MIDDLE EAST TECHNICAL UNIVERSITY

DEPARTMENT OF ARCHITECTURE, SPRING '14

ARCH332: STRUCTURAL DESIGN IN ARCHITECTURE II

HOUSE PROJECT IN ÜMİTKÖY

2013-14, Spring

INSTRUCTORS
M. HALİS GÜNEL
DENİZ ÜÇER

GROUP 7
Aktaş Betül
Duman Oya Merve
Sungur Alican

DIAGRAMS

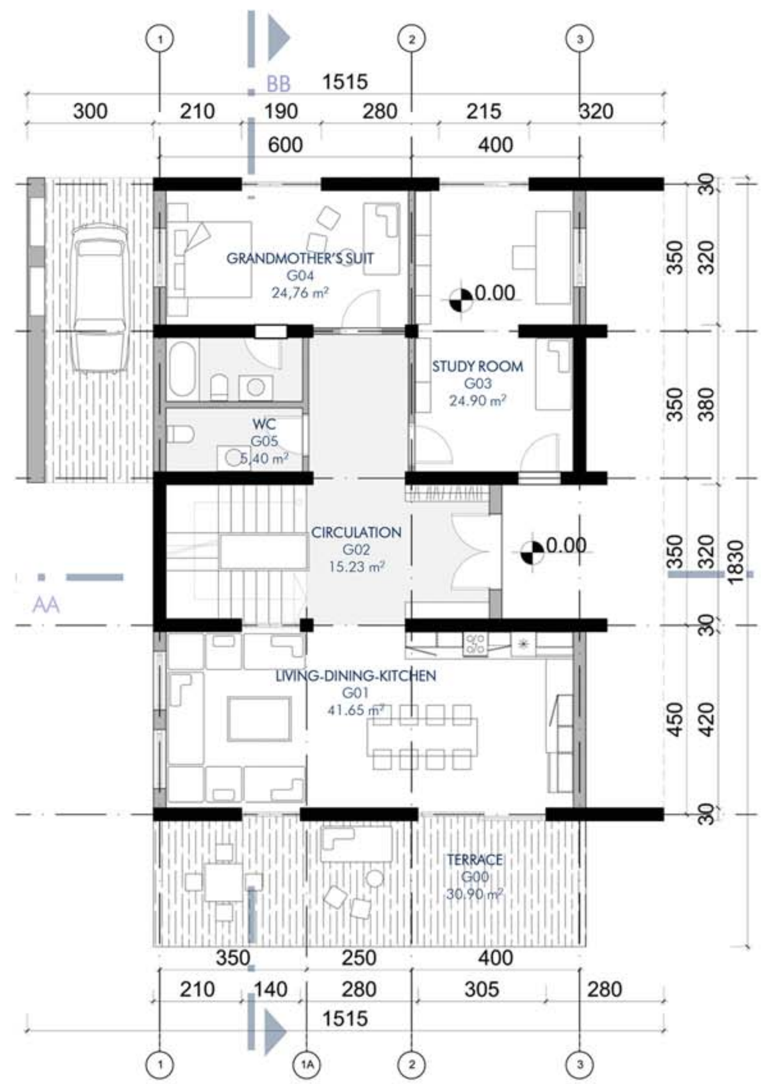

TERRACE
LIVING AREA
BEDROOM
RESTROOM
FITNESS ROOM
GRANDMA'S SUIT
STUDY ROOM
RESTROOM
LIVING AREA
KITCHEN
BEDROOM
BEDROOM
BATHROOM
MASTER BEDROOM
TERRACE

BASEMENT FLOOR PLAN

-3.20 LEVEL

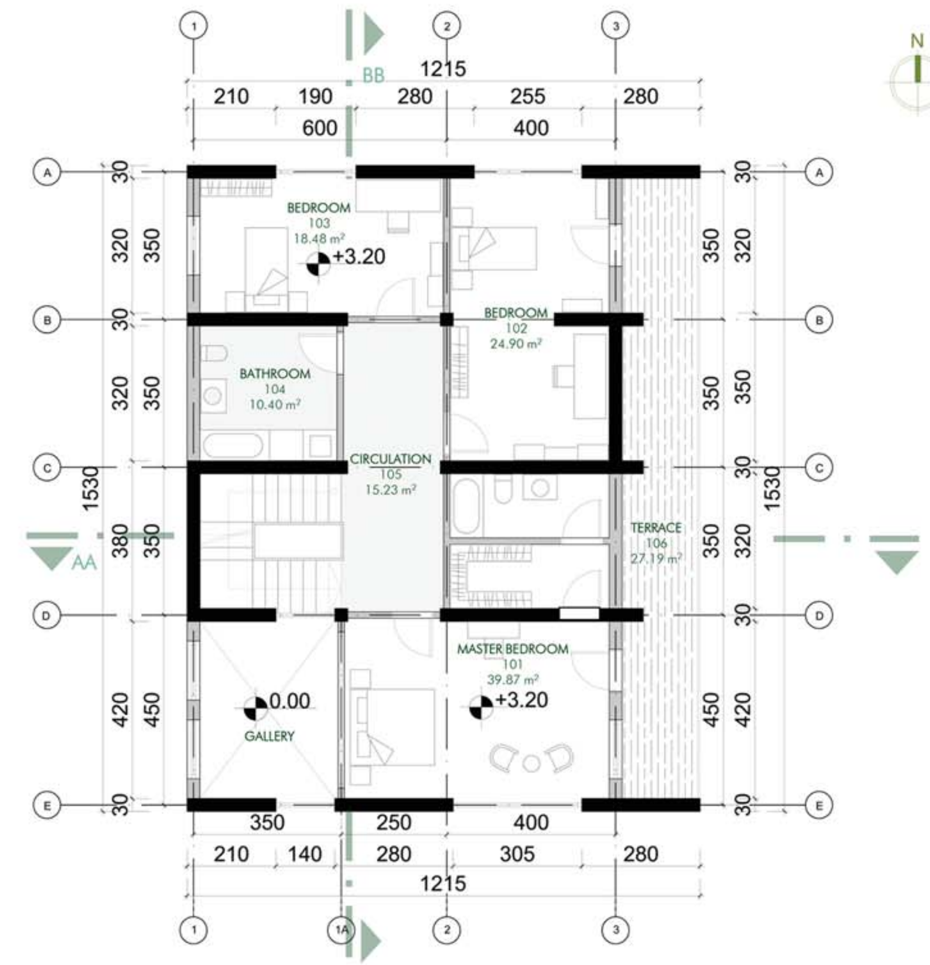
GROUND FLOOR PLAN

+0.00 LEVEL

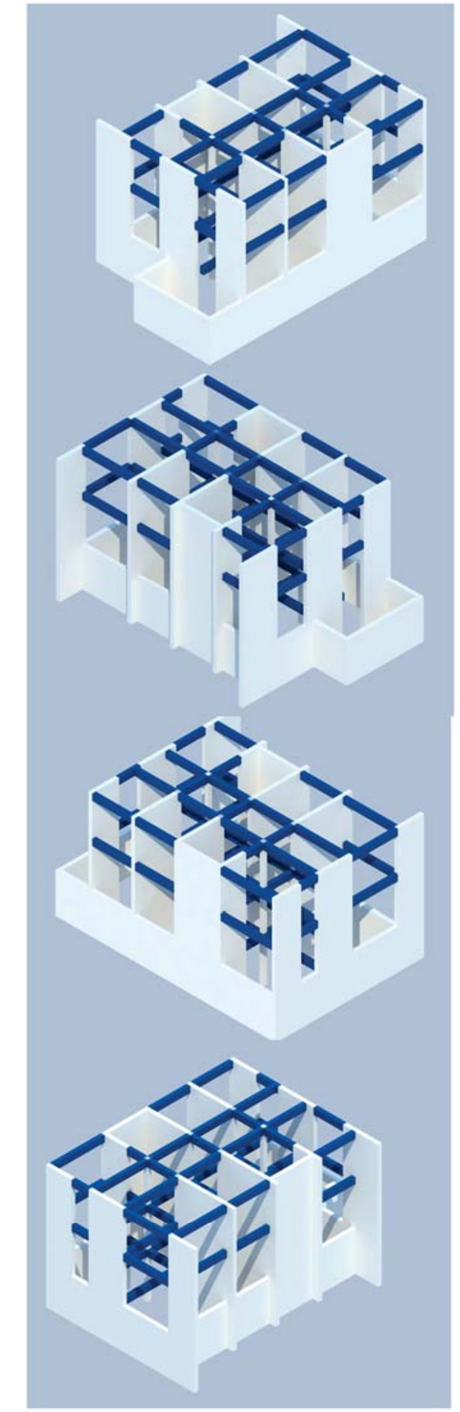


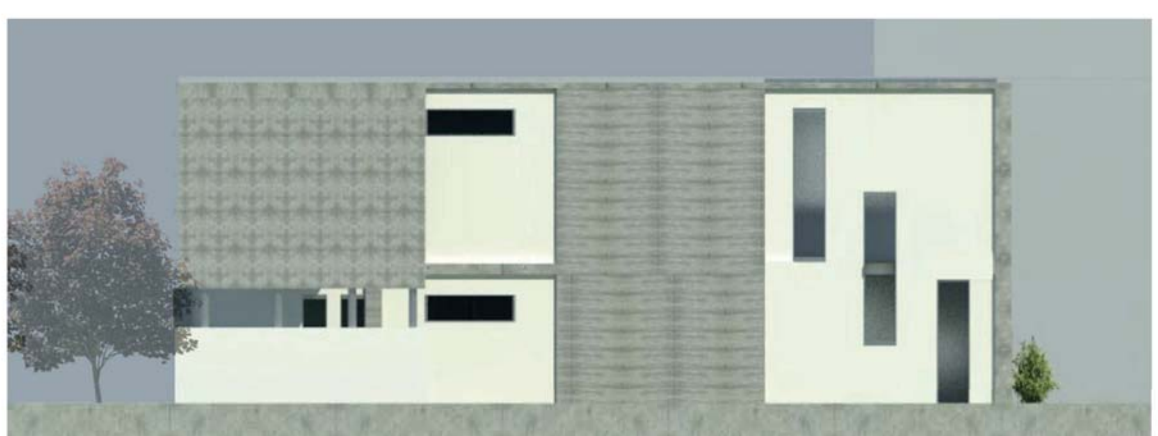
FIRST FLOOR PLAN

+3.20 LEVEL

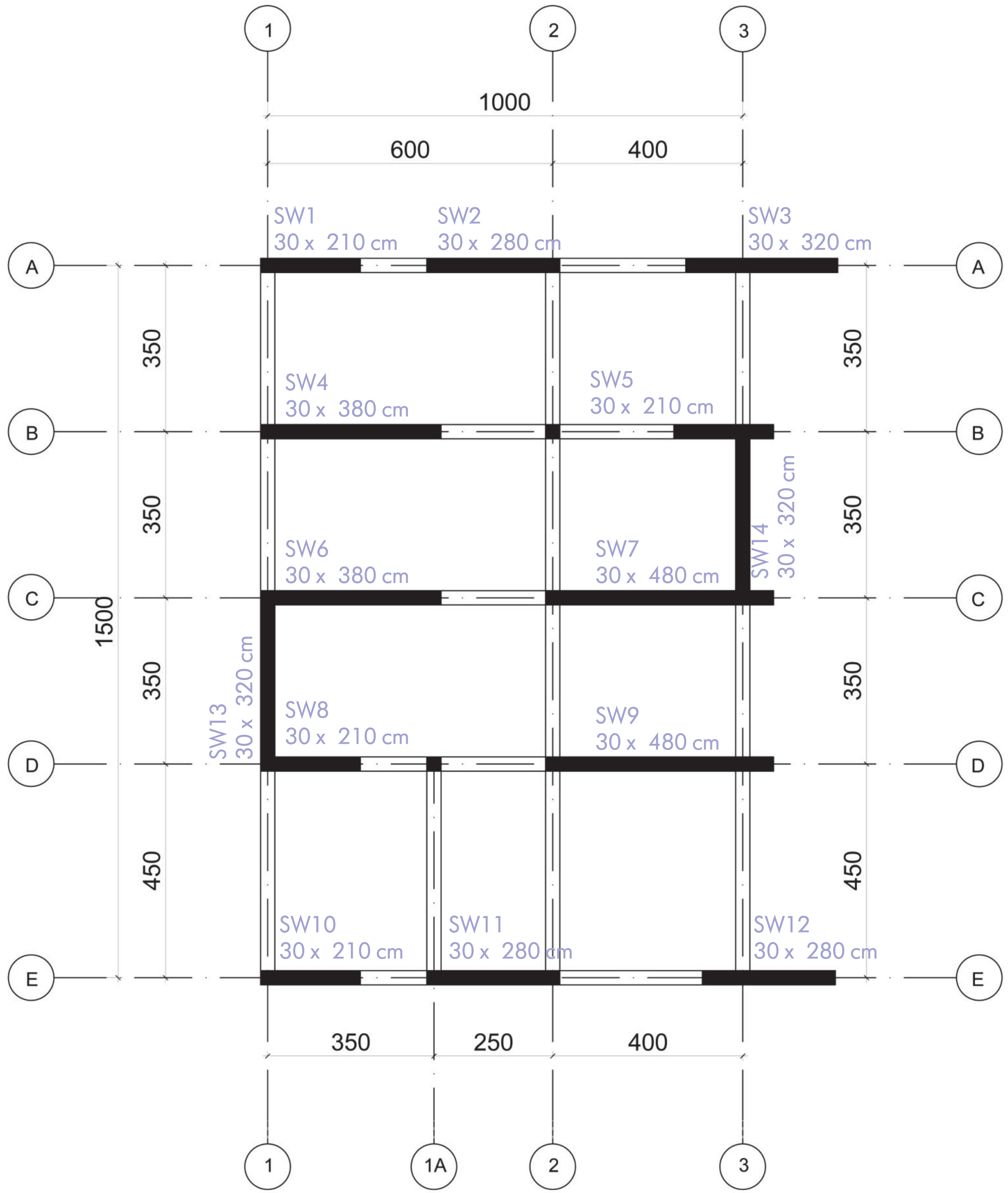



SECTION
BB
+6,40
+0,00
-3,20





SHEAR WALLS
PERCENTAGE & CALCULATIONS



Ground Floor Area : 150,00 m²

First Floor Area : 180,00 m²

Since first floor area is greater than the ground floor area, it is the critical one. Thus, the area of first floor should be utilized during shear wall percentage calculations.

X DIRECTION

Area of Shear Walls on X Direction

[(2,1x4)+(2,8x3)+(3,8x2)+(4,8x2)+(3,2x1)] x 0,3 = 11,16 m²

Ratio of Shear Wall Area to Floor Area on X Direction

11,16 / 180,00 = 0,062 ⟶ 6,2 %

Y DIRECTION

Area of Shear Walls on Y Direction

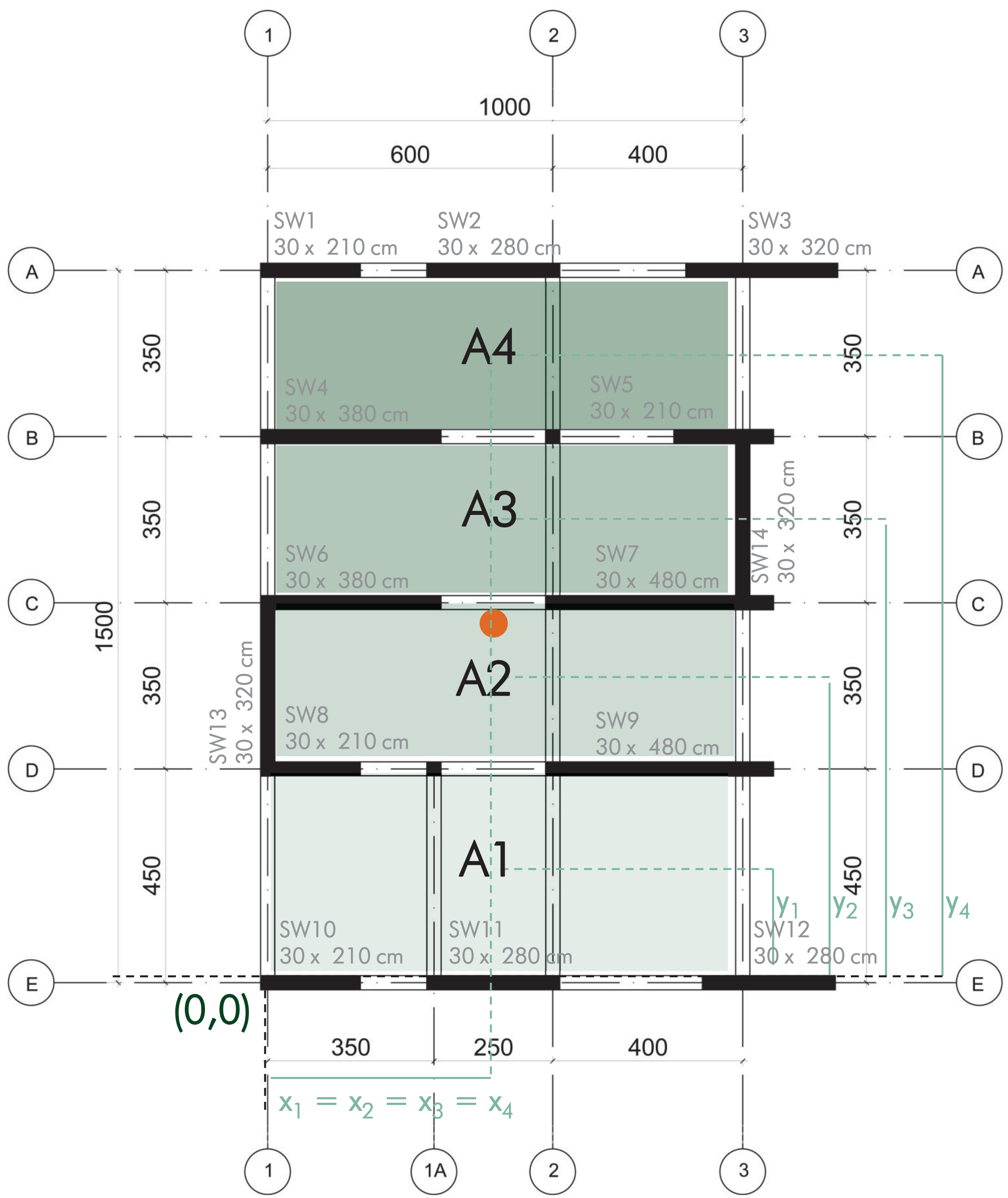
3,2 x 2 x 0,3 = 1,92 m²

Ratio of Shear Wall Area to Floor Area on Y Direction

1,92 / 180,00 = 0,0106 ⟶ 1,1 %

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

6,2 % > 1 %
1,1 % > 1 % . ⟶ **So, total shear wall cross sectional area is within acceptable range.**



Since the plan has a simple geometry, it can be easily understood that geometric center is (5, 7.5). However, the detailed calculations are as follows:

$$C_{GY} = \frac{\Sigma\, C_{iy} \,.\, A_i}{\Sigma .\, A_i} \qquad C_{GX} = \frac{\Sigma\, C_{ix} \,.\, A_i}{\Sigma .\, A_i}$$

$A_1 = 4{,}5 \times 10 = 45\ m^2$ $\quad A_2 = 3{,}5 \times 10 = 35\ m^2$

$A_3 = 3{,}5 \times 10 = 35\ m^2$ $\quad A_4 = 3{,}5 \times 10 = 35\ m^2$

X DIRECTION

$$C_{GX} = \frac{(A_1 \times X_1) + (A_2 \times X_2) + (A_3 \times X_3) + (A_4 \times X_4)}{A_1 + A_2 + A_3 + A_4}$$

$$C_{GX} = \frac{5\,(A_1 + A_2 + A_3 + A_4)}{A_1 + A_2 + A_3 + A_4}$$

$$C_{GX} = 5\ m$$

Y DIRECTION

$$C_{GY} = \frac{(A_1 \times y_1) + (A_2 \times y_2) + (A_3 \times y_3) + (A_4 \times y_4)}{A_1 + A_2 + A_3 + A_4}$$

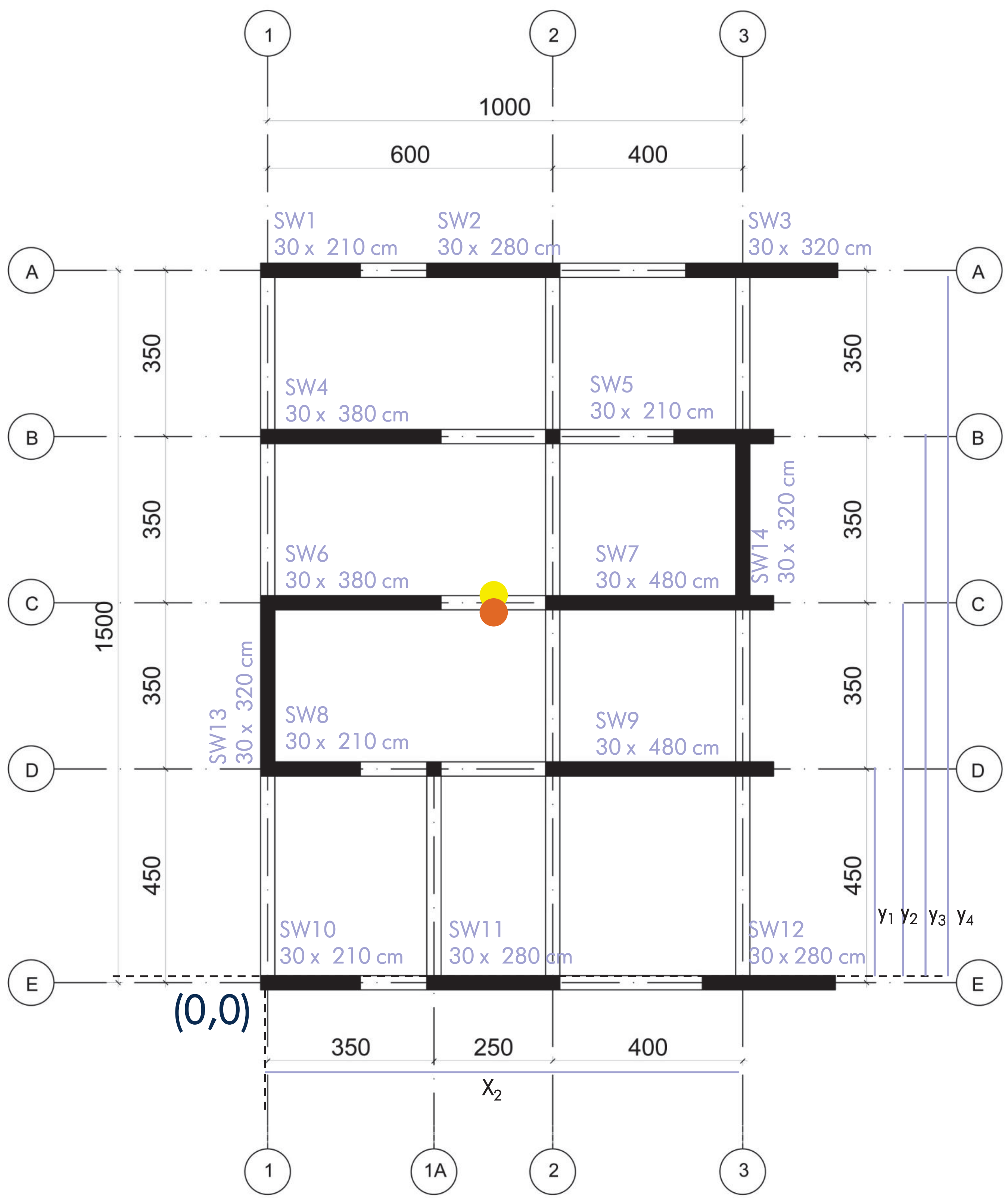
$$C_{GY} = \frac{(45 \times 2.25) + (35 \times 6{,}25) + (35 \times 9{,}75) + (35 \times 13{,}25)}{45 + 35 + 35 + 35}$$

$$C_{GY} = \frac{1125}{150} = 7.5\ m$$

$(C_{GX}, C_{GY}) = (5, 7.5)$

STIFFNESS CENTER

CALCULATIONS



$$C_{GX,Y} = \frac{\Sigma\, I_i \,.\, l_i}{\Sigma\, I_i}$$

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

$$I_{SW\ 1,5,8,10} = 1/12 \times 0,3 \times (2,1)^3 = 0,23\ m^4$$

$$I_{SW\ 2,11,12} = 1/12 \times 0,3 \times (2,8)^3 = 0,54\ m^4$$

$$I_{SW\ 4,6} = 1/12 \times 0,3 \times (3,8)^3 = 1,37\ m^4$$

$$I_{SW\ 7,9} = 1/12 \times 0,3 \times (4,8)^3 = 2,76\ m^4$$

$$I_{SW\ 13,14,3} = 1/12 \times 0,3 \times (3,2)^3 = 0,81\ m^4$$

X DIRECTION

$$C_{SX} = \frac{(X_1 \times I_{13}) + (X_2 \times I_{14})}{I_{13} + I_{14}}$$

$$C_{SX} = \frac{(0 \times 2,76) + (10 \times 2,76)}{2,76 + 2,76}$$

$$C_{SX} = \frac{27,6}{5,52} = 5\ m$$

Y DIRECTION

$$C_{SY} = \frac{[y_1(I_8+I_9)] + [y_2(I_6+I_7)] + [y_3(I_4+I_5)] + [y_4(I_1+I_2+I_3)]}{(I_1+I_2+I_3+I_4+I_5+I_6+I_7+I_8+I_9+I_{10}+I_{11}+I_{12})}$$

$$C_{SY} = \frac{(4,5 \times 2,99) + (8 \times 4,13) + (11,5 \times 1,6) + (15 \times 1,58)}{(0,23 \times 4) + (0,54 \times 3) + (1,37 \times 2) + (2,76 \times 2) + (0,81 \times 1)}$$

$$C_{SY} = \frac{88,64}{11,61} = 7,63\ m$$

$$(C_{GX}, C_{GY}) = (5, 7.63)$$

GEOMETRIC & STIFFNESS CENTERS CHECK

$$0,95 \leq \frac{\overline{Y}}{Y_{SC}} \leq 1,05 \qquad 0,95 \leq \frac{7,50}{7,63} \leq 1,05$$

$$0,95 \leq 1,01 \leq 1,05$$

SELECTION & THICKNESS CALCULATIONS

Selected slab type is solid slab with beams. Since, $l_l / l_s \leq 2$. Then two way solid slab system should be utilised.

CALCULATION STEPS

STEP I

Determine edge ratio (α) for each critical slab.

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

STEP II

By using α value, calculate slab thickness (t) for each critical slab

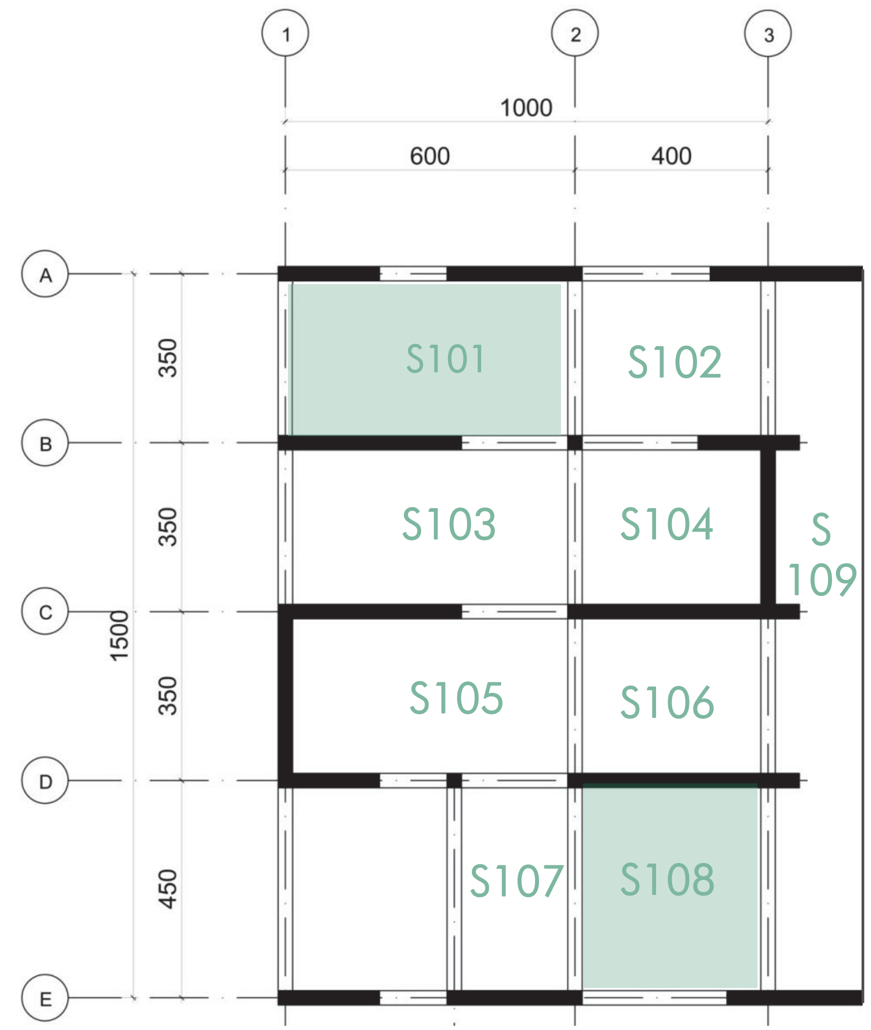
$$t = \frac{l_s}{15 + \frac{20}{l_l / l_s}} \times (1 - \alpha/4)$$

$t \geq 8$ cm,

$t \geq l/30$, $t \geq l/10$ (for cantilever slabs)

STEP III

Comparing found thicknesses, decide the slab thickness.



STEP I: Determining α Values

$A_{S101} = 21 \text{ m}^2$

$$\alpha_{S101} = \frac{6 + 3{,}5 + 6}{6 + 6 + 3{,}5 + 3{,}5} = \frac{15{,}5}{19}$$

$\alpha_{S101} = 0{,}81$

$A_{S108} = 18 \text{ m}^2$

$$\alpha_{S108} = \frac{4 + 4{,}5 + 4{,}5}{4 + 4 + 4{,}5 + 4{,}5} = \frac{13}{17}$$

$\alpha_{S108} = 0{,}76$

STEP II: Calculation of slab thicknesses

$$t_{S101} \geq \frac{3{,}5}{15 + \frac{20}{6 / 3{,}5}} \times (1 - 0{,}81/4)$$

$$t_{S101} \geq \frac{3{,}5}{26{,}69} \times (0{,}80)$$

$t_{S101} \geq 0{,}104$ m = <u>10,40 cm</u>

$$t_{S108} \geq \frac{4}{15 + \frac{20}{4{,}5 / 4}} \times (1 - 0{,}76/4)$$

$$t_{S108} \geq \frac{4}{32{,}77} \times (0{,}81)$$

$t_{S108} \geq 0{,}0972$ m = <u>9,72 cm</u>

STEP III: Determining slab thickness

Since the most critical slab is S101, Slab thickness should be larger than 10,40 cm.

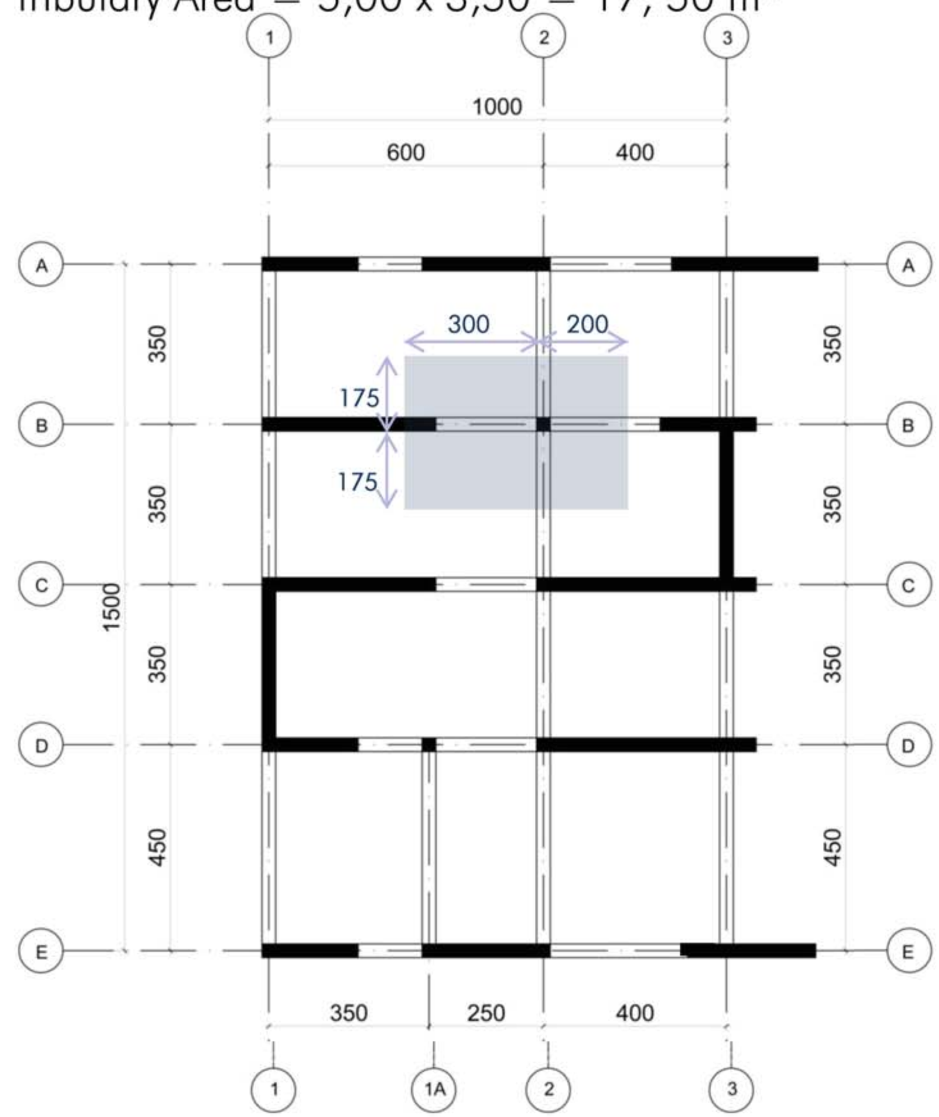
So, t = 11 cm

TRIBUTARY AREA & MINIMUM COLUMN AREA CALCULATIONS

TRIBUTARY AREA

Column 2B is selected since it is the column which have the largest tributary area.

Tributary Area = 5,00 x 3,50 = 17, 50 m^2



Total Load (N_d) :

(N_d) = (16600 x 3) + 12404 + 11018

(N_d) = 73222 kg

$$Ac \geq \frac{N_d}{0,75 \times f_{cd}} \qquad Ac \geq \frac{73222}{0,75 \times 130}$$

$Ac \geq 750,99\ cm^2$

LOADS

Dead Load of Solid Slabs .

Own Weight:	0,110 x 2,4 =	0,26 t/m^2	Load for Slabs: 0,45 t/m^2
Leveling:	0,040 x 2,4 =	0,09 t/m^2	
Covering:	0,025 x 2,0 =	0,05 t/m^2	
Plastering:	0,020 x 2,0 =	0,04 t/m^2	

Live Load:

0,2 t/m^2 for residential buildings

Total load: 0,45 x 1,4 + 0,2 x 1,6 = 0,95 t/m^2

Slab Load on the Tributary Area:

Load x tributary area = 0,95 x 17,5 = 16,6 t

Dead Load of Walls.

Wall Load: 450 kg/m^2 =0,45 t/m^2

Floor-to-Floor Height: 3,2 m & Assumed Beam Depth: 450 / 12,5 = 0,36 m

To be on the safe side, a greater beam depth than 0,36 is chosen. (0,48 m)

Wall Height: 3,2 – 0,48 = 2,72 m

Wall Load on the Tributary Area for Ground Floor:

[(wall height x wall length) – (door height x door length)] x wall load

[(2,72 x 8,05) – (2,2 x 1)] x 0,45 = 8,86 t

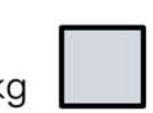
Wall Load x Load Factor: 8,86 x 1,4 = 12,404 t = 12404 kg

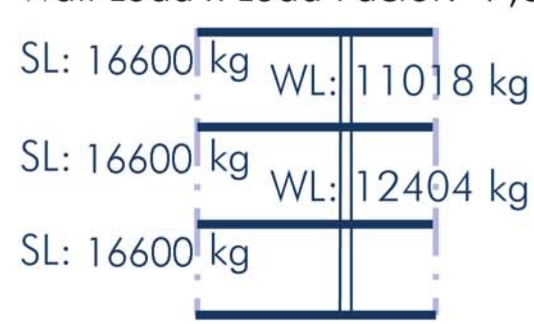
Wall Load on the Tributary Area for First Floor:

[(wall height x wall length) – (door height x door length)] x wall load

[(2,72 x 8,05) – (2,2 x 1 x 2)] x 0,45 = 7,87 t

Wall Load x Load Factor: 7,87 x 1,4 = 11,018 t = 11018 kg



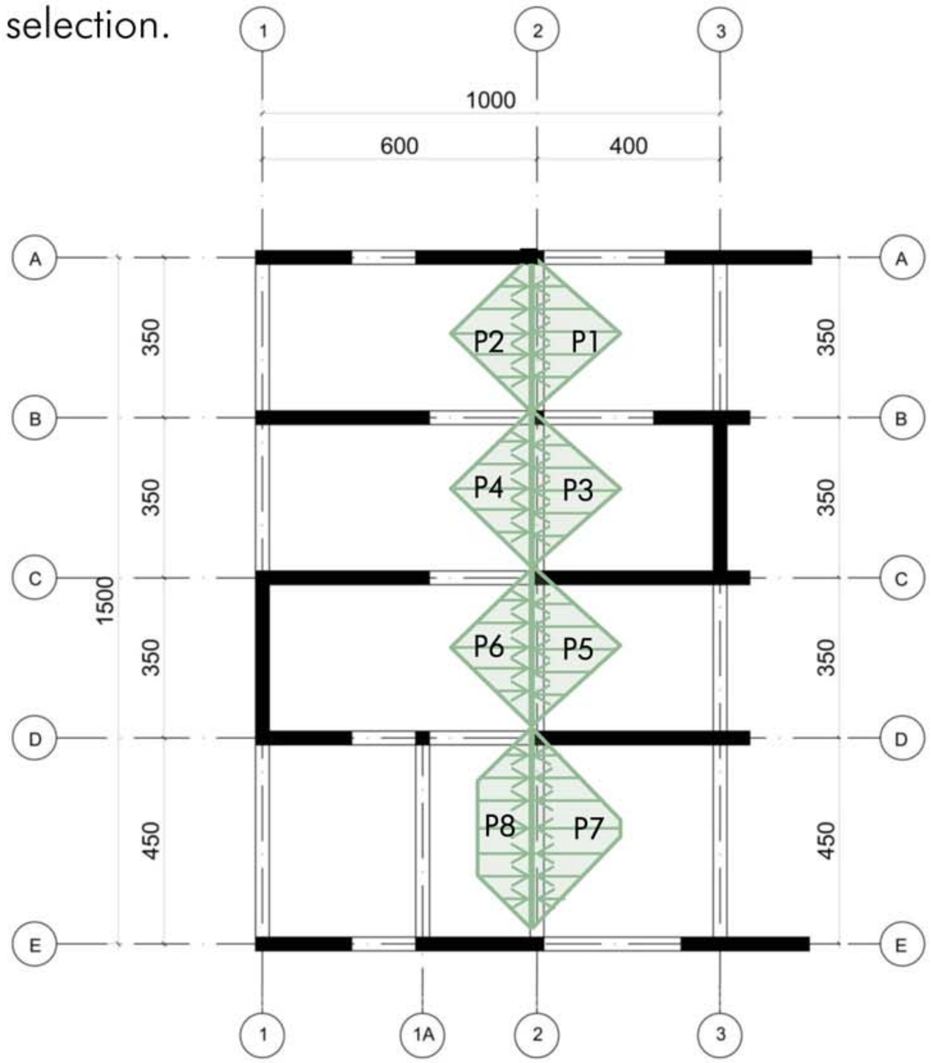


Column cross section area should be larger than 750 cm^2. To be on the safe side columns dimensions are chosen as **30 x 30 cm** with a cross section area of **900 cm^2**.

BEAM ANALYSIS

LOAD TRANSFERS

The beam on axis 2 is selected to be analyzed since it has the least amount of shear walls. Span length is also taken into consideration during selection.



$$P = P_d \times \frac{L_{short}}{3} \times \left[1{,}5 - \frac{0{,}5}{(L_{long}/L_{short})^2}\right]$$

$$P = P_d \times \frac{L_{short}}{3}$$

P_d = (Dead Load x Load Factor) + (Live Load x Load Factor)

P_d = (0,45 x 1,4) + (0,2 x 1,6)

P_d = 0,95 t/m ^{2}

$P_1 = P_3 = P_5$, $P_2 = P_4 = P_6$

Floor-to-Floor Height: 3,2 m & Assumed Beam Depth: 450 / 12,5 ≅ 0,48m

Wall Height: 3,2 – 0,48 = 2,72 m

Dist. Wall Load on Beam = Wall Height x Wall Load x Dead Load Factor
= 2,72 x 0,45 x 1,4
= 1,71 t/m

Beam's Own Weight (W_b) = Volume of beam x 2,4 x Dead Load Factor

$W_{b\ (A\text{-}B\ ,\ B\text{-}C\ ,C\text{-}D)}$ = 0,48 x 0,30 x 3,5 x 2,4 x 1,4 = 1,69 t

$W_{b\ (A\text{-}B\ ,\ B\text{-}C\ ,C\text{-}D)}$ / 3,5 = 0,48 t/m

$W_{b\ (D\text{-}E)}$ = 0,48 x 0,30 x 4,5 x 2,4 x 1,4 = 2,17 t

$W_{b\ (D\text{-}E)}$ / 4,5 = 0,48 t/m

Loads on Beams 2 A-B, 2 B-C and 2 C-D

$$P_1 = P_2 = P_3 = P_4 = P_5 = P_6 = 0{,}95 \times \frac{3{,}5}{3} = 1{,}10 \text{ t/m}$$

So, loads on Beams 2A-B, 2B-C, 2C-D are all equal and 1,10 t/m.

$P_1 + P_2$ + Wall Load + Beam's Own Weight

1,10 + 1,10 +1,71 + 0,48 = 4,39 t/m

Loads on Beam 2 D-E

$$P_7 = 0{,}95 \times \frac{4{,}0}{3} \times \left[1{,}5 - \frac{0{,}5}{(4{,}5/4)^2}\right]$$

P_7 = 1, 39 t/m

$$P_8 = 0{,}95 \times \frac{2{,}5}{3} \times \left[1{,}5 - \frac{0{,}5}{(4{,}5/2{,}5)^2}\right]$$

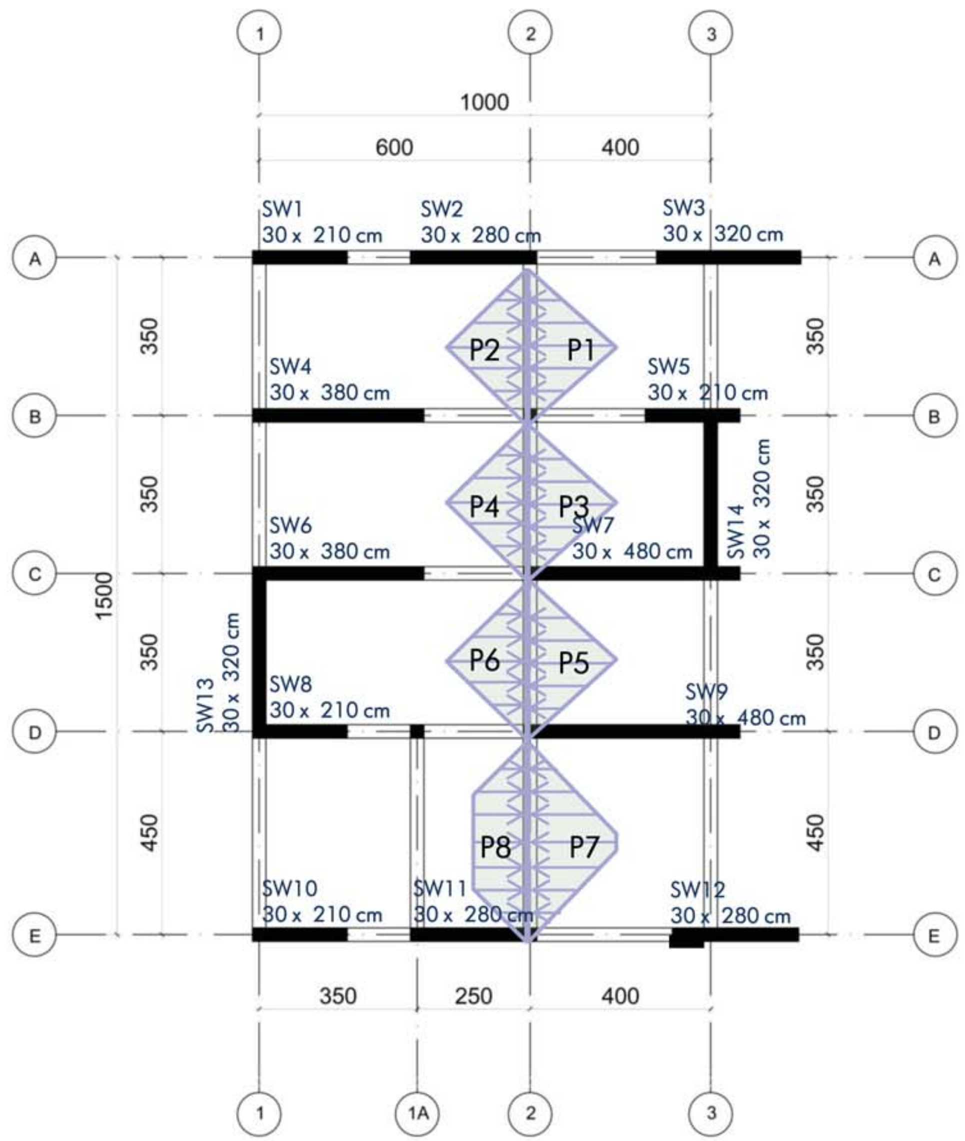
P_8 = 1, 06 t/m

So, loads on Beam 2D-E is:

$P_7 + P_8$ + Wall Load + Beam's Own Weight

1,39 + 1,06 + 1,71 + 0,48 = 4,64 t/m

MOMENT OF INERTIA & LOAD DISTRIBUTION FACTORS IA



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

$$I_{beam} = 1/12 \times (0{,}30) \times (0{,}48)^3 = 2{,}76 \times 10^{-3}\ m^4$$

$$I_{colB2} = 1/12 \times (0{,}30) \times (0{,}30)^3 = 6{,}75 \times 10^{-4}\ m^4$$

$$I_{SW2} = I_{SW11} = 1/12 \times (2{,}80) \times (0{,}30)^3 = 6{,}30 \times 10^{-3}\ m^4$$

$$I_{SW7} = I_{SW9} = 1/12 \times (4{,}80) \times (0{,}30)^3 = 0{,}0108\ m^4$$

$$R_{ED} = \frac{I_{beamED} / L_1}{I_{beamED} / L_1 + I_{SW11} / L_5 + I_{SW11} / L_5}$$

$$R_{ED} = \frac{(2{,}76 \times 10^{-3} / 4{,}5)}{(2{,}76 \times 10^{-3} / 4{,}5) + (6{,}30 \times 10^{-3}/3{,}2) \times 2 + (6{,}30 \times 10^{-3}/3{,}2)}$$

$$R_{ED} = 0{,}13$$

$$R_{DE} = \frac{I_{beamED} / L_1}{I_{beamED} / L_1 + I_{beamDC} / L_2 + I_{SW9} / L_5 + I_{SW9} / L_5}$$

$$R_{DE} = \frac{2{,}76 \times 10^{-3} / 4{,}5}{(2{,}76 \times 10^{-3}/4{,}5) + (2{,}76 \times 10^{-3}/3{,}5) + (0{,}0108/3{,}2) + (0{,}0108/3{,}2)}$$

$$R_{DE} = 0{,}075$$

$$R_{DC} = \frac{I_{beamDC} / L_2}{I_{beamED} / L_1 + I_{beamDC} / L_2 + I_{SW9} / L_5 + I_{SW9} / L_5}$$

$$R_{DC} = \frac{(2{,}76 \times 10^{-3} / 3{,}5)}{(2{,}76 \times 10^{-3}/4{,}5) + (2{,}76 \times 10^{-3} / 3{,}5) + (0{,}0108/3{,}2) + (0{,}0108/3{,}2)}$$

$$R_{DC} = 0{,}096$$

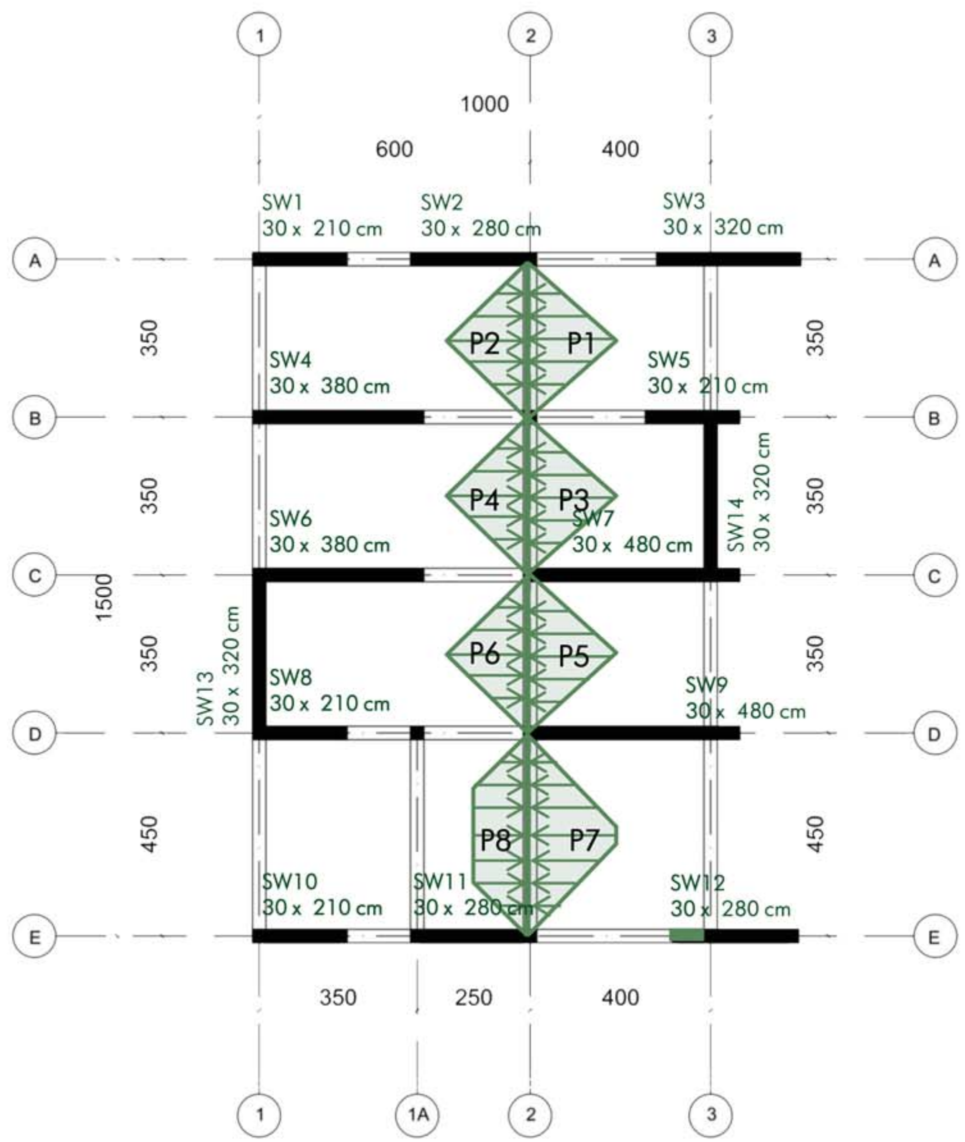
$$R_{CD} = \frac{I_{beamDC} / L_2}{I_{beamDC} / L_2 + I_{beamCB} / L_3 + I_{SW7} / L_5 + I_{SW7} / L_5}$$

$$R_{CD} = \frac{(2{,}76 \times 10^{-3} / 3{,}5)}{(2{,}76 \times 10^{-3} / 3{,}5) + (2{,}76 \times 10^{-3} / 3{,}5) + (0{,}0108/3{,}2) + (0{,}0108/3{,}2)}$$

$$R_{CD} = 0{,}094$$

BEAM ANALYSIS

MOMENT OF INERTIA & LOAD DISTRIBUTION FACTORS IB



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

$$I_{beam} = 1/12 \times (0{,}30) \times (0{,}48)^3 = 2{,}76 \times 10^{-3}\ m^4$$

$$I_{colB2} = 1/12 \times (0{,}30) \times (0{,}30)^3 = 6{,}75 \times 10^{-4}\ m^4$$

$$I_{SW2\ ,SW11} = 1/12 \times (2{,}80) \times (0{,}30)^3 = 6{,}30 \times 10^{-3}\ m^4$$

$$I_{SW7\ ,\ SW9} = 1/12 \times (4{,}80) \times (0{,}30)^3 = 0{,}0108\ m^4$$

$$R_{CB} = \frac{I_{beamCB} / L_3}{I_{beamDC} / L_2 + I_{beamCB} / L_3 + I_{SW7} / L_5 + I_{SW7} / L_5}$$

$$R_{CB} = \frac{(2{,}76 \times 10^{-3}/3{,}5)}{(2{,}76 \times 10^{-3}/3{,}5) + (2{,}76 \times 10^{-3}/3{,}5) + (0{,}0108/3{,}2) + (0{,}0108/3{,}2)}$$

$$R_{CB} = 0{,}094$$

$$R_{BC} = \frac{I_{beamCB} / L_3}{I_{beamCB} / L_3 + I_{beamBA} / L_4 + I_{colB2} / L_5 + I_{colB2} / L_5}$$

$$R_{BC} = \frac{(2{,}76 \times 10^{-3}/3{,}5)}{(2{,}76 \times 10^{-3}/3{,}5) + (2{,}76 \times 10^{-3}/3{,}5) + (6{,}75 \times 10^{-4}/3{,}2) \times (6{,}75 \times 10^{-4}/3{,}2)}$$

$$R_{BC} = 0{,}094$$

$$R_{BA} = \frac{I_{beamBA} / L_4}{I_{beamCB} / L_3 + I_{beamBA} / L_4 + I_{colB2} / L_5 + I_{colB2} / L_5}$$

$$R_{BA} = \frac{(2{,}76 \times 10^{-3}/3{,}5)}{(2{,}76 \times 10^{-3}/3{,}5) + (2{,}76 \times 10^{-3}/3{,}5) + (6{,}75 \times 10^{-4}/3{,}2) \times (6{,}75 \times 10^{-4}/3{,}2)}$$

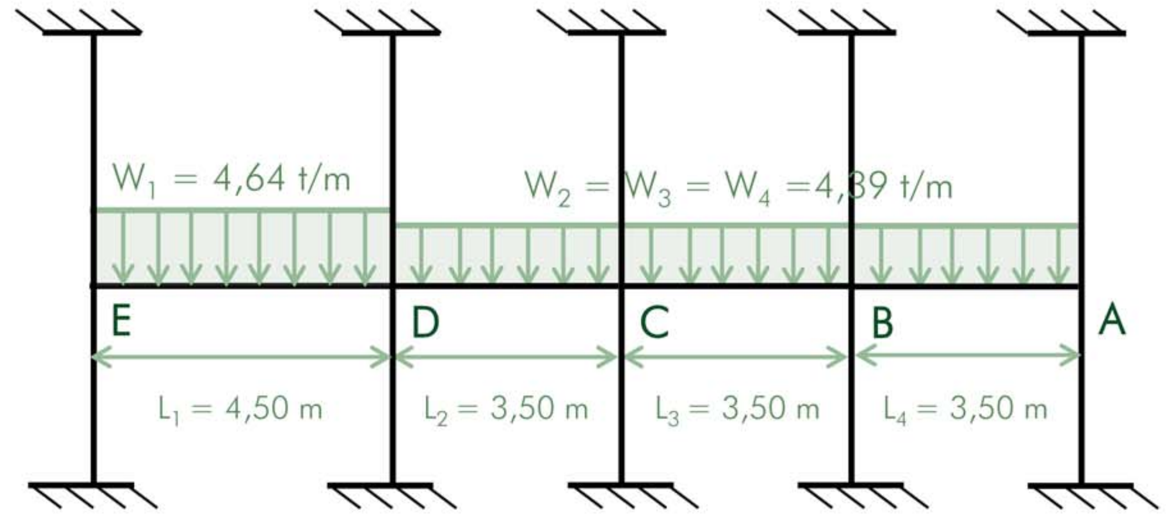
$$R_{BA} = 0{,}094$$

$$R_{AB} = \frac{I_{beamBA} / L_4}{I_{beamBA} / L_4 + I_{SW2} / L_5 + I_{SW2} / L_5}$$

$$R_{AB} = \frac{(2{,}76 \times 10^{-3} / 3{,}5)}{(2{,}76 \times 10^{-3} / 3{,}5) + (6{,}30 \times 10^{-3}/3{,}2) + (6{,}30 \times 10^{-3}/3{,}2)}$$

$$R_{AB} = 0{,}16$$

TWO CYCLE METHOD I



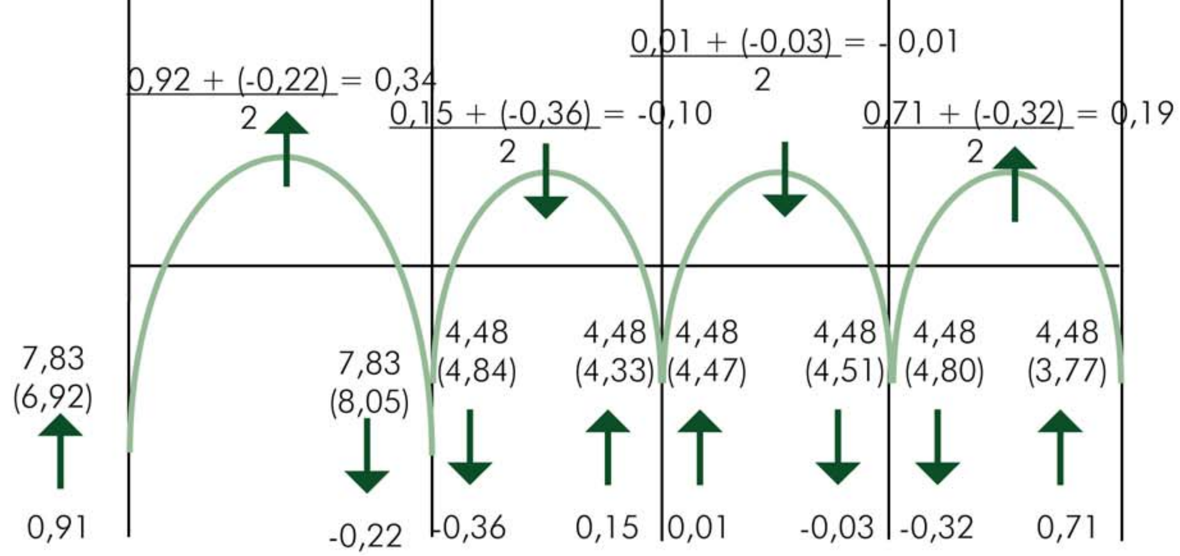
$$FEM_{ED} = \frac{4{,}64 \times (4{,}5)^2}{12} = 7{,}83 \text{ t.m}$$

$$FEM_{DC} = FEM_{CB} = FEM_{BA} = \frac{4{,}39 \times (3{,}5)^2}{12} = 4{,}48 \text{ t.m}$$

$$M_{midspanED} = \frac{4{,}64 \times (4{,}5)^2}{24} = 3{,}91 \text{ t.m}$$

$$M_{midspan\,CB,BA,DC} = \frac{4{,}39 \times (4{,}5)^2}{24} = 2{,}24 \text{ t.m}$$

r	0,13	0,075	0,096	0,094	0,094	0,094	0,094	0,16
FEM	7,83	-7,83	4,48	-4,48	4,48	-4,48	4,48	-4,48
1st Cycle	0,12	-0,50	0	0,16	0	0	0,35	0
Σ	7,95	-8,33	4,48	-4,32	4,48	-4,48	4,83	-4,48
2nd Cycle	-1,03	0,28	0,36	-0,01	-0,01	-0,03	-0,03	0,71
Σ	6,92	-8,05	4,84	-4,33	4,47	-4,51	4,80	-3,77



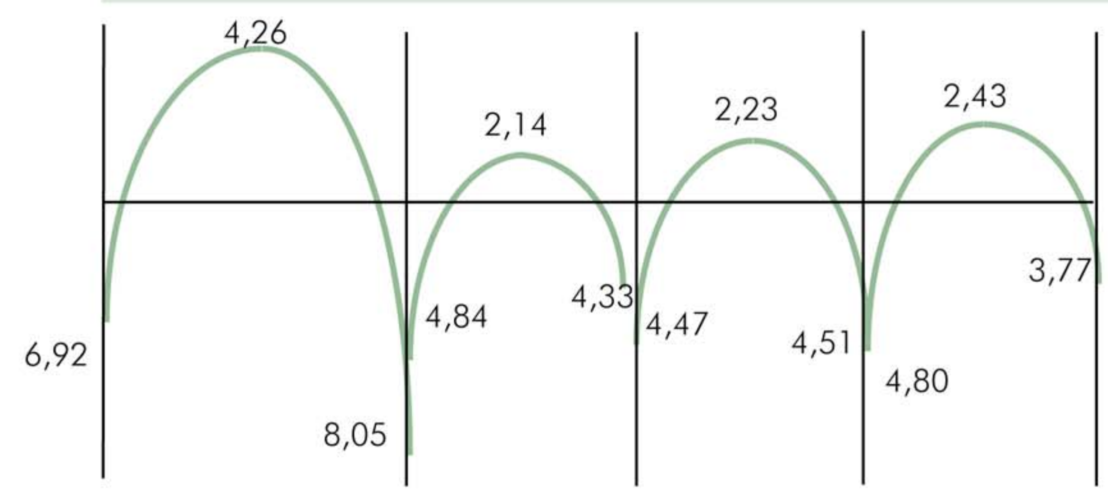
$$K_0 = \frac{b_w \times (d)^2}{M_{max}} = \frac{30 \times (d)^2}{805000}$$

$K_0 = 0{,}025$ $b_w = 30$ cm

$M_{max} = 8{,}05$ tm $= 805000$ kg.cm

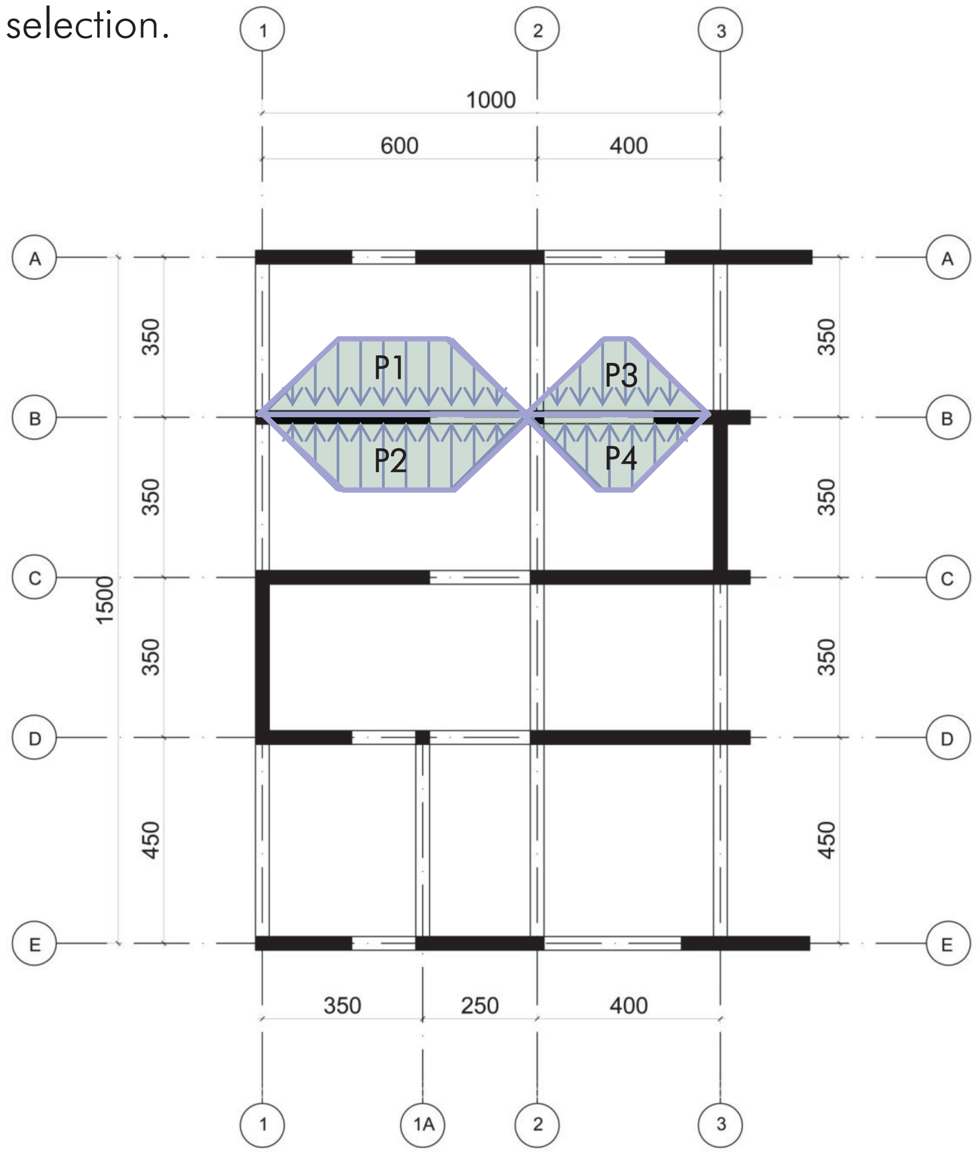
$d = 25{,}90$ cm, $h = d + 5$ (clear cover) So, $h = 30{,}90$ cm

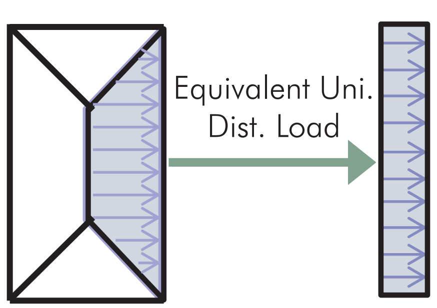
Beam depth found as the result of first two cycle method was 18,50 cm. The second two cycle method gives the depth as 30,90 cm. Since beam depth should be as three times larger than slab thickness (3 x 11), **the beam depth is selected as 35 cm.**



BEAM ANALYSIS
LOAD TRANSFERS

The beam on axis B is selected to be analyzed since it has the least amount of shear walls. Span length is also taken into consideration during selection.





$$P = P_d \times \frac{L_{short}}{3} \times \left[1,5 - \frac{0,5}{(L_{long}/L_{short})^2}\right]$$

$$P = Pd \times \frac{L_{short}}{3} \times \left[1,5 - \frac{0,5}{(L_{long} / L_{short})^2}\right]$$

$P_d = (DL \times 1,4) + (LL \times 1,6)$
$P_d = (0,45 \times 1,4) + (0,2 \times 1,6)$
$P_d = 0,95\ t/m^2$

Wall Load = wall height x 0,45 x 1,4
= 2,72 x 0,45 x 1,4
= 1,71 t/m

Beam's Own Weight = Volume x 2,4 x Dead Load Factor
$W_{b\,(1\text{-}2)}$ = 0,48 x 0,30 x 6 x 2,4 x 1,4 = 2,90 t
$W_{b\,(1\text{-}2)}$ / 6 = 0,48 t/m
$W_{b\,(2\text{-}3)}$ = 0,48 x 0,30 x 4 x 2,4 x 1,4 = 1,93 t
$W_{b\,(2\text{-}3)}$ / 4 = 0,48 t/m

Loads on Beam B1-2

$$P_1 = P_2 = 0,95 \times \frac{3,5}{3} \times \left[1,5 - \frac{0,5}{(6/3,5)^2}\right]$$

= 1, 47 t/m

So, load on Beam B1-2 are:
1,47 + 1,47 +1,71 + 0,48= 5,13 t/m

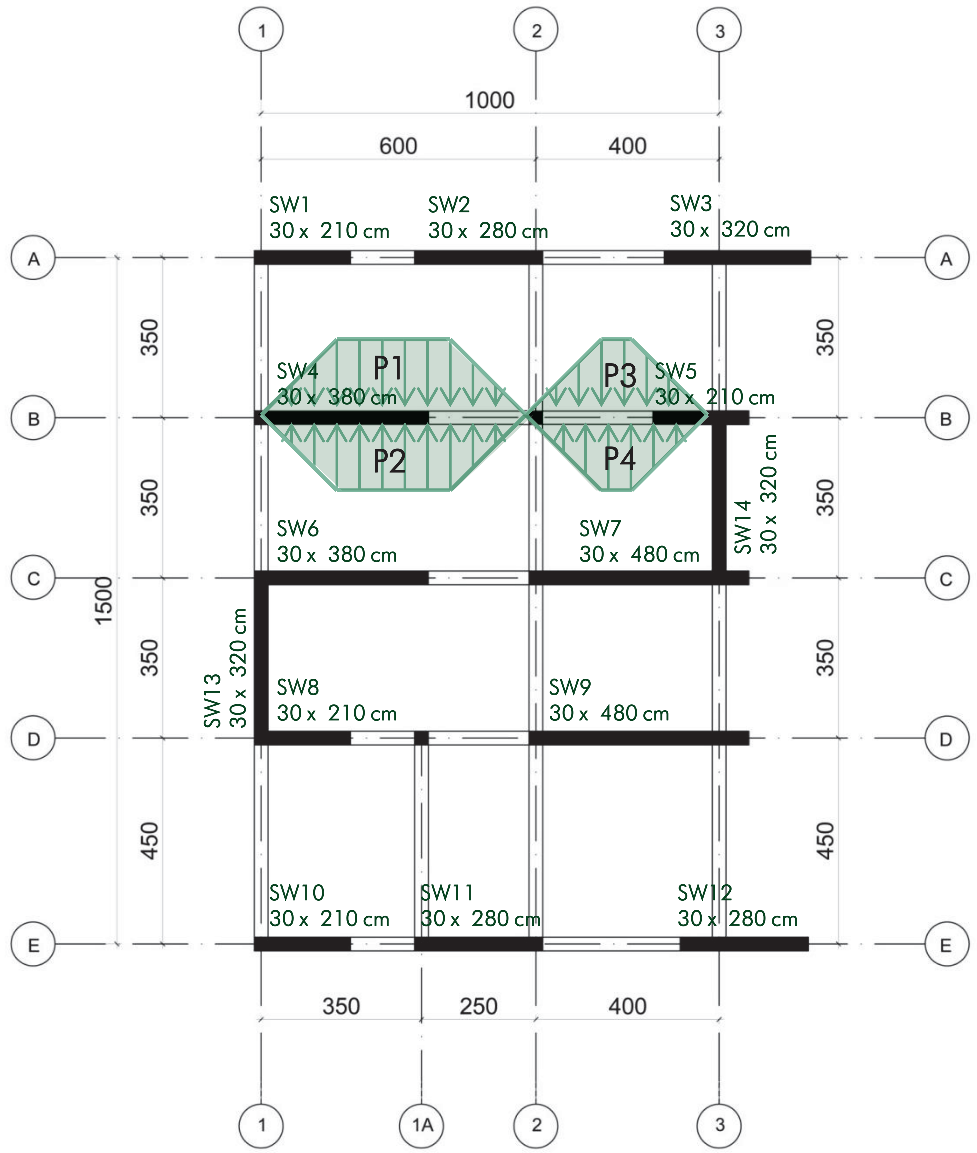
Loads on Beam B2-3

$$P_2 = P_3 = 0,95 \times \frac{3,5}{3} \times \left[1,5 - \frac{0,5}{(4/3,5)^2}\right]$$

= 1, 23 t/m

So, loads on Beam B2-3 are:
$P_2 + P_2 +$ Wall Load + Beam's Own Weight
1,23 + 1,23 + 1,71 + 0,48 = 4,65 t/m

MOMENT OF INERTIA & LOAD DISTRIBUTION FACTORS I



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

$$I_{beam} = 1/12 \times (0{,}30) \times (0{,}48)^3 = 2{,}76 \times 10^{-3}\ m^4$$

$$I_{colB2} = 1/12 \times (0{,}30) \times (0{,}30)^3 = 6{,}75 \times 10^{-4}\ m^4$$

$$R_{12} = 0$$

$$R_{21} = \frac{I_{beam12} / L_1}{I_{beam12} / L_1 + I_{beam23} / L_2 + I_{colB2} / L_3 + I_{colB2} / L_3}$$

$$R_{21} = \frac{2{,}76 \times 10^{-3} / 2{,}2}{(2{,}76 \times 10^{-3} / 2{,}2) + (2{,}76 \times 10^{-3} / 1{,}90) + (6{,}75 \times 10^{-4} / 3{,}2) + (6{,}75 \times 10^{-4} / 3{,}2)}$$

$$R_{21} = 0{,}40$$

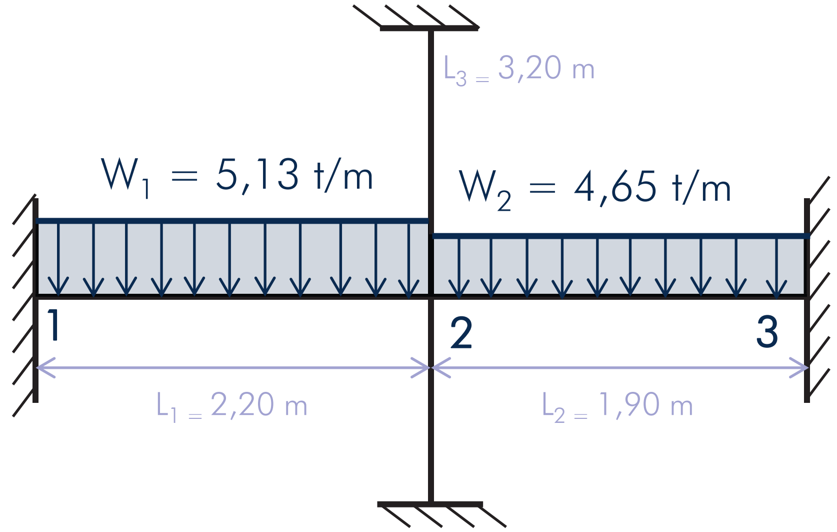
$$R_{23} = \frac{I_{beam23} / L_2}{I_{beam23} / L_2 + I_{beam12} / L_1 + I_{colB2} / L_3 + I_{colB2} / L_3}$$

$$R_{23} = \frac{(2{,}76 \times 10^{-3} / 1{,}9)}{(2{,}76 \times 10^{-3} / 1{,}9) + (2{,}76 \times 10^{-3} / 2{,}2) + (6{,}75 \times 10^{-4} / 3{,}2) + (6{,}75 \times 10^{-4} / 3{,}2)}$$

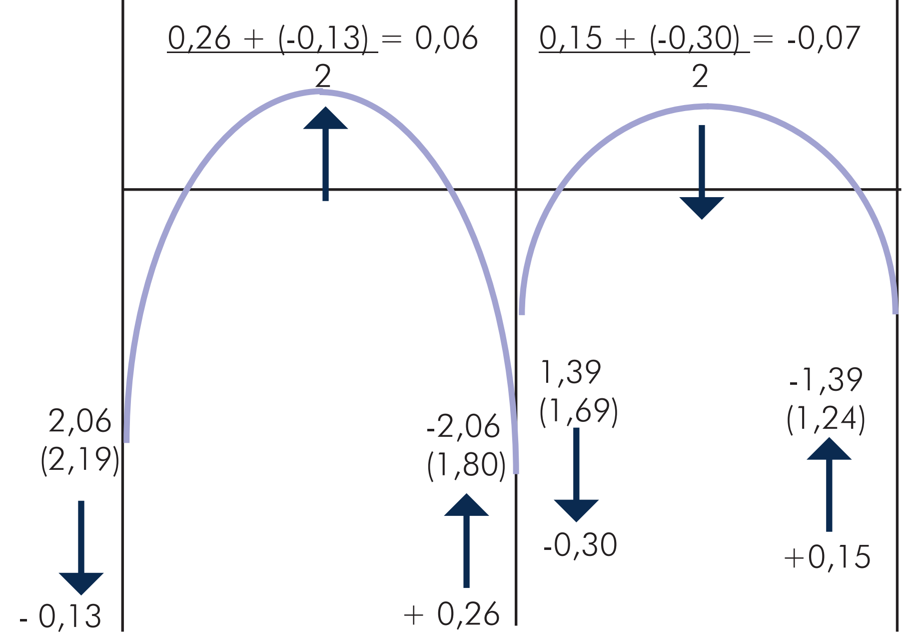
$$R_{23} = 0{,}46$$

$$R_{32} = 0$$

TWO CYCLE METHOD II



r	0	0,40	0,46	0
FEM	2,06	-2,06	1,39	-1,39
1st Cycle	0,13	0	0	0,15
Σ	2,19	-2,06	1,39	-1,24
2nd Cycle	0	0,26	0,30	0
Σ	2,19	-1,80	1,69	-1,24



$$FEM_{12} = FEM_{21} = \frac{W_1 \times (L_1)^2}{12} = \frac{5,13 \times (2,2)^2}{12} = 2,06 \text{ t.m}$$

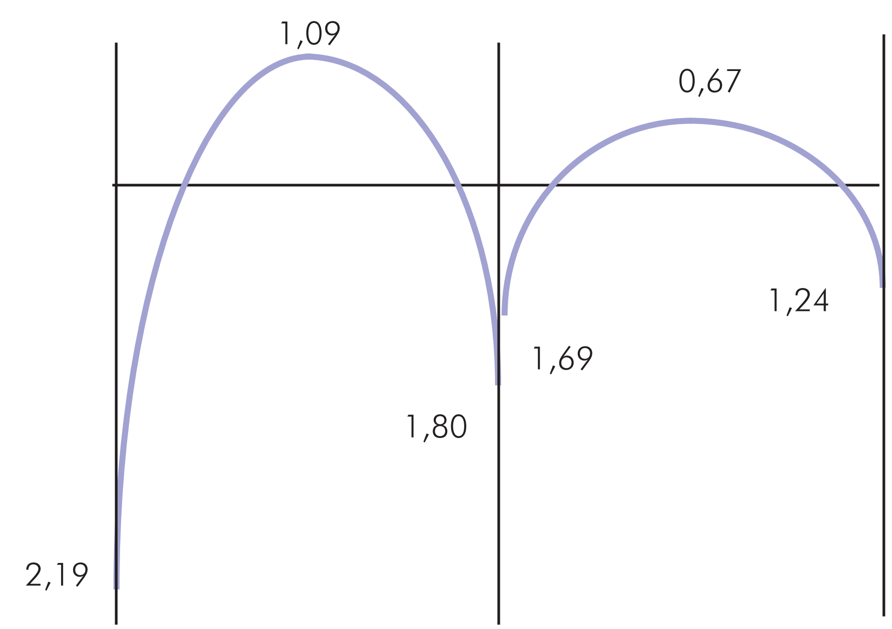
$$FEM_{23} = FEM_{32} = \frac{W_1 \times (L_1)^2}{12} = \frac{4,65 \times (1,9)^2}{12} = 1,39 \text{ t.m}$$

$$M_{midspan12} = \frac{W_1 \times (L_1)^2}{24} = \frac{5,13 \times (2,2)^2}{24} = 1,03 \text{ t.m}$$

$$M_{midspan23} = \frac{W_2 \times (L_2)^2}{24} = \frac{4,65 \times (1,9)^2}{24} = 0,69 \text{ t.m}$$

$$K_0 = \frac{b_w \times (d)^2}{M_{max}} = \frac{30 \times (d)^2}{219000}$$

$K_0 = 0,025$ $b_w = 30$ cm
$M_{max} = 2,19$ tm $= 219000$ kg.cm
$d = 13,50$ cm, $h = 13,50 + 5$ (clear cover),
$h = 18,50$ cm



h ≥ 3 x slab thickness (t)

As this condition should be fulfilled, h should at least be larger than 33 cm (11 x 3).

As another beam depth will be calculated via the second two cycle method, beam depth will be decided afterwards.