STRUCTURAL DESIGN IN ARCHITECTURE II

House Project in Ümitköy

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‘Simplicity is the ultimate sophistication.’
Leonardo Da Vinci

CONCEPT DIAGRAM

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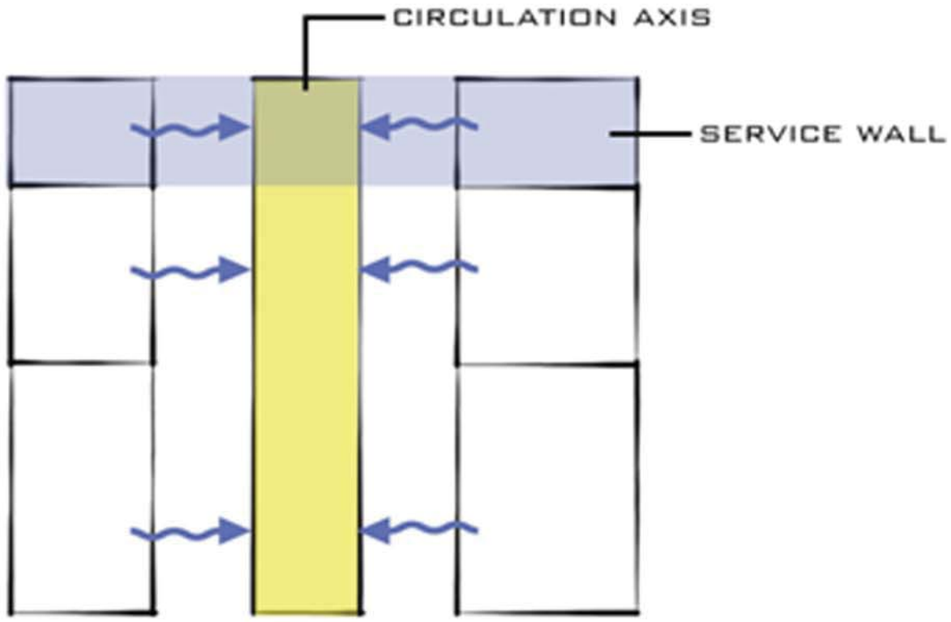
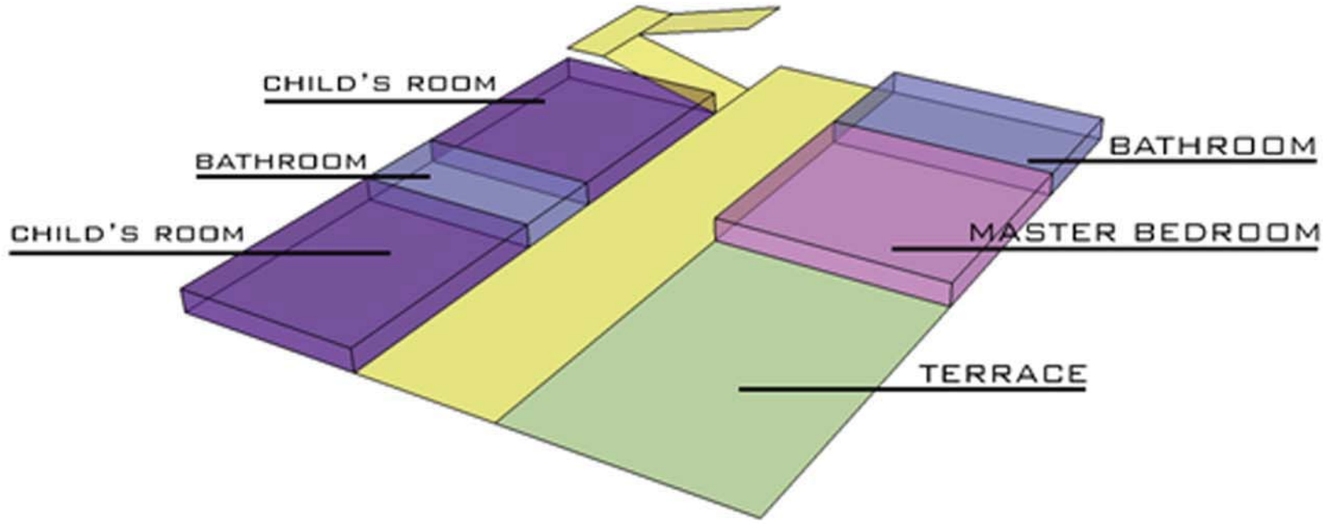
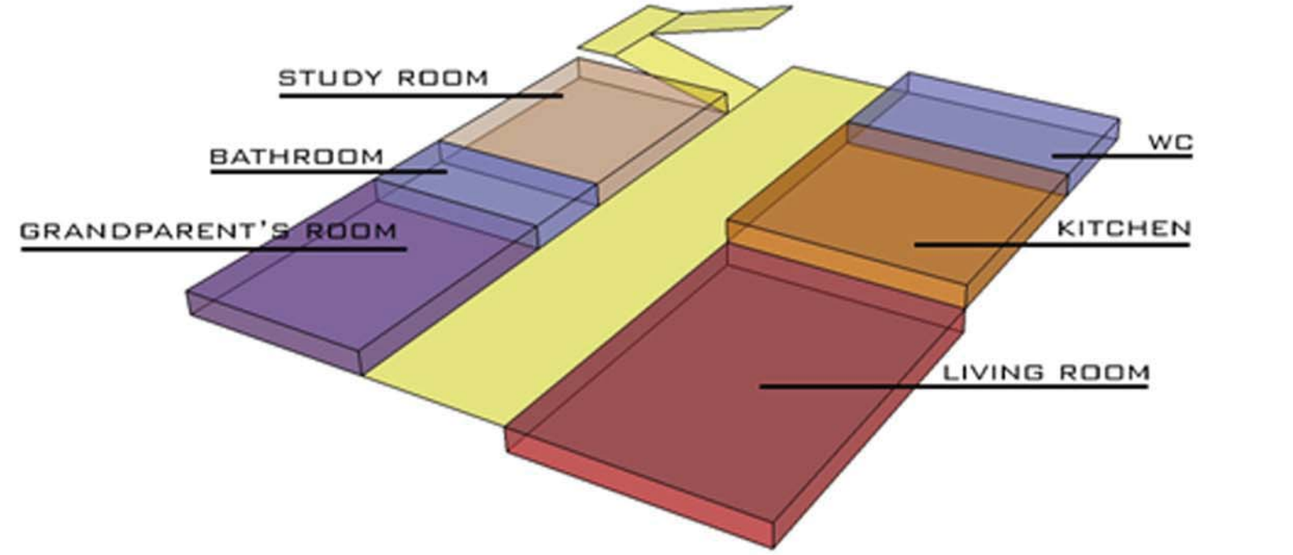


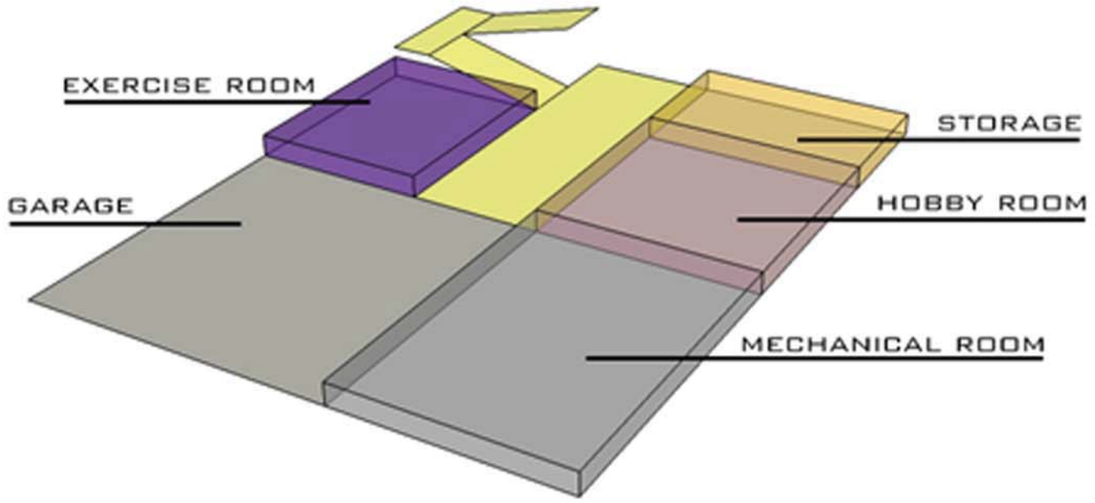
A circulation axis carrying the southern light to inner parts of the house was created and all the other volumes were plugged to that axis.

Service functions which need least light was gathered on a service wall located on the northern edge of the house, this move also created a buffer zone between living spaces and the main road.

To give more privacy to grandparent's room, a level difference between that room and the living room was created.







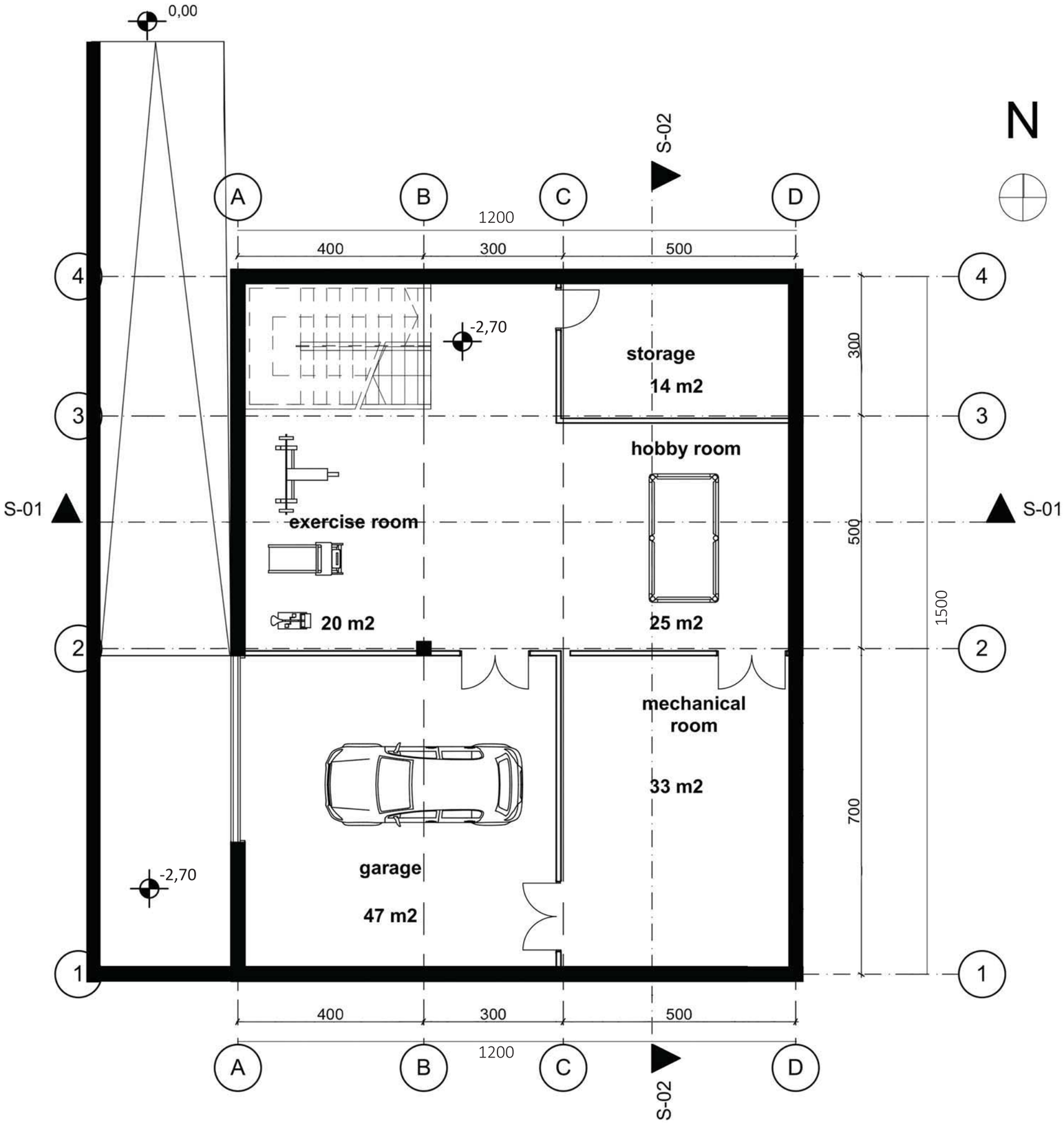
SITE PLAN

SITE PLAN

N

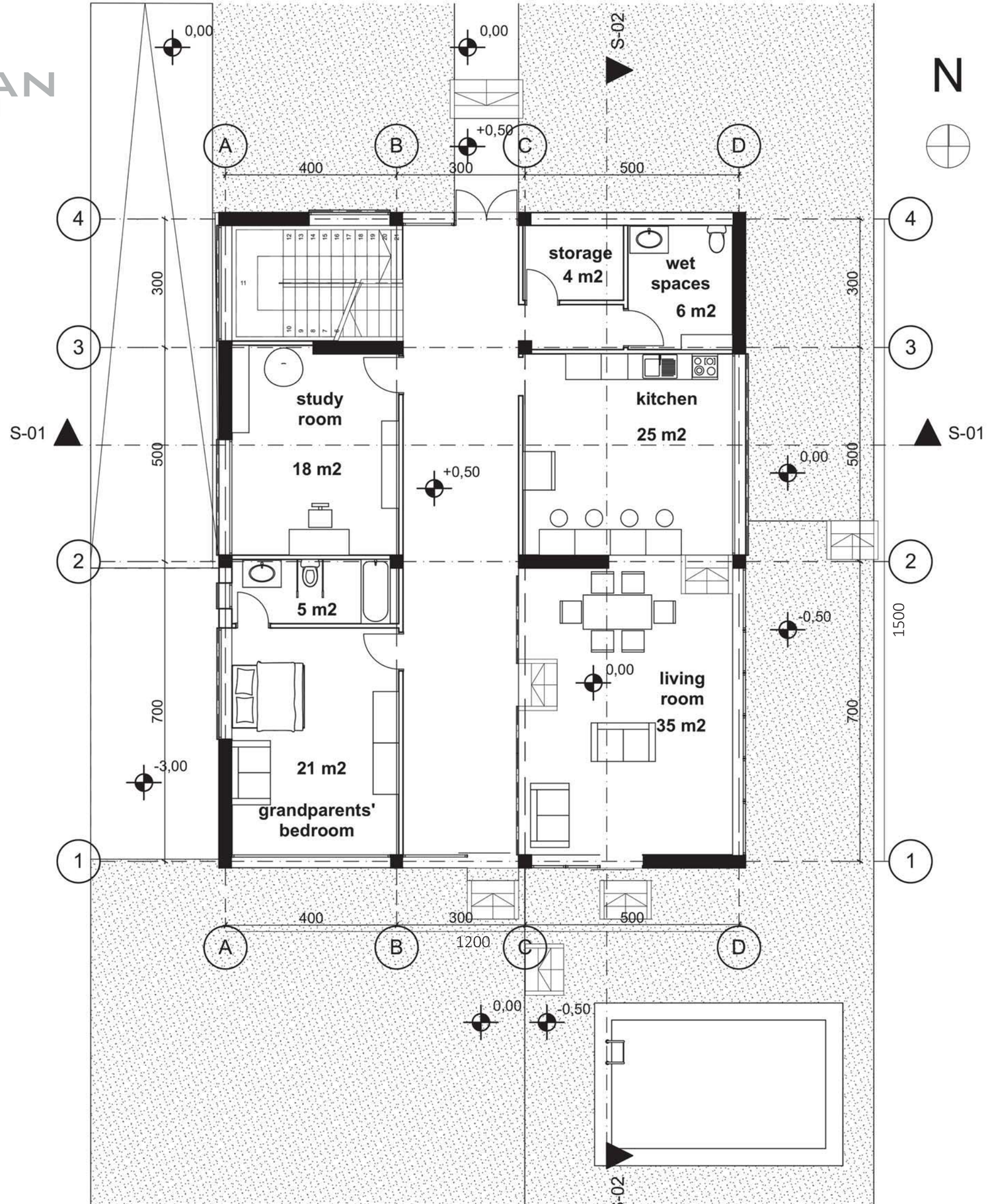
-2,70 PLAN

-2,70 PLAN



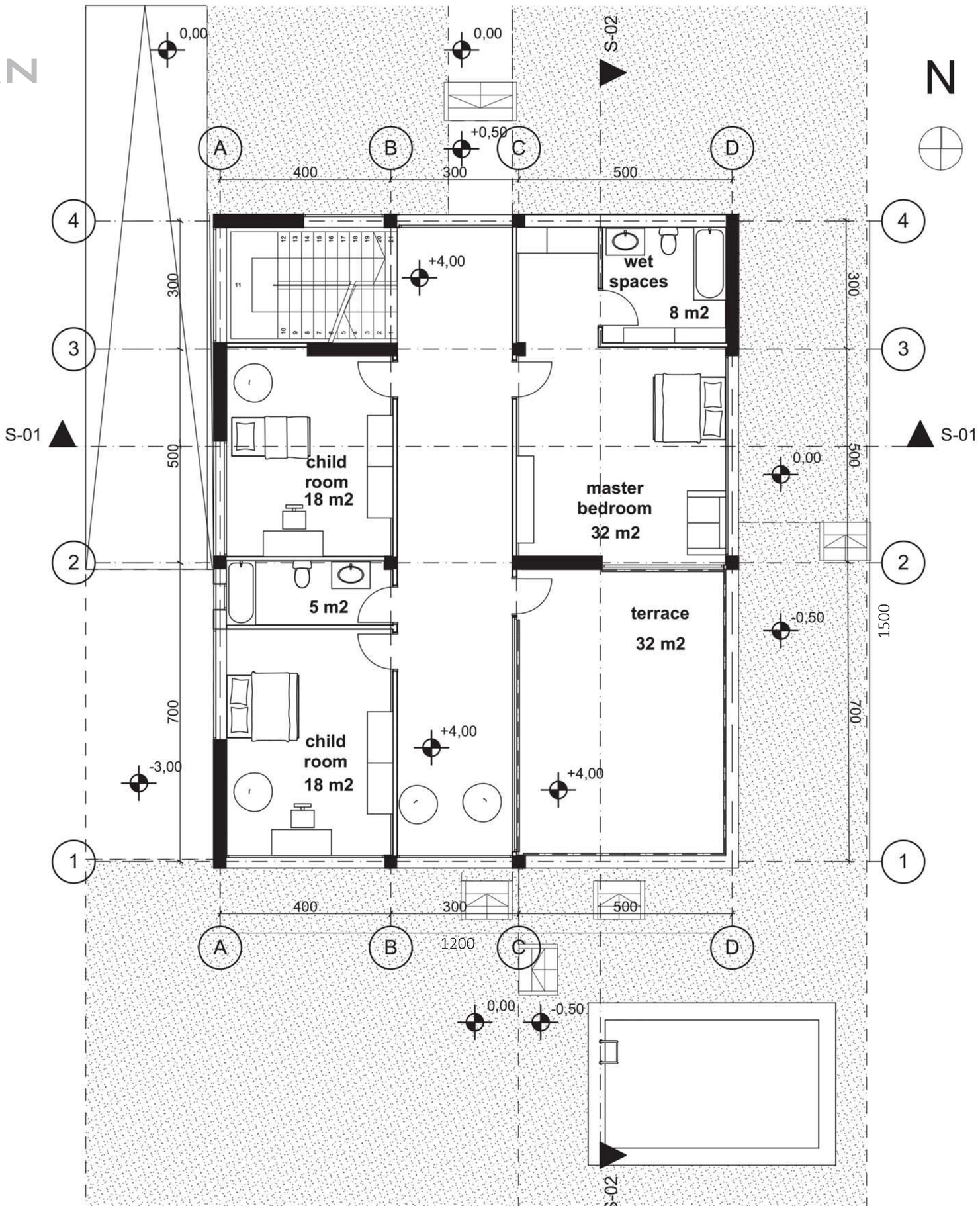
+0,50 PLAN

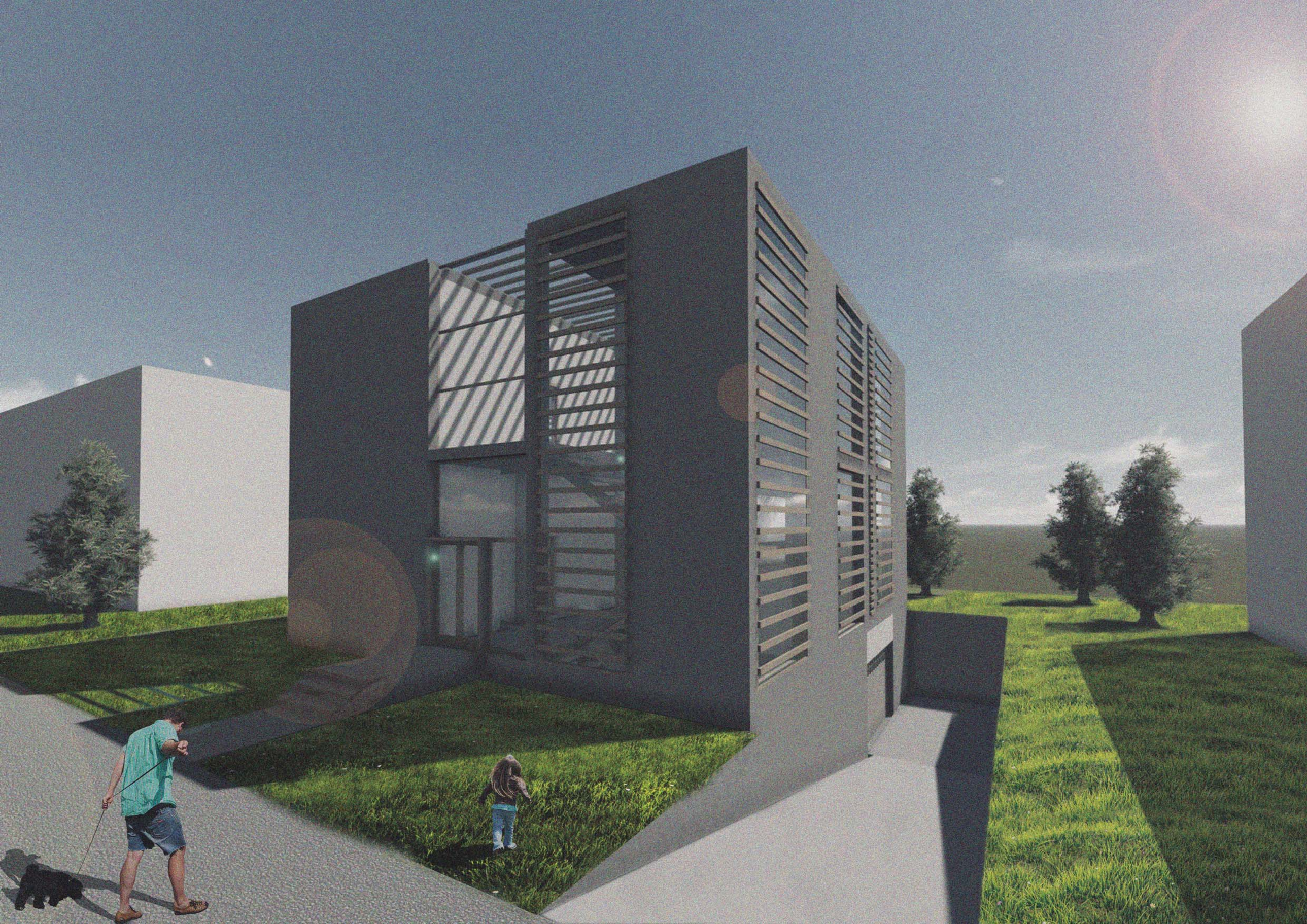
+0,50 PLAN



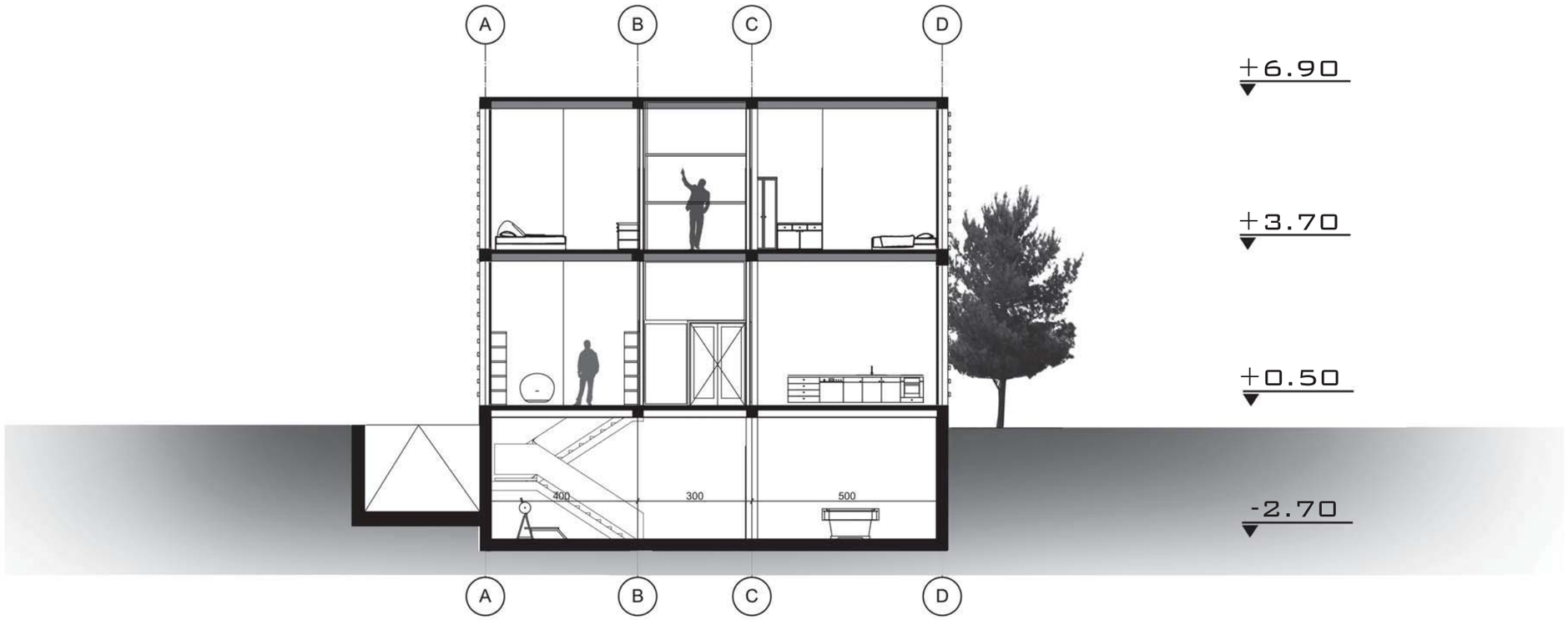
+3,70 PLAN

+3,70 PLAN

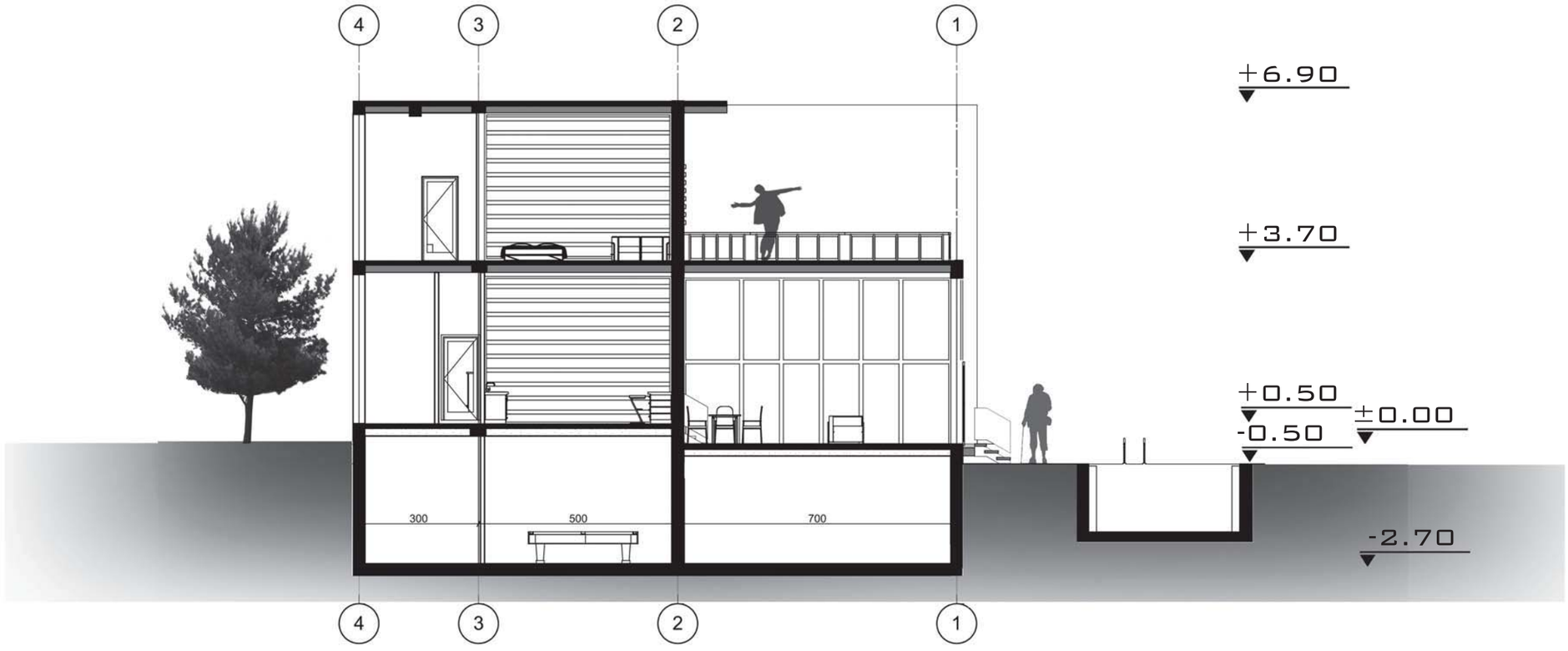




SECTION 01



SECTION 02



NORTH ELEVATION

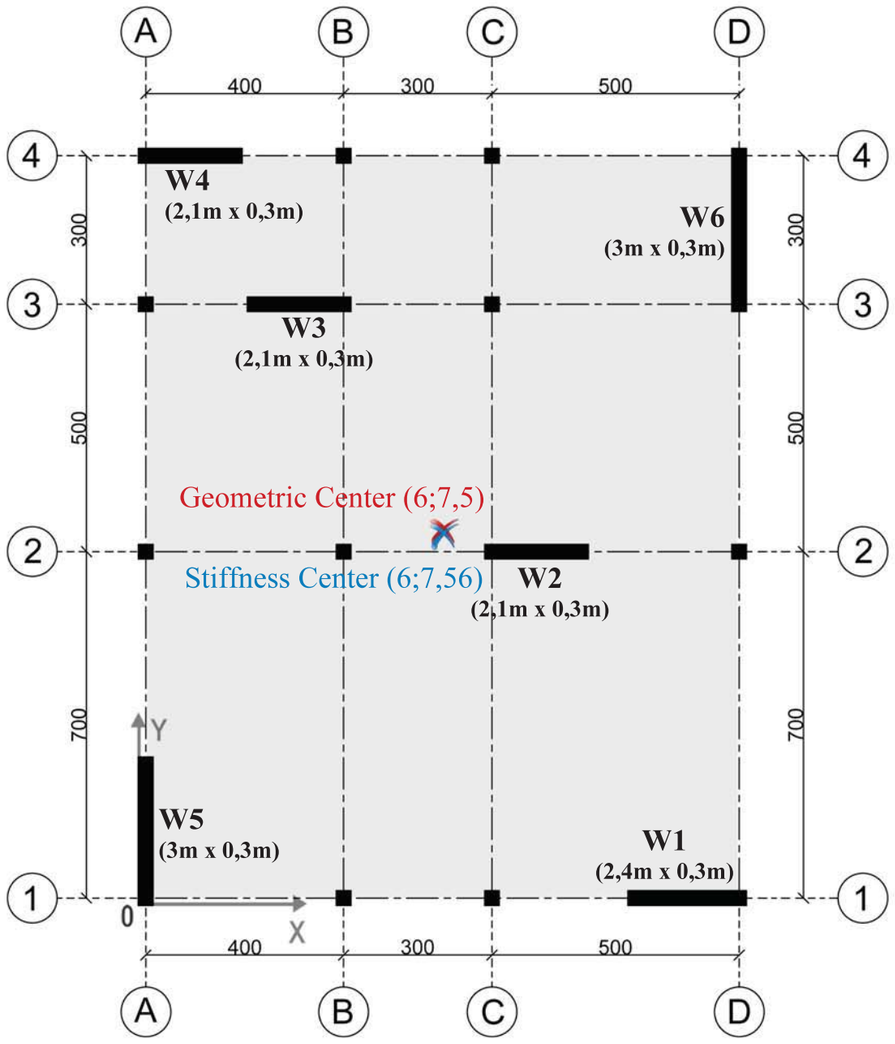
SOUTH ELEVATION

WEST ELEVATION

EAST ELEVATION

STRUCTURAL SYSTEM

STRUCTURAL SYSTEM



Geometric Center

- Since the form is symmetric, geometric center is at the center of building (6,00;7,50)

Stiffness Center

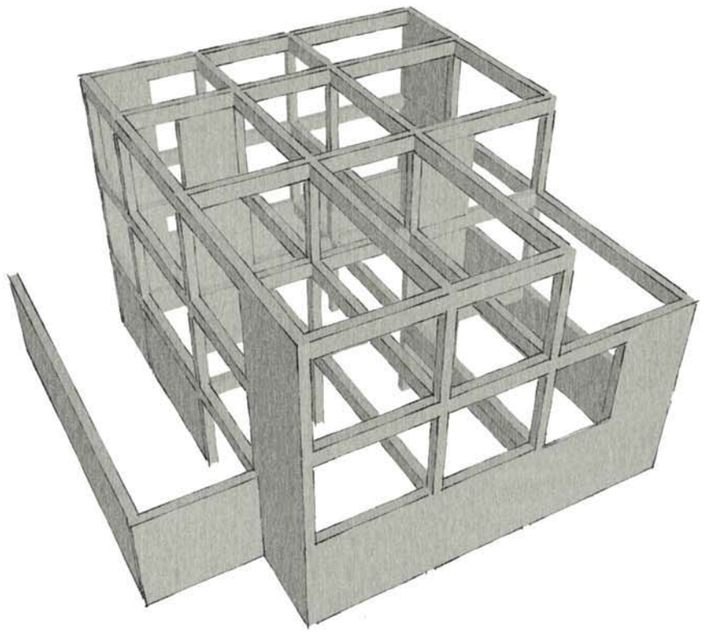
The dimensions of shear walls on x axis are (0,3)x(3,0). According to x axis:

$$\frac{[(1/12)\ x\ (0,3)\ x\ 3^3]\ x\ 0 + [(1/12)\ x\ (0,3)\ x\ 3^3]\ x\ 12}{[(1/12)\ x\ (0,3)\ x\ 3^3]\ x\ 2} = 6m$$

The dimensions of shear walls on y axis are (0,3)x(1,5). According to y axis:

$$\frac{[(1/12)x(0,3)x(2,4)^3]x0 + [(1/12)x(0,3)x(2,1)^3]x7 + [(1/12)x(0,3)x(2,1)^3]x12 + [(1/12)x(0,3)x(2,1)^3]x15}{[(1/12)x(0,3)x(2,1)^3]x3 + [(1/12)x(0,3)x(2,4)^3]} = 7,56m$$

- According to these calculations, stiffness center is on (6,00;7,56)



Shear Wall Percentage

Total Floor Area: 12m x 15m = 180 m²

Area of Shear Walls On X Axis:

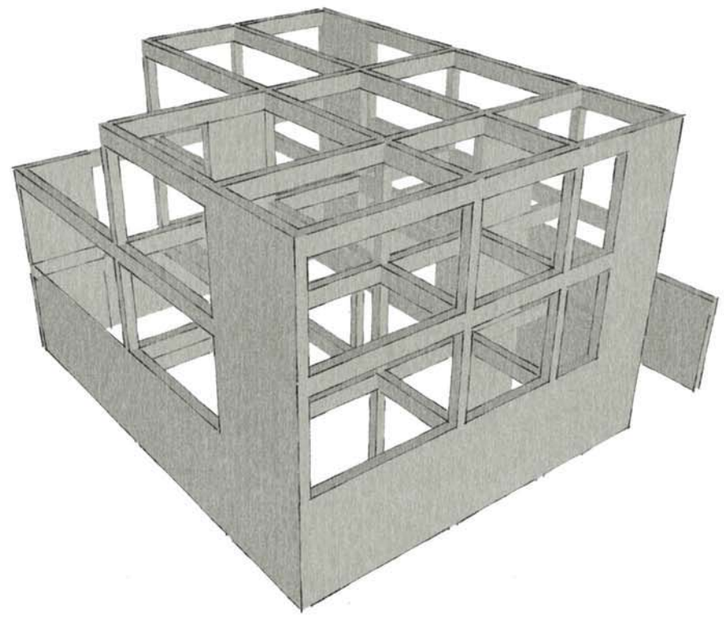
(0,30 m x 2,10 m) x 3 + (0,30 m x 2,40 m) = 2,61 m²

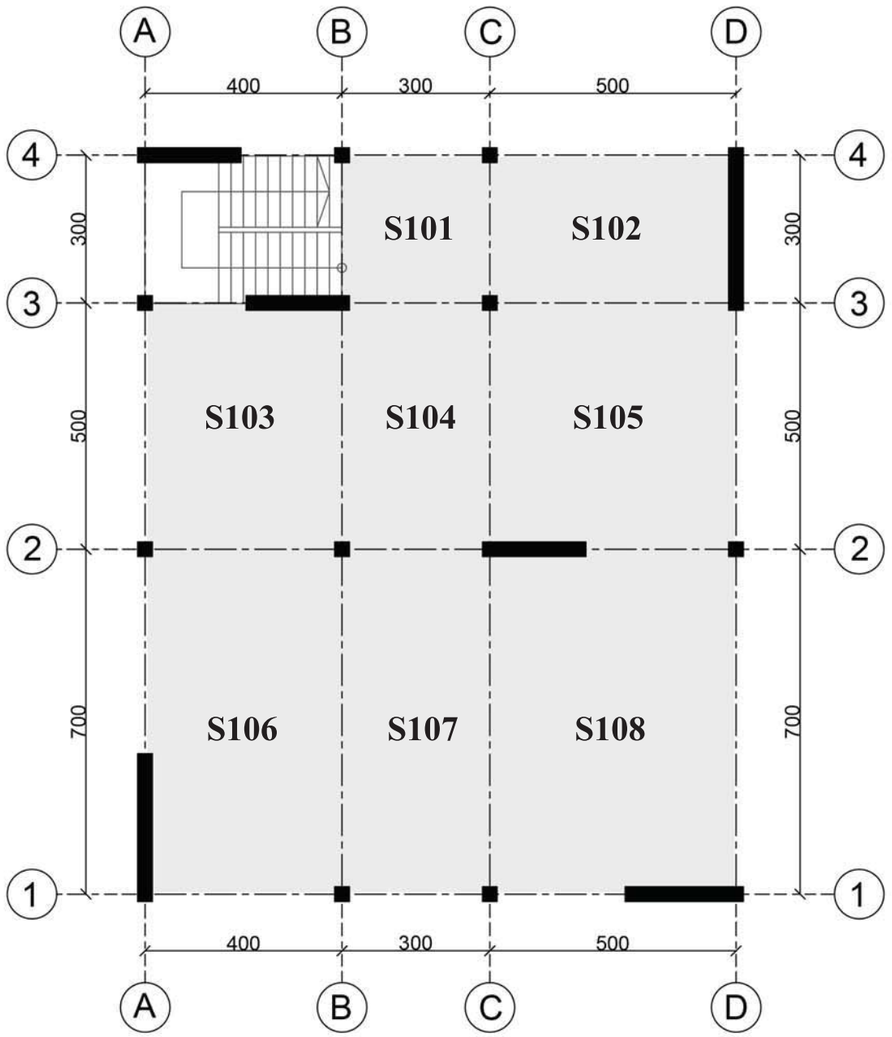
Percentage: 2,61 / 180 = %1,45

Area of Shear Walls On Y Axis:

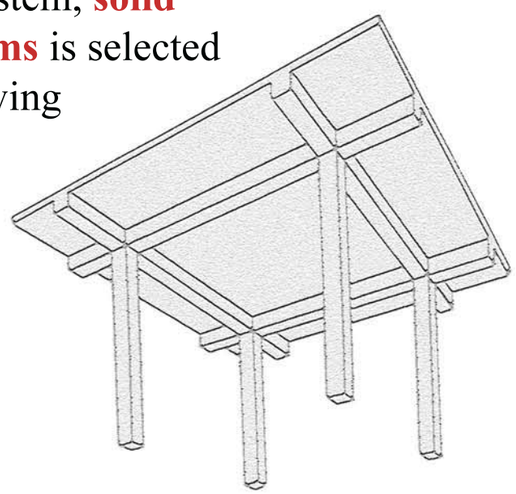
(0,30 m x 3,00 m) x 2 = 1,80 m²

Percentage: 1,80 / 180 = %1





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



SLAB THICKNESS

$$\alpha = \frac{\Sigma \text{ length of continuous edges}}{\Sigma \text{ length of all edges}}$$

- Since there is no slab in stairwell (between A-B and 3-4 axis) as shown in the figure, slab thickness and α value cannot be talked about.

- **The most critical 3 slabs were selected and calculated as shown below;**

$$\alpha_{S105} = \frac{5+5+5}{5+5+5+5} = 0.75 \qquad \alpha_{S106} = \frac{4+7}{4+4+7+7} = 0.5 \qquad \alpha_{S108} = \frac{5+7}{5+5+7+7} = \mathbf{0.5}$$

$$t \geq \frac{l_{short}}{15+\frac{20}{\frac{l_{long}}{l_{short}}}} \chi \left(1-\frac{\alpha}{4}\right)$$

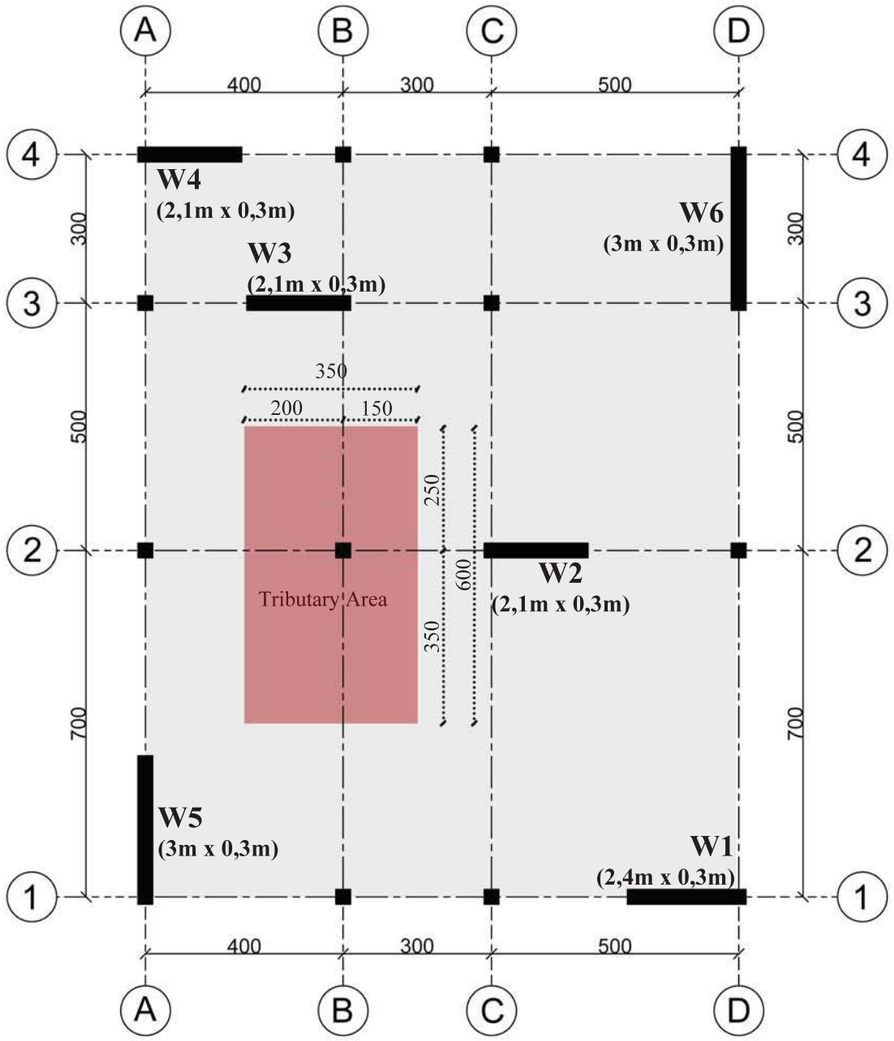
- **Slab thickness ≥ Most critical slab thickness**

$$t_{S105} = \frac{5}{15+\frac{20}{\frac{5}{5}}} \chi \left(1-\frac{0.75}{4}\right) = 11.53 \text{ cm} \qquad t_{S106} = \frac{4}{15+\frac{20}{\frac{7}{4}}} \chi \left(1-\frac{0.5}{4}\right) = 13.24 \text{ cm}$$

$$t_{S108} = \frac{5}{15+\frac{20}{\frac{7}{5}}} \chi \left(1-\frac{0.5}{4}\right) = \mathbf{14.93 \text{ cm}}$$

- **Since the most critical slab is t_{S108} = 14.93 cm , slab thickness is 15cm.**

COLUMN DIMENSIONS



Design Loads for slab:

Dead Loads

Own Weight: 0,15 x 2,4 = 0,36 t/m²

Levelling: 0,04 x 2,4 = 0,096 t/m²

Covering: 0,025 x 2 = 0,05 t/m²

Plastering: 0,02 x 2 = 0,04 t/m² +

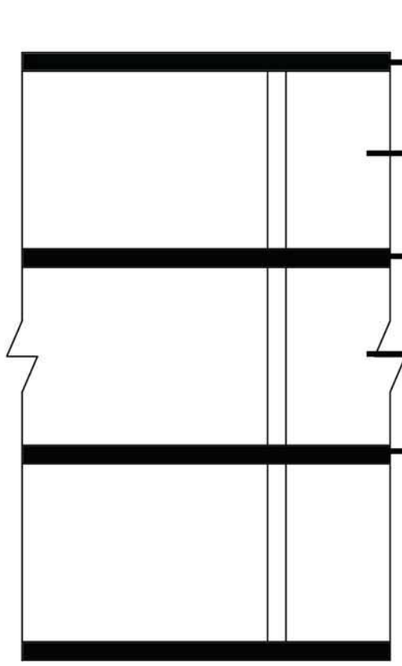
0,36 + 0,096 + 0,05 + 0,04 ≅ 0,546 t/m²

Live Load : 0,2 t/m²

TOTAL LOAD : (1,4)(0,546) + (1,6)(0,2) = **1,08 t/m²**

Tributary Area (Assume beam depth as longest span / 12,5)

Beam depth assumption ; 700 / 12,5 = 56 cm so wall height is 2,64m



(SKYLIGHT OPENING)

Slab Load: [(3,5x6) x 1,08] - [(1,5x6) x 1,08] = 12,96 t = 12960 kg

Wall Load: [(6+2) x 2,64] x (0,45 x 1,4) = 13,305 t = 13305 kg

Slab Load: [(3,5x6) x 1,08] = 22,680 t = 22680 kg

Wall Load: [(6+2) x 2,64] x (0,45 x 1,4) = 13,305 t = 13305 kg

Slab Load: [(3,5x6) x 1,08] = 22,680 t = 22680 kg +

Total Load: 84930 kg

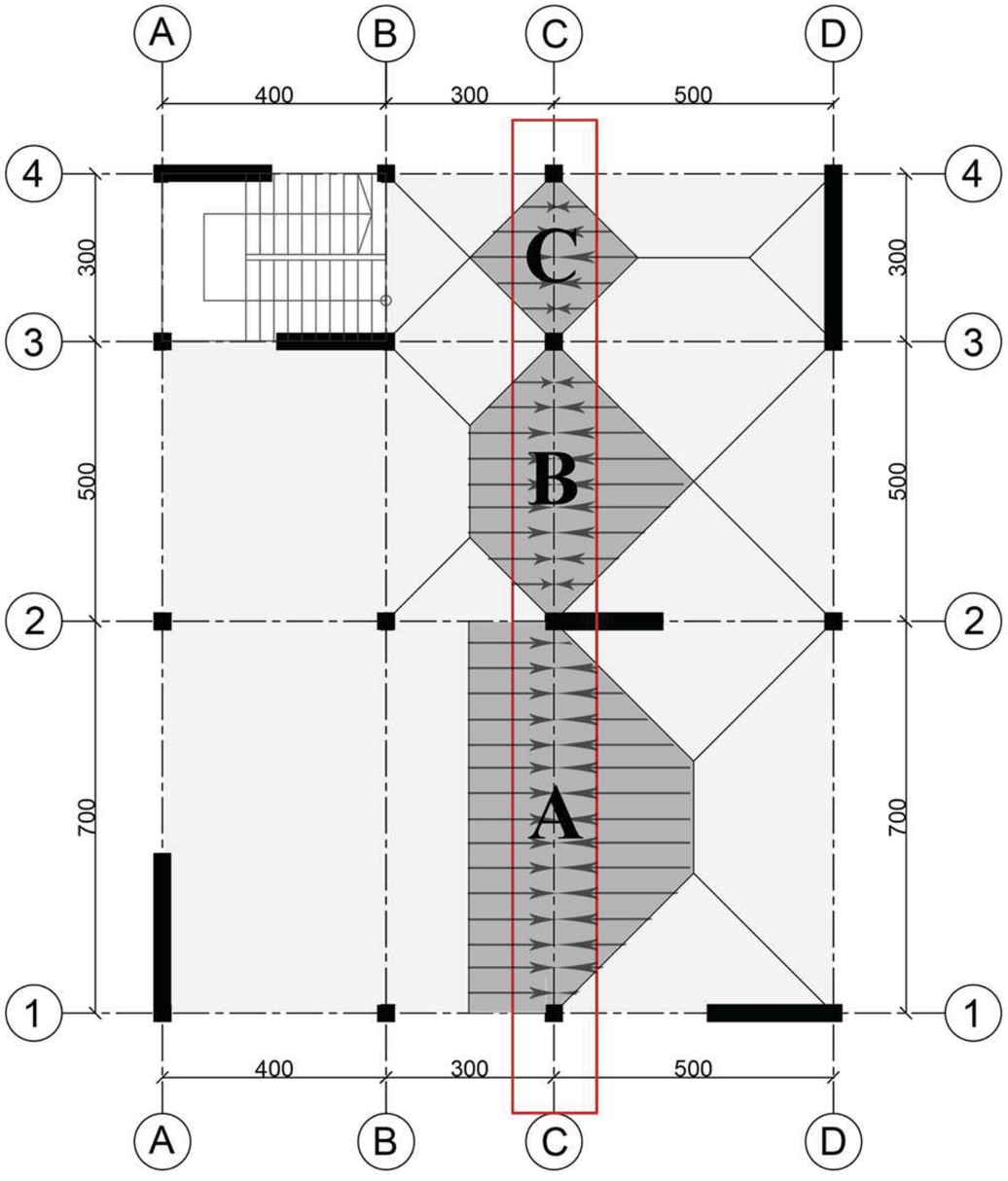
- Note: To be on the safe side, door openings were ignored

Then; $A_c \geq \frac{N_d}{0,75 x f_{cd}}$

$= \frac{84930}{0,75x130} = 871\ cm^2$

- Since 30 x 30 = 900 > 871 and min A_c must be bigger than 750 cm²
- Column dimensions are **30cm x 30cm** according to TS-500

BEAM ANALYSIS



FOR THE SHORT SPAN OF TWO-WAY

- $W = P_d \times \frac{l_{short}}{3}$

FOR THE LONG SPAN OF TWO-WAY

- $W = P_d \times \frac{l_{short}}{3} \times [1.5 - \frac{0.5}{[\frac{l_{long}}{l_{short}}]^2}]$

FOR THE ONE-WAY

- $W = P_d \times \frac{l_{short}}{2}$

$P_d = (1.4 \times 0.546) + (1.6 \times 0.2) = 1.0844 \ t/m^2$

Load on Region A:

- Since the ratio of long span to short span which is $\frac{7}{3}$, is greater than 2 in region A between B-C axes, the slab distributes the load in one way.

$$W_{1\text{-}2} = (1.08) \times \frac{3}{2} + (1.08) \times \frac{5}{3} \times (1.5 - \frac{0.5}{(\frac{7}{5})^2}) = 3.860 \ t/m$$

$$W_{Load} = 1.4 \times 0.45 \times 2.64 = 1.663 \ t/m$$

$$W_{Total\text{-}A} = 3.860 + 1.663 = 5.523 \ t/m$$

Load on Region B:

$$W_{2\text{-}3} = (1.08) \times \frac{5}{3} + (1.08) \times \frac{3}{3} \times (1.5 - \frac{0.5}{(\frac{5}{3})^2}) = 3.225 \ t/m$$

$$W_{Load} = 1.4 \times 0.45 \times 2.64 = 1.663 \ t/m$$

$$W_{Total\text{-}B} = 3.225 + 1.663 = 4.888 \ t/m$$

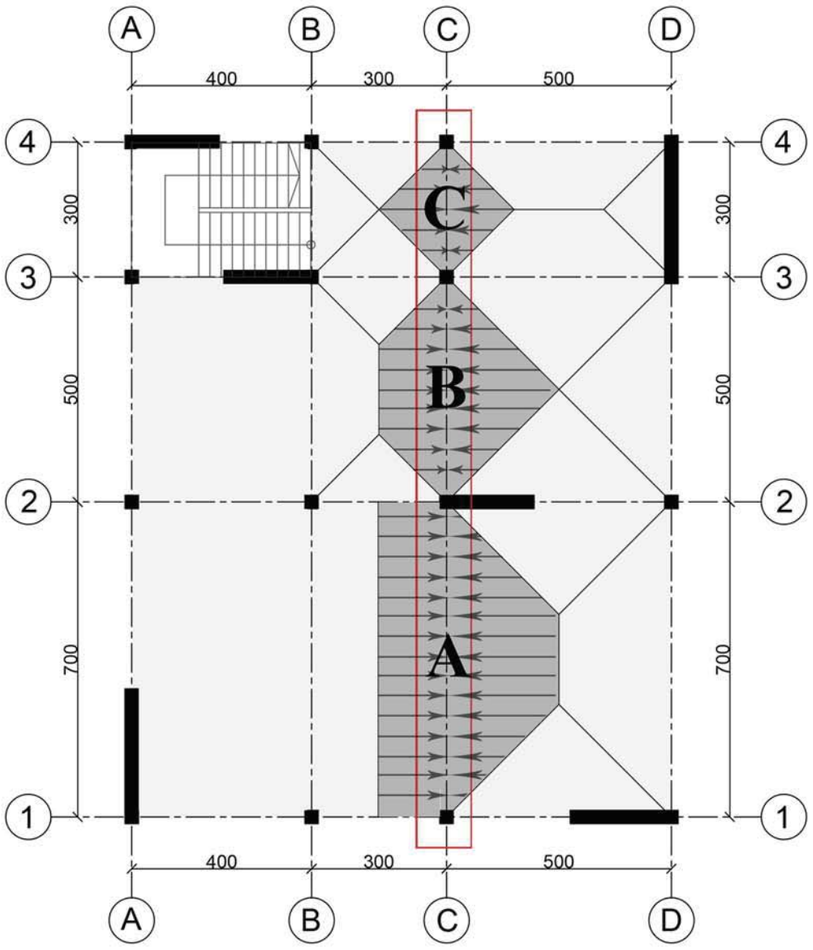
Load on Region C:

$$W_{3\text{-}4} = (1.08) \times \frac{3}{3} + (1.08) \times \frac{3}{3} = 2.16 \ t/m$$

$$W_{Load} = 1.4 \times 0.45 \times 2.64 = 1.663 \ t/m$$

$$W_{Total\text{-}C} = 2.16 + 1.663 = 3.823 \ t/m$$

BEAM ANALYSIS



$$r = \frac{(I / l)}{\sum (I / l)}$$

$$r_{12} = \frac{(0{,}00439 / 7)}{(0{,}00439 / 7) + (0{,}000675 / 3{,}2) \times 2} = 0{,}598$$

$$r_{21} = \frac{(0{,}00439 / 7)}{(0{,}00439 / 7) + (0{,}00439 / 5) + (0{,}004725 / 3{,}2) \times 2} = 0{,}140$$

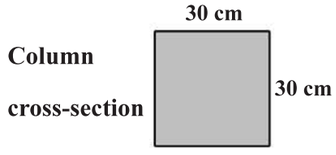
$$r_{23} = \frac{(0{,}00439 / 5)}{(0{,}00439 / 5) + (0{,}00439 / 7) + (0{,}004725 / 3{,}2) \times 2} = 0{,}197$$

$$r_{32} = \frac{(0{,}00439 / 5)}{(0{,}00439 / 5) + (0{,}00439 / 3) + (0{,}000675 / 3{,}2) \times 2} = 0{,}317$$

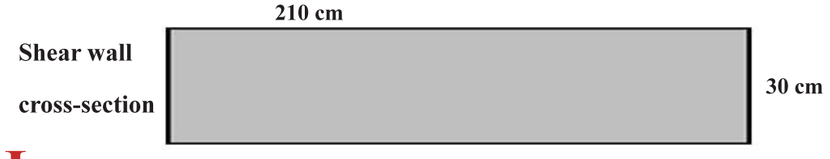
$$r_{34} = \frac{(0{,}00439 / 3)}{(0{,}00439 / 3) + (0{,}00439 / 5) + (0{,}000675 / 3{,}2) \times 2} = 0{,}529$$

$$r_{43} = \frac{(0{,}00439 / 3)}{(0{,}00439 / 3) + (0{,}000675 / 3{,}2) \times 2} = 0{,}776$$

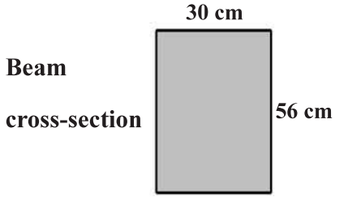
$I_{column} = (1/12) \times 0{,}3 \times (0{,}3)^3 = 0{,}000675\ m^4$



$I_{shear\ wall} = (1/12) \times 2{,}1 \times (0{,}3)^3 = 0{,}004725\ m^4$



$I_{beam} = (1/12) \times 0{,}3 \times (0{,}56)^3 = 0{,}004390\ m^4$



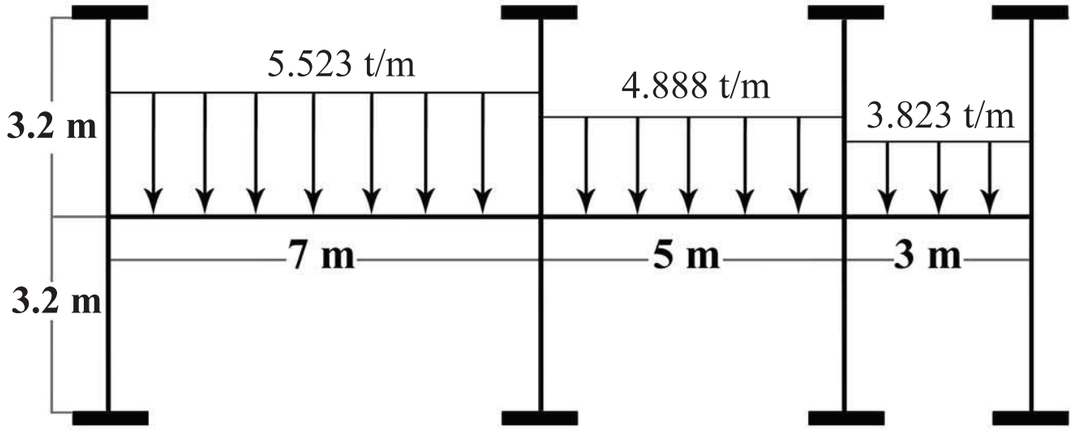
$$FEM = \frac{W \times l^2}{12} \qquad \text{mid-span moment} = \frac{W \times l^2}{24}$$

$$FEM_{1\text{-}2} = \frac{5{,}523 \times 7^2}{12} = 22{,}55\ tm \qquad \text{mid-span moment}_{1\text{-}2} = \frac{5{,}523 \times 7^2}{24} = 11{,}27\ tm$$

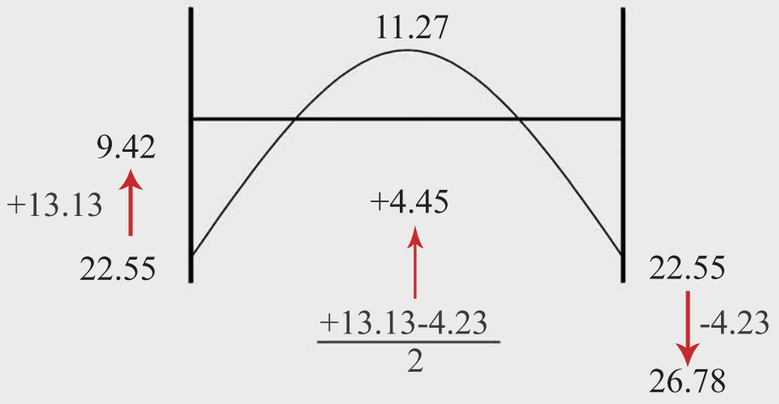
$$FEM_{2\text{-}3} = \frac{4{,}888 \times 5^2}{12} = 10{,}18\ tm \qquad \text{mid-span moment}_{2\text{-}3} = \frac{4{,}888 \times 5^2}{24} = 5{,}09\ tm$$

$$FEM_{3\text{-}4} = \frac{3{,}823 \times 3^2}{12} = 2{,}86\ tm \qquad \text{mid-span moment}_{3\text{-}4} = \frac{3{,}823 \times 3^2}{24} = 1{,}43\ tm$$

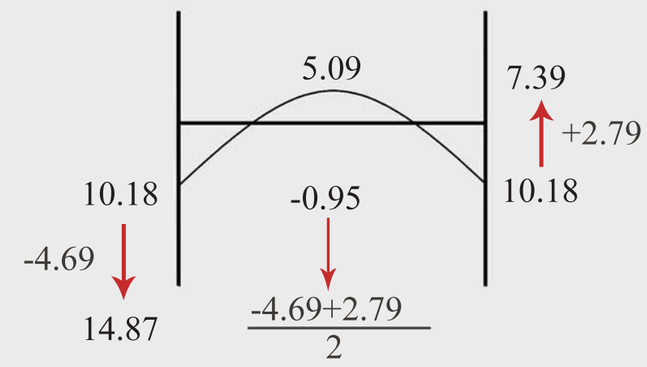
BEAM ANALYSIS



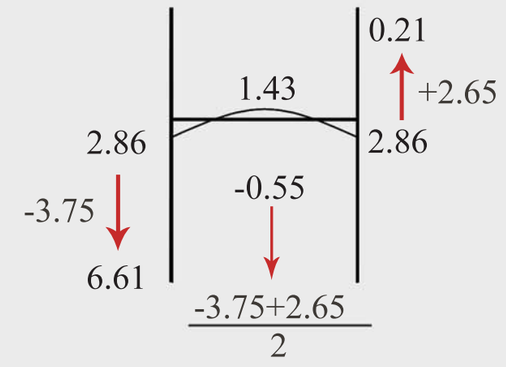
r	0.598	0.14	0.197	0.317	0.529	0.776
FEM	+22.55	-22.55	+10.18	-10.18	+2.86	-2.86
	+0.86	-6.74	+1.16	+1.21	+1.10	+1.93
Σ_1	+23.41	-29,29	+11.34	-8.97	+3.96	-0.93
	-13.99	+2.51	+3.53	+1.58	+2.65	+0.72
Σ_2	**+9.42**	**-26.78**	**+14.87**	**-7.39**	**+6.61**	**-0.21**



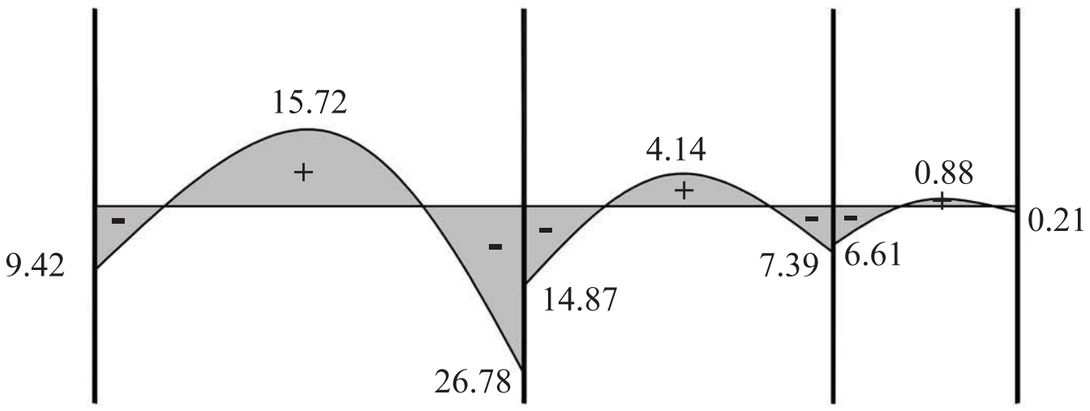
- Mid-span moment = 11.27+4.45 = **15.72 t.m**



- Mid-span moment = 5.09-0.95 =**4.14 t.m**



- Mid-span moment = 1.43-0.55 = **0.88 t.m**



BEAM DEPTH

$$K = \frac{bw \times d^2}{M} \qquad 0{,}025 = \frac{30 \times d^2}{2678000} \rightarrow d = 47{,}24cm$$

$h \geq d + 5 = 52{,}24$ cm $t = 15$ cm and $h \geq 3t = 45$

→ **Beam Depth = 55 cm**