DESIGN CONCEPT

SYMMETRY HOUSE
Concept of design is based on symmetry or basically on symmetric areas. Symmetry creates balance, and balance in design creates harmony, order, and aesthetically pleasing results. It is found everywhere in nature, and is probably why we find it to be so beautiful. Here; reflection symmetry type was selected to be used on concept stage.

For the design, it can be seen that main areas created according to reflection symmetry, both on the ground floor and the first floor.

DIAGRAM OF FIRST CONCEPTUAL STAGE

GROUND FLOOR

FIRST FLOOR
STRUCTURE AXONOMETRIC

NORTH EAST

NORTH WEST

SOUTH WEST

SOUTH EAST
Since the plan is symmetric in both directions, it can be easily seen that the geometric center of a plan is (8m;10m).

However; it can also be determined by using following calculations.

**GEOMETRIC CENTER**

\[
\begin{align*}
X_m &= \frac{\sum A_i \cdot l_x}{\sum A_i} \\
Y_m &= \frac{\sum A_i \cdot l_y}{\sum A_i}
\end{align*}
\]

**X DIRECTION**

\[
X = \frac{(A_1 \cdot x_1) + (A_2 \cdot x_2) + (A_3 \cdot x_3) + (A_4 \cdot x_4) + (A_5 \cdot x_5)}{A_1 + A_2 + A_3 + A_4 + A_5}
\]

\[
X = \frac{(60 \cdot 8) + (40 \cdot 8) + (100 \cdot 8) + (60 \cdot 8) + (60 \cdot 8)}{60 + 40 + 100 + 60 + 60} = 8m
\]

**Y DIRECTION**

\[
Y = \frac{(A_1 \cdot y_1) + (A_2 \cdot y_2) + (A_3 \cdot y_3) + (A_4 \cdot y_4) + (A_5 \cdot y_5)}{A_1 + A_2 + A_3 + A_4 + A_5}
\]

\[
Y = \frac{(60 \cdot 5) + (40 \cdot 5) + (100 \cdot 15) + (60 \cdot 15) + (60 \cdot 5)}{60 + 40 + 100 + 60 + 60} = 10m
\]
**STIFFNESS CENTER**

\[
I_{SW1} = I_{SW2} = \frac{1}{12} \cdot 0.25 \cdot (4) = 1.33 \text{ m}^4
\]

\[
I_{SW3} = I_{SW4} = \frac{1}{12} \cdot 0.30 \cdot (6) = 5.4 \text{ m}^4
\]

\[
I_{SW5} = \frac{1}{12} \cdot 0.25 \cdot (6) = 4.5 \text{ m}^4
\]

\[
X = (I_{SW3} \cdot X_3) + (I_{SW4} \cdot X_4)
\]

\[
Y = (I_{SW1} \cdot Y_1) + (I_{SW2} \cdot Y_2) + (I_{SW5} \cdot Y_5)
\]

\[
X_s = \frac{\sum I_i \cdot x_i}{\sum I_i}
\]

\[
Y_s = \frac{\sum I_i \cdot y_i}{\sum I_i}
\]

\[
X_s = (5.4 \cdot 6) + (5.4 \cdot 10) = 8 \text{ m}
\]

\[
Y_s = (0.133) + (20.133) + (10.45) = 10 \text{ m}
\]

**Eccentricity**

\[
e_x = \left| \frac{8 - 8}{2} \right| = 0 < \%5
\]

\[
e_y = \left| \frac{10 - 10}{2} \right| = 0 < \%5
\]

Stiffness center is (8m;10m). Since geometric center is also (8m;10m), shear walls are in right direction and distance in both axis.
**STRUCTURAL SYSTEM**

**SHEAR WALL PERCENTAGE**

Area of the footprint of shear walls on X, Y axis \( \geq 1\% \)

Floor Area

**AREA OF GROUND FLOOR**

- A1: 60 m\(^2\)
- A2: 40 m\(^2\)
- A3: 100 m\(^2\)
- A4: 60 m\(^2\)
- A5: 60 m\(^2\)

Since both ground floor and first floor have same areas, area of ground floor is used to calculate the percentage of shear walls.

**Total Area of Ground Floor**: 320 m\(^2\)

Area of shear walls on Y direction: \(0,25 \cdot 4 \cdot 2 = 2\) m\(^2\)

\(0,25 \cdot 6 = 1,5\) m\(^2\)

\(\frac{3,5}{320} = 0,01 \quad 1\%\)

Area of shear walls on X direction: \(0,30 \cdot 6 \cdot 2 = 3,6\) m\(^2\)

\(\frac{3,6}{320} = 0,01125 \quad 1,125\%\)

Shear wall cross sectional areas should be minimum 1% of the plan area in both directions.
SLAB SYSTEM

SELECTION AND THICKNESS CALCULATION

Since all slabs meet the condition of two way solid slab by \( \frac{L}{L_s} \leq 2 \);
Two way solid slab is selected as a slab system.

\[
\alpha = \frac{\sum \text{length of all continuous slab edges}}{\sum \text{length of all edges}}
\]

\[
t \geq \frac{L_s}{15 + \frac{20}{L/L_s}} \cdot (1 - \alpha/4)
\]

\[
\alpha_{S101} = \frac{6+5}{2 \cdot (6+5)} = 0.5
\]

\[
t_{S101} = \frac{5}{15+20} \cdot (1-0.5/4) = 13.8
\]

\[
\alpha_{S102} = \frac{4+5+5}{2 \cdot (4+5)} = 0.77
\]

\[
t_{S102} = \frac{4}{15+20} \cdot (1-0.77/4) = 10.4
\]

\[
\alpha_{S105} = \frac{4+5+5+4}{2 \cdot (4+5)} = 1
\]

\[
t_{S105} = \frac{4}{15+20} \cdot (1-1/4) = 9.7
\]

Slab thickness is selected as **15 cm.**
COLUMN DIMENSION

DESIGN LOADS
DEAD LOAD OF SOLID SLABS
- 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 = 0.05 t/m²
- Plastering: 0.020 x 2.0 = 0.04 t/m²

LIVE LOAD
- 0.2 t/m for residential buildings

TOTAL LOAD: (0.2 x 1.6) + (0.546 x 1.4) = 1.084 t/m²

SLAB LOAD ON TRIBUTARY AREA
Load x Tributary Area = 1.084 x 25 = 27.1 t

WALL LOAD ON TRIBUTARY AREA
1.4 x 0.15 x Tributary Area = 1.4 x 0.15 x 25 = 5.25 t

The column cross section area (Ac) should satisfy the following requirements:

The smallest dimension of a rectangular column section shall not be less than 30 cm. (TEC 2018 - 7.3.1.1).

\[
A_c \geq \frac{N_d}{0.4 \times fck}
\]

According to solutions, minimum allowable area of column is 743,125 cm², and the allowable dimension of a rectangular column can not be less than 30 cm according to TEC 2018; column dimensions are selected as 30 cm x 30 cm.

TRIBUTARY AREA = (3+2) x (2.5+2.5) = 25 m²

Column 2B is selected for calculation of dimension, since it has the largest tributary area.

Slab Load: 27.1 t
Wall Load: 5.25 t
TOTAL: 30 cm column
30 cm column
TOTAL: 59.45
The beam on axis 2 is selected to be analyzed since it has the least amount of shear walls.

In order to analyze the load transfer of structures on beam, first we have to know the design load of slab, walls and beam’s own weight. According to TS 500 - TEC 2018 codes, we know that wall load is 0.15 t/m per square meter. We can find loads by adding wall load with slab load as follows;

\[ P = (Wall \ load + Dead \ Load \ of \ slab \times \ Load \ Factor) + (Live \ Load \times \ Load \ Factor) \]

\[ P_d = ((0.15 + 0.546) \times 1.4) + (0.2 \times 1.6) \]

\[ P_d = 1.3 \ t/m \]

\[ W_1 = W_2 = W_3 = W_4 \]

\[ W_{1,2,3,4} = 1.3 \times 5/3 \]

\[ W_{1,2,3,4} = 2.17 \ t/m \]

\[ W_5 = W_6 = W_7 = W_8 \]

\[ W_{5,6,7,8} = 1.3 \times 4/3 \times (1.5 - 0.5/(5/4)) \]

\[ W_{5,6,7,8} = 2.04 \ t/m \]

**BEAM’S OWN WEIGHT (Wb)**

\[ W_b = Volume \ of \ member \times \ unit \ of \ materials \times \ Dead \ Load \ Factor \]

\[ W_b = (5 \times 0.50 \times 0.25) \times 2.4 \times 1.4 = 2.1 \ t \]

\[ W_b = 2.1/5 \]

\[ W_b = 0.42 \ t/m \]

**Beam’s own weight is omitted.**

**Beam AB** = 2.17 + 2.04 = 4.21 t/m

**Beam BC** = 2.17 + 2.04 = 4.21 t/m

**Beam CD** = 2.17 + 2.04 = 4.21 t/m

**Beam DE** = 2.17 + 2.04 = 4.21 t/m
In order to find load distribution factors we have to know moment of inertia of beam, column and shear wall.

To find beam’s moment of inertia we should know the beam depth. According to design beam depth is chosen as 50 cm. However; it can also be determined by using average beam depth which is;

**Average beam depth** : longest span / 12.5
Longest beam is 600 cm so;

**Average beam depth** : 600 / 12.5 = 48 cm

**Load Distribution Factor**

\[ r_{ij} = \left( \frac{I_{ij}}{L_{ij}} \right) / \sum \left( \frac{I_j}{L_j} \right) \]

- \( r_{AB} = \frac{(0.0026/5) / ((0,0026/5) + 2x(0,000675/4))}{0.6} \)
- \( r_{BA} = \frac{(0.0026/5) / (2x (0,0026/5)+2x(0,000675/4))}{0.38} \)
- \( r_{BC} = \frac{(0.0026/5) / (2x (0,0026/5)+2x(0,000675/4))}{0.38} \)
- \( r_{CD} = \frac{(0.0026/5) / (2x (0,0026/5)+2x(0,000675/4))}{0.38} \)
- \( r_{DC} = 0 \)
- \( r_{DE} = 0 \)
- \( r_{ED} = 0 \)

**Fixed End Moments**

- \( F_{E}^{AB} = 4.21 \times 5 \times 1/12 = 8.77 \text{ tm} \)
- \( F_{E}^{BC} = 4.21 \times 5 \times 1/12 = 8.77 \text{ tm} \)
- \( F_{E}^{CD} = 4.21 \times 5 \times 1/12 = 8.77 \text{ tm} \)
- \( F_{E}^{DE} = 0 \)

**Mid Span Moment**

- \( M_{AB} = 4.21 \times 5^2 \times 1/24 = 4.38 \text{ tm} \)
- \( M_{BC} = 4.21 \times 5^2 \times 1/24 = 4.38 \text{ tm} \)
- \( M_{CD} = 4.21 \times 5^2 \times 1/24 = 4.38 \text{ tm} \)
- \( M_{DE} = 0 \)

Moment of Inertia

\[ I = \frac{1}{12} b x h^3 \]

- \( I_{\text{beam}} = 0.25 \times (0.50)^3 / 12 = 0.0026 \text{ m}^4 \)
- \( I_{\text{column}} = 0.30 \times (0.3)^3 / 12 = 0.000675 \text{ m}^4 \)
- \( I_{\text{sw3,4}} = 0.30 \times (6)^3 / 12 = 5.4 \text{ m}^4 \)
- \( I_{\text{sw1,2}} = 0.25 \times (4)^3 / 12 = 1.33 \text{ m}^4 \)
- \( I_{\text{sw5}} = 0.25 \times (6)^3 / 12 = 4.5 \text{ m}^4 \)
**BEAM ANALYSIS**

**BEAM DEPTH**

\[ K_0 = \frac{b_w \times d^2}{M_{\text{max}}} \]

- \( K_0 = 250 \text{ mm}^2/\text{KN} \)
- \( K_0 = 25 \text{ cm}^2/\text{t} \)
- \( b_w = 25 \text{ cm} \)
- \( M = 10,4 \)
- \( d = 32,25 \)
- \( h = 32,25 + 5 = 37,25 \text{ cm} \)

According to building regulations beam depth can not be three times smaller than the slab thickness. Thus, the **beam depth > 45 cm**. The beam depth chosen as **50 cm**.
In order to analyze the load transfer of structures on beam, first we have to know the design load of slab, walls and beam’s own weight. According to TS 500 - TEC 2018 codes, we know that wall load is 0.15 t/m per square meter. We can find loads by adding wall load with slab load as follows:

\[
P_d = ((\text{Wall load} + \text{Dead Load of slab}) \times \text{Load Factor}) + (\text{Live Load} \times \text{Load Factor})
\]

\[
P_d = ((0.15 + 0.546) \times 1.4) + (0.2 \times 1.6)
\]

\[
P_d = 1.3 \text{ t/m}
\]

\[
W_{9,12,11,14} = 1.3 \times 5/3 \times (1.5 - 0.5/(6/5)^2)
\]

\[
W_{9,12,11,14} = 2.5 \text{ t/m}
\]

\[
W_{10} = W_{13}
\]

\[
W_{10,13} = 1.3 \times 4/3
\]

\[
W_{10,13} = 1.73 \text{ t/m}
\]

**BEAM’S OWN WEIGHT (W)**

\[
W_b = \text{Volume of member} \times \text{unit of materials} \times \text{Dead Load Factor}
\]

\[
W_b = (6 \times 0.50 \times 0.25) \times 2.4 \times 1.4 = 2.52 \text{ t}
\]

\[
W_b = 2.52/6
\]

\[
W_b = 0.42 \text{ t/m}
\]

\[
W_b = (4 \times 0.50 \times 0.25) \times 2.4 \times 1.4 = 1.68 \text{ t}
\]

\[
W_b = 1.68/4
\]

\[
W_b = 0.42 \text{ t/m}
\]

Beam’s own weight is omitted.

**Beam 12** = 2.5 + 2.5 = 5 t/m

**Beam 23** = 1.73 + 1.73 = 3.46 t/m

**Beam 34** = 2.5 + 2.5 = 5 t/m
In order to find load distribution factors we have to know moment of inertia of beam, column and shear wall.

To find beam’s moment of inertia we should know the beam depth. According to design beam depth is chosen as 50 cm. However; it can also be determined by using average beam depth which is;

**Average beam depth** : longest span / 12,5
Longest beam is 600 cm so;
**Average beam depth**: 600 / 12,5 = 48 cm

**Load Distribution Factor**

\[ r_{ij} = \left( \frac{I_{ij}}{L_{ij}} \right) / \sum \left( \frac{I_{ij}}{L_{ij}} \right) \]

\[ r_{12} = \frac{(0,0026/6)}{(0,0026/6) + 2x(0,000675/4)} = 0,56 \]
\[ r_{21} = \frac{(0,0026/6)}{(0,0026/6)+(0,000675/4)+2x(0,000675/4))} = 0,3 \]
\[ r_{23} = \frac{(0,0026/4)}{(0,0026/4)+(0,000675/4)+2x(0,000675/4))} = 0,46 \]
\[ r_{32} = 0 \]
\[ r_{34} = 0 \]
\[ r_{43} = r = \frac{(0,0026/6)}{(0,0026/6) + 2x(0,000675/4))} = 0,56 \]

**Fixed End Moments**

\[ FEM_{12} = 5 \times 6^2 \times 1/12 = 15 \text{ tm} \]
\[ FEM_{23} = 3,46 \times 4^2 \times 1/12 = 4,61 \text{ tm} \]
\[ FEM_{34} = 5 \times 6^2 \times 1/12 = 15 \text{ tm} \]

**Mid Span Moment**

\[ M_{12} = 5 \times 6 \times 1/24 = 7,5 \text{ tm} \]
\[ M_{23} = 3,46 \times 4^2 \times 1/24 = 2,3 \text{ tm} \]
\[ M_{34} = 5 \times 6^2 \times 1/24 = 7,5 \text{ tm} \]
**BEAM ANALYSIS**

**BEAM DEPTH**

\[ K_0 = \frac{b_w \times d^2}{M_{\text{max}}} \]

\[ 25 = \frac{25 \times d^2}{1920} \]

\[ d = 43.81 \]

\[ h = 43.81 + 5 = 48.81 \text{ cm} \]

\[ K_0 = 250 \text{ mm} / \text{ KN} \]

\[ K_0 = 25 \text{ cm} / \text{ t} \]

According to building regulations beam depth cannot be three times smaller than the slab thickness. Thus, the **beam depth > 45 cm**. The beam depth chosen as **50 cm**.

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**Diagrams:**

1. **Diagram 1:**
   - Beam depth calculation diagram
   - Beam depth chosen as 50 cm.

2. **Diagram 2:**
   - Distribution of forces and moments
   - Maximum moments indicated.