Choosing of cross-section dimensions of concrete structures

For choosingg the dimensions it is taken into account

a) Ultimate limit state
   - Over-reinforced cross-section is **not** recommended =>
     reinforcement should yield so the steel strain $\varepsilon \geq \varepsilon_{yk}$ (yield strain) when compression strain of concrete is restricted to the value $\varepsilon \leq \varepsilon_{cu}$ =0,035 %.

     Depth of the compression zone $x_b \leq \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_{yk}} = \frac{0.0035}{0.0035 + 0.0025} = 0{,}583$

     Un-dimensional reinforcement degree

     $$\omega = \beta = \frac{y}{d} = \frac{0{,}8x}{d} \leq 0{,}8 \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_{yk}} = \omega_b = \beta_b = 0{,}467$$ balanced reinforcent degree

     Un-dimensional bendiong moment $\mu \leq \omega_b (1 - \frac{\omega_b}{2}) = 0{,}358$

     For assuring adequite rotational capacity the proportional depth of the compression zone should be below
     in statical determinate beams $\beta \leq 0.9\ \beta_b$ => $\mu \leq 0{,}322$
     continuous (undetermininate) $\beta \leq 0{,}3$ => $\mu \leq 0{,}255$

b) Economically optimum

If a depth of the cross-section is chosen so that the balanced reinforcement amount is needed in the ultimate limit state, deflections are mostly critical and the structure is uneconomical due to the great reinforcement amount.

The cross-section is economical if $\omega \approx 0{,}3 \ldots 0{,}4$

Rectangular beam

Flexural resistance $M_{Rd} = \mu \cdot b \cdot d^2 \cdot f_{cd}$ => $d = \sqrt{\dfrac{M_{Ed}}{\mu \cdot b \cdot f_{cd}}} = 2 \ldots 1{,}8 \sqrt{\dfrac{M_{Ed}}{b \cdot f_{cd}}}$

$M_{Rd} = M_{Ed}$ $\qquad$ $\omega = 0{,}3 \ldots 0{,}4$

Proper width b= 0,4...0,6 d => $d = 2 \ldots 1{,}6 \cdot \sqrt[3]{\dfrac{M_{Ed}}{f_{cd}}}$

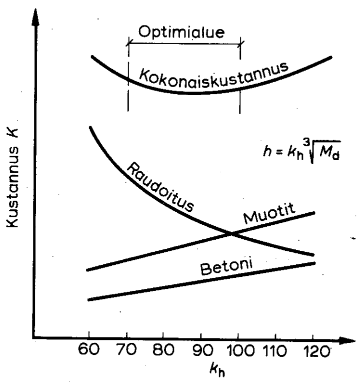
If it is assumed that $\omega=0{,}3$ ja b= 0,5 d => $d = 2 \cdot \sqrt[3]{\dfrac{M_{Ed}}{f_{cd}}}$

Flange beam

Total depth (the depth of the web + the thickness of the slab)

$h = (70 \ldots 100) \cdot \sqrt[3]{|M_{Ed}|}$ $\qquad$ h (mm) ; M_{Ed} (kNm)

Width of the web $b_w = (0{,}4 \ldots 0{,}5)\,h$



Laattapalkin optimikorkeus.

Precast beam

$$h \geq 1{,}75 \cdot \sqrt{\frac{M_{Ed}}{b_w \cdot f_{cd}}}$$

width of the web $b_w = (0{,}4 \ldots 0{,}5)\,h$

Slab

One-way slab:
Imposed load 30...40 % of the total load, the un-dimensional reinforcement degree ω=0,2...0,25

Dimensioning width of a slab b = 1m => $d = 2{,}5 \cdot \sqrt{\frac{m_{Ed}}{f_{cd}}}$

Optimum value of un-dimensional reinforcement degree $\omega_{opt} = \frac{1}{1+k}$ $k = \frac{\rho_s \cdot k_s \cdot f_{cd}}{\frac{h}{d} \cdot k_c \cdot f_{yd}}$

where ρ_s is the density of steel 7850 kg/m^3
k_s is the price of the assembled reinforcement €/kg
k_c is the price of casted concrete €/m^3
f_{cd} is the design compressive value of concrete
f_{yd} on raudoituksen vetolujuuden laskenta-arvo
h is the detph of the slab
d is the effective detph of the slab

Two-way slab:
Un-dimensional reinforcement degree ω = 0,10 ... 0,15

Dimensioning width of a slab b = 1m => $d = 3 \cdot \sqrt{\frac{m_{Ed}}{f_{cd}}}$

The rotational capasity is adequite for instance the using of yiel-line theory ($\omega \le 0{,}1$)

c) Deflection

Beam

Simply supported beam h = L/12 .... L/16

(Total depth= depth of the web+ thickness of the slab)

Contnuous beam h = L/20

Suitable guidance value due to loading and supporting h = L/10 .... L/18

When one-way slab is supported on a beam, the depth of the beam should be at least

$$\frac{h_b}{L_b} \geq \frac{5}{3} \cdot \frac{h_s}{L_s}$$

When two-way slab is supported on a beam, the depth of the beam should be at least

$$\frac{h_b}{L_b} \geq 2{,}5 \cdot \frac{h_s}{\min(L_s, L_x)}$$

where h_b is the total depth of the beam(the depth of the web + the thickness of the slab)
L_b is the span of the beam
h_s is the thickness of the slab
L_s is the span of the slab in the direction of the beam
L_x is the smaller span of the two-way slab

Then the deflection of the beam does affect essentially to the distribution of the section forces of the slab. The section ferces of the slab can be calculated as the slab is supported on the rigid supports or walls.

Slab

One-way slab or flat slab supportd on cloumns:

- simply supported slab $d \approx L/24$
- continuous slab $d \approx L/30$
- cantilever slab $d \approx L/12$

d) Fore resisistance

e) Requirements of noise insulation (slabs)

f) Stability

To avoid the lateral bucling of a preacast beam during lifting and transporting the dimensions of the cross-section should be fulfill the requirements:

$$\frac{L}{b} < 60$$

$$\frac{L \cdot h}{b^2} < 250$$

The later condition is critical if b > 0,25 h.

g) Dimension recommendation

Thickness of the slab is nx20 mm (160 mm, 180 mm, 200 mm....)

The deth of the web is nx1M (100 mm):n kerrannainen – 20 mm (380,480,580 mm)

The width of the beam is nx 1M – 20 mm

The side dimension of the column is nx1M:n kerrannainen – 20 mm :

280*280 380*380 480*480 580*580

280*380 380*480 480*580

1M is the modul size = 100 mm (2M=200 mm, 10M=1000 mm)

20 mm is reserved for tolerancies and joints

Columns

For prelimanary dimensioning:

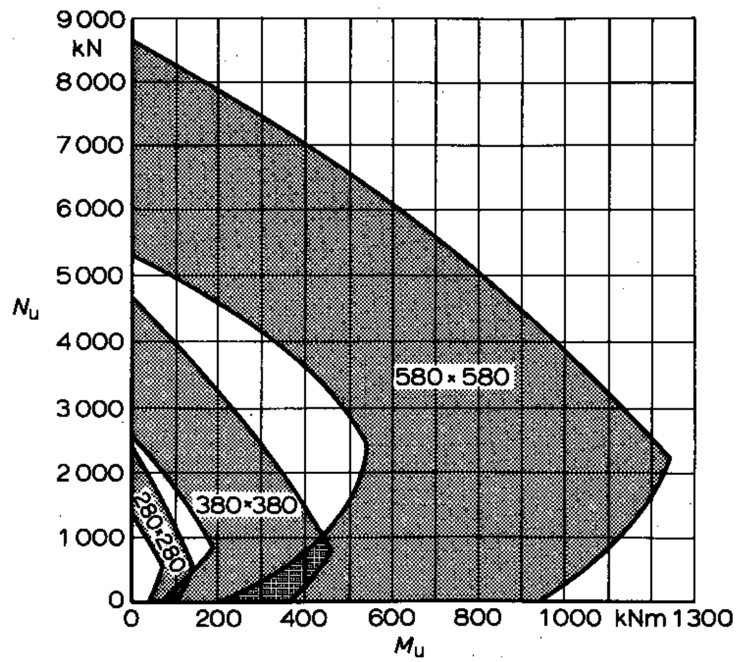
Initial eccentricity: lateral supported (braced) structure $e_i \approx L_c/300$
(L_c is the bucling lenth of the column)
un-braced structure $e_i \approx L/150$
(L is the length of the column) Eccentricity
Effeentricty of the load: braced structure $e_2 \approx 0$
un-braced structure $e_2 \approx e_i$ (structure cast in place)

If $N_{Ed}\, e_d < 450$ kNm: if $e_d < 100$ mm $\Rightarrow A_c > \frac{1{,}1 N_{Ed}}{f_{cd}}$

if 200 mm $< e_d <$ 500 mm $\Rightarrow A_c > \frac{(2...3) N_{Ed}}{f_{cd}}$

if $e_d > 700$ mm $\Rightarrow h \geq 2{,}5 \cdot \sqrt{\frac{N_{Ed}}{b \cdot f_{cd}}}$

For ensuring the adequite rotational capacity the ud-dimensional normal force should not be greater than $\nu = \frac{N_{Ed}}{b \cdot h \cdot f_{cd}} \leq 0{,}4$



Mittasuosituksen mukaisten neliöpilarien kapasiteettikäyrästöt.

Resistance curves for square cross-section columns according to dimension recommendation
Concrete C25/30

Reinforced walls

Thickness of reinforced wall $h \geq (1{,}2....4{,}0) \cdot \frac{n_d}{f_{cd} \cdot (1 + 2 \cdot \omega)}$

For preliminary dimensiong $\omega \approx 0$ or the minimum reinforcement ratio $\omega_{min} = 0{,}002 \cdot \frac{f_{yd}}{f_{cd}}$