ARCH 332 STRUCTURAL DESIGN IN ARCHITECTURE II

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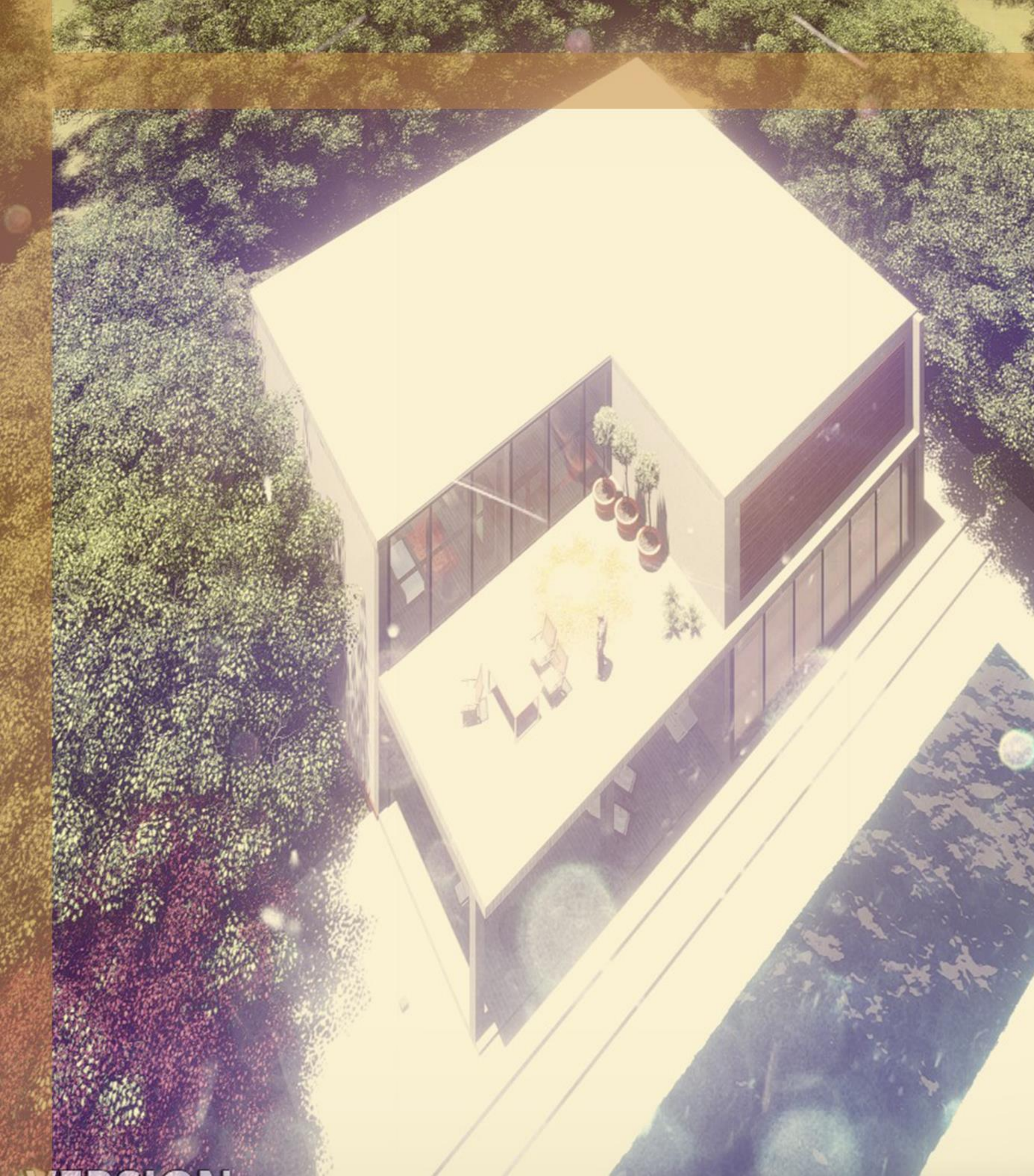
Project 30

Guljahan Annadurdiyew



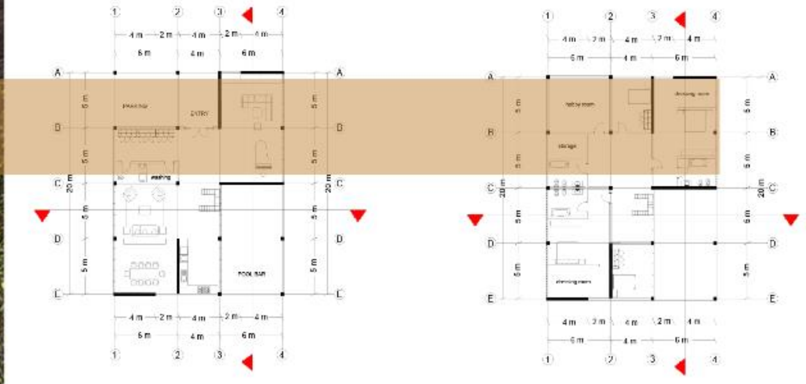
Living Room

Master Bedroom

Kitchen

Library/Music Room

3D SECTION



+0,00 GROUND FLOOR PLAN

+4,00 FIRST FLOOR PLAN

3D SECTION

BATHROOM

ENTRANCE

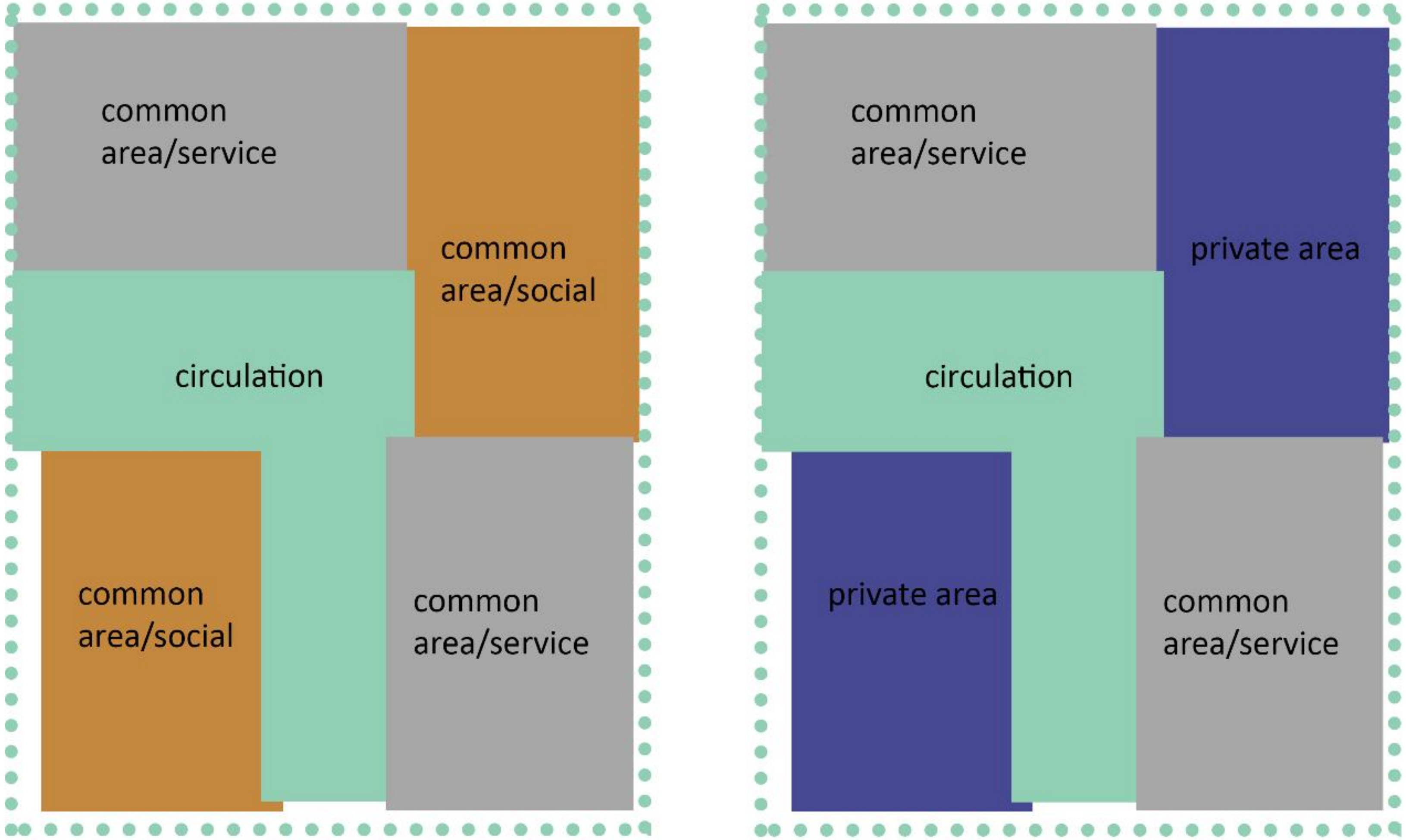
DESIGN CONCEPT

SYMMETRY HOUSE

Concept of design is based on **symmetry** or basicly on symmetric areas.Symmetry creates balance, and balance in design creates harmony, order, and aesthetically pleasing results. It is found everywhere in nature, and is probably why we find it to be so beautiful.Here; reflection symmetry type was selected to be used on concept stage.

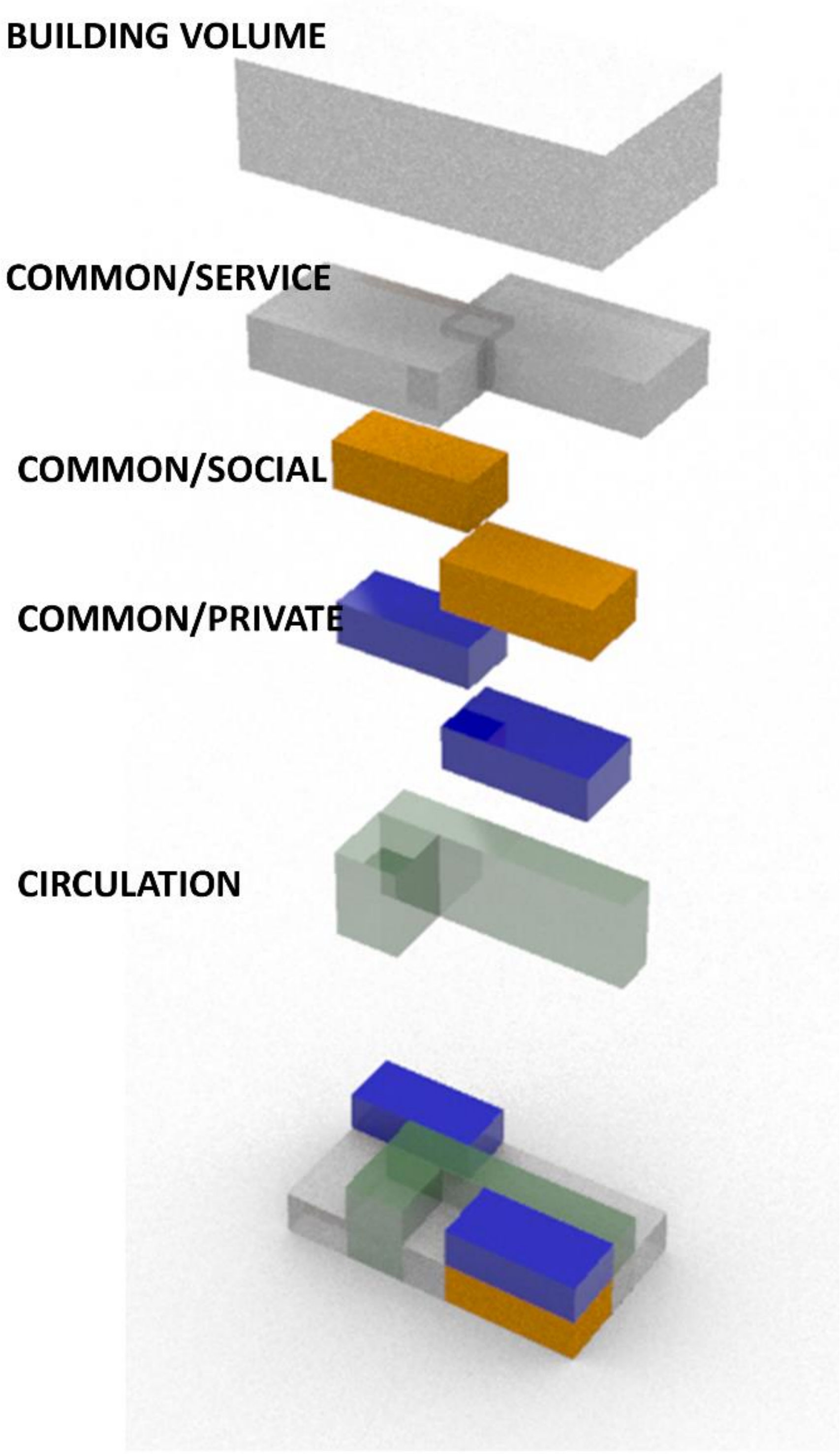
For the design, it can be seen that main areas created according to reflection symmetry, both on the ground floor and the first floor.

DIAGRAM OF FIRST CONCEPTUAL STAGE

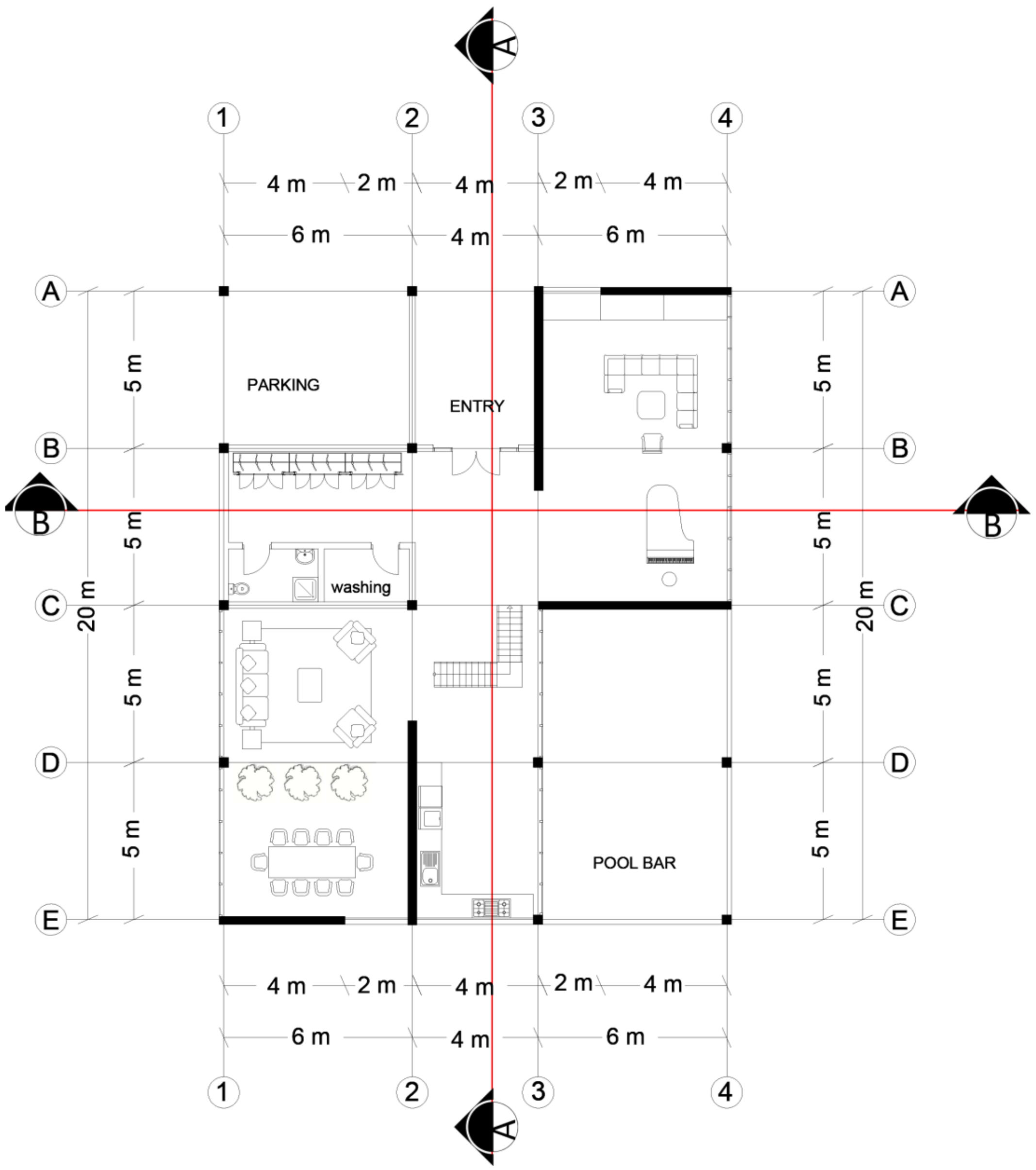


GROUND FLOOR

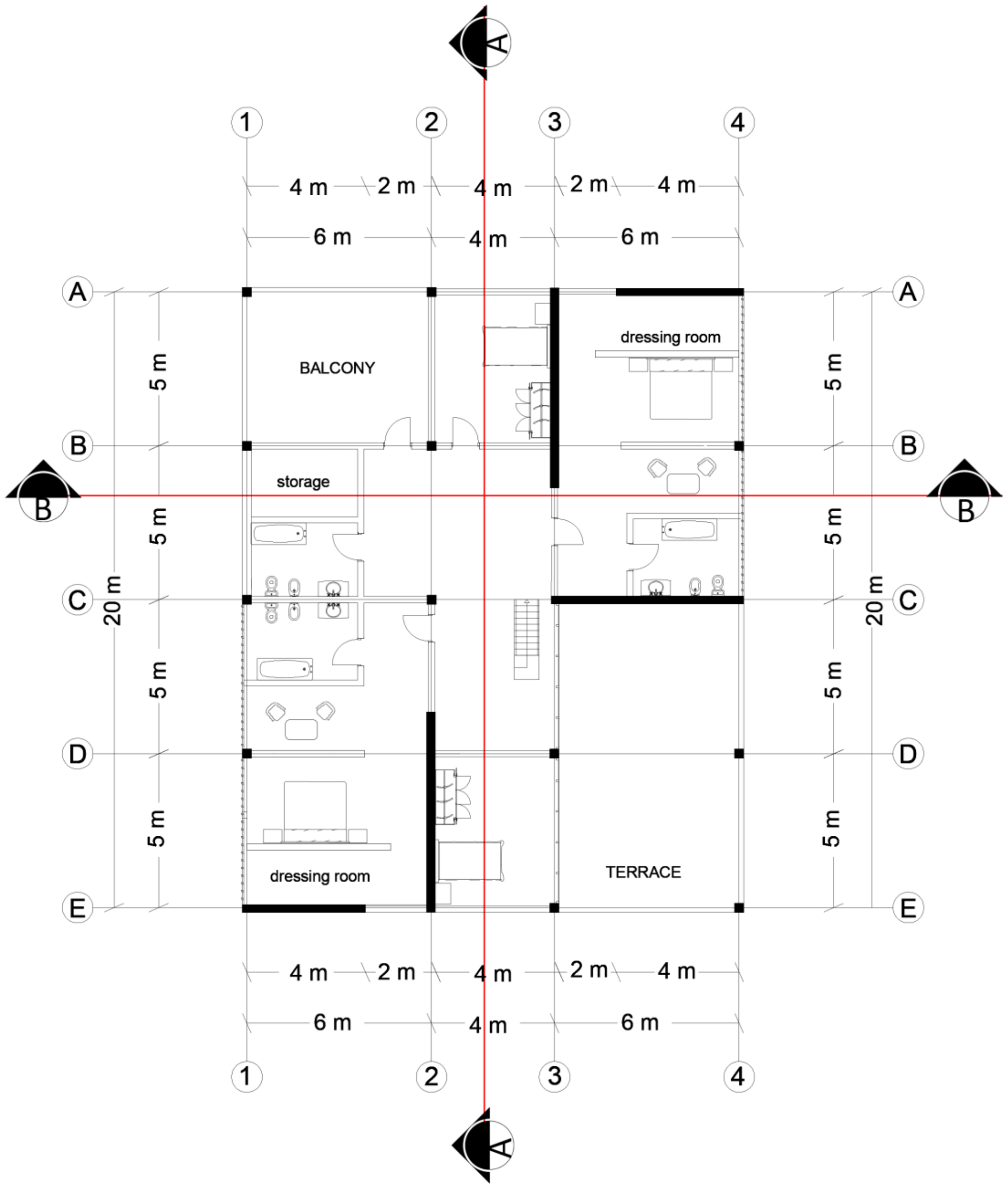
FIRST FLOOR



FLOOR PLANS



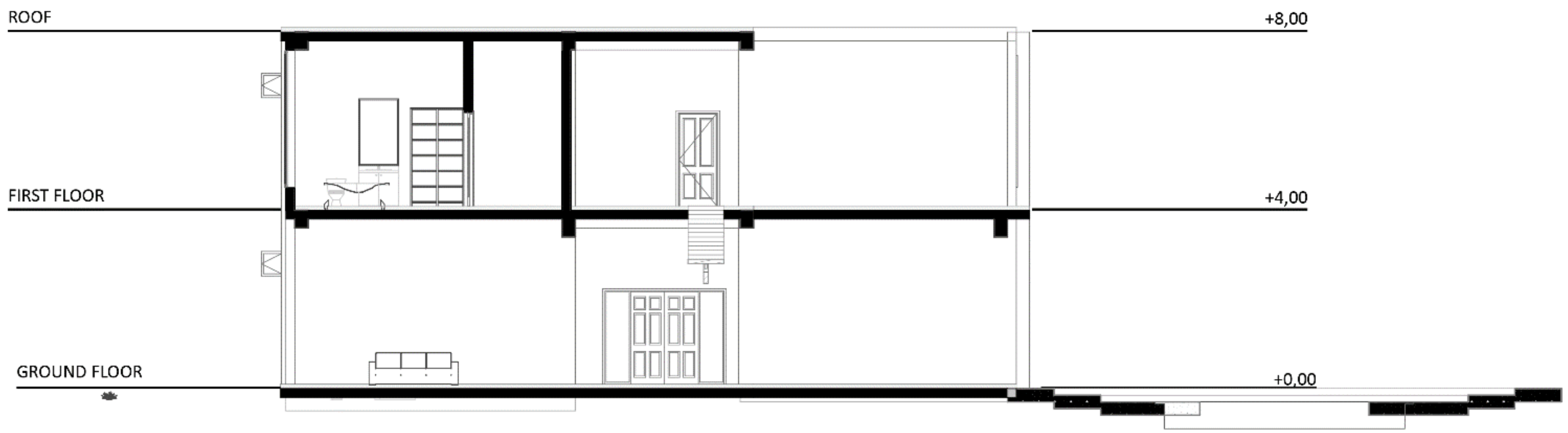
+0,00 GROUND FLOOR PLAN



+4,00 FIRST FLOOR PLAN

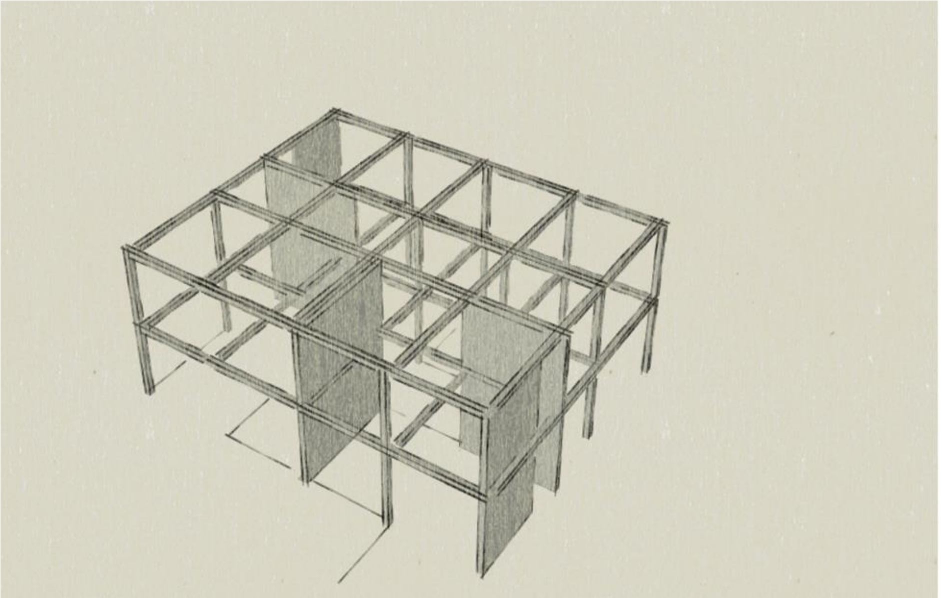
SECTIONS

SECTION AA

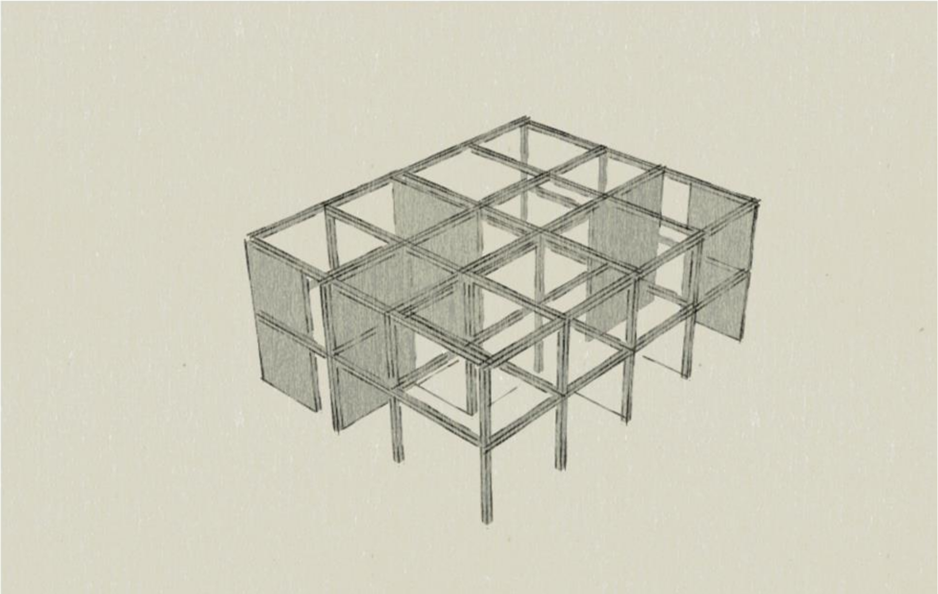


SECTION BB

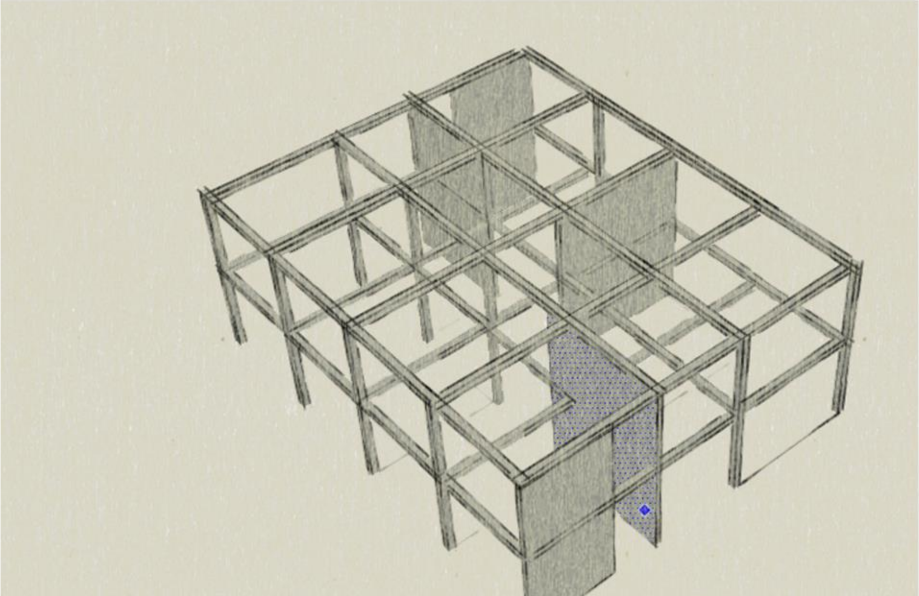
STRUCTURE AXONOMETRIC



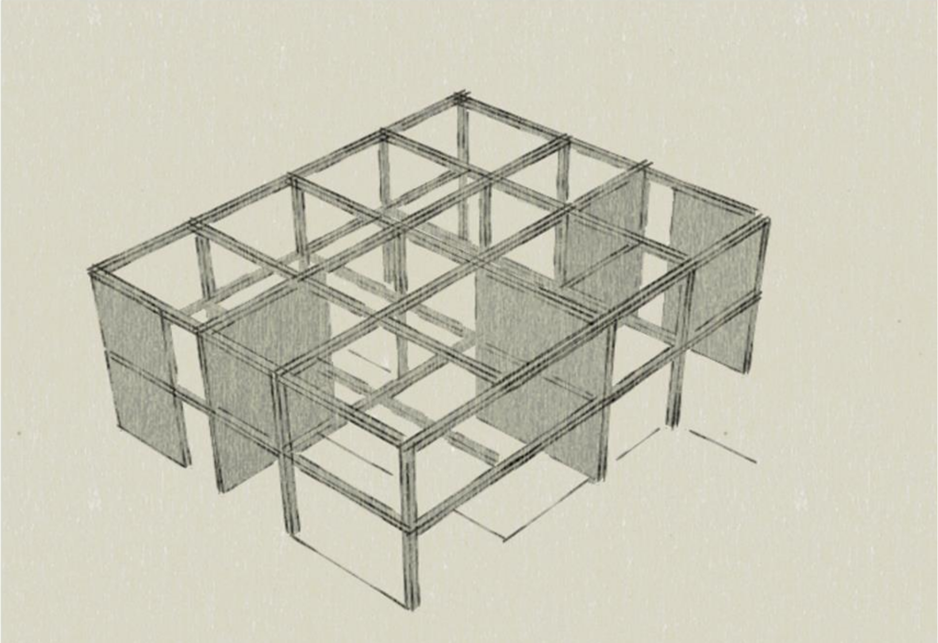
NORTH EAST



NORTH WEST

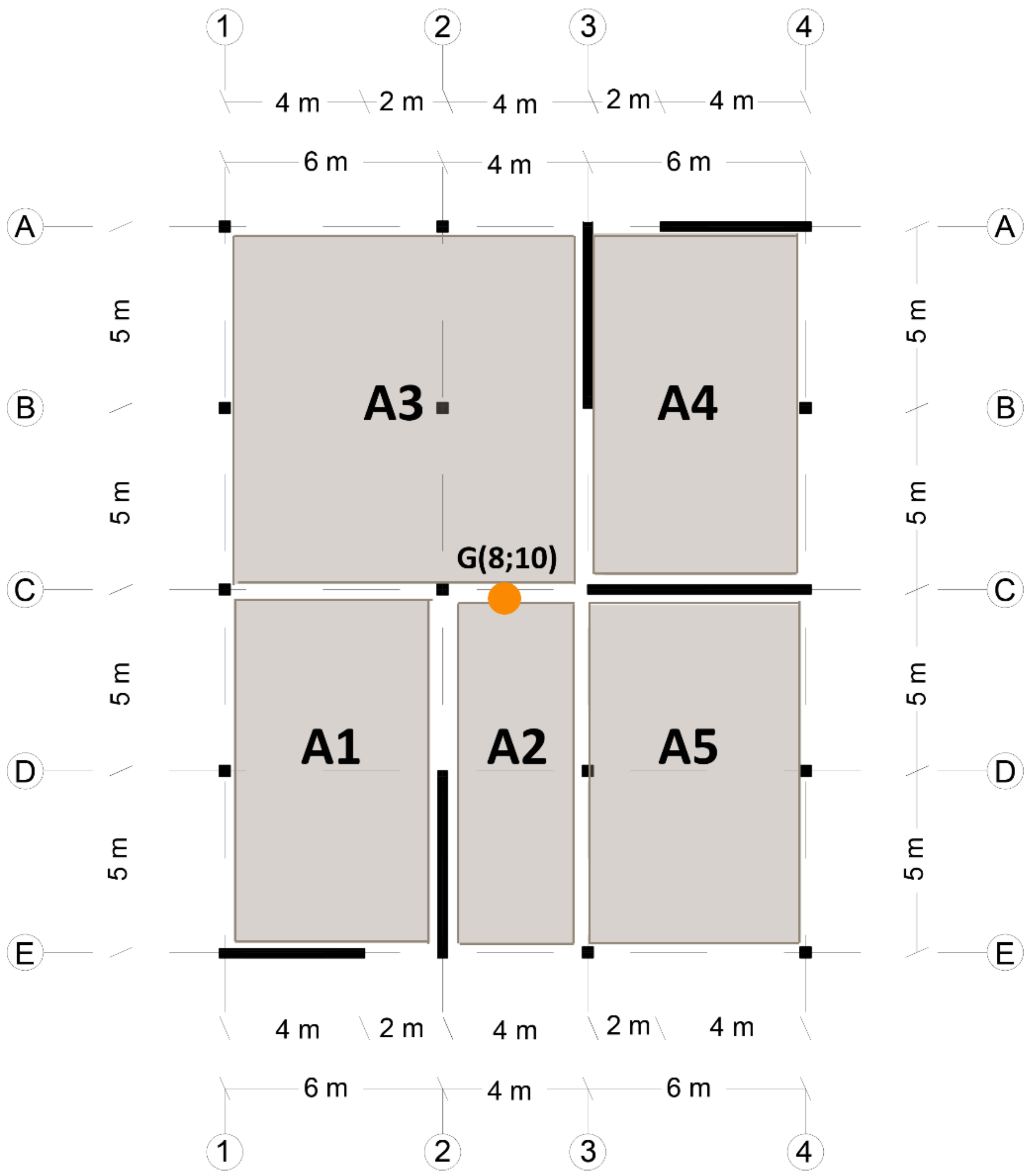


SOUTH WEST



SOUTH EAST

STRUCTURAL SYSTEM



Since the plan is symmetric in both directions, it can be easily seen that the geometric center of a plan is (8m;10m).

However; it can also be determined by using following calculations.

GEOMETRIC CENTER
A1: 6x10 = 60
A2: 4x10=40
A3: 10x10=100
A4: 6x10=60
A5: 6x10=60

$$X_m = \frac{\Sigma A_i \cdot l_x}{\Sigma A_i}$$

$$Y_m = \frac{\Sigma A_i \cdot l_y}{\Sigma A_i}$$

X DIRECTION

$$X_m = \frac{(A_1 \cdot X_1) + (A_2 \cdot X_2) + (A_3 \cdot X_3) + (A_4 \cdot X_4) + (A_5 \cdot X_5)}{A_1 + A_2 + A_3 + A_4 + A_5}$$

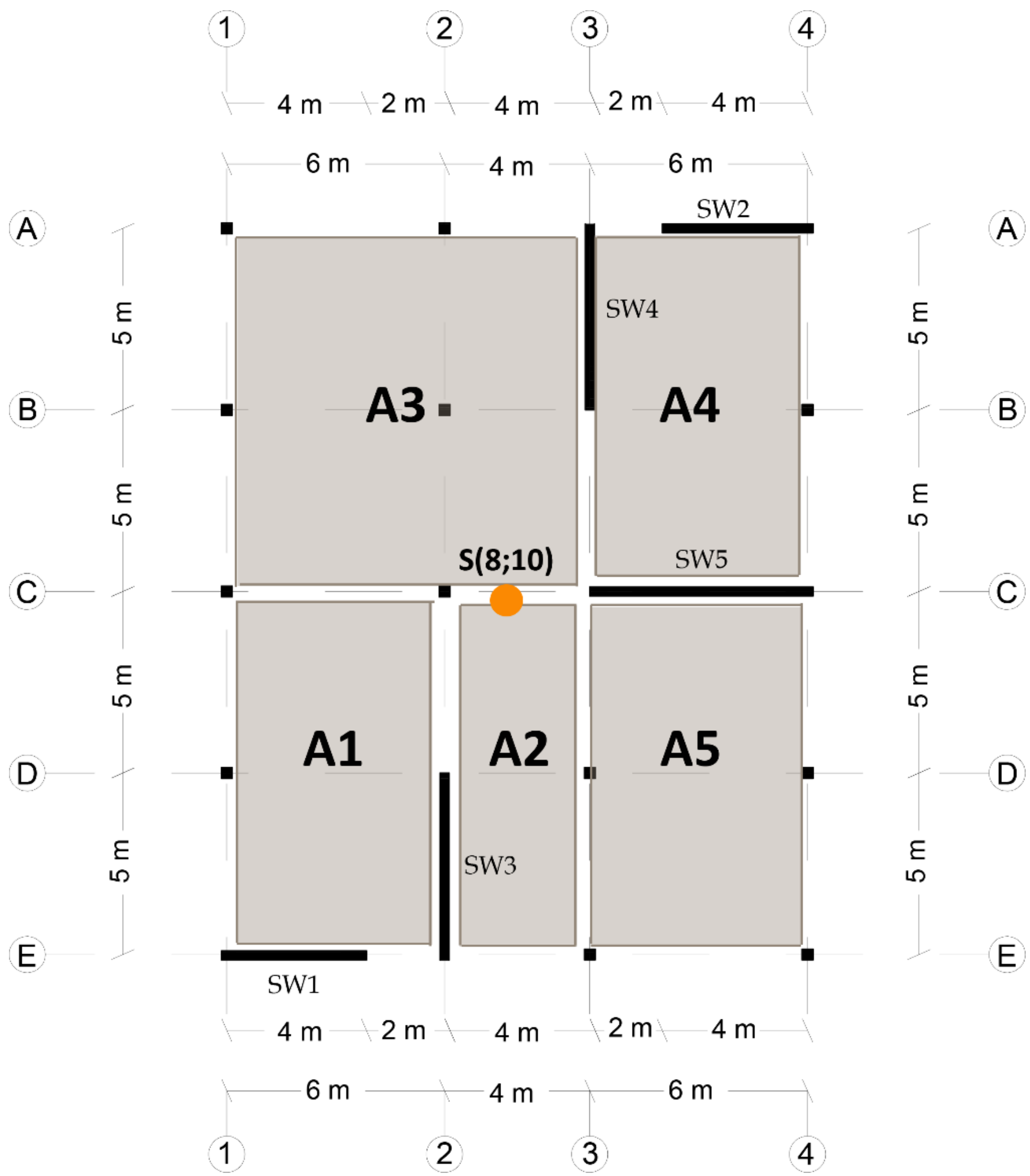
$$X = \frac{(60.3) + (40.8) + (100.5) + (60.13) + (60.13)}{60+40+100+60+60} = 8m$$

Y DIRECTION

$$Y_m = \frac{(A_1 \cdot Y_1) + (A_2 \cdot Y_2) + (A_3 \cdot Y_3) + (A_4 \cdot Y_4) + (A_5 \cdot Y_5)}{A_1 + A_2 + A_3 + A_4 + A_5}$$

$$Y = \frac{(60.5) + (40.5) + (100.15) + (60.15) + (60.5)}{60+40+100+60+60} = 10m$$

STRUCTURAL SYSTEM



STIFFNESS CENTER

$I_{SW1} = I_{SW2} = 1/12 \cdot 0{,}25 \cdot (4) = 1{,}33$ m

$I_{SW3} = I_{SW4} = 1/12 \cdot 0{,}30 \cdot (6) = 5{,}4$ m

$I_{SW5} = 1/12 \cdot 0{,}25 \cdot (6) = 4{,}5$ m

$I = 1/12 \cdot b \cdot h^3$

$$X_S = \frac{\Sigma I_i \cdot l_x}{\Sigma I_i}$$

$$Y_S = \frac{\Sigma I_i \cdot l_y}{\Sigma I_i}$$

X DIRECTION

$$X_S = \frac{(I_{SW3} \cdot X_1)+(I_{SW4} \cdot X_2)}{I_{SW3} + I_{SW4}}$$

$$X_S = \frac{(5{,}4 \cdot 6)+(5{,}4 \cdot 10)}{5{,}4+5{,}4} = 8m$$

Y DIRECTION

$$Y_S = \frac{(I_{SW1} \cdot Y)+(I_{SW2} \cdot Y)+(I_{SW5} \cdot Y)}{I_{SW1} + I_{SW2} + I_{SW5}}$$

$$Y_S = \frac{(0 \cdot 1{,}33) + (20 \cdot 1{,}33)+(10 \cdot 4{,}5)}{1{,}33+1{,}33+4{,}5} = 10m$$

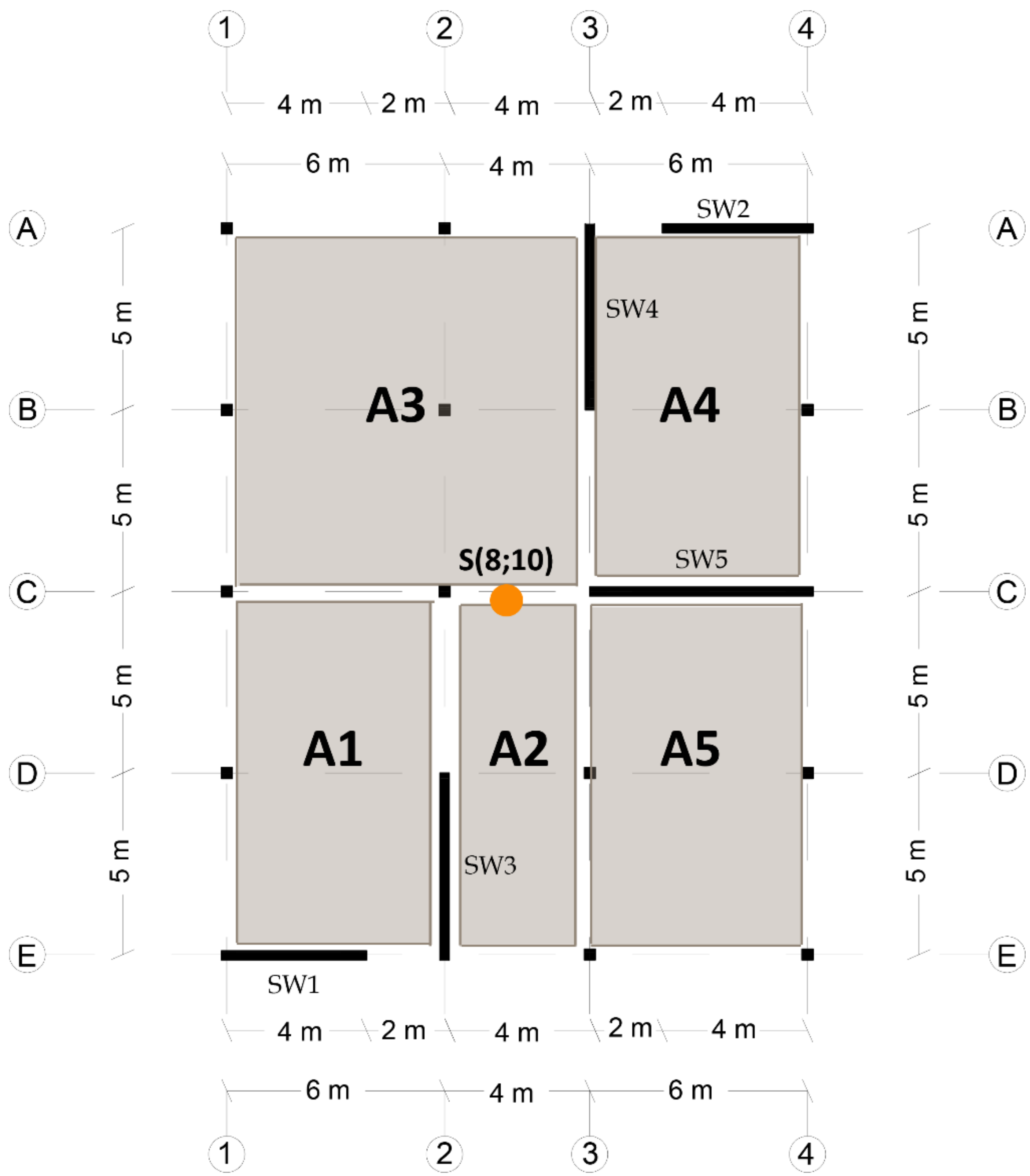
Stiffness center is (8m;10m). Since geometric center is also (8m;10m), shear walls are in right direction and distance in both axis.

Eccentricity

$$e_x = \frac{|8 - 8|}{2} = 0 < \%5$$

$$e_y = \frac{|10 - 10|}{2} = 0 < \%5$$

STRUCTURAL SYSTEM



SHEAR WALL PERCENTAGE

$$\frac{\text{Area of the footprint of shear walls on X,Y axis}}{\text{Floor Area}} \geq 1\%$$

AREA OF GROUND FLOOR

A1: 60 m^2
A2: 40 m^2
A3: 100 m^2
A4: 60 m^2
A5: 60 m^2

Since both ground floor and first floor have same areas, area of ground floor is used to calculate the percentage of shear walls.

Total Area of Ground Floor; 320 m^2

Area of shear walls on Y direction : 0,25 . 4 . 2 = 2 m^2
0,25 . 6 = 1,5 m^2

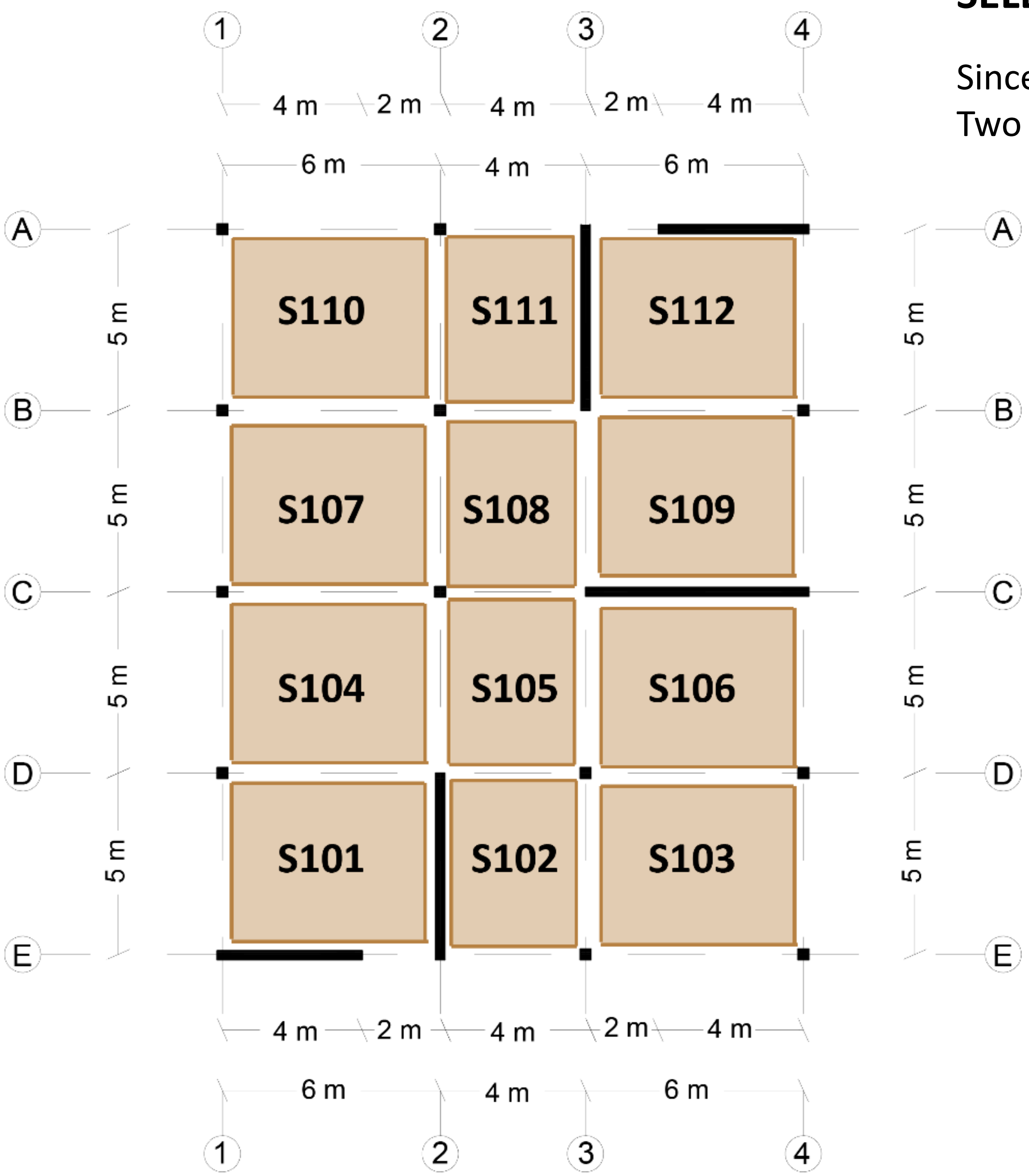
3,5 / 320 = 0,01 1% ✓

Area of shear walls on X direction : 0,30 . 6 . 2 =3,6 m

3,6 / 320 = 0,01125 1,125% ✓

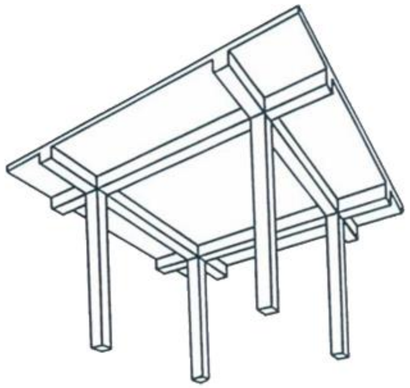
Shear wall cross sectional areas should be minimum 1% of the plan area in both directions.

SLAB SYSTEM



SELECTION AND THICKNESS CALCULATION

Since all slabs meet the condition of two way solid slab by $L_l / L_s \leq 2$; Two way solid slab is selected as a slab system.



$$\alpha = \frac{\Sigma \text{ length of all continuous slab edges}}{\Sigma \text{ length of all edges}}$$

$$t \geq \frac{L_s}{15 + \frac{20}{L/L_s}} \cdot \left(1 - \alpha/4\right)$$

$$\alpha_{S101} = \frac{6+5}{2.(6+5)} = 0,5$$

$$\alpha_{S102} = \frac{4+5+5}{2.(4+5)} = 0,77$$

$$\alpha_{S105} = \frac{4+5+5+4}{2.(4+5)} = 1$$

$$t_{S101} = \frac{5}{15+\frac{20}{6/5}} .(1-0,5/4)$$

$t_{S101} > 13,8$

$$t_{S102} = \frac{4}{15+\frac{20}{5/4}} .(1-0,77/4)$$

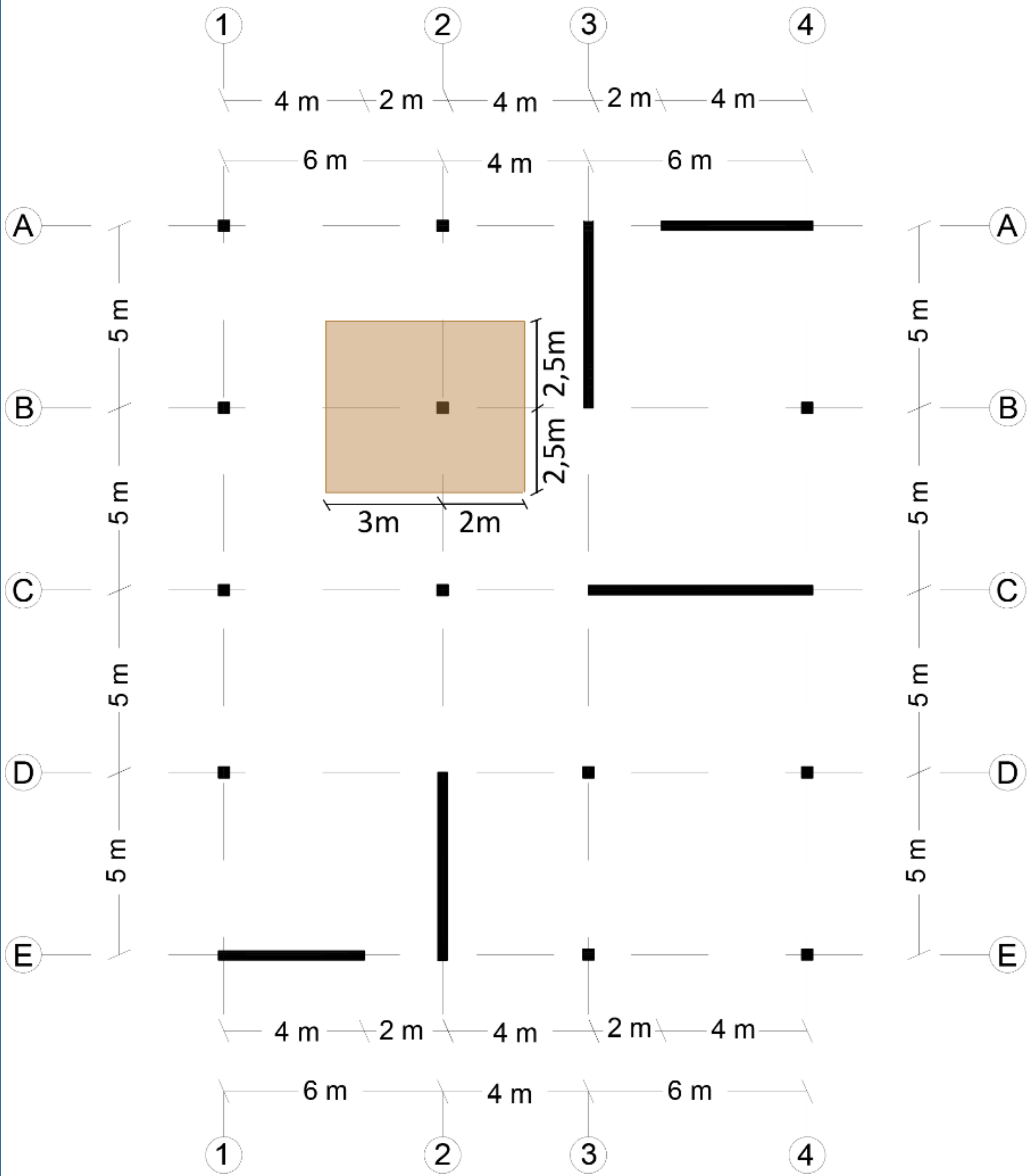
$t_{S102} > 10,4$

$$t_{S105} = \frac{4}{15+\frac{20}{5/4}} .(1-1/4)$$

$t_{S105} > 9,7$

Slab thickness is selected as **15 cm.**

COLUMN DIMENSION



Column **2B** is selected for calculation of dimension, since it has the largest tributary area.

TRIBUTARY AREA = (3+2) x (2,5+2,5) =25 m^2

SLAB LOAD ON TRIBUTARY AREA

Load x Tributary Area = 1,084 x 25 = **27,1 t**

WALL LOAD ON TRIBUTARY AREA

1,4 x 0,15 x Tributary Area = 1,4 x 0,15 x 25 = **5,25 t**

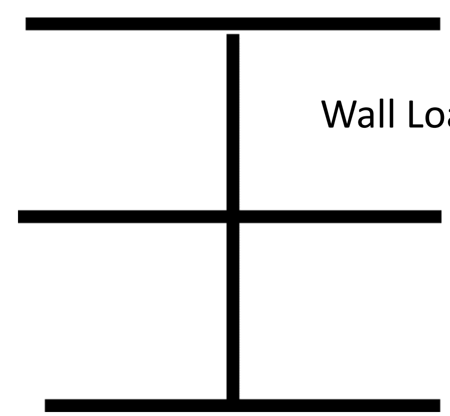
The column cross section area (Ac) should satisfy following requirements:

The smallest dimension of a rectangular column section shall not be less than 30 cm. (TEC 2018 - 7.3.1.1).

$$A_c \geqslant \frac{N_d}{0{,}40 \, . \, fck}$$

$$A_c > \frac{59450}{0{,}40.200}$$

$$A_c > 743{,}125cm$$



DESIGN LOADS

DEAD LOAD OF SOLID SLABS

Own Weight : 0,15 x 2,4 = 0,36 t/m 2
Levelling : 0,04 x 2,4 = 0,096 t/m 2
Covering : 0,025x2,0 = 0,05 t/m 2
Plastering : 0,020x2,0 = 0,04 t/m 2

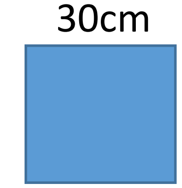
0,546 t/m^2

LIVE LOAD

0,2 t/m for residential buildings

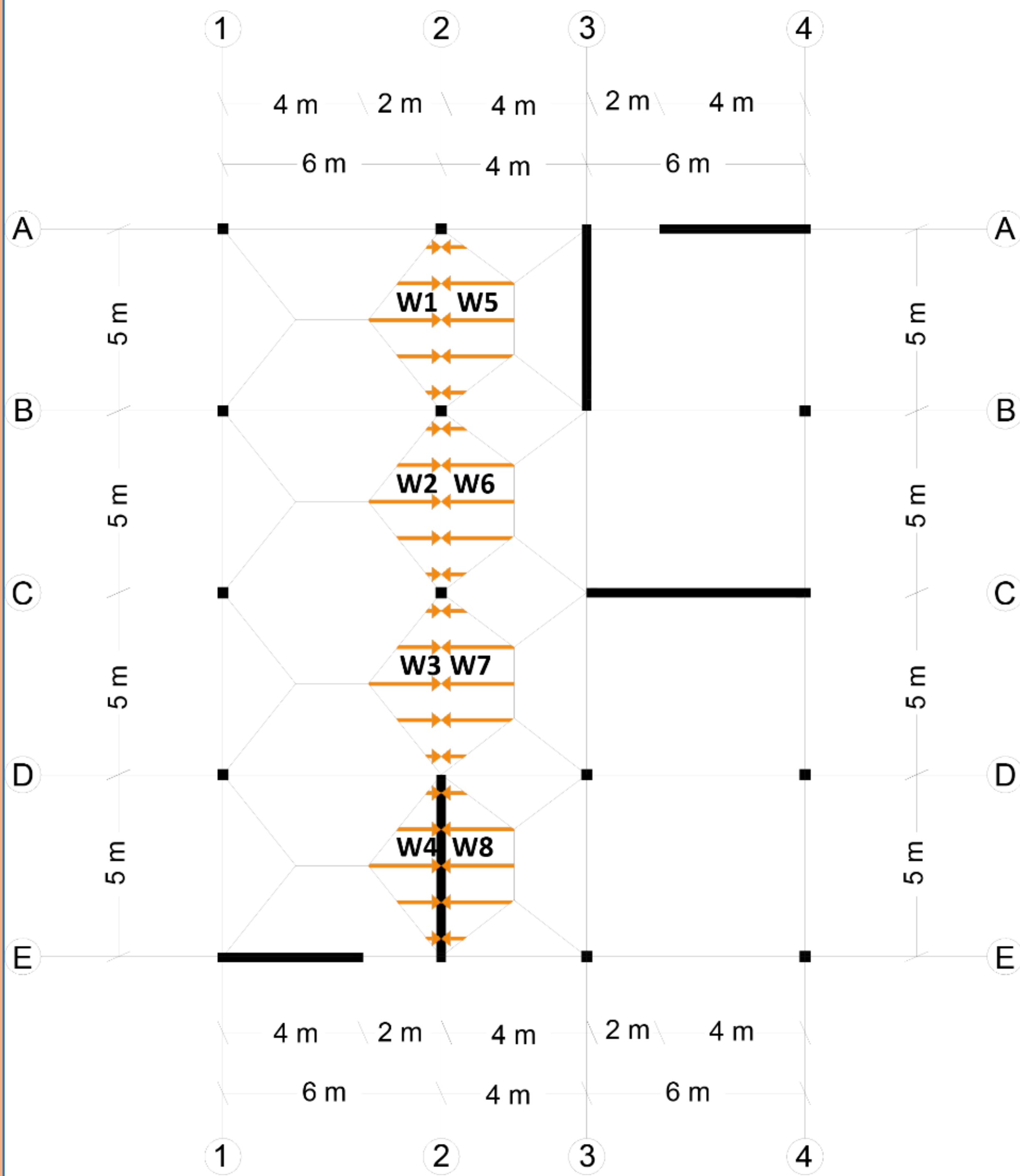
TOTAL LOAD : (0,2 x 1,6) + (0,546 x 1,4) =**1, 084** t/m^2

According to solutions minimum allowable area of column is **743,125 cm**, and the allowable dimension of a rectangular column can not be less than 30 cm according to TEC 2018; column dimensions are selected as **30cm x 30cm**.



BEAM ANALYSIS

The beam on axis 2 is selected to be analyzed since it has the least amount of shear walls.



In order to analyze the load transfer of structures on beam, first we have to know the design load of slab, walls and beam's own weight. According to TS 500 - TEC 2018 codes ,we know that wall load is **0.15 t/m** per square meter. We can find loads by adding wall load with slab load as follows;

P_d= ((Wall load+Dead Load of slab)x Load Factor) + (Live Load x Load Factor)

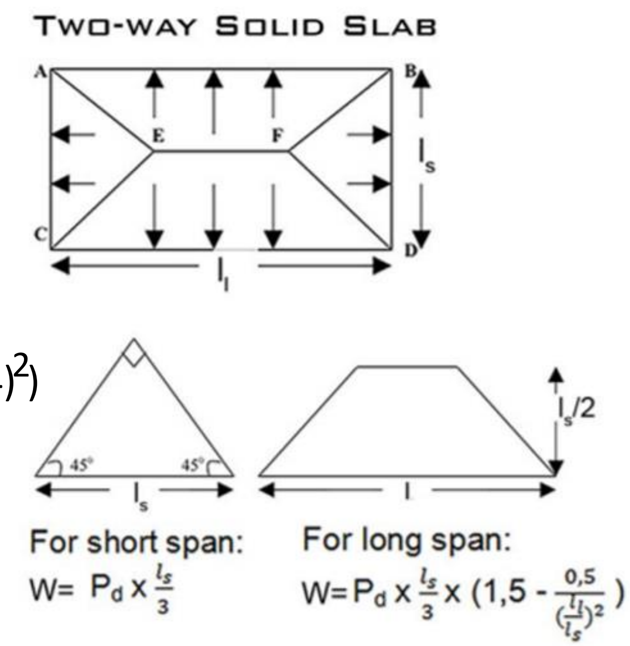
P_d= ((**0,15**+0,546)x 1,4) + (0,2 x 1,6)

P_d= 1,3 t/m

W1=W2=W3=W4

$W_{1,2,3,4}$ =1,3 x 5/3

$W_{1,2,3,4}$ =2,17 t/m



W5=W6=W7=W8

$W_{5,6,7,8}$=1,3 x 4/3 x (1,5 - 0,5/(5/4)^2)

$W_{5,6,7,8}$ =2,04 t/m

BEAM'S OWN WEIGHT (W_b)

W_b= Volume of member x unit of materials x Dead Load Factor

W_b= (5 x 0,50 x 0,25) x 2,4 x 1,4 = 2,1 t

W_b = 2,1/ 5

W_b= 0,42t/m

Beam's own weight is ommitted.

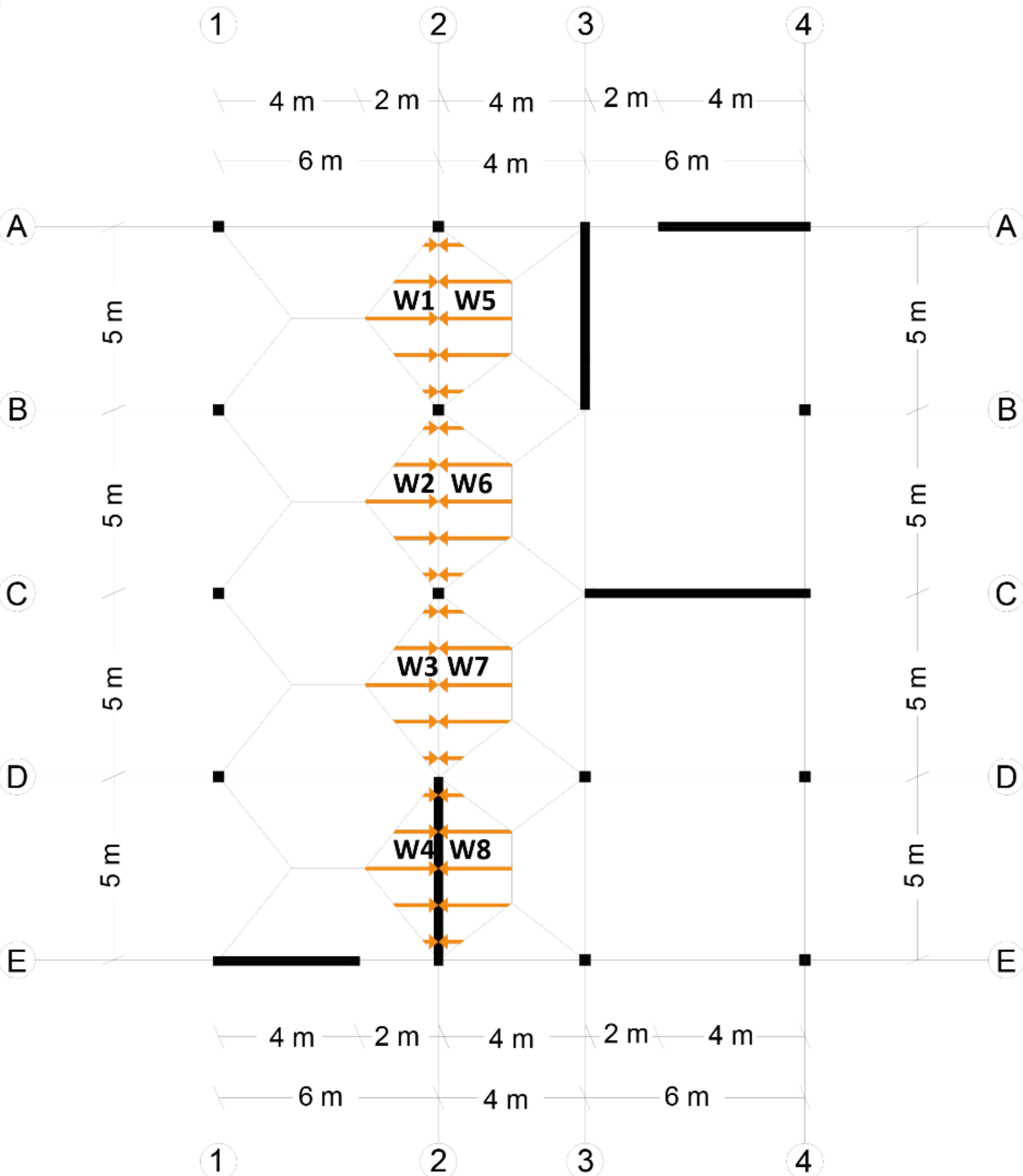
Beam AB = 2,17 + 2,04 = 4,21 t/m

Beam BC = 2,17 + 2,04 = 4,21 t/m

Beam CD = 2,17 + 2,04 = 4,21 t/m

Beam DE = 2,17 + 2,04 = 4,21 t/m

BEAM ANALYSIS



In order to find load distribution factors we have to know moment of inertia of beam, column and shear wall.

To find beam's moment of inertia we should know the beam depth. According to design beam depth is chosen as **50 cm**. However; it can also be determined by using average beam depth which is;

Average beam depth : longest span / 12,5
Longest beam is 600 cm so;
Average beam depth: 600 / 12,5 =**48 cm**

Load Distribution Factor

$$r_{ij} = (I_{ij}/L_{ij}) / \sum (I_{ij}/L_{ij})$$

r_{AB} = (0,0026/5)/ ((0,0026/5) + 2x(0,000675/4)) =0,6
r_{BA} = (0,0026/5) / (2x (0,0026/5)+2x(0,000675/4)) =0,38
r_{BC} = (0,0026/5) / (2x (0,0026/5)+2x(0,000675/4)) =0,38
r_{CB} = (0,0026/5) / (2x (0,0026/5)+2x(0,000675/4)) =0,38
r_{CD} = (0,0026/5) / (2x (0,0026/5)+2x(0,000675/4))=0,38
r_{DC} = 0
r_{DE} = 0
r_{ED} = 0

Moment of Inertia

$I = 1/12 \times b \times h^3$

I_{beam} = 0,25 x $(0,50)^3$/ 12 = 0,0026m^4
I_{column} = 0,30 x $(0,3)^3$/12 = 0,000675 m^4
$I_{Sw3,4}$ = 0,30 x $(6)^3$ /12 = 5,4 m^4
$I_{Sw1,2}$ = 0,25 x $(4)^3$ /12 = 1,33m^4
I_{Sw5} = 0,25 x $(6)^3$ /12 = 4,5 m^4

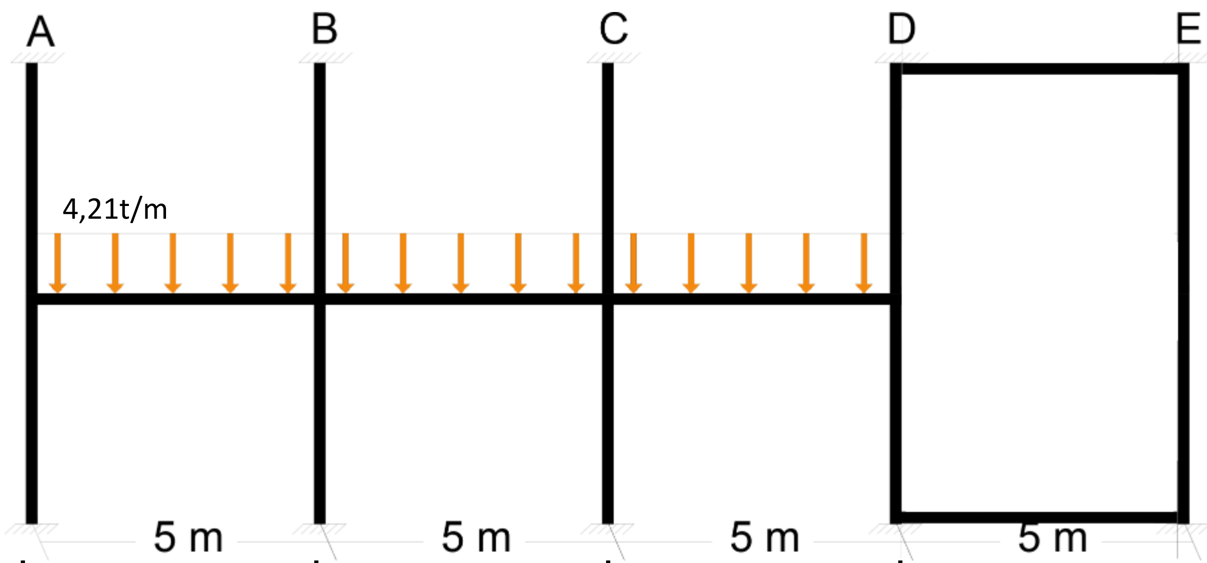
Fixed End Moments

FEM_{AB} = 4,21 x 5^2x 1/12 = 8,77 tm
FEM_{BC} = 4,21 x 5^2x 1/12 = 8,77 tm
FEM_{CD} = 4,21 x 5^2x 1/12 = 8,77 tm
FEM_{DE} = 0

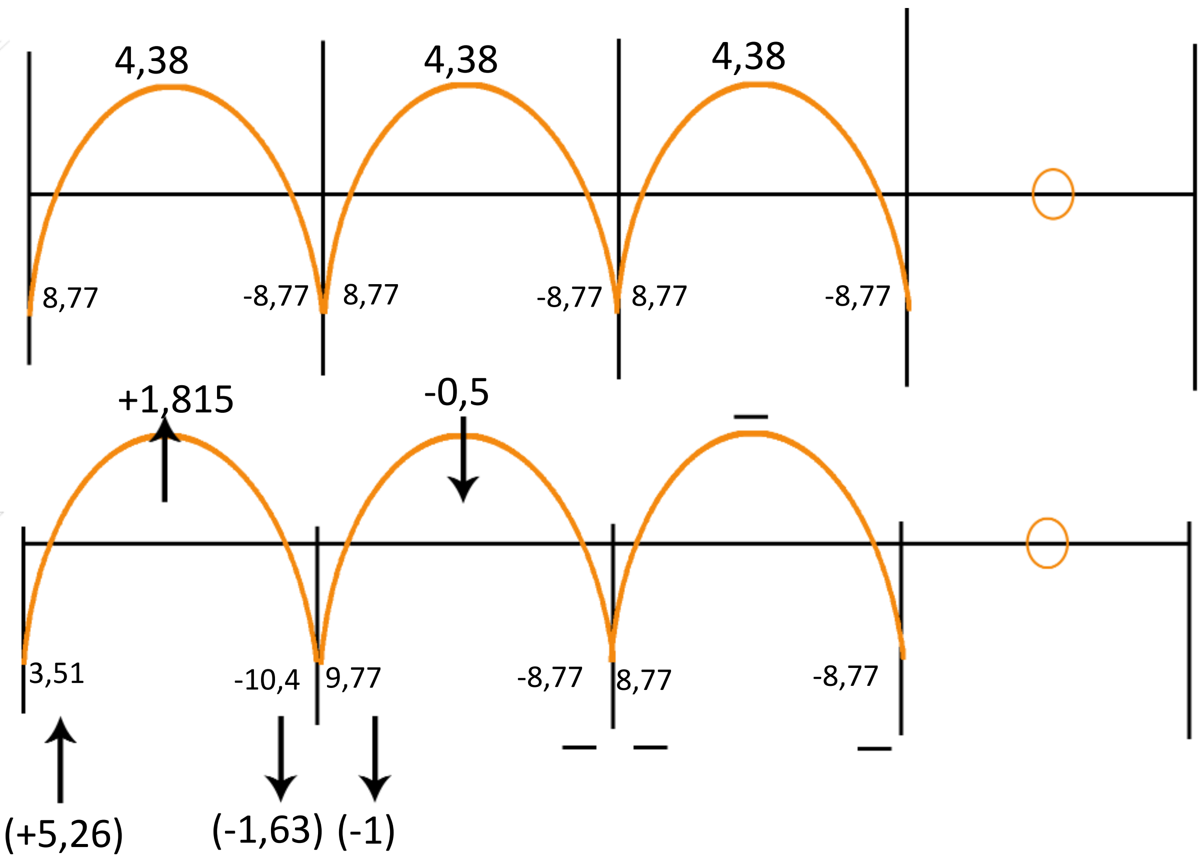
Mid Span Moment

M_{AB} = 4,21 x 5^2x 1/24 =4,38tm
M_{BC} = 4,21 x 5^2x 1/24 =4,38tm
M_{CD} = 4,21 x 5^2x 1/24 =4,38tm
M_{DE} = 0

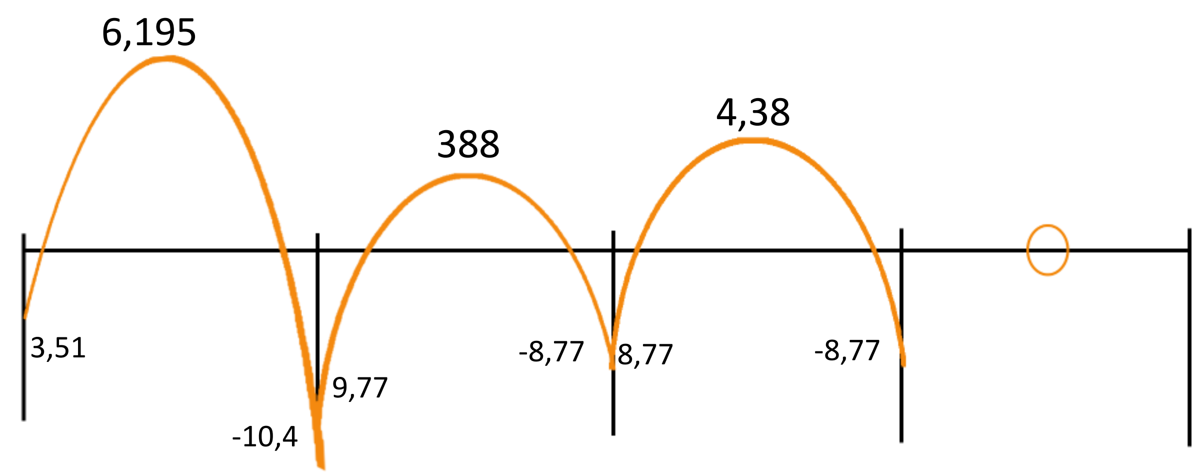
BEAM ANALYSIS



r	0,6	0,38	0,38	0,38	0,38	0
FEM	8,77	-8,77	8,77	-8,77	8,77	-8,77
1st	0	-2,63	0	0	0	0
$\sum$	8,77	-11,4	8,77	-8,77	8,77	-8,77
2nd	-5,26	1	1	0	0	0
	3,51	-10,4	9,77	-8,77	8,77	-8,77



MOMENT DIAGRAM



BEAM DEPTH

$$K_0 = \frac{b_w x\ d^2}{M_{max}}$$

$$25 = \frac{25 \times d^2}{1040}$$

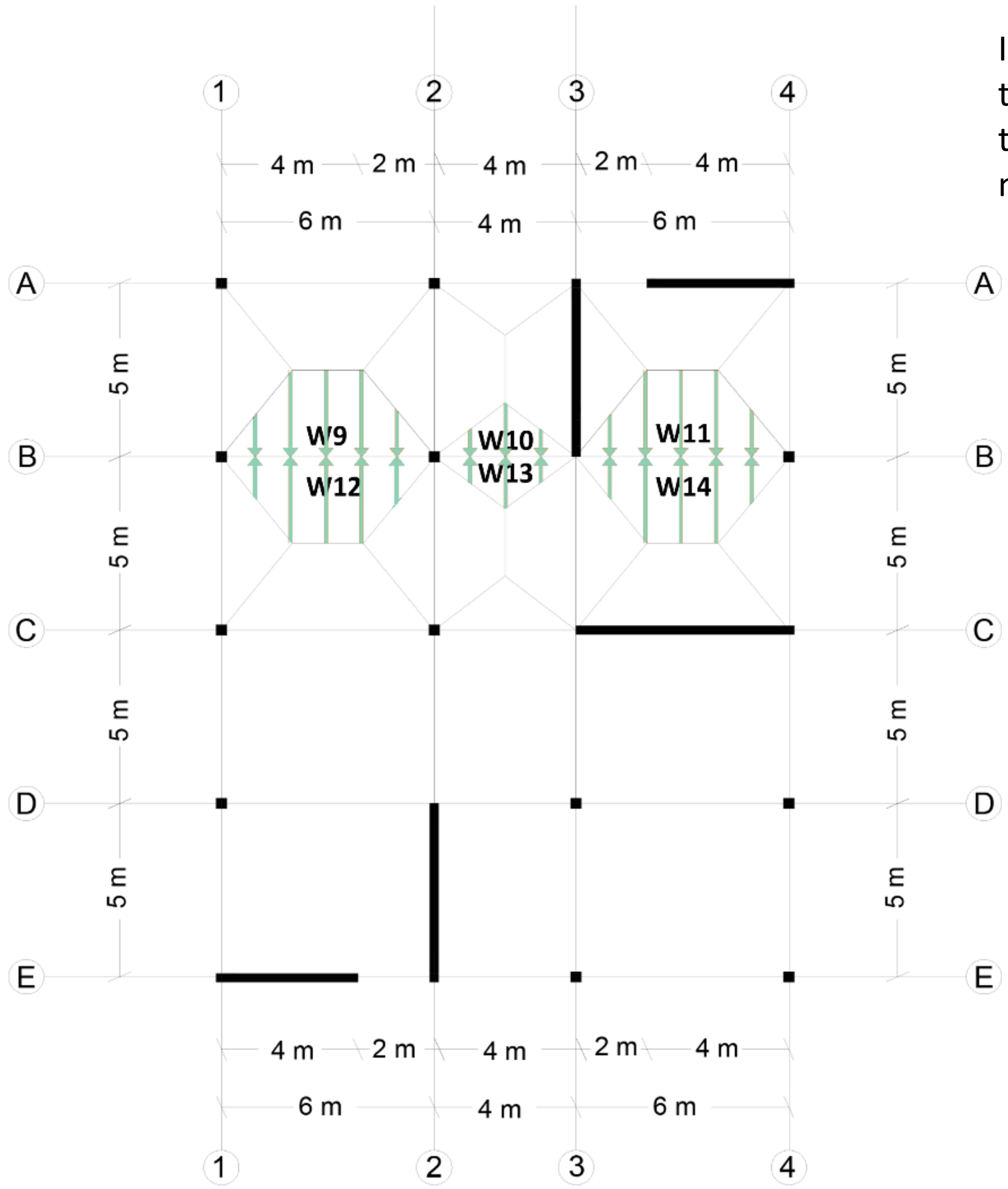
d = 32,25

h = 32,25 + 5 = 37,25 cm

K_0 = 250 mm^2/ KN
K_0 = 25 cm^2/t
b_w = 25 cm
M = 10,4

According to building regulations beam depth can not be three times smaller than the slab thickness. Thus, the **beam depth > 45 cm.** The beam depth chosen as **50 cm.**

BEAM ANALYSIS

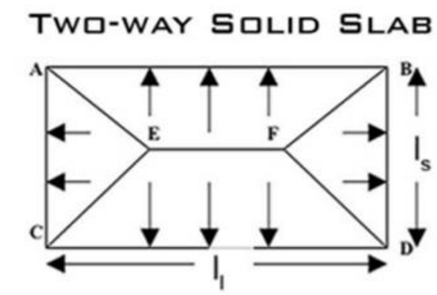


In order to analyze the load transfer of structures on beam, first we have to know the design load of slab, walls and beam's own weight. According to TS 500 - TEC 2018 codes ,we know that wall load is **0.15 t/m** per square meter. We can find loads by adding wall load with slab load as follows;

P_d= ((Wall load+Dead Load of slab)x Load Factor) + (Live Load x Load Factor)

P_d= ((**0,15**+0,546)x 1,4) + (0,2 x 1,6)

P_d= 1,3 t/m



W9=W12=W11=W14

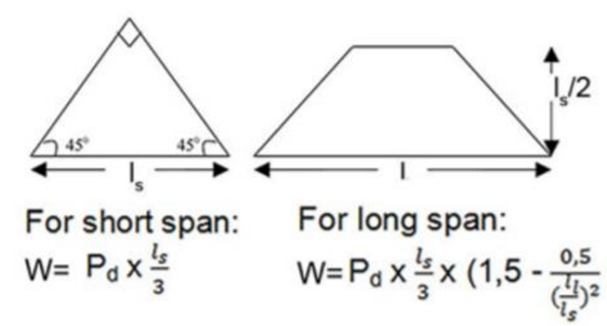
$W_{9,12,11,14}$=1,3 x 5/3x(1,5 -0,5/(6/5)^2)

$W_{9,12,11,14}$=2,5 t/m

W10=W13

$W_{10,13}$=1,3 x 4/3

$W_{10,13}$=1,73 t/m



BEAM'S OWN WEIGHT (W)

W_b= Volume of member x unit of materials x Dead Load Factor

W_b= (6 x 0,50x 0,25) x 2,4 x 1,4 = 2,52 t

W_b= 2,52/ 6

W_b= 0,42 t/m

W_b= (4 x 0,50 x 0,25) x 2,4 x 1,4 = 1,68 t

W_b= 1,68/4

W_b= 0,42 t/m

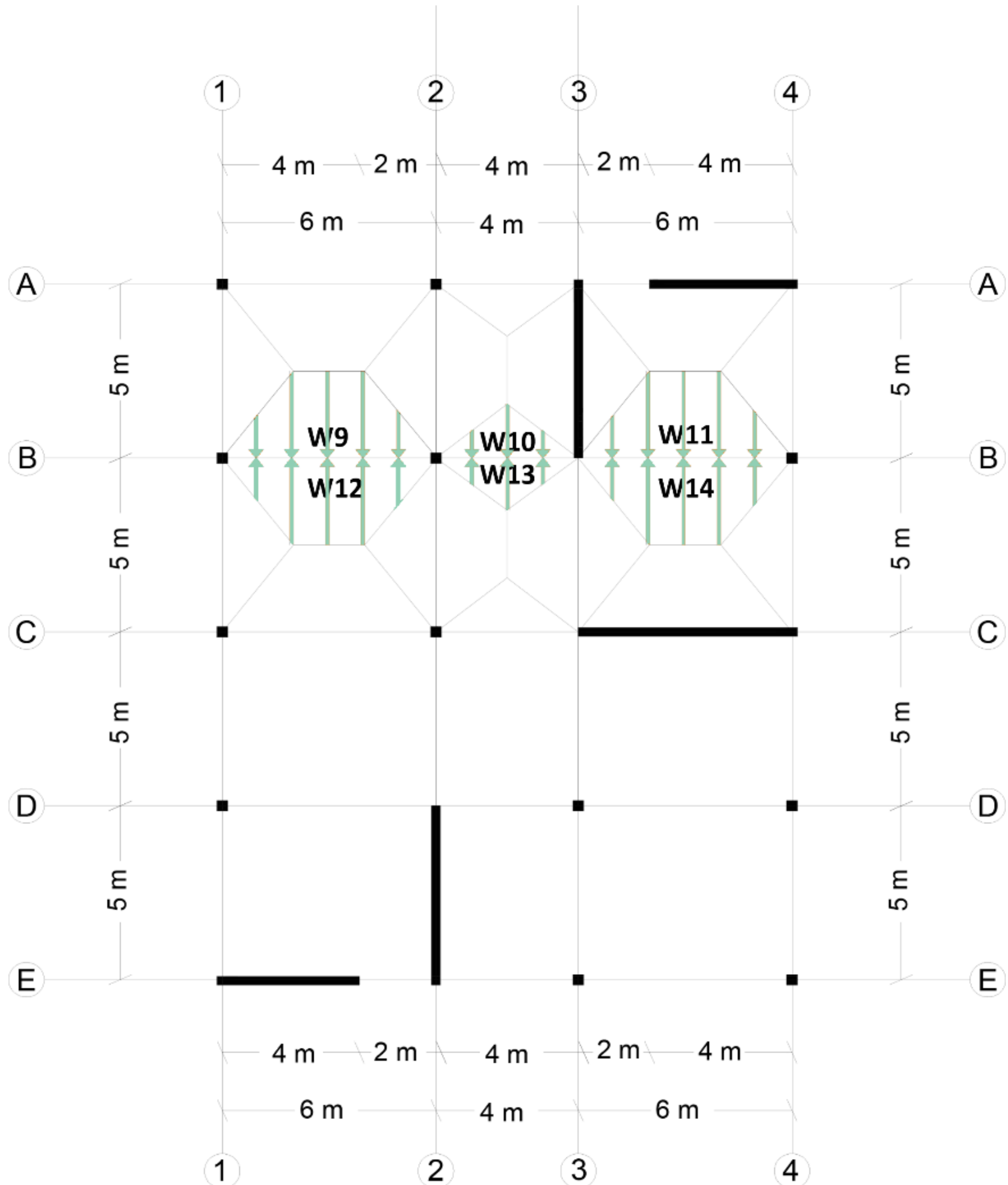
Beam's own weight is ommitted.

Beam 12 = 2,5 + 2,5 =5t/m

Beam 23 = 1,73 + 1,73 = 3,46t/m

Beam 34 = 2,5 + 2,5 = 5 t/m

BEAM ANALYSIS



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Average beam depth : longest span / 12,5
Longest beam is 600 cm so;
Average beam depth: 600 / 12,5 =**48 cm**

Load Distribution Factor

$r_{ij} = (I_{ij}/L_{ij}) / \sum (I_{ij}/L_{ij})$

r_{12} = (0,0026 /6)/ ((0,0026/6) + 2x(0,000675/4)) =0,56
r_{21} = (0,0026/6) / ((0,0026/6)+(0,0026/4)+2x(0,000675/4)) =0,3
r_{23} = (0,0026/4) / ((0,0026/4)+(0,0026/6)+2x(0,000675/4)) = 0,46
r_{32} = 0
r_{34} = 0
r_{43} = r = (0,0026 /6)/((0,0026/6) + 2x(0,000675/4)) =0,56

Moment of Inertia

$I = 1/12 \times b \times h^3$

I = 0,25 x $(0,50)^3$/ 12 = 0,0026m^4
I = 0,30 x $(0,3)^3$/12 = 0,000675 m^4
I = 0,30 x $(6)^3$ /12 = 5,4 m^4
I = 0,25 x $(4)^3$ /12 = 1,33m^4
I = 0,25 x $(6)^3$ /12 = 4,5 m^4

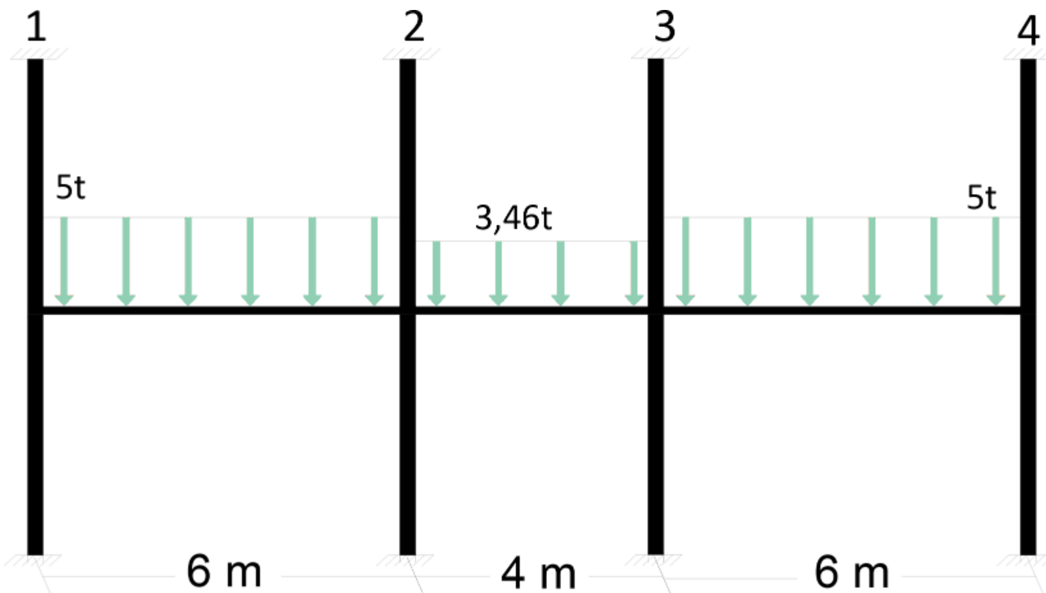
Fixed End Moments

FEM_{12} = 5 x 6^2x 1/12 = 15 tm
FEM_{23} = 3,46 x 4^2x 1/12 = 4,61 tm
FEM_{34} = 5 x 6^2x 1/12 = 15 tm

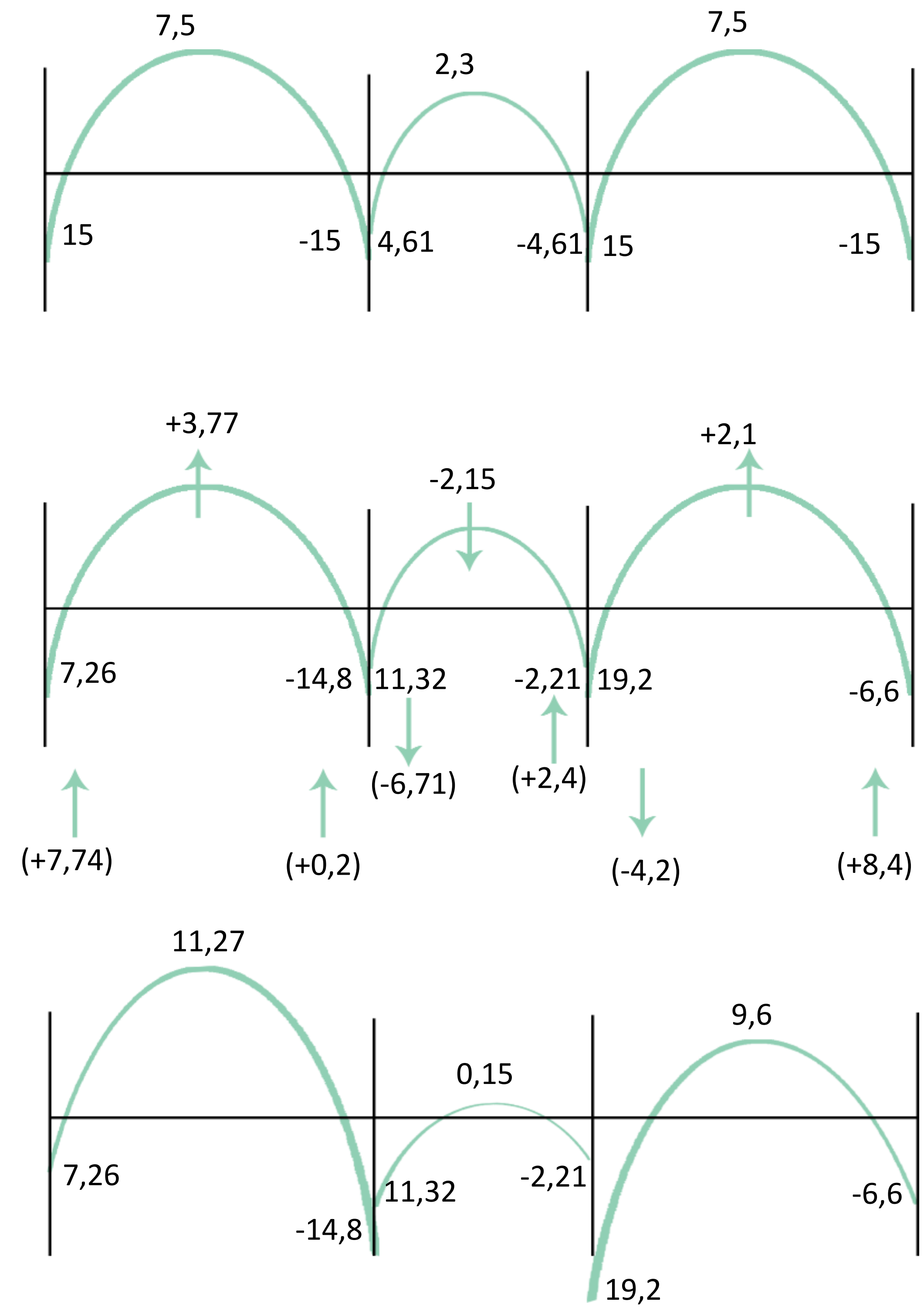
Mid Span Moment

M_{12} = 5 x 6^2x 1/24 =7,5tm
M_{23} = 3,46x 4^2x 1/24 =2,3tm
M_{34} = 5 x 6^2x 1/24 =7,5tm

BEAM ANALYSIS



r	0,56	0,3	0,46	0	0	0,56
FEM	15	-15	4,61	-4,61	15	-15
1st	1,56	-4,2	0	2,4	4,2	0
∑	16,56	-19,2	4,61	-2,21	19,2	-15
2nd	-9,3	4,4	6,71	0	0	8,4
	7,26	-14,8	11,32	-2,21	19,2	-6,6



BEAM DEPTH

$$K_0 = \frac{b_w x\ d^2}{M_{max}}$$

$$25 = \frac{25 \times d^2}{1920}$$

d = 43,81

h =43,81+ 5=48,81 cm

K_0= 250 mm / KN

K_0= 25 cm /t

b_w= 25 cm

M = 19,20

According to building regulations beam depth can not be three times smaller than the slab thickness. Thus, the **beam depth > 45 cm.** The beam depth chosen as **50 cm.**