Flat Slabs (Flat Plates with Drop Panels)
Exercises
Flat Slabs (Flat Plates with Drop Panels)

A flat plate system is the most economical design. However, when a flat plate encounters a problem with regard to two-way (punching) shear, the flat plate is thickened locally around columns of concern, creating drop panels, and the resulting system is known as a flat slab. The drop panel shall extend in each direction, from centerline of column support, a distance not less than $1/6$ the span length, measured from center-to-center of columns in that direction (i.e. in x-direction → extend $L_x/6$ from center of column support and in y-direction $L_y/6$). Projection of drop panel below slab shall be at least $h_f/4$ beyond the slab (i.e. depth of drop panel $\geq 1.25h_f$).

For example, for a typical interior column, the cross-section of column/drop panel area is shown.

\[
\begin{align*}
\text{C. L.} & \quad \frac{L}{6} \\
& \quad \frac{d_1}{2} \\
& \quad \frac{d_2}{2} \\
& \quad L/6 \\
& \quad L/6 \\
& \quad h_f \\
& \quad 1.25 h_f \\
& \quad (\text{based on slab thickness}) \\
& \quad \rightarrow d_2 = h_f - \text{concrete cover} - d_b \\
& \quad (\text{based on drop panel thickness}) \\
& \quad \rightarrow d_1 = \text{drop panel thickness} - \text{concrete cover} - d_b
\end{align*}
\]
Two critical sections need to be investigated for punching shear. The plan view of these two sections (for a typical interior column) is the following:

A similar approach may be carried out for side and corner columns, but in these cases the extension of drop panel cannot go both ways both directions.

**Note:**

- Length of drop panel shall be in multiples of 50 mm.
- Depth of drop panel shall be in multiples of 10 mm.
Example 1

A multi-story residential building is to be designed as a flat plate system with floors of uniform thickness. The layout of an intermediate floor is as shown. Specified service live load is 2.12 \( kN/m^2 \). Dead load includes 1.85 \( kN/m^2 \) in addition to own weight. Normal weight concrete to be used with \( f'_c = 28 \text{ MPa} \) and \( \phi 14 \) bars are used with \( f_y = 420 \text{ MPa} \) throughout. Columns have 400 mm square sections.

1) Show that the slabs are two-way.
2) Establish slab thickness, \( h_f \).
3) Check that the floor system satisfies the limitations of DDM.
4) Considering a typical interior frame in E-W direction:
   a) Determine the total factored static moment per span.
   b) Distribute the total factored static moment to negative and positive sections.
   c) Distribute negative and positive moments to column and middle strips.
   d) Design the reinforcement including spacing of reinforcing bars and bar cutoff points. Sketch the design.
   e) Check that one-way shear strength capacity is adequate.
   f) Check that two-way shear strength capacity is adequate.
   g) Check for unbalanced moment transfer through shear.
   h) Is there a need for extra steel bars to be provided over columns?
5) Obtain the loading on columns A-1, A-2, B-1, and B-2.
   Assume the floor is the first story of a 10-story high building. Clear story height is 2.75 m.
Example 2

Consider the following layout for an intermediate floor (meeting the limitations of DDM) of a multi-story commercial building. A flat plate system supported by 600 mm × 450 mm rectangular columns is to be used. Service live load is 7.00 kN/m² and dead load includes 2.25 kN/m² for partition allowance in addition to own weight. Normal weight concrete is used with $f'_c = 28 \text{ MPa}$ and Ø14 bars are used with $f_y = 420 \text{ MPa}$. A uniform slab thickness of 250 mm is used throughout.

1) Show that two-way (punching) shear strength of the slab is not adequate.

2) Rectify the situation in (1) by using a drop panel.
Example 3

The floor system shown consists of solid slabs and beams in two directions supported on 500 mm square columns. Use normal weight concrete with $f'_c = 21 \, MPa$ and Ø14 bars are used with $f_y = 420 \, MPa$. Concrete is normal weight. Overall depth of beams is 500 mm and they have a web width of 400 mm. Service live load is 4.25 kN/m$^2$ and service dead load consists of 2.12 kN/m$^2$ of floor finish in addition to own weight.

2) Establish slab thickness, $h_f$.

3) Check that the floor system satisfies the limitations of DDM.

4) Considering a typical interior frame in E-W direction:
   a) Determine the total factored static moment per span.
   b) Distribute the total factored static moment to negative and positive sections.
   c) Distribute negative and positive moments to column and middle strips.
   d) Design the reinforcement including spacing of reinforcing bars and bar cutoff points. Sketch the design.

5) Repeat step (4) for a typical exterior frame in E-W direction.

6) Obtain the loading on beams b1, b3, b4 and b6.