METU DEPARTMENT OF ARCHITECTURE

ARCH 332 - STRUCTURAL DESIGN IN ARCHITECTURE II

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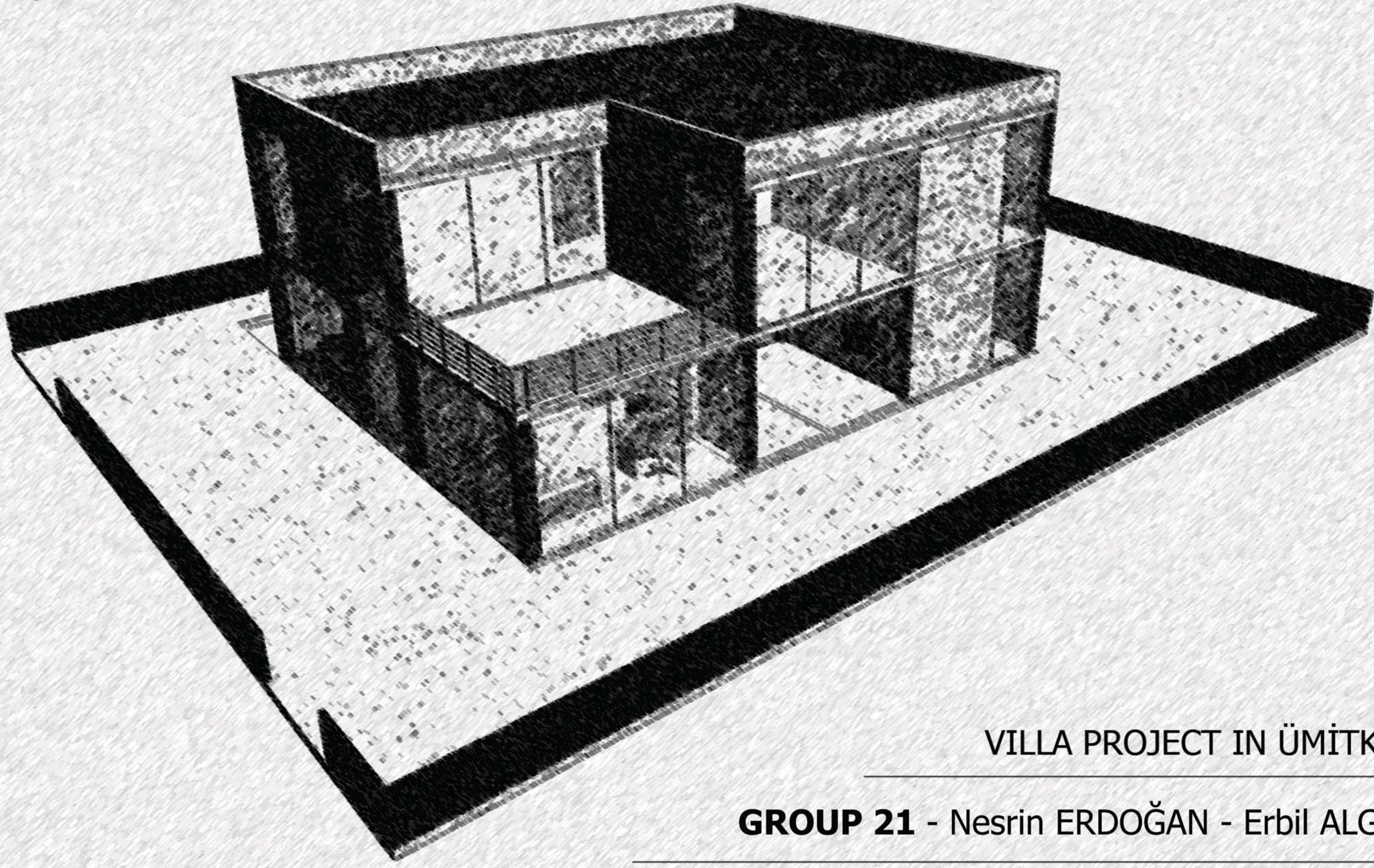
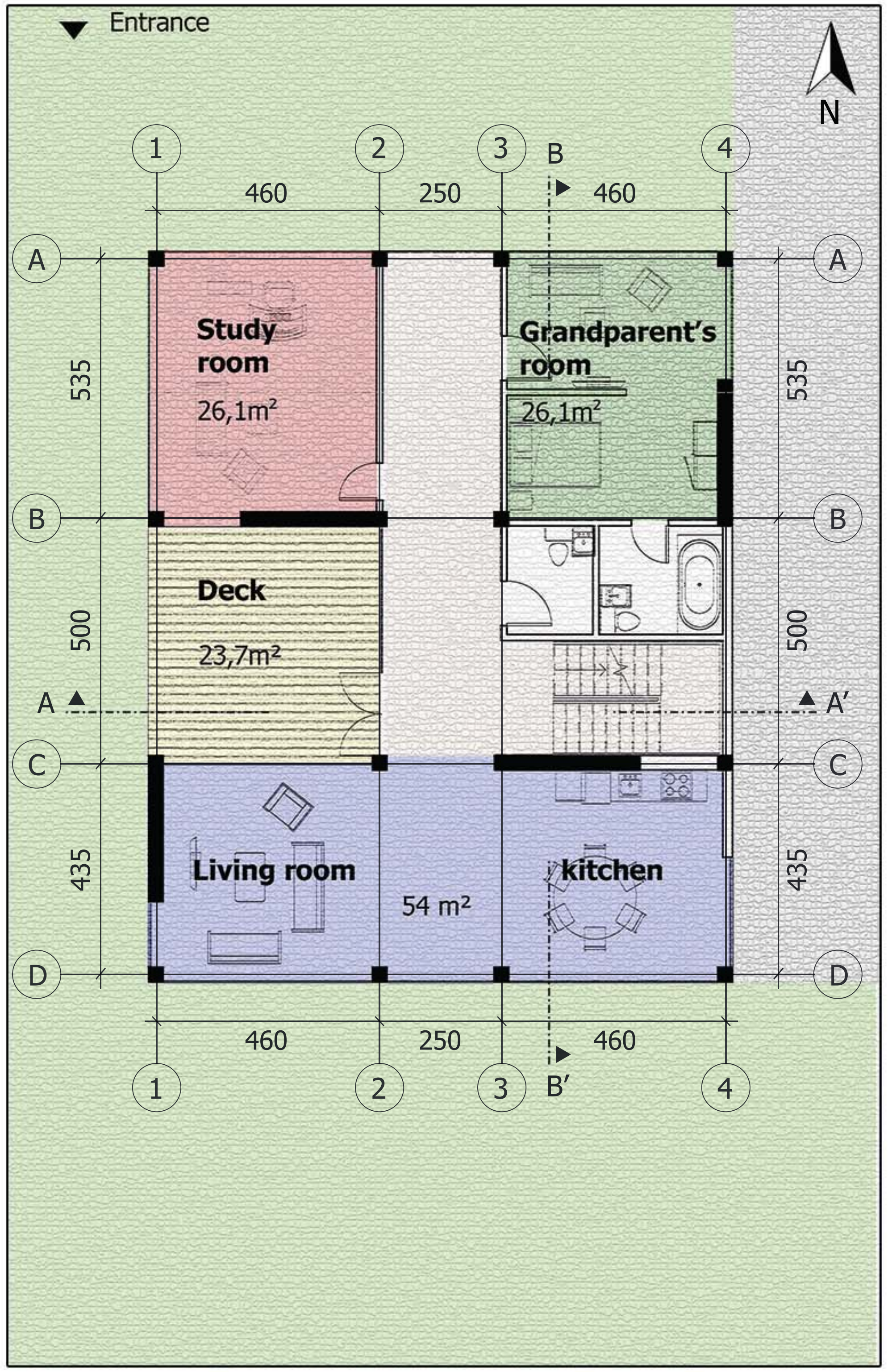
2013-14, Spring



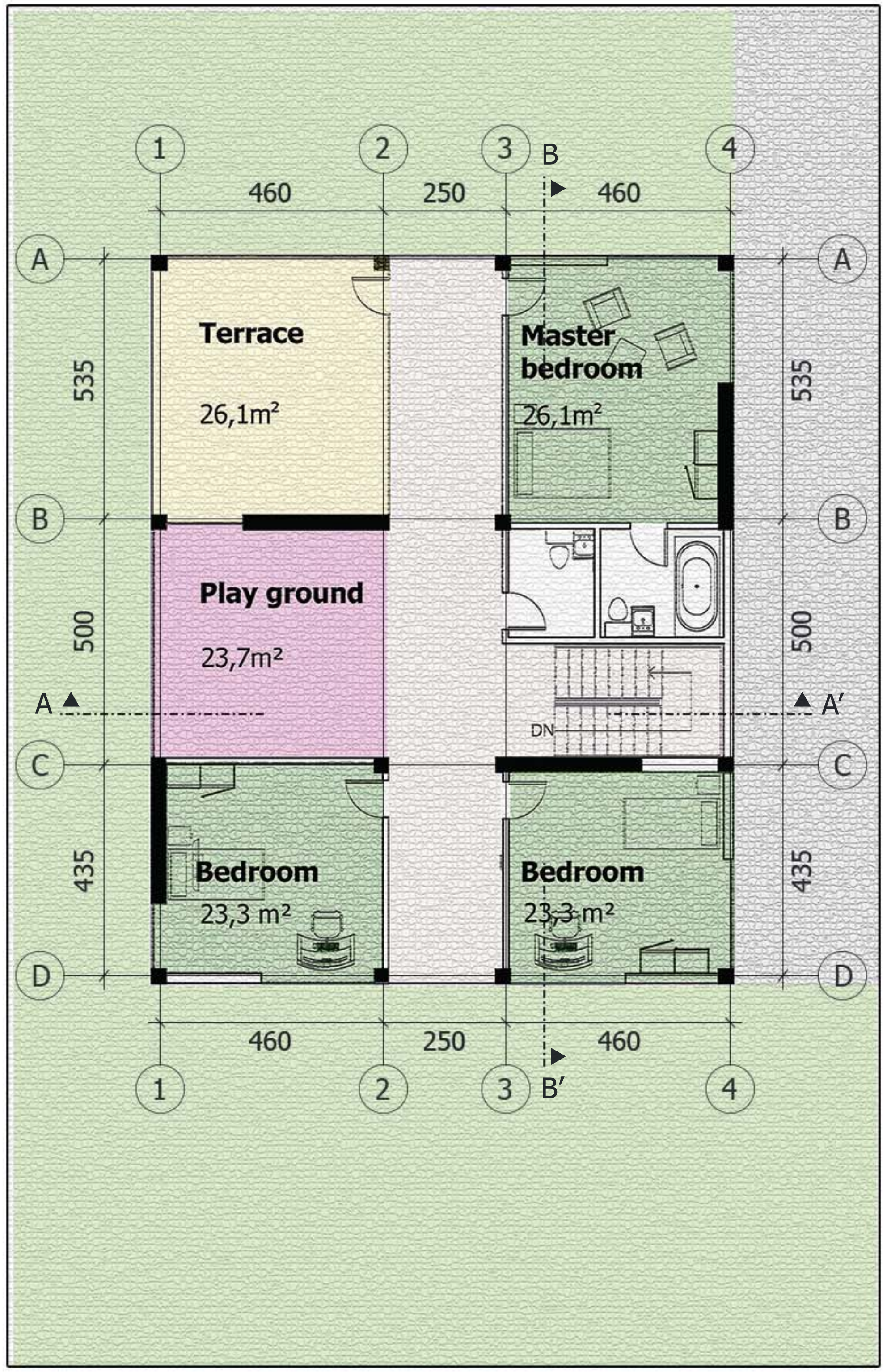
VILLA PROJECT IN ÜMİTKÖY

GROUP 21 - Nesrin ERDOĞAN - Erbil ALGAN

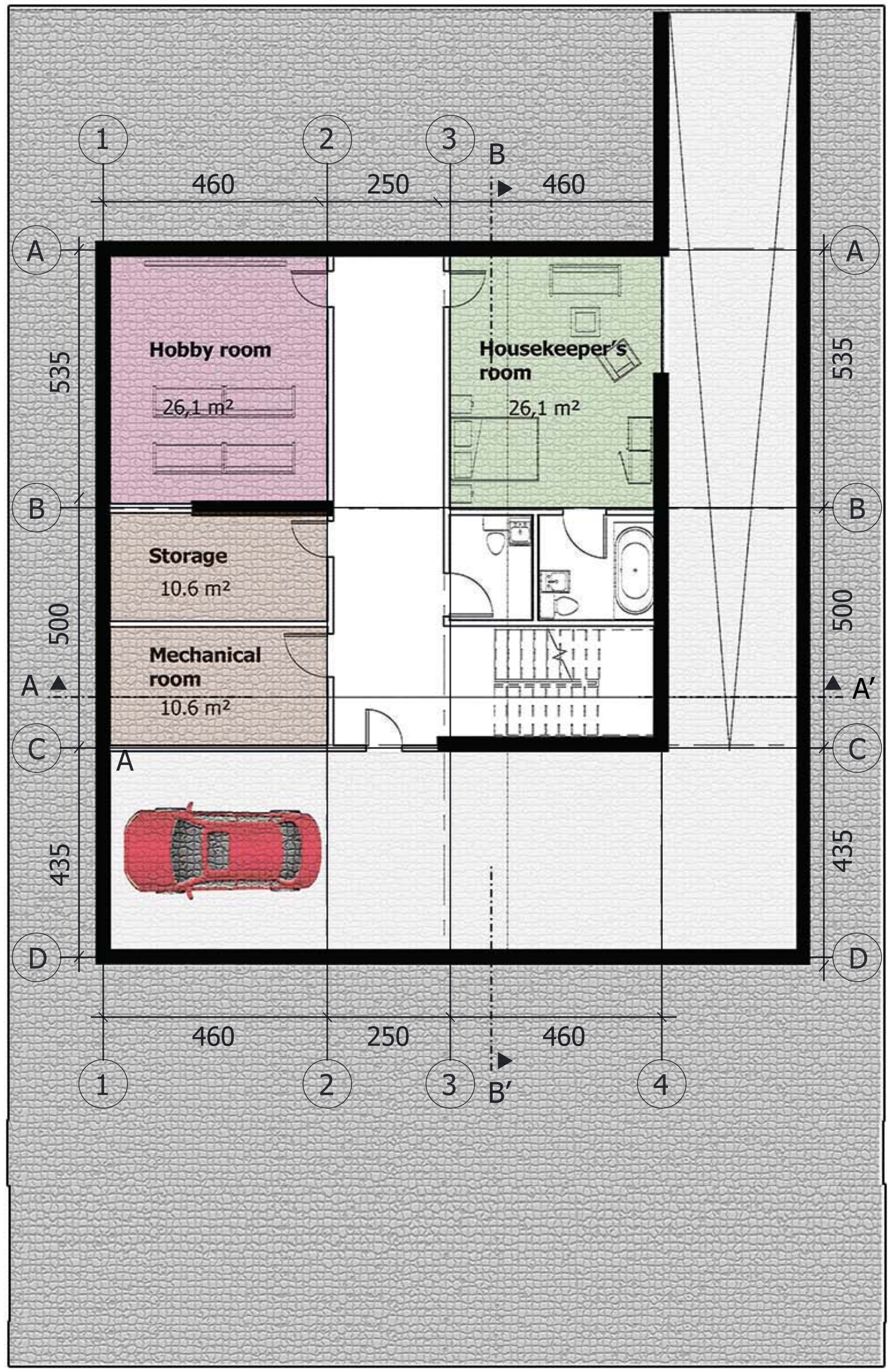
Floor Plans



Ground Floor Plan
(Level ±0.00)



First Floor Plan
(Level +3.00)



Basement Floor Plan
(Level -3.00)

Elevations

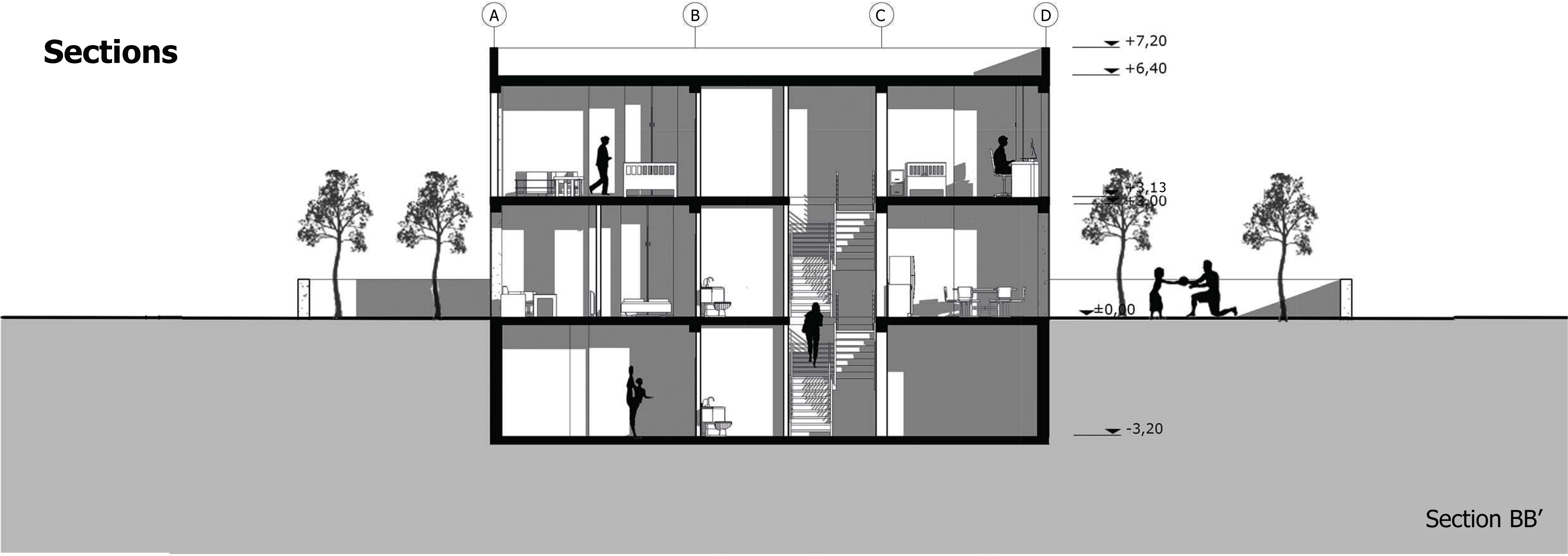
South Elevation

North Elevation

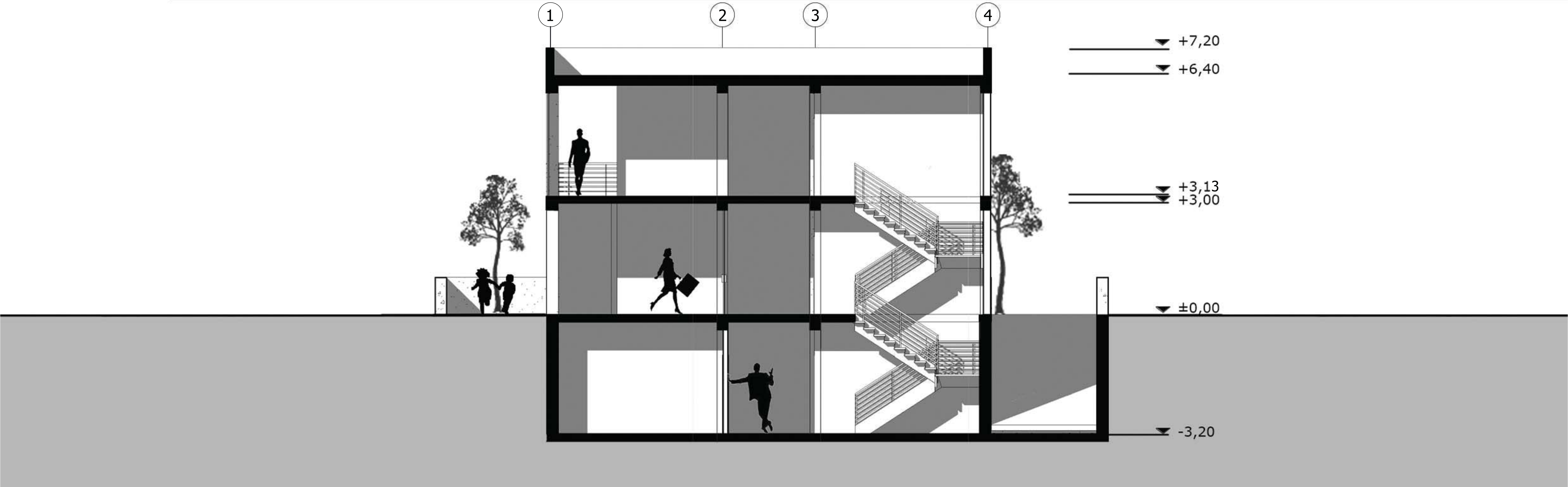
East Elevation

West Elevation

Sections



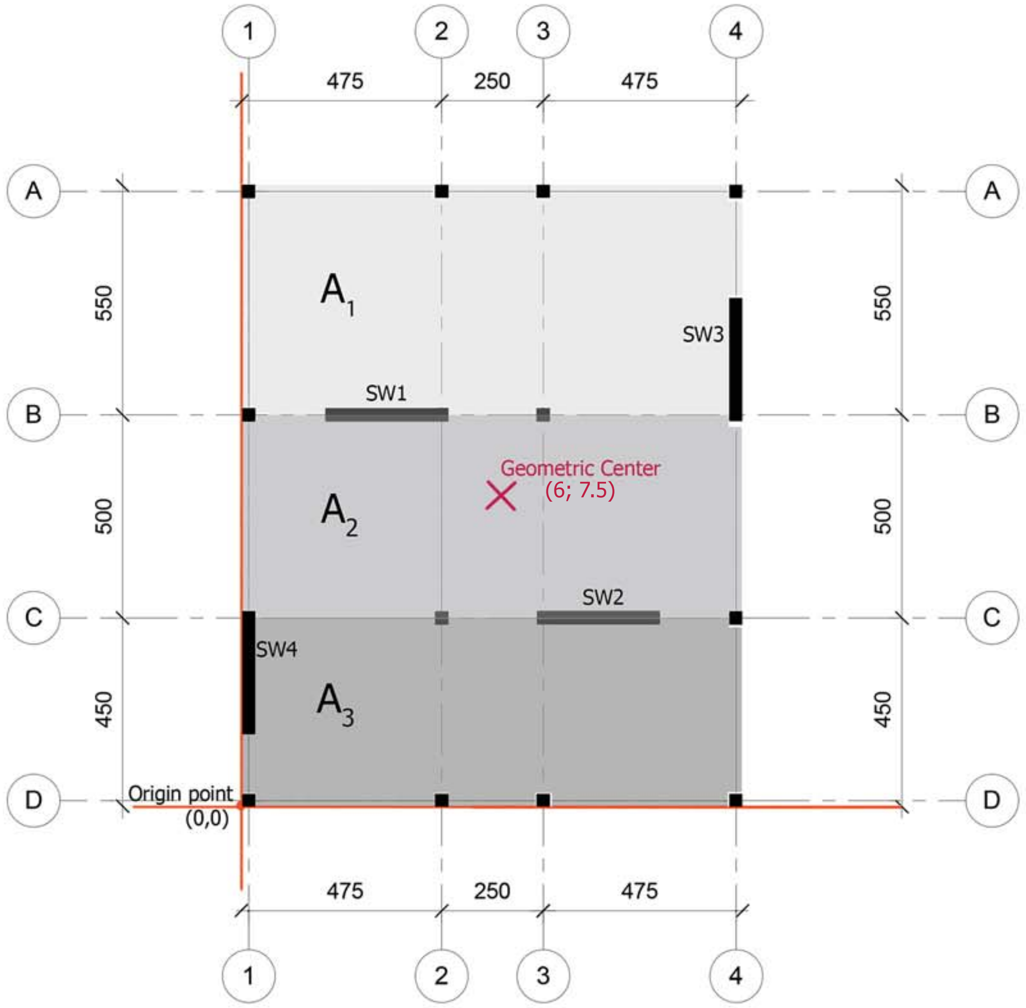
Section BB′



Section AA′

STRUCTURAL SYSTEM

-GEOMETRIC CENTER



$$G_x = \frac{(A_1 \times 6) + (A_2 \times 6) + (A_3 \times 6)}{A_1 + A_2 + A_3}$$

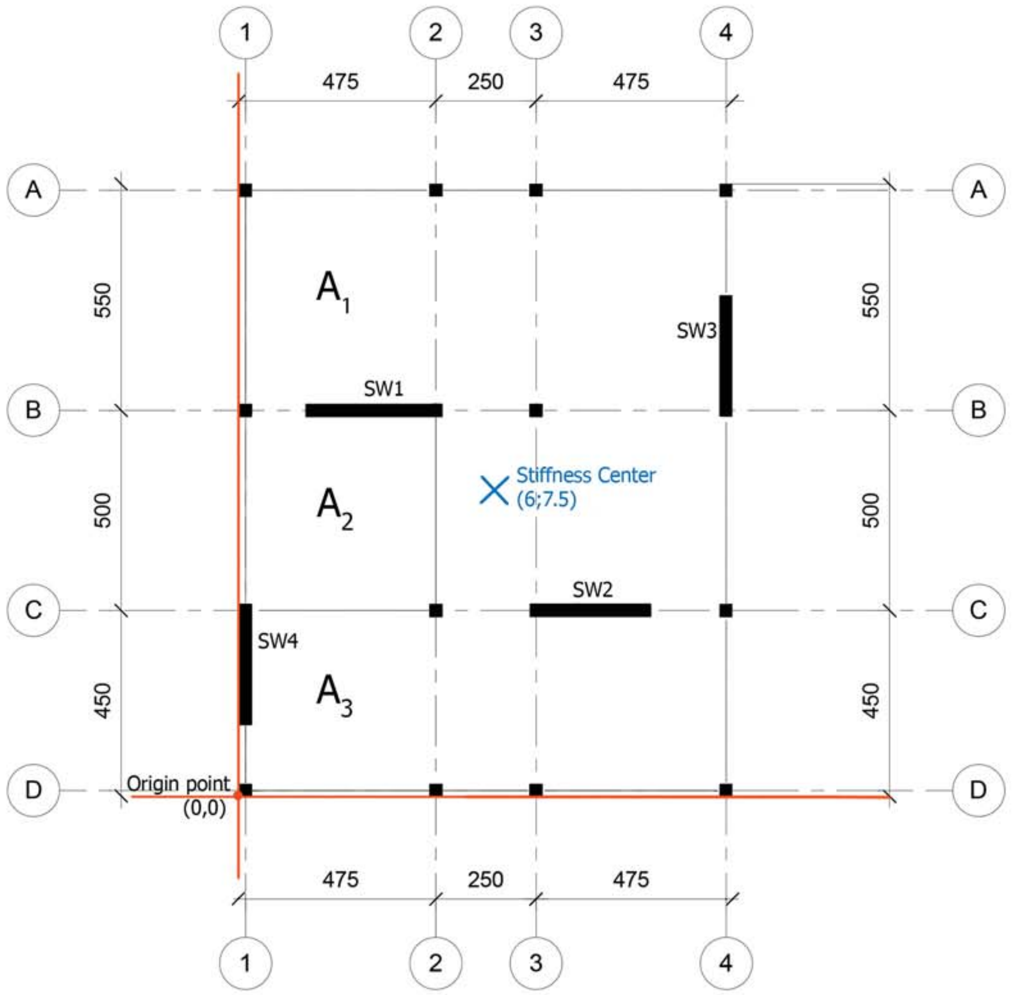
$$= \frac{(66 \times 6) + (60 \times 6) + (54 \times 6)}{66 + 60 + 54}$$

A_1=5.5 x 12= 66 m²
A_2= 5 x 12 = 60 m²
A_3=4.5 x 12 =54 m²

$$G_y = \frac{(A_1 \times 12.25) + (A_2 \times 7) + (A_3 \times 2.25)}{A_1 + A_2 + A_3}$$

G_x = 6m G_y = 7.5m
Geometric Center = (G_x , G_y) = (6; 7.5)

-STIFFNESS CENTER



I_1 = 1/12 x 0.3 x $(3.4)^3$ = 1 $I_2 = I_3 = I_4$ = 1/12 x 0.3 x 33 = 0.67
L_1 = 9.5 m L_2 = 4.5 m L_3 = 12 m L_4= 0

$$S_x = \frac{(I_3 \times L_3) + (I_4 \times L_4)}{I_3 + I_4}$$

$$= \frac{(0.67 \times 12) + (0.67 \times 0)}{0.67 + 0.67} = 6\text{m}$$

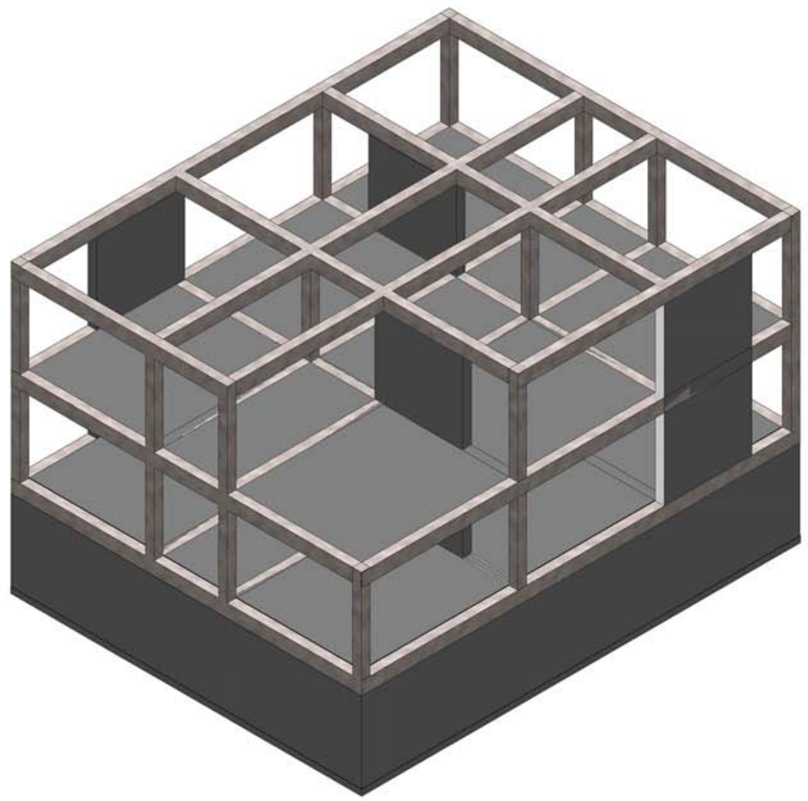
$$S_y = \frac{(I_1 \times L_1) + (I_2 \times L_2)}{I_1 + I_2}$$

$$= \frac{(1 \times 9.5) + (0.67 \times 4.5)}{0.67 + 0.67} = 7.5\text{m}$$

S_x = 6m S_y = 7.5m   Stiffness Center = (S_x , S_y) = (6; 7.5)

In x and y directions, there is no dislocation.

-SHEAR WALL PERCENTAGE

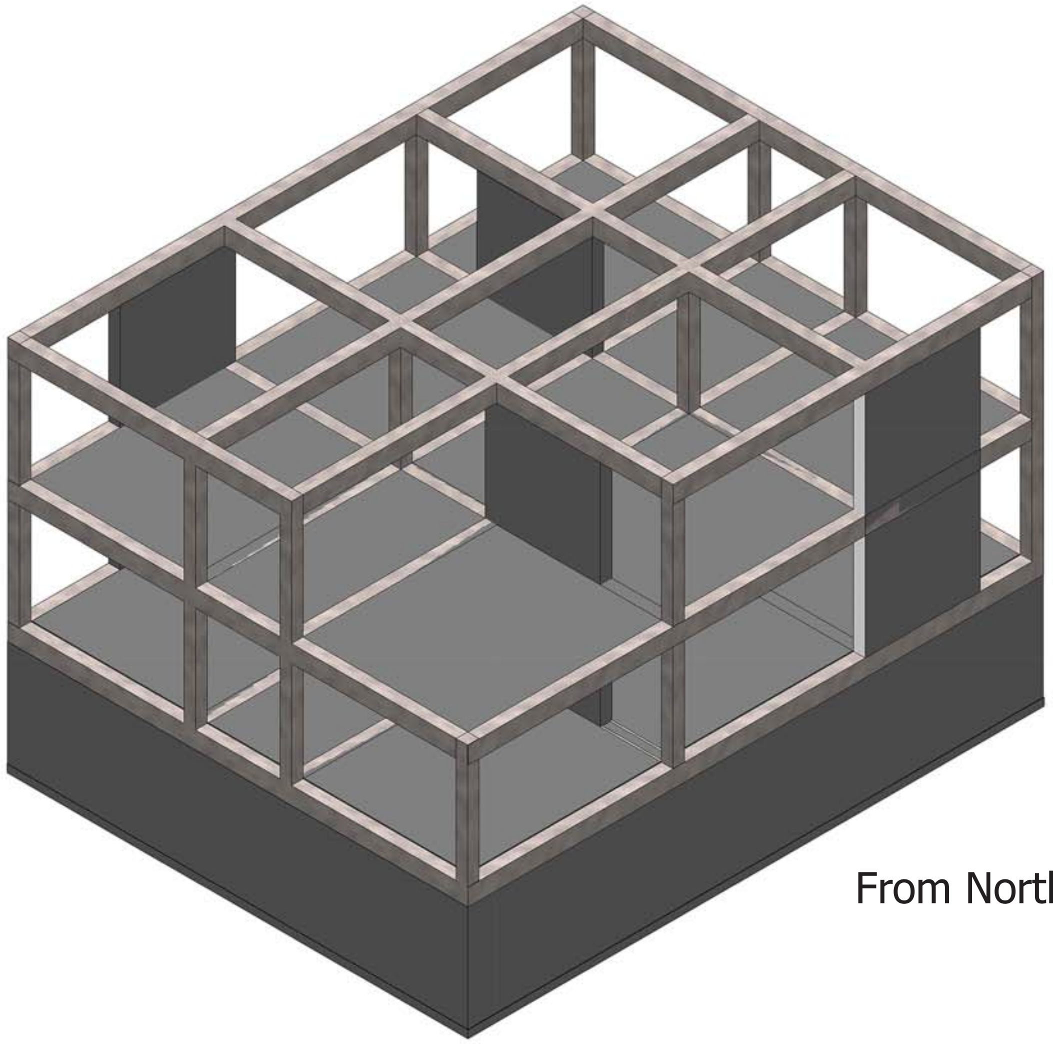


From Northwest

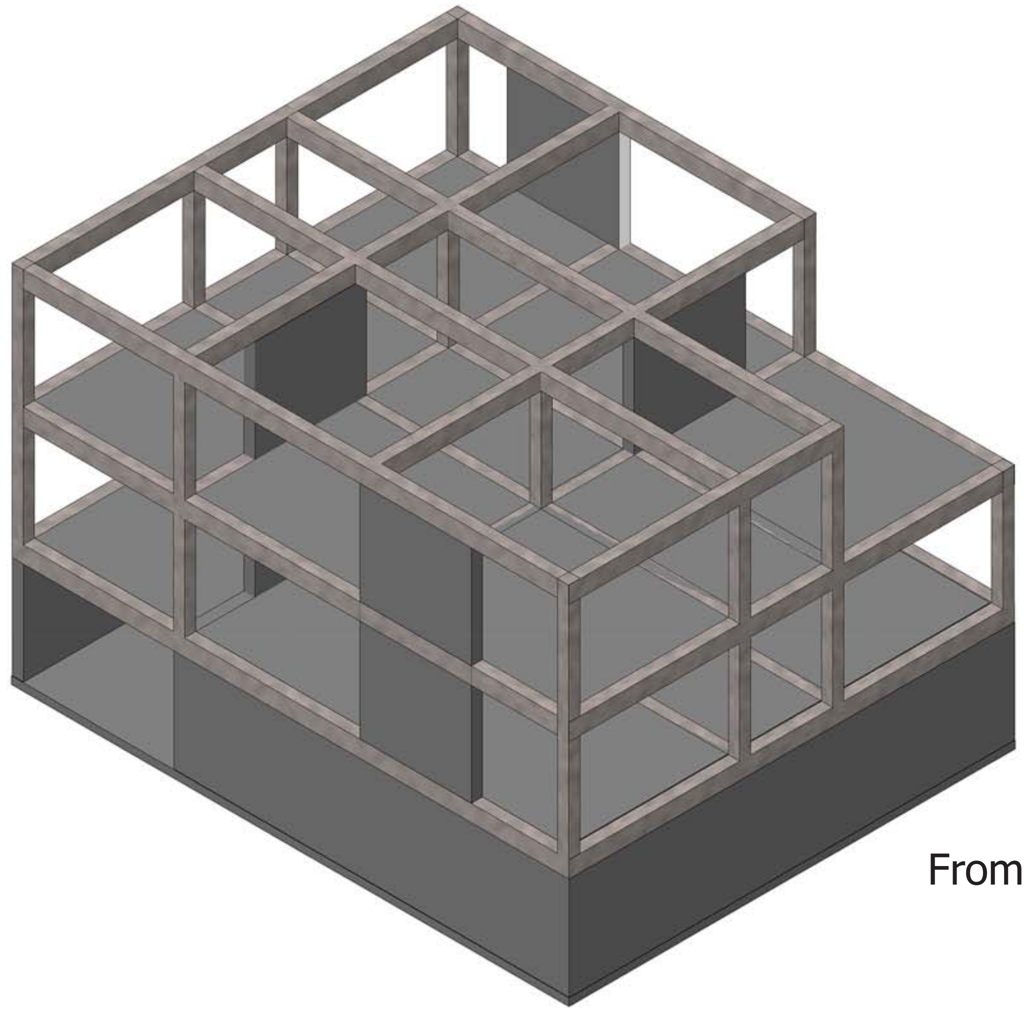
Total floor area : 180 m2

Area of shear walls in x direction :
SW_1 = 0.3 x 3.4 = 1.02 m²
SW_2 = 0.3 x 3 = 0.9 m²
The ratio of shear wall area in x direction to floor area :
2.1 / 180 = 0.011 ---> 1%

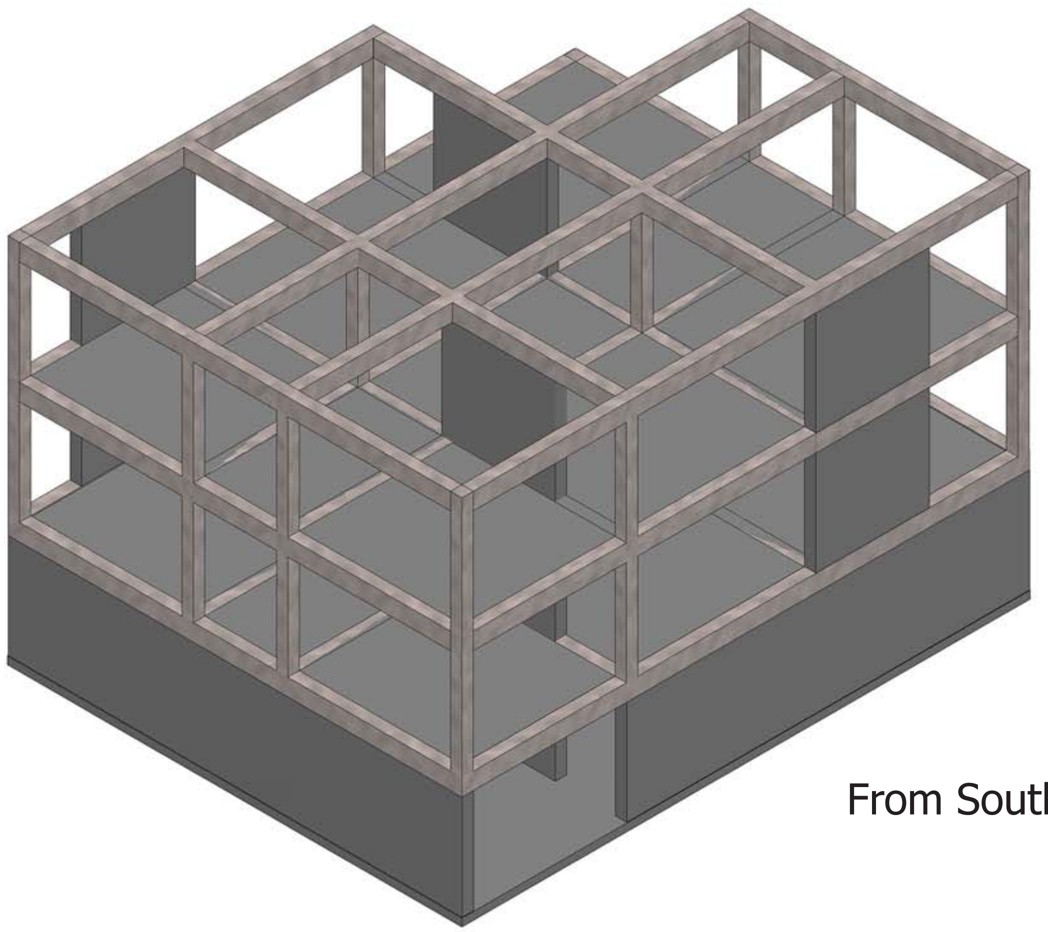
Area of shear walls in y direction :
0.3 x 3 x 2 = 1.8 m2
The ratio of shear wall area in y direction to floor area :
1.8 / 180 = 0.01 ---> 1%



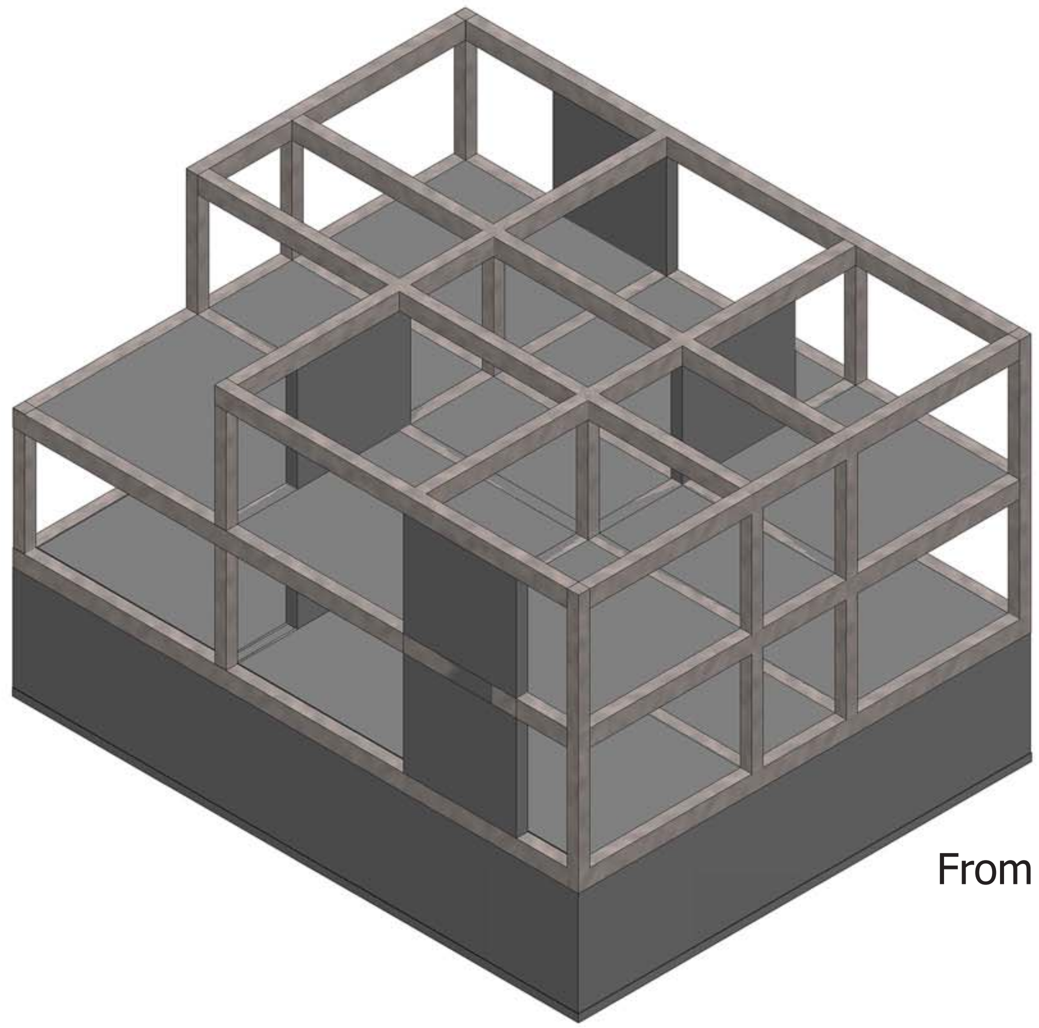
From Northwest



From Northeast

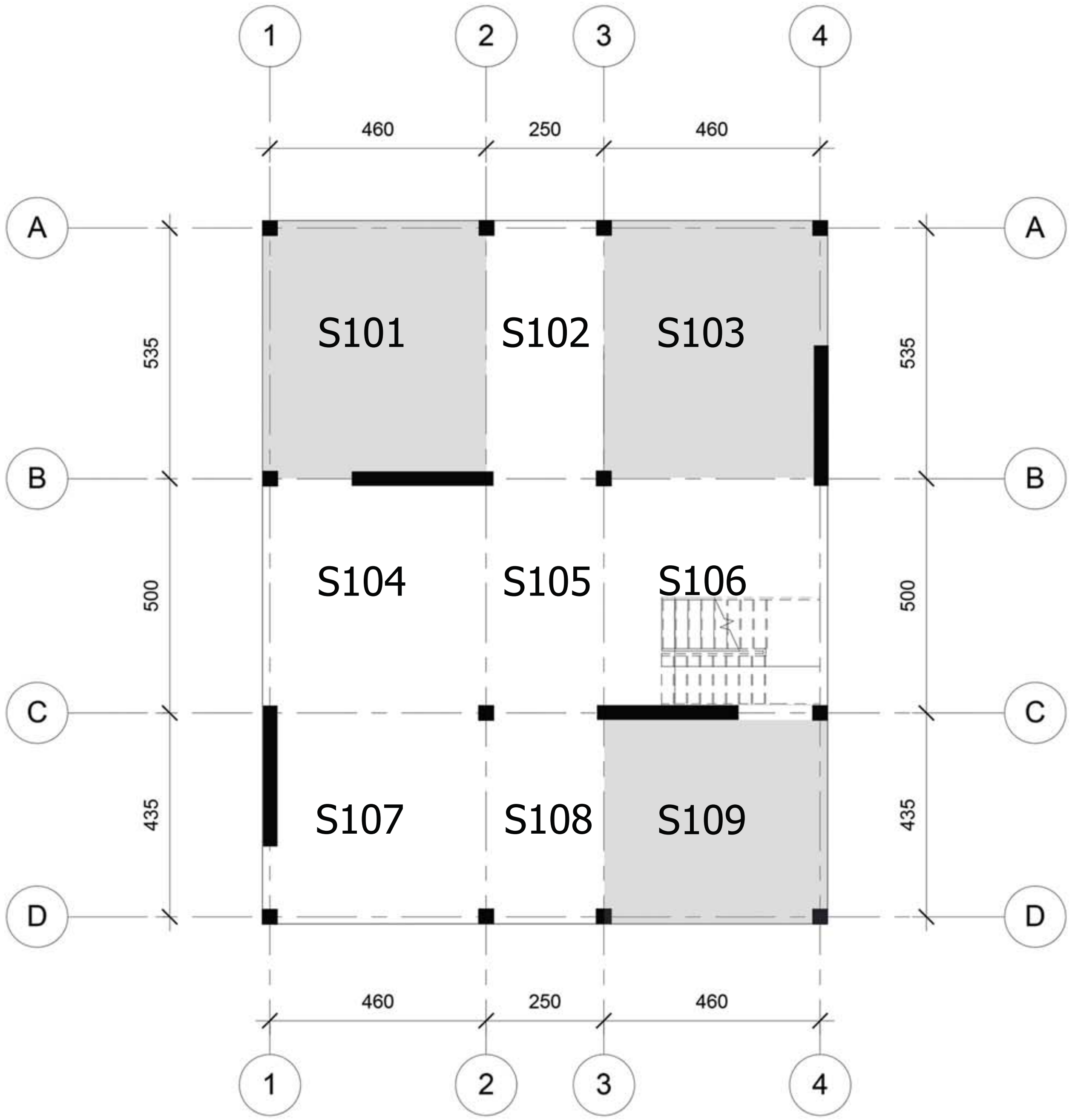


From Southeast



From Southwest

SLAB SYSTEM



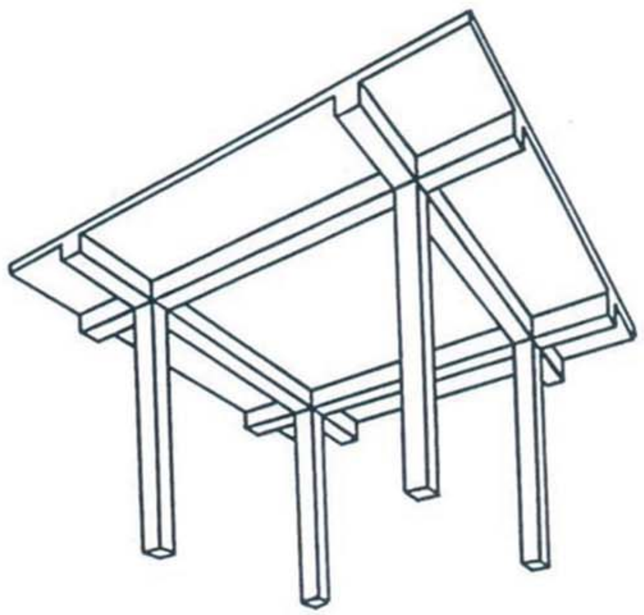
Solid Slab with Beams Thickness

$$\alpha = \frac{\text{length of continious edges}}{\text{total length of edges}} \qquad t \geq \frac{l_s}{15 + \frac{20}{\frac{l_l}{l_s}}} \, x \, (1 - \frac{\alpha}{4})$$

$$\alpha_{S101} = \frac{5.35 + 4.60}{(4.60 + 5.35) x\ 2} = 0.5 \qquad t_{101} = \frac{4.60}{15 + \frac{20}{\frac{5.35}{4.60}}} \, x \left(1 - \frac{0.5}{4}\right) = 12.50\ cm$$

$$\alpha_{S103} = \frac{(2\ x\ 5.35) + 4.60}{(4.60 + 5.35) x\ 2} = 0.76 \qquad t_{103} = \frac{4.60}{15 + \frac{20}{\frac{5.35}{4.60}}} \, x \left(1 - \frac{0.76}{4}\right) = 11.57\ cm$$

$$\alpha_{S109} = \frac{4.60 + 4.35}{(4.60 + 4.35) x\ 2} = 0.5 \qquad t_{109} = \frac{4.35}{15 + \frac{20}{\frac{4.60}{4.35}}} \, x \left(1 - \frac{0.5}{4}\right) = 11.22\ cm$$



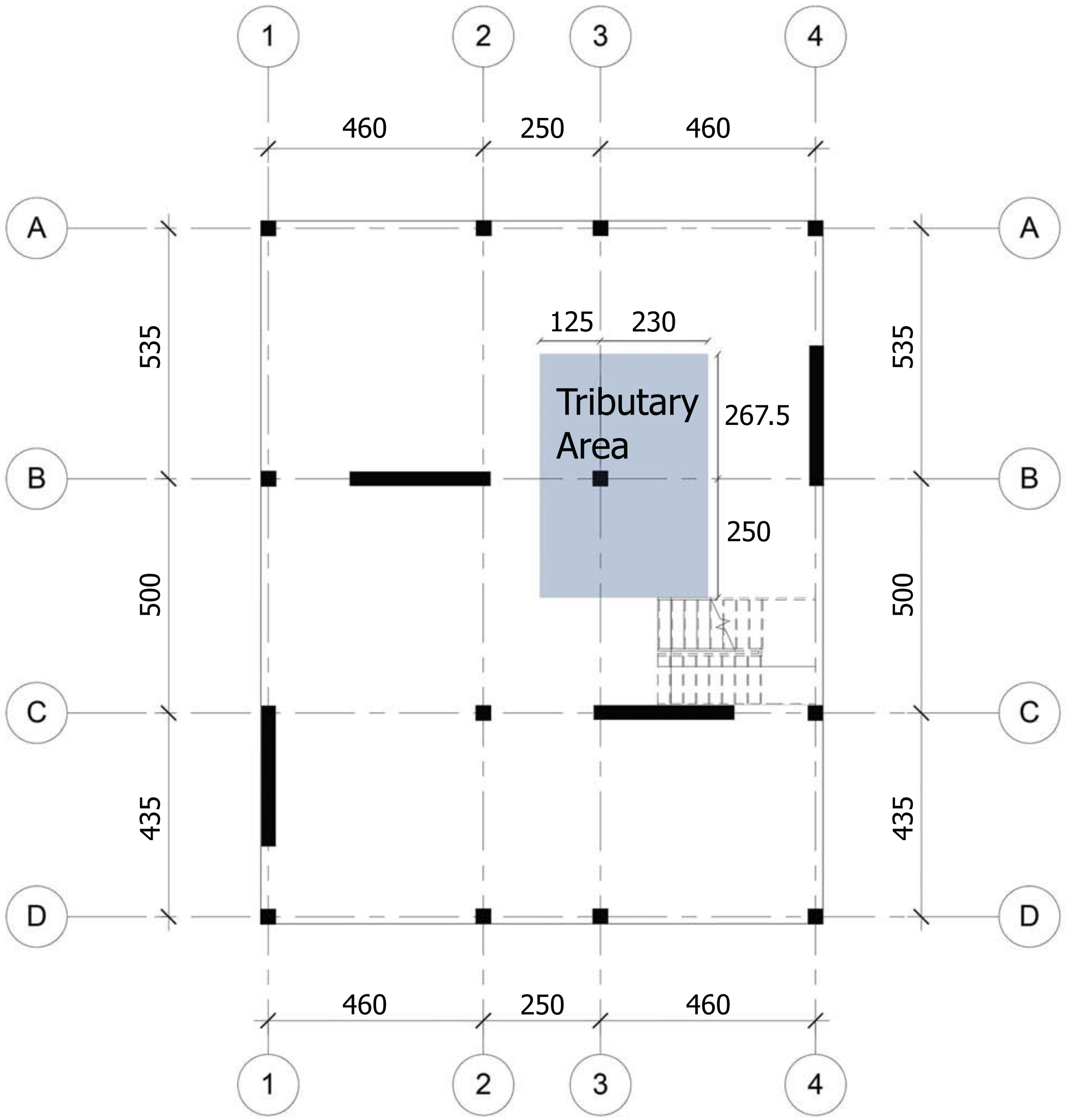
Solid slab with beams is selected with the following calculations.

Since they are the most critical ones, we only calculated S_{101}, S_{103} and S_{109}.

- Since the most critical slab thickness is t_{101} = 12.50 cm and slab thickness ≥ most critical slab

Slab Thickness = 13 cm

COLUMN DIMENSIONS



Column B3 is chosen since it has the largest tributary area.

DESIGN LOADS FOR SLAB

SLAB DEAD LOAD = 0.498 t/m² $\cong$ 0.5 t/m²

own weight : 0.13 cm x 2.4 = 0.312 t/m2
levelling: 0.04 cm x 2.4 = 0.096 t/m2
covering: 0.025 cm x 2.0 = 0.050 t/m2
plastering : 0.02 cm x 2.0 = 0.04 t/m2

SLAB LIVE LOAD = 0.2 t/m2

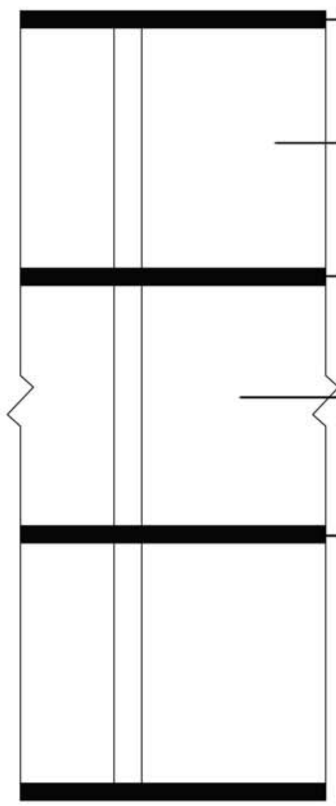
Total Load = 1,4 x DL + 1.6 x LL

SOLID SLAB TOTAL LOAD=
(1,4 x 0.498) + (1.6 x 0.2) = 1.02 t/m²

Tributary Area

Assume beam depth is 50 cm so net wall height is 2.50m

T.A= 3.55 X 5.17 = 18.35 m²



Slab Load = (3.55m x 5.17m) x 1.02 = 18.720 t = 18720 kg

WL_1 = (9.41m x 2.5m) x 0.45 t/m² x 1.4 = 14.820 t = 14820 kg

Slab Load = (3.55m x 5.17m) x 1.02 = 18.720 t = 18720kg

WL_2 = (9.41m x 2.5m) x 0.45 t/m² x 1.4 = 14.820 t = 14820 kg

Slab Load = (3.55m x 5.17m) x 1.02 = 18.720 t = 18720kg

-Note: to be on the safe side, door openings are neglected.

TOTAL LOAD = 18720 + 14820 + 18720 + 14820 + 18720 = **85800 kg**

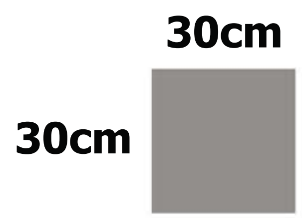
then; $Ac \geq \dfrac{Nd}{0.75 \times fcd}$

= 85800 / (0.75 x 130) = 880 cm²

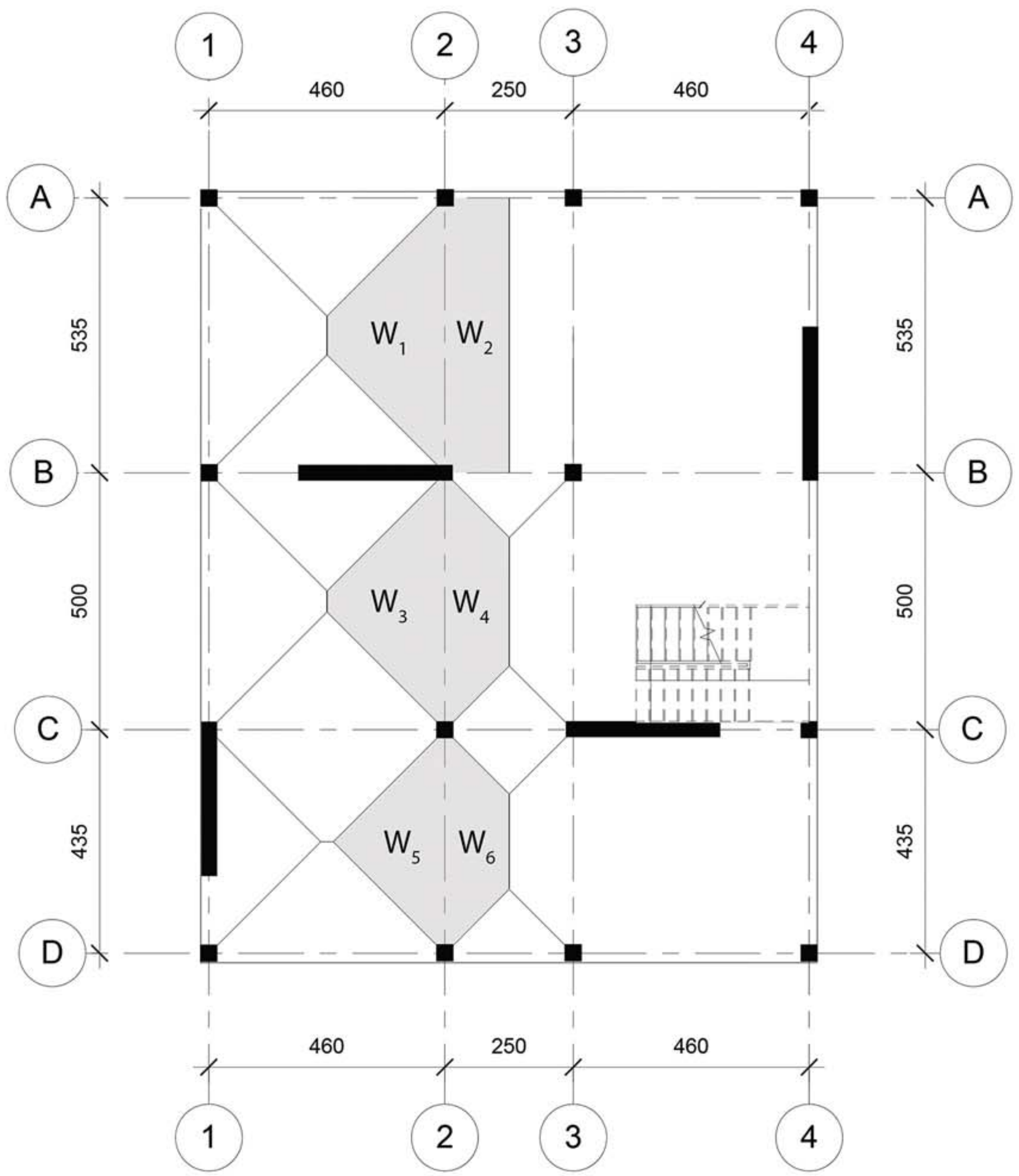
then; Ac ≥ 880 cm²

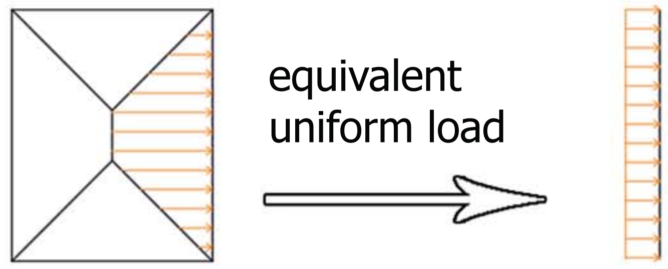
30 x 30 = 900 > 880

so according to TS - 500 Column Dimensions ; **30cm x 30cm**

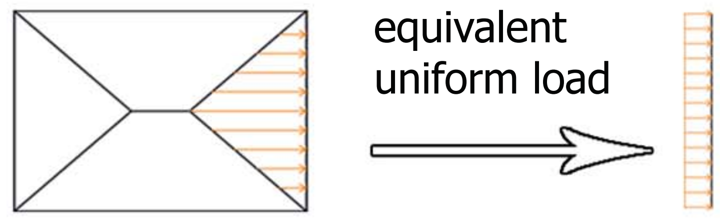


BEAM ANALYSIS





$$W = P_d \times \frac{L_{short}}{3} \times \left[1.5 - \frac{0.5}{(L_{long}/L_{short})^2} \right]$$



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

$P_d = (1.4 \times D.L) + (1.6 \times L.L)$
$P_d = (1.4 \times 0.5) + (1.6 \times 0.2) = 1.02\ t/m^2$

Since $l_{long} / l_{short} > 2$, W_2 is carried by only long beams.

Loads on 2_{A-B} Beam:

$W_1 = 1.02 \times \frac{4.6}{3} \times \left[1.5 - \frac{0.5}{(5.35/4.6)^2}\right]$
$= 1.767\ t/m$

$W_2 = \frac{(1.25 \times 5.35)}{5.35} \times 1.02$
$= 1.275\ t/m$

Wall load = $2.5 \times 0.45 \times 1.4$
= 1.575 t/m

W_{2A-B} = $W_1 + W_2$ + Wall Load
= 4.61 t/m

Loads on 2_{B-C} Beam:

$W_3 = 1.02 \times \frac{4.6}{3} \times \left[1.5 - \frac{0.5}{(5/4.6)^2}\right]$
$= 1.684\ t/m$

$W_4 = 1.02 \times \frac{2.5}{3} \times \left[1.5 - \frac{0.5}{(5/2.5)^2}\right]$
$= 1.168\ t/m$

Wall load = $2.5 \times 0.45 \times 1.4$
= 1.575 t/m

W_{2B-C} = $W_3 + W_4$ + Wall Load
= 4.42 t/m

Loads on 2_{C-D} Beam:

$W_5 = 1.02 \times \frac{4.35}{3}$
$= 1.479\ t/m$

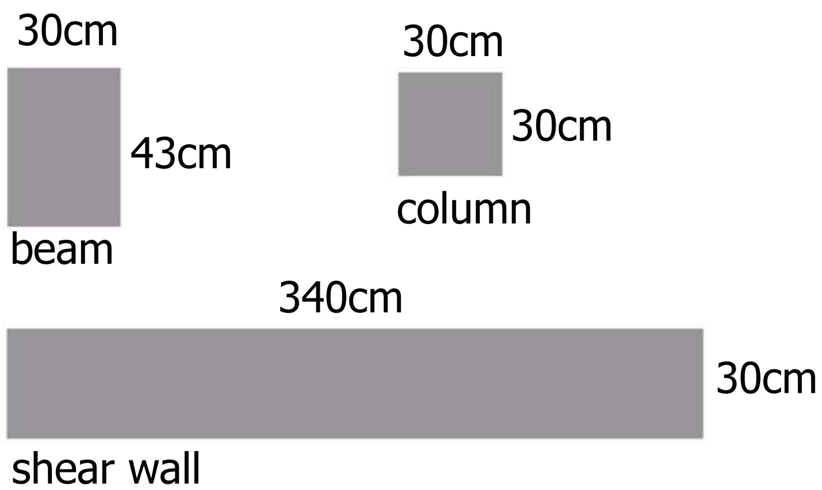
$W_6 = 1.02 \times \frac{2.5}{3} \times \left[1.5 - \frac{0.5}{(4.35/2.5)^2}\right]$
$= 1.134\ t/m$

Wall load = $2.5 \times 0.45 \times 1.4$
= 1.575 t/m

W_{2C-D} = $W_5 + W_6$ + Wall Load
= 4.18 t/m

2_{A-B} has the longest span having no shear walls.
The longest span : 535 cm

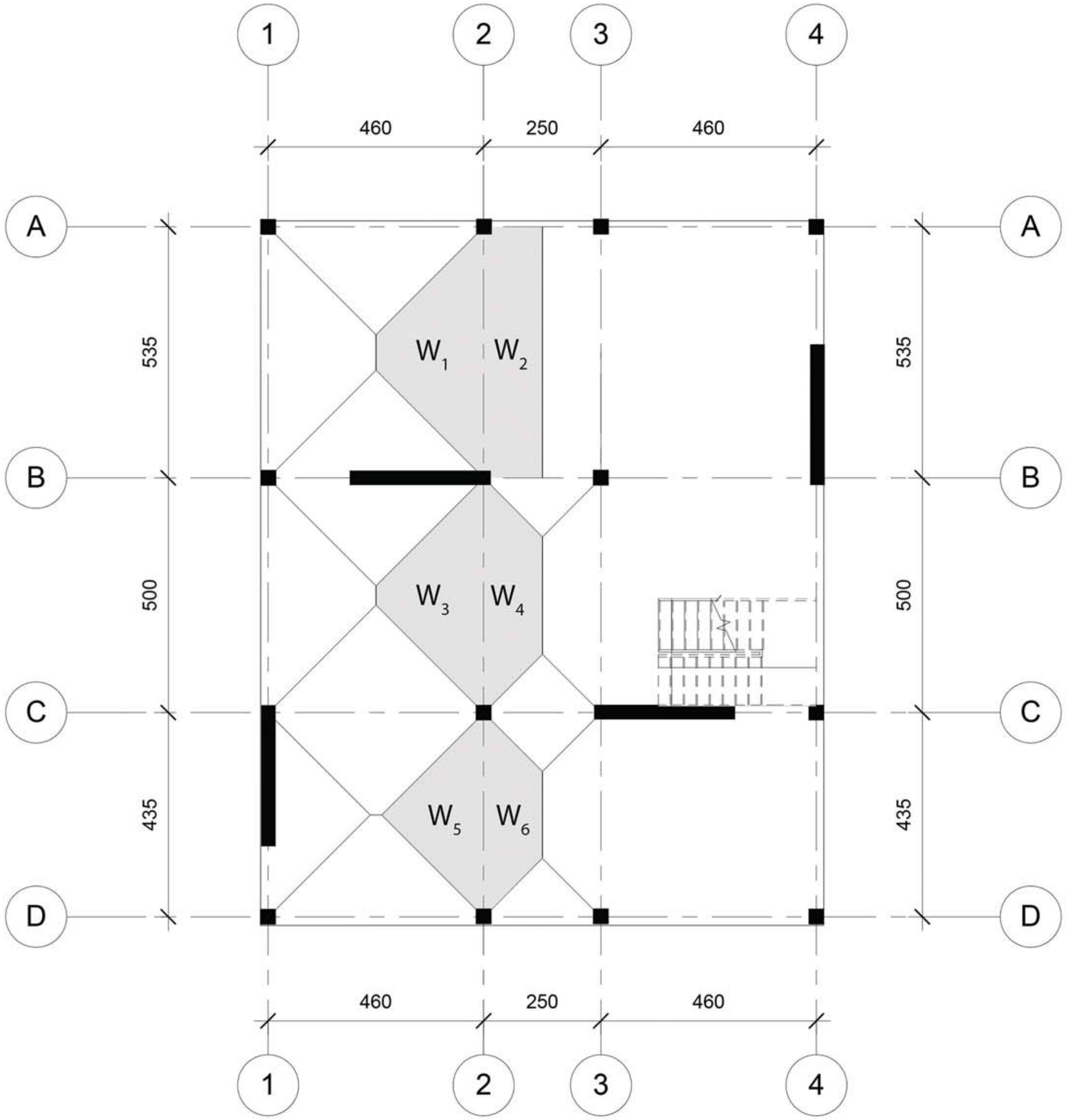
$\frac{535}{12.5} = 42.8 \cong 43$ cm (assumption in order to find the inertia of beam)



$$I_{beam} = \frac{0.3 \times (0.43)^3}{12} = 0.001987\ m^4$$

$$I_{column} = \frac{0.3 \times (0.3)^3}{12} = 0.000675\ m^4$$

$$I_{shear\ wall} = \frac{3.4 \times (0.3)^3}{12} = 0.00765\ m^4$$



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

$$I_{beam} = \frac{0.3 \times (0.43)^3}{12} = 0.001987\ m^4$$

$$I_{column} = \frac{0.3 \times (0.3)^3}{12} = 0.000675\ m^4$$

$$I_{shear\ wall} = \frac{3.4 \times (0.3)^3}{12} = 0.00765\ m^4$$

$$FEM = \frac{q \times l^2}{12}$$

$$FEM_{AB} = \frac{4.61 \times (5.35)^2}{12} = 10.99\ tm$$

$$FEM_{BC} = \frac{4.42 \times 5^2}{12} = 9.20\ tm$$

$$FEM_{CD} = \frac{4.18 \times (4.35)^2}{12} = 6.59\ tm$$

$$r = \frac{(I/L)}{\Sigma(I/L)}$$

$$r_{AB} = \frac{0.001987 / 5.35}{\left(\frac{0.001987}{5.35}\right) + 2 \times \left(\frac{0.000675}{3}\right)} = 0.452$$

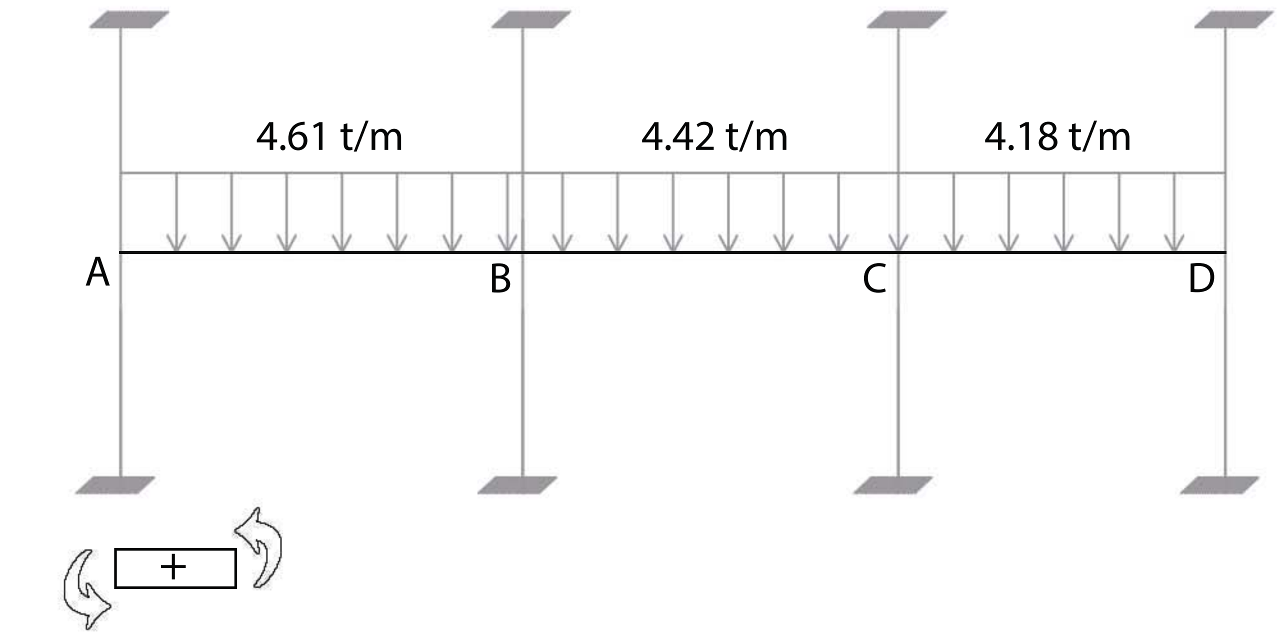
$$r_{BA} = \frac{0.001987 / 5.35}{\left(\frac{0.001987}{5.35}\right) + \left(\frac{0.001987}{5}\right) + 2 \times \left(\frac{0.00765}{3}\right)} = 0.063$$

$$r_{BC} = \frac{0.001987 / 5}{\left(\frac{0.001987}{5}\right) + \left(\frac{0.001987}{5.35}\right) + 2 \times \left(\frac{0.00765}{3}\right)} = 0.067$$

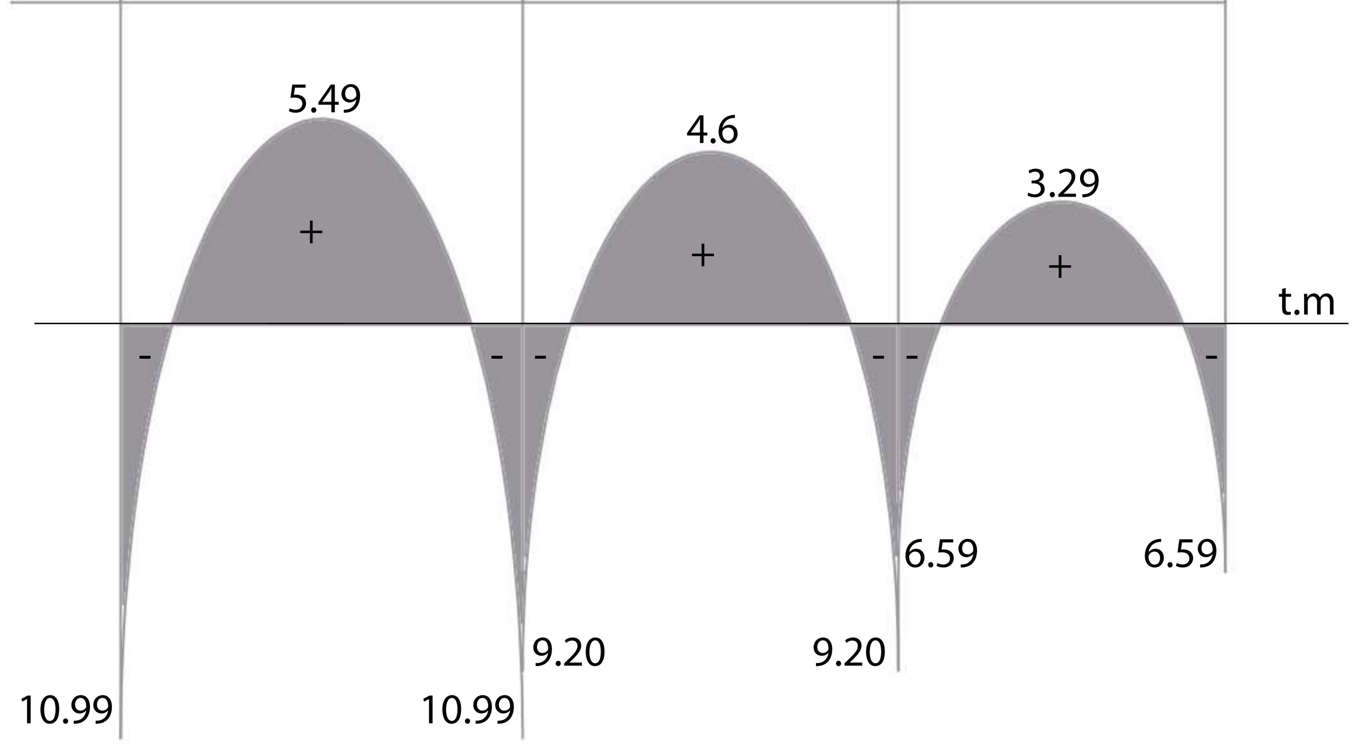
$$r_{CB} = \frac{0.001987 / 5}{\left(\frac{0.001987}{5}\right) + \left(\frac{0.001987}{4.35}\right) + 2 \times \left(\frac{0.000675}{3}\right)} = 0.304$$

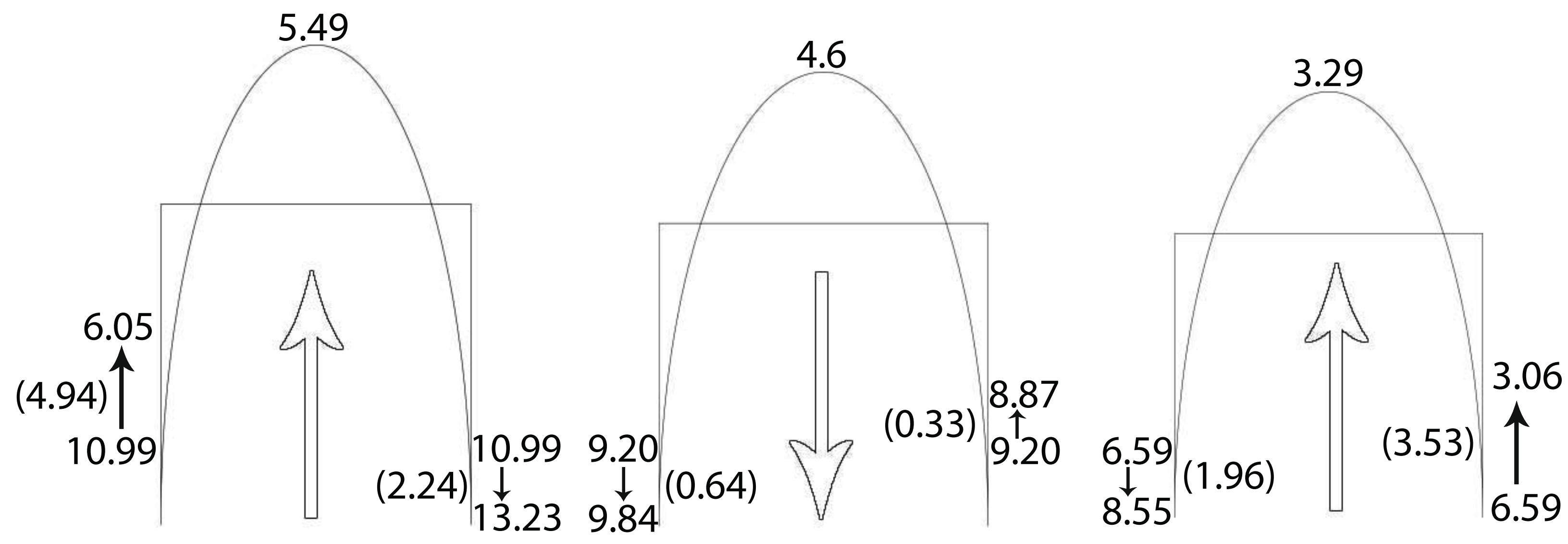
$$r_{CD} = \frac{0.001987 / 4.35}{\left(\frac{0.001987}{4.35}\right) + \left(\frac{0.001987}{5}\right) + 2 \times \left(\frac{0.000675}{3}\right)} = 0.35$$

$$r_{DC} = \frac{0.001987 / 4.35}{\left(\frac{0.001987}{4.35}\right) + 2 \times \left(\frac{0.000675}{3}\right)} = 0.503$$



	A	B	B	C	C	D
	0.452	0.063	0.067	0.304	0.350	0.503
FEM	10.99	-10.99	9.20	-9.20	6.59	-6.59
1st cycle	0.05	-2.48	0.39	0.06	1.65	0.45
Σ	11.04	-13.47	9.59	-9.14	8.24	-6.14
2nd cycle	-4.99	0.24	0.25	0.27	0.31	3.08
Σ	6.05	-13.23	9.84	-8.87	8.55	-3.06





<u>SPAN A-B</u>

$$\frac{4.94 - 2.24}{2} = 1.35$$

Midspan moment :

5.49 + 1.35 = **6.84**

<u>SPAN B-C</u>

$$\frac{0.33 - 0.64}{2} = -0.15$$

Midspan moment :

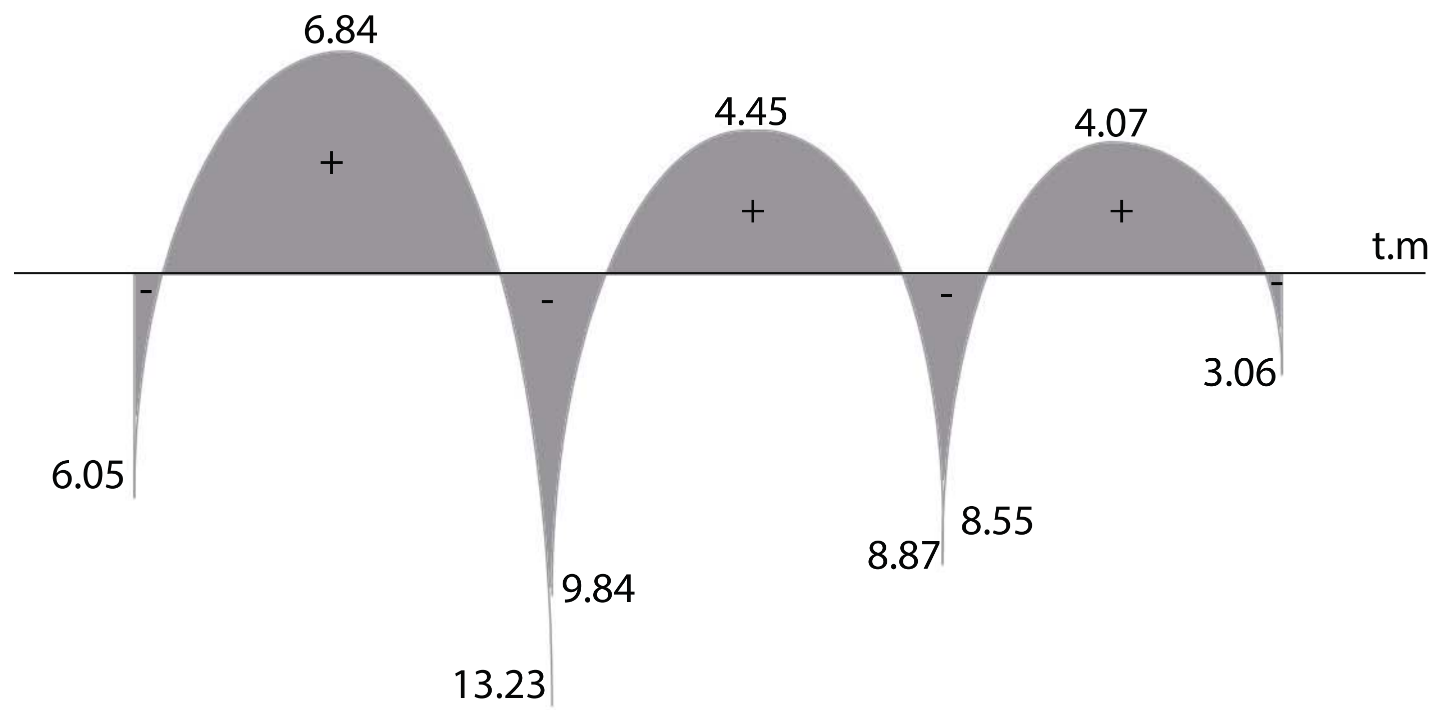
4.60 - 0.15 = **4.45**

<u>SPAN C-D</u>

$$\frac{3.53 - 1.96}{2} = 0.78$$

Midspan moment :

3.29 + 0.78 = **4.07**



Beam Depth:

$$K = \frac{b_w \times d^2}{M_{max}}$$

$K_0 = 25\ cm^2/t$

$$25 = \frac{30 \times d^2}{1323} = 33.2\ cm$$

Clear cover : 5 cm

d = 33.2 + 5 = 38.2 = 39 cm

Beam depth >3 x Slab thickness = 39 cm
To be on the safe side,
beam depth should be **40 cm**