0.389	0	-0.509	0	-24.3	0	1.2	UDL	B39	**STORY4**
9.9	0	-0.509	0	-23.25	0	1.6	UDL	B39	**STORY4**
9.932	0	0.704	0	15.16	0	1.6	UDL	B39	**STORY4**
3.658	0	0.704	0	16.21	0	2	UDL	B39	**STORY4**
-3.035	0	0.704	0	17.26	0	2.4	UDL	B39	**STORY4**
-3.398	0	1.925	0	49.51	0	2.4	UDL	B39	**STORY4**
-20.258	0	1.925	0	50.4	0	2.738	UDL	B39	**STORY4**
-37.416	0	1.925	0	51.28	0	3.075	UDL	B39	**STORY4**
-34.761	0	-1.322	0	-41.96	0	0.125	UDLWX	B39	**STORY4**
-20.728	0	-1.322	0	-41.2	0	0.463	UDLWX	B39	**STORY4**
-6.951	0	-1.322	0	-40.44	0	0.8	UDLWX	B39	**STORY4**
-6.651	0	-0.353	0	-17.93	0	0.8	UDLWX	B39	**STORY4**
0.34	0	-0.353	0	-17.03	0	1.2	UDLWX	B39	**STORY4**
6.971	0	-0.353	0	-16.13	0	1.6	UDLWX	B39	**STORY4**
6.993	0	0.495	0	10.54	0	1.6	UDLWX	B39	**STORY4**
2.598	0	0.495	0	11.44	0	2	UDLWX	B39	**STORY4**
-2.157	0	0.495	0	12.34	0	2.4	UDLWX	B39	**STORY4**
-2.411	0	1.35	0	34.81	0	2.4	UDLWX	B39	**STORY4**
-14.286	0	1.35	0	35.57	0	2.738	UDLWX	B39	**STORY4**
-26.418	0	1.35	0	36.32	0	3.075	UDLWX	B39	**STORY4**
-80.092	0	-1.612	0	-104.84	0	0.125	UDL	B42	**STORY4**
-36.549	0	-1.612	0	-103.75	0	0.543	UDL	B42	**STORY4**
6.535	0	-1.612	0	-102.65	0	0.96	UDL	B42	**STORY4**
7.132	0	-0.1	0	-59.36	0	0.96	UDL	B42	**STORY4**
35.323	0	-0.1	0	-58.1	0	1.44	UDL	B42	**STORY4**
62.909	0	-0.1	0	-56.84	0	1.92	UDL	B42	**STORY4**

63.105	0	1.299	0	-6.76	0	1.92	UDL	B42	**STORY4**
66.049	0	1.299	0	-5.5	0	2.4	UDL	B42	**STORY4**
68.388	0	1.299	0	-4.24	0	2.88	UDL	B42	**STORY4**
68.275	0	2.442	0	45.64	0	2.88	UDL	B42	**STORY4**
46.064	0	2.442	0	46.9	0	3.36	UDL	B42	**STORY4**
23.248	0	2.442	0	48.16	0	3.84	UDL	B42	**STORY4**
22.751	0	3.295	0	89.63	0	3.84	UDL	B42	**STORY4**
-14.901	0	3.295	0	90.73	0	4.258	UDL	B42	**STORY4**
-53.01	0	3.295	0	91.83	0	4.675	UDL	B42	**STORY4**
-56.219	0	-1.129	0	-73.8	0	0.125	UDLWX	B42	**STORY4**
-25.603	0	-1.129	0	-72.86	0	0.543	UDLWX	B42	**STORY4**
4.622	0	-1.129	0	-71.92	0	0.96	UDLWX	B42	**STORY4**
5.038	0	-0.07	0	-41.8	0	0.96	UDLWX	B42	**STORY4**
24.843	0	-0.07	0	-40.72	0	1.44	UDLWX	B42	**STORY4**
44.129	0	-0.07	0	-39.64	0	1.92	UDLWX	B42	**STORY4**
44.267	0	0.904	0	-4.92	0	1.92	UDLWX	B42	**STORY4**
46.367	0	0.904	0	-3.84	0	2.4	UDLWX	B42	**STORY4**
47.949	0	0.904	0	-2.76	0	2.88	UDLWX	B42	**STORY4**
47.869	0	1.701	0	31.84	0	2.88	UDLWX	B42	**STORY4**
32.327	0	1.701	0	32.92	0	3.36	UDLWX	B42	**STORY4**
16.268	0	1.701	0	34	0	3.84	UDLWX	B42	**STORY4**
15.92	0	2.302	0	62.87	0	3.84	UDLWX	B42	**STORY4**
-10.524	0	2.302	0	63.81	0	4.258	UDLWX	B42	**STORY4**
-37.361	0	2.302	0	64.75	0	4.675	UDLWX	B42	**STORY4**

Column analysis

M3	M2	T	V3	V2	P	Loc	Load	Column	Story
-47.584	37.264	0	28.83	-37.55	-112.59	0	UDL	C6	**STORY4**
3.114	-1.662	0	28.83	-37.55	-109.64	1.35	UDL	C6	**STORY4**
53.812	-40.588	0	28.83	-37.55	-106.69	2.7	UDL	C6	**STORY4**
-33.483	26.227	-0.002	20.3	-26.41	-81.19	0	UDLWX	C6	**STORY4**
2.173	-1.177	-0.002	20.3	-26.41	-78.66	1.35	UDLWX	C6	**STORY4**
37.828	-28.581	-0.002	20.3	-26.41	-76.12	2.7	UDLWX	C6	**STORY4**
37.338	-14.776	0	-11.44	28.49	-389.65	0	UDL	C21	**STORY4**
-1.125	0.666	0	-11.44	28.49	-386.7	1.35	UDL	C21	**STORY4**
-39.588	16.108	0	-11.44	28.49	-383.75	2.7	UDL	C21	**STORY4**
26.37	-10.353	-0.002	-8.01	20.12	-275.79	0	UDLWX	C21	**STORY4**
-0.79	0.465	-0.002	-8.01	20.12	-273.26	1.35	UDLWX	C21	**STORY4**
-27.95	11.284	-0.002	-8.01	20.12	-270.73	2.7	UDLWX	C21	**STORY4**
37.028	-1.557	0	-1.11	28.32	-331.51	0	UDL	C27	**STORY4**
-1.202	-0.053	0	-1.11	28.32	-328.55	1.35	UDL	C27	**STORY4**
-39.431	1.452	0	-1.11	28.32	-325.6	2.7	UDL	C27	**STORY4**
26.164	-1.096	-0.002	-0.78	20	-235	0	UDLWX	C27	**STORY4**
-0.841	-0.039	-0.002	-0.78	20	-232.47	1.35	UDLWX	C27	**STORY4**
-27.846	1.018	-0.002	-0.78	20	-229.94	2.7	UDLWX	C27	**STORY4**

Supports reaction on Frame 2

MZ	MY	MX	FZ	FY	FX	Load	Point	Story
0	24.548	-3.41	886.85	3.42	24.72	UDL	5	**BASE**
0.023	16.711	-2.016	631.81	2.17	17.07	UDLWX	5	**BASE**
0	16.909	-2.35	612.48	2.36	17.03	SDL	5	**BASE**
0	-24.548	-3.41	886.85	3.42	-24.72	UDL	15	**BASE**
0.023	-17.737	-2.785	632.57	2.64	-17.62	UDLWX	15	**BASE**
0	-16.909	-2.35	612.48	2.36	-17.03	SDL	15	**BASE**
0	-12.438	-5.137	1508.55	5.16	-12.53	UDL	21	**BASE**
0.023	-9.313	-3.397	1067.83	3.49	-9.14	UDLWX	21	**BASE**
0	-8.567	-3.538	1040.66	3.55	-8.63	SDL	21	**BASE**
0	8.196	-5.08	1372.16	5.1	8.25	UDL	22	**BASE**
0.023	5.166	-3.479	972.72	3.53	5.44	UDLWX	22	**BASE**
0	5.645	-3.498	946.72	3.51	5.69	SDL	22	**BASE**
0	-8.196	-5.08	1372.16	5.1	-8.25	UDL	23	**BASE**
0.023	-6.333	-3.645	972.11	3.63	-6.14	UDLWX	23	**BASE**
0	-5.645	-3.498	946.72	3.51	-5.69	SDL	23	**BASE**
0	12.438	-5.137	1508.55	5.16	12.53	UDL	24	**BASE**
0.023	8.139	-3.809	1068.32	3.74	8.44	UDLWX	24	**BASE**
0	8.567	-3.538	1040.66	3.55	8.63	SDL	24	**BASE**