HOW TO DESIGN AND CHECK SIMPLE JOINTS?

…worked examples for CO001

SECONDARY BEAM TO PRIMARY BEAM CONNECTION

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<th>Alternative 1 – end plate</th>
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**Perspective view**

**Side view**

**Side view**
PRIMARY BEAM TO COLUMN CONNECTION

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<td><img src="image3" alt="Plan view" /></td>
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BRACING CONNECTIONS

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<th>Alternative 2</th>
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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)

\[ N_{Ed} = 454 \text{ kN} \]

Diagonal section: 2×L80/8, thickness of leg \( t_a = 8 \text{ mm} \), steel S235

Gusset plate: thickness \( t_p = 15 \text{ mm} \), steel S235

Bolts

Design: bolts M20, material 8.8

\[ f_y = 640 \text{ MPa} \] \( f_y \) bolt yield strength

\[ f_{ub} = 800 \text{ MPa} \] \( f_{ub} \) bolt ultimate strength

\[ d = 20 \text{ mm} \] \( d \) bolt diameter

\[ d_0 = 22 \text{ mm} \] \( d_0 \) bolt hole diameter

\[ A = 314 \text{ mm}^2 \] \( A \) gross cross section of the bolt

\[ A_s = 245 \text{ mm}^2 \] \( A_s \) tensile stress area of the bolt

\[ e_1 = 50 \text{ mm} \] \( e_1 \) end distance

\[ p_1 = 80 \text{ mm} \] \( p_1 \) spacing

\[ e_2 = 35 \text{ mm} \] \( e_2 \) edge distance (smaller of them)
bolt connection in shear

Shear resistance

\[ F_{v,Rd} = n_s \cdot \frac{a_v \cdot f_{ub} \cdot A_s}{\gamma_{M2}} = 2 \cdot \frac{0.6 \cdot 800 \cdot 245}{1.25} = 188 \text{ kN} \]

where

- \( n_s \) is number of shear planes
- \( a_v \) 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

\[ F_{b,Rd} = k_1 \cdot \frac{a_b \cdot f_u \cdot d \cdot t}{\gamma_{M2}} = 2.5 \cdot 0.76 \cdot 360 \cdot 20 \cdot 15 = 164 \text{ kN} \]

where

- \( k_1 = \min \left\{ 2.8 \cdot \frac{e_2}{d_0} - 1.7 \cdot 1.4 \cdot \frac{p_2}{d_0} - 1.7 \cdot 2.5 \right\} = \min \left\{ 2.8 \cdot \frac{35}{22} - 1.7 ; - ; 2.5 \right\} = \min \left\{ 2.75 ; - ; 2.5 \right\} = 2.5 \)
- \( a_0 = \min \left\{ \frac{e_1}{3d_0} \cdot \frac{p_1}{3d_0} \cdot \frac{1}{4} \cdot \frac{f_{ub}}{f_u} ; 1 \right\} = \min \left\{ \frac{50}{3.22} \cdot \frac{80}{3.22} \cdot \frac{1}{4} \cdot \frac{800}{360} ; 1 \right\} = \min \left\{ 0.76 ; 0.96 ; 2.22 ; 1 \right\} = 0.76 \)
- \( t = \min \left\{ t_p ; 2 \cdot t_u \right\} = \min \left\{ 15 ; 2 \cdot 8 \right\} = 15 \text{ mm} \)

Number of bolts to satisfied condition

\[ n_{bolt} = \frac{N_{Ed}}{\min \left\{ F_{v,Rd} ; F_{b,Rd} \right\}} = \frac{454}{\min \{188 ; 164\}} = 2.77 \]

\( \Rightarrow 3 \text{ bolts M20, 8.8} \)

Angle

Ultimate resistance of the net-cross section at holes

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

\[ N_{u,Rd} = \beta \cdot \frac{A_{net} \cdot f_u}{\gamma_{M2}} = \frac{0.59 \cdot 2108 \cdot 360}{1.25} = 358 \text{ kN} \]

where \( A_{net} \) is net area of angle without holes for bolts

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

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

$$\frac{N_{Ed}}{N_{u,Rd}} = \frac{454}{358} = 1.27 \geq 1.0$$

$\Rightarrow$ 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

$$V_{\text{eff}, Rd} = \frac{0.5 \cdot f_u \cdot A_{nt}}{\gamma_{M2}} + \frac{f_y / \sqrt{3} \cdot A_{nv}}{\gamma_{M0}} = 0.5 \cdot 360 \cdot 384 \cdot 1.25 + \frac{235 / \sqrt{3} \cdot 2480}{1.00} = 55 + 336 = 391 \, kN$$

where

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

$$A_{nt} = 2 \cdot t_a \cdot (l_{nt}) = 2 \cdot 8 \cdot (35 - 11) = 384 \, \text{mm}^2$$

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

$$A_{nv} = 2 \cdot t_a \cdot (l_{nv}) = 2 \cdot 8 \cdot (50 + 80 + 80 - 22 - 22 - 11) = 2480 \, \text{mm}^2$$

Reliability condition:

$$\frac{N_{Ed}}{V_{\text{eff}, Rd}} = \frac{454}{391} = 1.16 \geq 1.0$$

$\Rightarrow$ condition is not satisfied

**Gusset plate**

**Block tearing**

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

$$V_{\text{eff}, Rd} = \frac{0.5 \cdot f_u \cdot A_{nt}}{\gamma_{M2}} + \frac{f_y / \sqrt{3} \cdot A_{nv}}{\gamma_{M0}} = 0.5 \cdot 360 \cdot 510 \cdot 1.25 + \frac{235 / \sqrt{3} \cdot 2325}{1.00} = 73 + 315 = 388 \, kN$$

where

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

$$A_{nt} = t_p \cdot (l_{nt}) = 15 \cdot (45 - 11) = 510 \, \text{mm}^2$$

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

$$A_{nv} = t_p \cdot (l_{nv}) = 15 \cdot (50 + 80 + 80 - 22 - 22 - 11) \ldots$$
Reliability condition:

\[
\frac{N_{\text{Ed}}}{V_{\text{eff2,Rd}}} = \frac{454}{388} = 1.17 \geq 1.0
\]

\[= \textit{condition is not satisfied}\]

**Fillet weld**

\[N_{\text{Ed}} = 454 \text{ kN}\]

force in diagonal

\[N_{h,\text{Ed}} = N_{\text{Ed}} \cdot \cos \alpha = 454 \cdot \cos 31^\circ = 389 \text{ kN}\]

horizontal force portion

\[N_{v,\text{Ed}} = N_{\text{Ed}} \cdot \sin \alpha = 454 \cdot \sin 31^\circ = 233 \text{ kN}\]

vertical force portion

\[a = 5 \text{ mm} \quad \text{effective throat thickness of a fillet weld}\]

\[L = 419 \text{ mm} \quad \text{effective length of a fillet weld}\]

\[e = 68 \text{ mm} \quad \text{force eccentricity (brace diagonal axis) to centroid of the fillet weld}\]

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

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

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

\[
\sigma_\perp = \tau_{\parallel} = \frac{\sigma_v + \sigma_M}{\sqrt{2}} = \frac{56 + 54}{\sqrt{2}} = 78 \text{ MPa}
\]
Reliability conditions:

\[
\sqrt{\sigma_1^2 + 3 \cdot \left( \tau_1^2 + \tau_n^2 \right)} \leq \frac{f_u}{\beta_w \cdot \gamma_{M2}} \\
\sqrt{78^2 + 3 \cdot (78^2 + 93^2)} \leq \frac{360}{0.8 \cdot 1.25}
\]

\[
224 \text{ MPa} \leq 360 \text{ MPa} \quad \Rightarrow \text{condition is satisfied}
\]

\[
\sigma_1 \leq \frac{0.9 \cdot f_u}{\gamma_{M2}}
\]

\[
78 \text{ MPa} \leq \frac{0.9 \cdot 360}{1.25} = 259 \text{ MPa} \quad \Rightarrow \text{condition is satisfied}
\]

where \( \beta_w \) is correlation factor according to the table 1.

**Table 1.**

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>( \beta_w )</th>
</tr>
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<tbody>
<tr>
<td>S235</td>
<td>0.80</td>
</tr>
<tr>
<td>S275</td>
<td>0.85</td>
</tr>
<tr>
<td>S355</td>
<td>0.90</td>
</tr>
<tr>
<td>S420</td>
<td>1.00</td>
</tr>
<tr>
<td>S460</td>
<td>1.00</td>
</tr>
</tbody>
</table>
WORKED EXAMPLE 2:
SECONDARY BEAM TO PRIMARY BEAM CONNECTION IN ALTERNATIVE 2

**Force in connection**

Action on connection is reaction of secondary beam

\[ F_{\text{ed}} = 70 \text{kN} \]

Secondary beam: IPE 200, thickness of web \( t_w = 5.6 \text{ mm} \), steel S235

Fin plate: thickness \( t_p = 10 \text{ mm} \), steel S235

**Bolts**

Design: bolts M16, material 8.8

- \( f_{yb} = 640 \text{ MPa} \) bolt yield strength
- \( f_{ub} = 800 \text{ MPa} \) bolt ultimate strength
- \( d = 16 \text{ mm} \) bolt diameter
- \( d_0 = 18 \text{ mm} \) bolt hole diameter
- \( A = 201 \text{ mm}^2 \) gross cross section of the bolt
- \( A_s = 157 \text{ mm}^2 \) tensile stress area of the bolt
- \( e_1 = 40 \text{ mm} \) end distance
- \( p_1 = 60 \text{ mm} \) spacing
- \( e_2 = 35 \text{ mm} \) edge distance (smaller of them)

\( \Rightarrow \) bolt connection in shear
Shear force per one bolt

\[ F_{v, Ed} = \frac{F_{Ed}}{n_{bolt}} = \frac{70}{2} = 35 \text{kN} \]

Shear resistance

Shear resistance per one bolt

\[ F_{v, Rd} = n_s \cdot \alpha_v \cdot f_{sb} \cdot A_s \cdot \frac{\gamma_{M2}}{\gamma} = 1 \cdot \frac{0.6 \cdot 800 \cdot 157}{1.25} = 60 \text{kN} \]

where

\( n_s \) is number of shear planes
\( \alpha_v \) is factor for 8.8 if shear plane passes through the threaded portion of the bolt
\( A_s \) is used if shear planes pass through threaded portion of the bolt

Reliability criterion

\[ \frac{F_{v, Ed}}{F_{v, Rd}} = \frac{35}{60} = 0.58 \leq 1.0 \]

\( \Rightarrow \) condition is satisfied

Bearing resistance

Bearing resistance per one bolt

\[ F_{b, Rd} = \frac{k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t}{\gamma_{M2}} = \frac{2.5 \cdot 0.74 \cdot 360 \cdot 16 \cdot 5.6}{1.25} = 48 \text{kN} \]

where

\[ k_1 = \min \left\{ 2.8 \cdot \frac{e_2}{d_0} - 1.7; 1.4 \cdot \frac{P_2}{d_0} - 1.7; 2.5 \right\} = \min \left\{ 2.8 \cdot \frac{35}{18}; -1.7; 2.5 \right\} = \min \{3.74; -; 2.5\} = 2.5 \]

\[ \alpha_b = \min \left\{ \frac{e_1 \cdot P_1}{3d_0 d_0}, \frac{1}{4} \cdot \frac{f_{sb}}{f_u} : 1 \right\} = \min \left\{ \frac{40}{3 \cdot 18}; \frac{60}{3 \cdot 18}; \frac{1}{4} \cdot \frac{800}{360} : 1 \right\} = \min \{0.74; 0.86; 2.22; 1\} = 0.74 \]

\[ t = \min \left\{ t_p, t_w \right\} = \min \{10; 5.6\} = 5.6 \text{ mm} \]

Reliability criterion

\[ \frac{F_{v, Ed}}{F_{b, Rd}} = \frac{35}{48} = 0.73 \leq 1.0 \]

\( \Rightarrow \) condition is satisfied
**Fin plate**

**Shear resistance**

\[ V_{\text{pl,Rd}} = A_v \cdot \frac{f_y}{\sqrt{3}} \cdot \frac{1400 \cdot 235}{\gamma_{M0}} = 190 \text{kN} \]

where \( A_v \) is gross cross area of fin plate

\[ A_v = h_g \cdot t_g = 140 \cdot 10 = 1400 \text{mm}^2 \]

**Reliability criterion**

\[ \frac{F_{\text{Ed}}}{V_{\text{pl,Rd}}} = \frac{70}{190} = 0.37 \leq 1.0 \]

\( \Rightarrow \text{condition is satisfied} \)

**Block tearing**

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

\[ V_{\text{eff2,Rd}} = \frac{0.5 \cdot f_u \cdot A_{nt}}{\gamma_{M2}} + \frac{f_y}{\sqrt{3}} \cdot \frac{A_{nv}}{\gamma_{M0}} = \frac{0.5 \cdot 360 \cdot 261}{1.25} + \frac{235}{1.00} = 38 + 99 = 137 \text{kN} \]

where

\[ A_{nt} \] is net area subjected to tension

\[ A_{nt} = t_p \cdot (l_{nt}) = 10 \cdot (35 - 9) = 261 \text{mm}^2 \]

\[ A_{nv} \] is net area subjected to shear

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

**Reliability condition:**

\[ \frac{F_{\text{Ed}}}{V_{\text{eff2,Rd}}} = \frac{70}{137} = 0.51 \leq 1.0 \]

\( \Rightarrow \text{condition is satisfied} \)

**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

\[ V_{\text{eff2,Rd}} = \frac{0.5 \cdot f_u \cdot A_{nt}}{\gamma_{M2}} + \frac{f_y}{\sqrt{3}} \cdot \frac{A_{nv}}{\gamma_{M0}} = \frac{0.5 \cdot 360 \cdot 146}{1.25} + \frac{235}{1.00} = 21 + 55 = 76 \text{kN} \]

where
**A**<sub>nt</sub> is net area subjected to tension
\[ A_{nt} = t_w \cdot (l_{nt}) = 5.6 \cdot (35 - 9) = 146 \text{ mm}^2 \]

**A**<sub>nv</sub> 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:
\[ \frac{F_{Ed}}{V_{eff, Rd}} = \frac{70}{76} = 0.92 \leq 1.0 \]
=> *condition is satisfied*

**Fillet weld**

\[ F_{Ed} = 70 \text{ kN} \]

\[ M_{Ed} = F_{Ed} \cdot e = 70 \cdot 0.075 = 5.25 \text{ kNm} \]

Action of secondary beam

**additional moment due to eccentricity**

\[ a = 4 \text{ mm} \quad \text{effective throat thickness of a fillet weld} \]

\[ L = 140 \text{ mm} \quad \text{effective length of a fillet weld} \]

\[ \tau_{ll} = \frac{F_{Ed}}{2 \cdot L \cdot a} = \frac{70 \cdot 10^3}{2 \cdot 140 \cdot 4} = 63 \text{ MPa} \]

\[ \sigma_M = \frac{M_{Ed}}{2 \cdot \frac{1}{6} \cdot L^2 \cdot a} = \frac{5.25 \cdot 10^6}{2 \cdot \frac{1}{6} \cdot 140^2 \cdot 4} = 201 \text{ MPa} \]

\[ \sigma_{\perp} = \frac{\sigma_M}{\sqrt{2}} = \frac{201}{\sqrt{2}} = 142 \text{ MPa} \]

Reliability conditions:
\[ \sqrt{\sigma_{ll}^2 + 3 \cdot (\tau_{ll}^2 + \tau_{ll}^2)} \leq \frac{f_u}{\beta_w \cdot \gamma_{M2}} \]
\[ \sqrt{142^2 + 3 \cdot (142^2 + 63^2)} \leq \frac{360}{0.8 \cdot 1.25} \]
\[ 304 \text{ MPa} \leq 360 \text{ MPa} \]
=> *condition is satisfied*

\[ \sigma_{\perp} \leq \frac{0.9 \cdot f_u}{\gamma_{M2}} \]
\[ 142 \text{ MPa} \leq \frac{0.9 \cdot 360}{1.25} = 259 \text{ MPa} \]
=> *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

\[ F_{\text{Ed}} = 150 \text{ kN} \]

Primary beam: castellated beam made of IPE 300, thickness of web \( t_w = 7.1 \text{ mm} \), steel S235

Column: HEB 300, thickness of flange \( t_f = 19 \text{ mm} \), steel S235

End plate: thickness \( t_p = 15 \text{ mm} \), steel S235

**Bolts**

Design: bolts M16, material 8.8

- \( f_{yb} = 640 \text{ MPa} \) bolt yield strength
- \( f_{ub} = 800 \text{ MPa} \) bolt ultimate strength
- \( d = 16 \text{ mm} \) bolt diameter
- \( d_0 = 18 \text{ mm} \) bolt hole diameter
- \( A = 201 \text{ mm} \) gross cross section of the bolt
- \( A_s = 157 \text{ mm} \) tensile stress area of the bolt
- \( e_1 = 45 \text{ mm} \) end distance
- \( p_1 = 95 \text{ mm} \) spacing
- \( e_2 = 50 \text{ mm} \) edge distance (smaller of them)
- \( p_2 = 110 \text{ mm} \) spacing
=> bolt connection in shear

Shear force per one bolt

\[ F_{v,Ed} = \frac{F_{Ed}}{n_{bolt}} = \frac{150}{6} = 25 \text{ kN} \]

Shear resistance

Shear resistance per one bolt

\[ F_{v,Rd} = n_s \cdot \frac{\alpha_v \cdot f_{sb} \cdot A_s}{\gamma_{M2}} = 1 \cdot \frac{0.6 \cdot 800 \cdot 157}{1.25} = 60 \text{ kN} \]

where

- \( n_s \) is number of shear planes
- \( \alpha_v \) is factor for 8.8 if shear plane passes through the thread portion of the bolt
- \( A_s \) is used if shear planes pass through thread portion of the bolt

Reliability criterion

\[ \frac{F_{v,Ed}}{F_{v,Rd}} = \frac{25}{60} = 0.42 \leq 1.0 \quad \Rightarrow \text{condition is satisfied} \]

Bearing resistance

Bearing resistance per one bolt

\[ F_{b,Rd} = k_1 \cdot \alpha_b \cdot f_a \cdot d \cdot t \cdot \frac{\gamma_{M2}}{1.25} = 2.5 \cdot 0.83 \cdot 360 \cdot 16 \cdot 15 = 143 \text{ kN} \]

where

\[ k_1 = \min \left\{ 2.8 \cdot \frac{e_3}{d_0} - 1.7 ; 1.4 \cdot \frac{p_3}{d_0} - 1.7 ; 2.5 \right\} = \min \left\{ 2.8 \cdot \frac{50}{18} - 1.7 ; 1.4 \cdot \frac{110}{18} - 1.7 ; 2.5 \right\} = \min \{6.08 ; 6.86 ; 2.5\} = 2.5 \]

\[ \alpha_b = \min \left\{ \frac{e_1}{3d_0} ; \frac{p_3}{3d_0} - \frac{1}{4} ; \frac{f_{sb}}{f_a} ; 1 \right\} = \min \left\{ \frac{45}{3 \cdot 18} ; \frac{95}{3 \cdot 18} - \frac{1}{4} ; \frac{800}{360} ; 1 \right\} = \min \{0.83 ; 1.51 ; 2.22 ; 1\} = 0.83 \]

\[ t = \min \left\{ t_p ; t_t \right\} = \min \{15 ; 19\} = 15 \text{ mm} \]

Reliability criterion

\[ \frac{F_{v,Ed}}{F_{b,Rd}} = \frac{25}{143} = 0.17 \leq 1.0 \quad \Rightarrow \text{condition is satisfied} \]
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

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

=> 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

\[ V_{eff1, Rd} = \frac{f_u \cdot A_{nt}}{\gamma_{M2}} + \frac{f_y / \sqrt{3} \cdot A_{nv}}{\gamma_{M0}} = \frac{360 \cdot 1230}{1,25} + \frac{235 / \sqrt{3} \cdot 5700}{1,00} = 354 + 773 = 1127 \text{kN} \]

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:

\[ \frac{F_{Ed}}{V_{eff2, Rd}} = \frac{150}{1127} = 0,13 \leq 1,0 \]

=> condition is satisfied

Fillet weld

\( F_{Ed} = 150 \text{kN} \)

action of secondary beam

\( a = 4 \text{ mm} \)

effective throat thickness of a fillet weld

\( L = 272 \text{ mm} \)

effective length of a fillet weld

\[ \tau_{ll} = \frac{F_{Ed}}{2 \cdot L \cdot a} = \frac{150 \cdot 10^3}{2 \cdot 272 \cdot 4} = 69 \text{ MPa} \]

\( \sigma_\perp = \tau_\perp = 0 \text{ MPa} \)
Reliability conditions:

\[
\sqrt{\sigma_1^2 + 3 \cdot \left( \tau_1^2 + \tau_2^2 \right)} \leq \frac{f_u}{\beta_u \cdot \gamma_{M2}}
\]

\[
\sqrt{0^2 + 3 \cdot (0^2 + 69^2)} \leq \frac{360}{0.8 \cdot 1.25}
\]

120 MPa \leq 360 MPa \quad \Rightarrow \text{condition is satisfied}

\[
\sigma_1 \leq \frac{0.9 \cdot f_u}{\gamma_{M2}}
\]

0 MPa \leq \frac{0.9 \cdot 360}{1.25} = 259 MPa \quad \Rightarrow \text{condition is satisfied}