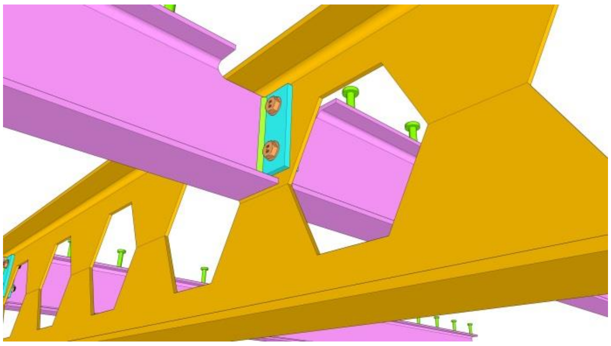
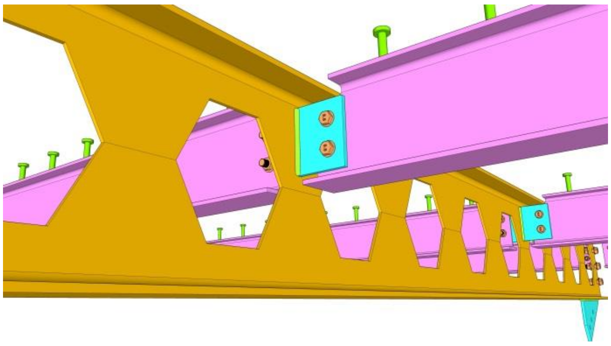
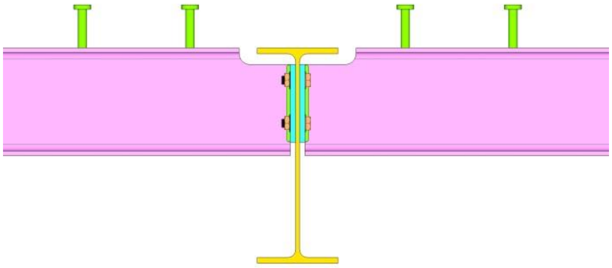
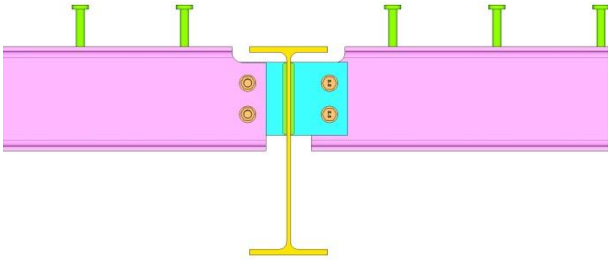
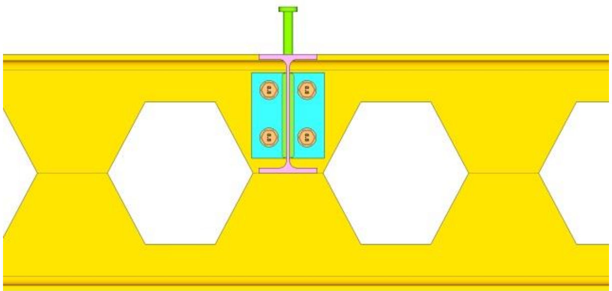
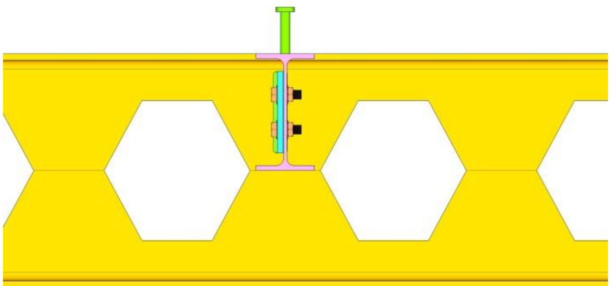
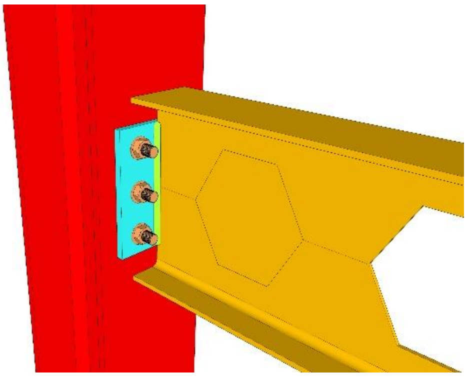
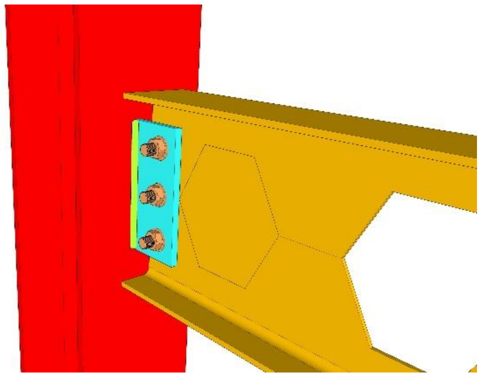
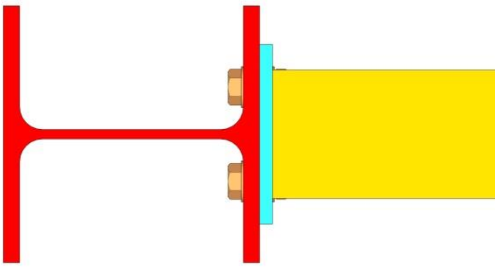
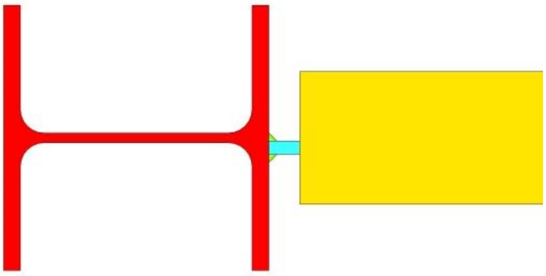
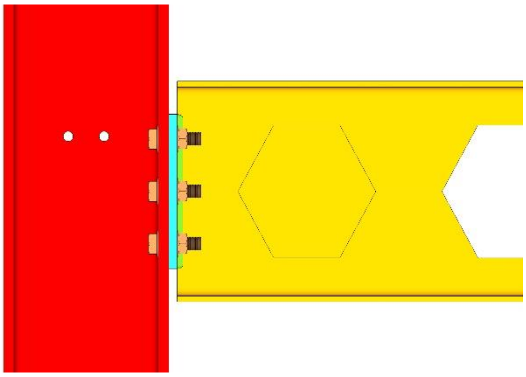
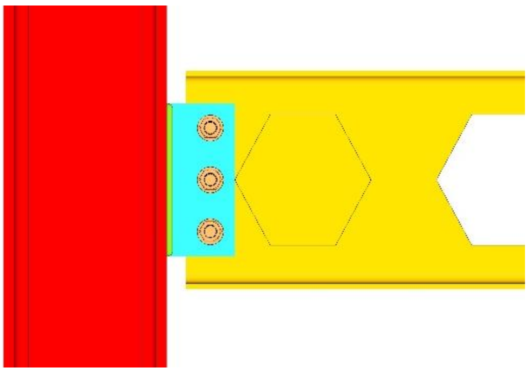
# HOW TO DESIGN AND CHECK SIMPLE JOINTS?

## …worked examples for NOA019

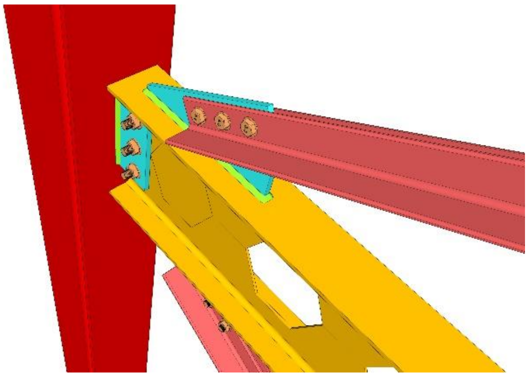
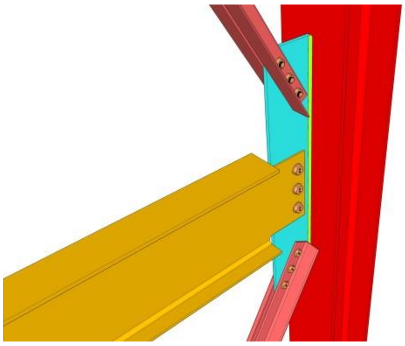
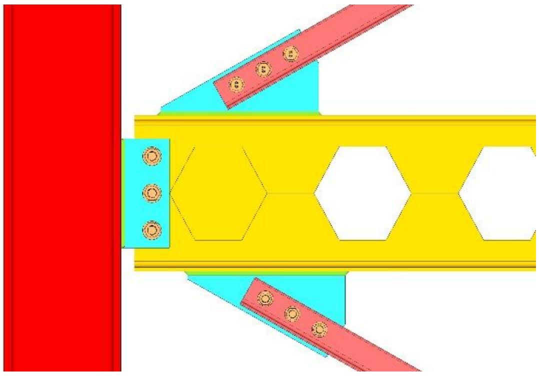
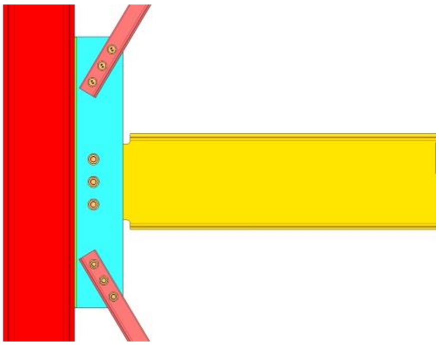
### SECONDARY BEAM TO PRIMARY BEAM CONNECTION

| Alternative 1 – end plate | Alternative 2 – fin plate |
|---|---|
|  |  |
| *Perspective view* | |
|  |  |
| *Side view* | |
|  |  |
| *Side view* | |

# PRIMARY BEAM TO COLUMN CONNECTION

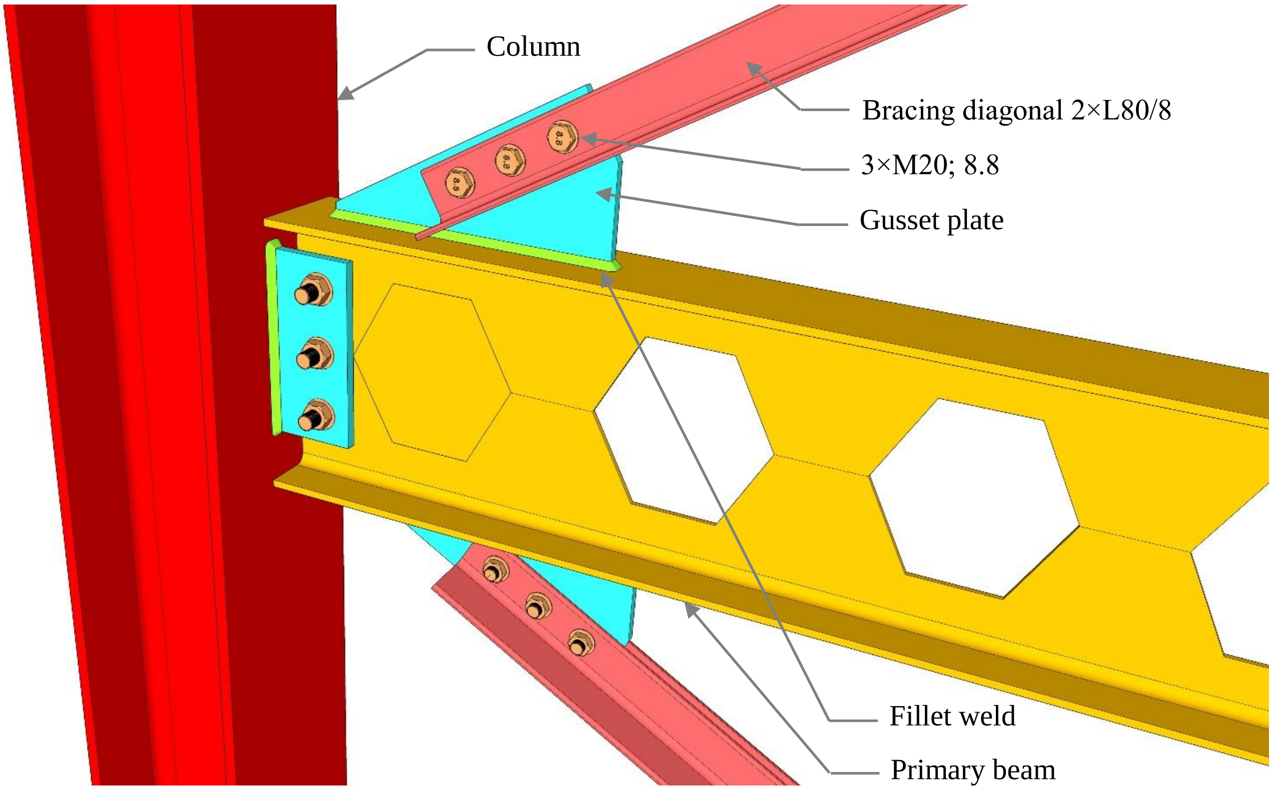
| Alternative 1 – end plate | Alternative 2 – fin plate |
|---|---|
|  |  |
| *Perspective view* | |
|  |  |
| *Plan view* | |
|  |  |
| *Side view* | |

# BRACING CONNECTIONS

| Alternative 1 | Alternative 2 |
|---|---|
|  |  |
| *Perspective view* | |
|  |  |
| *Side view* | |

# WORKED EXAMPLE 1:

# BRACING CONNECTION IN ALTERNATIVE 1




## Normal force in bracing diagonal

Due to wind load (design of vertical bracing, only tension diagonal is active)

$$N_{\mathrm{Ed}} = 454\ \mathrm{kN}$$

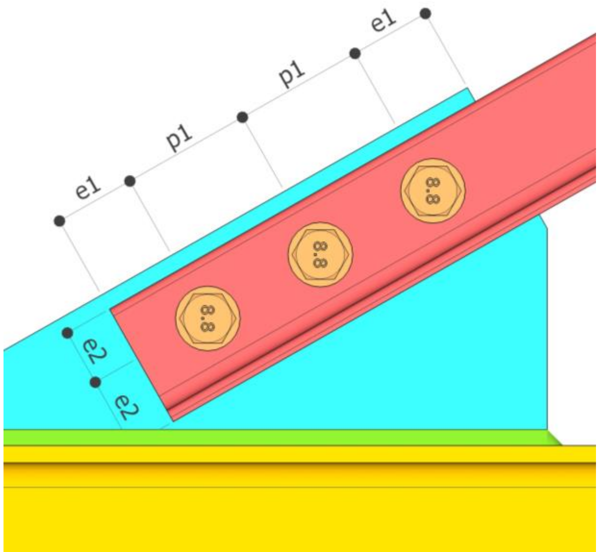
Diagonal section: 2×L80/8, thickness of leg $t_a$ = 8 mm, steel S235

Gusset plate: thickness $t_p$ = 15 mm, steel S235

## Bolts

Design: bolts M20, material 8.8

| | |
|---|---|
| $f_{yb}$ = 640 MPa | bolt yield strength |
| $f_{ub}$ = 800 MPa | bolt ultimate strength |
| $d$ = 20 mm | bolt diameter |
| $d_0$ = 22 mm | bolt hole diameter |
| $A$ = 314 mm | gross cross section of the bolt |
| $A_s$ = 245 mm | tensile stress area of the bolt |
| $e_1$ = 50 mm | end distance |
| $p_1$ = 80 mm | spacing |
| $e_2$ = 35 mm | edge distance (smaller of them) |



*=> bolt connection in shear*

**Shear resistance**

$$F_{v,Rd} = n_s \cdot \frac{\alpha_v \cdot f_{ub} \cdot A_s}{\gamma_{M2}} = 2 \cdot \frac{0{,}6 \cdot 800 \cdot 245}{1{,}25} = 188 \text{ kN}$$

where

$n_s$ is number of shear planes

$\alpha_v$ is factor for 8.8 if shear plane passes through the threated portion of the bolt

$A_s$ is used if shear planes passes through threated portion of the bolt

**Bearing resistance**

$$F_{b,Rd} = \frac{k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t}{\gamma_{M2}} = \frac{2{,}5 \cdot 0{,}76 \cdot 360 \cdot 20 \cdot 15}{1{,}25} = 164 \text{ kN}$$

where

$$k_1 = \min\left\{2{,}8 \cdot \frac{e_2}{d_0} - 1{,}7\,;\, 1{,}4 \cdot \frac{p_2}{d_0} - 1{,}7\,;\, 2{,}5\right\} = \min\left\{2{,}8 \cdot \frac{35}{22} - 1{,}7\,;\, -\,;\, 2{,}5\right\} = \min\{2{,}75\,;\, -\,;\, 2{,}5\} = 2{,}5$$

$$\alpha_b = \min\left\{\frac{e_1}{3d_0}\,;\, \frac{p_1}{3d_0} - \frac{1}{4}\,;\, \frac{f_{ub}}{f_u}\,;\, 1\right\} = \min\left\{\frac{50}{3 \cdot 22}\,;\, \frac{80}{3 \cdot 22} - \frac{1}{4}\,;\, \frac{800}{360}\,;\, 1\right\} = \min\{0{,}76\,;\, 0{,}96\,;\, 2{,}22\,;\, 1\} = 0{,}76$$

$$t = \min\{t_p\,;\, 2 \cdot t_a\} = \min\{15\,;\, 2 \cdot 8\} = 15 \text{ mm}$$

**Number of bolts to satisfied condition**

$$n_{bolt} = \frac{N_{Ed}}{\min\{F_{v,Rd}\,;\, F_{b,Rd}\}} = \frac{454}{\min\{188\,;\, 164\}} = 2{,}77$$

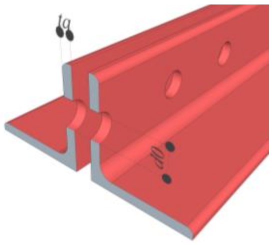
*=> **3 bolts M20, 8.8***

## <u>Angle</u>

**Ultimate resistance of the net-cross section at holes**

Due to holes for bolts, angle gross cross section is reduced, net area resistance is:

$$N_{u,Rd} = \frac{\beta \cdot A_{net} \cdot f_u}{\gamma_{M2}} = \frac{0{,}59 \cdot 2108 \cdot 360}{1{,}25} = 358 \text{ kN}$$



where $A_{net}$ is net area of angle without holes for bolts

$$A_{net} = 2 \cdot (A - d_0 \cdot t_a) = 2 \cdot (1230 - 22 \cdot 8) = 2108 \text{ mm}^2$$

$\beta$ is reduction factor for angle connected by one leg according to the table below (linear interpolation for intermediate values of $p_1$)

| Spacing $p_1$ | $\leq 2.5\ d_0$ | $\geq 5\ d_0$ |
|---|---|---|
| $\beta_2$ for two bolts | 0.4 | 0.7 |
| $\beta_3$ for three or more bolts | 0.5 | 0.7 |

Reliability condition:

$$\frac{N_{\mathrm{Ed}}}{N_{\mathrm{u,Rd}}}=\frac{454}{358}=1{,}27 \quad \geq \quad 1{,}0$$

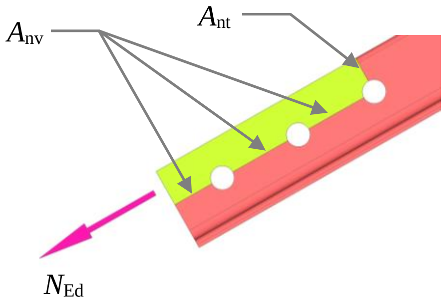
=> ***condition is not satisfied***

**Block tearing**

Due to hole group, diagonal gross cross section is reduced. Design block tearing resistance for bolt group subject to eccentric loading

$$V_{\mathrm{eff2,\,Rd}}=\frac{0{,}5\cdot f_{\mathrm{u}}\cdot A_{\mathrm{nt}}}{\gamma_{\mathrm{M2}}}+\frac{f_{\mathrm{y}}/\sqrt{3}\cdot A_{\mathrm{nv}}}{\gamma_{\mathrm{M0}}}=\frac{0{,}5\cdot 360\cdot 384}{1{,}25}+\frac{235/\sqrt{3}\cdot 2480}{1{,}00}=55+336=391\,\mathrm{kN}$$

where




$A_{nt}$ is net area subjected to tension

$$A_{\mathrm{nt}}=2\cdot t_{\mathrm{a}}\cdot(l_{\mathrm{nt}})=2\cdot 8\cdot(35-11)=384\ \mathrm{mm}^2$$

$A_{nv}$ is net area subjected to shear

$$A_{\mathrm{nv}}=2\cdot t_{\mathrm{a}}\cdot(l_{\mathrm{nv}})=2\cdot 8\cdot(50+80+80-22-22-11)=2480\ \mathrm{mm}^2$$

Reliability condition:

$$\frac{N_{\mathrm{Ed}}}{V_{\mathrm{eff2,\,Rd}}}=\frac{454}{391}=1{,}16 \quad \geq \quad 1{,}0$$

=> ***condition is not satisfied***

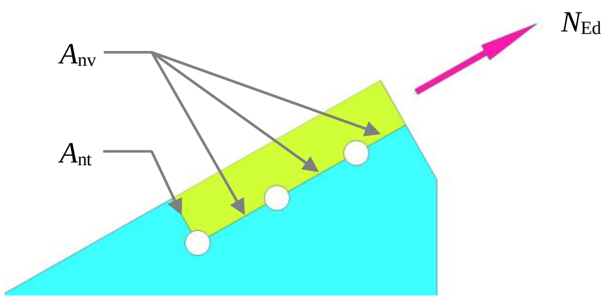
## <u>Gusset plate</u>

**Block tearing**

Due to hole group, gusset plate gross cross section is reduced. Design block tearing resistance for bolt group subject to eccentric loading

$$V_{\mathrm{eff2,\,Rd}}=\frac{0{,}5\cdot f_{\mathrm{u}}\cdot A_{\mathrm{nt}}}{\gamma_{\mathrm{M2}}}+\frac{f_{\mathrm{y}}/\sqrt{3}\cdot A_{\mathrm{nv}}}{\gamma_{\mathrm{M0}}}=\frac{0{,}5\cdot 360\cdot 510}{1{,}25}+\frac{235/\sqrt{3}\cdot 2325}{1{,}00}=73+315=388\,\mathrm{kN}$$

where




$A_{nt}$ is net area subjected to tension

$$A_{\mathrm{nt}}=t_{\mathrm{p}}\cdot(l_{\mathrm{nt}})=15\cdot(45-11)=510\ \mathrm{mm}^2$$

$A_{nv}$ is net area subjected to shear

$$A_{\mathrm{nv}}=t_{\mathrm{p}}\cdot(l_{\mathrm{nv}})=15\cdot(50+80+80-22-22-11$$

Reliability condition:

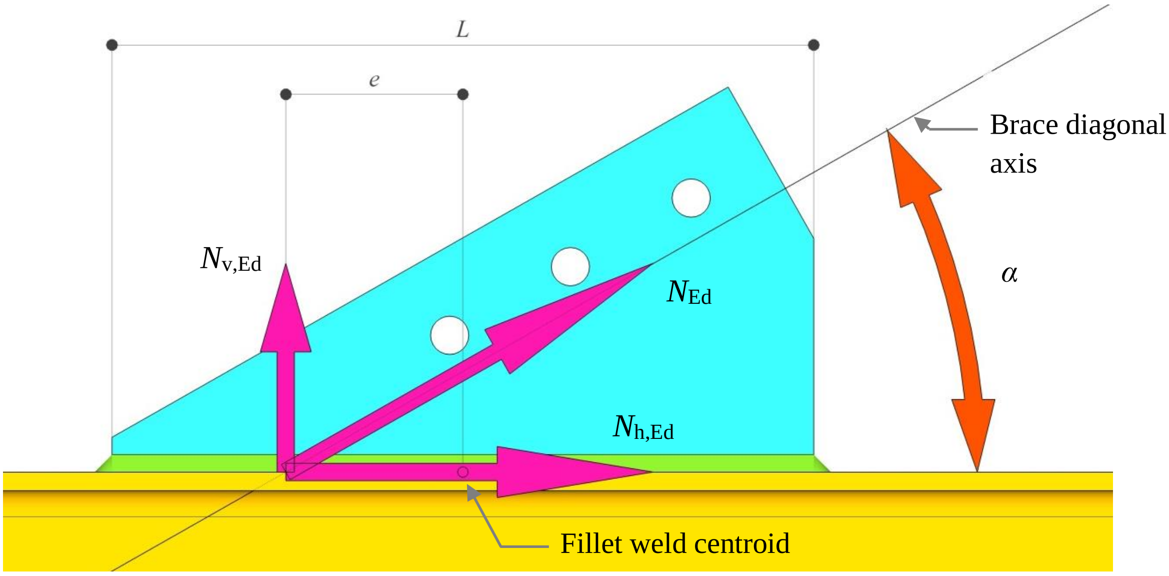
$$\frac{N_{\text{Ed}}}{V_{\text{eff,2, Rd}}} = \frac{454}{388} = 1{,}17 \quad \geq \quad 1{,}0$$ => ***condition is not satisfied***

**Fillet weld**

$N_{\text{Ed}} = 454 \text{ kN}$ force in diagonal

$N_{\text{h,Ed}} = N_{\text{Ed}} \cdot \cos\alpha = 454 \cdot \cos 31° = 389 \text{ kN}$ horizontal force portion

$N_{\text{v,Ed}} = N_{\text{Ed}} \cdot \sin\alpha = 454 \cdot \sin 31° = 233 \text{ kN}$ vertical force portion




$a$ = 5 mm effective throat thickness of a fillet weld

$L$ = 419 mm effective length of a fillet weld

$e$ = 68 mm force eccentricity (brace diagonal axis) to centroid of the fillet weld

$$\tau_{\text{II}} = \frac{N_{\text{h,Ed}}}{2 \cdot L \cdot a} = \frac{389.10^3}{2 \cdot 419 \cdot 5} = 93 \text{ MPa}$$

$$\sigma_{\text{v}} = \frac{N_{\text{v,Ed}}}{2 \cdot L \cdot a} = \frac{233.10^3}{2 \cdot 419 \cdot 5} = 56 \text{ MPa}$$

$$\sigma_{\text{M}} = \frac{N_{\text{v,Ed}} \cdot e}{2 \cdot \frac{1}{6} \cdot L^2 \cdot a} = \frac{233.10^3 \cdot 68}{2 \cdot \frac{1}{6} \cdot 419^2 \cdot 5} = 54 \text{ MPa}$$

$$\sigma_{\perp} = \tau_{\perp} = \frac{\sigma_{\text{v}} + \sigma_{\text{M}}}{\sqrt{2}} = \frac{56 + 54}{\sqrt{2}} = 78 \text{ MPa}$$

Reliability conditions:

$$\sqrt{\sigma_{\perp}^2 + 3 \cdot \left(\tau_{\perp}^2 + \tau_{\mathrm{II}}^2\right)} \leq \frac{f_{\mathrm{u}}}{\beta_{\mathrm{w}} \cdot \gamma_{\mathrm{M2}}}$$

$$\sqrt{78^2 + 3 \cdot \left(78^2 + 93^2\right)} \leq \frac{360}{0{,}8 \cdot 1{,}25}$$

$224\ \mathrm{MPa} \quad \leq \quad 360\ \mathrm{MPa}$ => *condition is satisfied*

$$\sigma_{\perp} \leq \frac{0{,}9 \cdot f_u}{\gamma_{M2}}$$

$78\ \mathrm{MPa} \quad \leq \quad \dfrac{0{,}9 \cdot 360}{1{,}25} = 259\ \mathrm{MPa}$ => *condition is satisfied*

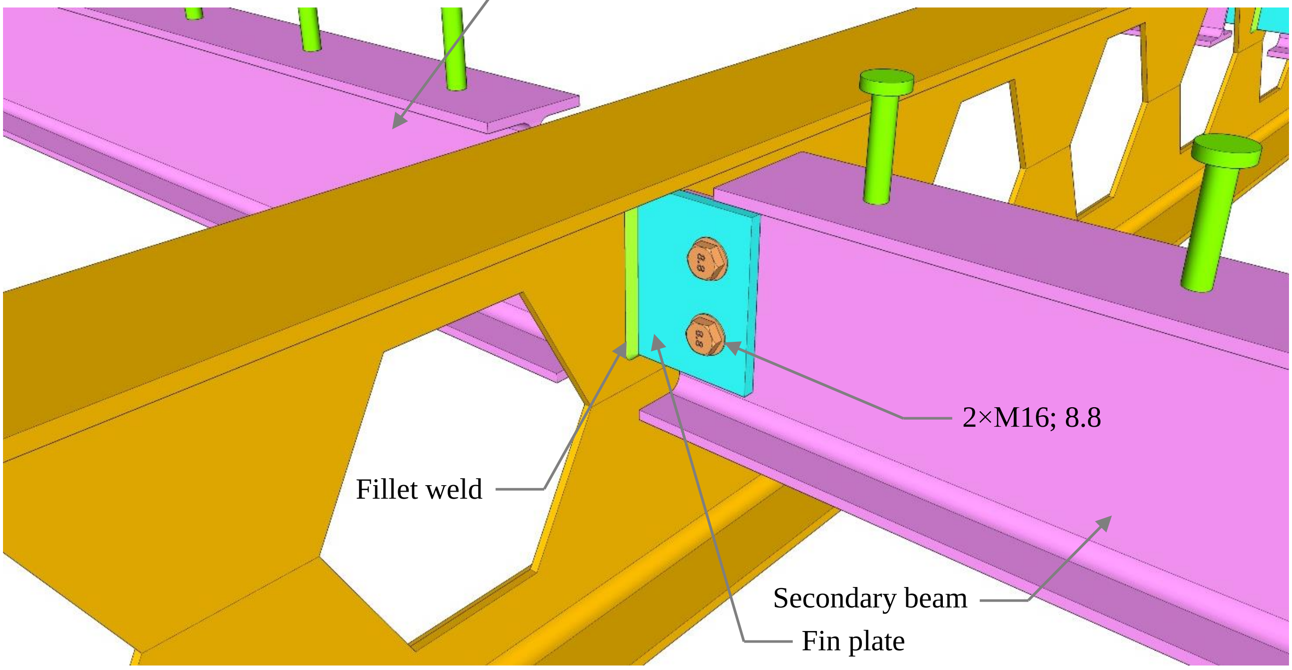
where $\beta_{\mathrm{w}}$ is correlation factor according to the table 1.

*Table 1.*

| Steel grade | $\beta_{\mathrm{w}}$ |
|---|---|
| S235 | 0.80 |
| S275 | 0.85 |
| S355 | 0.90 |
| S420 | 1.00 |
| S460 | 1.00 |

# WORKED EXAMPLE 2:

# SECONDARY BEAM TO PRIMARY BEAM CONNECTION IN ALTERNATIVE 2




## Force in connection

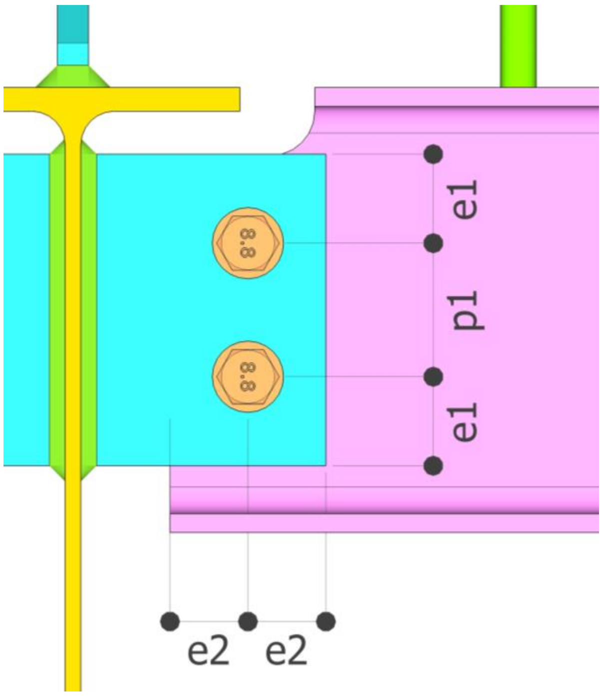
Action on connection is reaction of secondary beam

$$F_{\mathrm{Ed}} = 70\,\mathrm{kN}$$

Secondary beam: IPE 200, thickness of web $t_w$ = 5,6 mm, steel S235

Fin plate: thickness $t_p$ = 10 mm, steel S235

## Bolts




Design: bolts M16, material 8.8

| | |
|---|---|
| $f_{yb}$ = 640 MPa | bolt yield strength |
| $f_{ub}$ = 800 MPa | bolt ultimate strength |
| $d$ = 16 mm | bolt diameter |
| $d_0$ = 18 mm | bolt hole diameter |
| $A$ = 201 mm | gross cross section of the bolt |
| $A_s$ = 157 mm | tensile stress area of the bolt |
| $e_1$ = 40 mm | end distance |
| $p_1$ = 60 mm | spacing |
| $e_2$ = 35 mm | edge distance (smaller of them) |

=> *bolt connection in shear*

**Shear force per one bolt**

$$F_{\mathrm{v,Ed}} = \frac{F_{\mathrm{Ed}}}{n_{\mathrm{bolt}}} = \frac{70}{2} = 35\ \mathrm{kN}$$

**Shear resistance**

Shear resistance per one bolt

$$F_{\mathrm{v,Rd}} = n_{\mathrm{s}} \cdot \frac{\alpha_{\mathrm{v}} \cdot f_{\mathrm{ub}} \cdot A_{\mathrm{s}}}{\gamma_{\mathrm{M2}}} = 1 \cdot \frac{0{,}6 \cdot 800 \cdot 157}{1{,}25} = 60\ \mathrm{kN}$$

where

$n_s$ is number of shear planes

$\alpha_v$ is factor for 8.8 if shear plane passes through the threated portion of the bolt

$A_s$ is used if shear planes pass through threated portion of the bolt

Reliability criterion

$$\frac{F_{\mathrm{v,Ed}}}{F_{\mathrm{v,Rd}}} = \frac{35}{60} = 0{,}58 \quad \leq \quad 1{,}0$$

=> *condition is satisfied*

**Bearing resistance**

Bearing resistance per one bolt

$$F_{\mathrm{b,Rd}} = \frac{k_1 \cdot \alpha_{\mathrm{b}} \cdot f_{\mathrm{u}} \cdot d \cdot t}{\gamma_{\mathrm{M2}}} = \frac{2{,}5 \cdot 0{,}74 \cdot 360 \cdot 16 \cdot 5{,}6}{1{,}25} = 48\ \mathrm{kN}$$

where

$$k_1 = \min\left\{2{,}8 \cdot \frac{e_2}{d_0} - 1{,}7\,;\, 1{,}4 \cdot \frac{p_2}{d_0} - 1{,}7\,;\, 2{,}5\right\} = \min\left\{2{,}8 \cdot \frac{35}{18} - 1{,}7\,;\, -\,;\, 2{,}5\right\} = \min\left\{3{,}74\,;\, -\,;\, 2{,}5\right\} = 2{,}5$$

$$\alpha_{\mathrm{b}} = \min\left\{\frac{e_1}{3d_0}\,;\, \frac{p_1}{3d_0} - \frac{1}{4}\,;\, \frac{f_{\mathrm{ub}}}{f_{\mathrm{u}}}\,;\, 1\right\} = \min\left\{\frac{40}{3 \cdot 18}\,;\, \frac{60}{3 \cdot 18} - \frac{1}{4}\,;\, \frac{800}{360}\,;\, 1\right\} = \min\left\{0{,}74\,;\, 0{,}86\,;\, 2{,}22\,;\, 1\right\} = 0{,}74$$

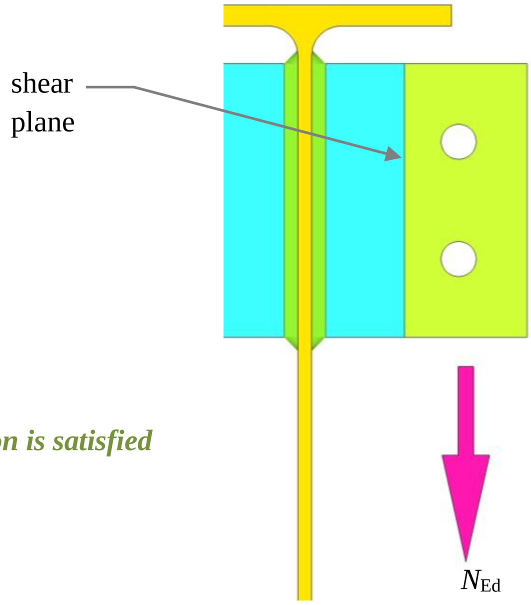
$$t = \min\left\{t_{\mathrm{p}}\,;\, t_{\mathrm{w}}\right\} = \min\left\{10\,;\, 5{,}6\right\} = 5{,}6\ \mathrm{mm}$$

Reliability criterion

$$\frac{F_{\mathrm{v,Ed}}}{F_{\mathrm{b,Rd}}} = \frac{35}{48} = 0{,}73 \quad \leq \quad 1{,}0$$

=> *condition is satisfied*

## Fin plate




### Shear resistance

$$V_{pl,Rd} = \frac{A_v \cdot f_y / \sqrt{3}}{\gamma_{M0}} = \frac{1400 \cdot 235/\sqrt{3}}{1,00} = 190\ \mathrm{kN}$$

where $A_v$ is gross cross area of fin plate

$$A_v = h_g \cdot t_g = 140 \cdot 10 = 1400\ \mathrm{mm}^2$$

Reliability criterion

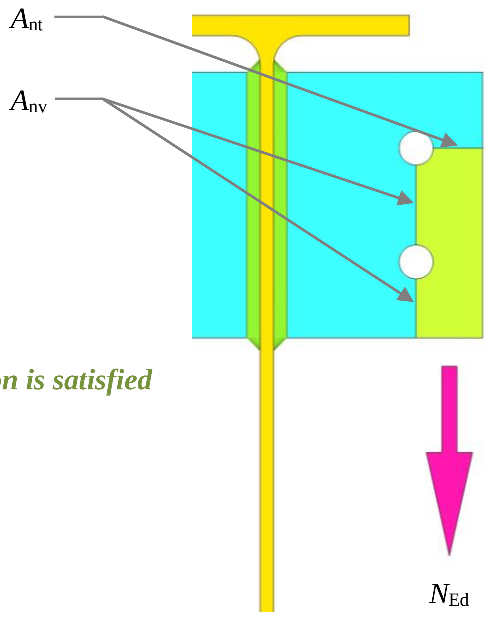
$$\frac{F_{Ed}}{V_{pl,Rd}} = \frac{70}{190} = 0,37 \quad \leq \quad 1,0$$ => *condition is satisfied*

### Block tearing

Due to hole group, fin plate gross cross section is reduced. Design block tearing resistance for bolt group subject to eccentric loading

$$V_{eff,2,Rd} = \frac{0,5 \cdot f_u \cdot A_{nt}}{\gamma_{M2}} + \frac{f_y/\sqrt{3} \cdot A_{nv}}{\gamma_{M0}} = \frac{0,5 \cdot 360 \cdot 261}{1,25} + \frac{235/\sqrt{3} \cdot 730}{1,00} = 38 + 99 = 137\ \mathrm{kN}$$

where




$A_{nt}$ is net area subjected to tension

$$A_{nt} = t_p \cdot (l_{nt}) = 10 \cdot (35 - 9) = 261\ \mathrm{mm}^2$$

$A_{nv}$ is net area subjected to shear

$$A_{nv} = t_p \cdot (l_{nv}) = 10 \cdot (60 + 40 - 18 - 9) = 730\ \mathrm{mm}^2$$

Reliability condition:

$$\frac{F_{Ed}}{V_{eff,2,Rd}} = \frac{70}{137} = 0,51 \quad \leq \quad 1,0$$ => *condition is satisfied*

## Secondary beam

### Block tearing

Due to hole group, secondary beam web gross cross section is reduced. Design block tearing resistance for bolt group subject to eccentric loading

$$V_{eff,2,Rd} = \frac{0,5 \cdot f_u \cdot A_{nt}}{\gamma_{M2}} + \frac{f_y/\sqrt{3} \cdot A_{nv}}{\gamma_{M0}} = \frac{0,5 \cdot 360 \cdot 146}{1,25} + \frac{235/\sqrt{3} \cdot 409}{1,00} = 21 + 55 = 76\ \mathrm{kN}$$

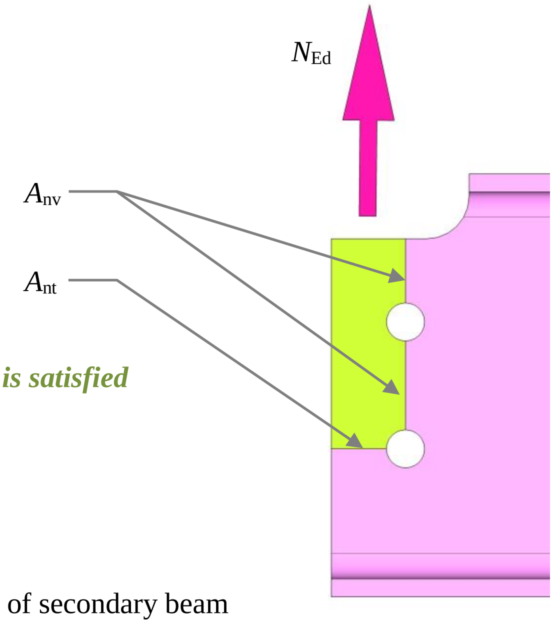
where

$A_{nt}$ is net area subjected to tension

$$A_{nt} = t_w \cdot (l_{nt}) = 5{,}6 \cdot (35 - 9) = 146 \text{ mm}^2$$

$A_{nv}$ is net area subjected to shear

$$A_{nv} = t_w \cdot (l_{nv}) = 5{,}6 \cdot (60 + 40 - 18 - 9) = 409 \text{ mm}^2$$




Reliability condition:

$$\frac{F_{Ed}}{V_{eff,2,Rd}} = \frac{70}{76} = 0{,}92 \quad \leq \quad 1{,}0$$ => *condition is satisfied*

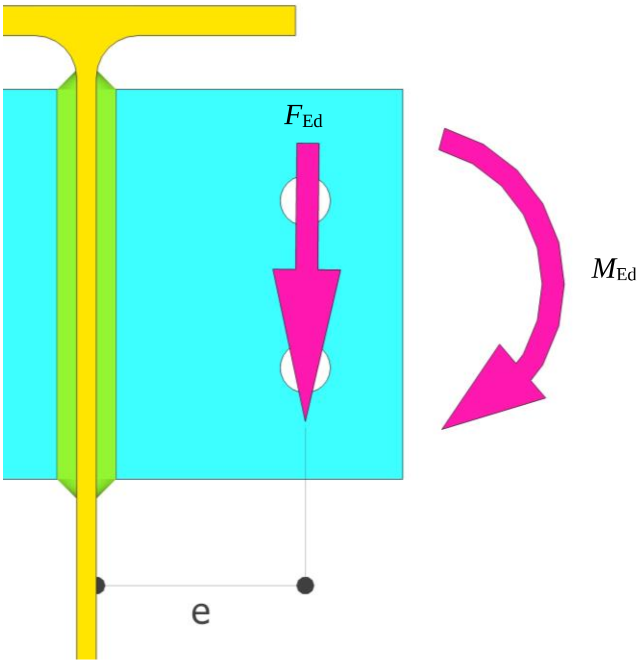
## Fillet weld

$F_{Ed} = 70 \text{ kN}$ action of secondary beam

$M_{Ed} = F_{Ed} \cdot e = 70 \cdot 0{,}075 = 5{,}25 \text{ kNm}$ additional moment due to eccentricity

$a$ = 4 mm effective throat thickness of a fillet weld

$L$ = 140 mm effective length of a fillet weld




$$\tau_{II} = \frac{F_{Ed}}{2 \cdot L \cdot a} = \frac{70.10^3}{2 \cdot 140 \cdot 4} = 63 \text{ MPa}$$

$$\sigma_M = \frac{M_{Ed}}{2 \cdot \frac{1}{6} \cdot L^2 \cdot a} = \frac{5{,}25.10^6}{2 \cdot \frac{1}{6} \cdot 140^2 \cdot 4} = 201 \text{ MPa}$$

$$\sigma_\perp = \tau_\perp = \frac{\sigma_M}{\sqrt{2}} = \frac{201}{\sqrt{2}} = 142 \text{ MPa}$$

Reliability conditions:

$$\sqrt{\sigma_\perp^2 + 3 \cdot (\tau_\perp^2 + \tau_{II}^2)} \leq \frac{f_u}{\beta_w \cdot \gamma_{M2}}$$

$$\sqrt{142^2 + 3 \cdot (142^2 + 63^2)} \leq \frac{360}{0{,}8 \cdot 1{,}25}$$

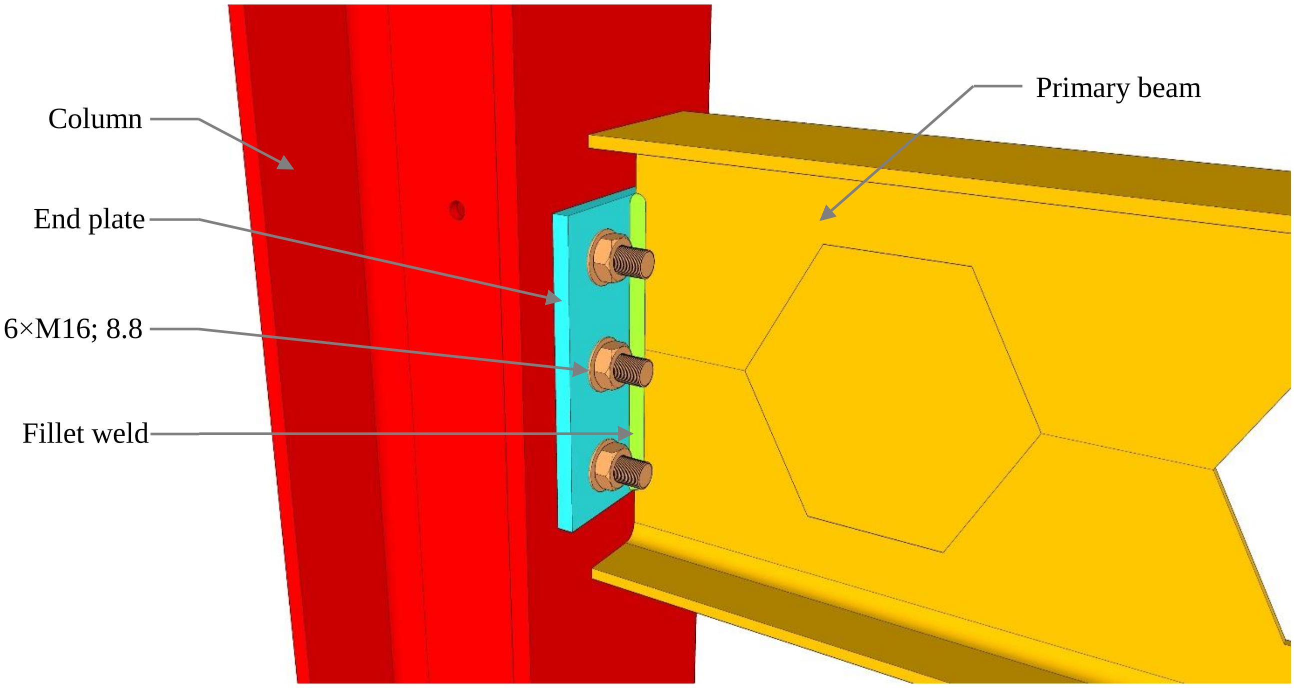
$304 \text{ MPa} \quad \leq \quad 360 \text{ MPa}$ => *condition is satisfied*

$$\sigma_\perp \leq \frac{0{,}9 \cdot f_u}{\gamma_{M2}}$$

$142 \text{ MPa} \quad \leq \quad \frac{0{,}9 \cdot 360}{1{,}25} = 259 \text{ MPa}$ => *condition is satisfied*

# WORKED EXAMPLE 3:

# PRIMARY BEAM TO COLUMN CONNECTION IN ALTERNATIVE 1




## Forces in connection

Action on connection is reaction of primary beam

$$F_{\mathrm{Ed}} = 150 \ \mathrm{kN}$$

Primary beam: castellated beam made of IPE 300, thickness of web $t_w$ = 7,1 mm, steel S235

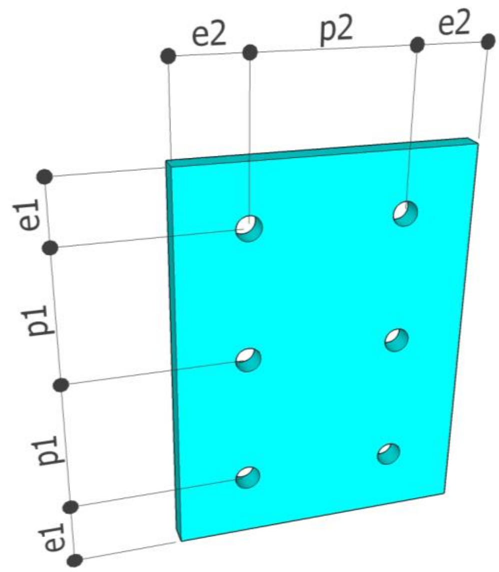
Column: HEB 300, thickness of flange $t_f$ = 19 mm, steel S235

End plate: thickness $t_p$ = 15 mm, steel S235

## Bolts

Design: bolts M16, material 8.8

| | |
|---|---|
| $f_{yb}$ = 640 MPa | bolt yield strength |
| $f_{ub}$ = 800 MPa | bolt ultimate strength |
| $d$ = 16 mm | bolt diameter |
| $d_0$ = 18 mm | bolt hole diameter |
| $A$ = 201 mm | gross cross section of the bolt |
| $A_s$ = 157 mm | tensile stress area of the bolt |
| $e_1$ = 45 mm | end distance |
| $p_1$ = 95 mm | spacing |
| $e_2$ = 50 mm | edge distance (smaller of them) |



$p_2$ = 110 mm spacing

=> *bolt connection in shear*

**Shear force per one bolt**

$$F_{\mathrm{v,Ed}} = \frac{F_{\mathrm{Ed}}}{n_{\mathrm{bolt}}} = \frac{150}{6} = 25\ \mathrm{kN}$$

**Shear resistance**

Shear resistance per one bolt

$$F_{\mathrm{v,Rd}} = n_{\mathrm{s}} \cdot \frac{\alpha_{\mathrm{v}} \cdot f_{\mathrm{ub}} \cdot A_{\mathrm{s}}}{\gamma_{\mathrm{M2}}} = 1 \cdot \frac{0{,}6 \cdot 800 \cdot 157}{1{,}25} = 60\ \mathrm{kN}$$

where

$n_s$ is number of shear planes

$\alpha_v$ is factor for 8.8 if shear plane passes through the threated portion of the bolt

$A_s$ is used if shear planes pass through threated portion of the bolt

Reliability criterion

$$\frac{F_{\mathrm{v,Ed}}}{F_{\mathrm{v,Rd}}} = \frac{25}{60} = 0{,}42 \quad \leq \quad 1{,}0$$ => *condition is satisfied*

**Bearing resistance**

Bearing resistance per one bolt

$$F_{\mathrm{b,Rd}} = \frac{k_1 \cdot \alpha_{\mathrm{b}} \cdot f_{\mathrm{u}} \cdot d \cdot t}{\gamma_{\mathrm{M2}}} = \frac{2{,}5 \cdot 0{,}83 \cdot 360 \cdot 16 \cdot 15}{1{,}25} = 143\ \mathrm{kN}$$

where

$$k_1 = \min\left\{2{,}8 \cdot \frac{e_2}{d_0} - 1{,}7\,; 1{,}4 \cdot \frac{p_2}{d_0} - 1{,}7\,; 2{,}5\right\} = \min\left\{2{,}8 \cdot \frac{50}{18} - 1{,}7\,; 1{,}4 \cdot \frac{110}{18} - 1{,}7\,; 2{,}5\right\} = \min\{6{,}08\,; 6{,}86\,; 2{,}5\} = 2{,}5$$

$$\alpha_{\mathrm{b}} = \min\left\{\frac{e_1}{3d_0}\,; \frac{p_1}{3d_0} - \frac{1}{4}\,; \frac{f_{\mathrm{ub}}}{f_{\mathrm{u}}}\,; 1\right\} = \min\left\{\frac{45}{3 \cdot 18}\,; \frac{95}{3 \cdot 18} - \frac{1}{4}\,; \frac{800}{360}\,; 1\right\} = \min\{0{,}83\,; 1{,}51\,; 2{,}22\,; 1\} = 0{,}83$$

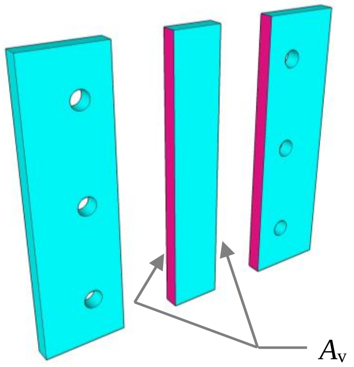
$$t = \min\{t_{\mathrm{p}}\,; t_{\mathrm{f}}\} = \min\{15\,; 19\} = 15\ \mathrm{mm}$$

Reliability criterion

$$\frac{F_{\mathrm{v,Ed}}}{F_{\mathrm{b,Rd}}} = \frac{25}{143} = 0{,}17 \quad \leq \quad 1{,}0$$ => *condition is satisfied*

## End plate

### Shear resistance




$$V_{pl,Rd} = \frac{A_v \cdot f_y / \sqrt{3}}{\gamma_{M0}} = \frac{8400 \cdot 235/\sqrt{3}}{1,00} = 1140\,\text{kN}$$

where $A_v$ is gross cross area of fin plate

$$A_v = 2 \cdot h_p \cdot t_p = 2 \cdot 280 \cdot 15 = 8400\,\text{mm}^2$$

Reliability criterion

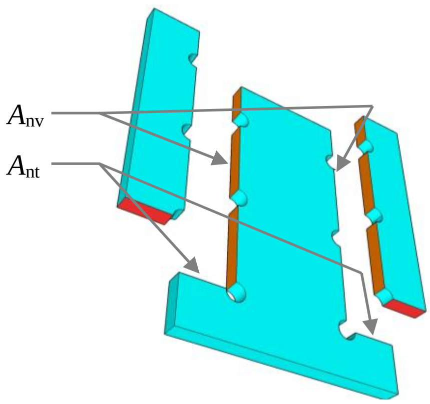
$$\frac{F_{Ed}}{V_{pl,Rd}} = \frac{150}{1140} = 0,13 \quad \leq \quad 1,0$$

=> ***condition is satisfied***

### Block tearing

Due to hole group, fin plate gross cross section is reduced. Design block tearing resistance for bolt group subject to concentric loading

$$V_{eff,1,Rd} = \frac{f_u \cdot A_{nt}}{\gamma_{M2}} + \frac{f_y/\sqrt{3} \cdot A_{nv}}{\gamma_{M0}} = \frac{360 \cdot 1230}{1,25} + \frac{235/\sqrt{3} \cdot 5700}{1,00} = 354 + 773 = 1127\,\text{kN}$$




where

$A_{nt}$ is net area subjected to tension

$$A_{nt} = 2 \cdot t_p \cdot (l_{nt}) = 2 \cdot 15 \cdot (50 - 9) = 1230\,\text{mm}^2$$

$A_{nv}$ is net area subjected to shear

$$A_{nv} = 2 \cdot t_p \cdot (l_{nv}) = 2 \cdot 15 \cdot (45 + 95 + 95 - 18 - 18 - 9) = 5700\,\text{mm}^2$$

Reliability condition:

$$\frac{F_{Ed}}{V_{eff,2,Rd}} = \frac{150}{1127} = 0,13 \quad \leq \quad 1,0$$

=> ***condition is satisfied***

## Fillet weld

$F_{Ed} = 150\,\text{kN}$ action of secondary beam

$a$ = 4 mm effective throat thickness of a fillet weld

$L$ = 272 mm effective length of a fillet weld

$$\tau_{II} = \frac{F_{Ed}}{2 \cdot L \cdot a} = \frac{150.10^3}{2 \cdot 272 \cdot 4} = 69\,\text{MPa}$$

$$\sigma_\perp = \tau_\perp = 0\,\text{MPa}$$

Reliability conditions:

$$\sqrt{\sigma_{\perp}^2 + 3 \cdot \left(\tau_{\perp}^2 + \tau_{\mathrm{II}}^2\right)} \leq \frac{f_{\mathrm{u}}}{\beta_{\mathrm{w}} \cdot \gamma_{\mathrm{M2}}}$$

$$\sqrt{0^2 + 3 \cdot \left(0^2 + 69^2\right)} \leq \frac{360}{0{,}8 \cdot 1{,}25}$$

$120\ \mathrm{MPa} \quad \leq \quad 360\ \mathrm{MPa}$ => *condition is satisfied*

$$\sigma_{\perp} \leq \frac{0{,}9 \cdot f_u}{\gamma_{M2}}$$

$0\ \mathrm{MPa} \quad \leq \quad \dfrac{0{,}9 \cdot 360}{1{,}25} = 259\ \mathrm{MPa}$ => *condition is satisfied*