CALCULATION SHEET	Document Ref:	SX034a-EN-EU	Sheet	1 of 8	
	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	

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

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

Mode of failure	Component Resistance
Bolts in shear	$N_{Rd,1}$
Bolts in bearing (on the angle leg)	$N_{Rd,2}$
Angle in tension	$N_{Rd,3}$
Weld design	a

CALCULATION SHEET	Document Ref:	*SX034a-EN-EU*	Sheet	*2* of *8*	
	Title	***Example: Bolted connection of an angle brace in tension to a gusset plate***			
	Eurocode Ref				
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Bracing Connection – Details

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

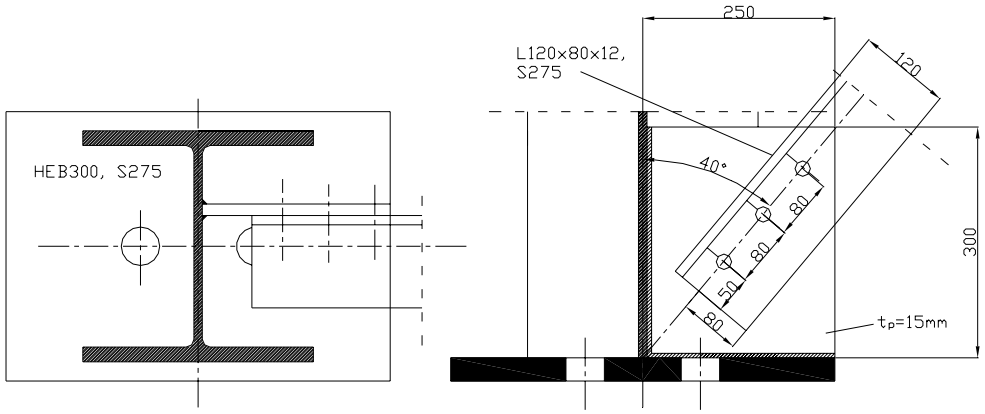

Figure 1.1 Detail of the bolted connection: plan and section view

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 mm (see section 4). Gusset plate to base plate: fillet weld, a = 4 mm (see section 4).

CALCULATION SHEET	Document Ref:	SX034a-EN-EU	Sheet 3 of 8	
	Title	Example: Bolted connection of an angle brace in tension to a gusset plate		
	Eurocode Ref			
	Made by	Edurne Nuñez	Date	April 2006
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Column HEB 300, S275

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

Angle 120 × 80 × 12, S275

Depth	h_{ac}	= 120 mm
Width	b_{ac}	= 80 mm
Thickness of the angle	t_{ac}	= 12 mm
Fillet radius	r_1	= 11 mm
Fillet radius	r_2	= 5,5 mm
Area	A_{ac}	= 22,7 cm^2
Second moment of area	I_y	= 322,8 cm^4
Yield strength	$f_{y,ac}$	= 275 N/mm^2
Ultimate tensile strength	$f_{u,ac}$	= 430 N/mm^2

CALCULATION SHEET	Document Ref:	SX034a-EN-EU	Sheet 4 of 8	
	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

Depth	h_p	= 300 mm
Width	b_p	= 250 mm
Thickness	t_p	= 15 mm
Yield strength	$f_{y,p}$	= 275 N/mm^2
Ultimate tensile strength	$f_{u,p}$	= 430 N/mm^2

Direction of load transfer (1)

Number of bolt rows	n_1	= 3
Angle edge to first bolt row	e_1	= 50 mm
Pitch between bolt rows	p_1	= 80 mm

Direction perpendicular to load transfer (2)

Number of lines of bolts	n_2	= 1
Angle attached leg edge to bolt line	e_2	= 80 mm

Bolts M20, 8.8

Total number of bolts ($n = n_1 \times n_2$)	n	= 3
Tensile stress area	A_s	= 245 mm^2
Diameter of the shank	d	= 20 mm
Diameter of the holes	d_o	= 22 mm
Diameter of the washer	d_w	=37 mm
Yield strength	f_{yb}	= 640 N/mm^2
Ultimate tensile strength	f_{ub}	= 800 N/mm^2

Partial safety factors

γ_{M0} = 1,0

γ_{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

CALCULATION SHEET	Document Ref:	SX034a-EN-EU	Sheet	5 of 8	
	Title	Example: Bolted connection of an angle brace in tension to a gusset plate			
	Eurocode Ref				
	Made by	Edurne Nuñez	Date	April 2006	
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1 Bolts in shear

EN1993-1-8 Table 3.4.

$$N_{\mathrm{Rd},1} = nF_{\mathrm{v,Rd}}$$

$$F_{\mathrm{v,Rd}} = \alpha_{\mathrm{v}} \frac{f_{\mathrm{ub}} A}{\gamma_{\mathrm{M,2}}} = 0{,}6 \times \frac{800 \times 245}{1{,}25} \times 10^{-3} = 94{,}08 \text{ kN}$$

$$N_{\mathrm{Rd},1} = 3 \times 94{,}08 = 282 \text{ kN}$$

2 Bolts in bearing (on the angle leg)

EN1993-1-8 Table 3.4.

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.

$$N_{\mathrm{Rd},2} = nF_{\mathrm{b,Rd}}$$

$$F_{\mathrm{b,Rd}} = \frac{k_1 \alpha_{\mathrm{b}} f_{\mathrm{u,ac}} d t_{\mathrm{ac}}}{\gamma_{\mathrm{M2}}}$$

All bolts

$$k_1 = \min\left(2{,}8 \times \frac{e_2}{d_0} - 1{,}7; \quad 2{,}5\right)$$

$$2{,}8 \times \frac{e_2}{d_0} - 1{,}7 = 2{,}8 \times \frac{80}{22} - 1{,}7 = 8{,}48$$

$$\therefore \; k_1 = \min(8{,}48; \quad 2{,}5) = 2{,}5$$

End bolt:

$$\alpha_{\mathrm{b}} = \min\left(\frac{e_1}{3d_0}; \quad \frac{f_{\mathrm{ub}}}{f_{\mathrm{u,ac}}}; \quad 1{,}0\right)$$

$$\frac{e_1}{3d_0} = \frac{50}{3 \times 22} = 0{,}76$$

$$\frac{f_{\mathrm{ub}}}{f_{\mathrm{u,ac}}} = \frac{800}{430} = 1{,}86$$

$$\therefore \; \alpha_{\mathrm{b}} = \min(0{,}76; \quad 1{,}86; \quad 1{,}0) = 0{,}76$$

$$F_{\mathrm{b,Rd,end\ bolt}} = \frac{2{,}5 \times 0{,}76 \times 430 \times 20 \times 12}{1{,}25} \times 10^{-3} = 156{,}9 \text{ kN}$$

CALCULATION SHEET	Document Ref:	SX034a-EN-EU	Sheet 6 of 8	
	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

Interior bolts:

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

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

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

$$\therefore\ \alpha_b = \min(0{,}96;\quad 1{,}86;\quad 1{,}0) = 0{,}96$$

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

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.

EN1993-1-8 §3.7(1)

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

3 Angle in tension

EN1993-1-8 §3.10.3

$$N_{Rd,3} = \frac{\beta_3 A_{net} f_u}{\gamma_{M2}}$$

$$2{,}5d_0 = 2{,}5\times 22 = 55\,\text{mm}$$

$$5d_0 = 5\times 22 = 110\,\text{mm}$$

$$2{,}5d_0 < p_1 < 5d_0$$

β_3 can be determined by linear interpolation:

$$\therefore\ \beta_3 = 0{,}59$$

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

$$\therefore\ N_{Rd,3} = \frac{0{,}59\times 2006\times 430}{1{,}25}\times 10^{-3} = 407\,\text{kN}$$

CALCULATION SHEET	Document Ref:	SX034a-EN-EU	Sheet	7 of 8	
	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	

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.

SN017

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:

EN1993-1-8 §4.5.3.3

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

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

$$f_{\text{vw,d}} = \frac{f_{\text{u}}/\sqrt{3}}{\beta_{\text{w}}\gamma_{\text{M2}}} = \frac{430/\sqrt{3}}{0{,}85\times 1{,}25} = 233{,}66\ \text{N/mm}^2$$

$$\therefore\ F_{\text{w,Rd}} = 233{,}66\times 4 = 934{,}6\ \text{N/mm}$$

$$\therefore\ N_{\text{Rd,w,hor}} = 2\times 934{,}6\times 250\times 10^{-3} = 467\ \text{kN}$$

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

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

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

Mode of failure	Component resistance	
Bolts in shear	$\boldsymbol{N_{\mathrm{Rd,1}}}$	**282 kN**
Bolts in bearing on the angle leg	$N_{\mathrm{Rd,2}}$	471 kN
Angle in tension	$N_{\mathrm{Rd,3}}$	407 kN

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

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