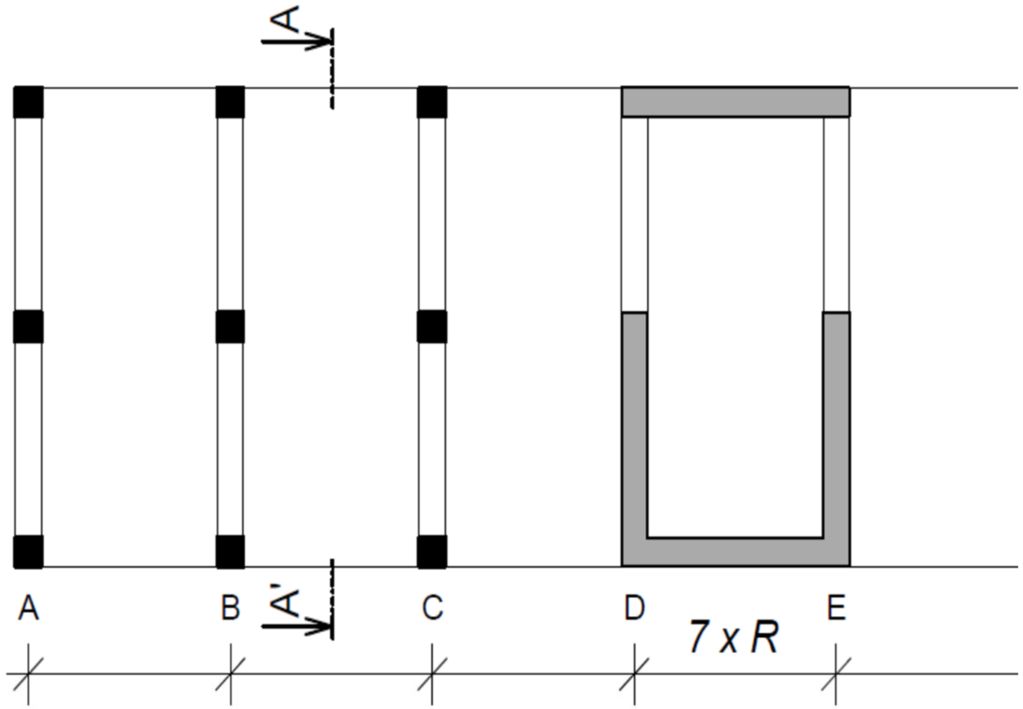
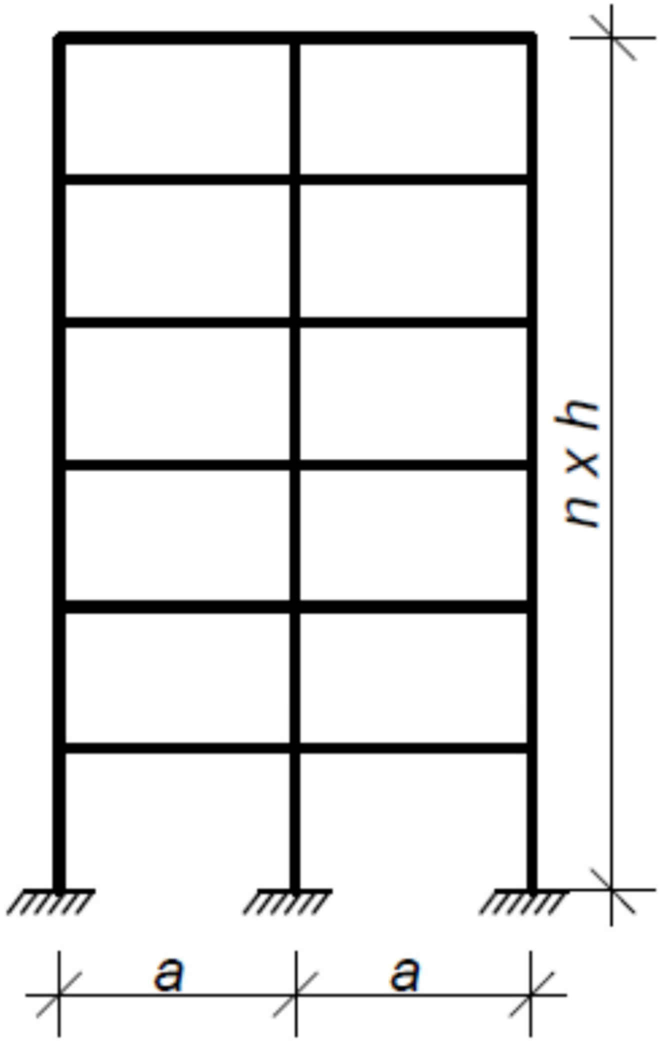
1st task:
Frame Structure





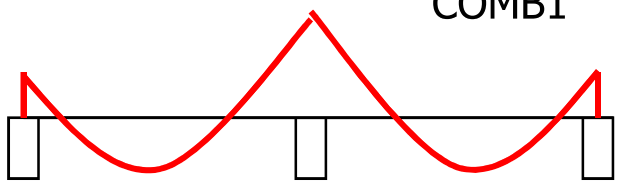
Drawing of reinforcement

- Bending moments layout
- Lengths of reinforcement
- Transversal reinforcement of columns (ties)
- Longitudinal section
- Transversal sections

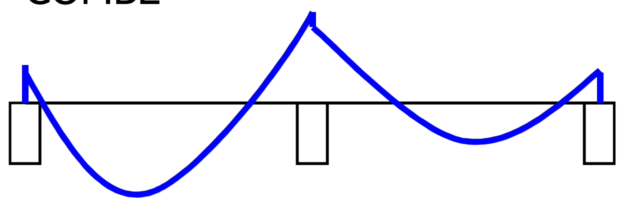
Bending moments layout

- Create an **envelope** of bending moments in the beam from 2 load combinations

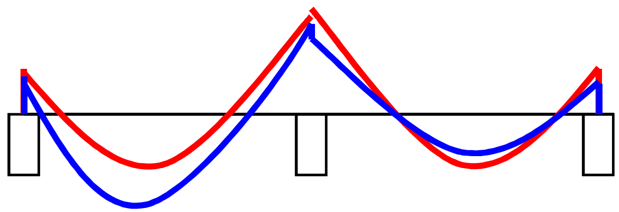
COMB1



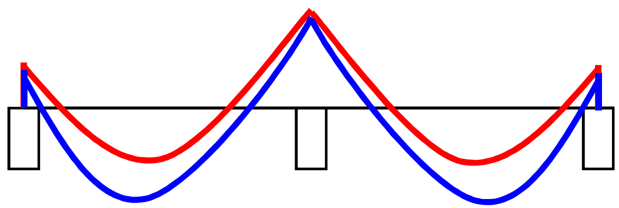
COMB2



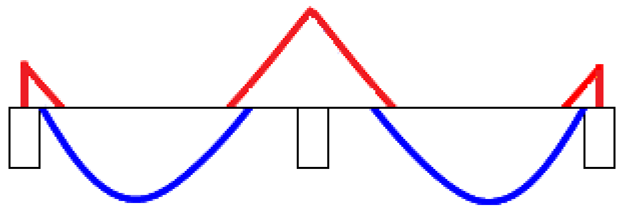
COMB1+COMB2 (this is what you received from Idea Statica)



Symmetry



Envelope

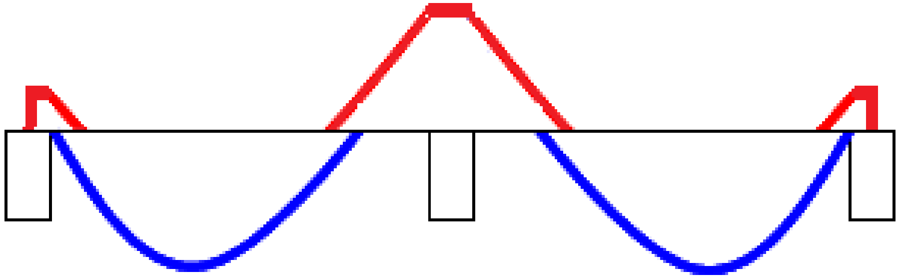


HOW?

- *In AutoCAD* – printscreen the curves from Idea Statica > insert to model space > adjust to the desired scale > trace the curves by **splines**
- *Manually* – draw the maximum bending moments in scale > connect by **paraboles**

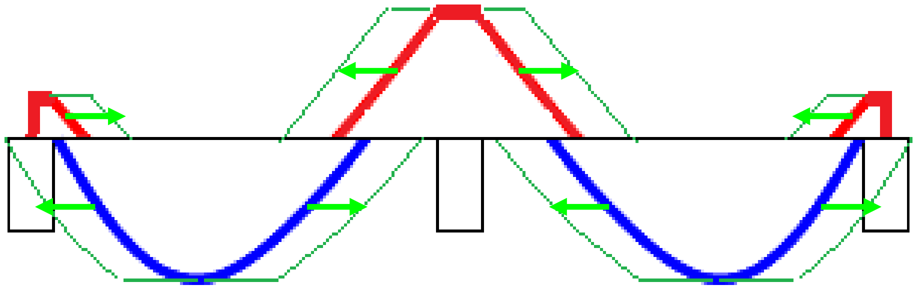
Bending moments layout

- Reduce support moments to values in the face of the column (like in design of reinforcement)



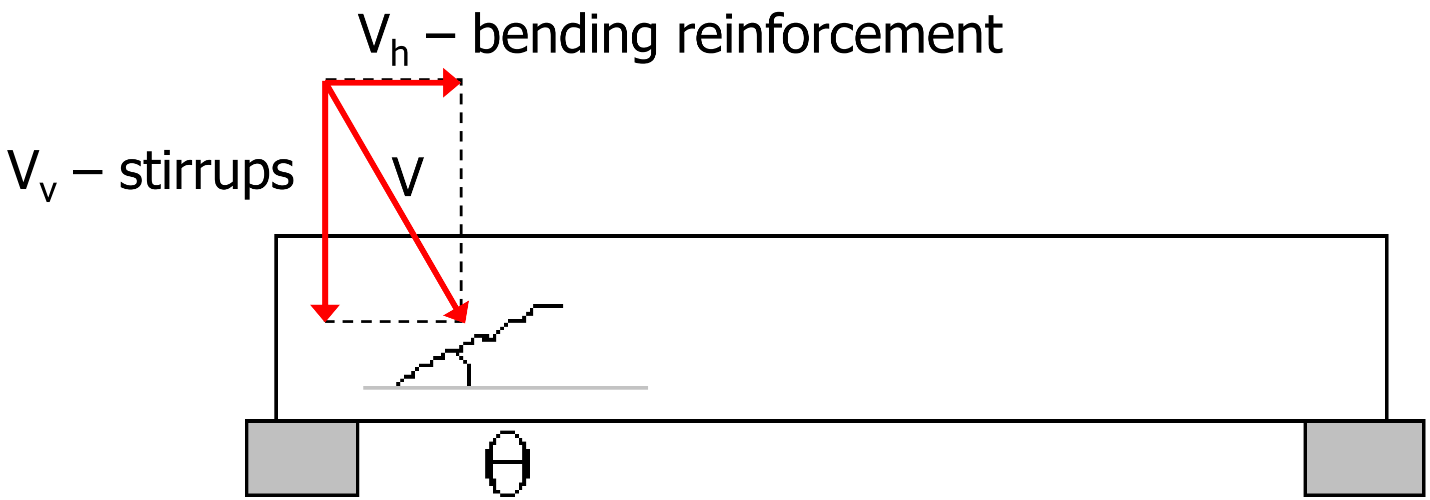
- Shift the envelope by $a_l = \frac{z}{2}\cot\theta$

Lever arm of internal forces, see design of reinforcement



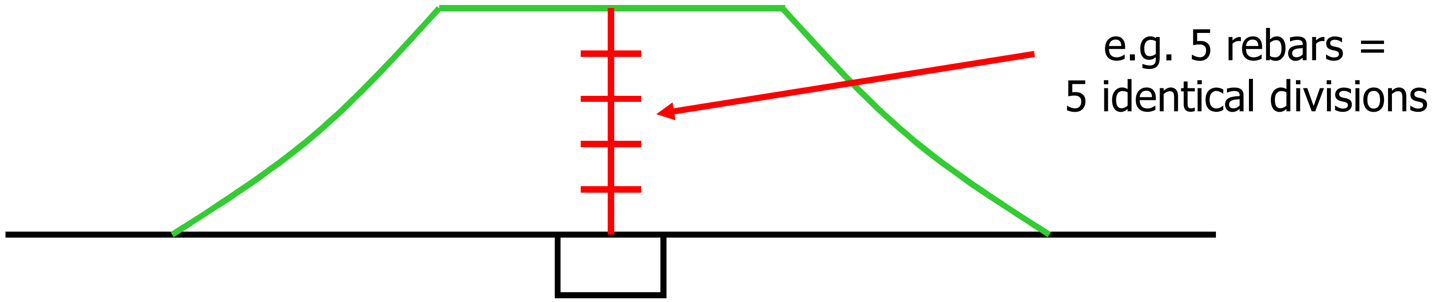
Why the shift is necessary?

- Shear stresses are perpendicular to shear cracks
- Shear force has vertical and horizontal part
- Stirrups are vertical => horizontal part of shear force is carried by bending reinforcement

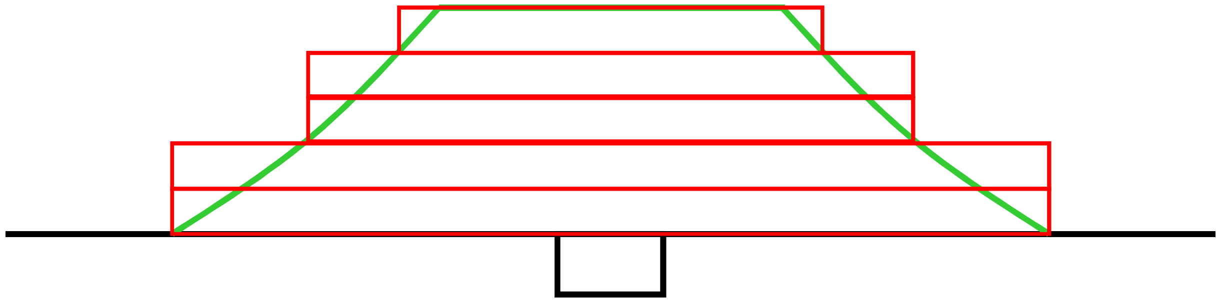


Lengths of bending reinforcement

- Divide the design bending moment by the number of rebars designed for the cross-section

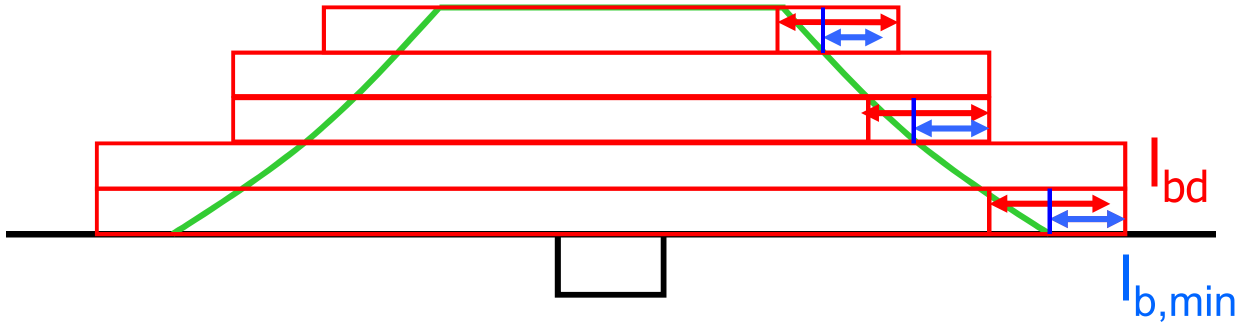


- 2 outer rebars must have the full length, remaining rebars can be shorter

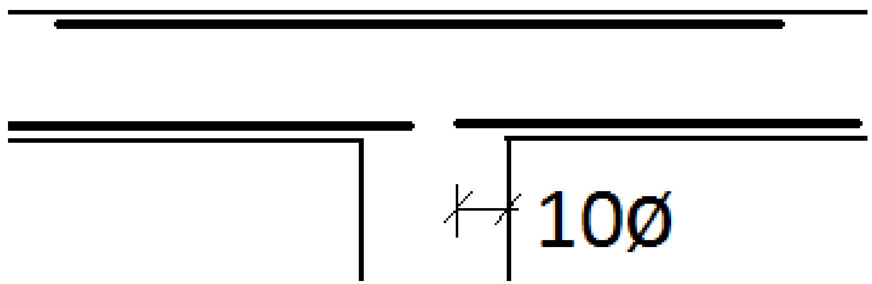


Lengths of bending reinforcement

- Add anchorage length (calculation – see later)



- For lower reinforcement, at least two outer bars must be extended at least 10ø behind the face of the column



Column ties

- Diameter – estimate:

Diameter of vertical column reinforcement

$$\varnothing_{\mathrm{tie}} \geq \max\left(\frac{\varnothing_{\mathrm{s}}}{4}; 6\ \mathrm{mm}\right)$$

- Basic spacing:

$$s_1 \leq \min\left(20\varnothing_{\mathrm{s}}; \min\left(b_{\mathrm{col}}; h_{\mathrm{col}}\right); 400\ \mathrm{mm}\right)$$

- Spacing in lapping area, spacing below beam and above slab in distance max(b_{col}; h_{col})

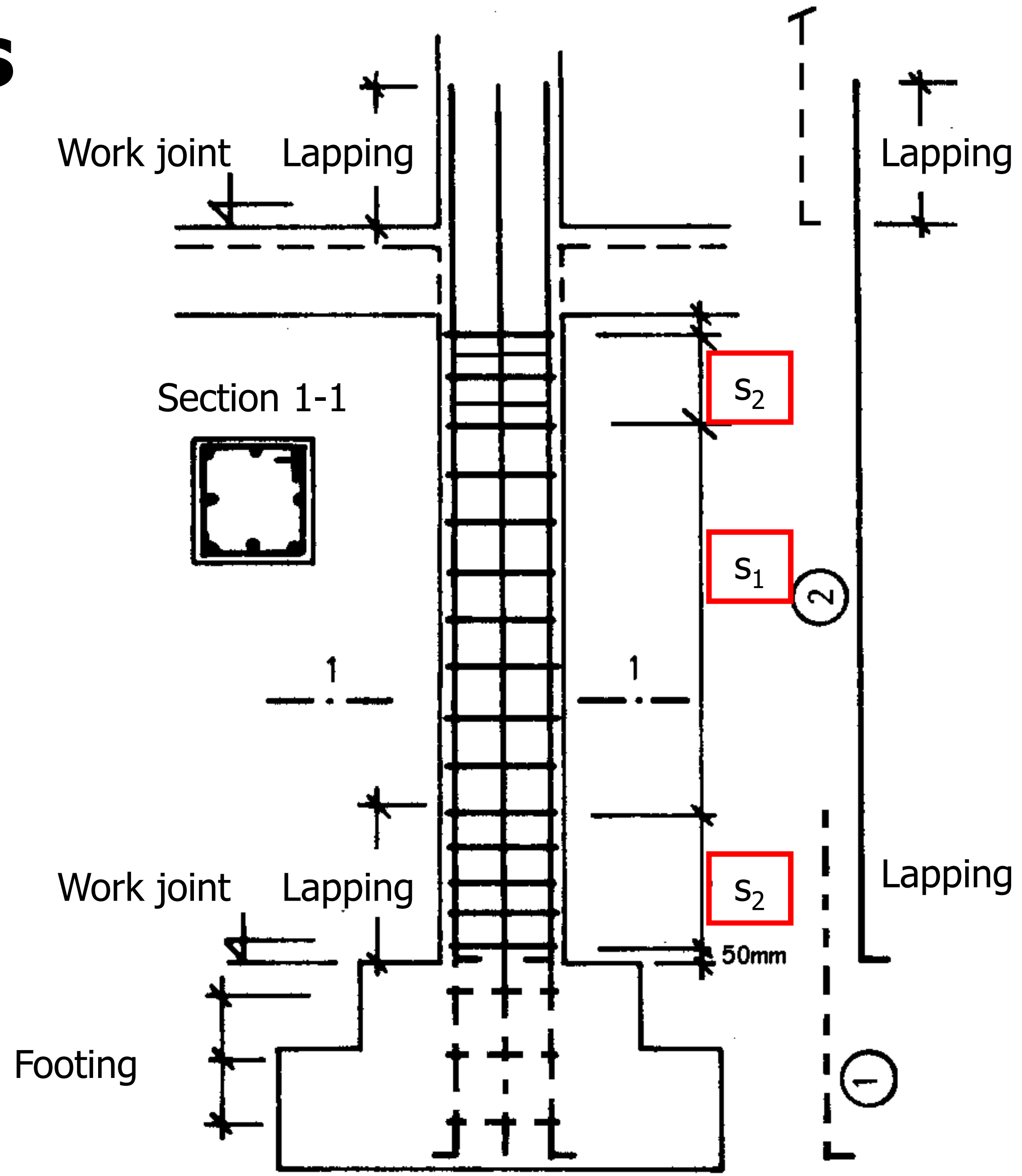
$$s_2 \leq 0.6 s_1$$

- Calculate lapping length – see later

Column ties

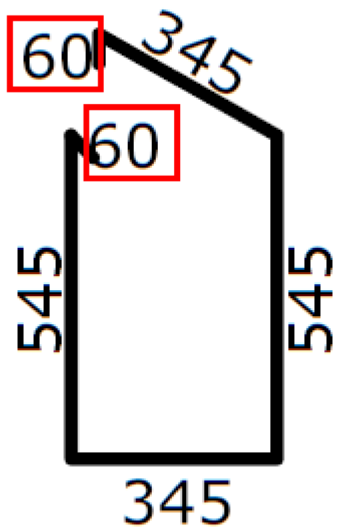
Column ties prevent buckling of reinforcement

Work joints: after concreting of 1st floor, you have to wait some time before you concrete the 2nd floor => column reinforcement is connected by lapping

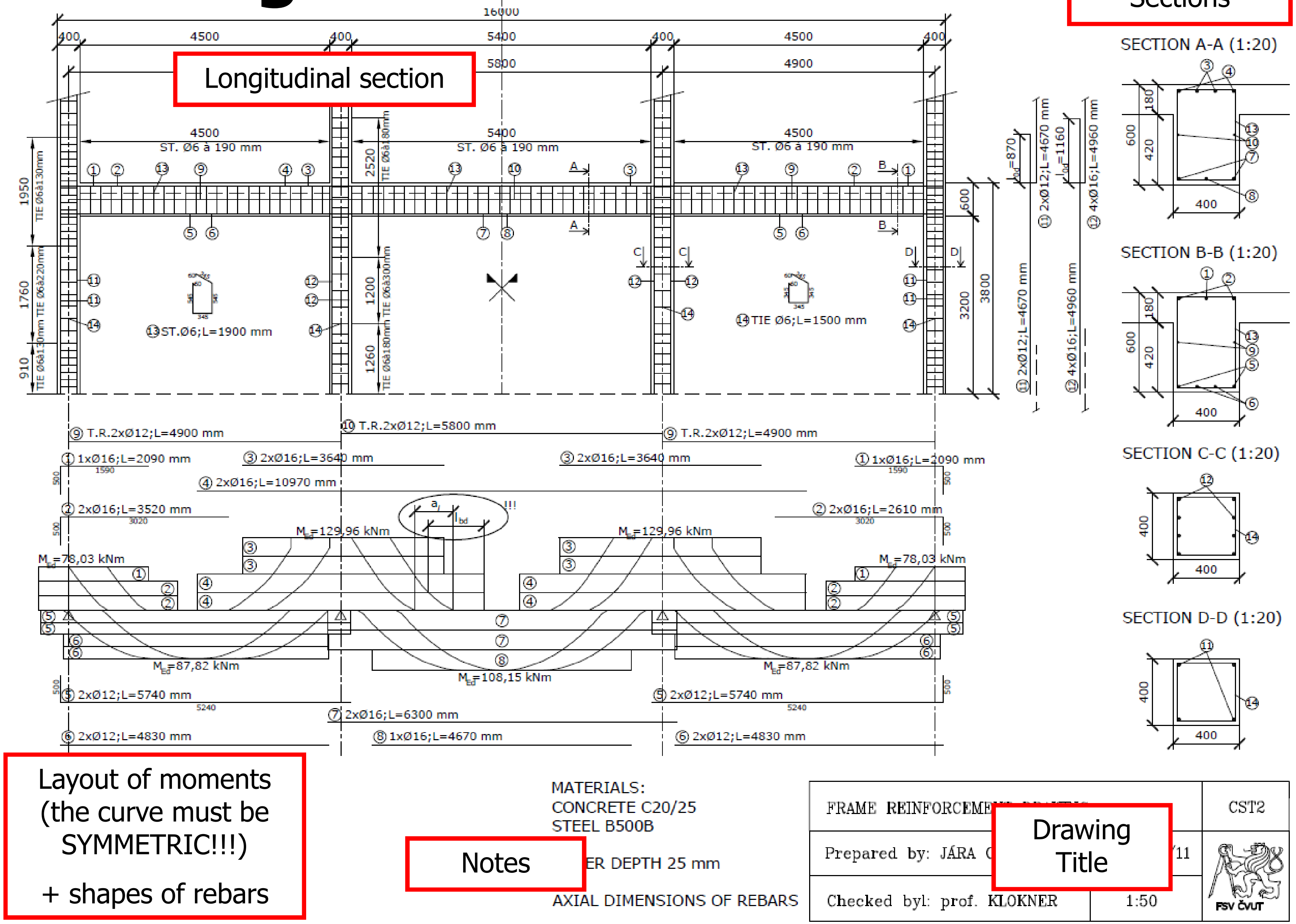


Tie/stirrup ends

- To close the tie/stirrup
- Length can be estimated as 10times the tie/stirrup diameter

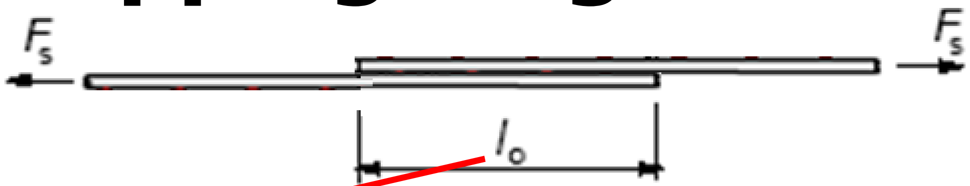


Drawing of reinforcement



Lapping length

The length required to transfer a force from one rebar to another rebar



$$\boxed{l_{0,\mathrm{d}} = \alpha_1 \alpha_2 \alpha_3 \alpha_5 \alpha_6 l_{\mathrm{b,rqd}} \geq l_{0,\mathrm{min}}}$$

Desing lapping length

$$\alpha_1 = \alpha_2 = \alpha_3 = \alpha_5 = 1.0$$

Coefficients expressing influence of shape of the end of rebars, cover depth, transverse unwelded rebars and transverse pressure

$$\alpha_6 = 1.5$$

Coefficient expressing amount of lapped reinforcement

$$l_{\mathrm{b,rqd}} = \frac{\varnothing}{4} \cdot \frac{\sigma_{\mathrm{sd}}}{f_{\mathrm{bd}}}$$

Diameter of steel bar

Basic anchorage length

$$\sigma_{\mathrm{sd}} = f_{\mathrm{yd}}$$

Stress in the reinforcement

$$f_{\mathrm{bd}} = 2.25 \cdot \eta_1 \cdot \eta_2 \cdot f_{\mathrm{ctd}}$$

Bond stress between the rebars and concrete

$$\eta_1 = \boxed{1.0} \text{ or } 0.7$$

Coefficient expressing position of steel bars during concreting. 0.7 for bars more than 250mm above formwork, 1.0 in other cases

$$\eta_2 = 1.0$$

Coefficient expressing diameter of steel bars

$$f_{\mathrm{ctd}} = \frac{f_{\mathrm{ctk,0.05}}}{1.5}$$

Tensile strength of concrete, see table of concrete strengths

$$l_{0,\mathrm{min}} = \max\left(0.3\alpha_6 l_{\mathrm{b,rqd}}, 15\varnothing, 200\ \mathrm{mm}\right)$$

Minimum lapping

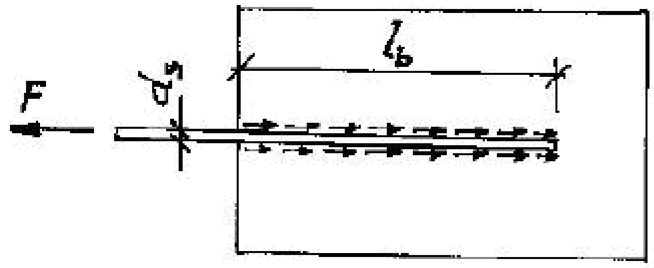
Anchorage length

The length required to transfer a force from a rebar to the surrounding concrete

- Very similar to calculation of lap length
- Basic anchorage length $l_{b.rqd}$ – see lap length
- Design anchorage length l_{bd}

$$l_{\mathrm{b,d}} = \alpha_1 \alpha_2 \alpha_3 \alpha_4 \alpha_5 l_{\mathrm{b,rqd}} \geq l_{\mathrm{b,min}}$$

$$l_{\mathrm{b,min}} = \max\left(0.3 l_{\mathrm{b,rqd}}, 10\varnothing, 100\ \mathrm{mm}\right)$$



- There is NOT coefficient α_6 expressing amount of lapped reinforcement (no lapping)
- There IS α_4 coefficient expressing effect of transverse welded reinforcement. In our case, $\alpha_4 = 1.0$