METU | ARCH332 Structural Design in Architecture II *2017-2018 Spring*

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Project 19

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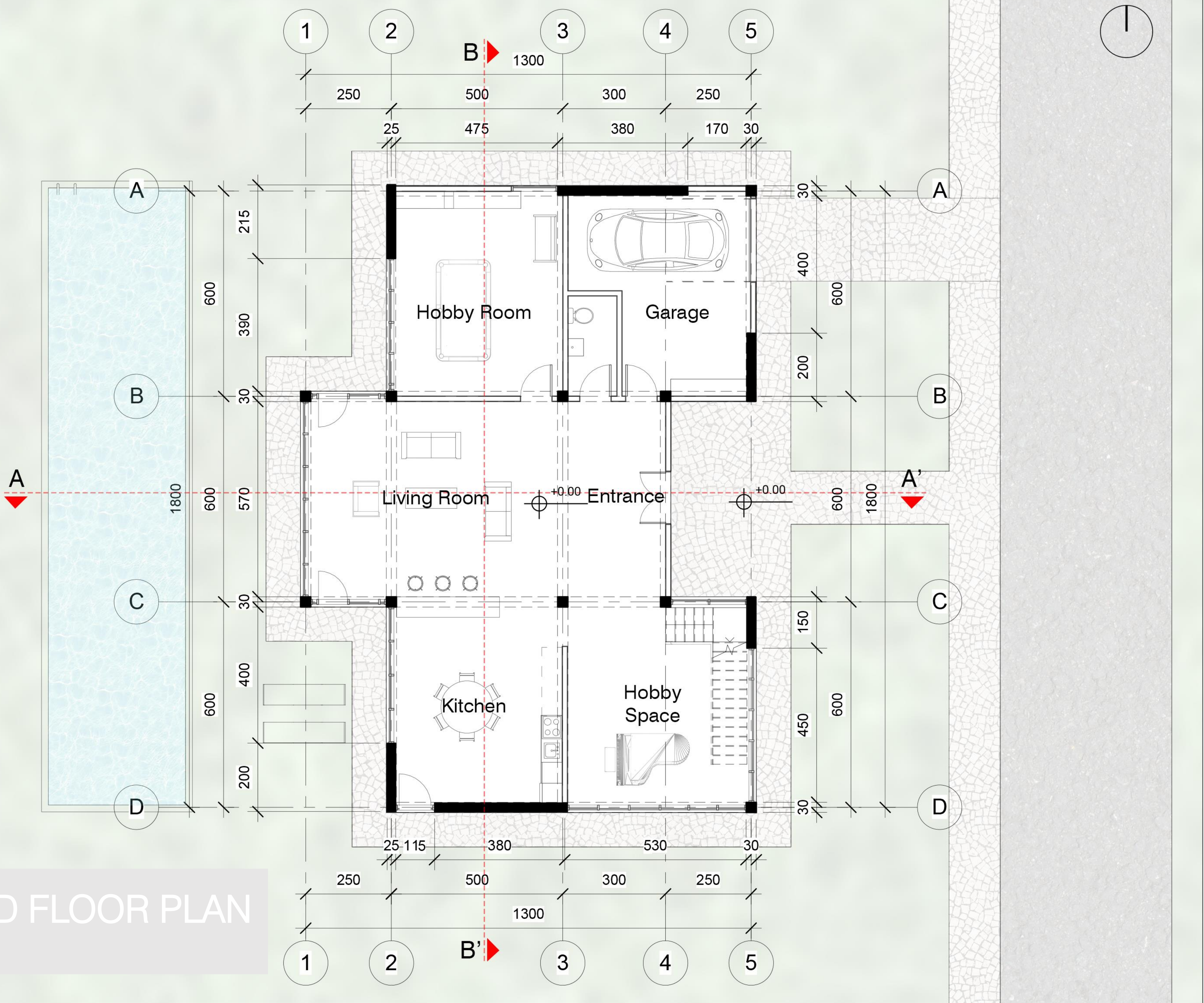
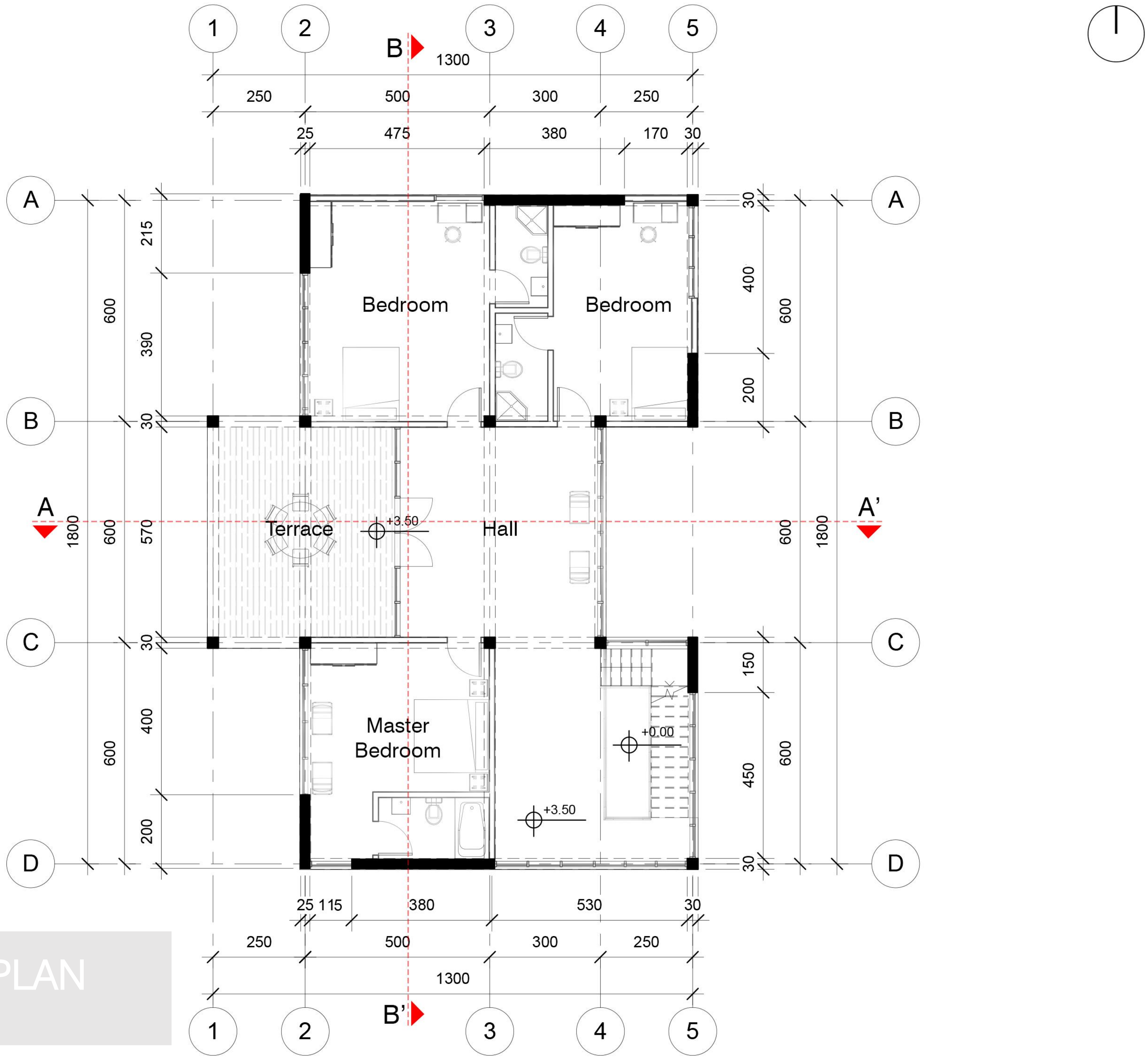


GROUND FLOOR PLAN

SCALE : 1/100



FIRST FLOOR PLAN

SCALE : 1/100

SOUTH ELEVATION
SCALE : 1/100

NORTH ELEVATION
SCALE : 1/100

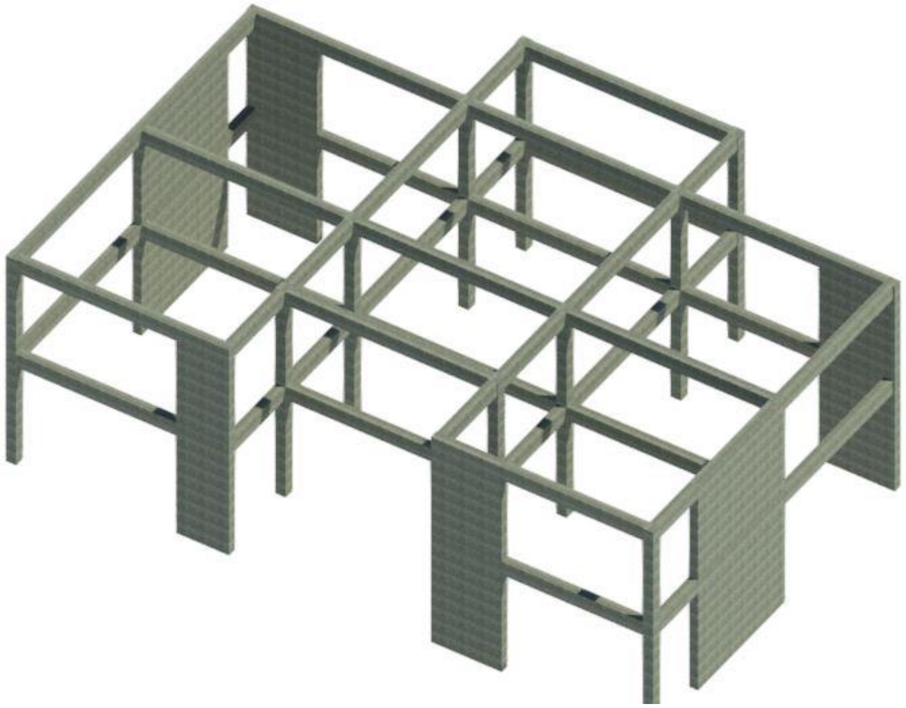
WEST ELEVATION
SCALE : 1/100

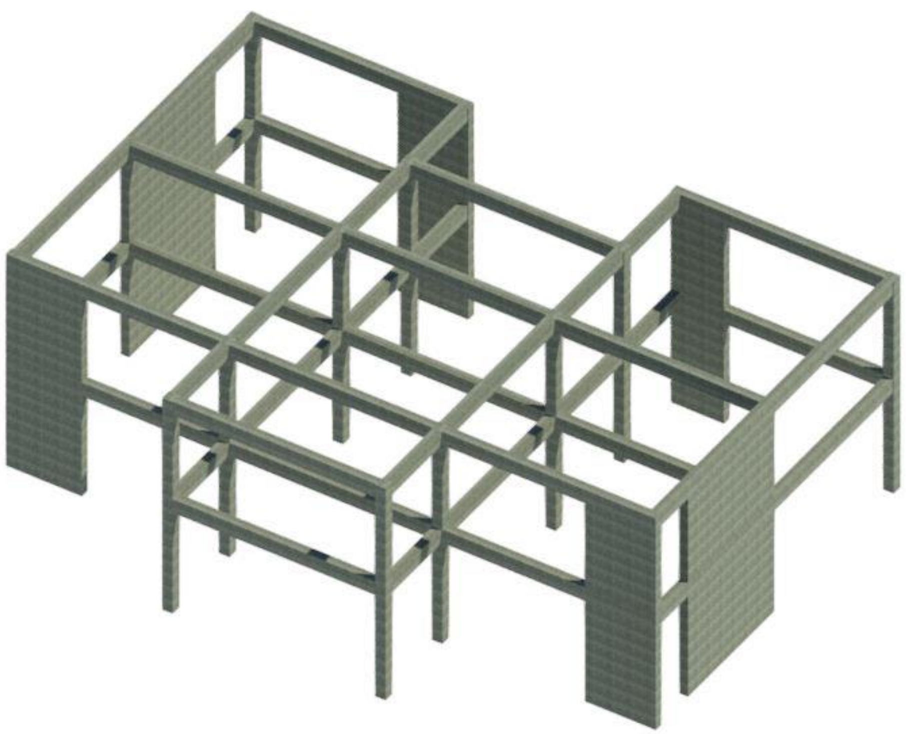
EAST ELEVATION
SCALE : 1/100

SECTION BB’
SCALE : 1/100

SECTION AA’
SCALE : 1/100

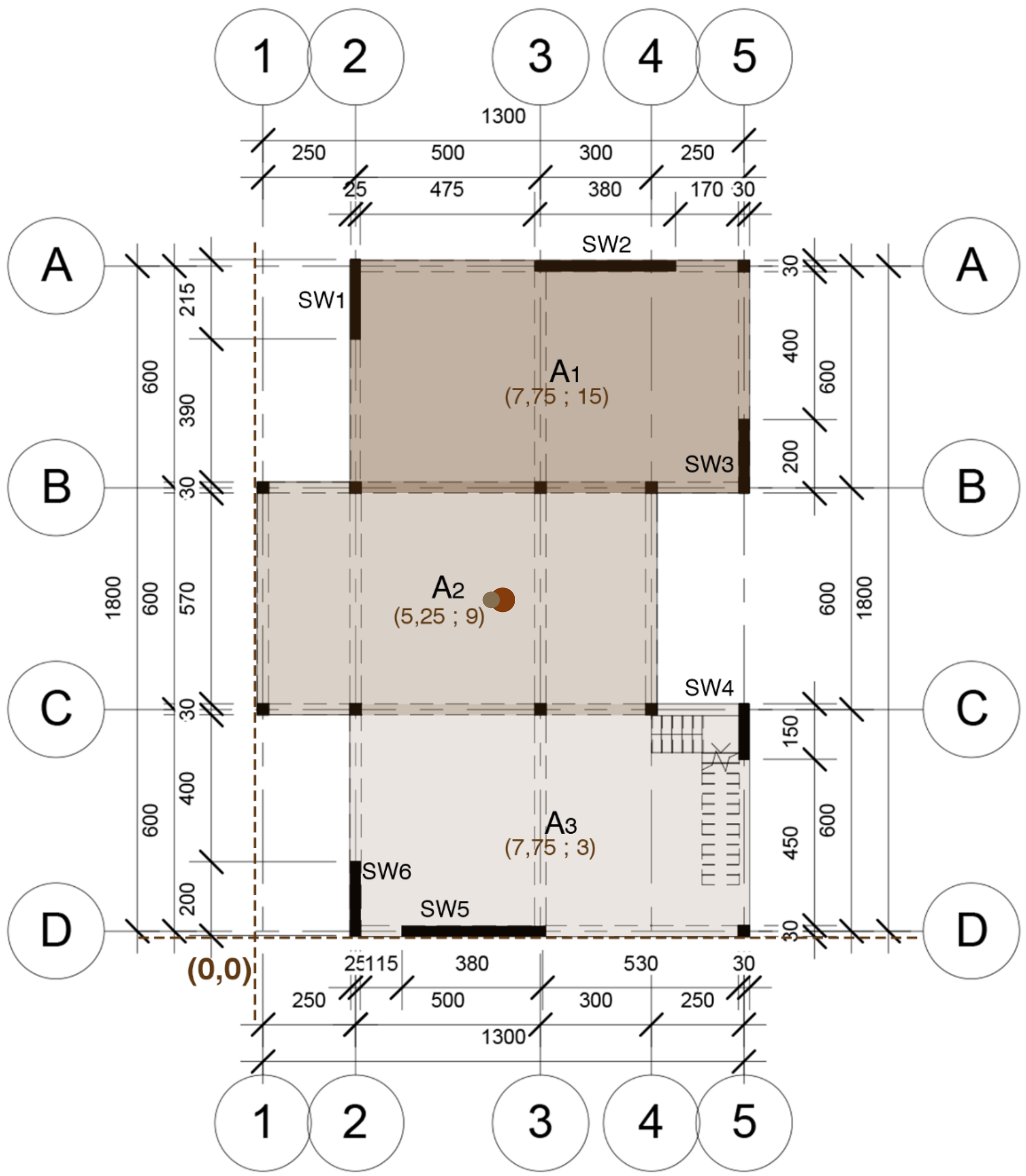
STRUCTURE SYSTEM
AXONOMETRIC VIEWS





INTERIOR VIEWS

STRUCTURAL CALCULATIONS



Geometric & Stiffness Center Check

Eccentricity Center

$$e_x = \frac{|S_x - M_x|}{L_x} \times 100 = \frac{|6{,}576 - 6{,}917|}{13} \times 100 = 2{,}62\% \quad (e_x \leq 5\%) ✓$$

$$e_y = \frac{|S_y - M_y|}{L_y} \times 100 = \frac{|9 - 9|}{13} \times 100 = 0\% \quad (e_y \leq 5\%) ✓$$

Geometric Center

*Beam weigths are ignored.

$$G = \frac{(A_1 \times d_1 + A_2 \times d_2 + \ldots + A_n \times d_x)}{A_1 + A_2 + \cdots + A_n}$$

$A_1 = A_2 = A_3 = 6 \times 10{,}5 = 63m^2$

Geometric Center in X Direction

- $G_x = \frac{(63x7{,}75)+(63x7{,}75)+(63x5{,}25)}{63+63+63} = 6{,}917$

Geometric Center in Y Direction

- $G_y = \frac{(63x15)+(63x9)+(63x3)}{63+63+63} = 9$

According to these calculations, geometric center is on M(6,917 ; 9)

Stiffness Center

$$I = \frac{b.h^3}{12}$$

Stiffness Center in X Direction

$$I_{sw1} = \frac{0{,}25 \times (2{,}15)3}{12} = 0{,}207$$

$$I_{sw3} = \frac{0{,}25 \times (2)3}{12} = 0{,}167$$

$$I_{sw4} = \frac{0{,}25 \times (1{,}5)3}{12} = 0{,}0703$$

$$I_{sw6} = \frac{0{,}25 \times (2)3}{12} = 0{,}167$$

$$S_x = \frac{(I_{sw1} \times L_{sw1})+(I_{sw3} \times L_{sw3})+(I_{sw4} \times L_{sw4})+(I_{sw6} \times L_{sw6})}{I_{sw1}+I_{sw3}+I_{sw4}+I_{sw6}}$$

$$S_x = \frac{(0{,}207 \times 2{,}5) + (0{,}167 \times 2{,}5) + (0{,}0703 \times 13) + (0{,}167 \times 13)}{0{,}207 + 0{,}167 + 0{,}0703 + 0{,}167} = 6{,}576$$

Stiffness Center in Y Direction

$$I_{sw2} = \frac{0{,}25 \times (3{,}8)3}{12} = 1{,}143$$

$$I_{sw5} = \frac{0{,}25 \times (3{,}8)3}{12} = 1{,}143$$

$$S_y = \frac{(I_{sw2} \times L_{sw2})+(I_{sw5} \times L_{sw5})}{I_{sw2}+I_{sw5}}$$

$$S_y = \frac{(1{,}143 \times 18) + (1{,}143 \times 0)}{1{,}143 + 1{,}143} = 9$$

According to these calculations, stiffness center is on S(6,576 ; 9)

Shear Wall Check

$I_{sw1}: \frac{215}{25} = 8{,}6 \geq 6$ ✓

$I_{sw2}: \frac{380}{25} = 15{,}2 \geq 6$ ✓

$I_{sw3}: \frac{200}{25} = 8 \geq 6$ ✓

$I_{sw4}: \frac{150}{25} = 6 \geq 6$ ✓

$I_{sw5}: \frac{380}{25} = 15{,}2 \geq 6$ ✓

$I_{sw6}: \frac{200}{25} = 8 \geq 6$ ✓

Shear Wall Percentage

Total Floor Area : 63 x 3= 189 m^2

Area of Shear Walls On X Axis:

(0,25 x 1,5)+(0,25 x 2 x 2)+(2,15 x 0,25)=1,913

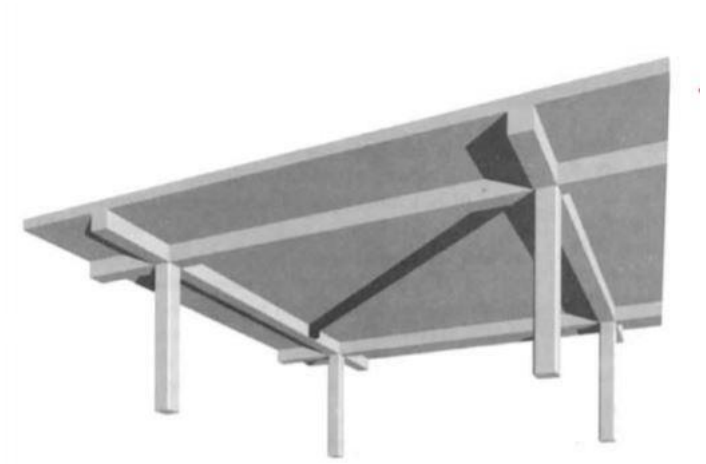
Percentage : 1,913 ÷ 189 = 1,01%

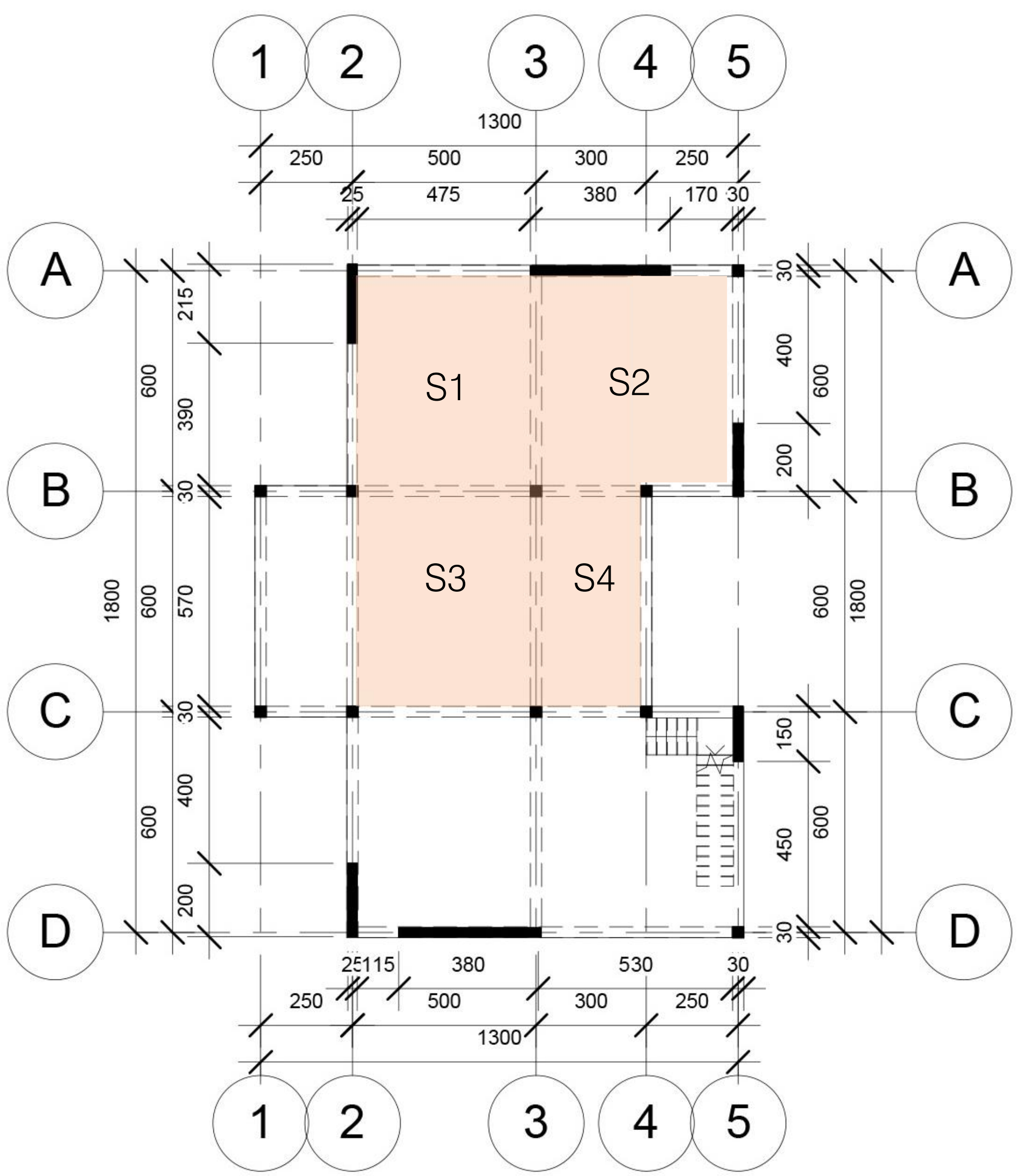
Area of Shear Walls On Y Axis:

(0,25 x 3,8)+(0,25 x 3,8) = 1,9

Percentage : 1,9 ÷ 189 = 1%

SLAB SYSTEM





SELECTION & THICKNESS CALCULATIONS

Selected slab type is solid slab with beams. Since, m=l long / l short ≤ 2 , two way solid slab system should be utilised.

$m_1=6/5=1{,}2$ $m_2= 6/5{,}5=1{,}091$ $m_3=6/5=1{,}2$ $m_4=6/3=2$

CALCULATION STEPS

STEP I : Determine edge ratio (α) for each critical slab.

$$\alpha = \frac{\textit{length of continuous edges}}{\textit{total length of all edges}}$$

$$\alpha_{S1}=\frac{5+6}{5+6+6+5}=0{,}5 \qquad \alpha_{S2}=\frac{6}{6+5{,}5+5{,}5+6}=0{,}261$$

$$\alpha_{S3}=\frac{6+5+6+5}{6+5+6+5}=1 \qquad \alpha_{S4}=\frac{3+6+3}{3+6+3+6}=0{,}667$$

STEP II : By using α value, calculate slab thickness (t) for each critical slab.

Formula: $t \geq \frac{l\ short}{15+\frac{20}{m}} \times (1-\frac{\alpha}{4})$

$$t_1 \geq \frac{5}{(15+\frac{20}{1{,}2})} \times (1-\frac{0{,}5}{4}) = 0.138 \qquad t_2 \geq \frac{5{,}5}{(15+\frac{20}{1{,}091})} \times (1-\frac{0{,}261}{4}) = 0{,}154$$

$$t_3 \geq \frac{5}{(15+\frac{20}{1{,}2})} \times (1-\frac{1}{4}) = 0{,}118 \qquad t_4 \geq \frac{3}{(15+\frac{20}{2})} \times (1-\frac{0{,}667}{4}) = 0{,}099$$

STEP III : Comparing found thicknesses, decide the slab thickness.

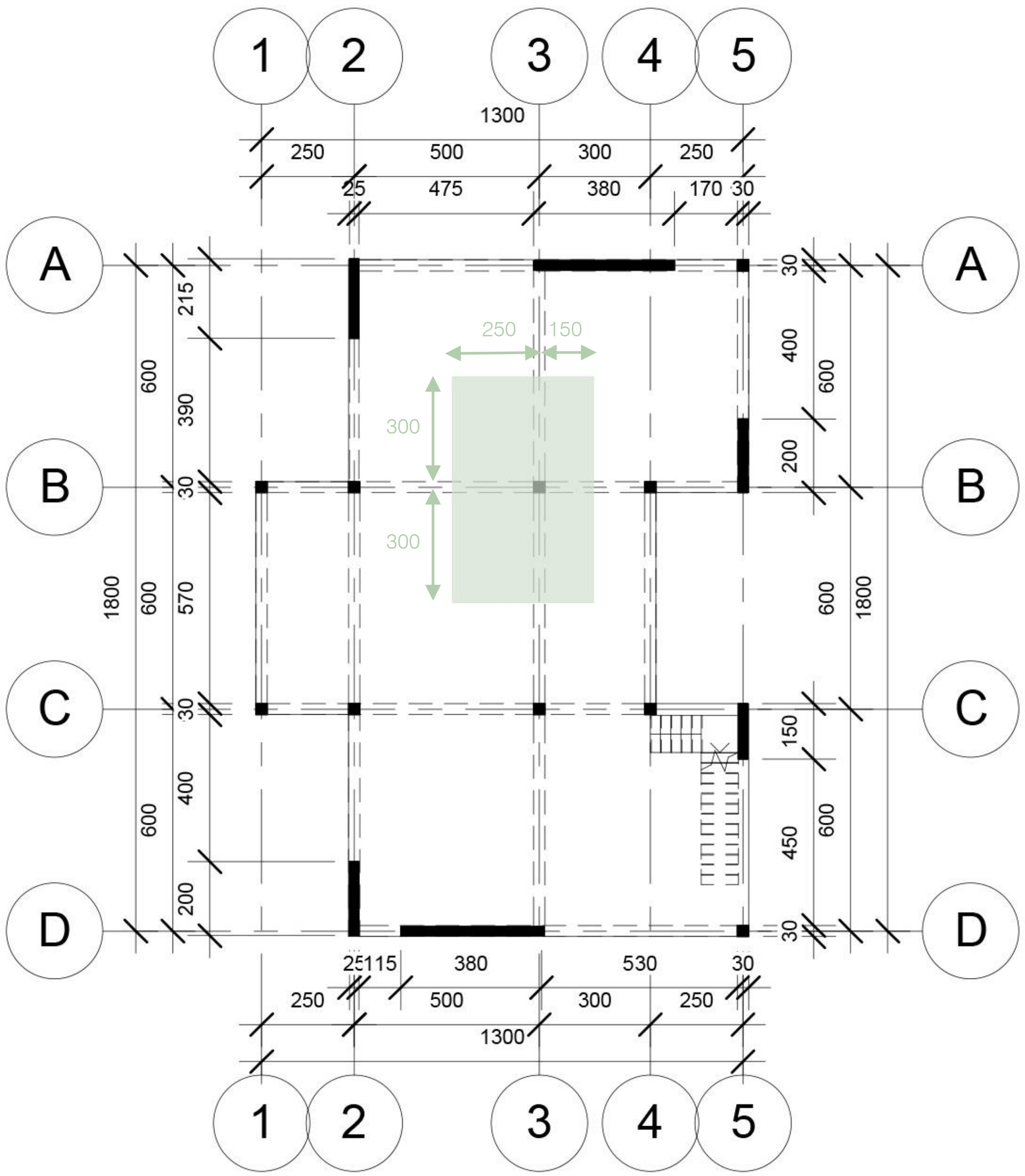
t ≥ 8 cm, t ≥ l /30, t ≥ l/10 (for cantilever slabs)

Since the most critical slab is **S2** , Slab thickness should be larger than 15,4 cm.

So, t = 16 cm

COLUMN DIMENSIONS

Tributary Area= 4 x 6 =24 m^2



TRIBUTARY AREA & MINIMUM COLUMN AREA DIMENSIONS

Since the column at 3B&3C has the largest tributary area, calculations for those:

Loads

Dead load of solid slabs

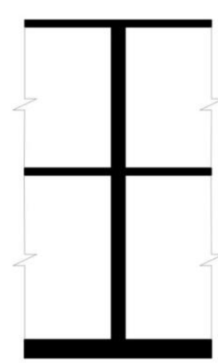
Own weight	: 0,16 x 2,4	= 0,384 t / m^2	
Levelling	: 0,04 x 2,4	= 0,1 t / m^2	
Covering	: 0,025 x 2,0	= 0,05 t / m^2	0,574 t/ m^2
Plastering	: 0,02 x 2,0	= 0,04 t / m^2	

Live Load

0,2 t / m^2 for residential buildings.

Total Load

P_D = 1,4 x 0, 574 + 1,6 x 0,2 = 1,1236 t / m^2



SL: 1,1236 x 24 = 26, 966 t

WL: 0,15 x 24 = 3,6 t

SL: 1,1236 x 24 = 26, 966 t

N_D (Total Load) = 57,533 t

$$\min A_C = \frac{N_D}{0.40 \times f_{ck}} \qquad f_{ck} = 200 \text{ kg /cm}^2$$

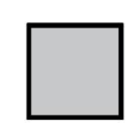
N_D (Total Load) = 57,533 t = 57533 kg

$$A_c \geq \frac{57533}{0{,}4 \times 200} \qquad A_c \geq 26{,}817 \text{ cm}$$

According to the regulations column cross section area should be minimum 900 cm^2 & 30x30 cm

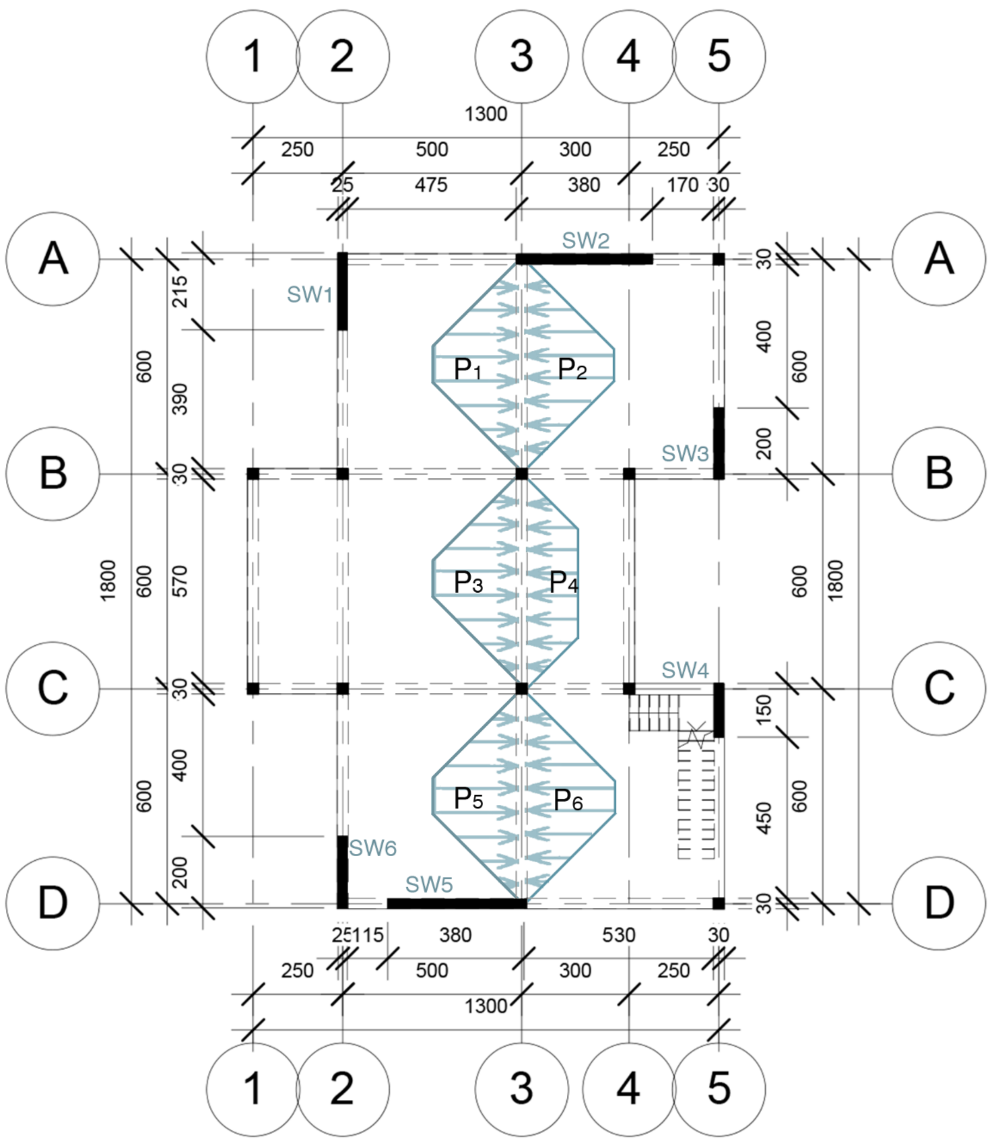
Therefore, column dimensions are choosen as 30 x 30 cm

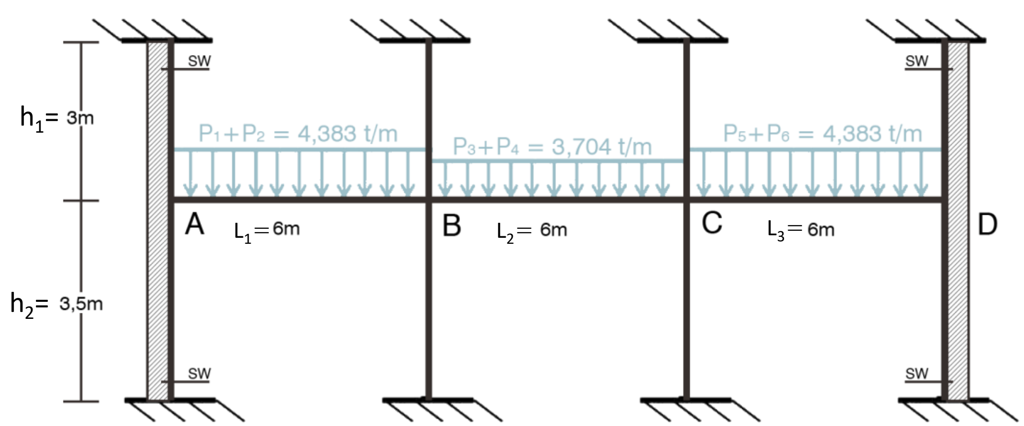
30 cm



30 cm

BEAM ANALYSIS
LOAD CALCULATIONS





Uniform Load Calculation

$$P= P_d x \frac{L_{short}}{3} x \left(1{,}5- \frac{0{,}5}{(Llong/L_{short})2}\right)$$

$$P_1=1{,}1236\ x \left(\frac{5}{3}\right) x \left(1{,}5 - \frac{0{,}5}{(6/5)^2}\right)= 2{,}159 \text{ t/m}$$

$$P_2=1{,}1236\ x \left(\frac{5{,}5}{3}\right) x \left(1{,}5 - \frac{0{,}5}{(6/5{,}5)^2}\right)= 2{,}224 \text{ t/m}$$

$$P_3=1{,}1236\ x \left(\frac{5}{3}\right) x \left(1{,}5 - \frac{0{,}5}{(6/5)^2}\right)= 2{,}159 \text{ t/m}$$

$$P_4=1{,}1236\ x \left(\frac{3}{3}\right) x \left(1{,}5 - \frac{0{,}5}{(6/3)^2}\right)= 1{,}545 \text{ t/m}$$

$$P_5=1{,}1236\ x \left(\frac{5}{3}\right) x \left(1{,}5 - \frac{0{,}5}{(6/5)^2}\right)= 2{,}159 \text{ t/m}$$

$$P_6=1{,}1236\ x \left(\frac{5{,}5}{3}\right) x \left(1{,}5 - \frac{0{,}5}{(6/5{,}5)^2}\right)= 2{,}224 \text{ t/m}$$

Moment Of Inertia

$$I = \frac{b.h^3}{12}$$

I_{column}= (1/12) x (0,3) x $(0,3)^3$ = 0,000675

I_{beam}= (1/12) x (0,25) x $(0,3)^3$ = 0,000563

I_{swalls}= (1/12) x (3,3) x $(0,25)^3$ = 0,0043

Load Distribution Factors

$$r_{AB}= \frac{I_{beam}/L_1}{\frac{I_{beam}}{L_1}+\frac{I_{swall}}{h_1}+\frac{I_{swall}}{h_2}} = \frac{0{,}000563/6}{\frac{0{,}000563}{6}+\frac{0{,}0043}{3}+\frac{0{,}0043}{3{,}5}} = 0{,}0341$$

$$r_{BA}= \frac{I_{beam}/L_1}{\frac{I_{beam}}{L_1}+\frac{I_{column}}{h_1}+\frac{I_{column}}{h_2}+\frac{I_{beam}}{L_2}} = \frac{0{,}000563/6}{\frac{0{,}000563}{6}+\frac{0{,}000675}{3}+\frac{0{,}000675}{3{,}5}+\frac{0{,}000563}{6}} = 0{,}155$$

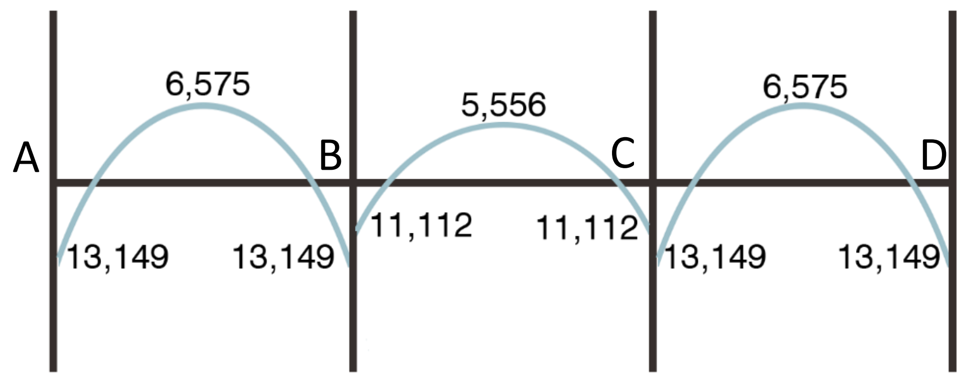
$$r_{BC}= \frac{I_{beam}/L_2}{\frac{I_{beam}}{L_1}+\frac{I_{column}}{h_1}+\frac{I_{column}}{h_2}+\frac{I_{beam}}{L_2}} = \frac{0{,}000563/6}{\frac{0{,}000563}{6}+\frac{0{,}000675}{3}+\frac{0{,}000675}{3{,}5}+\frac{0{,}000563}{6}} = 0{,}155$$

$$r_{CB}= \frac{I_{beam}/L_2}{\frac{I_{beam}}{L_2}+\frac{I_{column}}{h_1}+\frac{I_{column}}{h_2}+\frac{I_{beam}}{L_3}} = \frac{0{,}000563/6}{\frac{0{,}000563}{6}+\frac{0{,}000675}{3}+\frac{0{,}000675}{3{,}5}+\frac{0{,}000563}{6}} = 0{,}155$$

$$r_{CD}= \frac{I_{beam}/L_3}{\frac{I_{beam}}{L_2}+\frac{I_{column}}{h_1}+\frac{I_{column}}{h_2}+\frac{I_{beam}}{L_3}} = \frac{0{,}000563/6}{\frac{0{,}000563}{6}+\frac{0{,}000675}{3}+\frac{0{,}000675}{3{,}5}+\frac{0{,}000563}{6}} = 0{,}155$$

$$r_{DC}= \frac{I_{beam}/L_3}{\frac{I_{beam}}{L_3}+\frac{I_{column}}{h_1}+\frac{I_{column}}{h_2}} = \frac{0{,}000563/6}{\frac{0{,}000563}{6}+\frac{0{,}0043}{3}+\frac{0{,}0043}{3{,}5}} = 0{,}0341$$

BEAM ANALYSIS
TWO CYCLE METHOD



$$FEM_{AB} = FEM_{CD} = \frac{4{,}383 \times 6^2}{12} = 13{,}149 \text{ t.m}$$

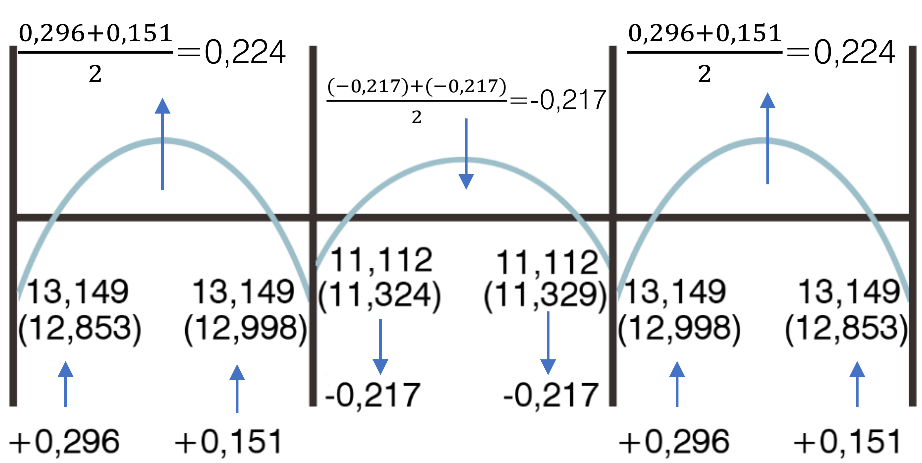
$$FEM_{CB} = \frac{3{,}704 \times 62}{12} = 11{,}112 \text{ t.m}$$

$$FEM = \frac{q.L^2}{12}$$

$$M_{midspanAB} = M_{midspanCD} = \frac{4{,}383 \times 6^2}{24} = 6{,}575 \text{ t.m}$$

$$M_{midspanBC} = \frac{3{,}704 \times 6^2}{24} = 5{,}556 \text{ t.m}$$

r	0,0341	0,155	0,155	0,155	0,155	0,0341
FEM	13,149	-13,149	11,112	-11,112	13,149	-13,149
1st Cycle	0,158	-0,224	-0,158	0,158	0,224	-0,158
Σ	13,307	-13,373	10,954	-10,954	13,373	-13,307
2nd Cycle	-0,454	0,375	0,375	-0,375	-0,375	0,454
M	12,853	-12,998	11,329	-11,329	12,998	-12,853



Beam Depth

According to TS500-7.3
h(total depth of the beam) ≥ 30cm and 3t(t=slab thickness)

$$K_0 = \frac{b_w x\ d^2}{M_{max}} = \frac{25 \times d^2}{1299{,}8} = 25$$

b_w=25 cm K_0= 25 cm^2/t M_{max}= 12,998 t.m= 1299,8 t.cm

d=36,05 cm ≈ 37 cm +5 cm clear cover h= 42 cm

However, 3t= 3 x 14=48 42<48 so slab thickness is **h=48**