Lecture no. 8:

ONE-WAY SLABS, STAIR SLABS
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I. One-way slabs
1. Definition of one-way and two-way slabs

Rectangular slab panel simply supported along the perimeter:

Indication of diff. support conditions

\[ \ell \quad \ell_{sh} \]

free edge      restrained edge

\( \ell : \) longer  \( \) sh: shorter

If \( \frac{\ell}{\ell_{sh}} \geq 2 \), the slab is regarded one-way slab, otherwise two-way slab
2. Special characteristics of rc slabs

-for convenience, 1 m wide strip of the slab is investigated:

\[ t \geq 70 \text{ mm (cantilever slab:100 mm)} \]

-with the exception of introduction of important concentrated loads at column heads of flat slabs or column support points on foundation slabs, no shear reinforcement is needed:

\[ u = 4a + 2 \cdot 2d\pi \]
\[ v_{Rd,c} = cf_{dt,d} \]

Shear reinforcement must be designed only, if:

\[ F \geq v_{Rd,c}ud \]
3. Static models

The way of determination of the *position of the support points* is the same as for beams with \( h = t \) (slab thickness)

Static models:
4. Fulfilment of the rigidity requirement of slabs

Slabs are flexible, ductile structures. At large (not allowable) deflections the suspension effect may impede rupture and fall down of slabs. 

\[
\left( \frac{\ell}{K} \right)_{\text{allowable}}
\]

rates range from 20 to 40 (see DA table) and can be effected by:
- over reinforcing \( (A_{s,\text{prov}} \succ A_{s,\text{req}}) \)
- pre-camber (overlifting) by \( \frac{\ell}{250} \) or \( \frac{\ell}{500} \)
- applying restraint at the support (that is increasing \( K \))
- prescribing higher concrete grade
- increasing slab thickness
5. Section design for moment (numerical example)

Concrete: C20/25-X0-24-F3
Steel: C15.H welded mesh
Concrete cover: $c_{\text{nom}} = 20$ mm

$m_{\text{Ed}} = -12$ kNm/m (- means tension on top!)
Design the necessary steel section!

Solution:

\[ d = 120 - 20 - 10/2 = 95 \text{ mm} \] (no link diameter subtracted!)

\[ \Sigma M_S = 0: \quad x_c = d(1 - \sqrt{1 - \frac{2m_{\text{Ed}}}{bd^2 f_{cd}}}) \]

\[ b = 1000 \text{ mm}, \quad f_{cd} = 13,3 \text{ N/mm}^2 \]

\[ x_c = 95 \cdot (1 - \sqrt{1 - \frac{2 \cdot 12 \cdot 10^6}{1000 \cdot 95^2 \cdot 13,3}}) = 10,0 \text{ mm} < \]

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\[ x_{co} = \xi_{co} \ d = 0,49 \cdot 95 = 46,6 \ mm \ OK! \]

\[ z = d - \frac{x_c}{2} = 95 - 10/2 = 90 \ mm \]

\[ \Sigma M_g = 0 : \ a_s f_{yd} \cdot z - m_{Ed} = 0, \ f_{yd} = 435 \ N/mm^2 \]

\[ a_s = \frac{m_{Ed}}{f_{yd} \cdot z} = \frac{12 \cdot 10^6}{435 \cdot 90} = 306,5 \ mm^2/m > a_{s,min} \ \text{OK!} \]

\[ a_{s,min} = \rho_{min} \cdot bd = \frac{1,3}{1000} \cdot 1000 \cdot 95 = 123,5 \ mm^2/m \]

Let use Ø8,2/150 (\( a_s = 352,1 \ mm^2 \)) intensity welded mesh!

Check of further constructional rules:

\[ t \leq 150 \ mm \ \text{esetén} \ s_{max} = 150 \ mm, \ \text{rendben!} \]

\[ \Theta_{max} \leq \frac{t}{10} = \frac{120}{10} = 12 \ mm, \ \text{OK!} \]
6. Reinforcement system of simple supported and continuous one-way slabs, the distribution steel

Simple supported slab
Plan detail

Reasons and quantity of distribution steel:
- lateral supports impede transverse contraction, provoking tension
  \[ \nu_c \equiv \frac{1}{6} \approx 0.2 \rightarrow 20\% \]
  \[ a_{s,distr} = 0.2a_s \]

Distribution steel is also needed to distribute effect of uneven (concentrated) loads
Continuous slab:

Plan detail:

\[
\begin{align*}
\ell_1 & \geq 0.15 \ell_1 \\
\ell_2 & \geq 0.2 \ell_1 \\
\ell_c & \geq 1.2 \ell_c \\
0.2 \ell_2 & \geq 0.3 \ell_2 \\
50\% & \geq 50\% \\
\ell_{b,\text{min}} & \\
\end{align*}
\]

When respecting the rules indicated on the figure, no enveloping of the extreme applied moment diagram is needed. Correct order of the layers of main and distribution steel on cross-section at intermediate support:

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7. Special reinforcement details: anti-crack reinforcement, free-edge reinforcement, additional reinforcement at holes and under linear loading

anti-crack reinforcement along lateral supports of one-way slabs:

\[
> 3t  \\
> 0.15 \ell \\
\]

Free edge reinforcement and elements of additional reinforcement at holes:

danger of diagonal cracking!
Local strengthening of the slab reinforcement needed for moments due to linear (or concentrated) loading of heavier partition wall, facade wall etc.
8. Example of a floor

Elements of the reinforcement to be designed for the slab indicated on the structural plan below:
II. Stair slabs
1. Static models

Acceptable static models and design moment diagrams
2. Substitutive static model of a two-flight staircase in flight direction

Landing slabs can be regarded as wide supports, considering the support line along the axis of them: this approximation reduces significantly moments in flight direction. (The practice has proved this approximation)
3. System of reinforcement

Elements of the reinforcement system from numerical example of a two flight staircase

![Diagram of staircase with reinforcement elements labeled.

1. 11 Ø12 / 150 - 6.865
2. 11 Ø10 / 150 - 2.750
3. 11 Ø8 / 150 - 1.52
4. 11 Ø8 / 150 - 2.62
5. 11 Ø6 / 150 - 1.07

Dimensions:
- 9 x 166.7 = 1.50
- 90
- 30
- 2170
- 1900

Re...
4. Stairs spanning transversally

Stair restrained in (rc) wall

supported by parallel walls

supported by parallel stringer beams

The way of flexural design for negative and positive moments:
5. Geometry of landing with and without transverse beam

Elaboration of details like this requires intensive cooperation of the architect and the structural designer.