Example: Bolted connection of an angle brace in tension to a gusset plate

This worked example shows the procedure to check the bolted connection of an angle brace in tension to a gusset plate welded to a column web. Non preloaded bolts are used (Category A: bearing type).

These types of connections are typical for cross bracings used both in facades and in roofs to withstand the actions of the horizontal wind load in the longitudinal axis of the single storey building. This is illustrated in SS048.

In order to avoid eccentricities of the loads brought to the foundation, the angle axis is aligned to meet the column vertical axis plane at the base plate and the gusset plate is placed as close as possible to the column major axis plane.

Table 1.1 Modes of failure of the bracing connection

<table>
<thead>
<tr>
<th>Mode of failure</th>
<th>Component Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolts in shear</td>
<td>$N_{Rd,1}$</td>
</tr>
<tr>
<td>Bolts in bearing (on the angle leg)</td>
<td>$N_{Rd,2}$</td>
</tr>
<tr>
<td>Angle in tension</td>
<td>$N_{Rd,3}$</td>
</tr>
<tr>
<td>Weld design</td>
<td>$a$</td>
</tr>
</tbody>
</table>
Bracing Connection – Details

The Figure 1.1 shows the long leg of the 120x80 angle that is attached to the gusset plate.

![Diagram of bracing connection]

Common practice is to minimize the eccentricity between the bracing member and the column axis. The gusset plate is welded to the column web and to the base plate using double fillet welds (see Figure 1.1). Although there is some eccentricity in order to avoid the anchor bolt on the column axis, this is much better than having the bracing plane on the column flange axis.

**Main joint data**

- **Configuration**: Angle to gusset plate welded to a column web
- **Column**: HEB 300, S275
- **Bracing**: 120 × 80 × 12 angle, S275
- **Type of connection**: Bracing connection using angle to a gusset plate and non-preloaded bolts
  - Category A: Bearing type
- **Gusset plate**: 250 × 300 × 15, S275
- **Bolts**: M20, grade 8.8
- **Welds**: Gusset plate to column web: fillet weld, \( a = 4 \text{ mm} \) (see section 4).
  - Gusset plate to base plate: fillet weld, \( a = 4 \text{ mm} \) (see section 4).
### Column HEB 300, S275

- **Depth** \( h_c = 300 \text{ mm} \)
- **Width** \( b_c = 300 \text{ mm} \)
- **Thickness of the web** \( t_{w,c} = 11 \text{ mm} \)
- **Thickness of the flange** \( t_{f,c} = 19 \text{ mm} \)
- **Fillet radius** \( r = 27 \text{ mm} \)
- **Area** \( A_c = 149,1 \text{ cm}^2 \)
- **Second moment of area** \( I_y = 25170 \text{ cm}^4 \)
- **Depth between fillets** \( d_c = 208 \text{ mm} \)
- **Yield strength** \( f_{y,c} = 275 \text{ N/mm}^2 \)
- **Ultimate tensile strength** \( f_{u,c} = 430 \text{ N/mm}^2 \)

### Angle 120 × 80 × 12, S275

- **Depth** \( h_{ac} = 120 \text{ mm} \)
- **Width** \( b_{ac} = 80 \text{ mm} \)
- **Thickness of the angle** \( t_{ac} = 12 \text{ mm} \)
- **Fillet radius** \( r_1 = 11 \text{ mm} \)
- **Fillet radius** \( r_2 = 5.5 \text{ mm} \)
- **Area** \( A_{ac} = 22,7 \text{ cm}^2 \)
- **Second moment of area** \( I_y = 322.8 \text{ cm}^4 \)
- **Yield strength** \( f_{y,ac} = 275 \text{ N/mm}^2 \)
- **Ultimate tensile strength** \( f_{u,ac} = 430 \text{ N/mm}^2 \)
## CALCULATION SHEET

**Title**: Example: Bolted connection of an angle brace in tension to a gusset plate  

**Eurocode Ref**:  

**Made by**: Edurne Nuñez  
**Date**: April 2006  
**Checked by**: Jose A Chica  
**Date**: April 2006

### Gusset plate 250 × 300 × 15, S275

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>(h_p = 300) mm</td>
</tr>
<tr>
<td>Width</td>
<td>(b_p = 250) mm</td>
</tr>
<tr>
<td>Thickness</td>
<td>(t_p = 15) mm</td>
</tr>
<tr>
<td>Yield strength</td>
<td>(f_{y,p} = 275) N/mm²</td>
</tr>
<tr>
<td>Ultimate tensile strength</td>
<td>(f_{u,p} = 430) N/mm²</td>
</tr>
</tbody>
</table>

### Direction of load transfer (1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of bolt rows</td>
<td>(n_1 = 3)</td>
</tr>
<tr>
<td>Angle edge to first bolt row</td>
<td>(e_1 = 50) mm</td>
</tr>
<tr>
<td>Pitch between bolt rows</td>
<td>(p_1 = 80) mm</td>
</tr>
</tbody>
</table>

### Direction perpendicular to load transfer (2)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of lines of bolts</td>
<td>(n_2 = 1)</td>
</tr>
<tr>
<td>Angle attached leg edge to bolt line</td>
<td>(e_2 = 80) mm</td>
</tr>
</tbody>
</table>

### Bolts M20, 8.8

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of bolts ((n = n_1 \times n_2))</td>
<td>(n = 3)</td>
</tr>
<tr>
<td>Tensile stress area</td>
<td>(A_s = 245) mm²</td>
</tr>
<tr>
<td>Diameter of the shank</td>
<td>(d = 20) mm</td>
</tr>
<tr>
<td>Diameter of the holes</td>
<td>(d_o = 22) mm</td>
</tr>
<tr>
<td>Diameter of the washer</td>
<td>(d_w = 37) mm</td>
</tr>
<tr>
<td>Yield strength</td>
<td>(f_{yb} = 640) N/mm²</td>
</tr>
<tr>
<td>Ultimate tensile strength</td>
<td>(f_{ub} = 800) N/mm²</td>
</tr>
</tbody>
</table>

### Partial safety factors

\(\gamma_{M0} = 1.0\)  
\(\gamma_{M2} = 1.25\) (for shear resistance of bolts)

### Design axial tensile force applied by the angle brace to the gusset plate.

\(N_{Ed} = 250\) kN
1  Bolts in shear

\[ N_{Rd,1} = nF_{v,Rd} \]

\[ F_{v,Rd} = \alpha_v f_{u,ac} = 0.6 \times 800 \times 245 \times 10^{-3} = 94.08 \text{ kN} \]

\[ N_{Rd,1} = 3 \times 94.08 = 282 \text{ kN} \]

2  Bolts in bearing (on the angle leg)

Note: The angle leg thickness, 12mm, being less than that of the gusset plate, 15mm, and assuming an end distance of 50 mm or greater for the gusset plate, only the attached angle leg requires a design check for bearing.

\[ N_{Rd,2} = nF_{b,Rd} \]

\[ F_{b,Rd} = \frac{k_1 \alpha_b f_{u,ac} dT_{ac}}{\gamma M_2} \]

All bolts

\[ k_i = \min \left( 2.8 \times \frac{e_2}{d_o} - 1.7, \ 2.5 \right) \]

\[ 2.8 \times \frac{e_2}{d_o} - 1.7 = 2.8 \times \frac{80}{22} - 1.7 = 8.48 \]

\[ \therefore k_i = \min(8.48, 2.5) = 2.5 \]

End bolt:

\[ \alpha_b = \min \left( \frac{e_1}{3d_o}, \frac{f_{ub}}{f_{u,ac}}, \ 1.0 \right) \]

\[ e_1 = \frac{50}{3 \times 22} = 0.76 \]

\[ \frac{f_{ub}}{f_{u,ac}} = \frac{800}{430} = 1.86 \]

\[ \therefore \alpha_b = \min(0.76, 1.86, 1.0) = 0.76 \]

\[ F_{b,Rd,\text{end bolt}} = \frac{2.5 \times 0.76 \times 430 \times 20 \times 12 \times 10^{-3}}{1.25} = 156.9 \text{ kN} \]
Interior bolts:

\[
\alpha_b = \min \left( \frac{p_1}{3d_0} - \frac{1}{4} ; \frac{f_{ub}}{f_{u,ac}} ; 1,0 \right)
\]

\[
p_1 - \frac{1}{3d_0} = \frac{80}{3 \times 22} - \frac{1}{4} = 0,96
\]

\[
\frac{f_{ub}}{f_{u,ac}} = \frac{800}{430} = 1,86
\]

\[
\therefore \alpha_b = \min(0,96; 1,86; 1,0) = 0,96
\]

\[
\therefore F_{b,Rd,\text{interior bolt}} = \frac{2,5 \times 0,96 \times 430 \times 20 \times 12}{1,25} \times 10^{-3} = 198,1 \text{kN}
\]

The bearing strength of the end bolt and of the interior bolt is greater than the bolt shear strength. The least value for the bearing strength of a bolt in the connection is adopted for all bolts.

\[
\therefore N_{Rd,2} = 3 \times 156,9 = 471 \text{ kN}
\]

**3 Angle in tension**

\[
N_{Rd,3} = \frac{\beta_3 A_{\text{net}} f_u}{\gamma_{M2}}
\]

2,5\(d_0\) = 2,5 \times 22 = 55 mm

5\(d_0\) = 5 \times 22 = 110 mm

2,5\(d_0\) < \(p_1\) < 5\(d_0\)

\(\beta_3\) can be determined by linear interpolation:

\[
\therefore \beta_3 = 0,59
\]

\[
A_{\text{net}} = A - t_{ac} d_0 = 2270 - 12 \times 22 = 2006 \text{ mm}^2
\]

\[
\therefore N_{Rd,3} = \frac{0,59 \times 2006 \times 430}{1,25} \times 10^{-3} = 407 \text{ kN}
\]
4 Weld design

The weld is designed as follows:

The gusset plate is welded to the column web and to the base plate using double fillet welds.

The procedure to determine the throat thickness of the double fillet welds is the same for the gusset plate/column web connection and for the gusset plate/base plate connection.

The following calculations show the design of the weld between the gusset plate and the base plate.

It is possible to provide full strength double fillet welds following simplified recommendations, see SN017, however that approach is too conservative for this example.

The recommended procedure to follow is to propose a size of the weld throat and to check whether it complies with the requirement of resistance:

Here, propose $a = 4 \text{ mm}$

Design resistance for the double weld, according to the simplified method is:

$$N_{Rd,w,\text{hor}} = 2F_{w,Rd}$$

$$F_{w,Rd} = f_{vw,d}a$$

$$f_{vw,d} = f_u / \sqrt{3}$$

$$\frac{430/\sqrt{3}}{0.85 \times 1.25} = 233.66 \text{ N/mm}^2$$

$$\therefore F_{w,Rd} = 233.66 \times 4 = 934.6 \text{ N/mm}$$

$$\therefore N_{Rd,w,\text{hor}} = 2 \times 934.6 \times 250 \times 10^{-3} = 467 \text{kN}$$

It supports the horizontal component of the force acting in the bracing, which is:

$$N_{Ed,\text{hor}} = N_{Ed} \sin 40 = 250 \times \sin 40 = 161 \text{kN}$$

Therefore the horizontal weld is OK.

Similar approach applies to the vertical weld (the gusset plate is welded to the column web).
5 Summary

The following table summarizes the resistance values for the critical modes of failure. The governing value for the joint (i.e. the minimum value) is shown in bold type.

Table 5.1 Summary of the resistance values in the bolted bracing connection

<table>
<thead>
<tr>
<th>Mode of failure</th>
<th>Component resistance</th>
<th>N_Rd,1</th>
<th>282 kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolts in shear</td>
<td></td>
<td>N_Rd,1</td>
<td>282 kN</td>
</tr>
<tr>
<td>Bolts in bearing on the angle leg</td>
<td></td>
<td>N_Rd,2</td>
<td>471 kN</td>
</tr>
<tr>
<td>Angle in tension</td>
<td></td>
<td>N_Rd,3</td>
<td>407 kN</td>
</tr>
</tbody>
</table>

Some modes of failure are not checked. For example, the gusset plate in bearing and in tension is not checked because its thickness is greater than that of the angle, and therefore the angle cleat would fail before the plate.
## Quality Record

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<td>Reference(s)</td>
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