GROUP 8

M. Hüseyin Sancar
İbrahim Yavuz
Hasan Arslan

METU Department of Architecture

2013-2014 Arch 332
Structural Design in Architecture

Instructors:
M. Halis Günel
Deniz Üçer
Integrating Different Functions

- Gallery
- Living & Eating Room
- Hobby Room

- Bedrooms
- Hall & Study Room
- Kitchen

- Master Bedroom
- Grandparents' Bedroom
- Housekeeper's Bedroom

Circulation Diagram

- Vertical Circulation
- Horizontal Circulation
Geometric Center

\[ G = \frac{\sum (A_i x d_i)}{\sum A_i} \]

\[ A_1 = 7.5 \times 4.5 = 33.75 \]
\[ A_2 = 5.5 \times 2.5 = 13.75 \]
\[ A_3 = 7.5 \times 5 = 37.5 \]
\[ A_4 = 4.5 \times 6.5 = 29.25 \]
\[ A_5 = 5.5 \times 4.5 = 24.75 \]

Geometric Center in X direction

\[ G_x = \frac{[(33.75) \times (8.25) + (13.75) \times (9.25) + (37.5) \times (8.25) + (29.25) \times (2.25) + (24.75) \times (9.75)]}{139} \]

\[ = 7.26 \]

Geometric Center in Y direction

\[ G_y = \frac{[(33.75) \times (2.25) + (13.75) \times (5.75) + (37.5) \times (9.5) + (29.25) \times (10.25) + (24.75) \times (14.25)]}{139} \]

\[ = 8.37 \]

Geometric Center

According to these calculations, geometric center is on \((7.26; 8.37)\)

Stiffness Center in X direction

\[ I_x = \frac{(0.25) \times (4.75)^3}{12} = 2.23 \]

\[ I = b \cdot h^3 \]

\[ S_x = \frac{I_x \cdot L_x}{I} \]

\[ S_x = \frac{(2.23) \times (12) + (1.33) \times (0)}{2.23 + 1.33} \]

\[ = 7.51 \]

Stiffness Center in Y direction

\[ I_y = \frac{(0.25) \times (3.75)^3}{12} = 1.1 \]

\[ I = b \cdot h^3 \]

\[ S_y = \frac{I_y \cdot L_y}{I} \]

\[ S_y = \frac{(12) \times (1.1) + (2.6) \times (7)}{1.1 + 2.6} \]

\[ = 8.48 \]

Stiffness Center

According to these calculations, stiffness center is on \((7.51; 8.48)\)

Shear Wall Percentage

Total Floor Area: 140 m²

Area of Shear Walls On X Axis:

\((0.25 \ m \times 4.75 \ m) + (0.25 \ m \times 4 \ m) = 2.187 \ m²\)

Percentage: \(2.187 / 140 = %1.56\)

Area of Shear Walls On Y Axis:

\((0.25 \ m \times 3.75 \ m) + (0.25 \ m \times 5) = 2.19 \ m²\)

Percentage: \(2.19 / 140 = %1.56\)

Stiffness Center and Geometric Center is very close and Shear Wall Percentage is above the average.
Slab Thickness Calculation

Formula: \[ t \geq \frac{1\text{short}}{15+20} \times \frac{(1-\alpha)}{4} \]

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

For S204

\[ \alpha_{204} = \frac{5.5}{21} = 0.26 \]

\[ t_{204} \geq \frac{500}{15+20} \times \frac{(1-0.26)}{4} \]

\[ t_{204} \geq 14.16 \text{ cm} \]

For 205

\[ \alpha_{205} = \frac{5.5}{20} = 0.275 \]

\[ t_{205} \geq \frac{450}{15+20} \times \frac{(1-0.276)}{4} \]

\[ t_{205} \geq 13.34 \text{ cm} \]

S204 and S205 are most critical slab types so we calculated these two slabs and find two different thicknesses. Thus, we consider the higher one to have a safe system.

Two Way Solid Slab with Beams

According to CODES TS 500 and TURKISH SEISMIC CODE two way solid slab with beams is selected with the calculations.

Slab Thickness

There are two critical slabs which have maximum spans and we calculated both of them. After find out two different slab thicknesses, we consider the one which has 14.16 cm in height, so we decided to use 15 cm for slab thickness.

Slab thickness is minimum: 15 cm
**Tributary Area** (Floor Height is 3 meter.)

Wall Load = Wall Length x Wall Height x 0.45 x 1.4

Slab Load = Slab Area x 1.02

Beam Average = Max. Span / 12.5 = 550 / 12.5 = 44 cm

Thus, wall height is 2.56 cm

Slab Load: [(4.75 x 2.75) x 1.02] = 13.32 t = 13320 kg

Wall Load: [(2.45 + 4.45) x 2.56 x 0.45 x 1.4] = 11,12832 t = 11128 kg

Slab Load: [(4.75 + 2.75) x 1.02] = 13.32 t = 13320 kg

Wall Load: [(2.45 + 4.45 + 2.25) x 2.56 x 0.45 x 1.4] = 14,757 t = 14757 kg

Slab Load: [(4.75 + 2.75) x 1.02] = 13.32 t = 13320 kg

Total Load: 65845 kg

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

Then: \[ A_c \geq \frac{N_d}{0.75 \times f_{cd}} \]

\[ = \frac{65845}{0.75 \times 130} = 675.56 \text{ cm}^2 \]

Since 25 x 30 = 750 > 675 and min \( A_c \) must be bigger than 750 cm²

Column dimensions are 25 cm x 30 cm according to TS-500

**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

Live Load: 0.2 t/m²

**Total Load:** (1.4)(0.5) + (1.6)(0.2) = 1.02 t/m²

25 cm

30 cm

Column
Beam Analysis

For Short Span
\[ W = \frac{P_d \times L_{\text{short}}}{3} \]
\[ P_d = (1.4 \times 0.5) + (1.6 \times 0.2) = 1.02 \text{ t/m}^2 \]

Load on region a:
\[ W_{1-2} = \frac{1.02 \times 5 \times (1.5 - 0.5)}{3} = 2.04 \text{ t/m} \]

Load on region b:
\[ W_{3-4} = \frac{1.02 \times 5 \times (1.5 - 0.5) + 1.02 \times 4.5 \times (1.5 - 0.5)}{3} = 3.83 \text{ t/m} \]

To calculate beams, we have to know ‘r’ values and FEM values so that we calculate FEM values at fix end beam system.

\[ FEM = WL^2/12 \]
\[ FEM_{1-2} = (2.04) \times (4.25)^2/12 = 3.08 \text{ t/m} \]
\[ FEM_{3-4} = (3.83) \times (4.5)^2/12 = 5.10 \text{ t/m} \]

\[ I_{\text{column}} = \frac{(0.25) \times (0.3)^3}{12} = 0.0005625 \text{ m}^4 \]
\[ I_{\text{shearwall}} = \frac{4 \times (0.25)^3}{12} = 0.0052 \text{ m}^4 \]
\[ I_{\text{beam}} = \frac{(0.3) \times (0.5)^3}{12} = 0.003125 \text{ m}^4 \]

We assume the depth of beam is 50 cm.
**Beam Analysis**

- **FEM** = \( \frac{WL^2}{12} \)
  - \( FEM_{1-2} = (2.04)(4.25)^2 / 12 = 3.08 \text{tm} \)
  - \( FEM_{3-4} = (3.83)(4)^2 / 12 = 5.10 \text{tm} \)

- **K** = \( \frac{bw \times d^3}{M} \)
  - 0.025 = \( \frac{30 \times d^3}{678000} \) → \( d = 23.76 \text{ cm} \)

**Beam Depth**
- \( h \geq d + 5 = 28.76 \text{ cm} \)
- \( t = 15 \text{ cm and } h \geq 3t = 45 \) → **Beam Depth = 50 cm**