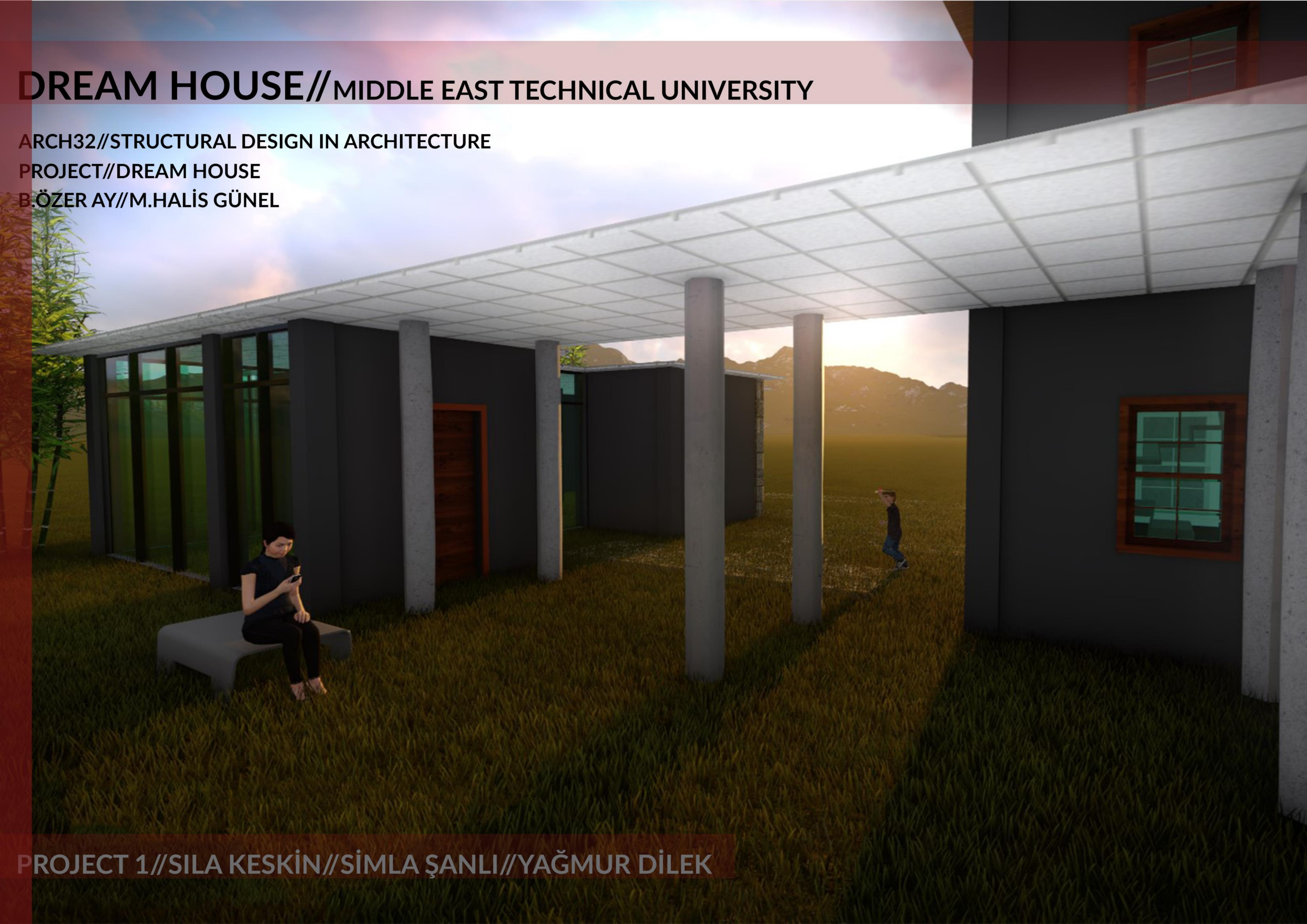
DREAM HOUSE//MIDDLE EAST TECHNICAL UNIVERSITY

ARCH32//STRUCTURAL DESIGN IN ARCHITECTURE

PROJECT//DREAM HOUSE

B.ÖZER AY//M.HALİS GÜNEL



PROJECT 1//SILA KESKİN//SİMLA ŞANLI//YAĞMUR DİLEK

PROJECT IMAGES

SUBJECT`S EYE VIEW//NORTH WEST

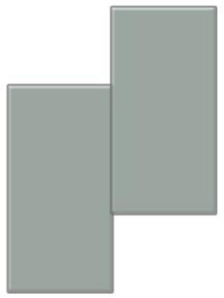
SUBJECT`S EYE VIEW//SOUTH EAST

HIGH ANGLE VIEW//SOUTH WEST

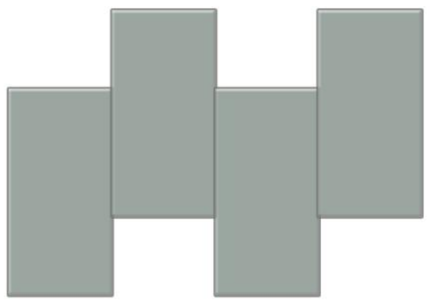
SUBJECT`S EYE VIEW//SOUTH WEST

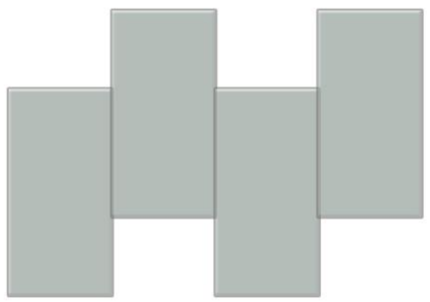
CONCEPTUAL DESIGN

UNIT

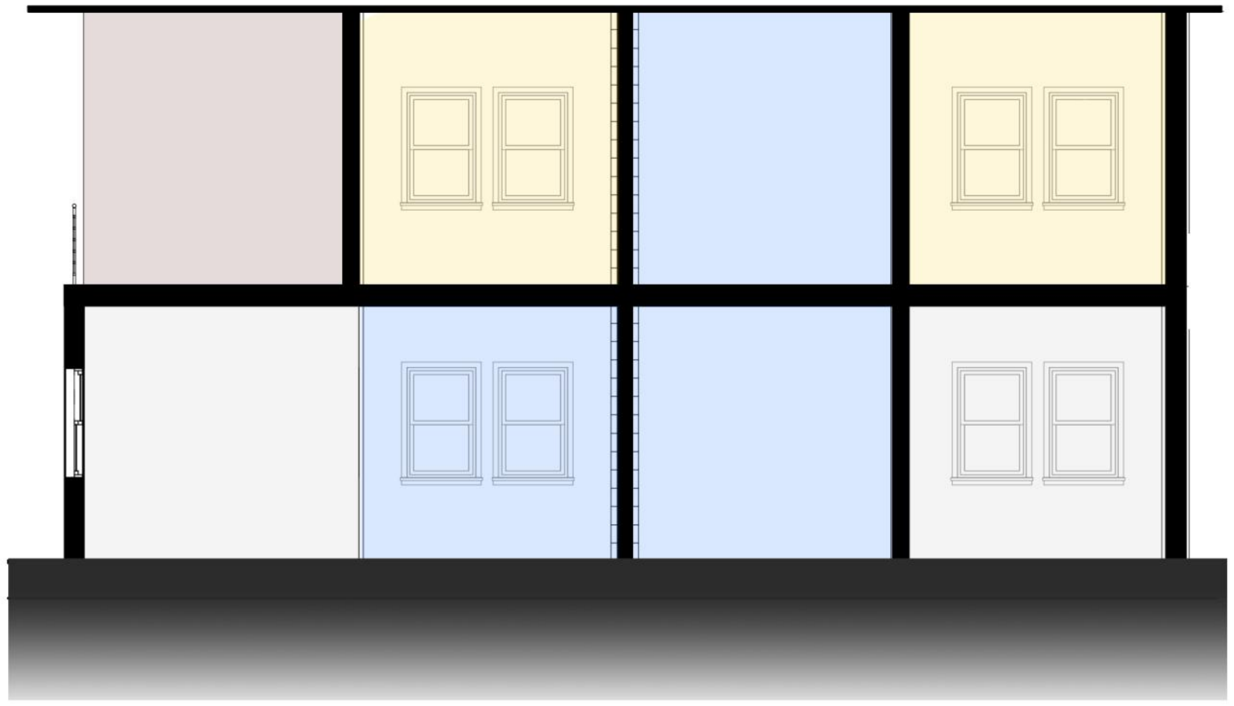


UNIT CONNECTION





SHIFTED CONNECTION



HOUSING

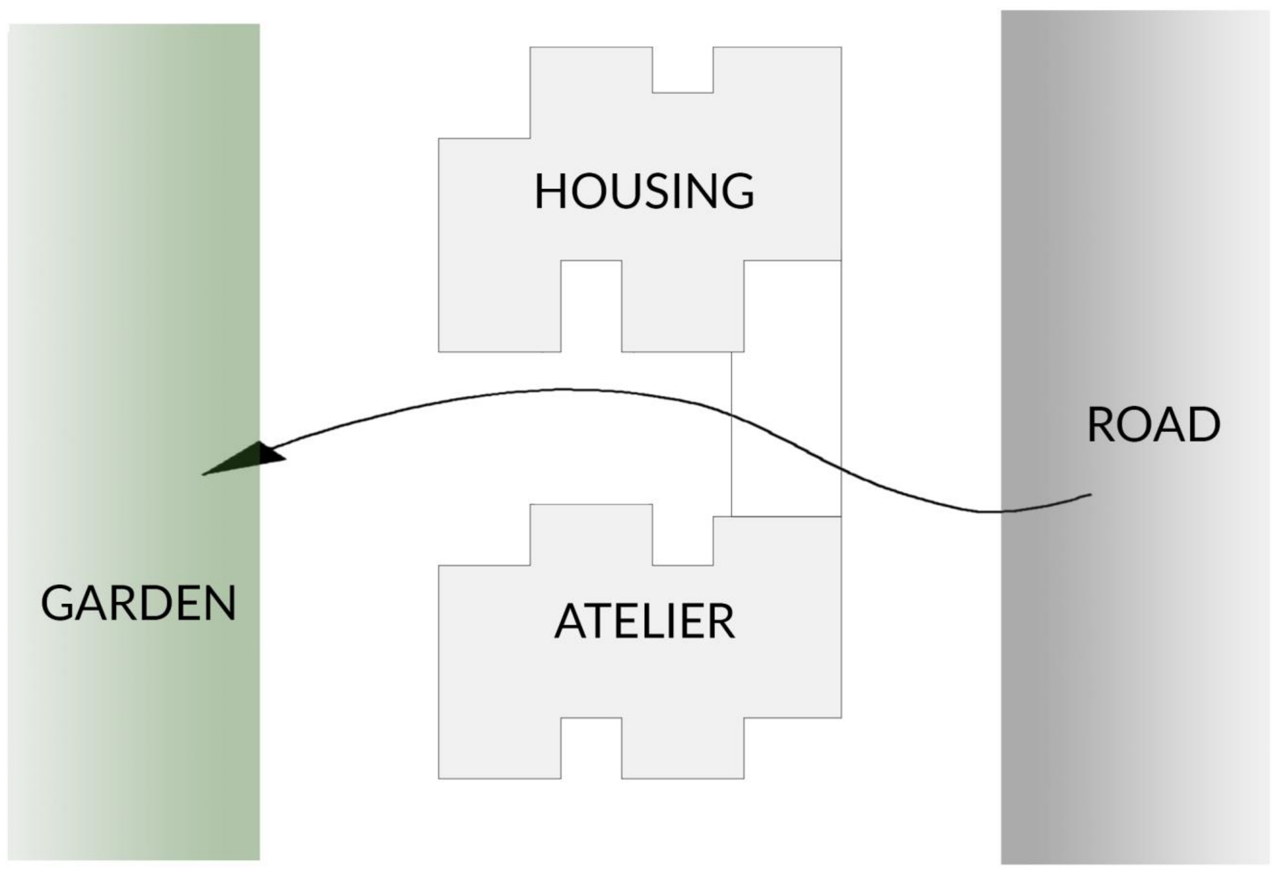
ROOM TYPES

WET SPACES

BEDROOMS

LIVING SPACES

BALCONY



ROAD TO GARDEN

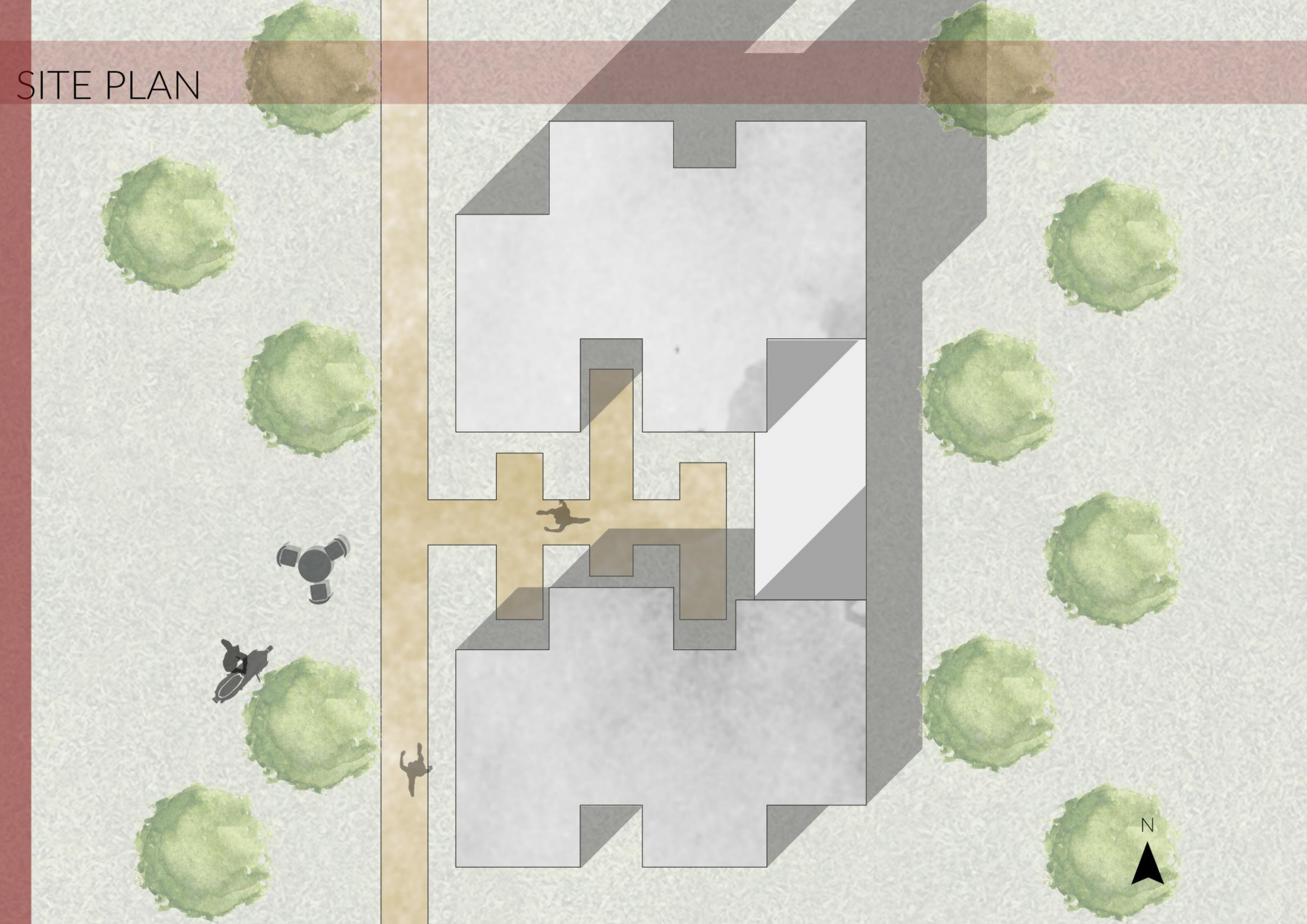
TRANSITION

UNIT REPETITION

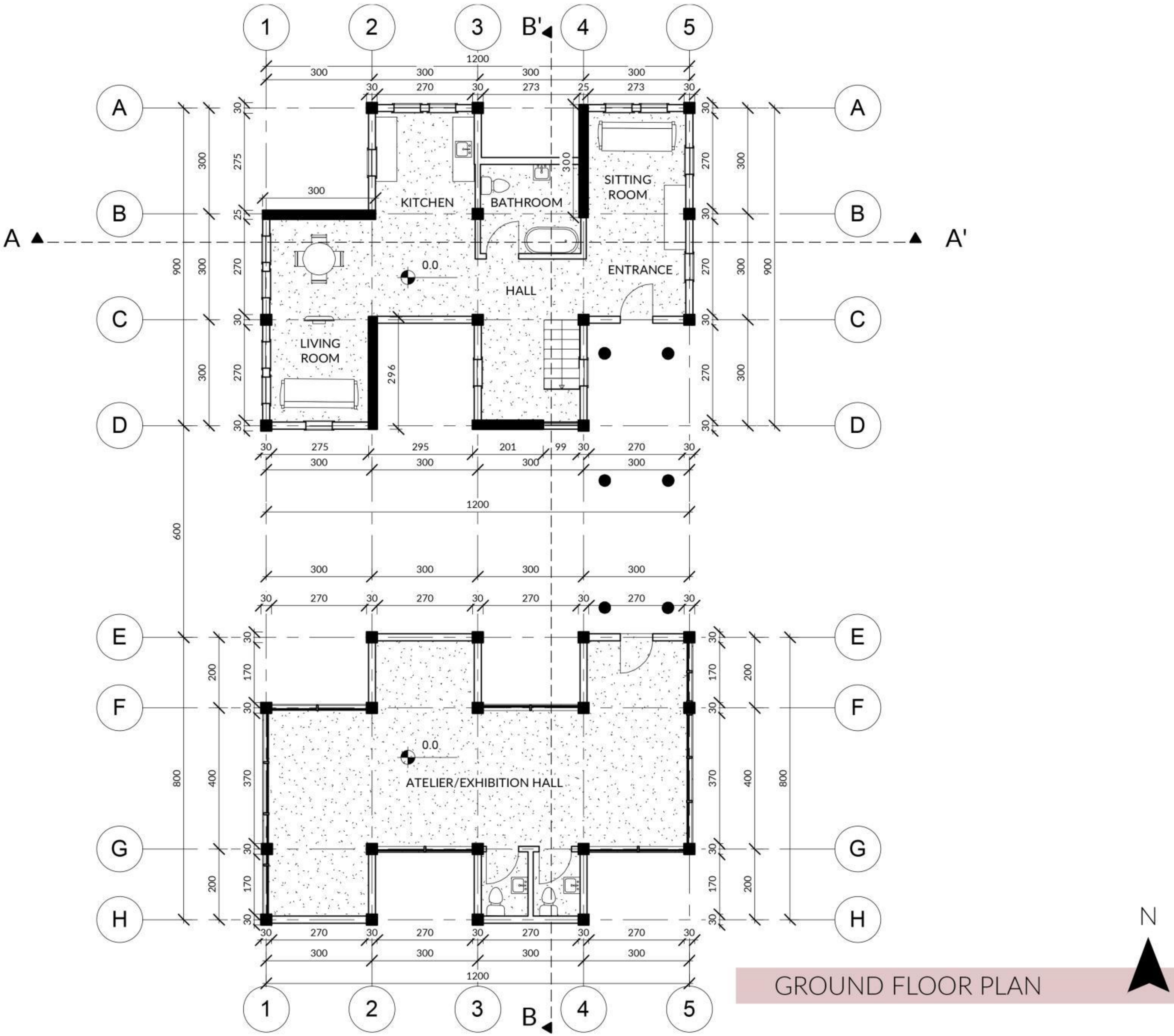
VISUAL CONNECTION

SEPERATION

SITE PLAN

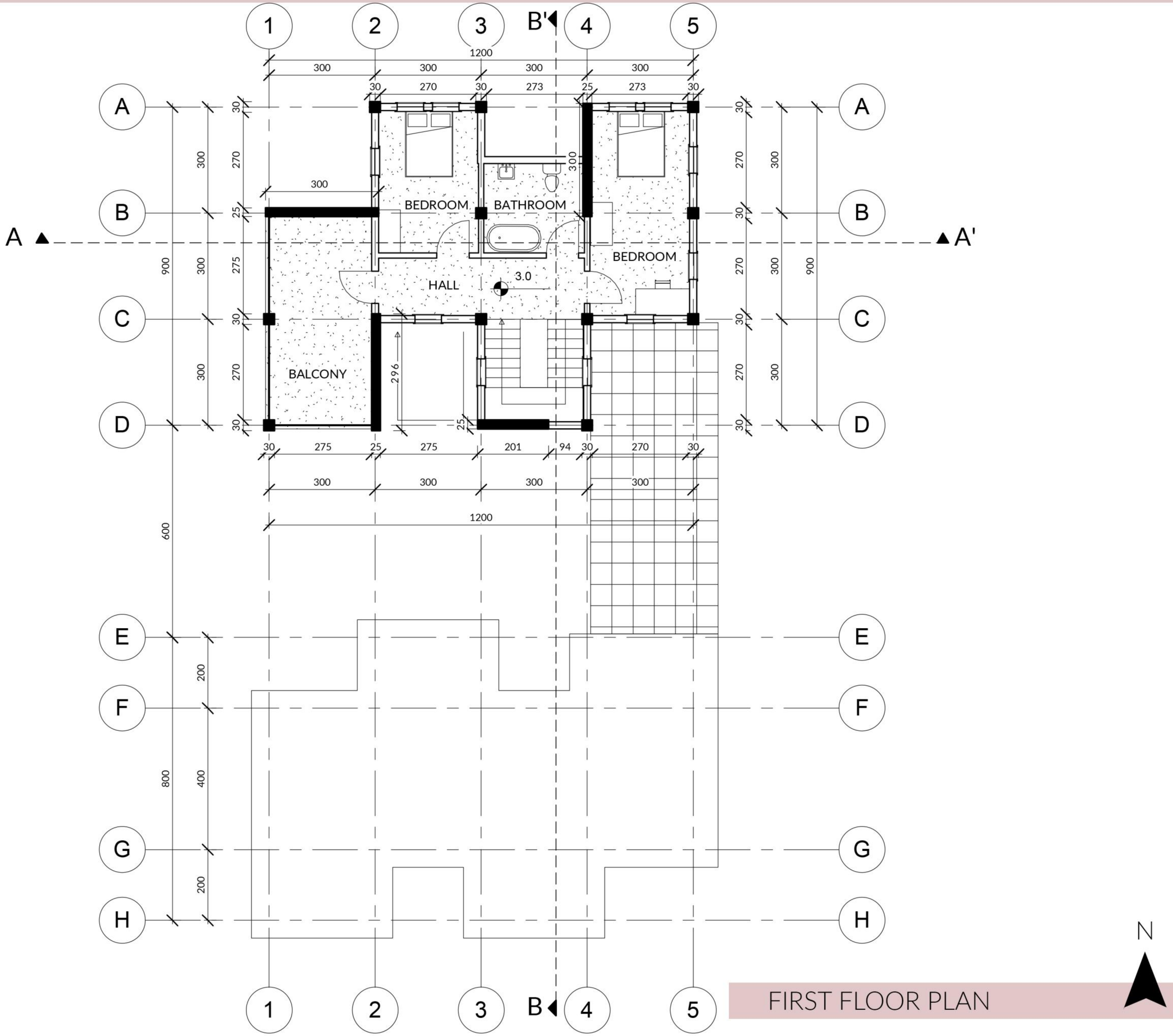


FLOOR PLANS



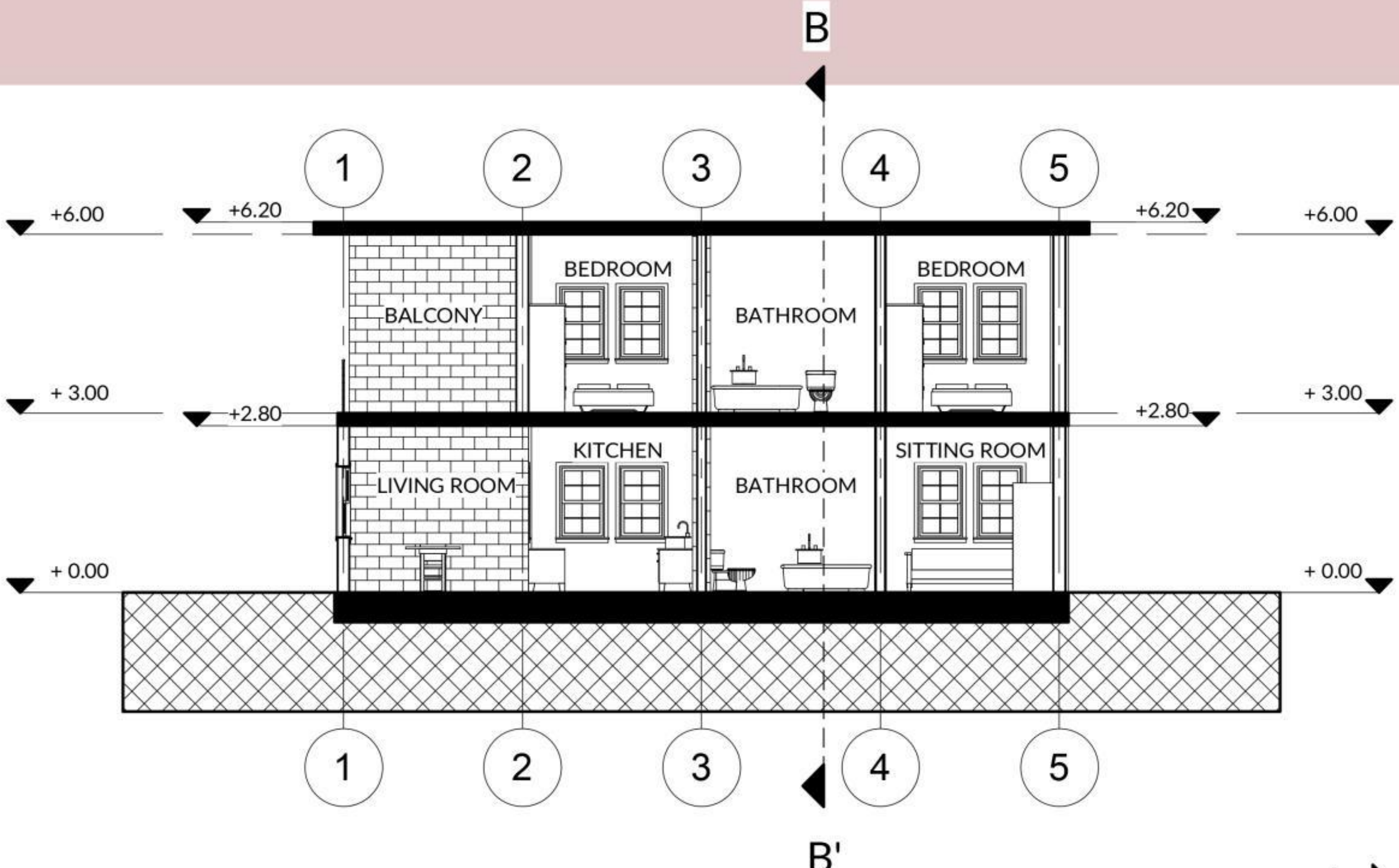
GROUND FLOOR PLAN

FLOOR PLANS

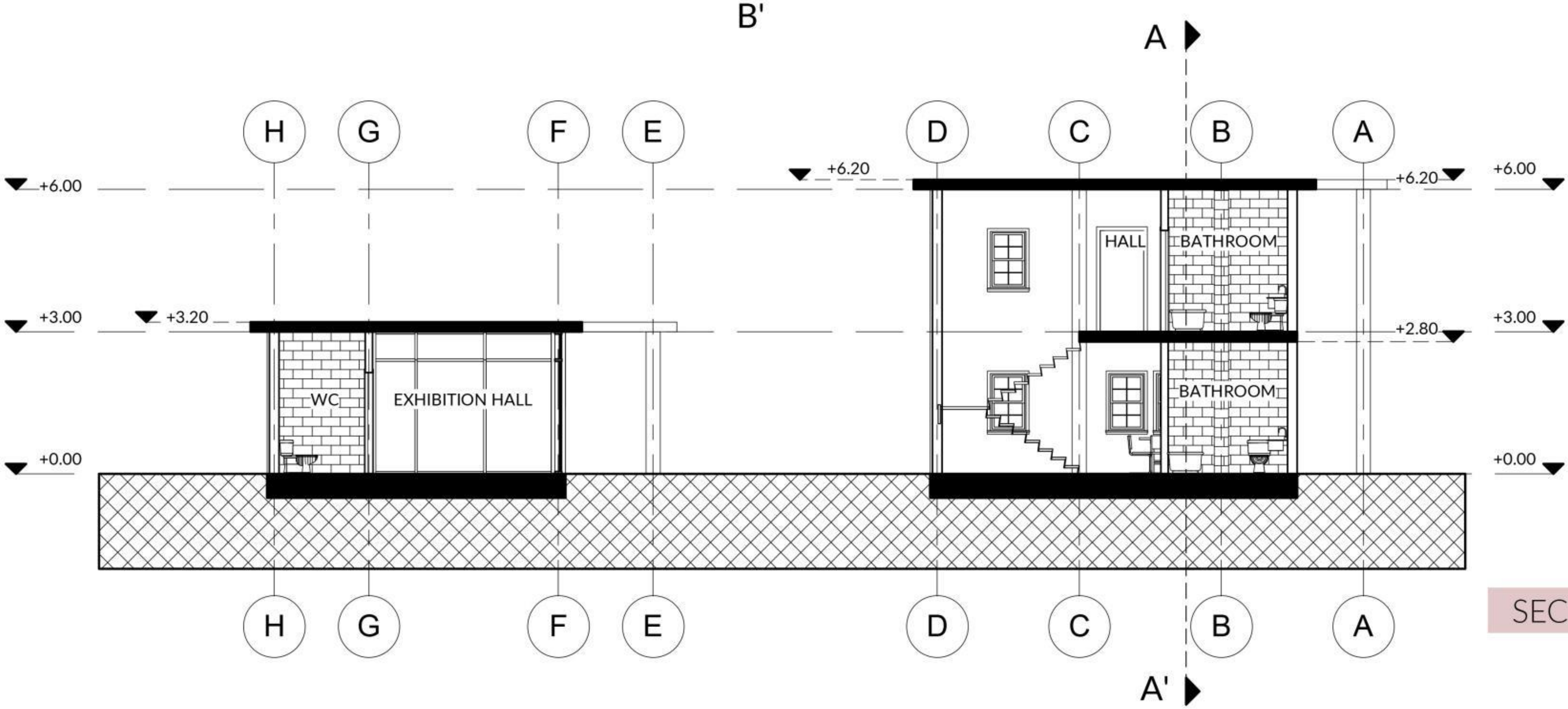


FIRST FLOOR PLAN

SECTIONS

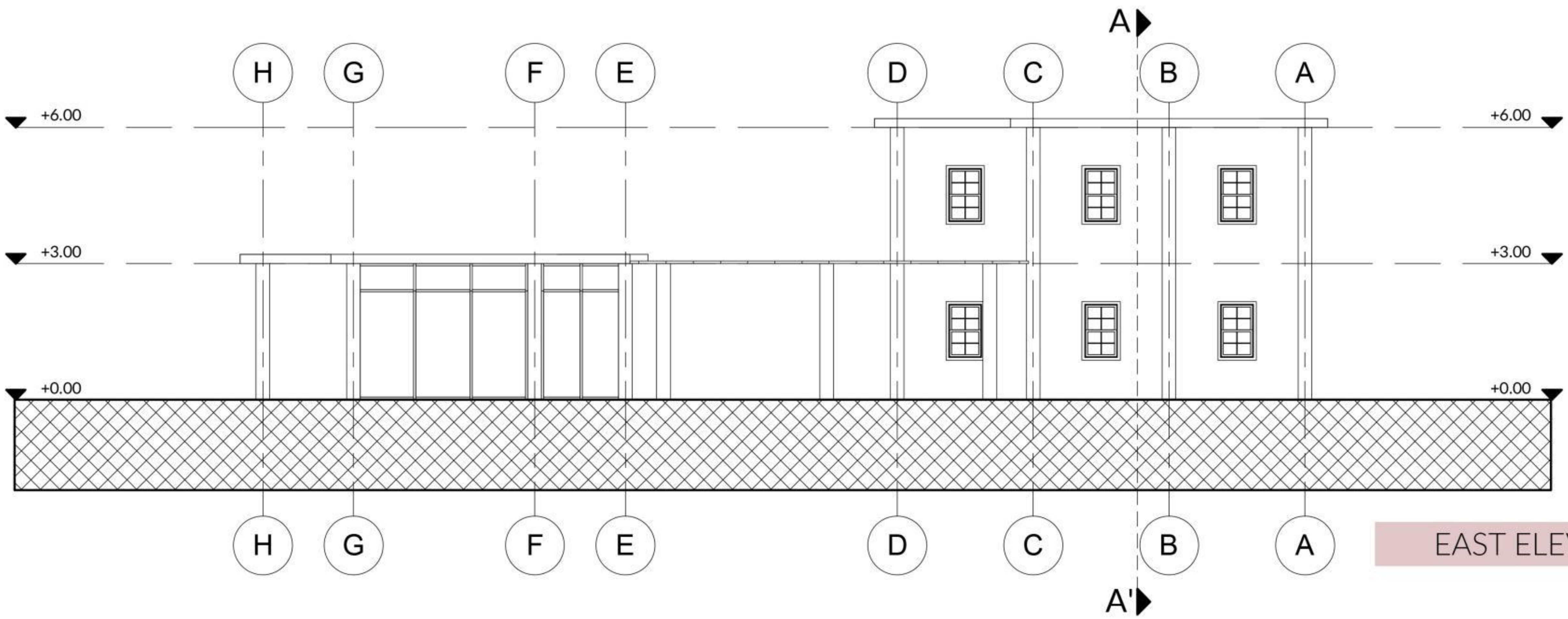


SECTION AA'

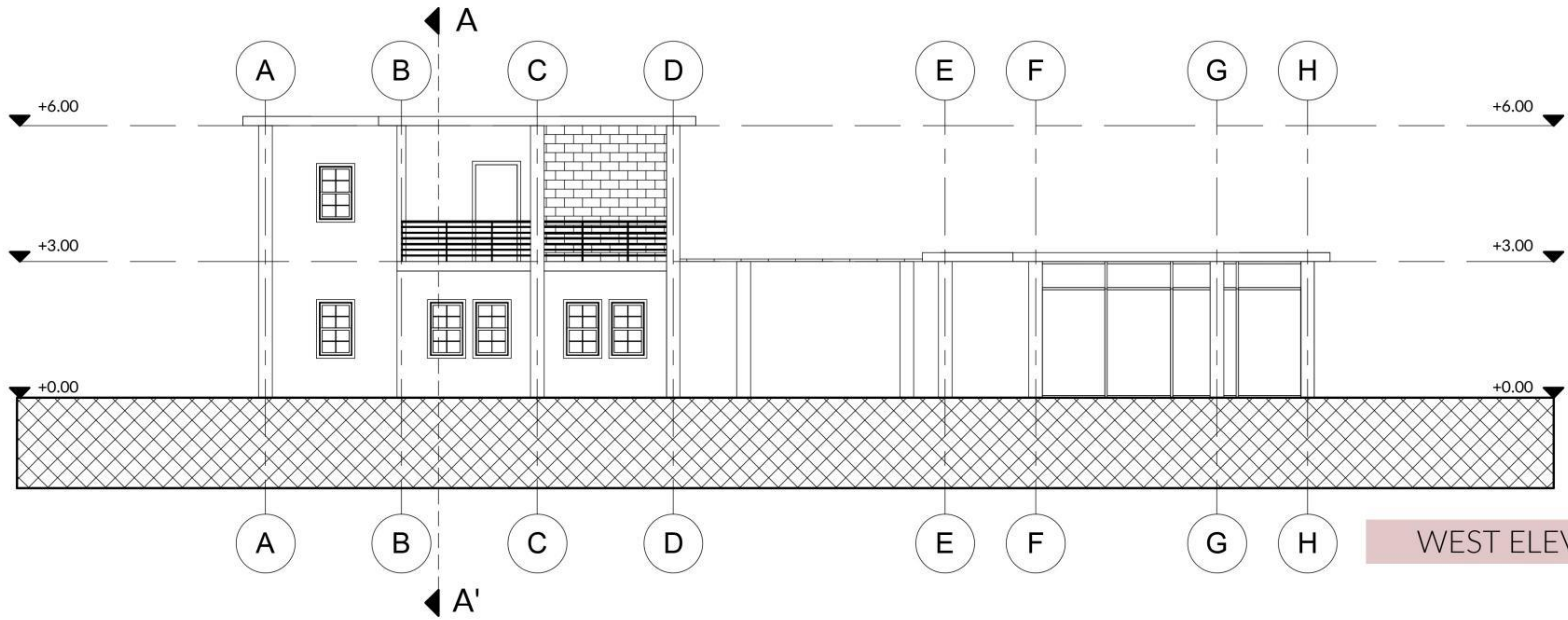


SECTION BB'

ELEVATIONS

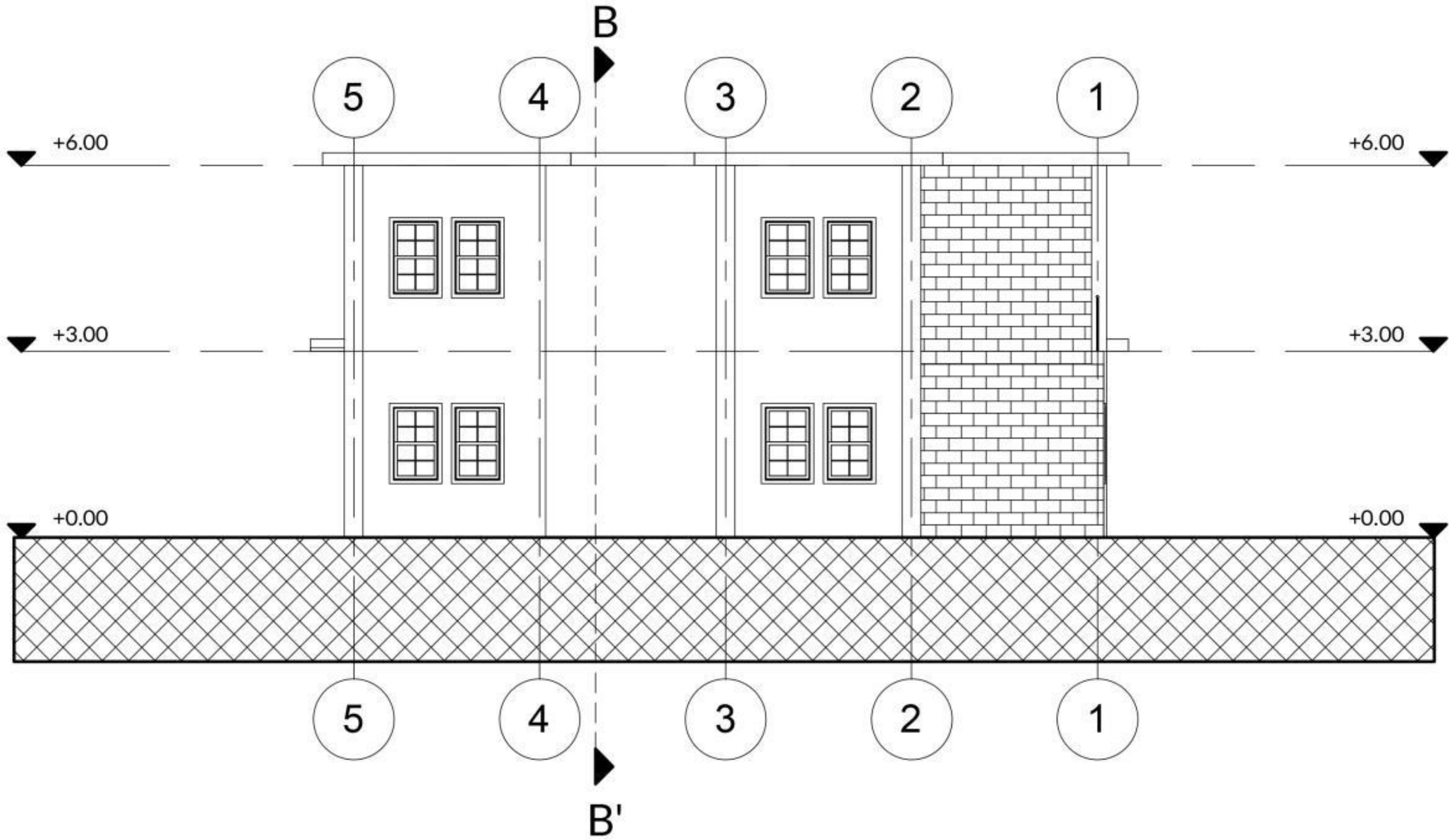


EAST ELEVATION

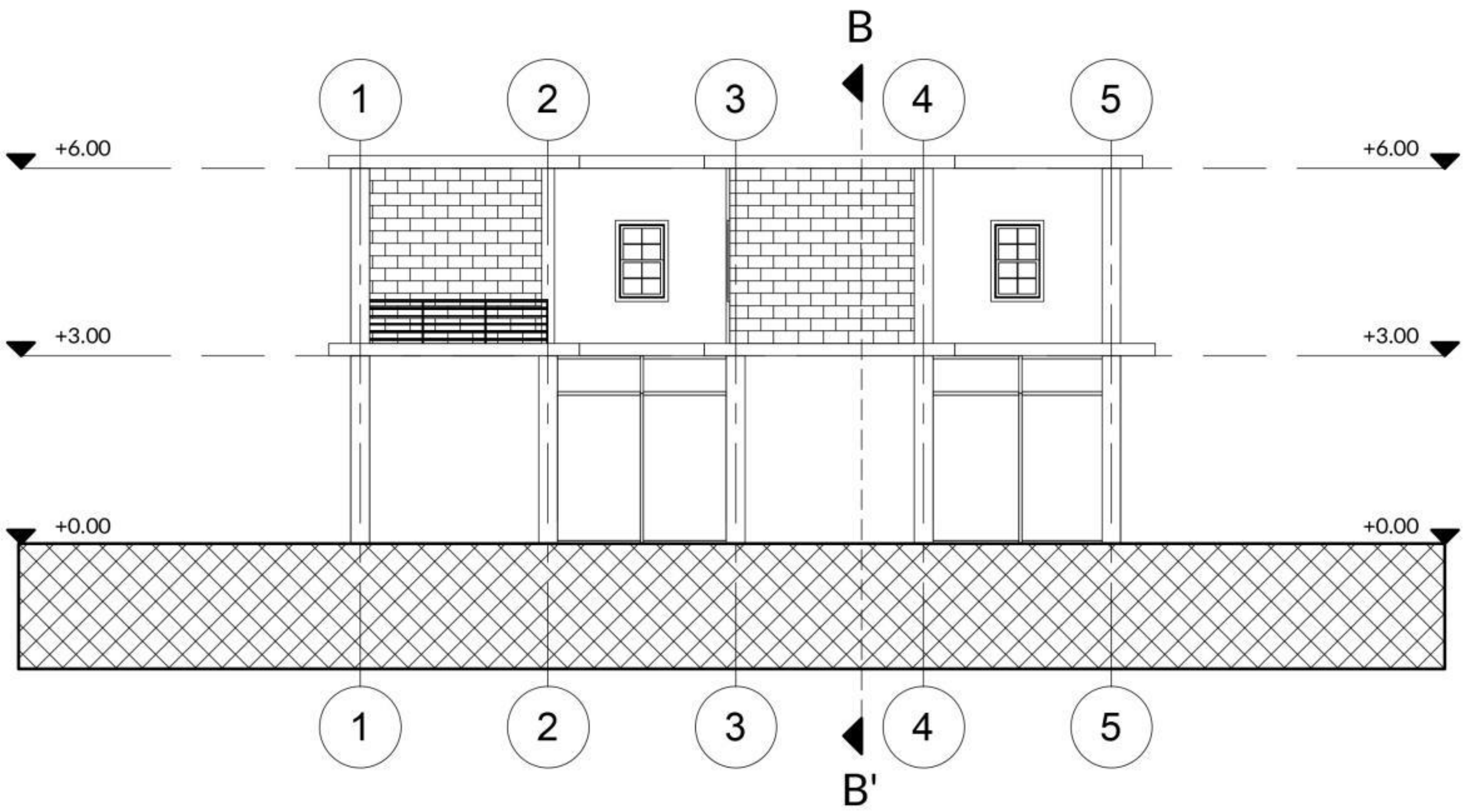


WEST ELEVATION

ELEVATIONS



NORTH ELEVATION

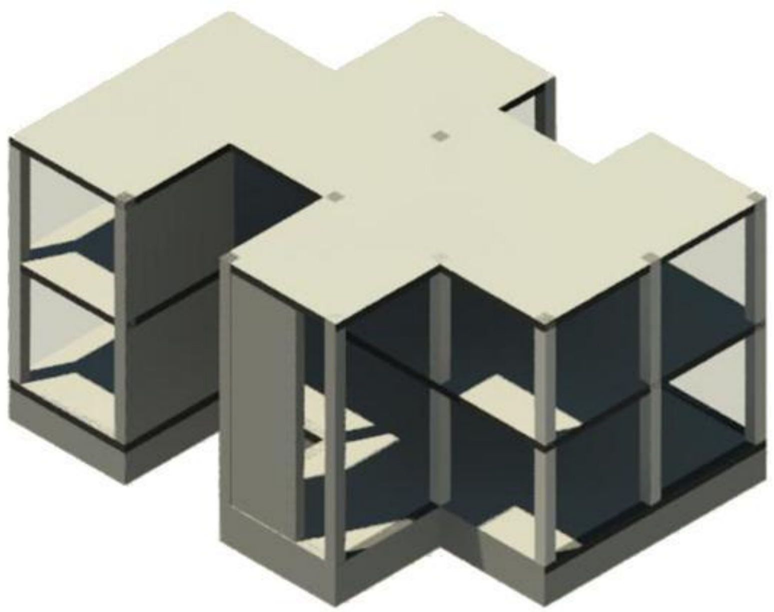


SOUTH ELEVATION

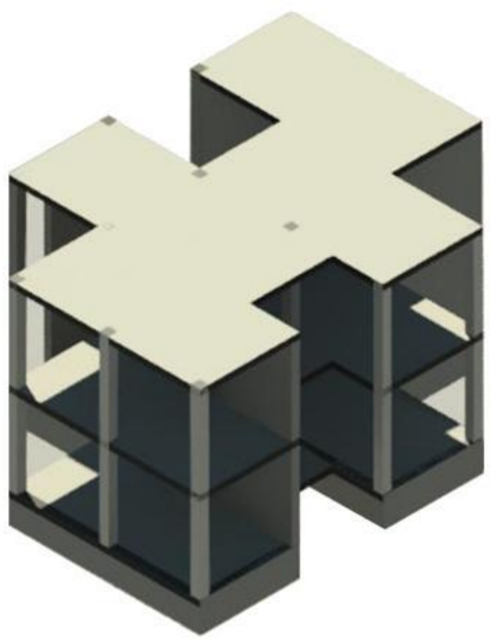
STRUCTURAL SYSTEM

The structures of housing, collonade and atelier work seperately, so we only take the housing into consideration for the calculations.

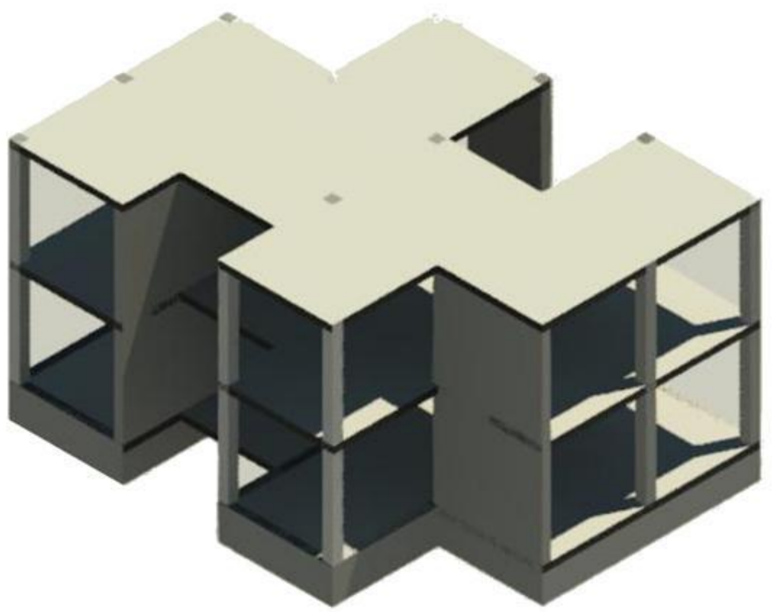
AXONOMETRIC VIEWS



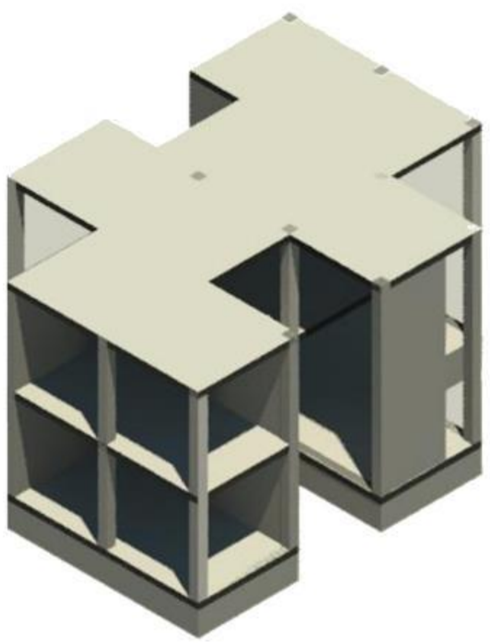
SOUTH-EAST



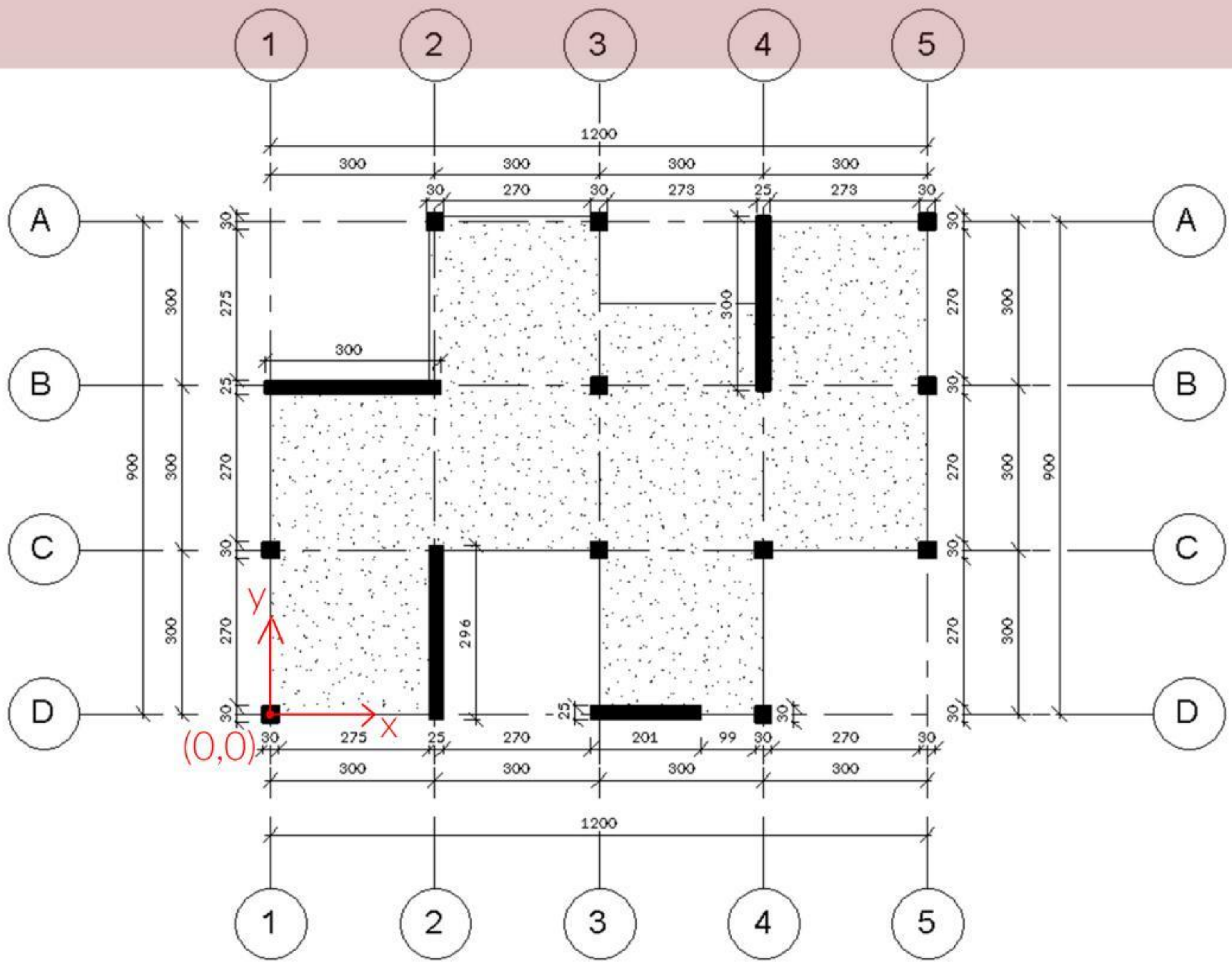
NORTH-EAST

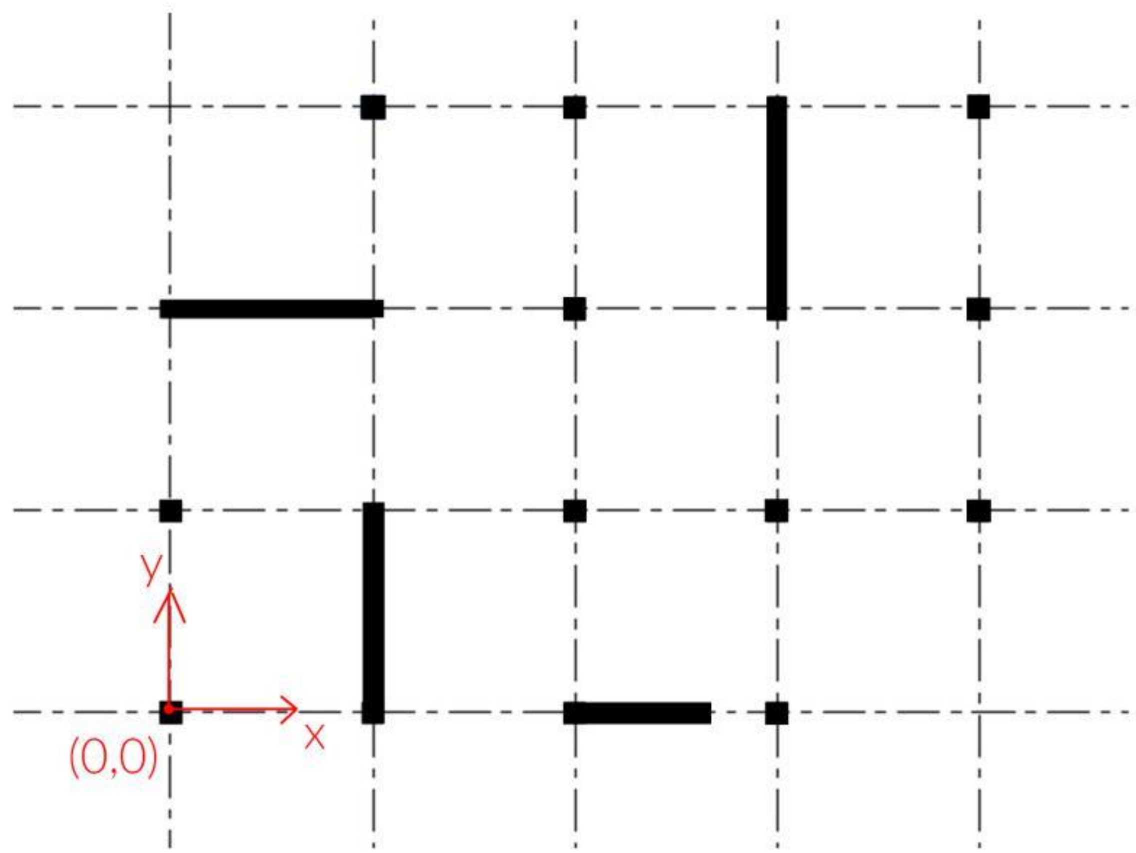


NORTH-WEST



SOUTH-WEST





MASS CENTER

$$x_m = \frac{\sum_{i=1}^{n} x_i \cdot A_i}{\sum Ai}$$

$$y_m = \frac{\sum_{i=1}^{n} y_i \cdot A_i}{\sum Ai}$$

$A_1 = 3 \times 6 = 18\ m^2$

$A_2 = 3 \times 6 = 18\ m^2$

$A_3 = 3 \times 7{,}5 = 22{,}5\ m^2$

$A_4 = 3 \times 6 = 18\ m^2$

X DIRECTION

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

$$x_m = \frac{(1.5 \times 18) + (4.5 \times 18) + (7.5 \times 22.5) + (10.5 \times 18)}{18 + 18 + 22.5 + 18}$$

$x_m = 6.09$ m

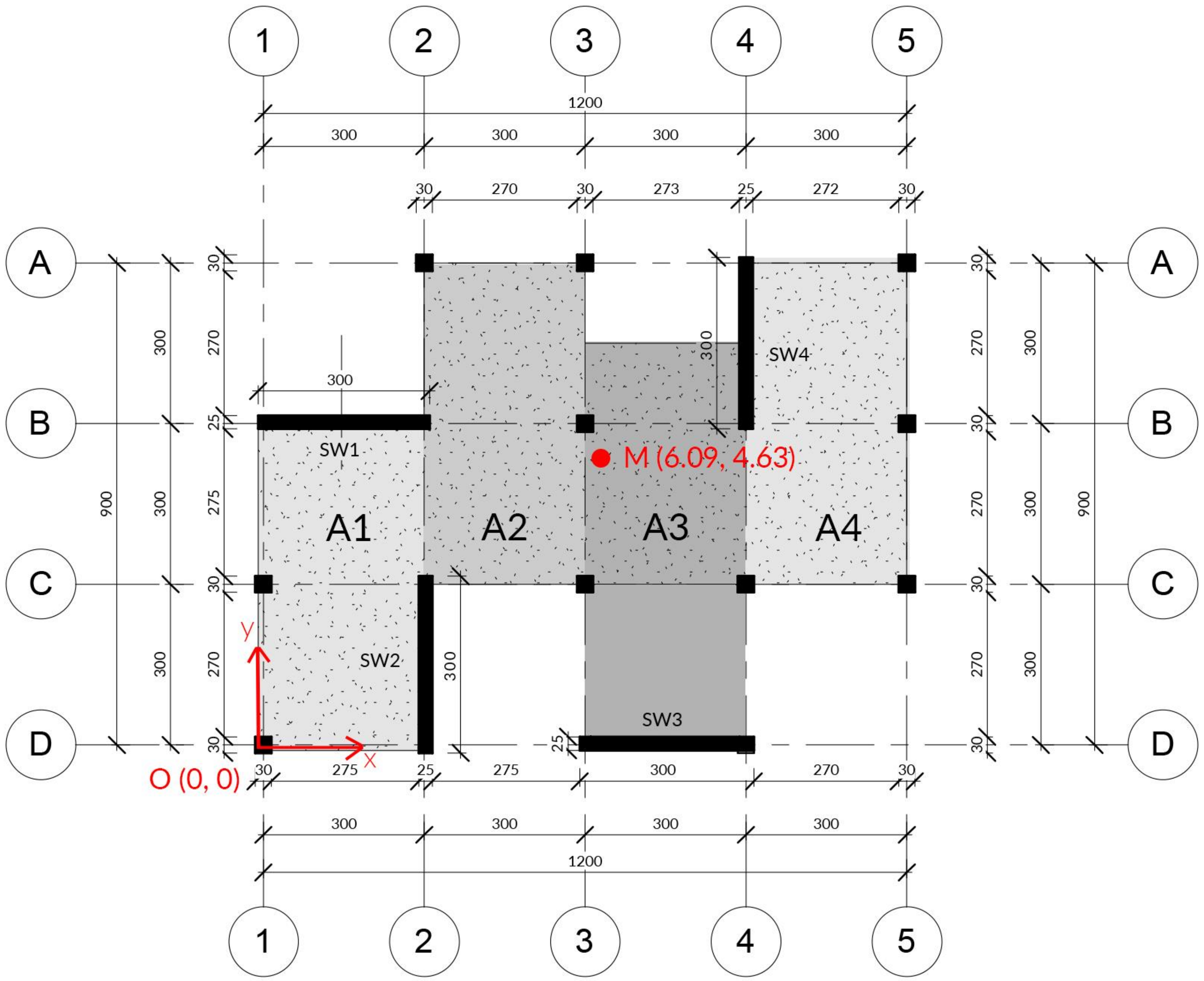
Y DIRECTION

$$y_m = \frac{(Y_1 \times A_1) + (Y_2 \times A_2) + (Y_3 \times A_3) + (Y_4 \times A_4)}{A_1 + A_2 + A_3 + A_4}$$

$$y_m = \frac{(3 \times 18) + (6 \times 18) + (3.75 \times 22.5) + (6 \times 18)}{18 + 18 + 22.5 + 18}$$

$y_m = 4.63$ m

$(x_m, y_m) = (6.09 , 4.63)$



DETERMINING THE SHEAR WALLS

> R.C. walls are members having the ratio of long side to short side in plan of at least ‘’ **6** ‘’. (TEC-7.6.1.2)

> The thickness of R.C. walls cannot be less than **<u>25 cm</u>** nor 1/16 of the story height and 1/30 of the wall length.

- Story height is 3 m = 300 cm in our project. Thus;

$t \geq \frac{300}{16}$; $t \geq 18.75$ cm

- Wall length is 3 m = 300 cm in our project. Thus;

$t \geq \frac{300}{30}$; $t \geq 10$ cm

- So, in order to meet the minimum criteria and above conditions, shear wall thickness is determined as **25 cm**.
- SW1 : $L_{long\ side} / L_{short\ side}$: 300 / 25 = 12 ≥6 √

Also for SW2, SW3 and SW4 : 300 /25 = 12 ≥6 √

Since long to short side ratio is ≥6 for all, they all are **shear walls**.

STIFFNESS CENTER

$x_S = \frac{\sum_{i=1}^{n} x_i \, . \, I_{xi}}{\sum_{i=1}^{n} I_{xi}}$

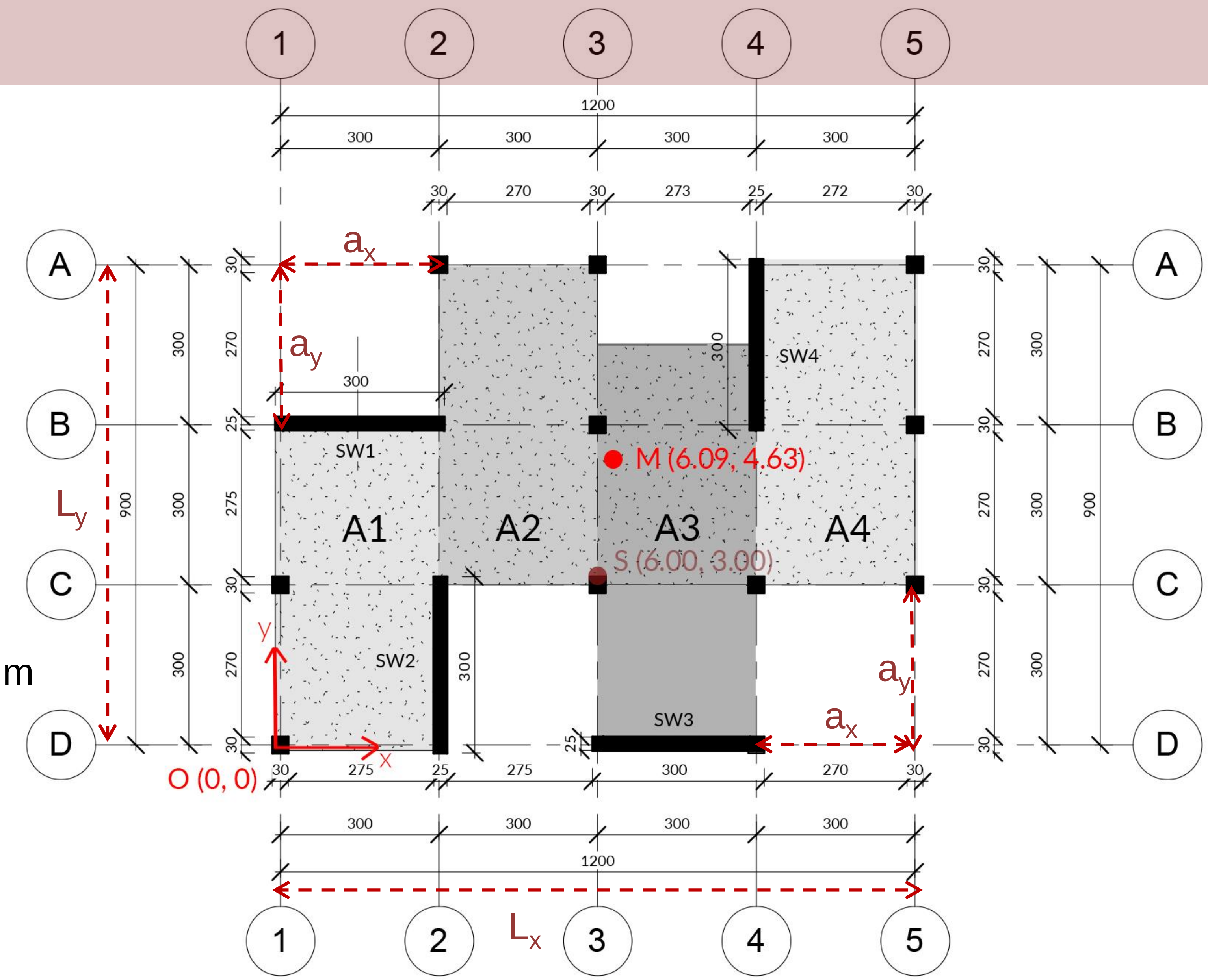
$I_X = \frac{1}{12} b.h^3 = \frac{1}{12} (0.25) \times 3^3 = 0.56 \; m^4$

for SW2 and SW4.

$y_S = \frac{\sum_{i=1}^{n} y_i \, . \, I_{yi}}{\sum_{i=1}^{n} I_{yi}}$

$I_y = \frac{1}{12} b.h^3 = \frac{1}{12} (0.25) \times 3^3 = 0.56 \; m^4$

for SW1 and SW3.



X DIRECTION

for SW2 and SW4;

$x_s = \frac{(3 \times 0.56) + (9 \times 0.56)}{2 \times 0.56} = 6$ m

Y DIRECTION

for SW1 and SW3;

$y_s = \frac{(6 \times 0.56) + (0 \times 0.56)}{2 \times 0.56} = 3$ m

$(x_s, y_s) = (6 , 3)$

IRREGULARITY

$\frac{a_x}{L_x} = \frac{300}{1200} = 0.25 \quad > 0.2$

$\frac{a_y}{L_y} = \frac{300}{900} = 0.33 \quad > 0.2$

So, there is A_3 (*projections in plan*) type irregularity in this building.

ECCENTRICITY

$e_x = \frac{|xm - xs|}{L_x} \times 100 = \frac{|6.09 - 6|}{12} \times 100 = \% \, 0.75 \quad < \% \, 5$

$e_y = \frac{|ym - ys|}{L_y} \times 100 = \frac{|4.63 - 3|}{9} \times 100 = \% \, 18 \quad > \% \, 5$

> Eccentricity value is smaller than % 5 in x direction (normally acceptable) and greater than % 5 in y direction. However, to be on the safe side, let's equalize both of them to zero so as to eliminate eccentricity completely.

RECONSIDERING THE SHEAR WALLS / LENGTHS

- Let's try to equalize x_s to x_m (6.09) by changing the length of SW2 ;

$x_s = \frac{\sum x. Ix}{\sum Ix} = \frac{(3 \times I'_x) + (9 \times 0.56)}{I'_x + 0.56} = 6.09 \rightarrow I'_x = 0.54 \; m^4$ it must be.

Since the wall thickness is 0.25 m ;

$\frac{1}{12} (0.25) \times (L'_{SW2})^3 = 0.54 \rightarrow$ **$L'_{SW2} = 2.96$ m** (the revised length of SW2)

- Let's try to equalize y_s to y_m (4.63) by changing the length of SW3 ;

$y_s = \frac{\sum y. Iy}{\sum I_y} = \frac{(0 \times I'_y) + (6 \times 0.56)}{I'_y + 0.56} = 4.63 \rightarrow I'_y = 0.17 \; m^4$ it must be.

Since the wall thickness is 0.25 m ;

$\frac{1}{12} (0.25) \times (L'_{SW3})^3 = 0.17 \rightarrow$ **$L'_{SW3} = 2.01$ m** (the revised length of SW3)

FINAL DECISION FOR THE STRUCTURAL SYSTEM

SHEAR WALL PERCENTAGE//CHECK

$$\% = \frac{\text{(Area of the Footprint of Shear Walls on X and Y Direction}}{\text{Floor Area}} \times 100$$

Total Floor Area = $A_1 + A_2 + A_3 + A_4 = (3 \times 18) + 22.5 = 76.5 \ m^2$

- Area of the Shear Walls laying in X direction (SW1 and SW3)

= (3 x 0.25) + (2.01 x 0.25) = 1.25 m^2

The ratio of the shear wall area on X direction to floor area ;

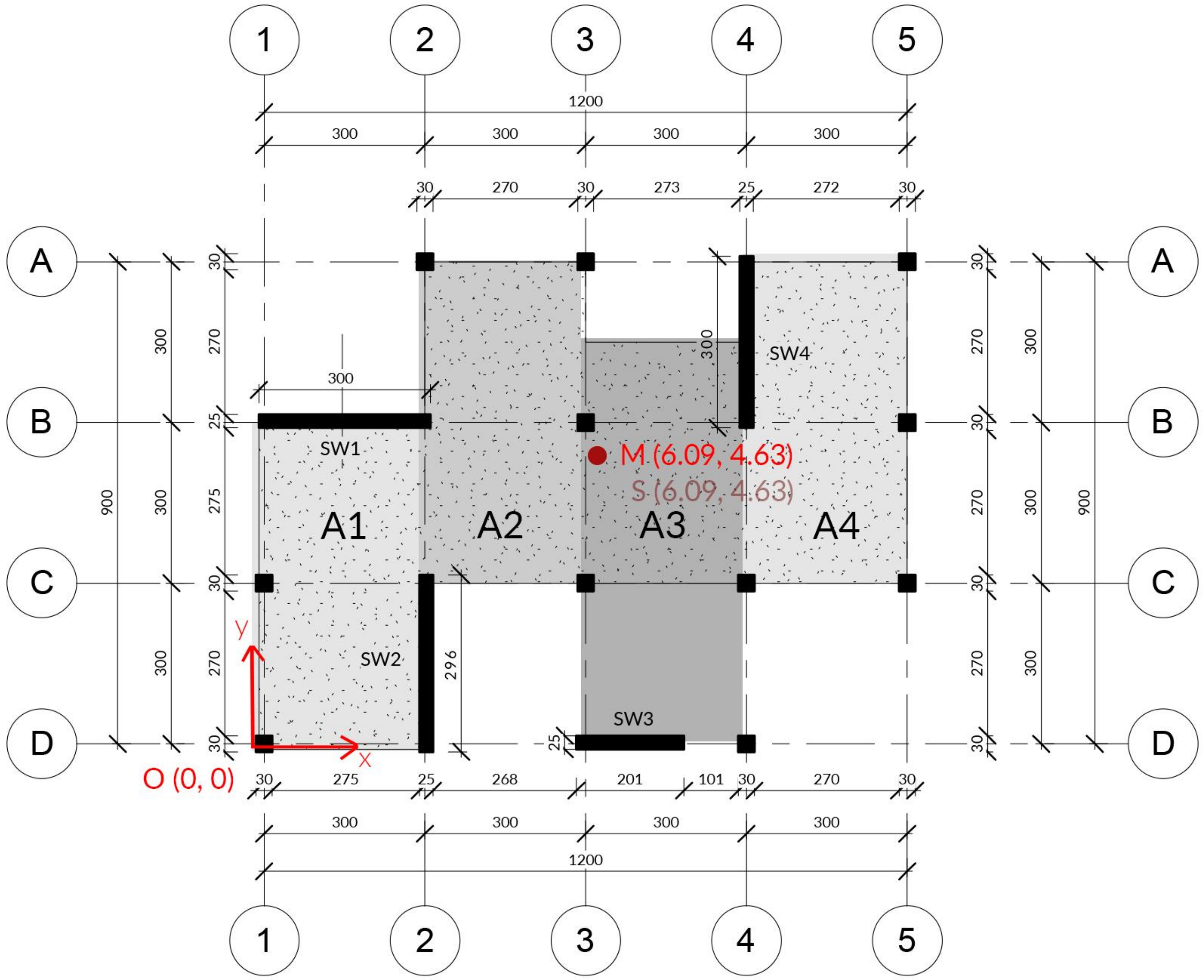
$\frac{1.25}{76.5} \times 100 = \% \ 1.63 \quad > \ \% \ 1 \ \surd$

- Area of the Shear Walls laying in Y direction (SW2 and SW4)

= (2.96 x 0.25) + (3 x 0.25) = 1.49 m^2

The ratio of the shear wall area on Y direction to floor area ;

$\frac{1.49}{76.5} \times 100 = \% \ 1.95 \quad > \ \% \ 1 \ \surd$



SELECTION OF THE SLAB SYSTEM

Flat plate is selected as the slab system for its visual smoothness.

According to the codes – namely TS 500 ;

- The min. slab thickness must satisfy the below condition ;

<u>h ≥ 20 cm </u> and <u>h ≥ long length / 30</u>

- Since the longest slab length in our project is 3m = 300 cm :

h ≥ 300 / 30 → h ≥ 10 cm

- So as to satisfy both of the conditions at the same time and to be on the safe side **20 cm** is chosen as the slab thickness.

Mass Center (x_m, y_m) = (6.09 , 4.63)

Stiffness Center (x_s, y_s) = (6.09 , 4.63)

COLUMN DIMENSIONS

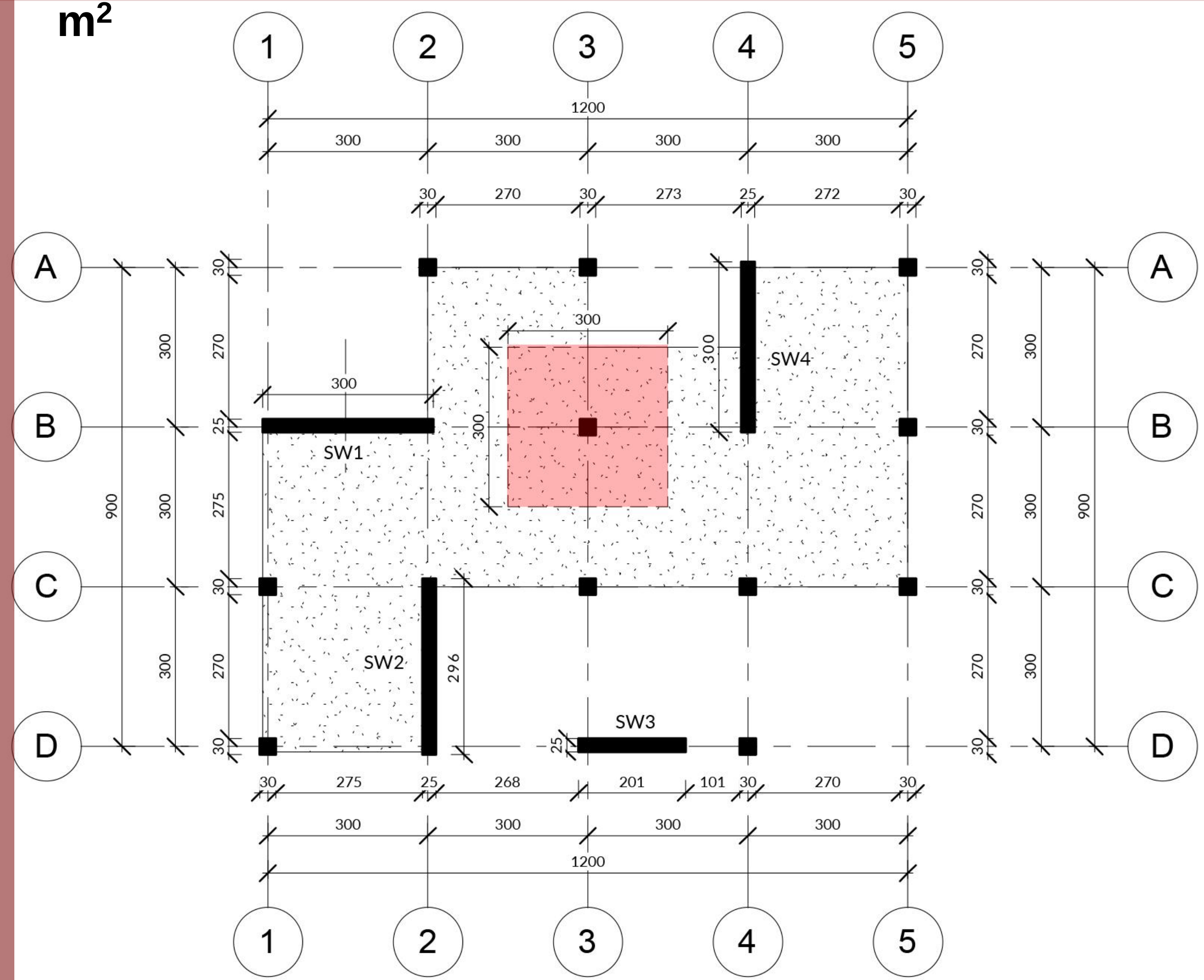
Column dimensions should be selected by considering the min. required dimensions stated in the codes and must satisfy the following condition ;

$$A_c \geq \frac{N_{dm}}{0.40 \times f_{ck}}$$

**Material properties to keep in mind;
Concrete: C_{20}, f_{ck} = 200 kg/cm^2
K_0 = 25 cm^2/t

- N_{dm} value in the formula is the maximum ''**Design Load**'' (with the load coefficients due to TS-500) coming from the tributary area of the column (and above columns).
- So as to be able to decide the column dimensions, we first need to calculate the design loads.

Tributary Area = 3 x 3 = 9 m²



DESIGN LOADS

1. FLOOR SLAB

A. Dead Load

For 20 cm thick flat plate :

- Own Weight : 0.20 x 2.4 = 0.48 t/m^2
- Levelling : 0.040 x 2.4 = 0.10 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
- Wall load** = 0.15 t/m^2

+

Dead load = **0.82 t/m²**

** Following the in-class discussions, 150 kg wall load per square meter (*0.15 t/m²*) is calculated in order to have considered the wall loads on our structure.

B. Live Load

According to TS 498 – 12.1 ;
Design Live Load for residential buildings is calculated as **0.2 t/m²**

>> Total Design Load of Floor Slab is calculated by taking into consideration both the dead and live loads and through their multiplication with certain coefficients as in below ;

P_d = (1.4 x Dead Load) + (1.6 x Live Load)
= (1.4 x 0.82) + (1.6 x 0.2)

P_d = **1.47 t/m²** *(for floor slab)*

COLUMN DIMENSIONS

DESIGN LOADS

2. ROOF SLAB

A. Dead Load

- Own Weight : 0.20 x 2.4 = 0.48 t/m^2
- Levelling : 0.040 x 2.4 = 0.10 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

+

Dead load = **0.67 t/m^2**

B. Live Load

According to TS 498 – 12.1 ;
Design Live Load for of roofs not accessible except for ordinary maintenance and repair purposes is calculated as **0.15 t/m^2**

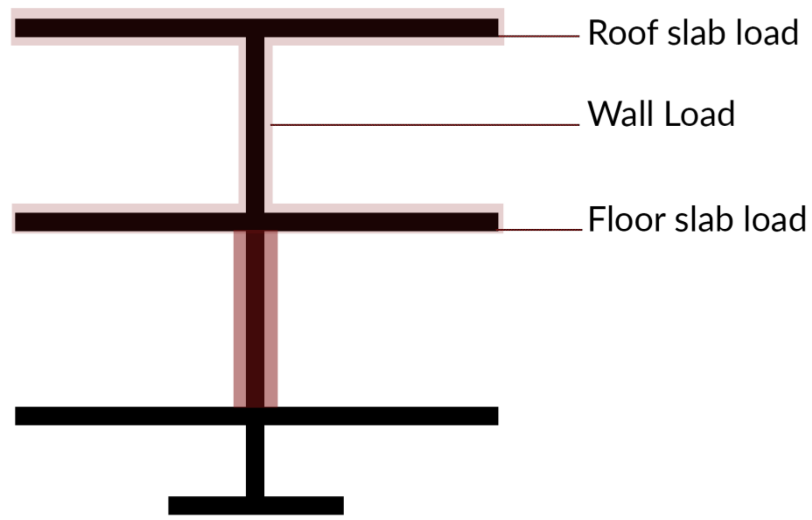
>> **Total Design Load of Roof Slab** is calculated by taking into consideration both the dead and live loads and through their multiplication with certain coefficients as in below ;

Pd = (1.4 x Dead Load) + (1.6 x Live Load)
= (1.4 x 0.67) + (1.6 x 0.15)

Pd = **1.18 t/m^2** *(for roof slab)*

TOTAL LOAD ON THE TRIBUTARY AREA

Slab Load = Total Design Load x Tributary Area
Wall Load = 1.4 x 0.15 x Tributary Area



Roof Slab Load = 1.18 x 9 = 10.62 t

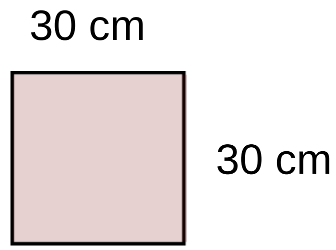
Floor Slab Load + Wall Load = 1.47 x 9 = 13.23 t
+

Total Load = **23.85 t** = **23850 kg**

>> After having calculated the design load that will apply on the tributary area of our column to be designed, we can decide the dimensions of our columns satisfying all the requirements ;

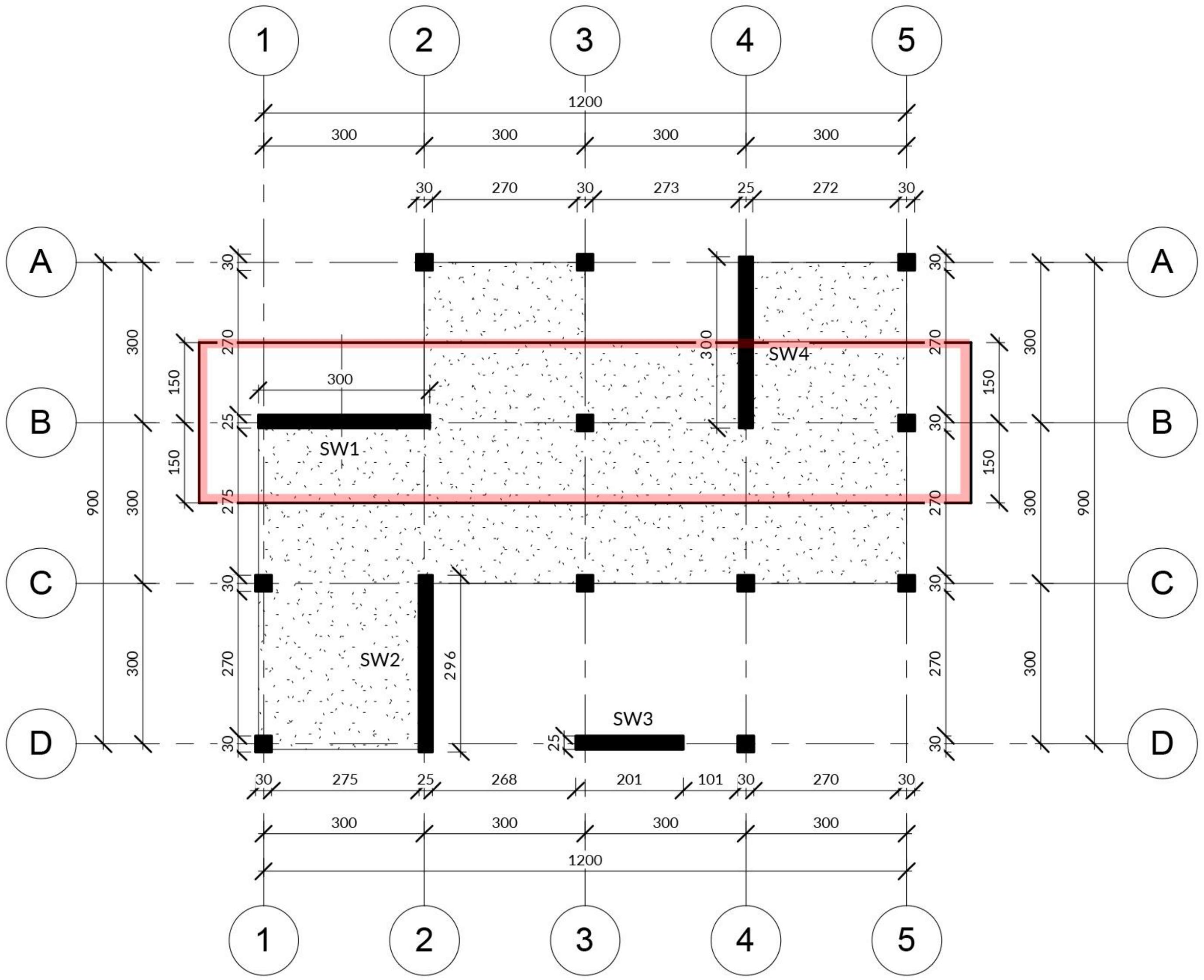
- $A_c \geq \dfrac{N_{dm}}{0.40 \times f_{ck}}$

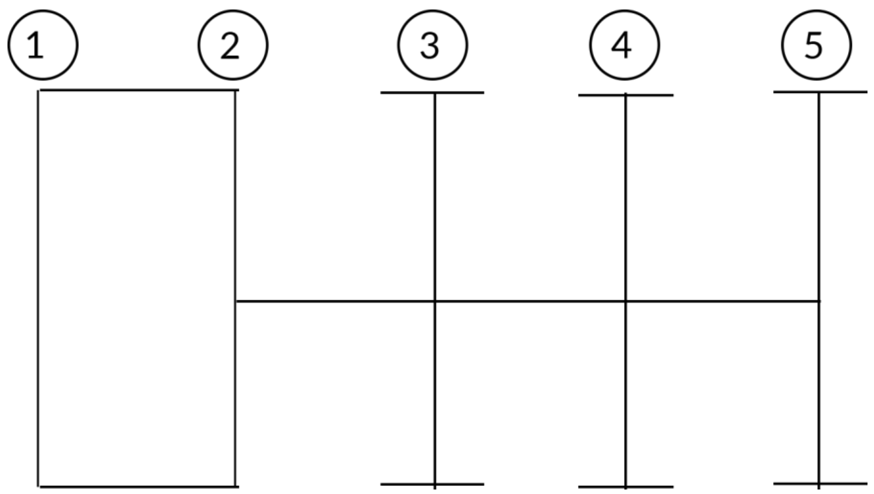
  $A_c \geq \dfrac{23850}{0.40 \times 200}$ → $\mathbf{A_c \geq 298.125\ cm^2}$



- According to TEC 2018 a column dimension cannot be less than 30 cm, so the area of the column footprint must be greater than 900 cm^2 → $\mathbf{A_c \geq 900\ cm^2}$
- So as to satisfy both of the given conditions above, **30 cm x 30 cm** is decided as the column dimensions. ($A_c = 900\ cm^2$)

TWO CYCLE METHOD





CALCULATION OF SLAB LOADS (FIRST FLOOR)

- Between 2 – 3 axis : (3 x 3) x 1.47 = 13.23 t
- Between 3 – 4 axis : (3 x 3) x 1.47 = 13.23 t
- Between 4 – 5 axis : (3 x 3) x 1.47 = 13.23 t

CALCULATION OF DISTRIBUTED LOAD (FIRST FLOOR)

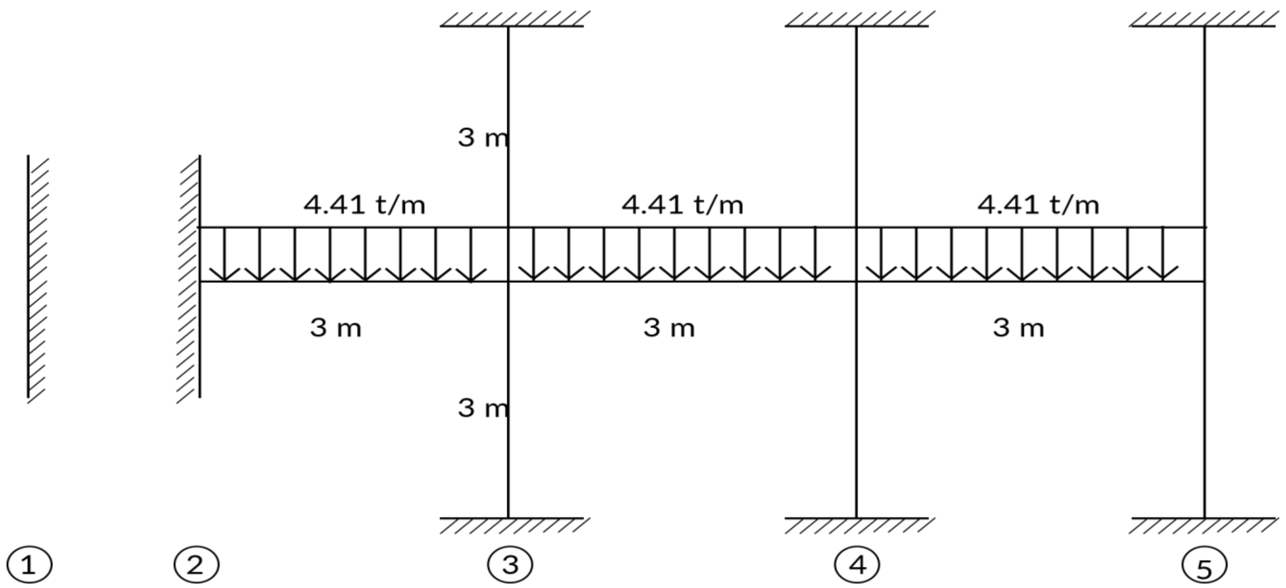
- Between 2 – 3 axis : 13.23 / 3 = 4.41 t/m
- Between 3 – 4 axis : 13.23 / 3 = 4.41 t/m
- Between 4 – 5 axis : 13.23 / 3 = 4.41 t/m

CALCULATION OF I VALUES

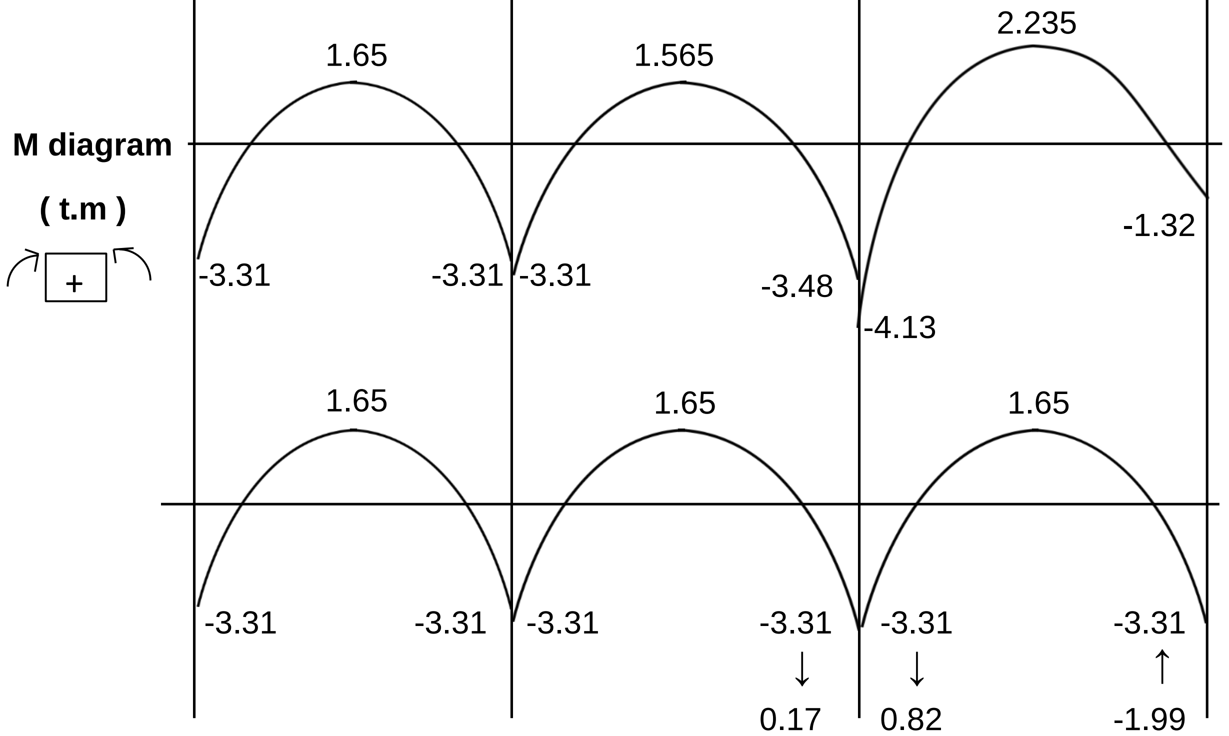
$$I = \frac{1}{12}\, b.h^3$$

- Columns; $I_{col\,3} = I_{col\,5} = 1/12 \times (0.3) \times (0.3)^3 = 0.00068\ m^4$
- Shear wall; $I_{SW4} = 1/12 \times 3 \times (0.25)^3 = 0.0039\ m^4$
- Slab; $I_{23} = I_{34} = I_{45} = 1/12 \times 3 \times (0.2)^3 = 0.002\ m^4$

TWO CYCLE METHOD



	2	3	3	4	4	5
r	0.00	0.37	0.37	0.17	0.17	0.60
FEM (+)	3.31	-3.31	3.31	-3.31	3.31	-3.31
1st Cycle	0	0	0	0	0.99	0
∑	3.31	-3.31	3.31	-3.31	4.30	-3.31
2nd Cycle	0	0	0	-0.17	-0.17	1.99
∑	3.31	-3.31	3.31	-3.48	4.13	-1.32



CALCULATION OF " r " VALUES

$$r = \frac{I / L}{\sum I / L}$$

- $r_{23} = \mathbf{0}$ (because of the shear wall)
- $r_{34} = r_{32} = \dfrac{\frac{0.002}{3}}{\frac{0.002}{3} + \frac{2 \times 0.00068}{3} + \frac{0.002}{3}} = \mathbf{0.37}$
- $r_{43} = r_{45} = \dfrac{\frac{0.002}{3}}{\frac{0.002}{3} + \frac{2 \times 0.0039}{3} + \frac{0.002}{3}} = \mathbf{0.17}$
- $r_{54} = \dfrac{\frac{0.002}{3}}{\frac{0.002}{3} + \frac{2 \times 0.00068}{3}} = \mathbf{0.60}$

CALCULATION OF FEM VALUES

FEM (fixed end moment) = $\dfrac{q \cdot L^2}{12}$

- $FEM_{23} = \dfrac{4.41 \times 3^2}{12} = 3.31$ t.m
- $FEM_{34} = \dfrac{4.41 \times 3^2}{12} = 3.31$ t.m
- $FEM_{45} = \dfrac{4.41 \times 3^2}{12} = 3.31$ t.m

TWO CYCLE METHOD

CALCULATION OF MID-SPAN MOMENTS

Midspan moment = $\frac{q \cdot L^2}{24}$
(*for fixed beams*)

Midspan $_{23}$ = MS $_{34}$ = MS $_{45}$ = $\frac{4.41 \times 3^2}{24}$ = **1.65 t.m**

FINAL MID-SPAN MOMENTS

Final Midspan $_{23}$ = $\frac{(-3.31 + 3.31) + (-3.31 + 3.31)}{2}$ + 1.65 = **1.65 t.m**

Final Midspan $_{34}$ = $\frac{(-3.31 + 3.31) + (-3.48 + 3.31)}{2}$ + 1.65 = **1.565 t.m**

Final Midspan $_{45}$ = $\frac{(-4.13 + 3.31) + (-1.32 + 3.31)}{2}$ + 1.65 = **2.235 t.m**

SLAB DEPTH

> To be on the safe side, we proceed with our calculations by taking *%80* of the moment value and *%50* of the ''bw'' value as shown below;

M_d = M_{max} x **0.8** = 4.13 x 0.8 = 3.30 t.m = *330 t.cm*

b_w' = b_w x **0.5** = 3 x 0.5 = 1.5 m = *150 cm*

K_0 = 25 cm² / t $\quad$ $K_0 = \frac{b_w \cdot d^2}{M_d}$

$25 = \frac{150 \cdot d^2}{330}$ → d^2 = 55 → **d ≈ 7.5 cm**

Cover for the slab is accepted as **3 cm.**

Thus, total thickness → 7.5 + 3 ≈ **11 cm**

>>> To conclude, we had assumed the slab thickness as 20 cm initially, now after the calculations we see that even with **11 cm** thick slab it would have been okay. **So, our 20 cm thick flat slab is safe** since 20 > 11 cm..

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