METU | ARCH 332, STRUCTURAL DESIGN IN ARCHITECTURE II | 2017-2018 SPRING

# TERM PROJECT

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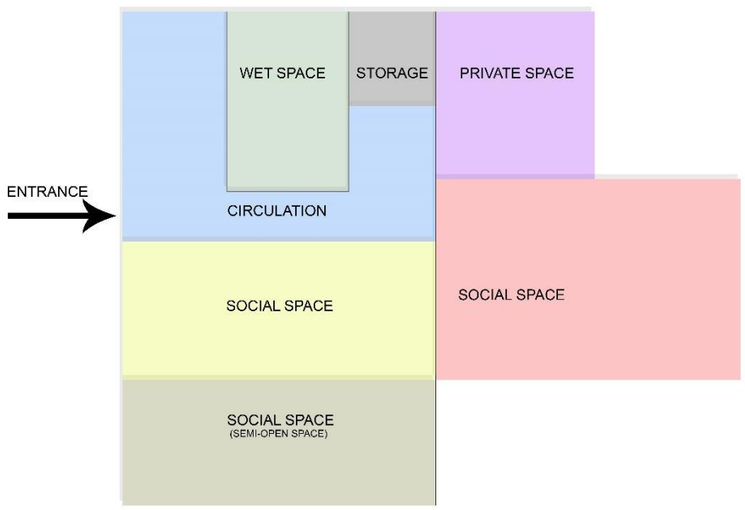
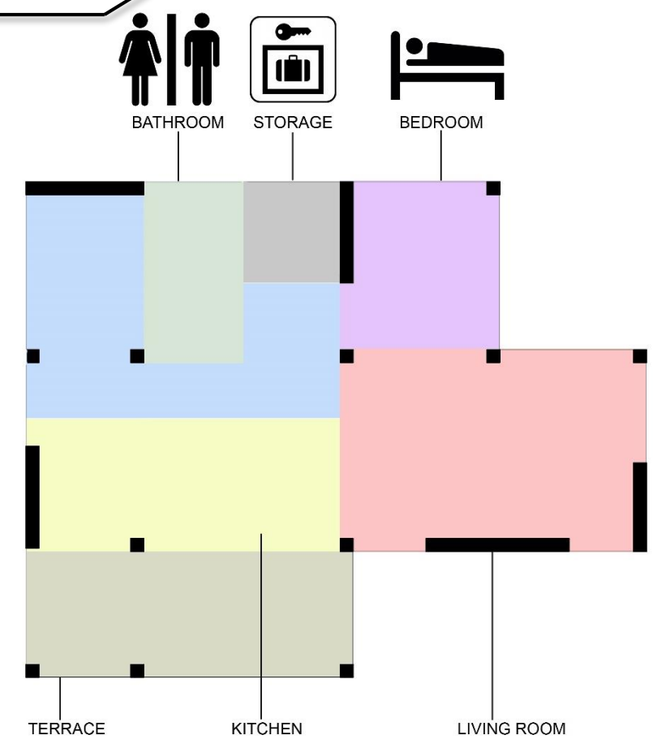
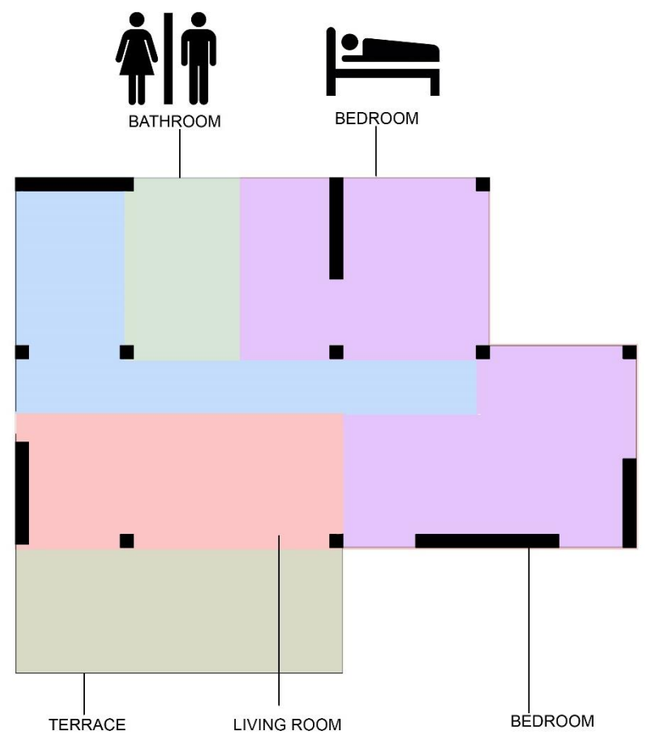
# DESIGN IDEA & 3D VIEWS

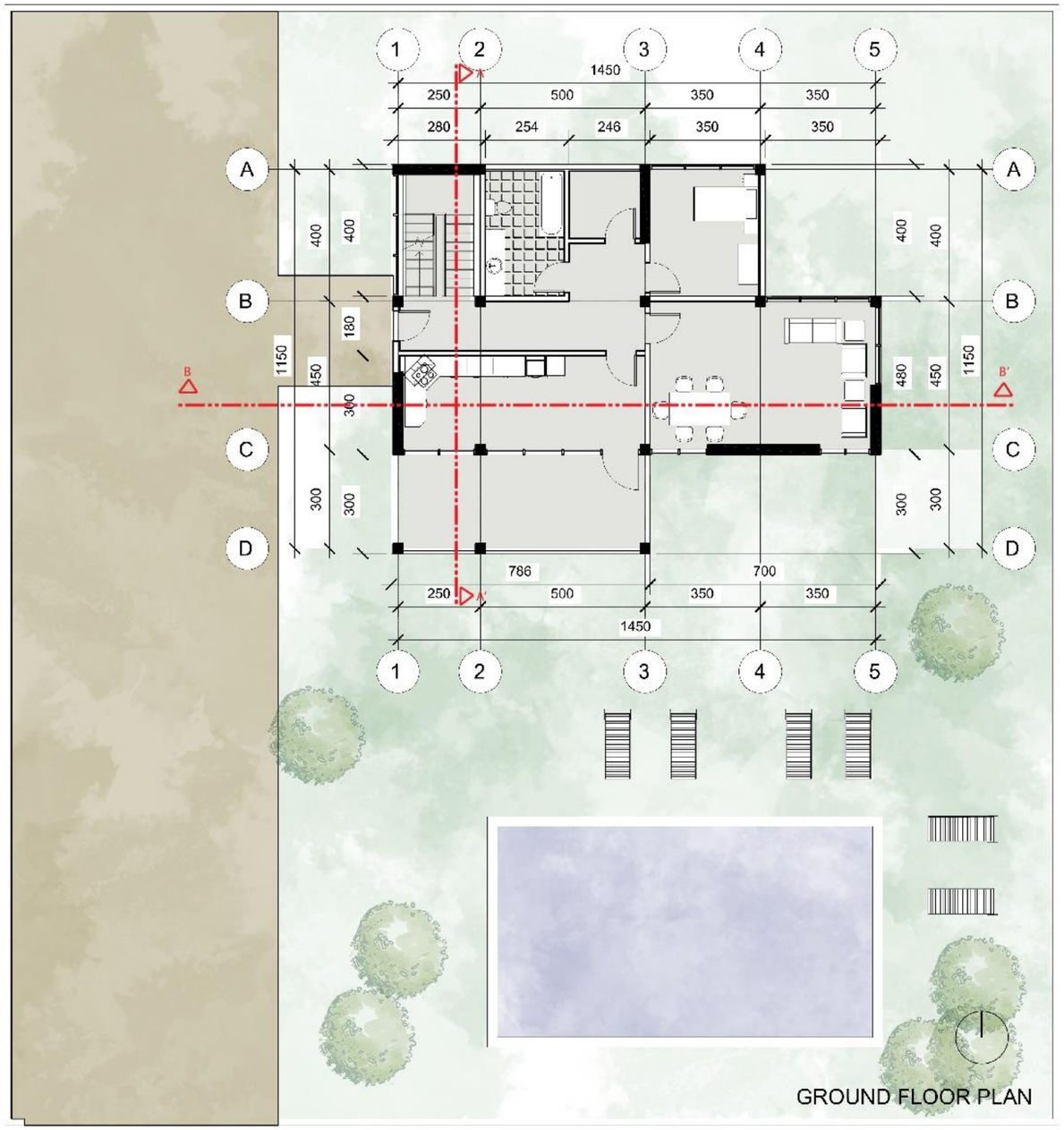



# 3D VIEWS

# PLANS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B'
786
700
250
A'
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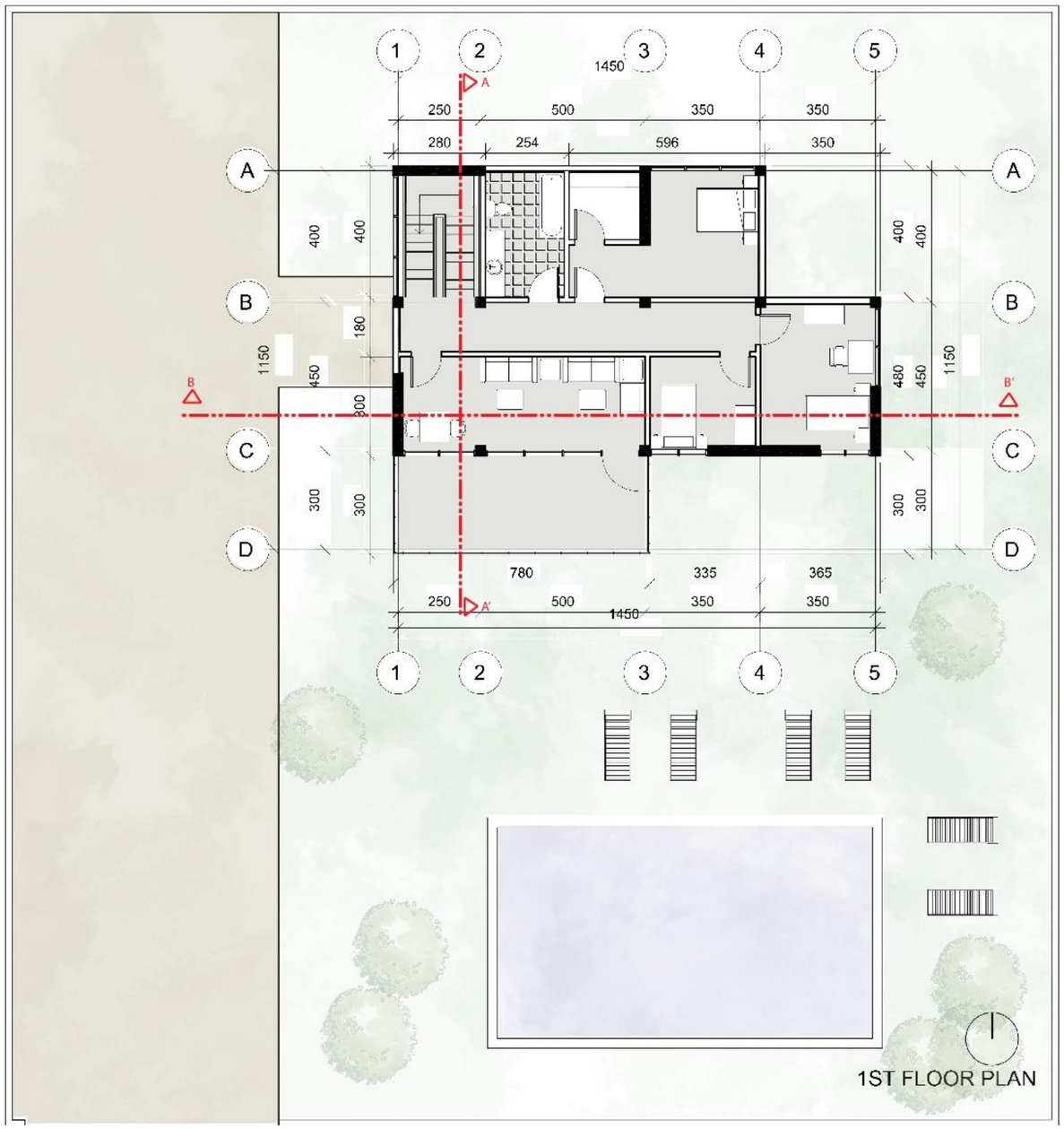
1450
GROUND FLOOR PLAN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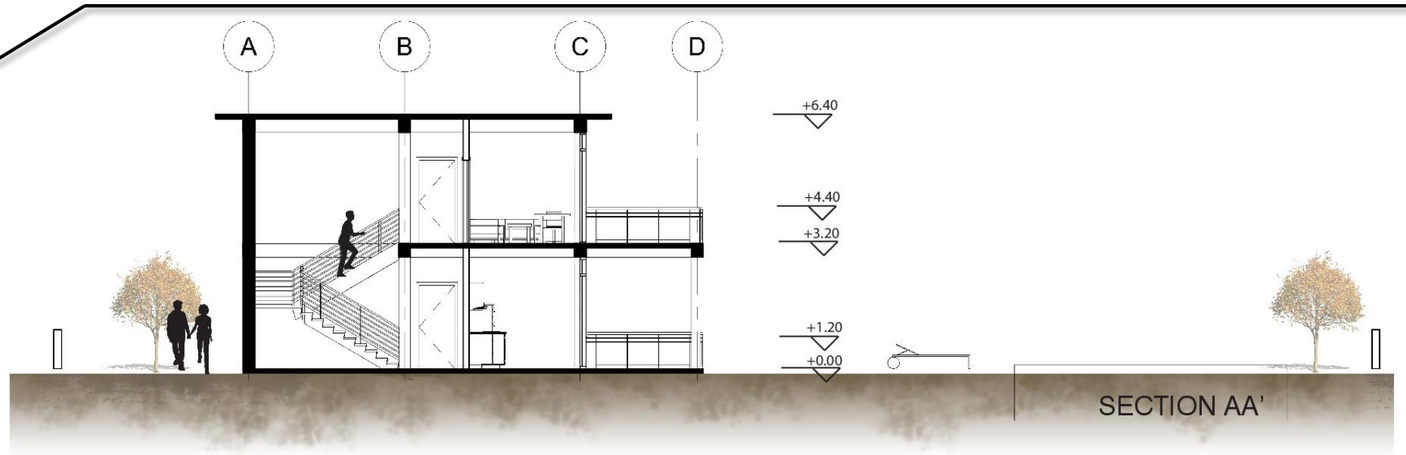
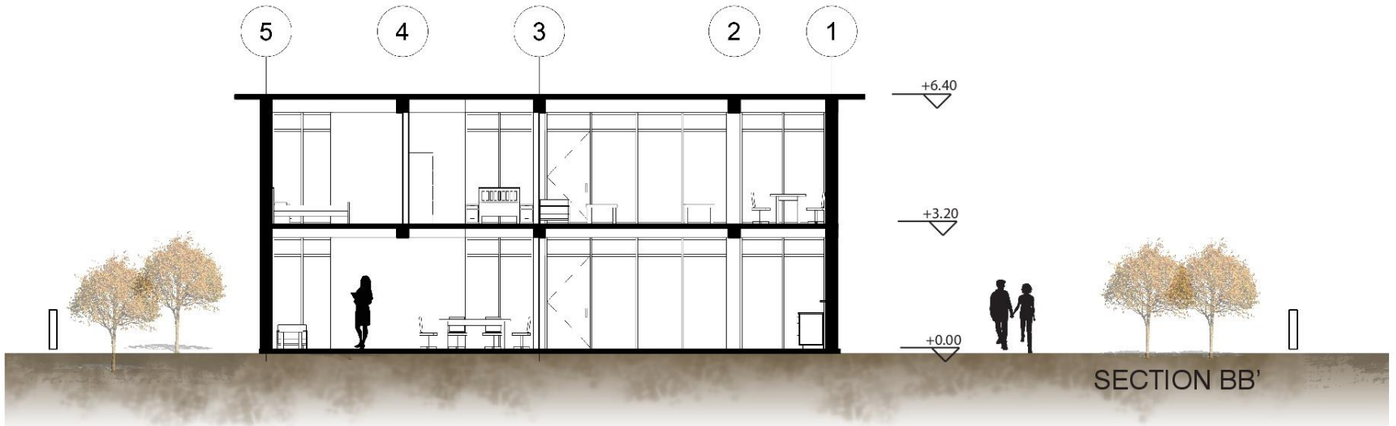
300
B
B'
780
335
365
250
A'
500
1450
350
350
1ST FLOOR PLAN

# ELEVATIONS & SECTIONS

SECTION B’B



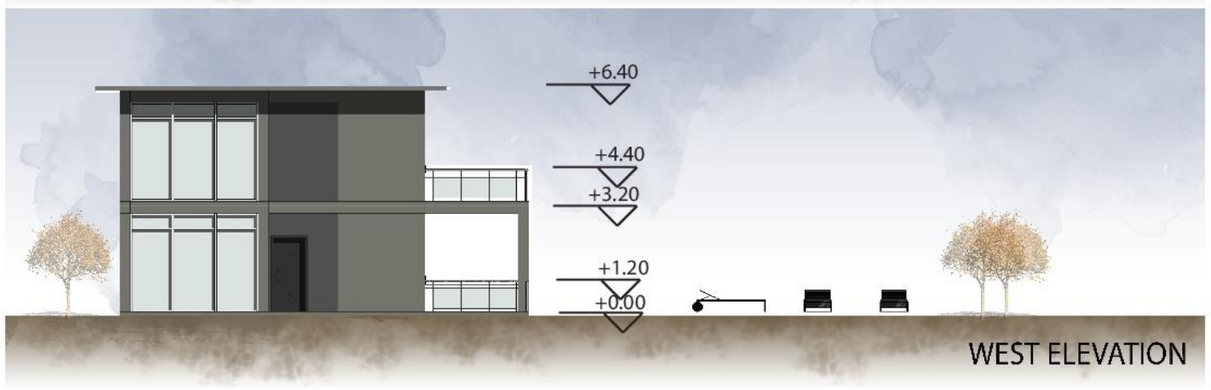

SECTION AA’




SECTION BB’


EAST ELEVATION

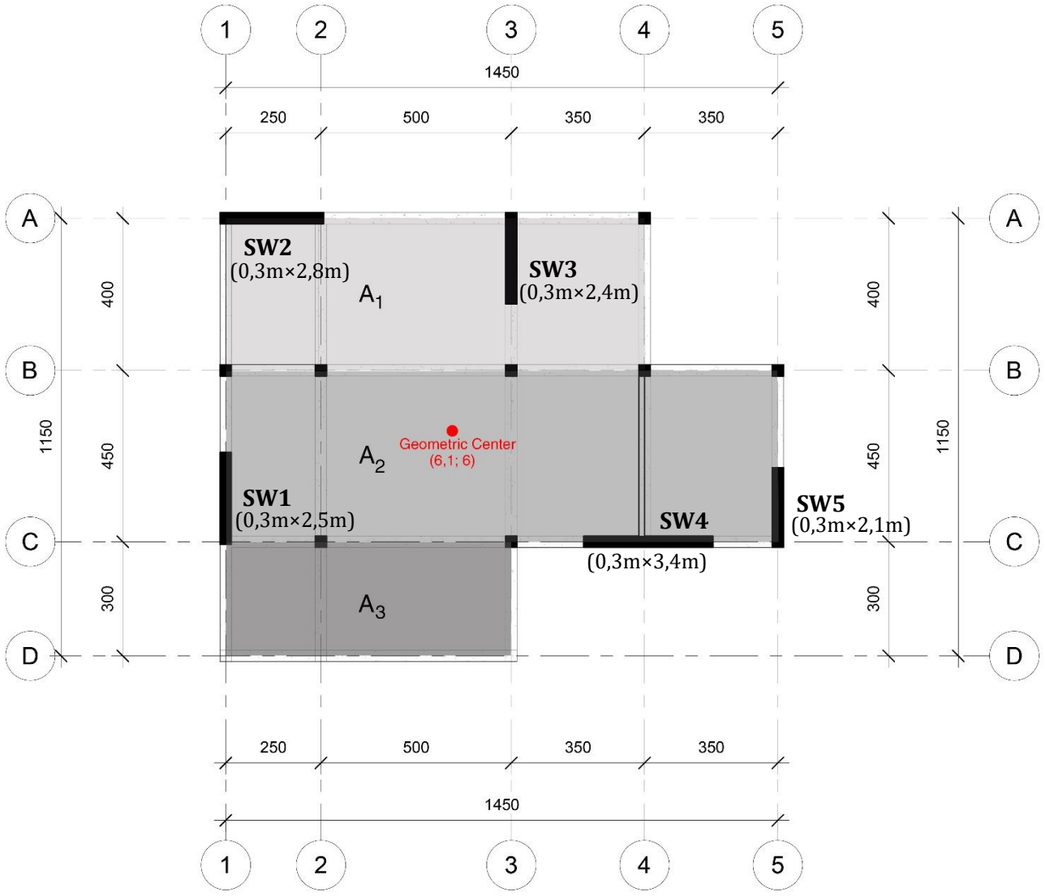

NORTH ELEVATION

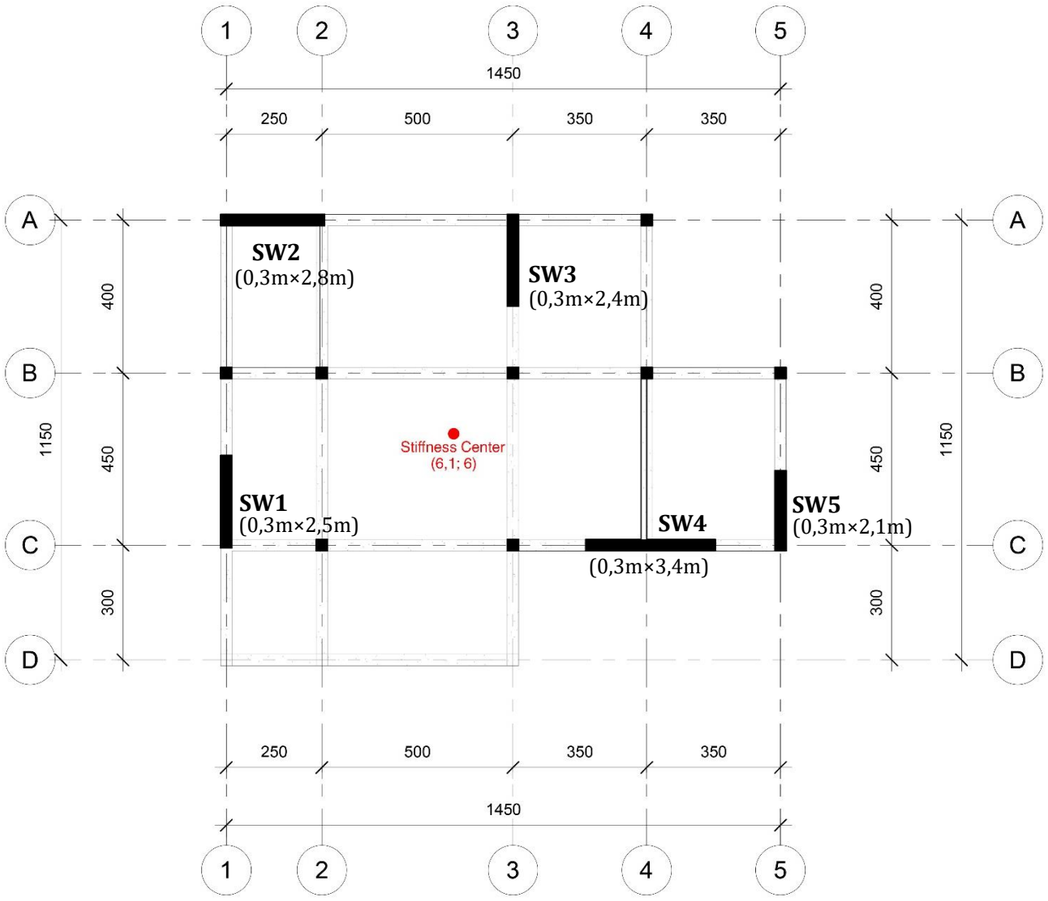



WEST ELEVATION


SOUTH ELEVATION

# STRUCTURAL SYSTEM




**Geometric Center** → $C_{GX}= \frac{\Sigma C_{ix} \times Ai}{\Sigma A_i}$ $C_{GY}= \frac{\Sigma C_{iy} \times Ai}{\Sigma A_i}$

$A_1= 11 \times 4 = 44\ m^2$

$A_2= 14{,}5 \times 4{,}5 = 65{,}25\ m^2$

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

$C_{GX}= \frac{(A_1 \times X_1)+(A_2 \times X_2)+(A_3 \times X_3)}{A_1+A_2+A_3}$ $C_{GY}= \frac{(A_1 \times Y_1)+(A_2 \times Y_2)+(A_3 \times Y_3)}{A_1+A_2+A_3}$

$C_{GX}= \frac{(44 \times 5{,}5)+(65{,}25 \times 7{,}25)+(22{,}5 \times 3{,}75)}{44+65{,}25+22{,}5}$ $C_{GY}= \frac{(44 \times 9{,}5)+(65{,}25 \times 5{,}25)+(22{,}5 \times 1{,}5)}{44+65{,}25+22{,}5}$

$C_{GX}= 6{,}1$ $C_{GY}= 6$

**Stiffness Center** → $I= \frac{1}{12} bh^3$

$I_1= \frac{1}{12} \times 0{,}3 \times (2{,}5)^3 = 0{,}39$ $I_2= \frac{1}{12} \times 0{,}3 \times (2{,}8)^3 = 0{,}55$ $I_3= \frac{1}{12} \times 0{,}3 \times (2{,}4)^3 = 0{,}34$

$I_4= \frac{1}{12} \times 0{,}3 \times (3{,}4)^3 = 0{,}98$ $I_5= \frac{1}{12} \times 0{,}3 \times (2{,}1)^3 = 0{,}23$

Shear walls on X axis : 1,3 and 5

$C_{SX}= \frac{(I_1 \times X_1)+(I_3 \times X_3)+(I_5 \times X_5)}{I_1+I_3+I_5}$

$C_{SX}= \frac{(0{,}39 \times 0)+(0{,}34 \times 7{,}5)+(0{,}23 \times 14{,}5)}{0{,}39+0{,}34+0{,}23}$

$C_{SX}= 6{,}1$

Shear walls on Y axis : 2 and 4

$C_{SY}= \frac{(I_2 \times Y_2)+(I_4 \times Y_4)}{I_2+I_4}$

$C_{SY}= \frac{(0{,}55 \times 11{,}5)+(0{,}98 \times 3)}{0{,}55+0{,}98}$

$C_{SY}= 6$

Geometric Center $(G_X,G_Y)=(6{,}1;6)$ ⟷ Stiffness Center $(S_X,S_Y)=(6{,}1;6)$

Geometric center and stiffness center are coincided.

# STRUCTURAL SYSTEM

## Shear Wall Percentage

Total Floor Area : 131,75 $m^2$

Area of Shear Walls on X Direction

SW2=0,3×2,8=0,84

SW4=0,3×3,4=1,02

The Ratio of Shear Wall Area on X Direction to Floor Area

$$\frac{0,84 + 1,02}{131,75} \times 100 = 1,41\%$$

$1,41\% > 1\%$

Area of Shear Walls on Y Direction

SW1=0,3×2,5=0,75

SW3=0,3×2,4=0,72

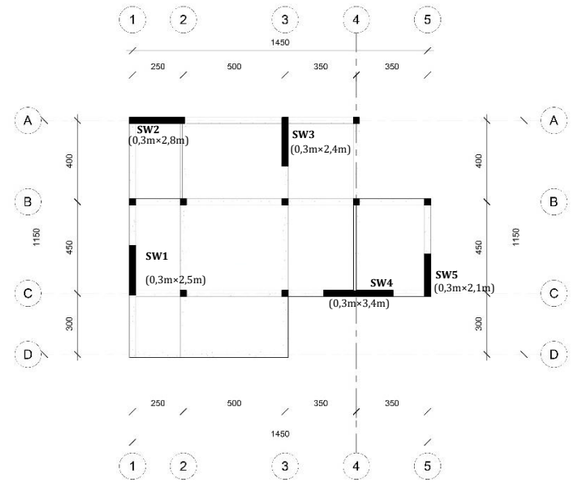
SW5=0,3×2,1=0,63

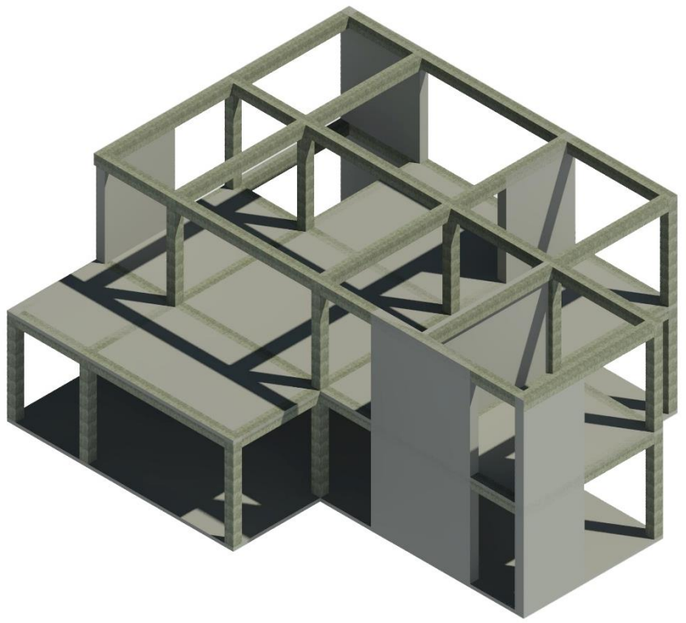
The Ratio of Shear Wall Area on Y Direction to Floor Area

$$\frac{0,75 + 0,72 + 0,63}{131,75} \times 100 = 1,59\%$$

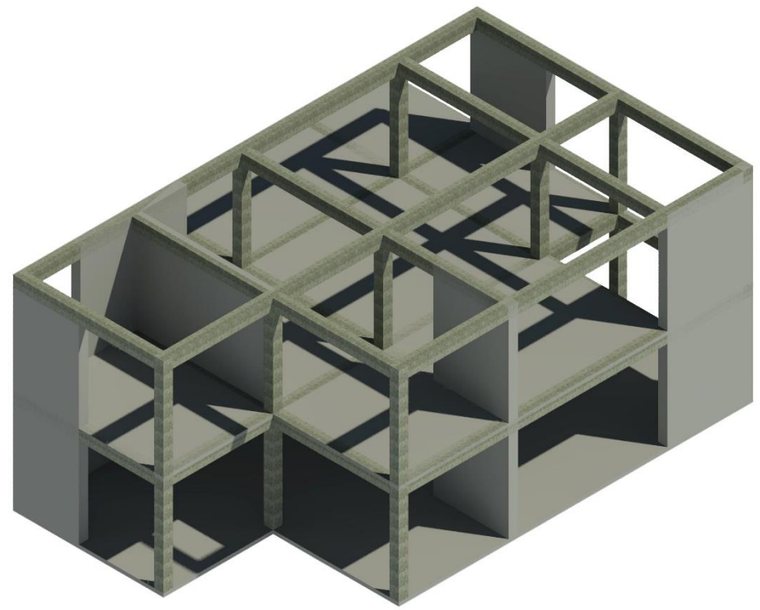
$1,59\% > 1\%$

Shear wall percentage is within acceptable range.

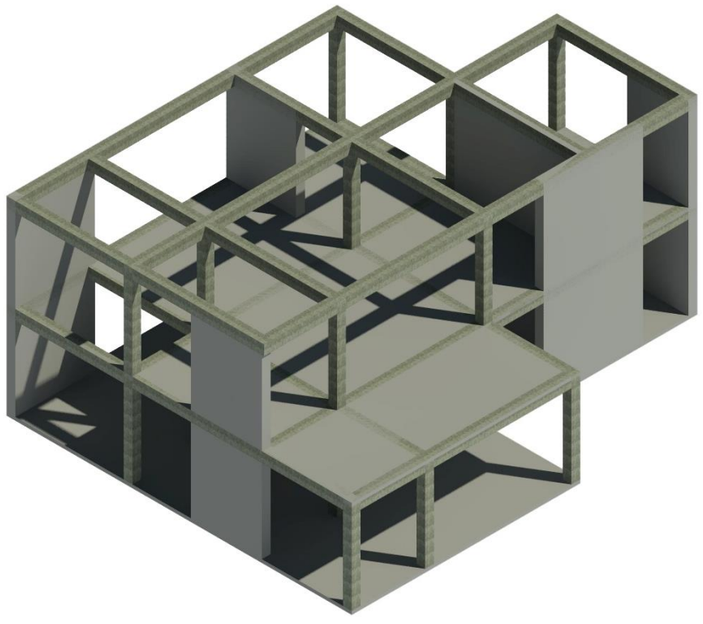


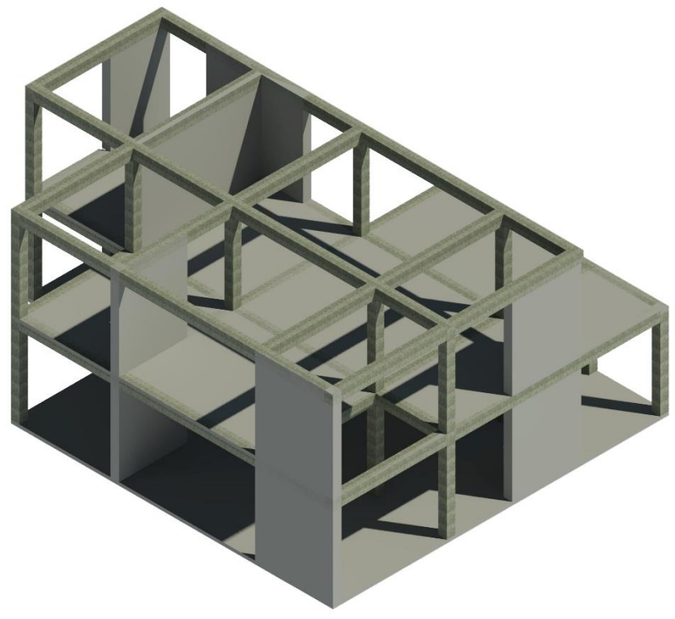
Southeast



Northeast

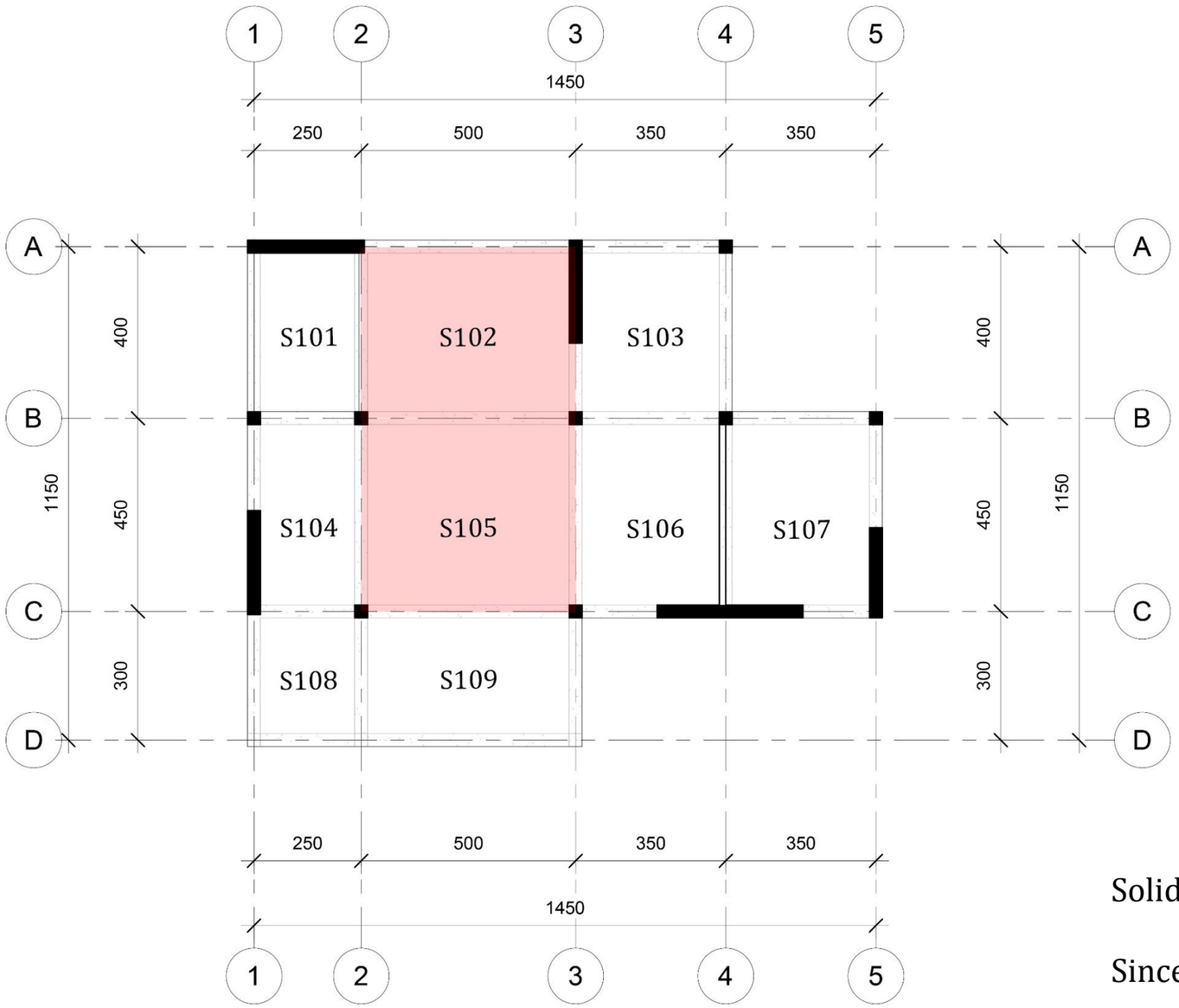


Southwest



Northwest

# SLAB SYSTEM




Solid Slab with Beams Thickness

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

$$t\geq\frac{l_s}{15+\frac{20}{\frac{l_l}{l_s}}}\times\left(1-\frac{\alpha}{4}\right)$$

Most critical ones—> S102 and S105

$\alpha_{S102}=\frac{4+5+4}{4+5+4+5}=0,72$ $\quad t_{S102}=\frac{4}{15+\frac{20}{\frac{5}{4}}}\times\left(1-\frac{0,72}{4}\right)=10,5$ cm

$\alpha_{S105}=\frac{4,5+5+4,5+5}{4,5+5+4,5+5}=1$ $\quad t_{S105}=\frac{4,5}{15+\frac{20}{\frac{5}{4,5}}}\times\left(1-\frac{1}{4}\right)=10,2$ cm

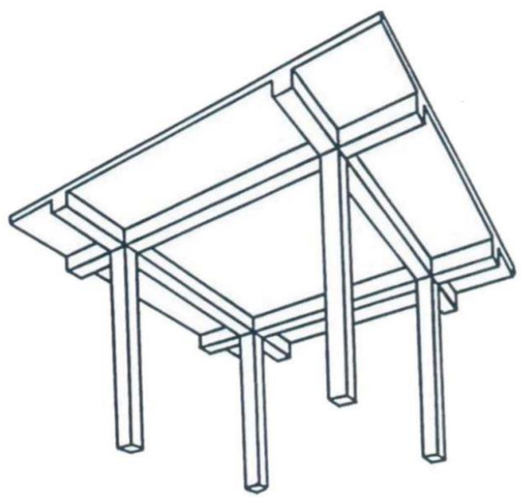
Slab thickness≥most critical slab thickness $\quad t\geq 8$ cm

Since the thickness of most critical slab is 10,5 cm

**Slab thickness=11 cm**

Solid slab with beams is selected.

Since $\frac{l_l}{l_s}\leq 2$ , two way solid slab system should be used.



# COLUMN DIMENSION

Dead Load of Slab
Own Weight : 0,11×2,4=0,26 t/m²
Levelling : 0,04×2,4=0,096 t/m²
Covering : 0,025×2=0,05 t/m²
\+ Plastering : 0,02×2=0,04 t/m²

Dead load for slabs = 0.45 t/m²

Live load for slabs = 0.2 t/m² (for residential buildings)

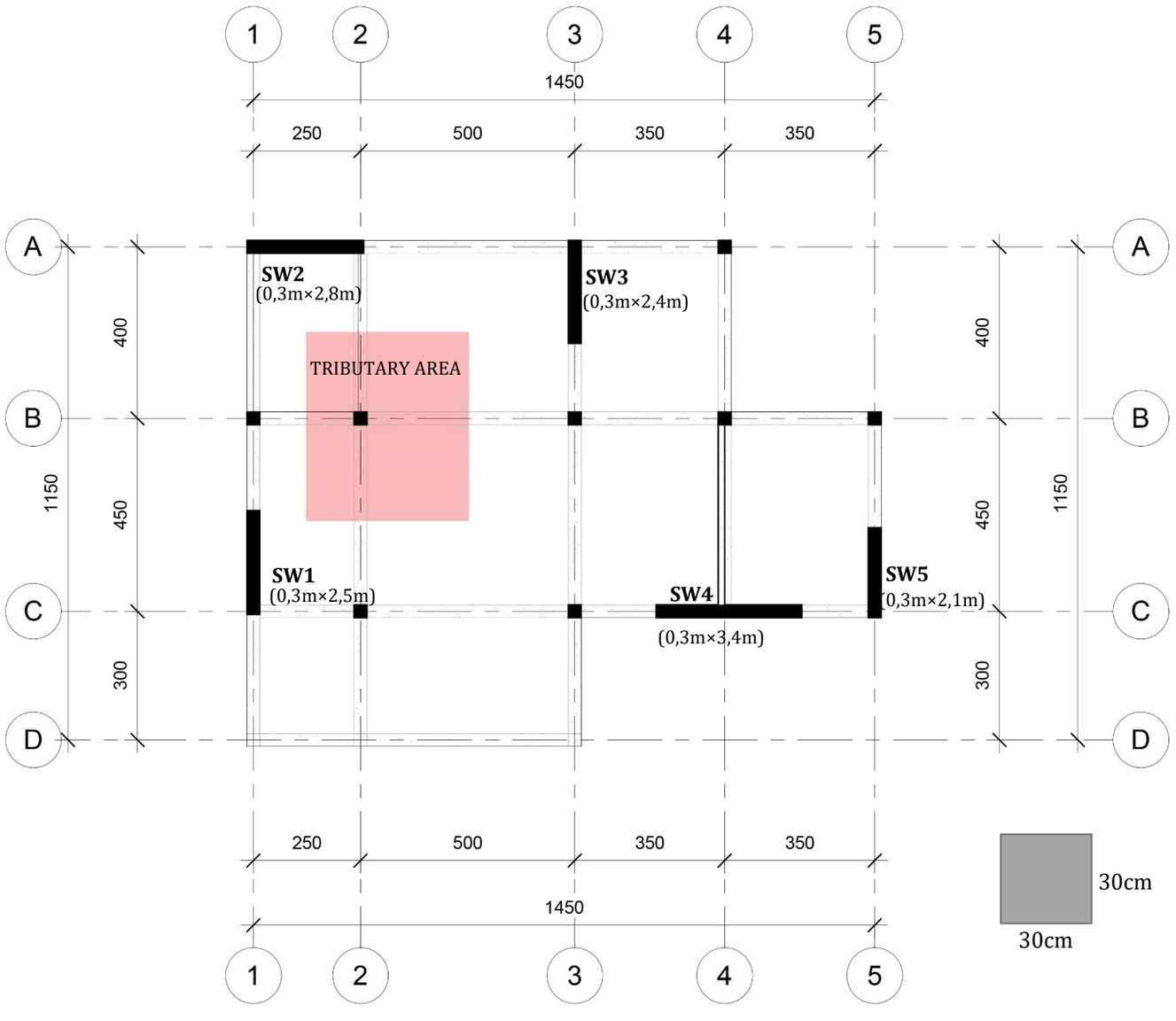
Total Load = (1,4×Dead Load)+(1,6×Live Load)

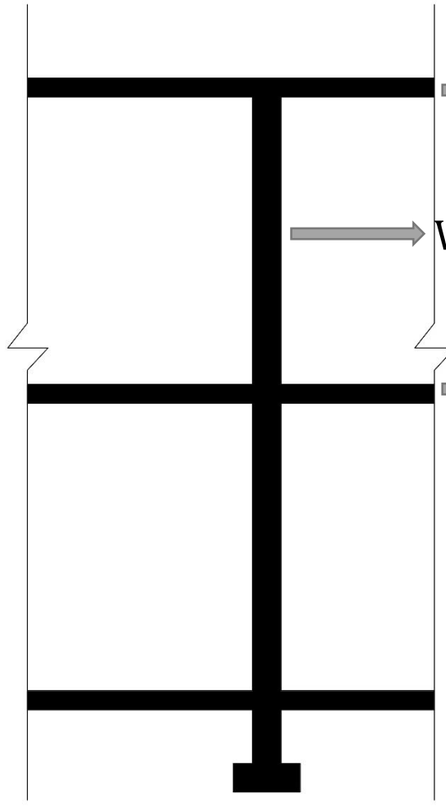
Total Load = (1,4×0,45)+(1,6×0,2)=0,95 t/m²

Tributary Area=3,75×4,25=15,93 m²

Wall Load=Tributary Area×0,15×1,4

Slab Load:Slab Area×0.95



Slab Load=15,93×0,95=15,133 t

Wall Load=(15,93)×0,15×1,4=3,345 t

Slab Load=15,93×0,95=15,133 t

\+

Total Load=33,611 t

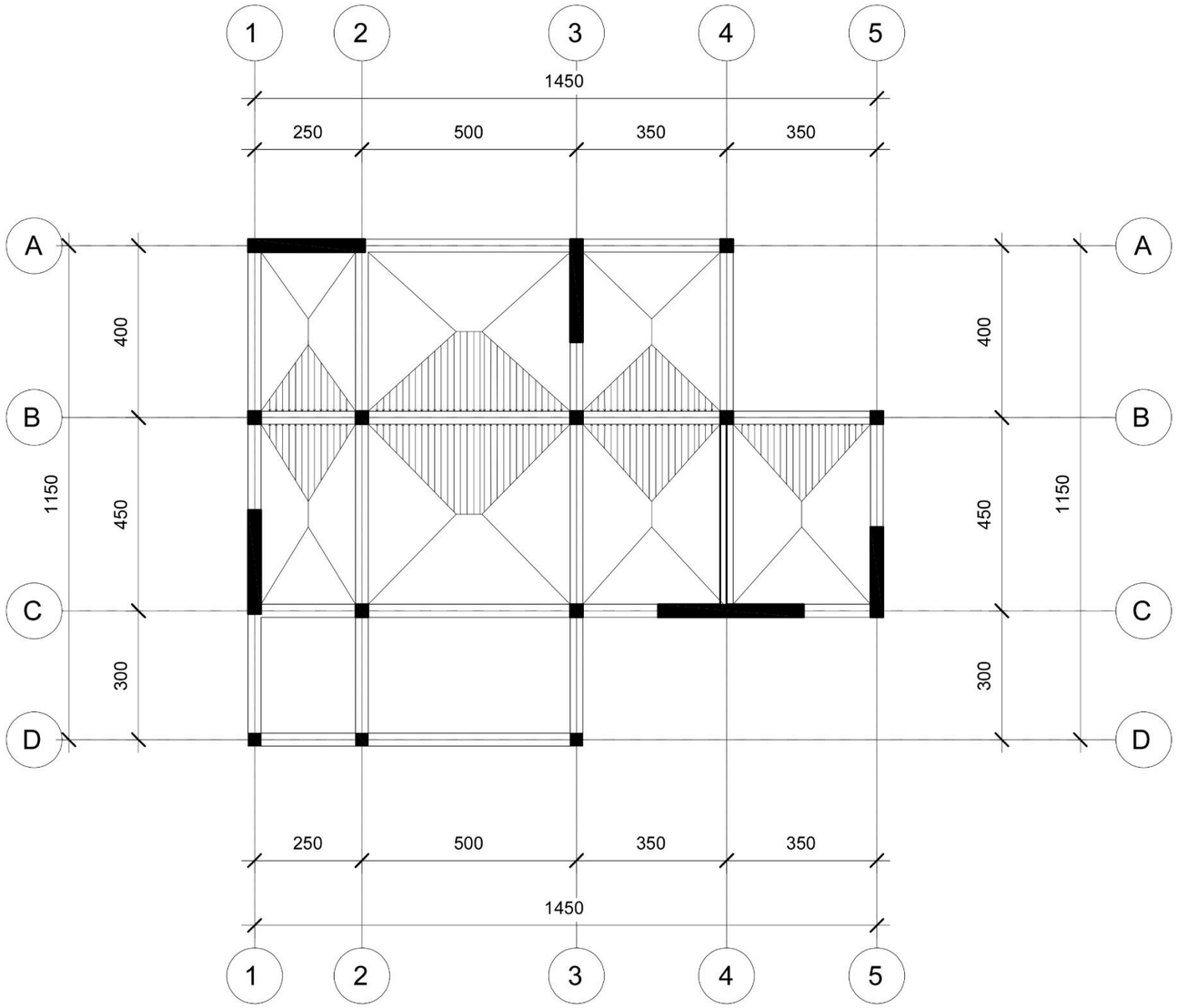
*To be on safe side,door openings are neglected.

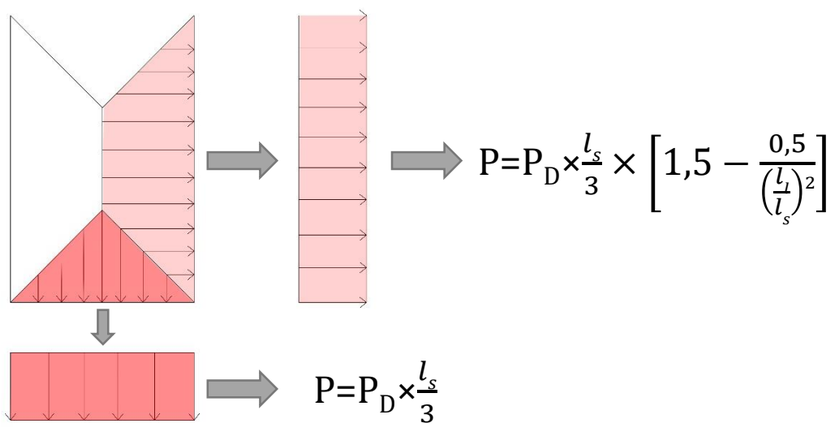
$A_C \geq \frac{N_D}{0,4 \times fck}$ $A_C \geq \frac{33611}{0,4 \times 200}$

$A_C \geq 420\ cm^2$ but $A_C$ should be bigger than $900\ cm^2$

Therefore, the column dimensions are 30cm×30cm according to TS-500

# BEAM ANALYSIS



$P=P_D\times\frac{l_s}{3}\times\left[1,5-\frac{0,5}{\left(\frac{l_l}{l_s}\right)^2}\right]$

$P=P_D\times\frac{l_s}{3}$

For beam analysis, the beam on axis B is selected since there is no shear wall and it is the longest span.

$P_D=(1,4\times\text{Dead Load})+(1,6\times\text{Live Load})$

$P_D=(1,4\times0,45)+(1,6\times0,2)=0,95\ t/m^2$

## Loads on B 1-2

$P_1=P_2=P_D\times\frac{l_s}{3}=0,95\times\frac{2,5}{3}=0,79\ t/m$

$P_1+P_2=0,79\times2=1,58\ t/m$

## Loads on B 2-3

$P_3=P_D\times\frac{l_s}{3}\times\left[1,5-\frac{0,5}{\left(\frac{l_l}{l_s}\right)^2}\right]=0,95\times\frac{4}{3}\times\left[1,5-\frac{0,5}{\left(\frac{5}{4}\right)^2}\right]=1,49\ t/m$

$P_4=P_D\times\frac{l_s}{3}\times\left[1,5-\frac{0,5}{\left(\frac{l_l}{l_s}\right)^2}\right]=0,95\times\frac{4,5}{3}\times\left[1,5-\frac{0,5}{\left(\frac{5}{4,5}\right)^2}\right]=1,56\ t/m$

$P_3+P_4=1,49+1,56=3,05\ t/m$

## Loads on B 3-4

$P_5=P_6=P_D\times\frac{l_s}{3}=0,95\times\frac{3,5}{3}=1.11\ t/m$

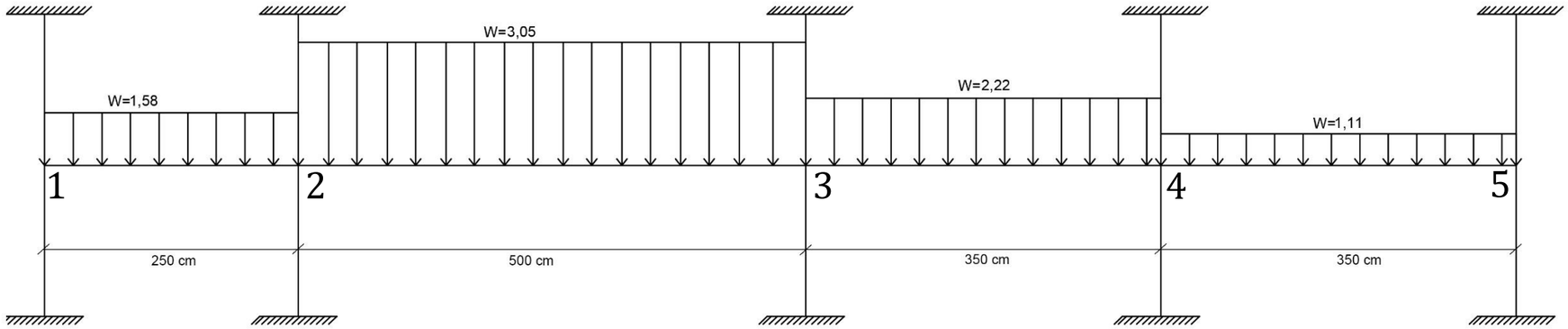
$P_5+P_6=1,11\times2=2,22\ t/m$

## Loads on B 4-5

$P_7=P_D\times\frac{l_s}{3}=0,95\times\frac{3,5}{3}=1.11\ t/m$

*The own weight of beam is neglected.

# BEAM ANALYSIS




## Moment of Inertia

$$I=\frac{1}{12}bh^3$$

Assumed beam depth = 0,5 m

$$I_{beam}=\frac{1}{12}bh^3=\frac{1}{12}\times 0{,}3\times(0{,}5)^3=0{,}003125\ m^4$$

$$I_{column}=\frac{1}{12}bh^3=\frac{1}{12}\times 0{,}3\times(0{,}3)^3=0{,}000675\ m^4$$

## Distribution Factors

$$r_{AB}=\frac{\left(\frac{I}{L}\right)_{AB}}{\Sigma\left(\frac{I}{L}\right)}$$

$$r_{12}=\frac{\frac{0{,}003125}{2{,}5}}{\frac{0{,}003125}{2{,}5}+\left(2\times\frac{0{,}000675}{3{,}2}\right)}=0{,}75$$

$$r_{21}=\frac{\frac{0{,}003125}{2{,}5}}{\frac{0{,}003125}{2{,}5}+\left(2\times\frac{0{,}000675}{3{,}2}\right)+\frac{0{,}003125}{5}}=0{,}55$$

$$r_{23}=\frac{\frac{0{,}003125}{5}}{\frac{0{,}003125}{2{,}5}+\left(2\times\frac{0{,}000675}{3{,}2}\right)+\frac{0{,}003125}{5}}=0{,}27$$

$$r_{32}=\frac{\frac{0{,}003125}{5}}{\frac{0{,}003125}{3{,}5}+\left(2\times\frac{0{,}000675}{3{,}2}\right)+\frac{0{,}003125}{5}}=0{,}32$$

$$r_{34}=\frac{\frac{0{,}003125}{3{,}5}}{\frac{0{,}003125}{3{,}5}+\left(2\times\frac{0{,}000675}{3{,}2}\right)+\frac{0{,}003125}{5}}=0{,}46$$

$$r_{43}=\frac{\frac{0{,}003125}{3{,}5}}{\frac{0{,}003125}{3{,}5}+\left(2\times\frac{0{,}000675}{3{,}2}\right)+\frac{0{,}003125}{3{,}5}}=0{,}4$$

$$r_{45}=\frac{\frac{0{,}003125}{3{,}5}}{\frac{0{,}003125}{3{,}5}+\left(2\times\frac{0{,}000675}{3{,}2}\right)+\frac{0{,}003125}{3{,}5}}=0{,}4$$

$$r_{54}=\frac{\frac{0{,}003125}{3{,}5}}{\frac{0{,}003125}{3{,}5}+\left(2\times\frac{0{,}000675}{3{,}2}\right)}=0{,}68$$

## FEM

$$FEM=\frac{qL^2}{12}$$

$$M_{midspan}=\frac{qL^2}{24}$$

$$FEM_{12}=\frac{1{,}58\times(2{,}5)^2}{12}=0{,}82\ tm$$

$$M_{midspan12}=\frac{1{,}58\times(2{,}5)^2}{24}=0{,}41\ tm$$

$$FEM_{23}=\frac{3{,}05\times(5)^2}{12}=6{,}35\ tm$$

$$M_{midspan23}=\frac{3{,}05\times(5)^2}{24}=3{,}18\ tm$$

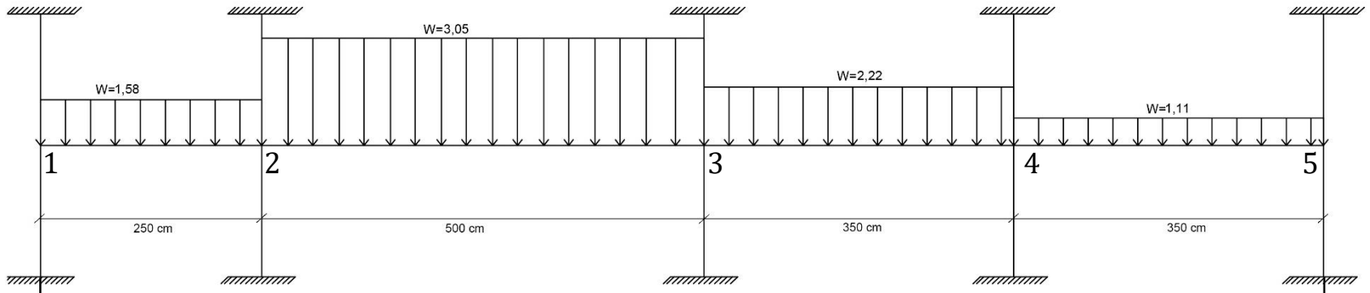
$$FEM_{34}=\frac{2{,}22\times(3{,}5)^2}{12}=2{,}26\ tm$$

$$M_{midspan34}=\frac{2{,}22\times(3{,}5)^2}{24}=1{,}13\ tm$$

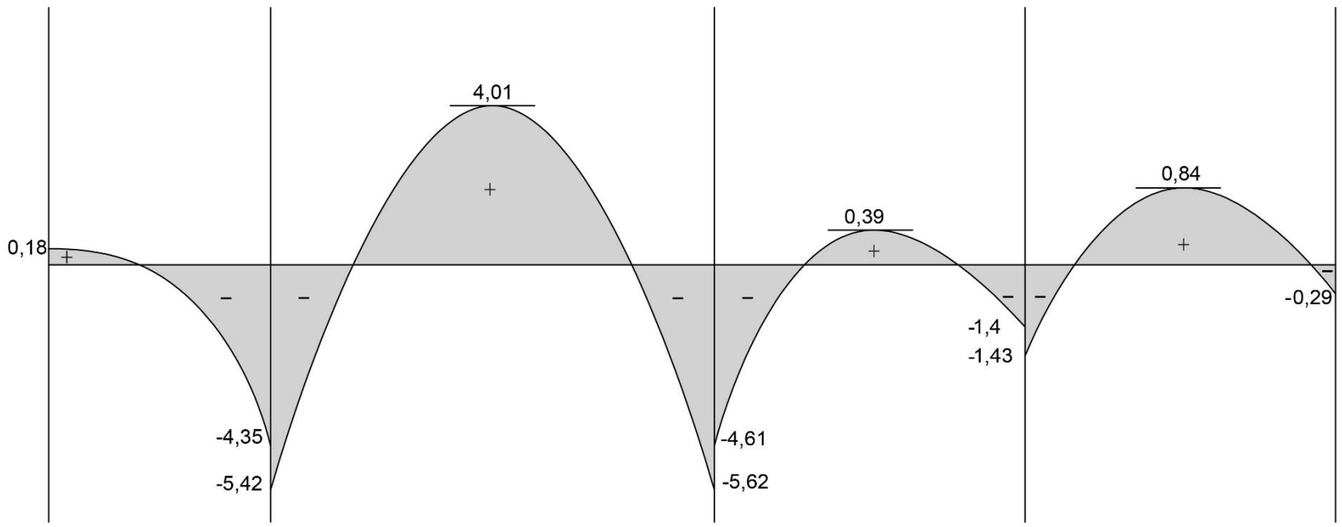
$$FEM_{45}=\frac{1{,}11\times(3{,}5)^2}{12}=1{,}13\ tm$$

$$M_{midspan45}=\frac{1{,}11\times(3{,}5)^2}{24}=0{,}57\ tm$$

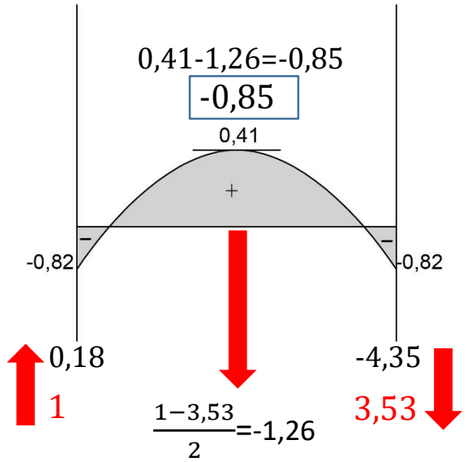
# BEAM ANALYSIS



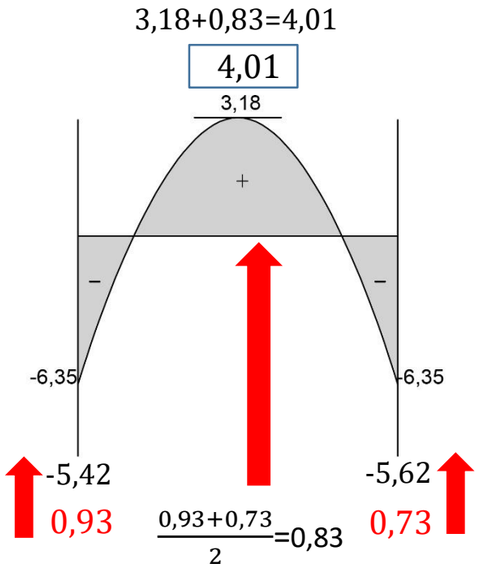

| + | 0.75 | 0,55 | 0,27 | 0,32 | 0,46 | 0,4 | 0,4 | 0,68 |
|---|---|---|---|---|---|---|---|---|
| FEM | 0,82 | -0,82 | 6,35 | -6,35 | 2,26 | -2,26 | 1,13 | -1,13 |
| 1st Cycle | -1,52 | -0,3 | 0,65 | -0,75 | 0,23 | 0,94 | 0,38 | 0,23 |
| Σ | -0,7 | -1,12 | 7 | -7,1 | 2,49 | -1,32 | 1,51 | -0,9 |
| 2nd Cycle | 0,52 | -3,23 | -1,58 | 1,48 | 2,12 | -0,08 | -0,08 | 0,61 |
| Σ | -0,18 | -4,35 | 5,42 | -5,62 | 4,61 | -1,4 | 1,43 | -0,29 |



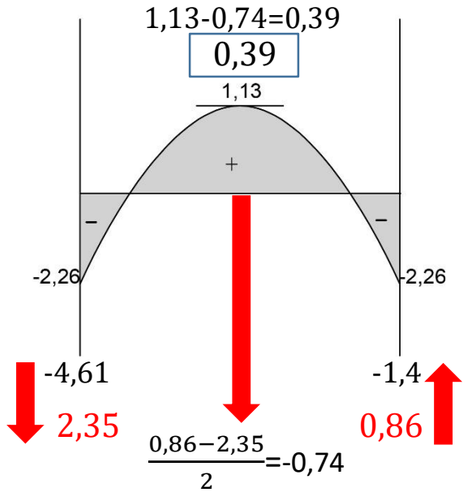

## Span 1-2



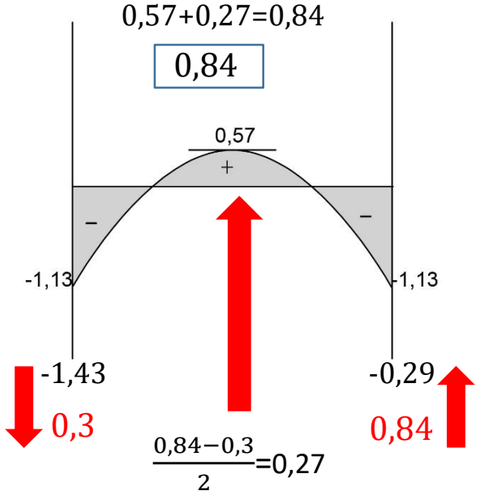

## Span 2-3




## Span 3-4




## Span 4-5




## Beam Depth

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

$K_0$=25 cm²/t

$M_{max}$= 5,62 tm

$$25=\frac{30\times d^2}{562} \longrightarrow$$

d=21,6 cm  Clear cover=5 cm

Beam depth=21.6+5=26,6 cm

However, beam depth>3×slab thickness=33 cm

To be on the safe side

**Beam depth = 35 cm**

# 3D VIEWS