ARCH 332 | Structural Design In Architecture II

Group 16

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Instructors

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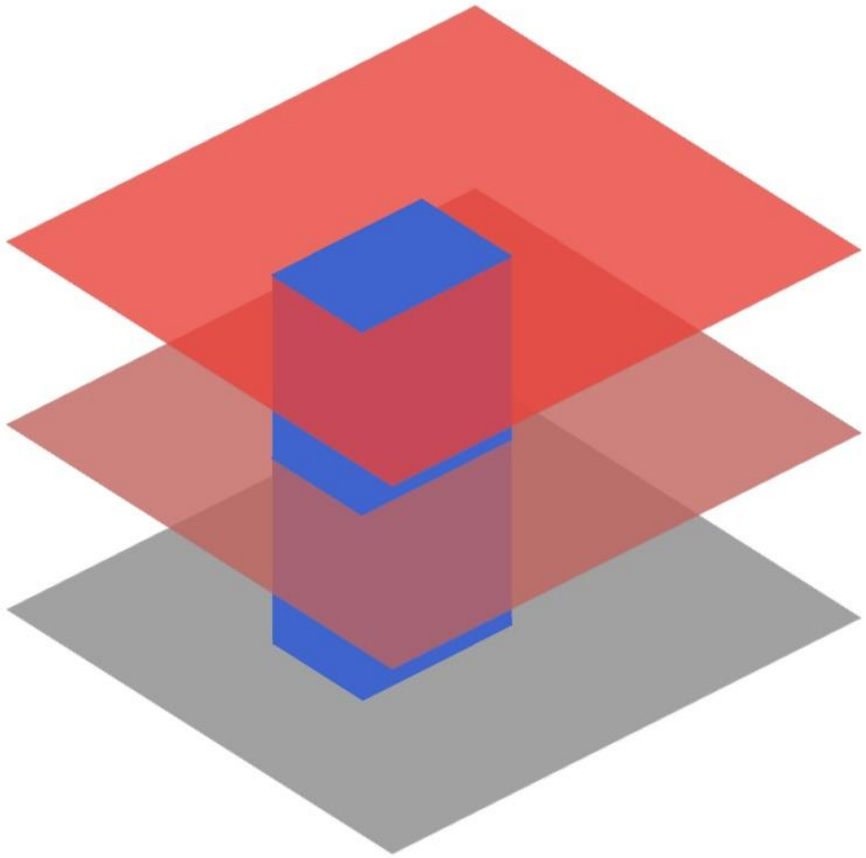
Diagrams

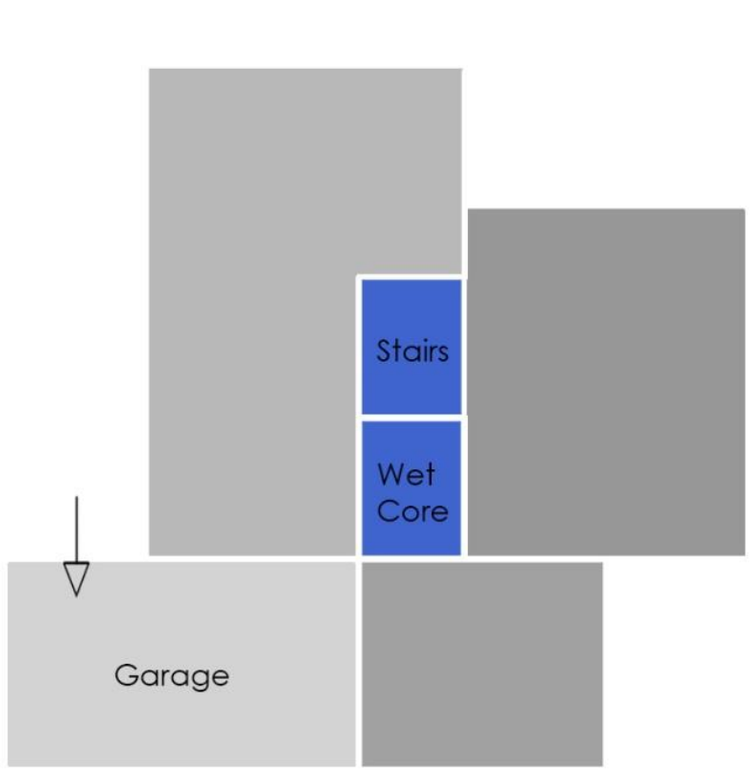


Bedrooms, library, study room, terrace

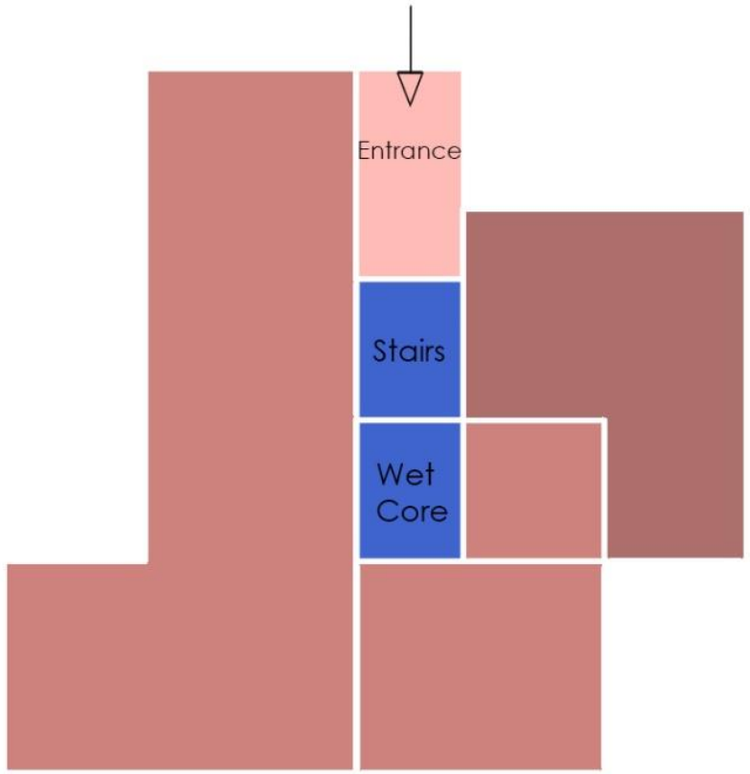
Living room, kitchen, dinning room, entrance, music/study room

Garage, storage, hobby room, technical room

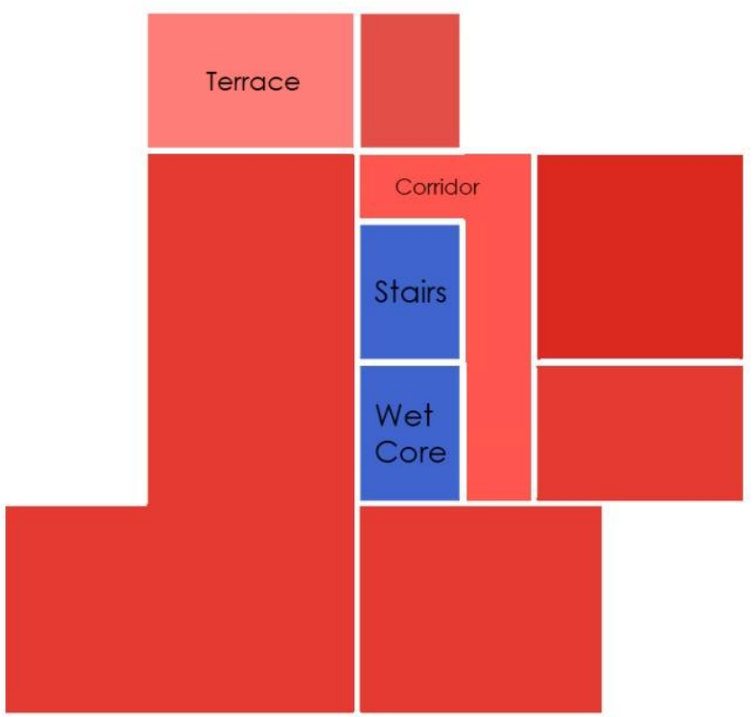
Wet spaces and horizontal circulation core



Basement Floor

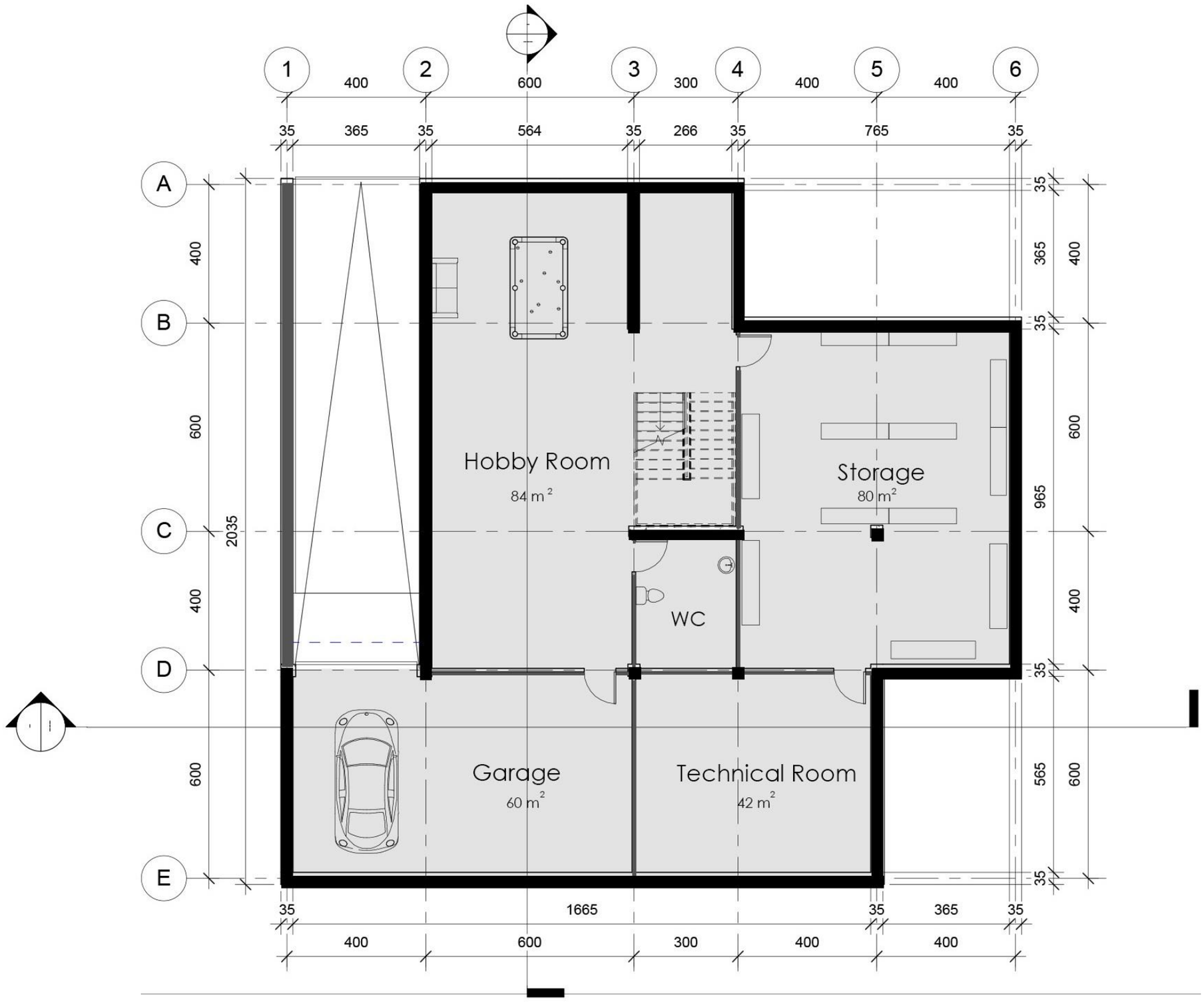


Ground Floor



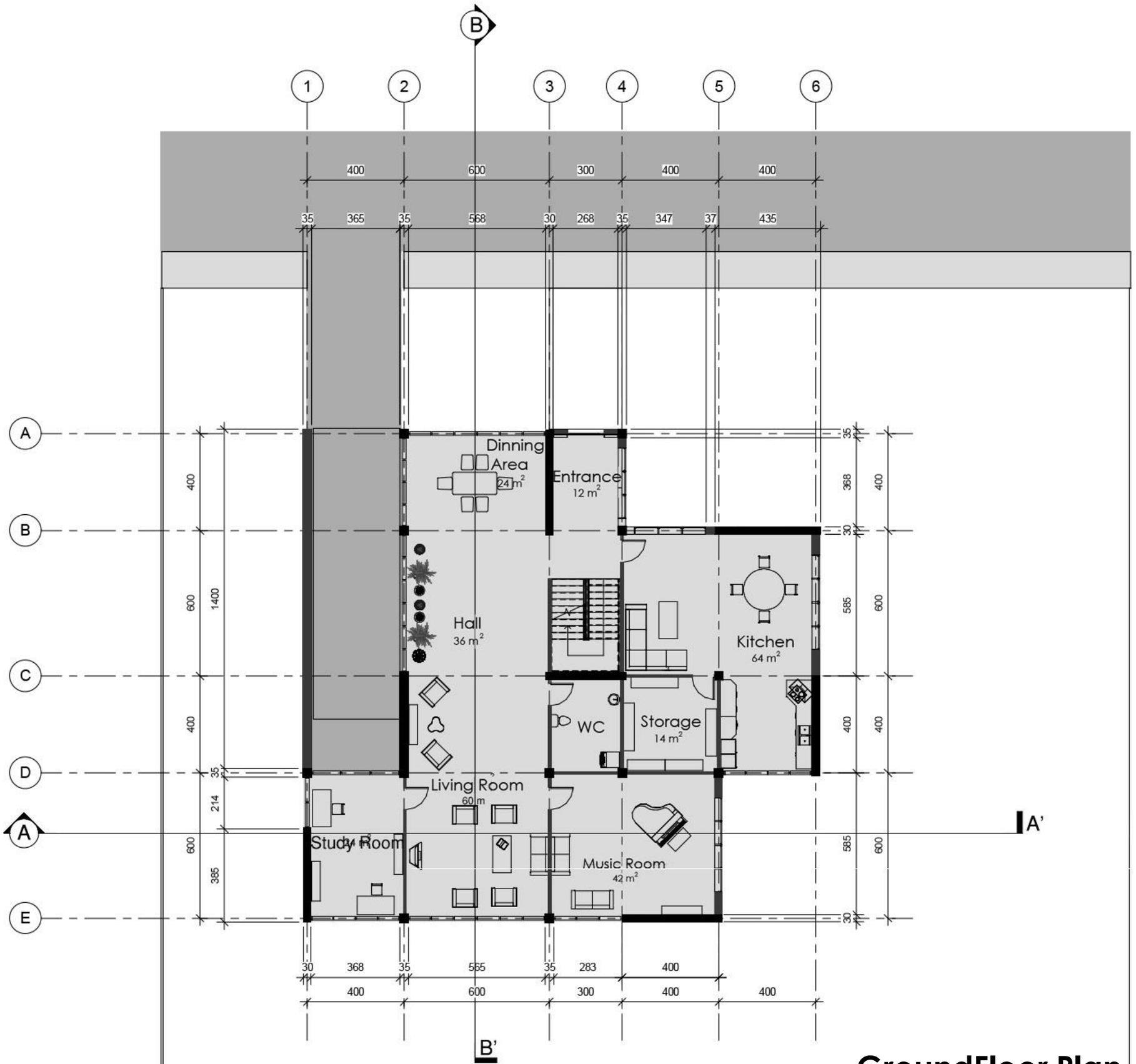
First Floor

Plans



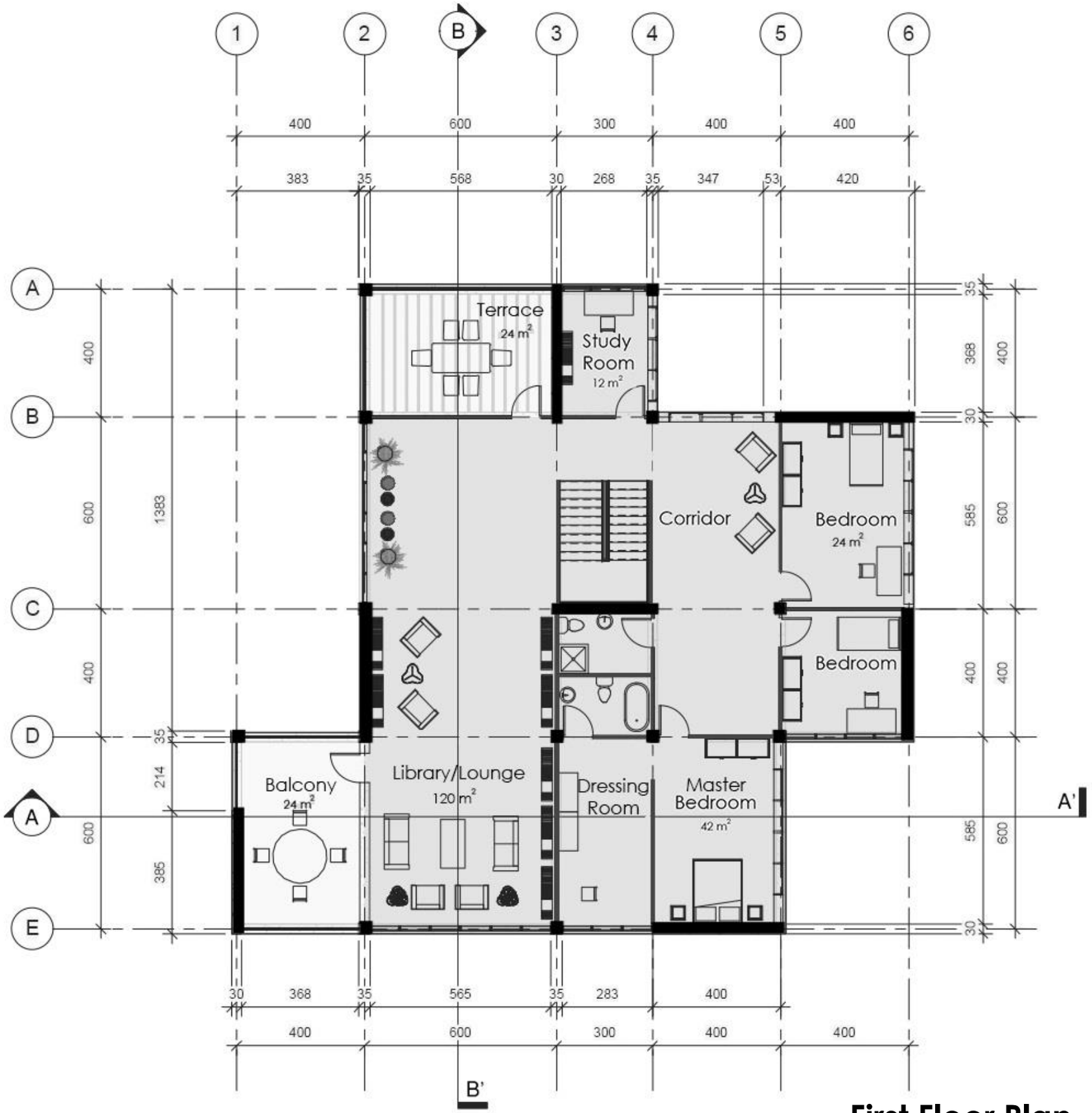
Basement Floor Plan

Plans



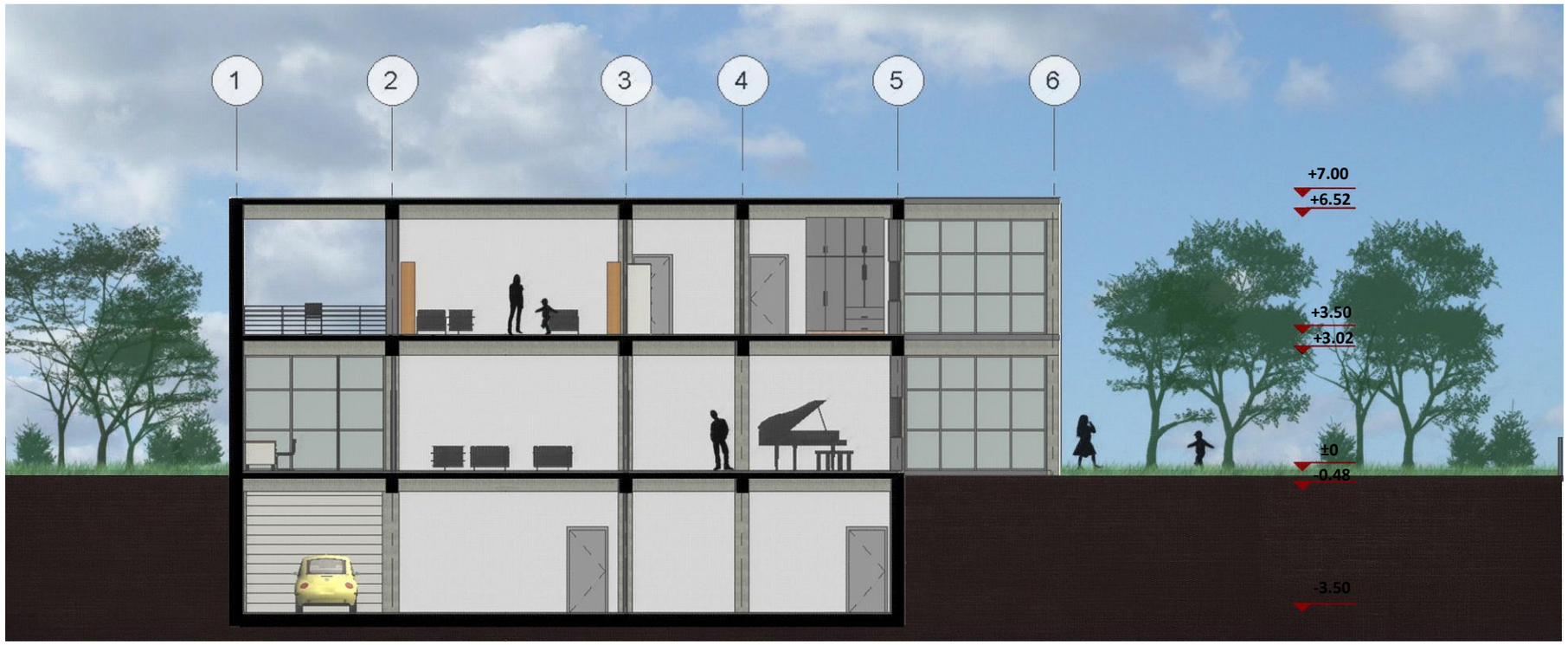
GroundFloor Plan

Plans

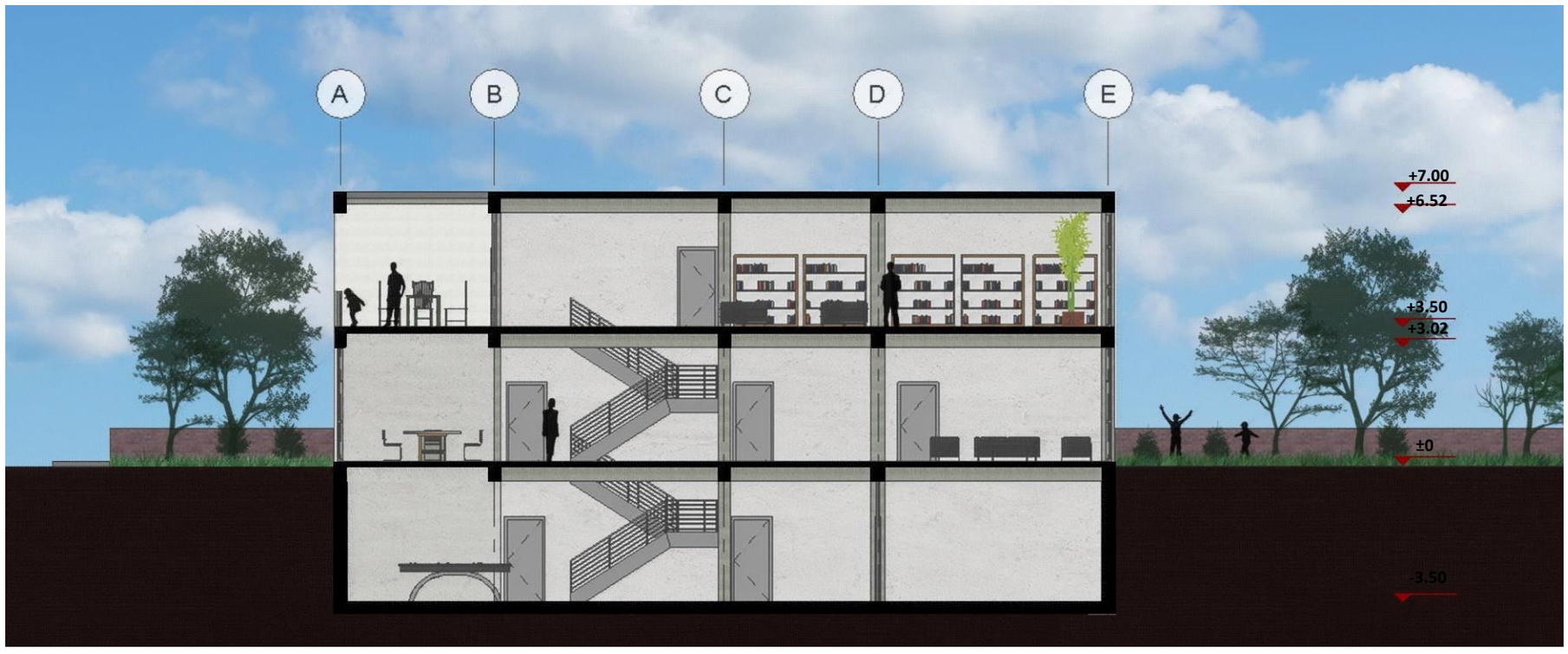


First Floor Plan

Sections

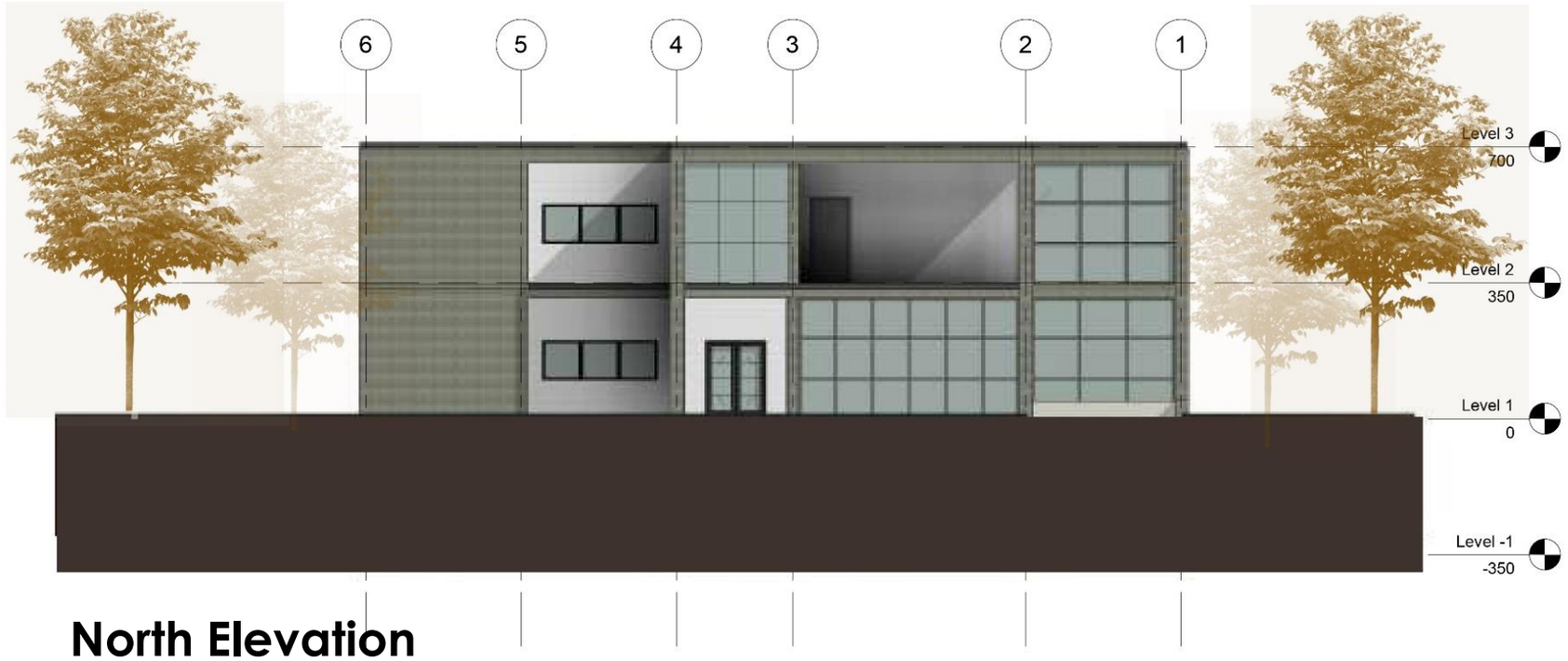


Section AA'

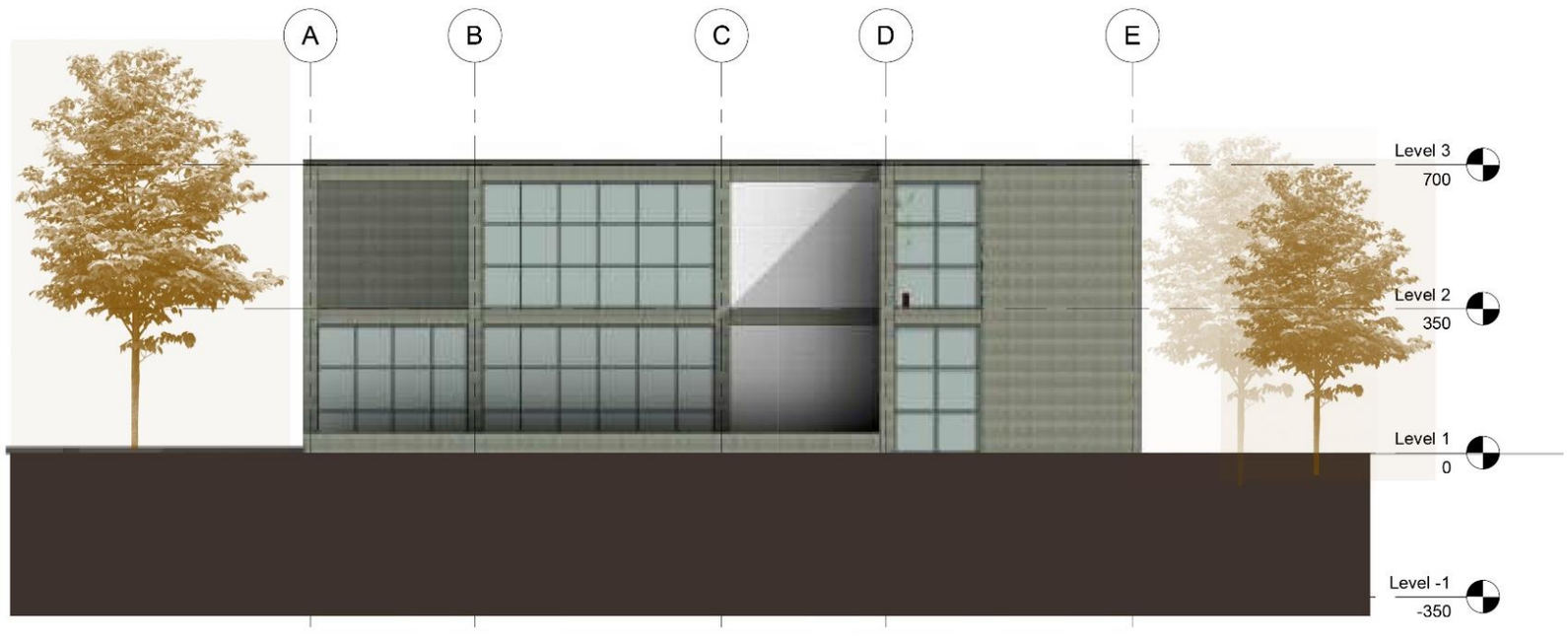


Section BB'

Elevations



North Elevation



West Elevation

Axonometric Views

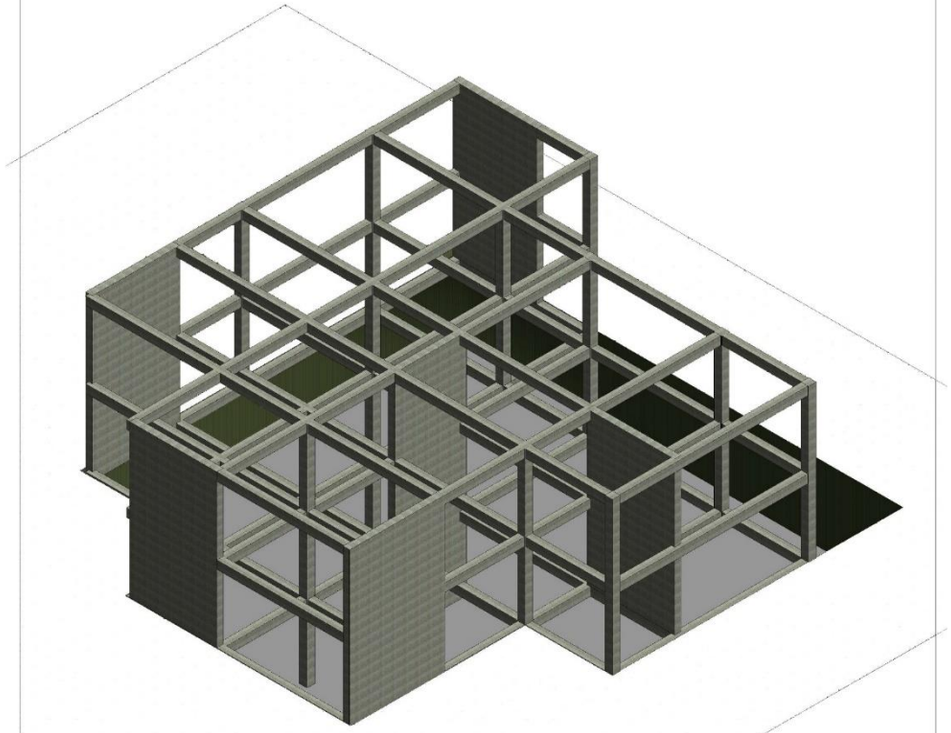
North-East Axonometric

North-West Axonometric

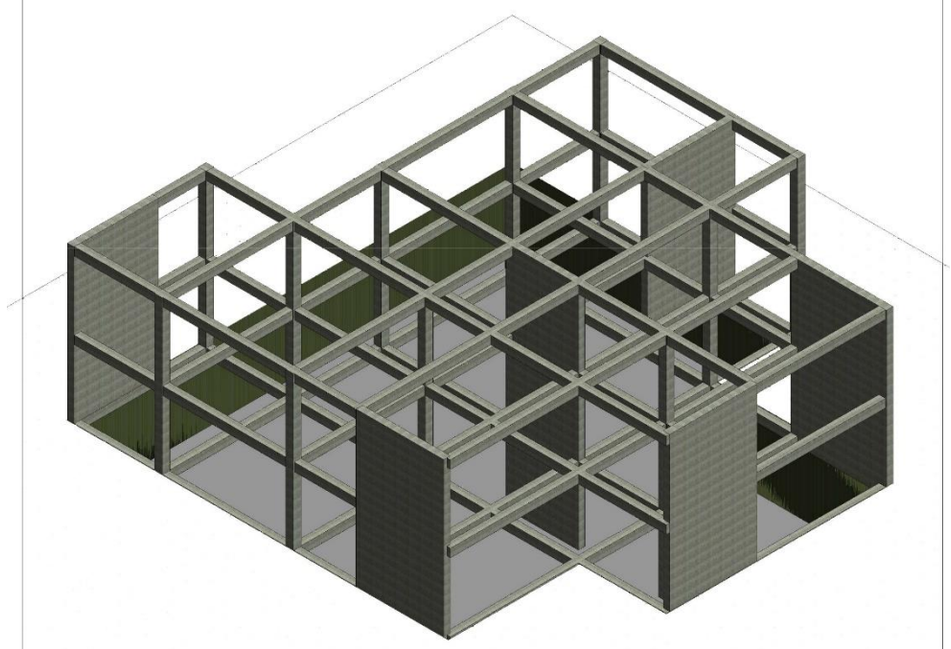
South-East Axonometric

South-West Axonometric

Structural System

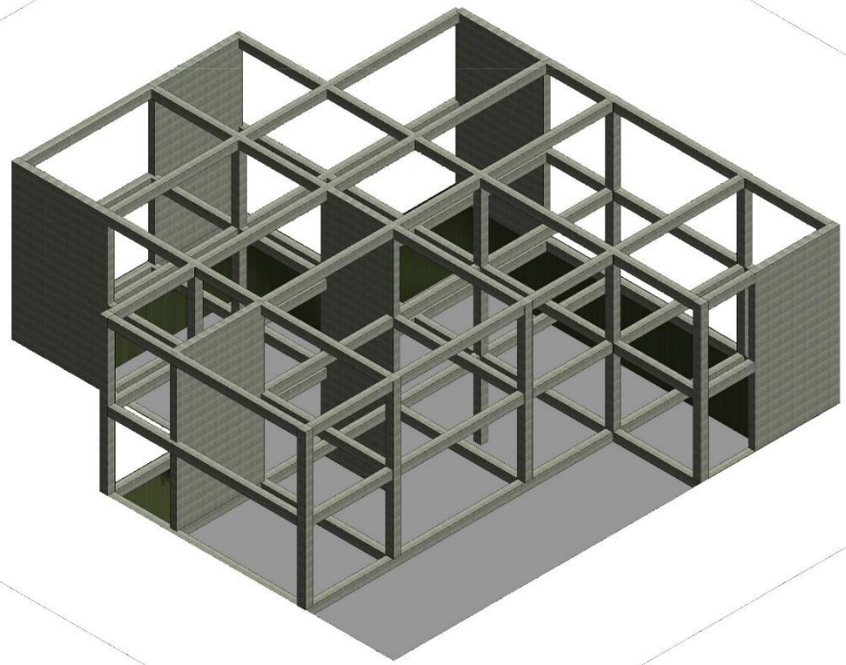


North-East Axonometric

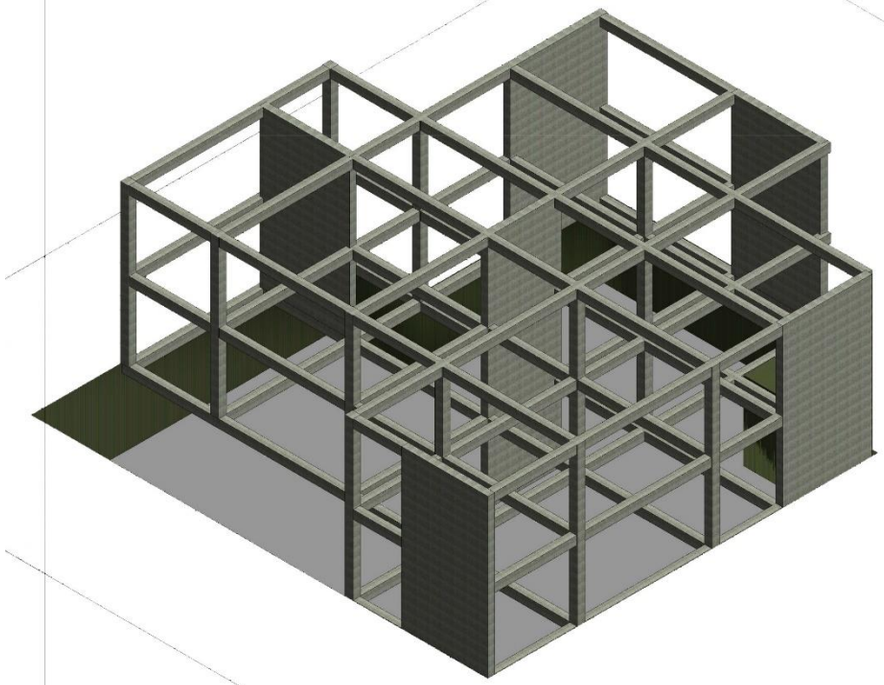


North-West Axonometric

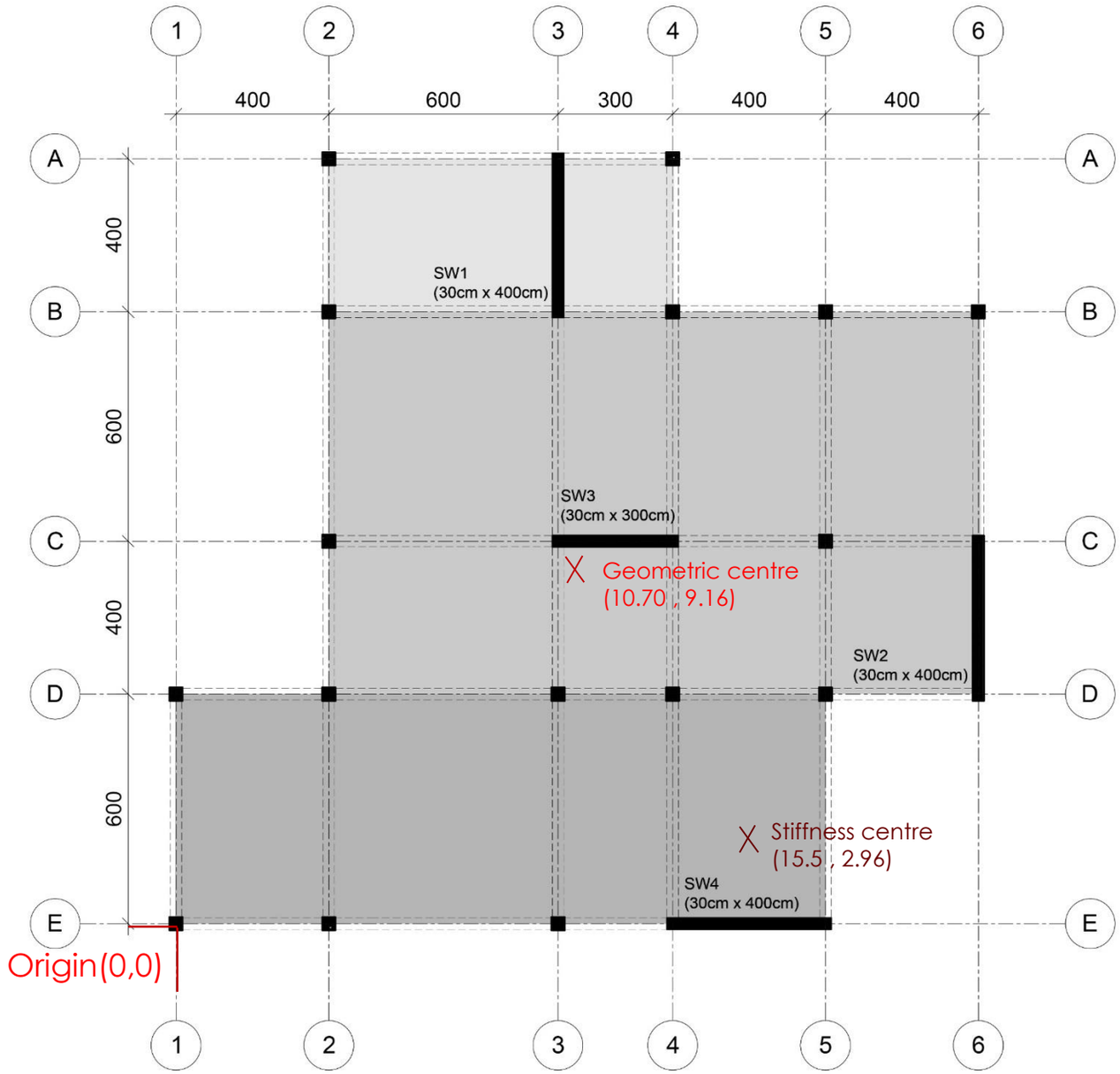
South-East Axonometric



South-West Axonometric



Structural Calculations



A_1 = 4×9=36
A_2=10×17=170
A_3 = 6×17=102

Geometric Centre

Geometric Centre In x Direction

$$G_x = \frac{(36\times8{,}5)+(170\times12{,}5)+(102\times8{,}5)}{36+170+102} = 10{,}70$$

Geometric Centre In y Direction

$$G_y = \frac{(36\times18)+(170\times11)+(102\times3)}{36+170+102} = 9{,}16$$

Stiffness Centre

Stifness Centre In x Direction

$$I_x = \frac{bh^3}{12}$$

$$I_{SW_1} = \frac{(0{,}3)\times(4^3)}{12} = 1{,}6$$

$$I_{SW_2} = \frac{(0{,}3)\times(4^3)}{12} = 1{,}6$$

$$S_x = \frac{(1{,}6\times10)+(1{,}6\times21)}{1{,}6+1{,}6} = 15{,}5$$

Stifness Centre In y Direction

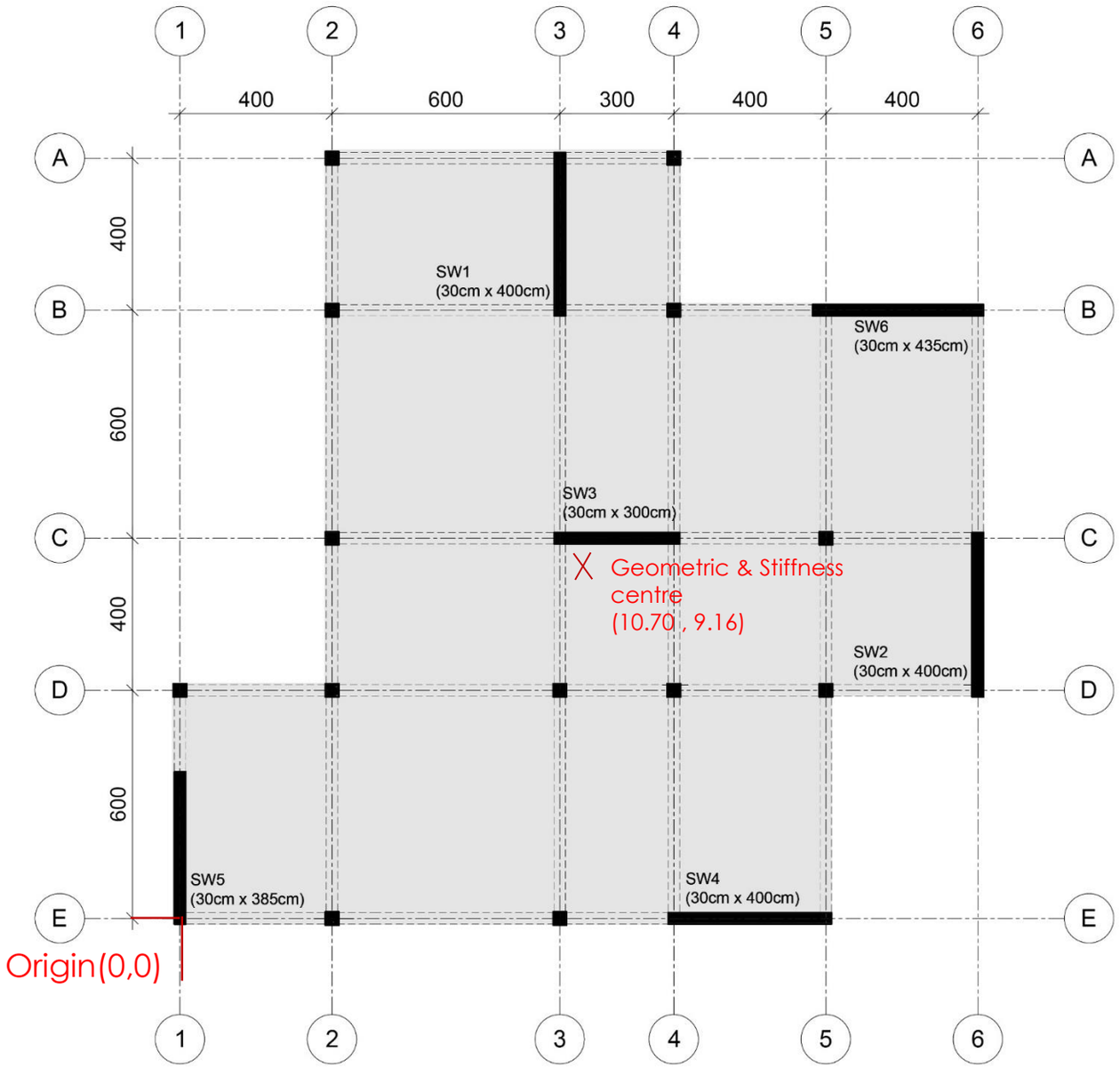
$$I_y = \frac{bh^3}{12}$$

$$I_{SW_3} = \frac{(0{,}3)\times(3^3)}{12} = 0{,}675$$

$$I_{SW_4} = \frac{(0{,}3)\times(4^3)}{12} = 1{,}6$$

$$S_y = \frac{(0{,}675\times10)+(1{,}6\times0)}{1{,}6+0{,}675} = 2{,}96$$

Structural Calculations



Adding New Shear Wall

in x direction on axis 1

$$I_{SW_5} = \frac{(0,3)\times(h^3)}{12} = 0,025h^3$$

$$S_x = G_x$$

$$S_x = \frac{(1,6\times10)+(1,6\times21)+(0,025h^3\times0)}{1,6+1,6+0,025h^3} = 10,7$$

$\Rightarrow$ h = 3,85

in y direction on axis A

$$I_{SW_6} = = \frac{(0,3)\times(h^3)}{12} = 0,025h^3$$

$$S_y = G_y$$

$$S_y = \frac{(0,675\times10)+(1,6\times0)+(0,025h^3\times16)}{1,6+0,675+0,025h^3} = 9,16$$

$\Rightarrow$ h = 4,35

Calculation of Eccentricity

$$e_x = \frac{|x_G - x_S|}{L_x} \times 100 = \frac{|15,5-10,7|}{21} \times 100 = \%22,85$$

$$e_y = \frac{|y_G - y_S|}{L_y} \times 100 = \frac{|9,16-2,96|}{20} \times 100 = \%31$$

Shear Wall Percentage

Total floor area = 36+102+170= 308 m^2

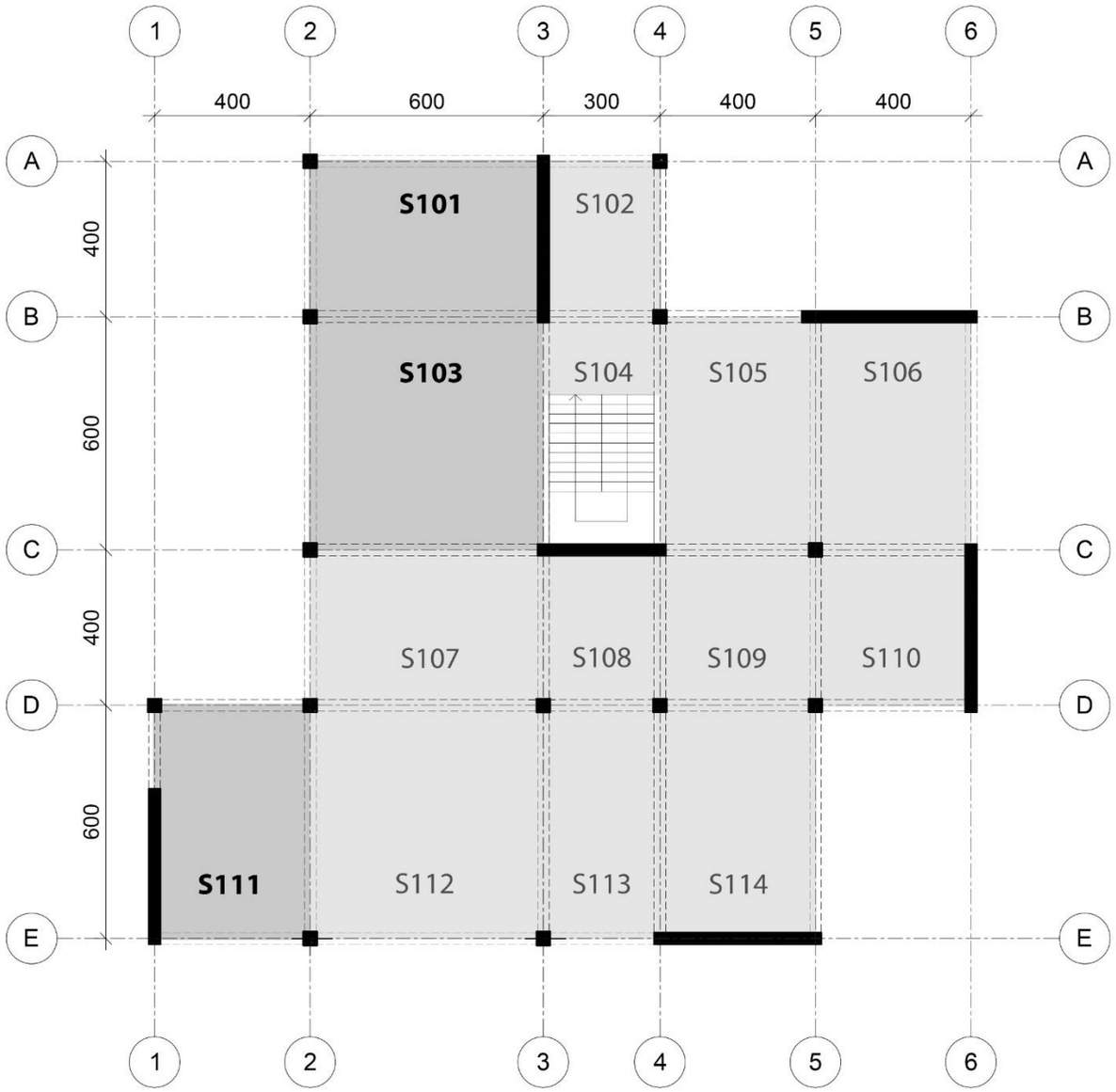
Area of shear Wall in x axis = (0,3×4) + (0,3×4) + (0,3×3,85) = 3,55

Percentage = $\frac{3,55}{308} \times 100 = \%1,15$

Area of shear Wall in y axis = (0,3×4) + (0,3×3) + (0,3×4,35) = 3,4

Percentage = $\frac{3,4}{308} \times 100 = \%1,1$

Slab System



Two way solid slab since m=$\frac{l_l}{l_s} \leq 2$

The smallest permissable thickness

t ≥ $8cm$

$$t \geq \frac{l_{sn}}{15+(\frac{20}{m})} \times \left[1 - \frac{\alpha_s}{4}\right]$$

l_{sn} = clear span lenght in short direction of slab

$$\alpha_s = \frac{\sum lenght\ of\ continuous\ edges}{\sum lenght\ of\ all\ edges}$$

For S101

α_{101}=$\frac{4+6}{12+8}$= 0,5

$$t_{101} \geq \frac{4}{15+(\frac{20}{6})\times 4} \times (1- \frac{0,5}{4})$$

t_{101} ≥ 12,25cm

For S103

α_{103}=$\frac{6+6+2}{36}$= 0,38

$$t_{103} \geq \frac{6}{15+(\frac{20}{1})} \times (1- \frac{0,38}{4})$$

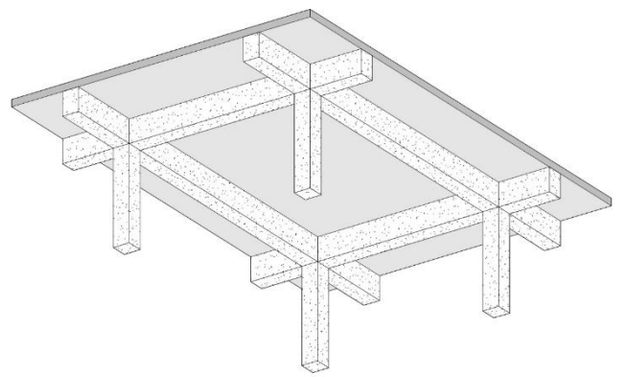
t_{103} ≥ 15,38cm

For S111

α_{111}=$\frac{6}{12+8}$=0,3

$$t_{111} \geq \frac{4}{15+(\frac{20}{6})\times 4} \times (1- \frac{0,3}{4})$$

t_{111} ≥ 12,95cm

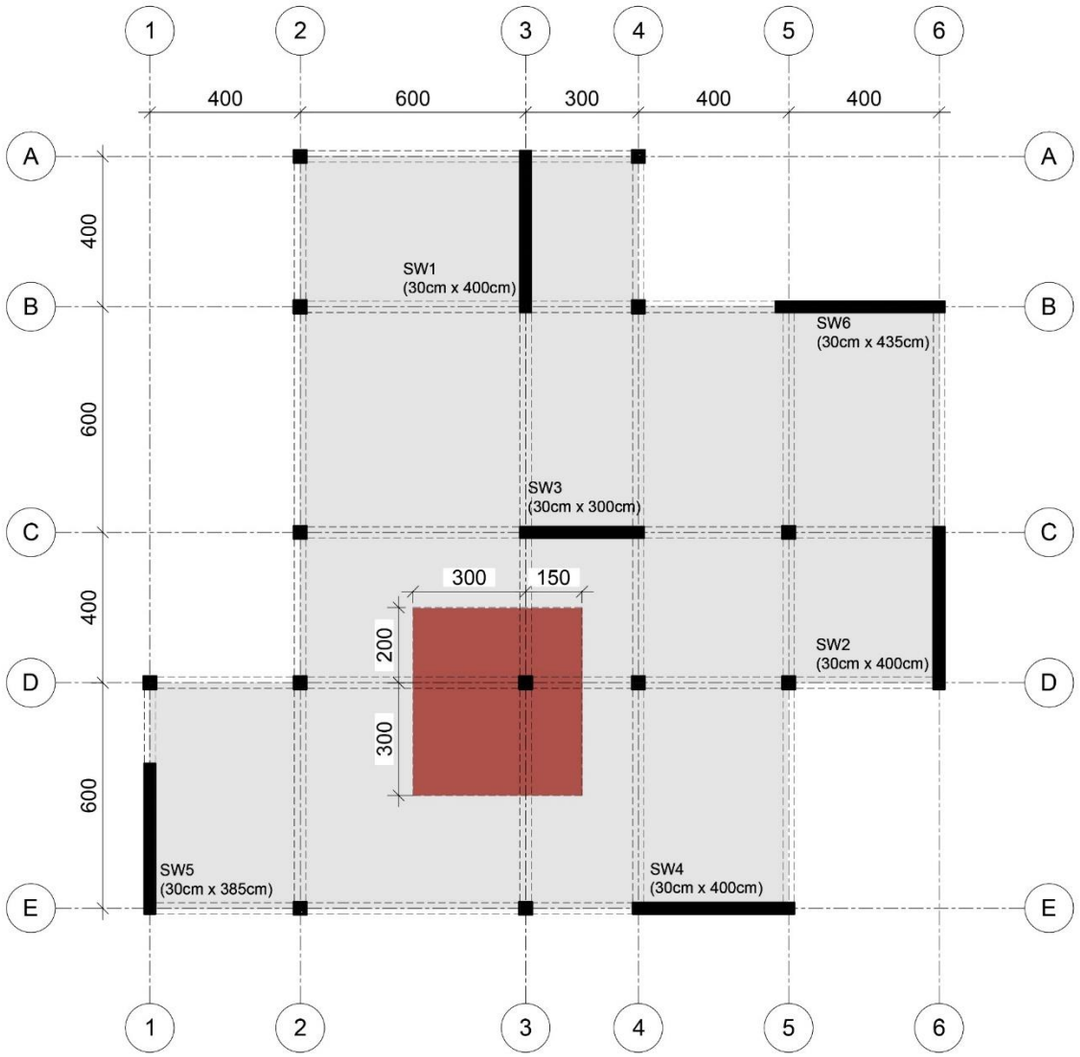


Since the most critical slab is S103 with thickness

t_{103}=15,38cm, **slab thickness is 15,5cm**

As a slab system **solid slab with beams** is selected with the following calculations.

Column Dimensions



Design load on slab = 1,1 t/m^2 (including beams weight)

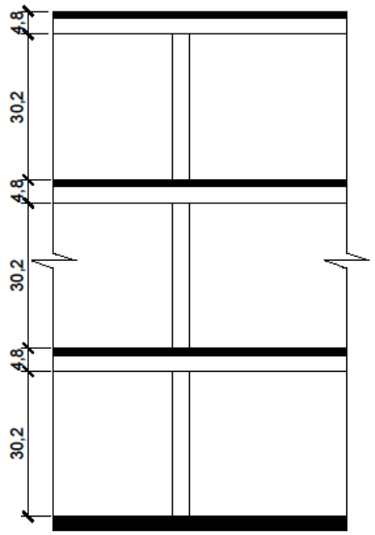
Wall load = 0,15 t/m^2

$$A_c = \frac{N_d \times m}{0{,}40 \times fck}$$

fck = 200 kg/cm^2

Tributary Area =4,5x5

=22.5 m^2



-slab load = (22,5)×(1,1) = 24,75t = 24 750 kg

-wall load = (22,5)×(0,15)x(1,4) = 4,725t = 4 725 kg

-slab load = 24 750 kg

-wall load = 4 725 kg

-slab load = 24 750 kg

Total load = 83 700 kg

Design loads per slab

Dead load

Own weight = 0,155×2,4= 0,372 t/m^2

Levelling = 0,04×2,4=0,096 t/m^2

Covering = 0,025×2= 0,05 t/m^2

Plastering = 0,02×2= 0,04 t/m^2

Total = 0,558 t/m^2

Live load = 0,2 t/m^2 (residential building)

Total load = (1,4 × 0,558) × (1,6 × 0,2)

= 1,1 t/m^2

Then, $A_c = \frac{N_{dm}}{0{,}40 \times fck}$

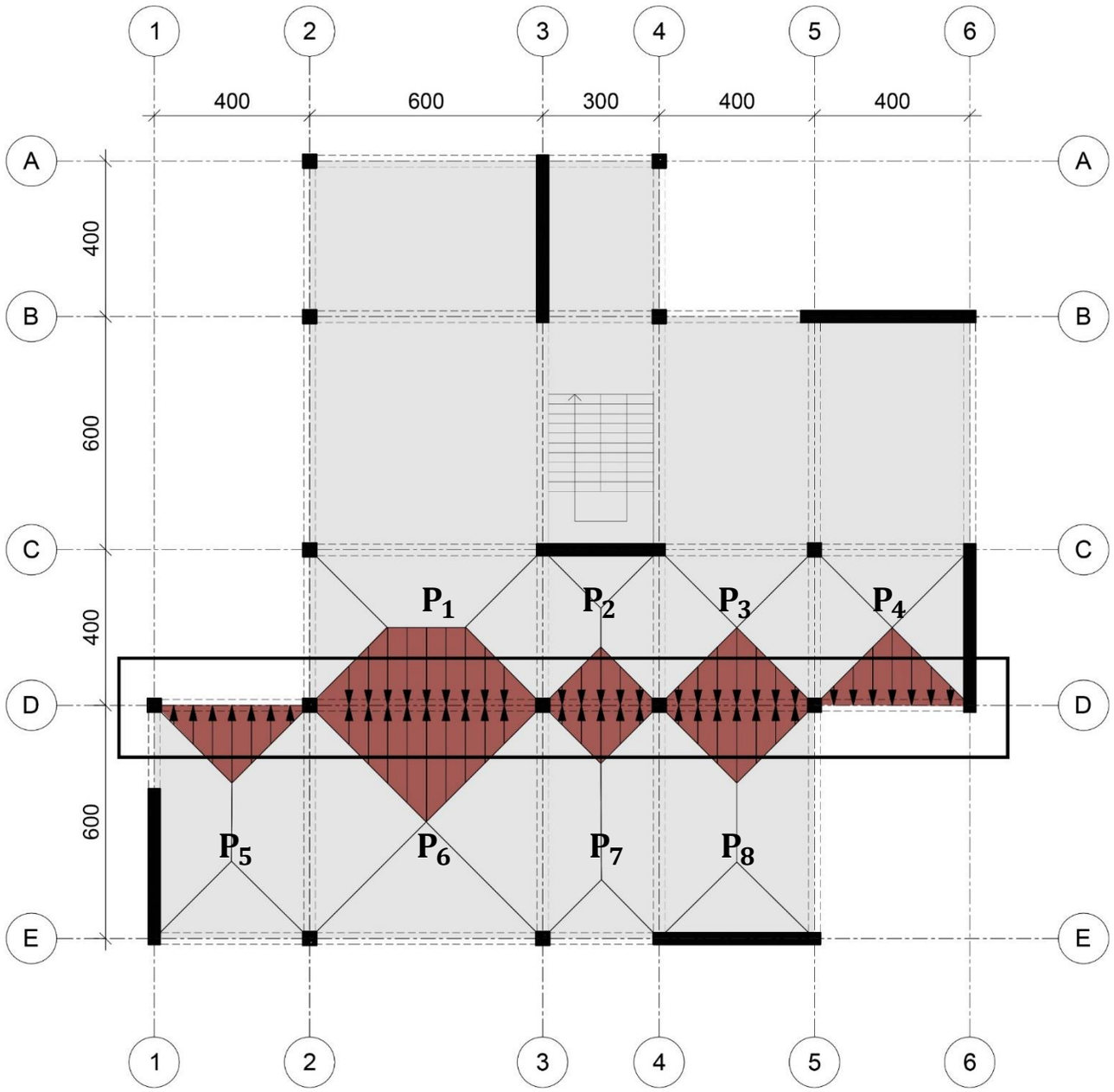
$A_c = \frac{83700}{0{,}40 \times 200}$

$A_c \geq 1046{,}25\ cm^2$

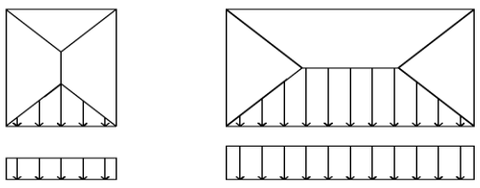
According to TS-500 minimum column size can be 30×30 cm^2

So, 35×35 cm^2 column dimension is chosen.

Beam Analysis



Equivalent uniform load on rectangular two-way solid slab



$P_{uni}=P_d \times \frac{L_s}{3}$ $\quad P_{uni}=P_d \times \frac{L_s}{3}\left[1{,}5-\frac{0{,}5}{(\frac{L_l}{L_s})^2}\right]$

Uniformly distributed wall load on beam

W_L= wall height × wall load × dead load factor
= 3,02 × 0,15 × 1,4
= 0,63 t/m

Note: beam own weight is neglected

P_d = 1,1 t/m^2
P_{uni} = 0,63 t/m

$P_1 = 1{,}1 \times \frac{4}{3}\left[1{,}5-\frac{0{,}5}{(\frac{6}{4})^2}\right]$
= 1,87 t/m
$P_2 = 1{,}1 \times \frac{3}{3}$ = 1,1 t/m
$P_3 = 1{,}1 \times \frac{4}{3}$ = 1,46 t/m
$P_4 = 1{,}1 \times \frac{4}{3}$ = 1,46 t/m
$P_5 = 1{,}1 \times \frac{4}{3}$ = 1,46 t/m
$P_6 = 1{,}1 \times \frac{6}{3}$ = 2,2 t/m
$P_7 = 1{,}1 \times \frac{3}{3}$ = 1,1 t/m
$P_8 = 1{,}1 \times \frac{4}{3}$ = 1,46 t/m

Total Load On Beams

Beam 1-2 = $P_5 + W_L$
= 1,46 + 0,63
= 2,09 t/m

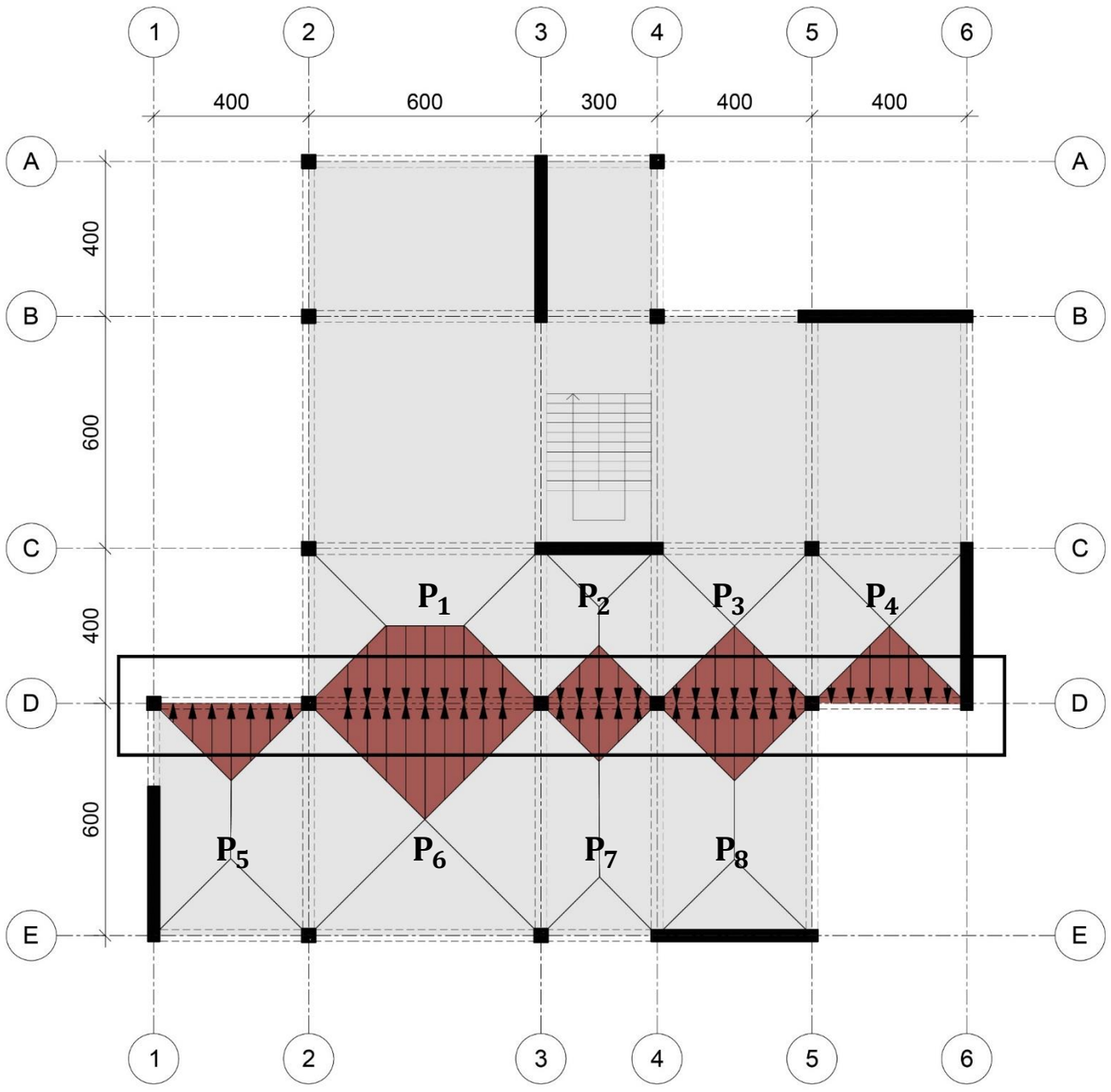
Beam 2-3 = $P_1 + P_6 + W_L$
= 1,87+ 2,2+ 0,63
= 4,7 t/m

Beam 3-4 = $P_2 + P_7 + W_L$
= 1,1+ 1,1+ 0,63
= 2,83 t/m

Beam 4-5 = $P_3 + P_8 + W_L$
= 1,46+ 1,46+ 0,63
= 23.55 t/m

Beam 5-6 = $P_3 + P_8 + W_L$
= 1,46+ 1,46+ 0,63
= 3,55 t/m

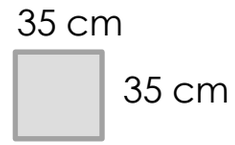
Beam Analysis



Moment Of Inertia

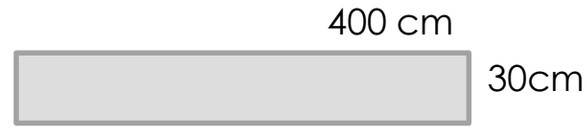
Column Cross-section

$I_{column} = \frac{35 \times 35^3}{12} = 125\,052\ cm^4$



Shear Wall Cross-section

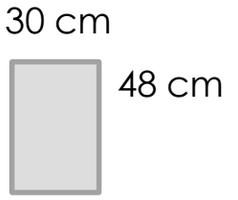
$I_{SW_4} = \frac{400 \times 30^3}{12} = 900\,000\ cm^4$



Beam Cross-section

Beam depth assumption = $\frac{600}{12,5} = 48$ cm

$I_{beam} = \frac{30 \times 48^3}{12} = 276\,480\ cm^4$



Load Distribution Factor

$$r = \frac{\frac{I}{L}}{\Sigma \frac{I}{L}}$$

$$r_{12} = \frac{\frac{276480}{4}}{\frac{276480}{4} + (\frac{125052}{3,5}) \times 2} = 0,49$$

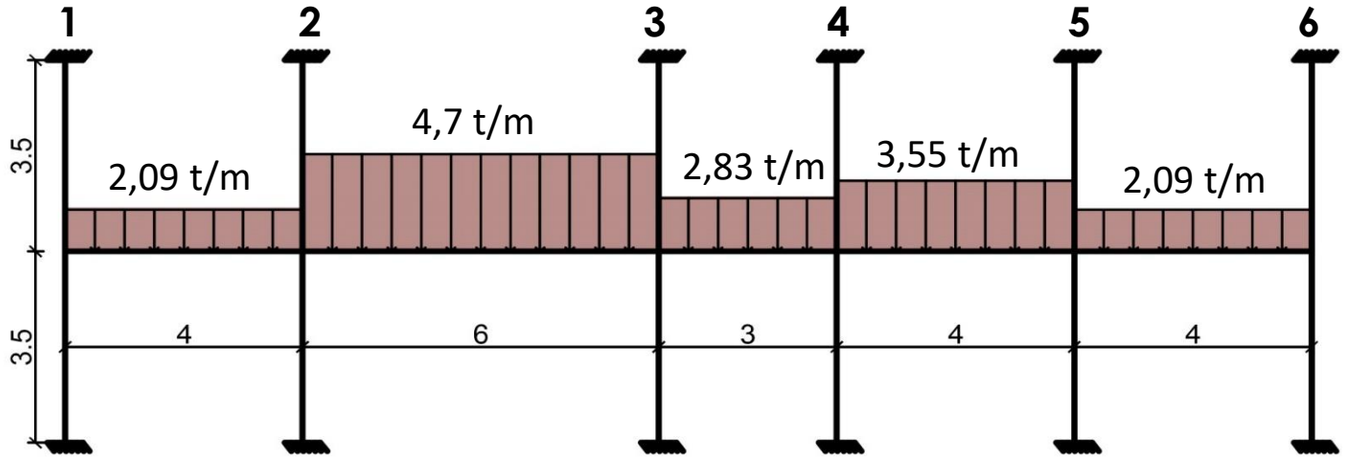
$$r_{21} = \frac{\frac{276480}{4}}{\frac{276480}{4} + \left(\frac{125052}{3,5}\right) \times 2 + \frac{276480}{6}} = 0,37$$

$$r_{23} = \frac{\frac{276480}{6}}{\frac{276480}{6} + \left(\frac{125052}{3,5}\right) \times 2 + \frac{276480}{4}} = 0,24$$

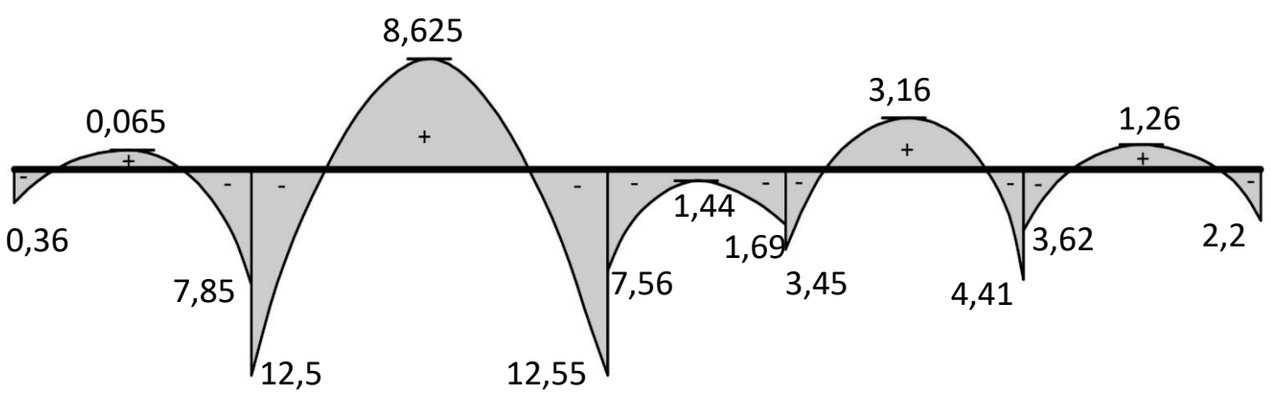
$$r_{32} = \frac{\frac{276480}{6}}{\frac{276480}{6} + \left(\frac{125052}{3,5}\right) \times 2 + \frac{276480}{3}} = 0,21$$

$$r_{34} = \frac{\frac{276480}{3}}{\frac{276480}{3} + \left(\frac{125052}{3,5}\right) \times 2 + \frac{276480}{6}} = 0,43$$

Beam Analysis



	1		2		3		4		5		6
	0,49	0,37	0,24	0,21	0,43	0,39	0,29	0,32	0,32	0,11	
+↺ FEM	+2,78	-2,78	+14,1	-14.1	+2,12	-2,12	+4,73	-4,73	+2,78	-2,78	
1st cycle	-2,09	-0.68	+1,25	-1,35	-0,5	+2,57	+0.31	-0,37	+0,15	+0,31	
Σ_1	+0.69	-3,46	+15,35	-15.45	+1,62	+0,45	+5,04	-5.10	+2,93	-2,47	
2nd cycle	-0,33	-4.39	-2,85	+2.90	+5,94	-2,14	-1,59	+0,69	+0,69	+0,27	
Σ_2	+0,36	-7,85	+12,5	-12,55	+7,56	-1,69	+3,45	-4,41	+3,62	-2,2	



Load Distribution Factor

$$r_{43} = \frac{\frac{276480}{3}}{\frac{276480}{3}+\left(\frac{125052}{3,5}\right)\times 2+\frac{276480}{4}} = 0,39$$

$$r_{45} = \frac{\frac{276480}{4}}{\frac{276480}{4}+\left(\frac{125052}{3,5}\right)\times 2+\frac{276480}{3}} = 0,29$$

$$r_{54} = \frac{\frac{276480}{4}}{\frac{276480}{4}+\left(\frac{125052}{3,5}\right)\times 2+\frac{276480}{4}} = 0,32$$

$$r_{56} = \frac{\frac{276480}{4}}{\frac{276480}{4}+\left(\frac{125052}{3,5}\right)\times 2+\frac{276480}{4}} = 0,32$$

$$r_{65} = \frac{\frac{276480}{4}}{\frac{276480}{4}+\left(\frac{900000}{3,5}\right)\times 2} = 0,11$$

Fixed End Moment

FEM= $\frac{WL^2}{12}$ $M_{mid} = = \frac{WL^2}{24}$

$FEM_{1-2} = \frac{2,09\times 4^2}{12}$ = 2,78 tm M_{mid1-2} = 1,39 tm

$FEM_{2-3} = \frac{4,7\times 6^2}{12}$ = 14,1 tm M_{mid2-3} = 7,05 tm

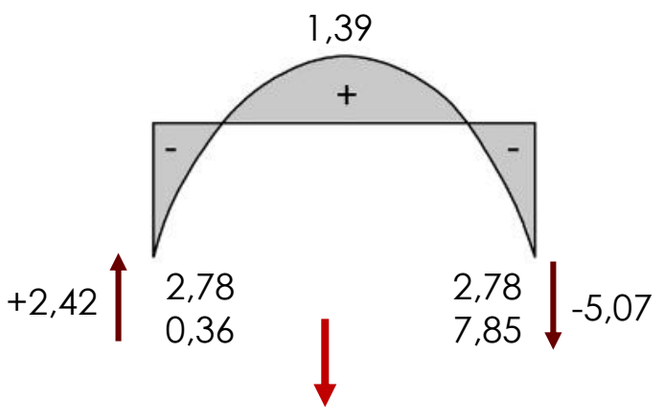
$FEM_{3-4} = \frac{2,83\times 3^2}{12}$ = 2,12 tm M_{mid1-2} = 1,06 tm

$FEM_{4-5} = \frac{3,55\times 4^2}{12}$ = 4,73 tm M_{mid1-2} = 2,36 tm

$FEM_{5-6} = \frac{2,09\times 4^2}{12}$ = 2,78 tm M_{mid5-6} = 1,39 tm

Beam Analysis

Region 1-2

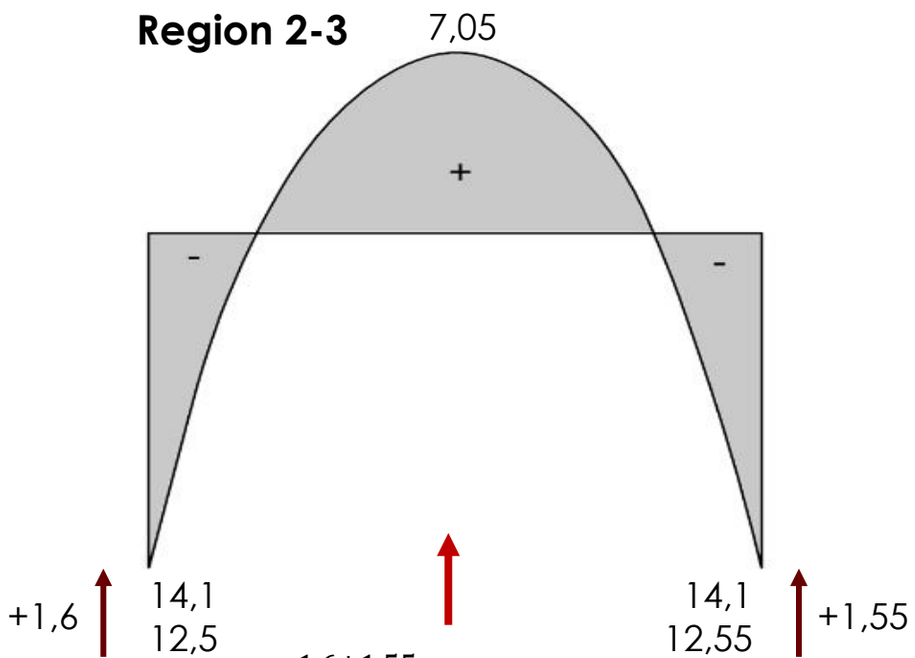


$\frac{2,42-5,07}{2}$ = -1,325

M_{mid1-2} = 1,39-1,325

= 0,065

Region 2-3

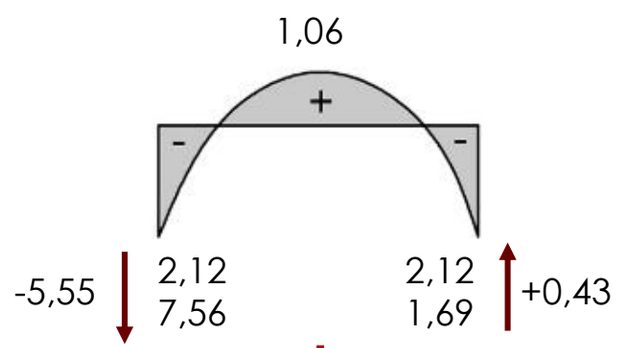


$\frac{1,6+1,55}{2}$ = -1,575

M_{mid2-3} = 7,0+1,575

= 8,625

Region 3-4

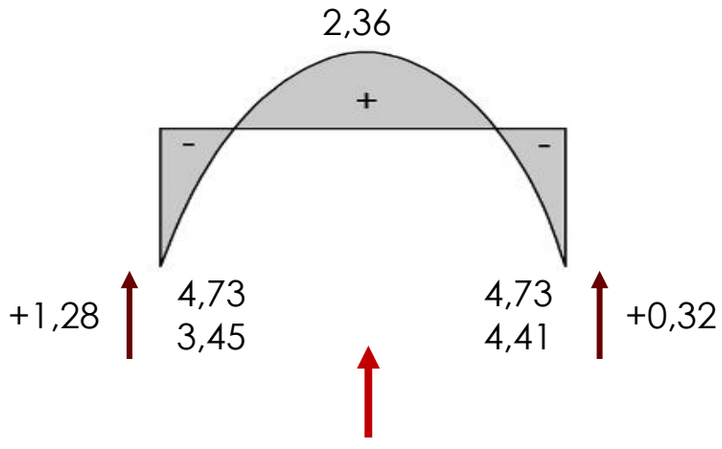


$\frac{-5,44+0,43}{2}$ = -2,5

M_{mid3-4} = 1,06-2,5

= -1,44

Region 4-5

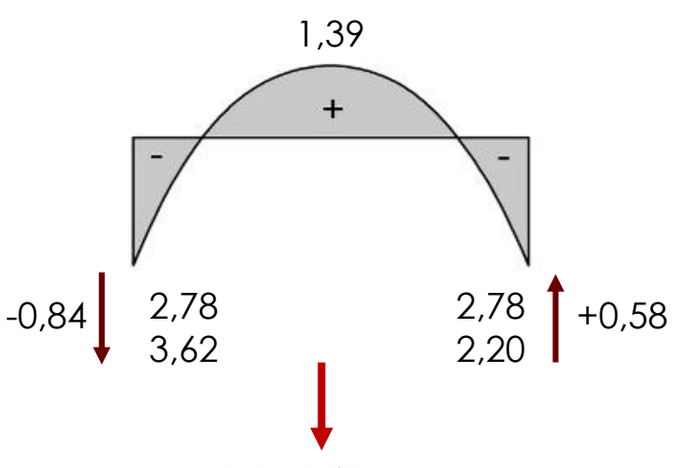


$\frac{1,28+0,32}{2}$ = +0,8

M_{mid4-5} = 2,36+0,8

= 3,16

Region 5-6



$\frac{-0,84+0,58}{2}$ = -0,13

M_{mid5-6} = 1,39-0,13

= 1,26

Beam Depth

$k_0 = \frac{bwd^2}{M_d}$, $k_0 = 25\ cm^2/t$

$25 = \frac{30d^2}{1255}$

d^2 = 1045,83

d = 32,33 cm

h ≥ d + 5

h ≥ 32,33 + 5

h ≥ 37,33 cm

According to TS500 codes, beam depth must be larger than three times of slab thichness.
Therefore, (15,5 x 3) **the beam depth is selected as 46.5 cm.**