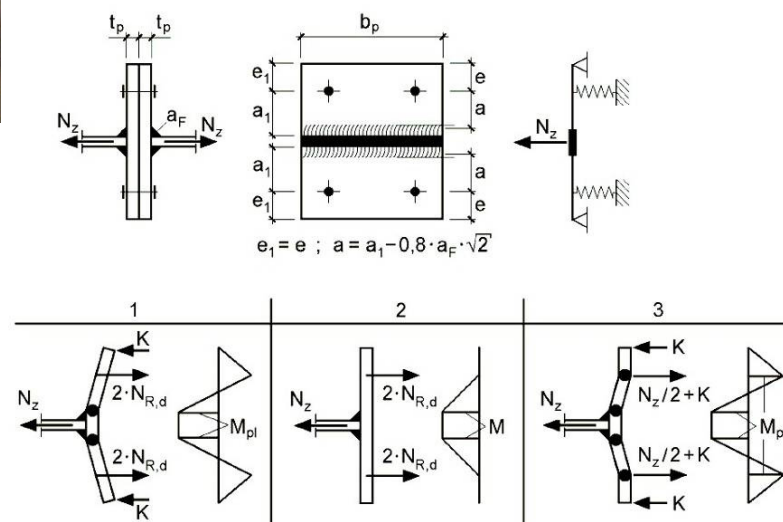
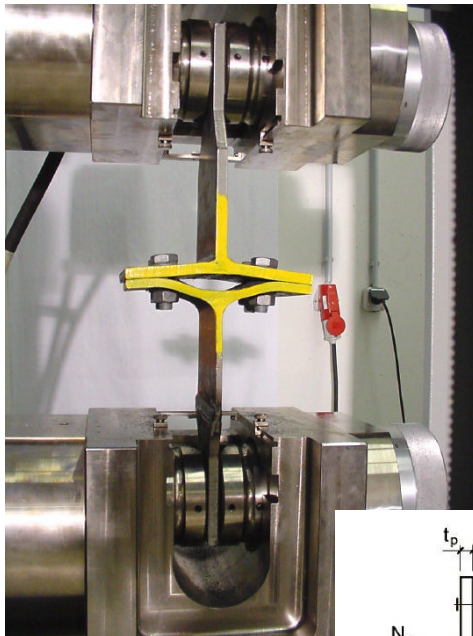
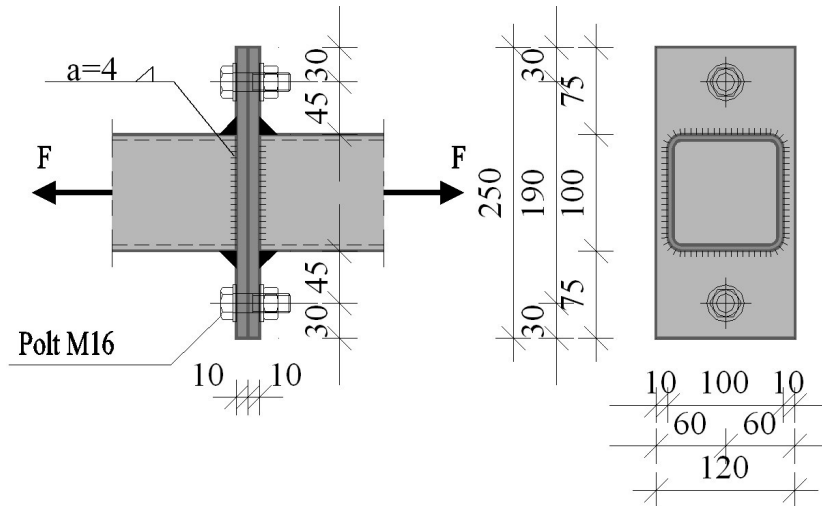
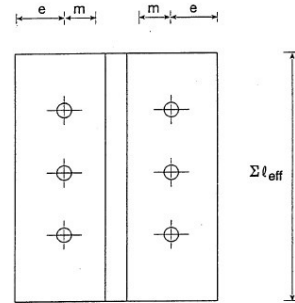
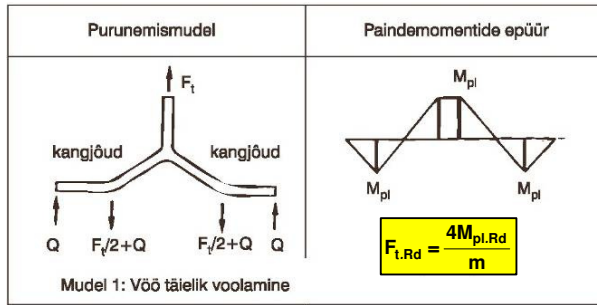


### Harjutus 5.

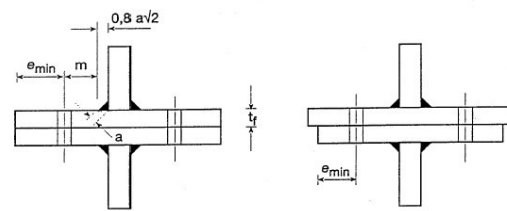
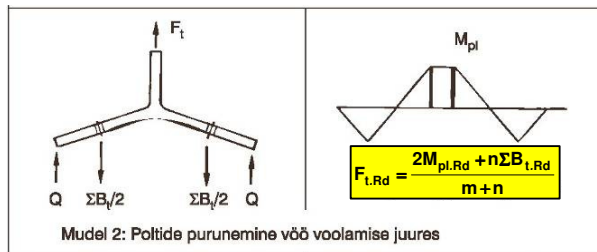
Kontrollida joonisel toodud poltide ja terasplaatide kandevõimet. Terasse tugevusklass S235, poltide tugevusklass 8.8, poldi keermestatud osa pindala  $A_s = 158\text{mm}^2$ .



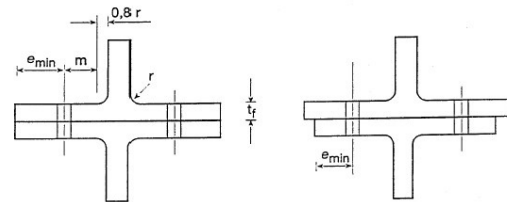
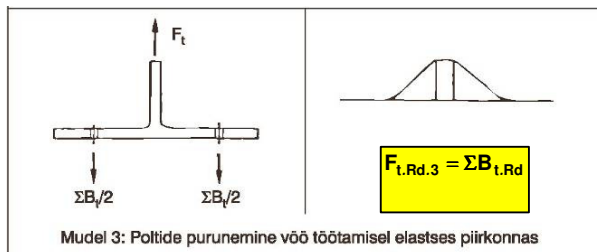
Mudel 1:



Mudel 2:



Mudel 3:



Mudel 1:

$$F_{t,Rd} = \frac{4M_{pl,Rd}}{m} = \frac{4 \cdot 0.64}{0.045} = 62.2 \text{ kN} = \text{min!}$$

$$M_{pl,Rd} = \frac{l_{eff} \cdot t^2 \cdot f_y}{4 \cdot \gamma_{M0}} = \frac{120 \cdot 10^2 \cdot 235}{4 \cdot 1.0} = 0.70 \text{ kNm}$$

Mudel 2:

$$F_{t,Rd} = \frac{2 \cdot M_{pl,Rd} + n \cdot \Sigma B_{t,Rd}}{m + n} = \frac{2 \cdot 0.70 + 0.030 \cdot 2 \cdot 91.0}{0.045 + 0.030} = 91.5 \text{ kN}$$

$$m = 45 \text{ mm}$$

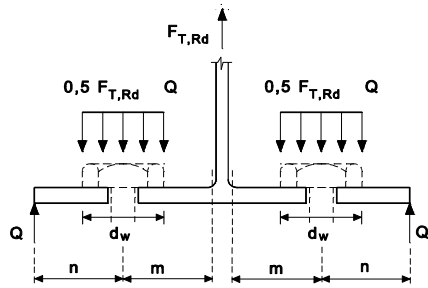
$$n = e_{\min} = 30 \text{ mm}$$

$$e_{\min} \leq 1.25m = 1.25 \times 45 = 56.3 \text{ mm} \rightarrow \text{OK}$$

Mudel 3:

$$F_{t,Rd.3} = \Sigma B_{t,Rd} = 2 \times 91.0 = 182.0 \text{ kN}$$

Liite kandevõime on 62kN, lisaks tuleb kontrollida keevist ja toru!

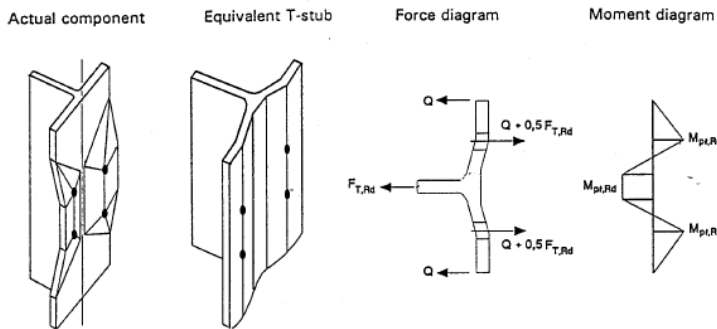


Poldi tõmbekandevõime: 
$$F_{t,Rd} = \frac{0.9 \cdot f_{ub} \cdot A_s}{\gamma_{Mb}} = \frac{0.9 \cdot 800 \cdot 158}{1.25} = 91.0 \text{ kN}$$

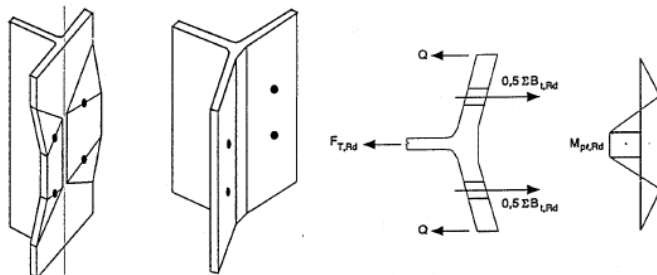
Poldipea läbistantsimine: 
$$F_{p,Rd} = \frac{0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u}{\gamma_{M2}} = \frac{0.6 \cdot 3.14 \cdot 37.5 \cdot 10 \cdot 360}{1.25} = 138.3 \text{ kN}$$

Poldipea keskmine läbimõõt: 
$$d_m = \frac{24 + 27}{2} = 25.5 \text{ mm}$$

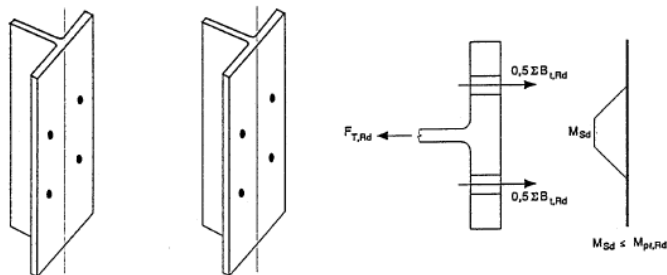
Määravaks saab poldi tõmbekandevõime:  $B_{t,Rd} = 91.0 \text{ kN}$



Mode 1: Complete yielding of the flange



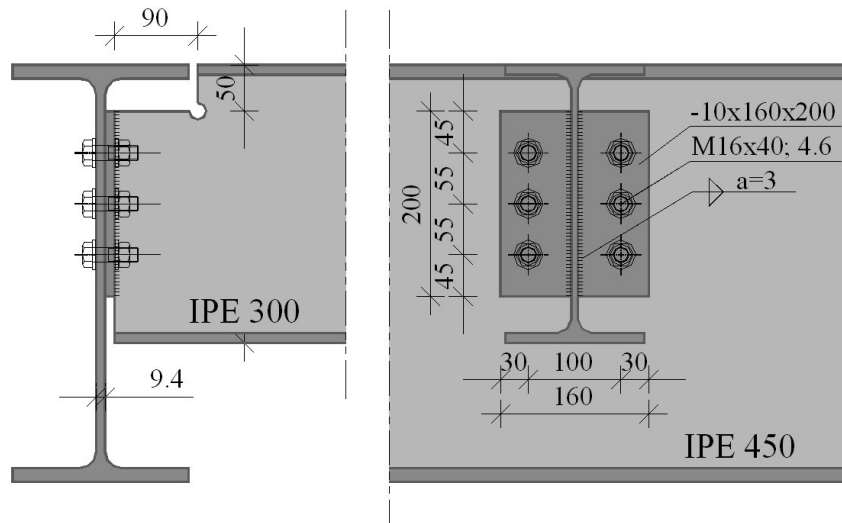
Mode 2: Bolt failure with yielding of the flange



Mode 3: Bolt failure

## Harjutus 6.

Leida joonisel toodud liite kandevõime. Terase tugevusklass S235, poltide M16 tugevusklass 4.6,  $d_0=18\text{mm}$ .



### Keevise kandevõime

$$F_{w,Rd} = \frac{360 \cdot 2 \cdot 200 \cdot 3}{\sqrt{3} \cdot 0.8 \cdot 1.25} = 249.4 \text{ kN}$$

### Poltide lõikekandevõime

$$F_{v,Rd} = 6 \cdot \frac{0.6 \cdot 400 \cdot 158}{1.25} = 6 \cdot 30.3 = 181.8 \text{ kN}$$

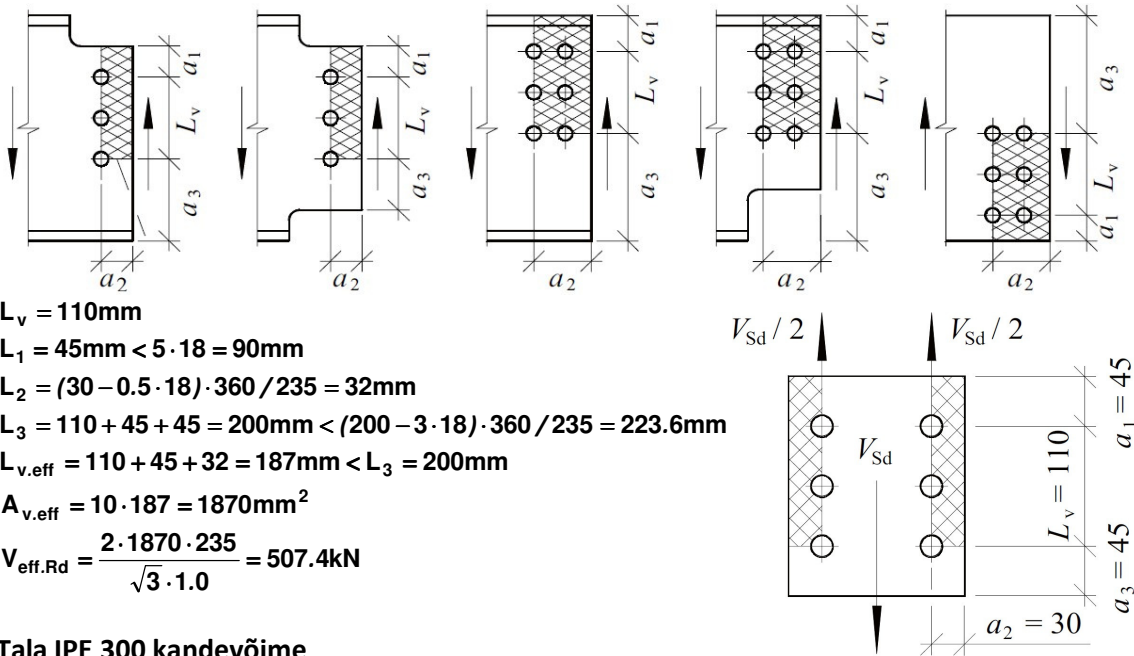
### Poldiavade muljumiskandevõime IPE450

$$F_{b,Rd} = 6 \cdot \frac{2.5 \cdot 0.76 \cdot 360 \cdot 16 \cdot 9.4}{1.25} = 6 \cdot 82.3 = 493.8 \text{ kN}$$

$$\alpha_b = \begin{cases} \frac{45}{3 \cdot 18} = 0.83 \\ \frac{400}{360} = 1.11 \\ \frac{55}{3 \cdot 18} - 0.25 = 0.76 \\ 1.0 \end{cases}$$

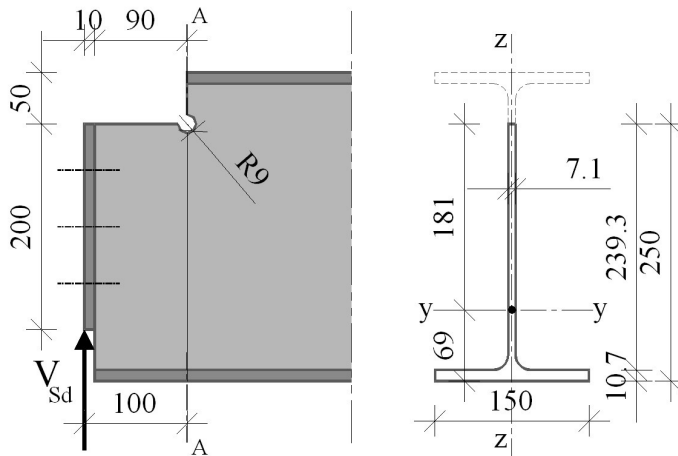
$$k_1 = \begin{cases} \frac{2.8 \cdot 30}{18} - 1.7 = 2.96 \\ \frac{1.4 \cdot 100}{18} - 1.7 = 6.07 \\ 2.5 \end{cases}$$

### Plaadi kandevõime mööda avade rida



### Tala IPE 300 kandevõime

$$V_{Rd} = \frac{200 \cdot 7.1 \cdot 235}{\sqrt{3} \cdot 1.0} = 192.6\text{kN}$$



$$y = \frac{150 \cdot 10.7 \cdot 5.3 + 239.3 \cdot 7.1 \cdot 130.4}{150 \cdot 10.7 + 239.3 \cdot 7.1} = 69\text{mm}$$

$$I_y = \frac{150 \cdot 10.7^3}{12} + 150 \cdot 10.7 \cdot 63.6^2 + \frac{7.1 \cdot 239.3^3}{12} + 7.1 \cdot 239.3 \cdot 61.1^2 = 20968362\text{mm}^4$$

$$M_{el,y,Rd} = \frac{W_{el,y} \cdot f_y}{\gamma_{M0}} = \frac{20968362 \cdot 235}{181 \cdot 1.0} = 27.2\text{kNm} \rightarrow V_{Sd} = \frac{27.2}{0.1} = 272\text{kN}$$

$$V_{el,z,Rd} = \frac{\tau_{Rd} \cdot I_y \cdot t_w}{S_y} = \frac{235 \cdot 20968362 \cdot 7.1}{\sqrt{3} \cdot 1.0 \cdot 7.1 \cdot 181 \cdot 90.5} = 173.6\text{kN}$$

Liite kandevõime on 173.6kN



### Poldi lõikekandevõime

$$F_{v,Rd} = \frac{0.6 \cdot 800 \cdot 158}{1.25} = 60.6 \text{ kN}$$

### Poldiava muljumiskandevõime IPE300

$$F_{b,Rd} = \frac{2.5 \cdot 0.49 \cdot 360 \cdot 16 \cdot 7.1}{1.25} = 40.0 \text{ kN}$$

$$\alpha_b = \begin{cases} \frac{35}{3 \cdot 18} = 0.64 \\ \frac{800}{360} = 2.22 \\ \frac{40}{3 \cdot 18} - 0.25 = 0.49 \\ 1.0 \end{cases}$$

$$k_1 = \begin{cases} \frac{2.8 \cdot 35}{18} - 1.7 = 3.74 \\ 2.5 \end{cases}$$

### Poldile tulev jõud

$$I_p = \sum r^2 = \sum (x_i^2 + y_i^2) = 2 \cdot (25^2 + 65^2) = 9700 \text{ mm}^2$$

$$F_y = \frac{M_d \cdot r_{max}}{I_p} = \frac{5.0 \cdot 65 \cdot 10^3}{9700} = 33.5 \text{ kN}$$

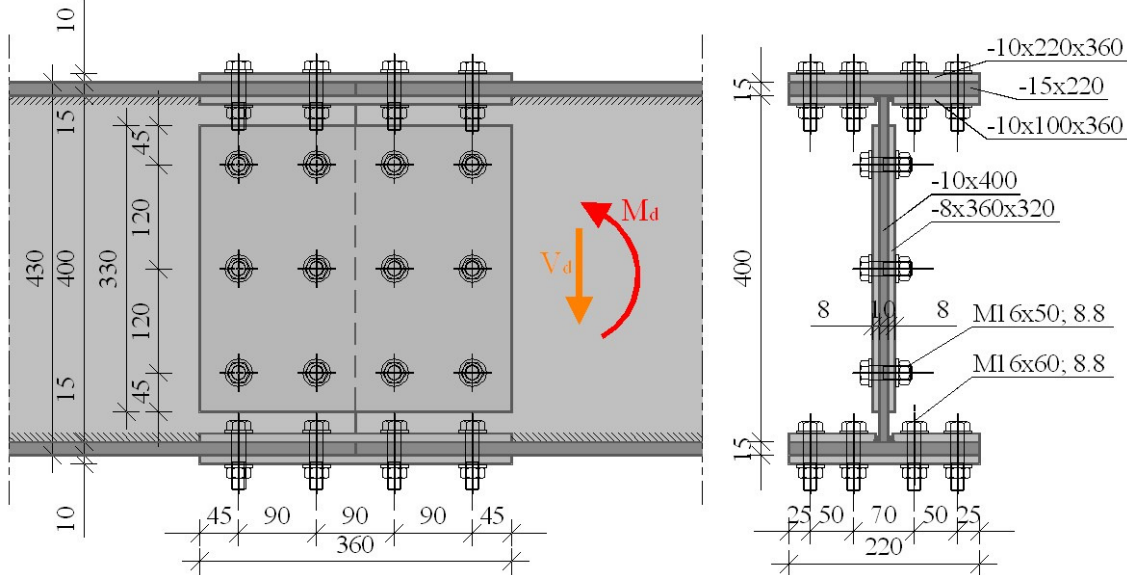
$$F_z = \frac{V_d}{4} = \frac{100}{4} = 25.0 \text{ kN}$$

$$F_{res} = \sqrt{33.5^2 + 25.0^2} = 41.8 \text{ kN} > 40.0 \text{ kN}$$

Liite kandevõime ei ole tagatud!

## Harjutus 8.

Leida sõlmes toodud poldühendusele tulevad jõud! Sõlmes mõjub painemoment  $M_{Ed} = 200\text{kNm}$  ja põikjõud  $V_{Ed} = 60\text{kN}$ . Poldid M16.



### Poldiaukude vahekaugused ja kaugused elementide äärtest

Sein:

$$e_1 = 45\text{mm} > 1.12d_0 = 1.12 \cdot 18 = 20.2\text{mm}$$

$$p_1 = 90\text{mm} > 2.2d_0 = 2.2 \cdot 18 = 39.6\text{mm}$$

$$e_2 = 45\text{mm} > 1.5d_0 = 1.5 \cdot 18 = 27\text{mm}$$

$$p_2 = 120\text{mm} > 3.0d_0 = 3.0 \cdot 18 = 54\text{mm}$$

Vöö:

$$e_1 = 45\text{mm} > 1.12d_0 = 1.12 \cdot 18 = 20.2\text{mm}$$

$$p_1 = 90\text{mm} > 2.2d_0 = 2.2 \cdot 18 = 39.6\text{mm}$$

$$e_2 = 25\text{mm} < 1.5d_0 = 1.5 \cdot 18 = 27\text{mm}$$

$$p_2 = 50\text{mm} < 3.0d_0 = 3.0 \cdot 18 = 54\text{mm}$$

Vöödel jäävad  $e_2$  ja  $p_2$  väärtused väiksemaks lubatust. Ääre- ja vahekaugust võib vähendada vastaval kuni  $e_2=1,2d_0$  ja  $p_2=2,4d_0$  juhul, kui muljumiskandevõimet vähendada teguriga  $2/3$ .

$$e_2 = 25\text{mm} > 1,2d_0 = 1,2 \cdot 18 = 21.6\text{mm}$$

$$p_2 = 50\text{mm} > 2,4d_0 = 2,4 \cdot 18 = 43.2\text{mm}$$

$$\{e_1, e_2\} < 12t = 12 \cdot 10 = 120$$

$$\{p_1, p_2\} < 14t = 14 \cdot 10 = 140$$



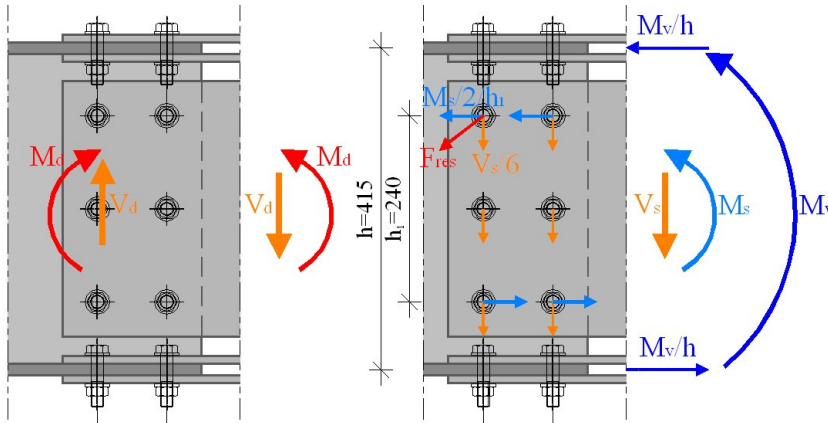
Keevitatud tala parameetrid:

$$I_{\text{sein}} = \frac{1 \cdot 40^3}{12} = 5333 \text{ cm}^4$$

$$I_{\text{vöö}} = 2 \cdot \left( \frac{22 \cdot 1.5^3}{12} + 22 \cdot 1.5 \cdot 20.75^2 \right) = 28429 \text{ cm}^4$$

$$I_{\text{tala}} = I_{\text{sein}} + I_{\text{vöö}} = 5333 + 28429 = 33762 \text{ cm}^4$$

Leiame paindemomendi jaotuse vööde ja seina vahel:



$$I_{\text{sein}}^{\%} = \frac{I_{\text{sein}}}{I_{\text{tala}}} \cdot 100\% = \frac{5333}{33762} \cdot 100\% = 16\%$$

$$I_{\text{vöö}}^{\%} = \frac{I_{\text{vöö}}}{I_{\text{tala}}} \cdot 100\% = \frac{28429}{33762} \cdot 100\% = 84\%$$

$$M_s = M_{sd} \cdot 17\% = 200 \cdot 16\% = 32 \text{ kNm}$$

$$M_v = M_{sd} \cdot 83\% = 200 \cdot 84\% = 168 \text{ kNm}$$

Poldi kandevõime (lõige, muljumine)

$$F_{Rd} = 60 \text{ kN}$$

Seinas ühele poldile tulev jõud:

$$I_p = \sum r^2 = \sum (x^2 + y^2) = 4 \cdot (120^2 + 45^2) + 2 \cdot 45^2 = 69750 \text{ mm}^2$$

$$F_{m,max} = \frac{32 \cdot 10^6 \cdot (120^2 + 45^2)}{69750} = 55.2 \text{ kN}$$

$$F_v = \frac{60.0}{6} = 10.0 \text{ kN}$$

$$F_{res} = 59 \text{ kN}$$

Vöös ühele poldile tulev jõud:

$$F_{vöö} = \frac{168}{8 \cdot 0.415} = 50.6 \text{ kN}$$

