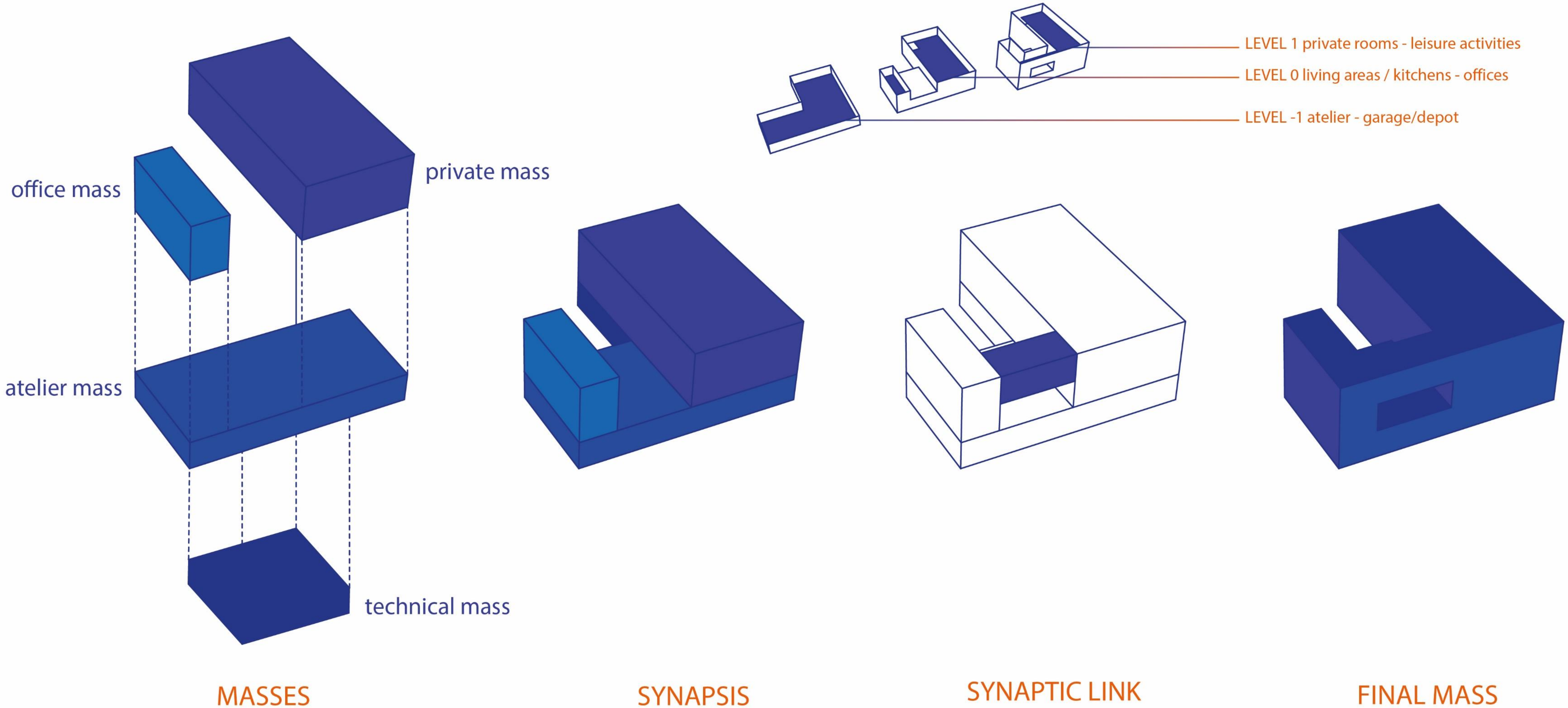
KUNST HAUS

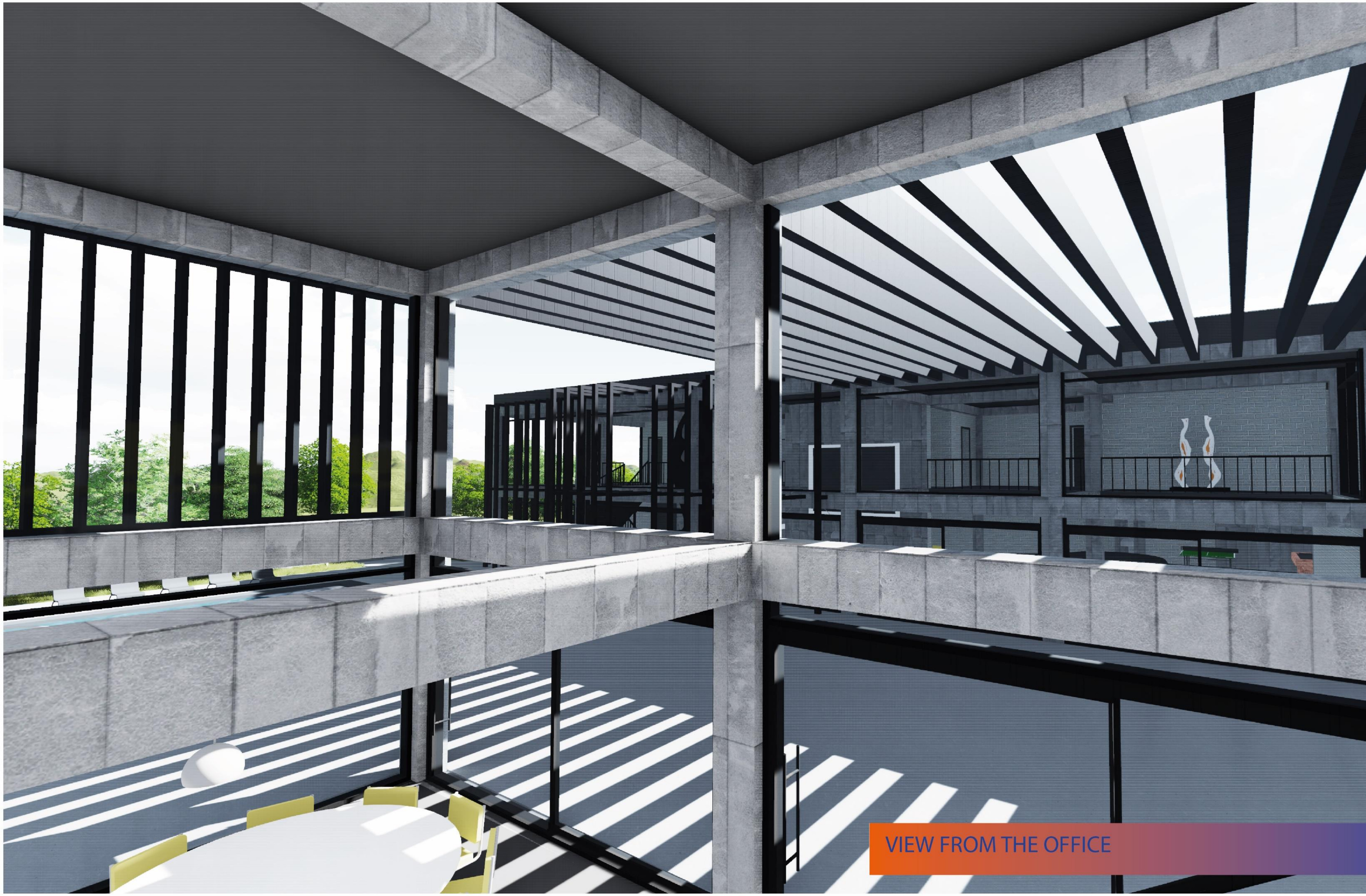
BEYAZIT-TURKER-UNAL

STRUCTURAL DESIGN IN ARCHITECTURE-AY-GUNEL-ERDIL-TASKIN

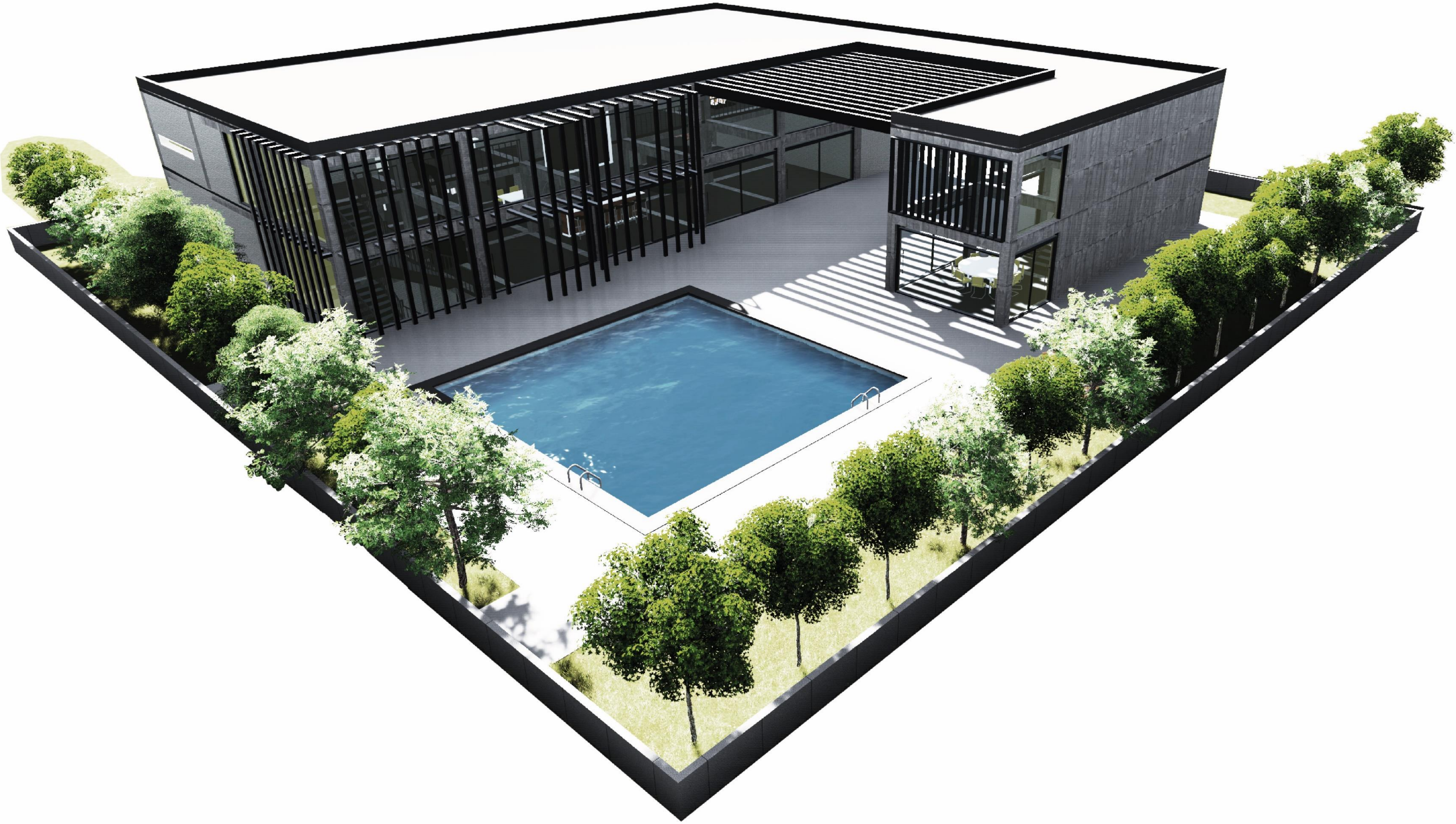


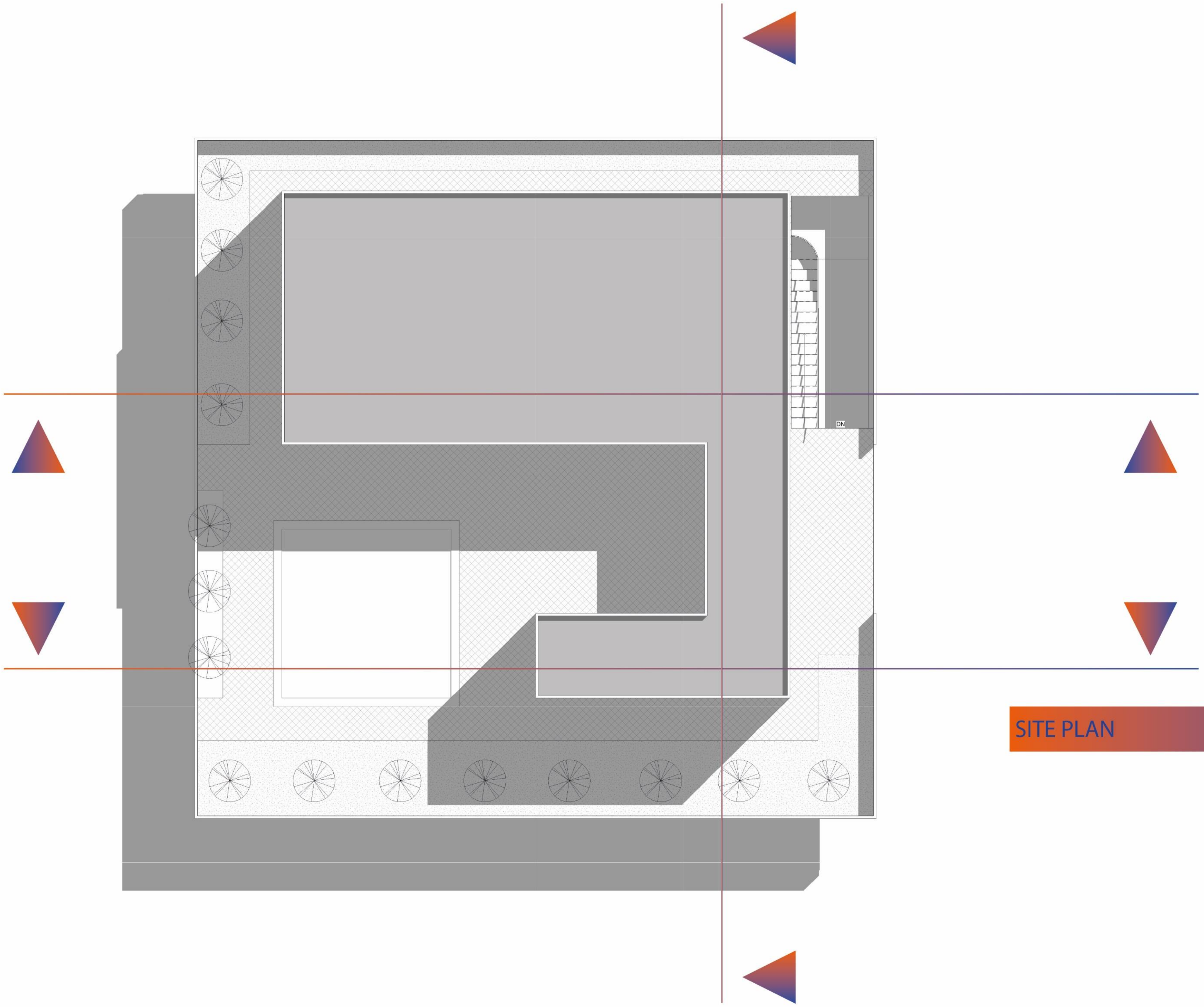
synapsis

Schematic design process was started by discussing how can we intersect private and common spaces to each other to create a syntesis of interrelated uses. As our dream house need to serve more uses than living spaces which are offices, studios and wide areas to keep our artworks, we generate mostly open spaces to another. In that sense to keep our art collection, we decided to create minimal and simple structure with galleries to reduce the complex view while artworks come together. Furthermore, apart from the private rooms, mostly all spaces communicates with each other for flexible uses.

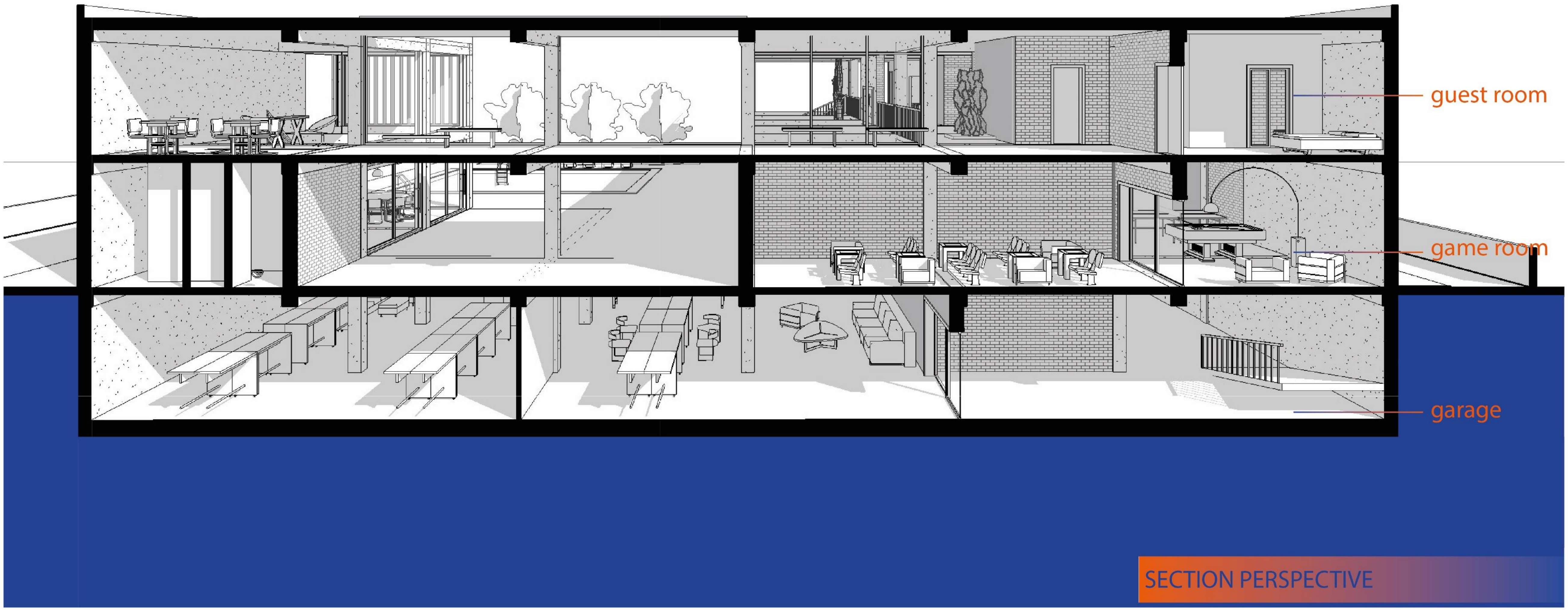

VIEW FROM THE OFFICE

VIEW FROM THE OFFICE

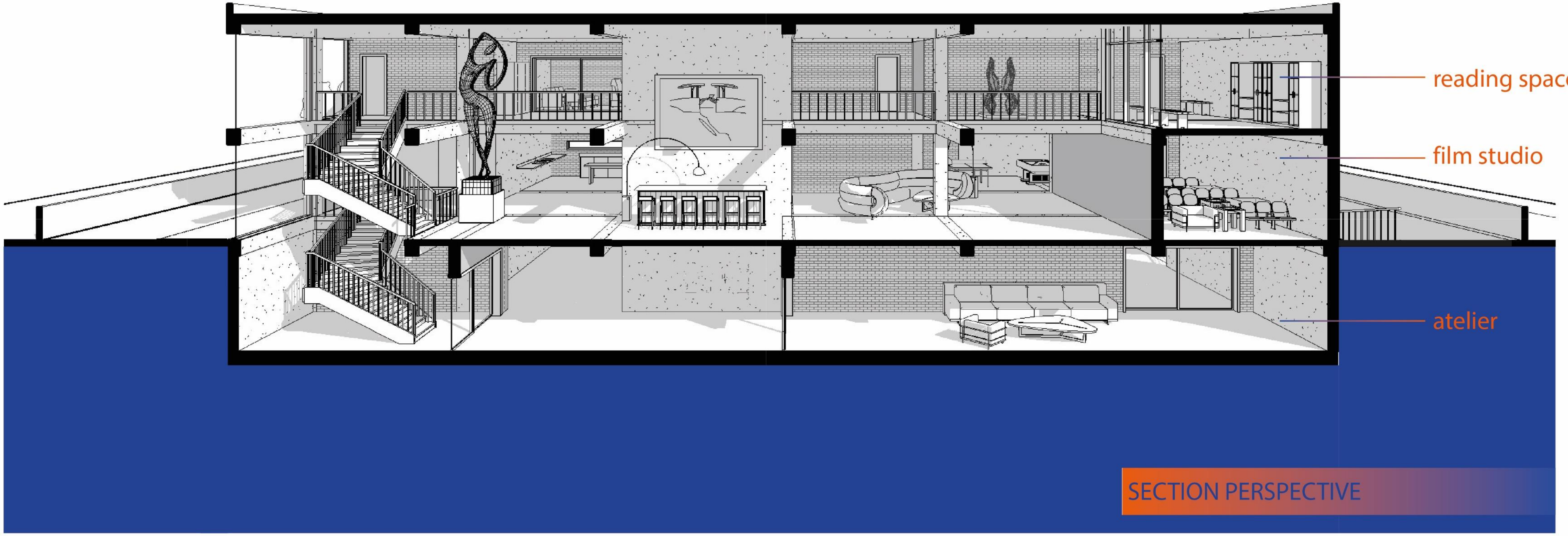




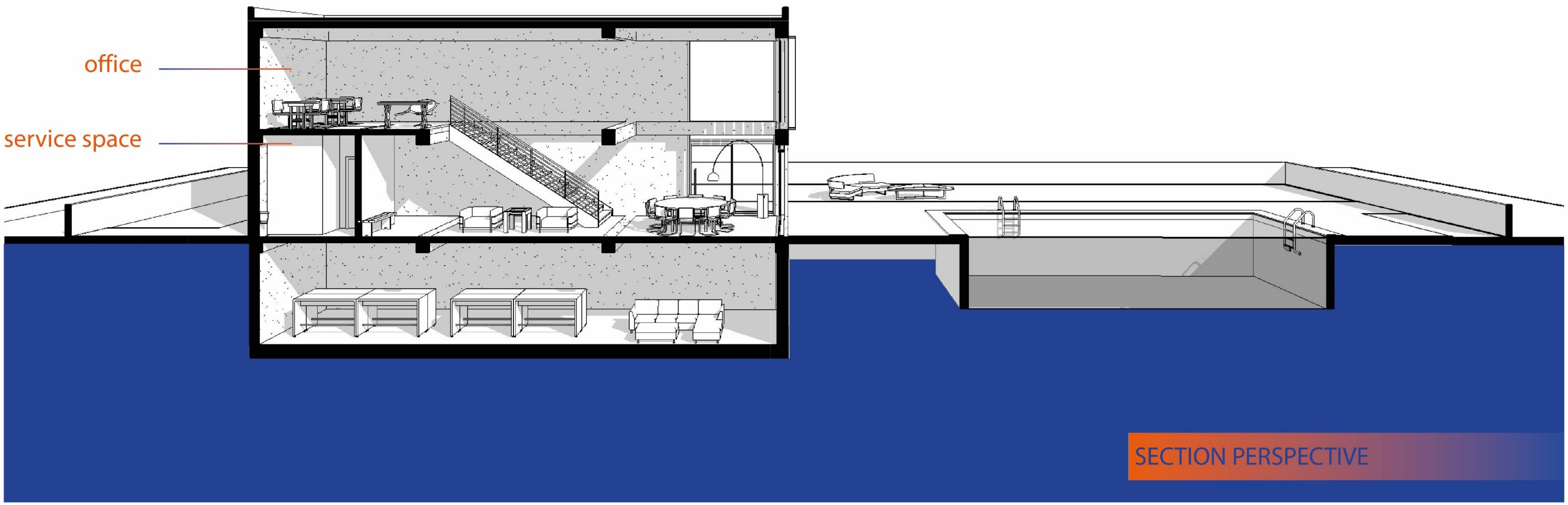
SITE PLAN



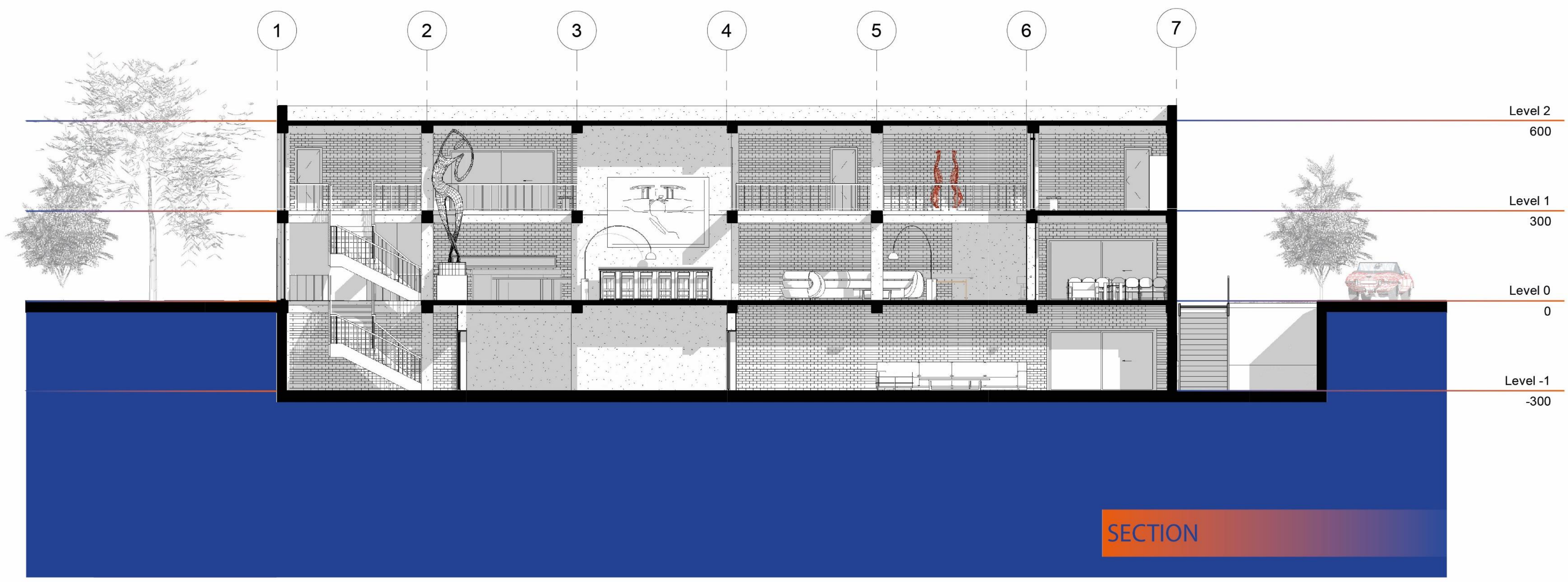
SECTION PERSPECTIVE

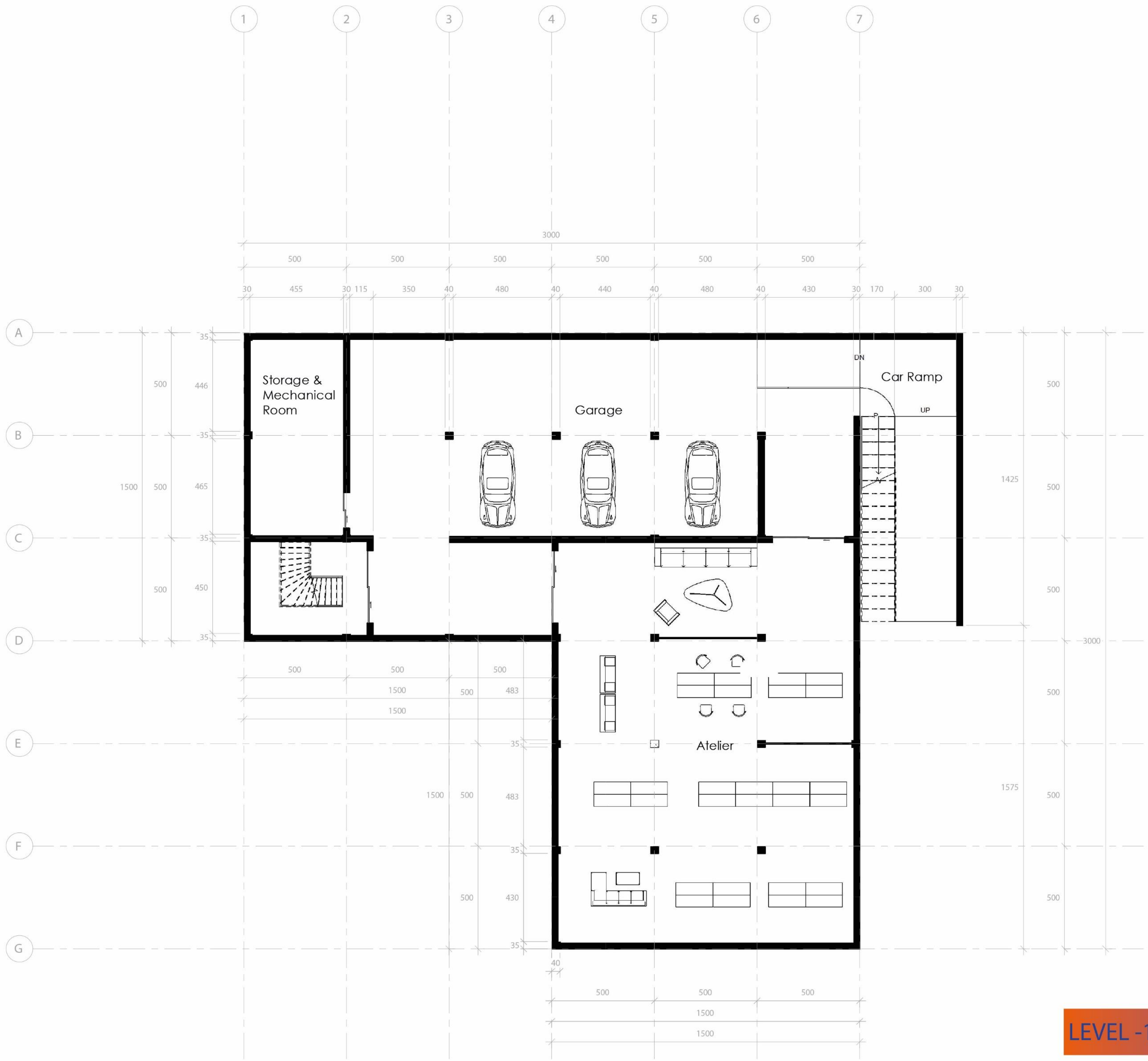


SECTION PERSPECTIVE

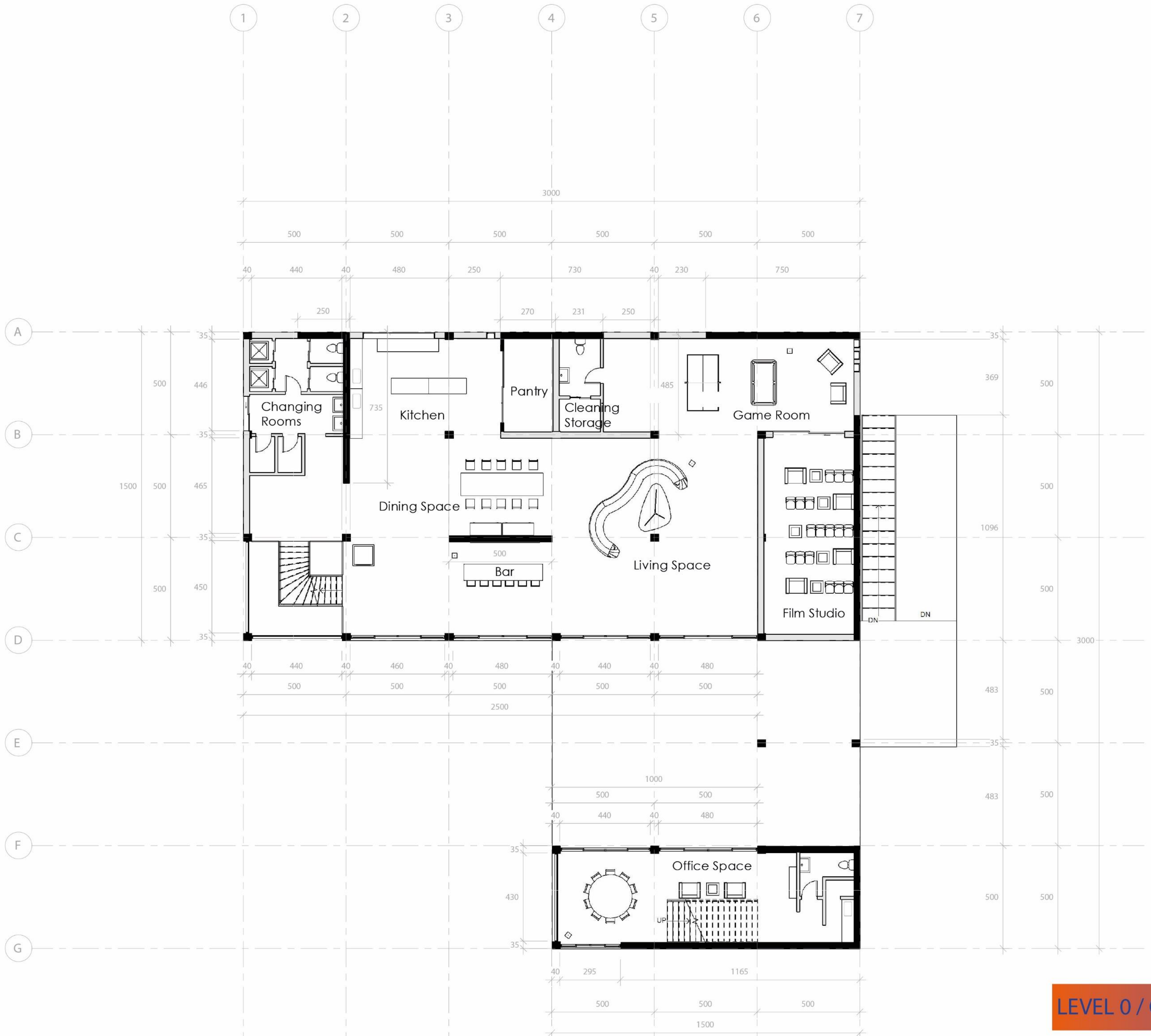


SECTION PERSPECTIVE

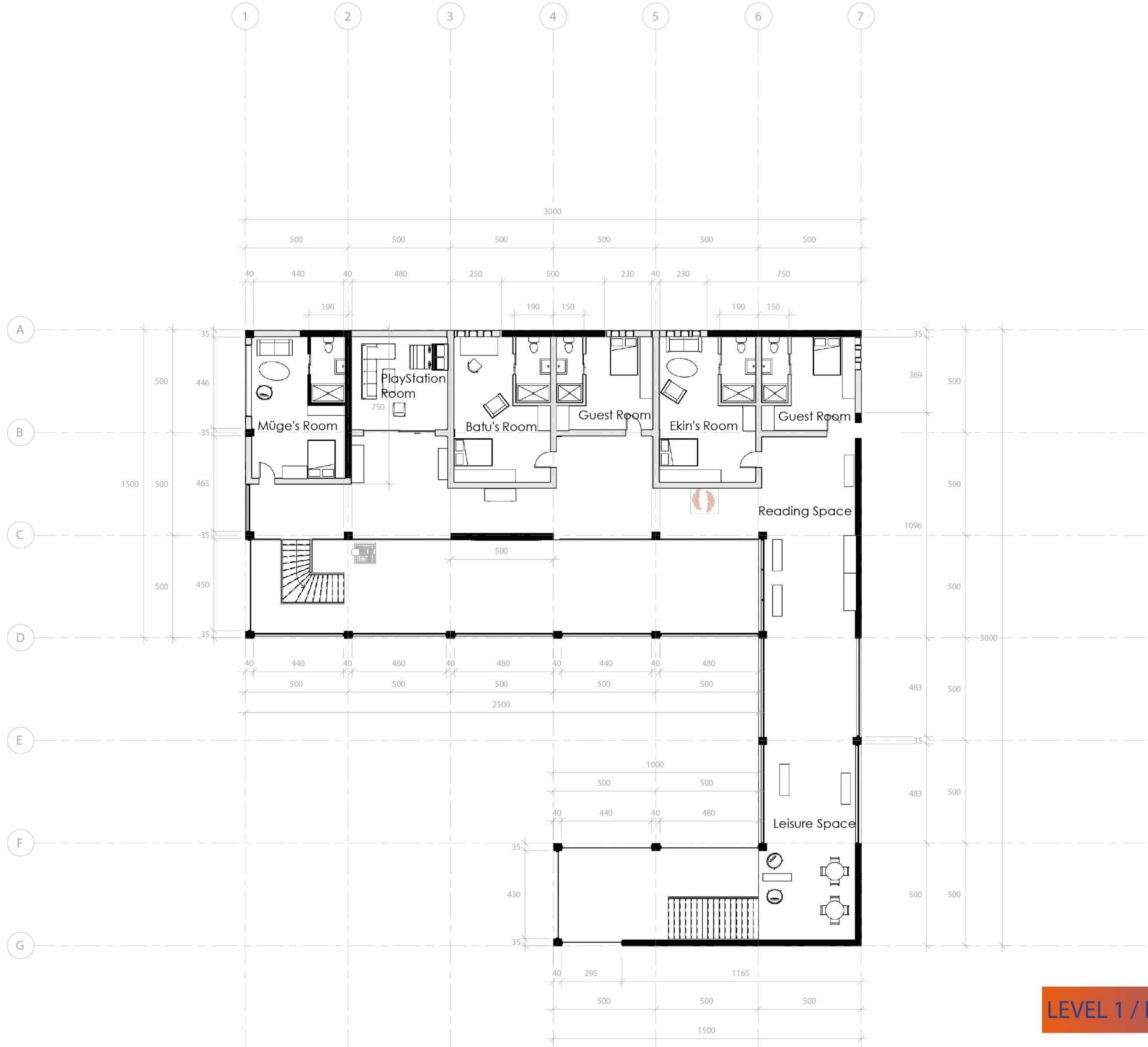

1
2
3
4
5
6
7
Level 2
600
Level 1
300
Level 0
0
Level -1
-300
SECTION



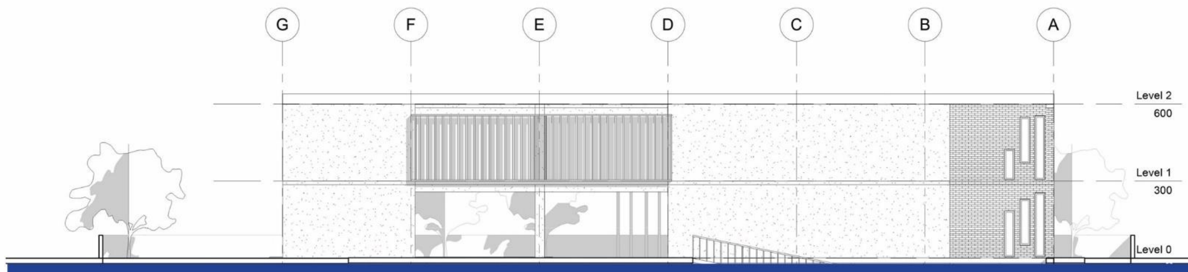
LEVEL -1 / BASEMENT PLAN



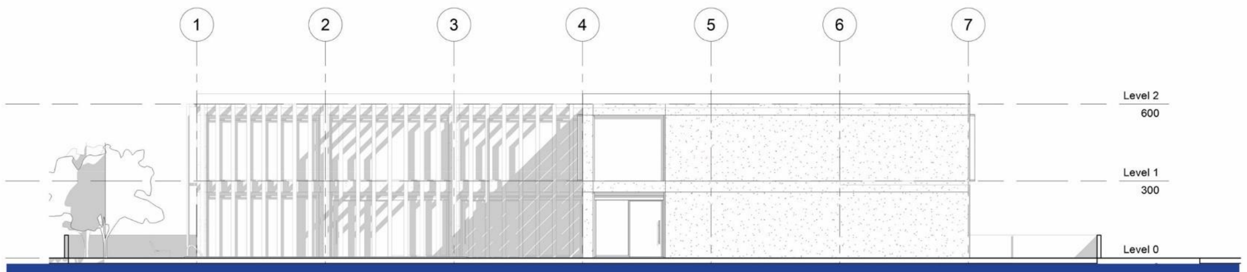
LEVEL 0 / GROUND FLOOR PLAN



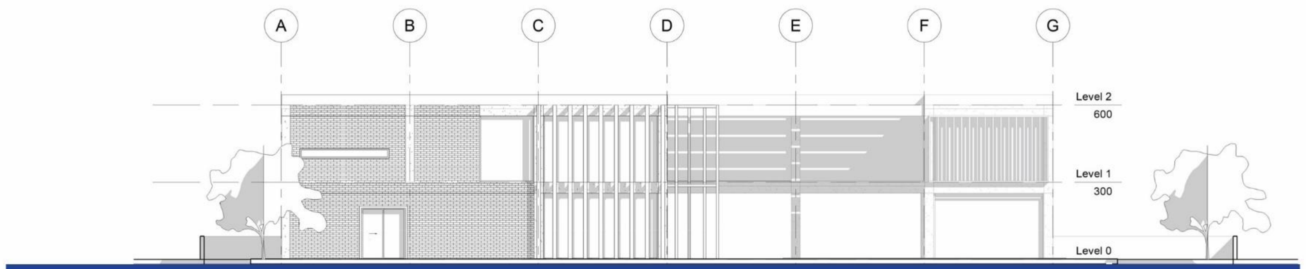
LEVEL 1 / FIRST FLOOR PLAN



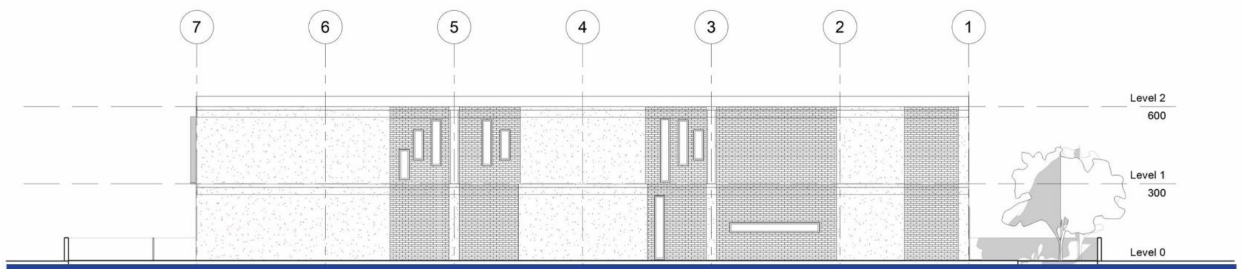
EAST ELEVATION



SOUTH ELEVATION



WEST ELEVATION



NORTH ELEVATION

PERCENTAGE AND CALCULATIONS

GEOMETRICAL CENTER

$$X_M = \frac{\sum_{i=1}^{n} X_i \cdot A_i}{\sum_{i=1}^{n} A_i} \qquad Y_M = \frac{\sum_{i=1}^{n} Y_i \cdot A_i}{\sum_{i=1}^{n} A_i}$$

$A_1 = 10 \cdot 5$

$A_2 = 10 \cdot 25$

$A_3 = 15 \cdot 15$

$x_1 = 2{,}5$

$x_2 = 17{,}5$

$x_3 = 22{,}5$

$y_1 = 25$

$y_2 = 22{,}5$

$y_3 = 7{,}5$

$$X_M = \frac{A_1 \cdot x_1 + A_2 \cdot x_2 + A_3 \cdot x_3}{A_1 + A_2 + A_3} = \frac{10 \cdot 5 \cdot 2{,}5 + 15 \cdot 25 \cdot 17{,}5 + 15 \cdot 15 \cdot 22{,}5}{10 \cdot 5 + 15 \cdot 25 + 15 \cdot 15} = 18{,}0769231 \cong 18{,}07$$

$$Y_M = \frac{A_1 \cdot y_1 + A_2 \cdot y_2 + A_3 \cdot y_3}{A_1 + A_2 + A_3} = \frac{10 \cdot 5 \cdot 25 + 15 \cdot 25 \cdot 22{,}5 + 15 \cdot 15 \cdot 7{,}5}{10 \cdot 5 + 15 \cdot 25 + 15 \cdot 15} = 17{,}5$$

STIFFNESS CENTER

$$X_S = \frac{\sum_{i=1}^{n} x_i \cdot I_{x,i}}{\sum_{i=1}^{n} I_{x,i}} \qquad Y_S = \frac{\sum_{i=1}^{n} x_i \cdot I_{x,i}}{\sum_{i=1}^{n} I_{x,i}}$$

$x_{6,7} = 30$

$x_8 = 5$

$y_{1,2,3} = 30$

$y_4 = 20$

$y_5 = 0$

$$I_1 = \frac{1}{12} \cdot 0{,}3 \cdot (2{,}5)^3 = 0{,}390625$$

$$I_{2,4,5,6,7} = \frac{1}{12} \cdot 0{,}3 \cdot (5)^3 = 3{,}125$$

$$I_{3,8} = \frac{1}{12} \cdot 0{,}3 \cdot (7{,}5)^3 = 10{,}546875$$

$$X_S = \frac{I_6 \cdot x_6 + I_7 \cdot x_7 + I_8 \cdot x_8}{I_6 + I_7 + I_8} = \frac{3{,}125 \cdot 30 + 3{,}125 \cdot 30 + 10{,}546875 \cdot 5}{3{,}125 + 3{,}125 + 10{,}546875} = \frac{240{,}234875}{16{,}796875} = 14{,}30235535 \cong 14{,}3$$

$$Y_S = \frac{I_1 \cdot y_1 + I_2 \cdot y_2 + I_3 \cdot y_3 + I_4 \cdot y_4 + I_5 \cdot y_5}{I_1 + I_2 + I_3 + I_4 + I_5} = \frac{0{,}390625 \cdot 30 + 3{,}125 \cdot 30 + 10{,}546875 \cdot 30 + 3{,}125 \cdot 20}{0{,}390625 + 3{,}125 + 10{,}546875 + 3{,}125 + 3{,}125} = \frac{484{,}375}{20{,}3125} = 23{,}84615385 \cong 23{,}84$$

In order to obtain %0 eccentricity, X_S must be equal to 18,07.
Add a shear wall on axis 7 named 9.

$$x_9 = 30 \qquad X_S = \frac{I_6 \cdot x_6 + I_7 \cdot x_7 + I_8 \cdot x_8 + I_9 \cdot x_9}{I_6 + I_7 + I_8 + I_9}$$

$$= \frac{240{,}234875 + I_9 \cdot 30}{16{,}796875 + I_9}$$

$$= 18{,}0769231 \Rightarrow I_9 = 5{,}31749843$$

$$I_9 = \frac{1}{12} \cdot 0{,}3 \cdot (a)^3 = 5{,}31749843$$

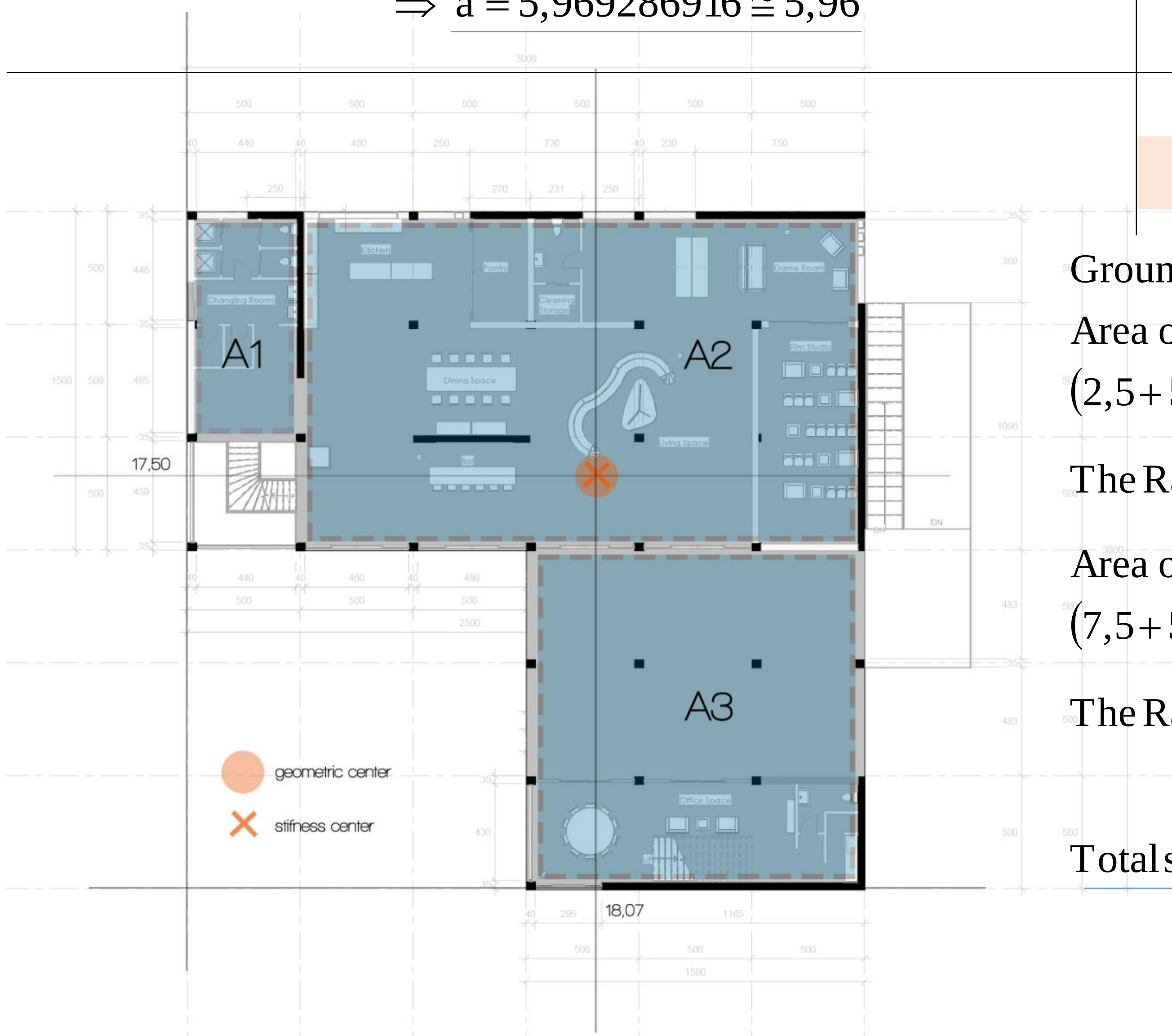
$$\Rightarrow a = 5{,}969286916 \cong 5{,}96$$

In order to obtain %0 eccentricity, Y_S must be equal to 17,5.
Add a shear wall on axis G named 10.

$$y_{10} = 0 \qquad Y_S = \frac{I_1 \cdot y_1 + I_2 \cdot y_2 + I_3 \cdot y_3 + I_4 \cdot y_4 + I_5 \cdot y_5 + I_{10} \cdot y_{10}}{I_1 + I_2 + I_3 + I_4 + I_5 + I_{10}}$$

$$= \frac{484{,}375}{20{,}3125 + I_{10}} = 17{,}5 \Rightarrow I_{10} = 7{,}366071429$$

$$I_{10} = \frac{1}{12} \cdot 0{,}3 \cdot (b)^3 = 7{,}366071429 \Rightarrow b = 6{,}65242734 \cong 6{,}65$$



SHEAR WALL PERCENTAGE

$\text{Ground Floor Area} = 650\ m^2$

Area of Shear Wall on x direction :

$$(2{,}5 + 5 + 5 + 7{,}5 + 5 + 6{,}65) \cdot 0{,}3 = 31{,}65 \cdot 0{,}3 = 9{,}495$$

The Ratio of Shear Wall on x direction is : $\frac{9{,}495}{650} = 0{,}01460769231 \Rightarrow \%1$

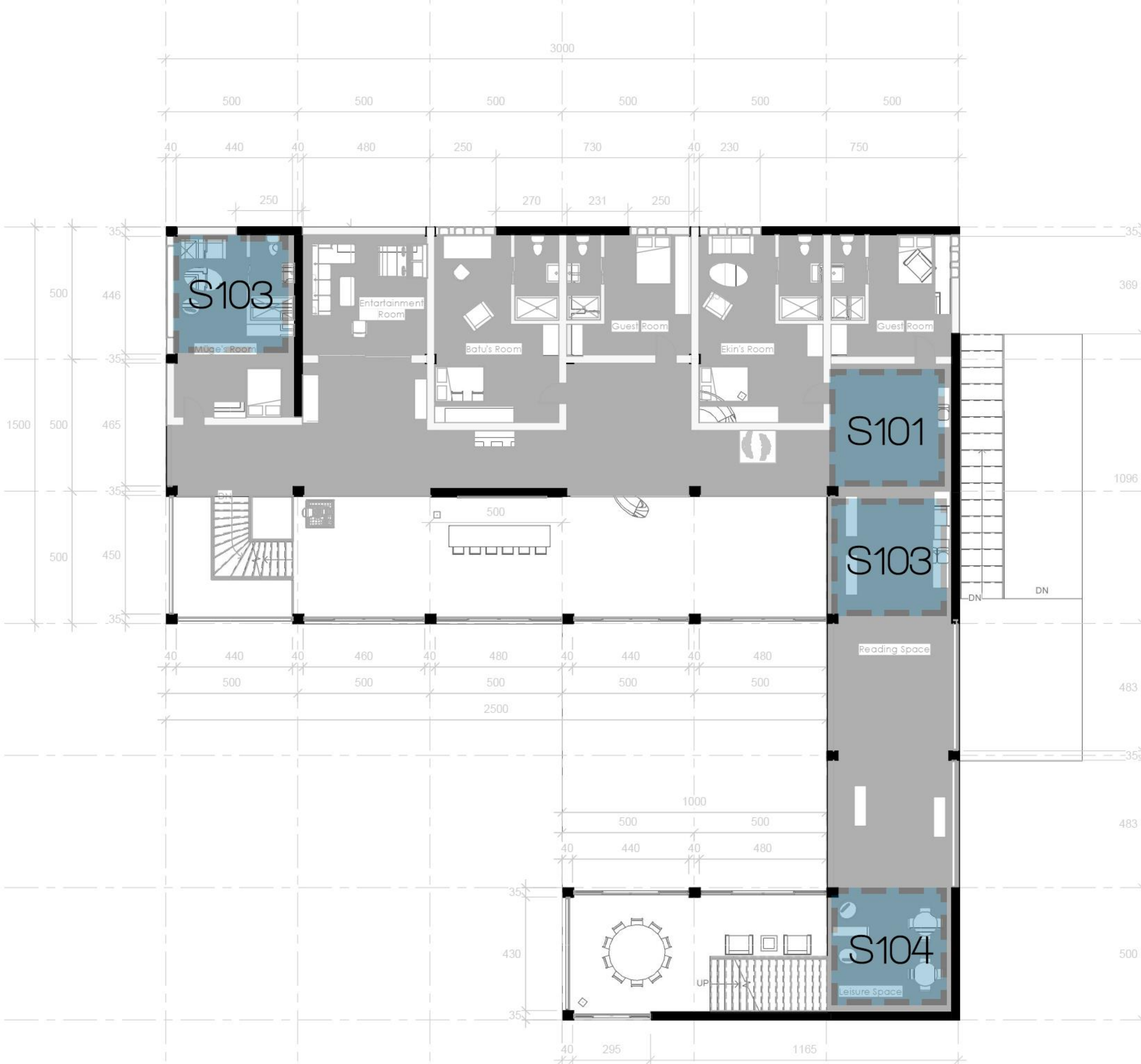
Area of Shear Wall on y direction :

$$(7{,}5 + 5 + 5 + 5{,}96) \cdot 0{,}3 = 23{,}46 \cdot 0{,}3 = 7{,}038$$

The Ratio of Shear Wall on y direction is : $\frac{7{,}038}{650} = 0{,}01082769231 \Rightarrow \%1$

Total shear wall cross sectional area is within acceptable range.

SELECTION AND THICKNESS CALCULATIONS



Selected slab type is solid slab with beams.

Since $\frac{l_1}{l_2} \leq 2$, two way solid slab system is valid.

$$t \geq \frac{l_{sn}}{15+\left(\frac{20}{m}\right)} \cdot \left[1-\frac{\alpha_s}{4}\right] \quad \text{where } m=\frac{l_l}{l_s}$$

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

$$\alpha_s = \frac{\sum length\ of\ cont.\ edges}{\sum length\ of\ all\ edges}$$

$$\alpha_{S101} = \frac{20}{20} = 1$$

$$\alpha_{S102} = \frac{15}{20} = 0,75$$

$$\alpha_{S103} = \frac{10}{20} = 0,5$$

$$\alpha_{S104} = \frac{5}{20} = 0,25$$

$$t_{S101} \geq \frac{500}{15+\left(\frac{20}{1}\right)} \cdot \left[1-\frac{1}{4}\right] = \frac{500}{35} \cdot 0,75 = 10,7142857$$

$$t_{S102} \geq \frac{500}{15+\left(\frac{20}{1}\right)} \cdot \left[1-\frac{0,75}{4}\right] = \frac{500}{35} \cdot 0,8125 = 11,6071429$$

$$t_{S103} \geq \frac{500}{15+\left(\frac{20}{1}\right)} \cdot \left[1-\frac{0,5}{4}\right] = \frac{500}{35} \cdot 0,875 = 12,5$$

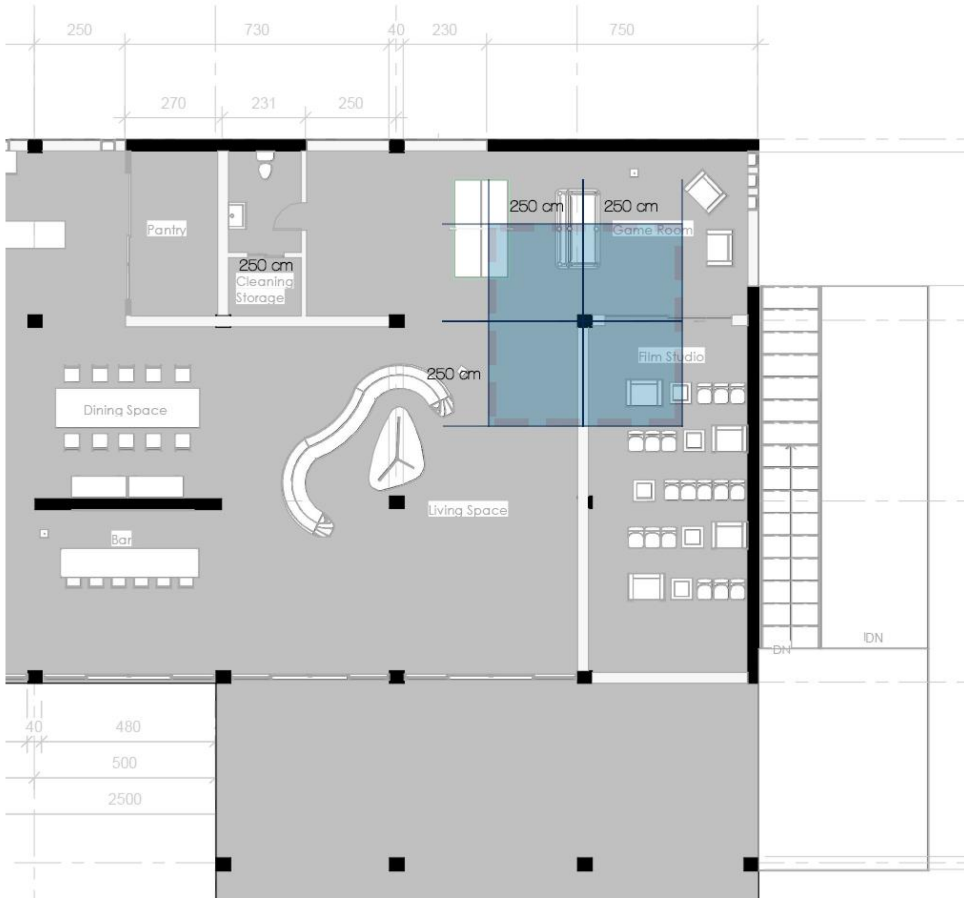
$$t_{S104} \geq \frac{500}{15+\left(\frac{20}{1}\right)} \cdot \left[1-\frac{0,25}{4}\right] = \frac{500}{35} \cdot 0,9375 = 13,3928572$$

therefore, $t \geq 13,3928572$

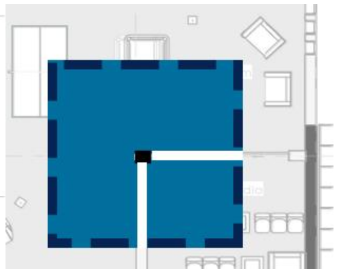
$t = 14$ cm is selected.

COLUMN DIMENSIONS

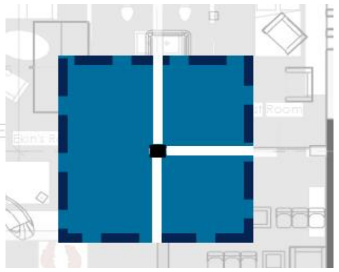
TRIBUTARY AREA AND MINIMUM COLUMN AREA CALCULATIONS



TRIBUTARY AREA

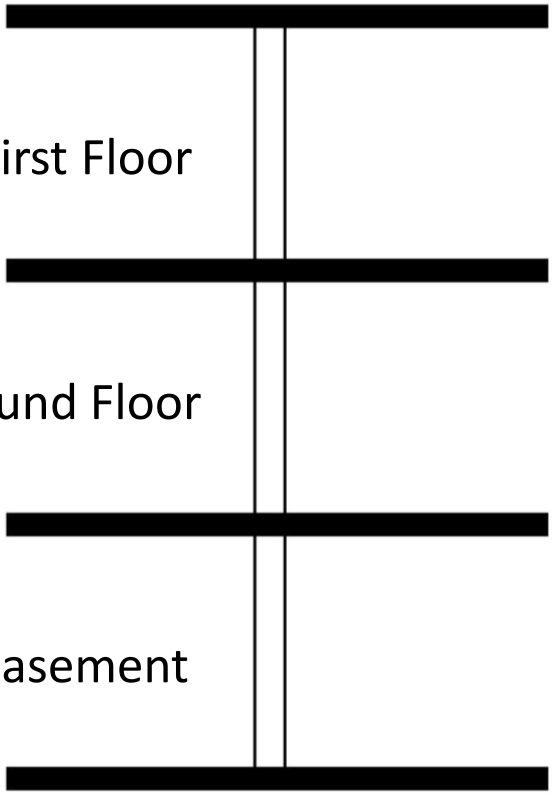


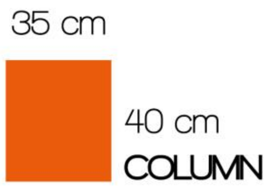
Ground Floor



First Floor

Beam B6 is chosen





Assume beam depth as longest span (12,5)

$$\frac{500}{12,5} = 40\text{ cm} \quad \text{So net wall height is} = 2,6\text{ m}$$

Dead load of solid slabs:

$$\underbrace{\begin{aligned}&\text{own weight}: 0,14 \cdot 2,4 = 0,336\text{ t/m}^2\\&\text{levelling}: 0,40 \cdot 2,4 = 0,096\text{ t/m}^2\\&\text{covering}: 0,025 \cdot 2,0 = 0,05\text{ t/m}^2\\&\text{plastering}: 0,020 \cdot 2,0 = 0,04\text{ t/m}^2\end{aligned}}_{\text{Total} = 0,522\text{ t/m}^2}$$

$$\text{Live load} = 0,02\text{ t/m}^2$$

$$\text{Total load} = P_d = 1,4 \cdot 0,522 + 1,6 \cdot 0,2$$

$$= 0,7308 + 0,32 = 1,0508\text{ t/m}^2$$

According to standards:

$$A_C \geq \frac{N_{dm}}{0,4 \cdot f_{ck}} = \frac{99285}{0,4 \cdot 200}$$

$$= \frac{99285}{80} = 1241,0625\text{ cm}^2$$

$$\sqrt{1241,0625} = 35,2271698$$

$$\Rightarrow 35 \cdot 40 = 1400$$

therefore, column dimensions are chosen as 35x40 cm

LOADS

$$\text{Slab load}: 5 \cdot 5 \cdot 1,0508 = 26,7\text{t} = 26270\text{kg}$$

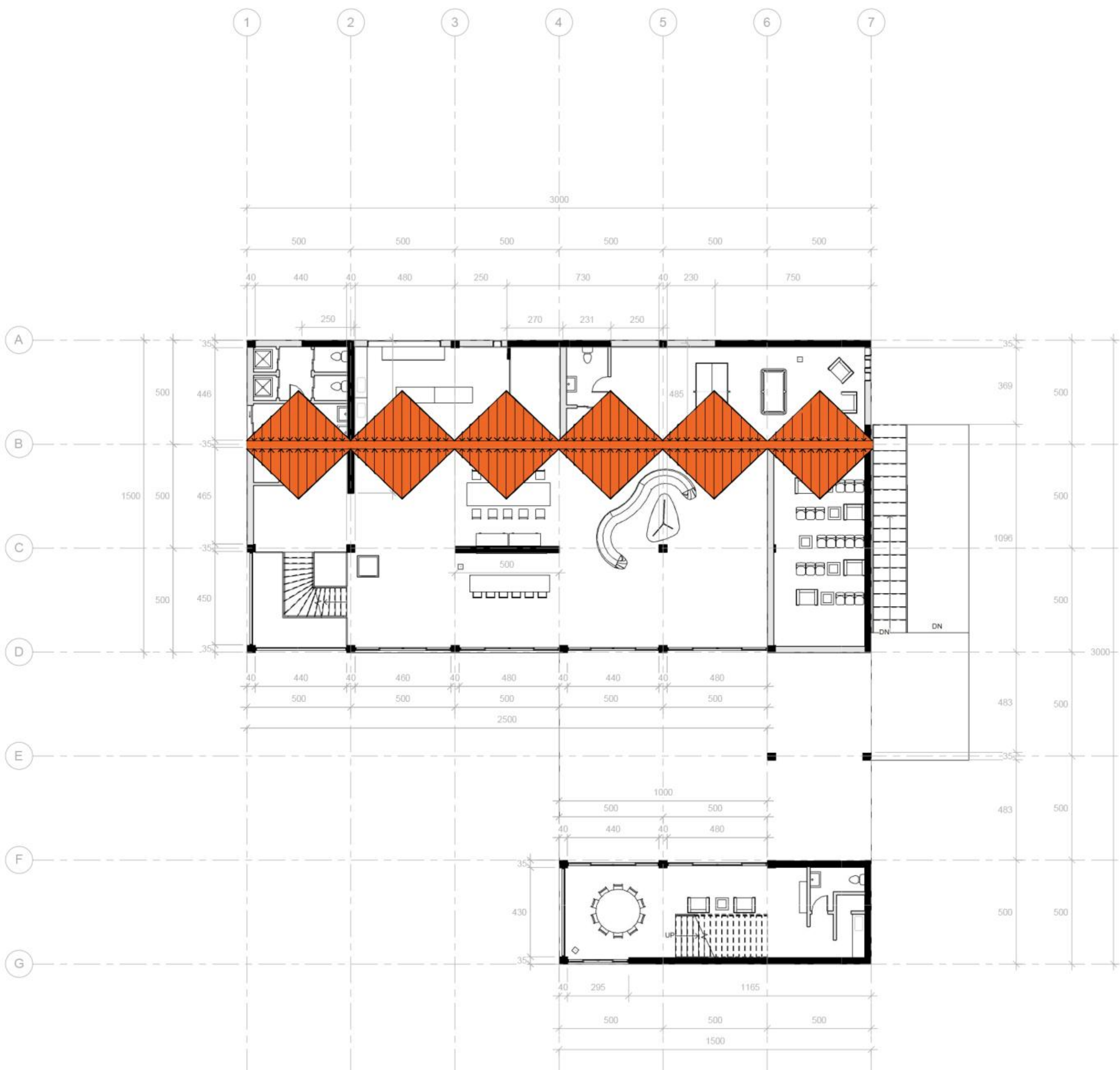
$$\text{Wall load}: 7,5 \cdot 2,6 \cdot 0,45 \cdot 1,4 = 12,285\text{t} = 12285\text{kg}$$

$$\text{Slab load}: 5 \cdot 5 \cdot 1,0508 = 26,7\text{t} = 26270\text{kg}$$

$$\text{Wall load}: 5 \cdot 2,6 \cdot 0,45 \cdot 1,4 = 8,19\text{t} = 8190\text{kg}$$

$$\text{Slab load}: 5 \cdot 5 \cdot 1,0508 = 26,7\text{t} = 26270\text{kg}$$

$$\text{Total load} = 26270 + 12285 + 26270 + 8190 + 26270 = 99285\text{kg}$$



LOADS ON BEAM

For the short span of two way :

$$W = P_d \cdot \frac{l_{short}}{3}$$

For the long span of two way :

$$W = P_d \cdot \frac{l_{short}}{3} \cdot \left(1{,}5 \cdot \frac{0{,}5}{\left(\frac{l_{long}}{l_{short}}\right)^2} \right)$$

$B_{1\text{-}7}$ has the longest span having no shear walls

$$\frac{500}{12{,}5} = 40 \text{ cm}$$

(assumption in order to find the moment of inertia of the beam)

since the slabs are square shaped;
long span is equal to short span.
Therefore, for each slab :

$$W = 1{,}0508 \cdot \frac{5}{3} = 1{,}7513 \text{ from single slab}$$

$1{,}7513 \cdot 2 = 3{,}5026$ t/m on a single portion of beam.

Uniformly distributed wall load on beam :

$$WL = \text{wall height} \cdot \text{wall load} \cdot \text{dead load factor}$$

$$= 2{,}6 \cdot 0{,}45 \cdot 1{,}4 = 1{,}638 \text{ t/m}$$

$$P_{B12} = P_{B23} = P_{B34} = P_{B45} = P_{B56} = P_{B67} =$$

$$3{,}5026 + 1{,}638 = 5{,}1406 \text{ t/m}$$

BEAM ANALYSIS

MOMENT OF INERTIA, LOAD DISTRIBUTION FACTOR AND FEM CALCULATIONS TWO CYCLE METHOD AND BEAM DEPTH CALCULATIONS

$$I_{beam} = \frac{1}{12} \cdot 0{,}35 \cdot (0{,}4)^3 = 0{,}001866667\, m^4$$

$$I_{column} = \frac{1}{12} \cdot 0{,}35 \cdot (0{,}4)^3 = 0{,}001866667\, m^4$$

$$I_{SW1} = \frac{1}{12} \cdot 7{,}5 \cdot (0{,}3)^3 = 0{,}016875\, m^4$$

$$I_{SW2} = \frac{1}{12} \cdot 10{,}96 \cdot (0{,}3)^3 = 0{,}02466\, m^4$$

$$a = \frac{0{,}001866667}{5} = 3{,}733334 \cdot 10^{-4}$$

$$2a = 7{,}466668 \cdot 10^{-4}$$

$$b = \frac{0{,}001866667}{3} \cdot 2 = 1{,}244444667 \cdot 10^{-3}$$

$$c = \frac{0{,}016875}{3} \cdot 2 = 0{,}01125$$

$$d = \frac{0{,}02466}{3} \cdot 2 = 0{,}01644$$

$$r_{12} = \frac{a}{a+b} = 0{,}2307692307 \cong 0{,}23$$

$$r_{21} = r_{23} = \frac{a}{2a+c} = 0{,}0321193058 \cong 0{,}03$$

$$r_{32} = r_{34} = r_{43} = r_{45} = r_{54} = r_{56} = r_{65} = r_{67} = \frac{a}{2a+b}$$

$$= 0{,}1875 \cong 0{,}18$$

$$r_{76} = \frac{a}{2a+d} = 0{,}2022204603 \cong 0{,}02$$

$$FEM = \frac{q \cdot l^2}{12} \qquad I = \frac{b \cdot h^3}{12} \qquad r = \frac{\frac{I}{l}}{\sum \frac{I}{l}}$$

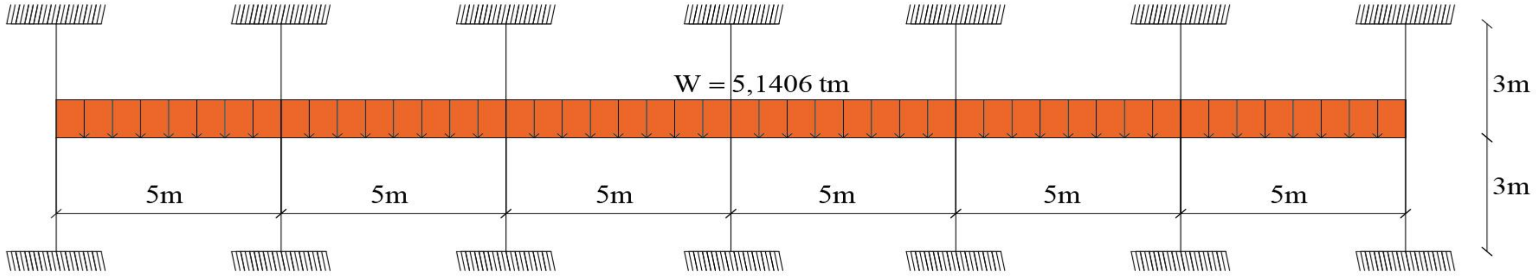
$$mid\text{-}span\ moment = \frac{q \cdot l^2}{24}$$

$$= \frac{10{,}7095833}{2}$$

$$= 5{,}35479165\, tm \cong 5{,}35\, tm$$

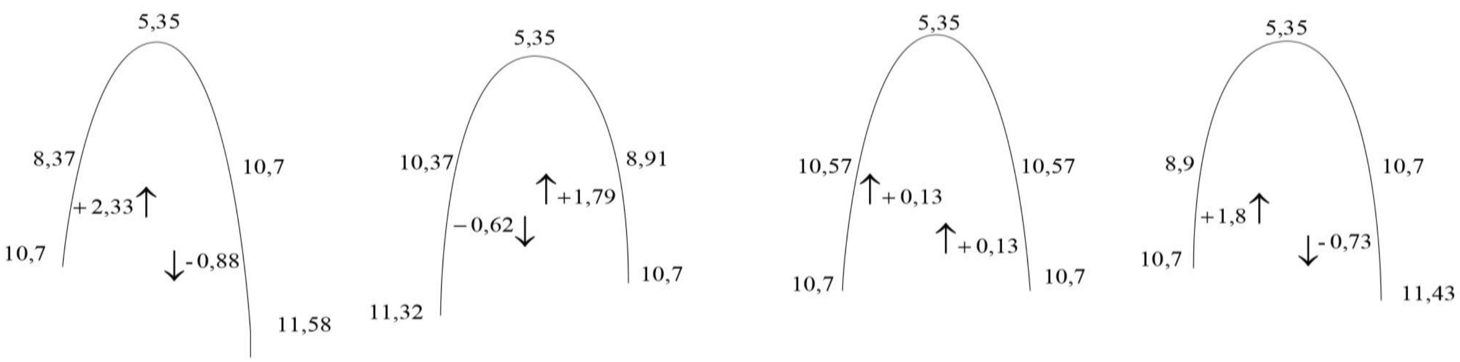
$$FEM_{12} = FEM_{23} = FEM_{34} = FEM_{45} = FEM_{56} = FEM_{67}$$

$$= \frac{5{,}1406 \cdot 5^2}{12} = \frac{128{,}515}{12} = 10{,}7095833\, tm \cong 10{,}7\, tm$$



r	0,23	0,03	0,03	0,18	0,18	0,18	0,18	0,18	0,18	0,18	0,18	0,02
FEM	10,7	-10,7	10,7	-10,7	10,7	-10,7	10,7	-10,7	10,7	-10,7	10,7	-10,7
1st cycle	0,16	-1,23	0,96	-0,16	0,96	-0,96	0,96	-0,96	0,96	-0,96	0,1	-0,96
$\sum_1$	10,86	-11,93	11,66	-10,86	11,66	-11,66	11,66	-11,66	11,66	-11,66	10,8	-11,66
2nd cycle	-2,49	0,35	-0,34	1,95	-2,09	2,09	-2,09	2,09	-2,09	2,09	-1,9	0,29
$\sum_2$	8,37	-11,58	11,32	-8,91	10,57	-10,57	10,57	-10,57	10,57	-10,57	8,9	-11,43

MOMENT OF INERTIA, LOAD DISTRIBUTION FACTOR AND FEM CALCULATIONS TWO CYCLE METHOD AND BEAM DEPTH CALCULATIONS

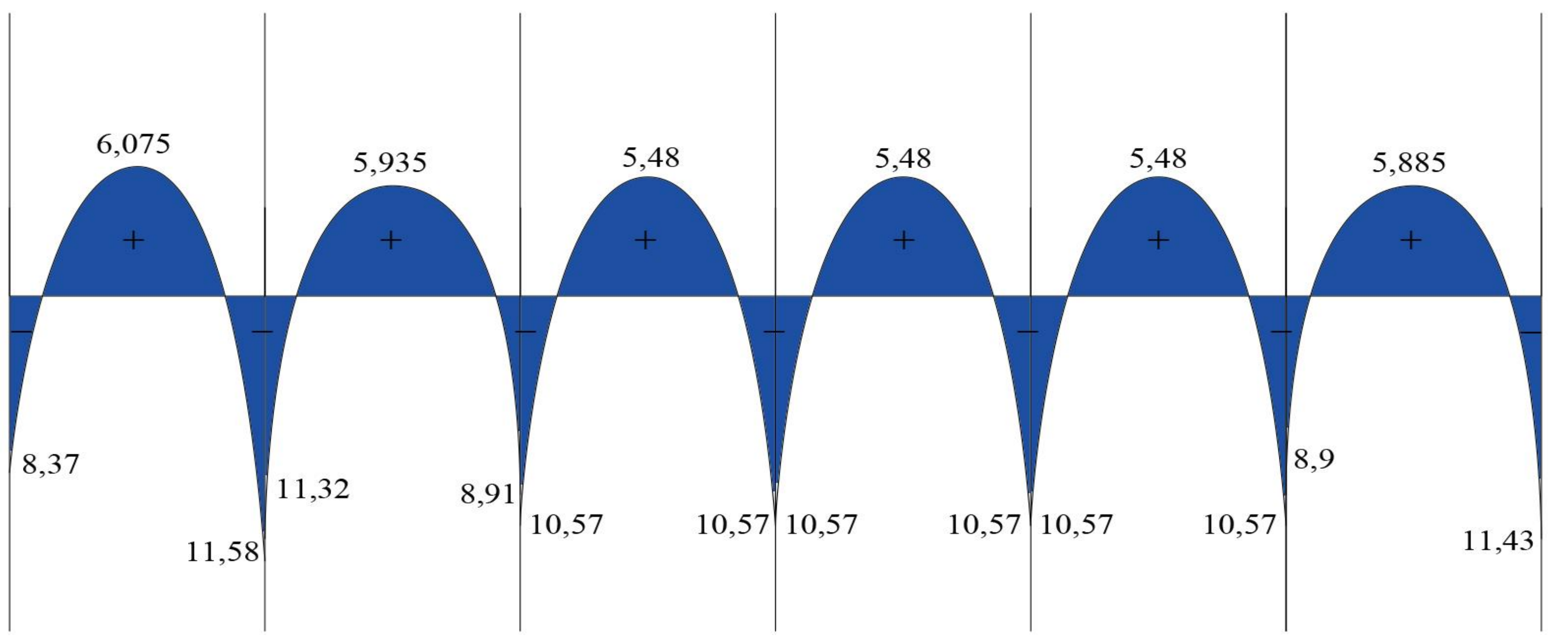


$$\frac{+2{,}33-0{,}88}{2}=0{,}725$$
mid-span moment
$=5{,}35+0{,}725=6{,}075$

$$\frac{+1{,}79-0{,}62}{2}=0{,}585$$
mid-span moment
$=5{,}35+0{,}585=5{,}935$

$$\frac{+0{,}13+0{,}13}{2}=0{,}13$$
mid-span moment
$=5{,}35+0{,}513=5{,}48$

$$\frac{+1{,}8-0{,}73}{2}=0{,}535$$
mid-span moment
$=5{,}35+0{,}535=5{,}885$



BEAM DEPTH $$K=\frac{b_w \cdot d^3}{M}$$

$K_0 = 25\ \text{cm}^2/\text{t}$

$M_{max} = 11{,}8\ \text{tm} = 1158\ \text{tcm}$

$b_w = 35\ \text{cm}$

$$25=\frac{35\cdot d^2}{1158} \Rightarrow d^2 = 827{,}1428571$$

$\Rightarrow 28{,}7600914\ \text{cm} \cong 28{,}7\ \text{cm}$

clear cover = 5 cm $\Rightarrow h = 28{,}7+5 = 33{,}7$ cm

since the beam depth can't be smaller than tree times of slab thickness ($14\cdot 3 = 42$ cm);

beam depth is chosen as 42 cm.