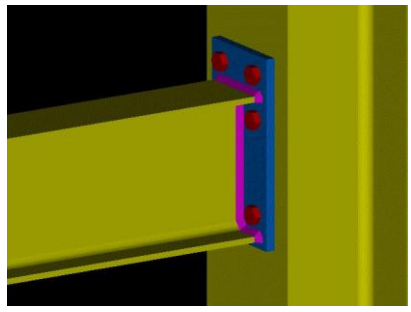


Ligações Aparafusadas – Parte III

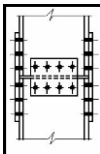
Programa de Pós-Graduação em Engenharia Civil

PGECIV - Mestrado Acadêmico

Faculdade de Engenharia – FEN/UERJ

Disciplina: Ligações em Estruturas de Aço e Mistas

Professor: Luciano Rodrigues Ornelas de Lima



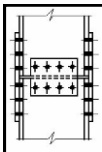
11. Dimensionamento

Table 2.1: Partial safety factors for joints

Resistance of members and cross-sections	γ_{M0} , γ_{M1} and γ_{M2} see EN 1993-1-1
Resistance of bolts	γ_{M2}
Resistance of rivets	
Resistance of pins	
Resistance of welds	
Resistance of plates in bearing	
Slip resistance - for hybrid connections or connections under fatigue loading - for other design situations	γ_{M3} γ_{M3}
Bearing resistance of an injection bolt	γ_{M4}
Resistance of joints in hollow section lattice girder	γ_{M5}
Resistance of pins at serviceability limit state	$\gamma_{M6,ser}$
Preload of high strength bolts	γ_{M7}
Resistance of concrete	γ_c see EN 1992

NOTE: Numerical values for γ_M may be defined in the National Annex. Recommended values are as follows: $\gamma_{M2} = 1,25$; $\gamma_{M3} = 1,25$ for hybrid connections or connections under fatigue loading and $\gamma_{M3} = 1,1$ for other design situations; $\gamma_{M4} = 1,0$; $\gamma_{M5} = 1,0$; $\gamma_{M6,ser} = 1,0$; $\gamma_{M7} = 1,1$.

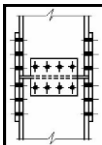
Joints subject to fatigue should also satisfy the principles given in EN 1993-1-9.



11. Dimensionamento

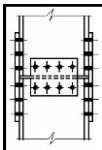
Table 3.2: Categories of bolted connections

Category	Criteria	Remarks
	Shear connections	
A bearing type	$F_{v,Ed} \leq F_{v,Rd}$ $F_{v,Ed} \leq F_{b,Rd}$	No preloading required. Bolt classes from 4.6 to 10.9 may be used.
B slip-resistant at serviceability	$F_{v,Ed,ser} \leq F_{s,Rd,ser}$ $F_{v,Ed} \leq F_{v,Rd}$ $F_{v,Ed} \leq F_{b,Rd}$	Preloaded 8.8 or 10.9 bolts should be used. For slip resistance at serviceability see 3.9.
C slip-resistant at ultimate	$F_{v,Ed} \leq F_{s,Rd}$ $F_{v,Ed} \leq F_{b,Rd}$ $F_{v,Ed} \leq N_{net,Rd}$	Preloaded 8.8 or 10.9 bolts should be used. For slip resistance at ultimate see 3.9. $N_{net,Rd}$ see EN 1993-1-1



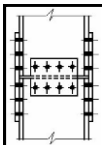
11. Dimensionamento

- **Resistência ao Cisalhamento EC3 - pt. 1.8**
  - a) Category A: Bearing type
    - ✓ Bolts from class 4.6 up to and including class 10.9 should be used
    - ✓ No preloading / special provisions for contact surfaces are required
    - ✓ The design ultimate shear load ≤ shear and/or bearing resistance
  - b) Category B: Slip-resistant at serviceability limit state
    - ✓ Preloads bolts - Only classes 8.8 and 10.9
  - c) Category C: Slip-resistant at ultimate limit state
    - ✓ Preloads bolts - Only classes 8.8 and 10.9 - Slip should not occur at the ULS
    - ✓ The design ultimate shear load should not exceed the design slip resistance nor the design bearing resistance
    - ✓ In addition for a connection in tension, the design plastic resistance of the net cross-section at bolt holes $N_{net,Rd}$ – other ULS



11. Dimensionamento

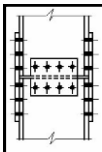
Tension connections		
D non-preloaded	$F_{t,Ed} \leq F_{t,Rd}$ $F_{t,Ed} \leq B_{p,Rd}$	No preloading required. Bolt classes from 4.6 to 10.9 may be used. $B_{p,Rd}$ see Table 3.4.
E preloaded	$F_{t,Ed} \leq F_{t,Rd}$ $F_{t,Ed} \leq B_{p,Rd}$	Preloaded 8.8 or 10.9 bolts should be used. $B_{p,Rd}$ see Table 3.4.
The design tensile force $F_{t,Ed}$ should include any force due to prying action, see 3.11. Bolts subjected to both shear force and tensile force should also satisfy the criteria given in Table 3.4.		



11. Dimensionamento

- **Resistência a Tração - Eurocode 3 pt. 1.8**
  - d) Category D: non-preloaded
    - ✓ Bolts from class 4.6 up to and including class 10.9 should be used
    - ✓ This category should not be used where the connections are frequently subjected to variations of tensile loading
    - ✓ However, they may be used in connections designed to resist normal wind loads.
  - e) Category E: non-preloaded
    - ✓ Preloads bolts - Only classes 8.8 and 10.9 with controlled tightening

$$F_{p,Cd} = 0,7\, f_{ub}\, A_s / \gamma_{M7}$$

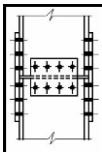


11. Dimensionamento

- Resistência Cisalhamento e ou Tração EC3 pt. 1.8

Table 3.4: Design resistance for individual fasteners subjected to shear and/or tension

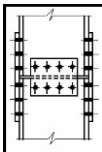
Failure mode	Bolts	Rivets
Shear resistance per shear plane	$F_{v,Rd} = \frac{\alpha_v \, f_{ub} \, A}{\gamma_{M2}}$ - where the shear plane passes through the threaded portion of the bolt (A is the tensile stress area of the bolt A_s): - for classes 4.6, 5.6 and 8.8: $\alpha_v = 0,6$ - for classes 4.8, 5.8, 6.8 and 10.9: $\alpha_v = 0,5$ - where the shear plane passes through the unthreaded portion of the bolt (A is the gross cross section of the bolt): $\alpha_v = 0,6$	$F_{v,Rd} = \frac{0,6 \, f_{ur} \, A_0}{\gamma_{M2}}$



11. Dimensionamento

- Resistência Cisalhamento e ou Tração EC3 pt. 1.8

Bearing resistance [1), 2), 3)]	$F_{b,Rd} = \frac{k_1 \, a_b \, f_u \, d \, t}{\gamma_{M2}}$ where α_b is the smallest of α_d ; $\frac{f_{ub}}{f_u}$ or 1,0; in the direction of load transfer: - for end bolts: $\alpha_d = \frac{e_1}{3d_0}$; for inner bolts: $\alpha_d = \frac{p_1}{3d_0} - \frac{1}{4}$ perpendicular to the direction of load transfer: - for edge bolts: k_1 is the smallest of $2,8\frac{e_2}{d_0} - 1,7$ or 2,5 - for inner bolts: k_1 is the smallest of $1,4\frac{p_2}{d_0} - 1,7$ or 2,5



11. Dimensionamento

Resistência Cisalhamento e ou Tração EC3 pt. 1.8

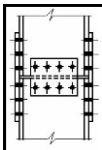
The bearing resistance $F_{b,Rd}$ for bolts

- in oversized holes is 0,8 times the bearing resistance for bolts in normal holes.
- in slotted holes, where the longitudinal axis of the slotted hole is perpendicular to the direction of the force transfer, is 0,6 times the bearing resistance for bolts in round, normal holes.

For countersunk bolt: (rosca inversa)

- the bearing resistance $F_{b,Rd}$ should be based on a plate thickness t equal to the thickness of the connected plate minus half the depth of the countersinking.
- for the determination of the tension resistance $F_{t,Rd}$ the angle and depth of countersinking should conform with 2.8 Reference Standards: Group 4, otherwise the tension resistance $F_{t,Rd}$ should be adjusted accordingly.

When the load on a bolt is not parallel to the edge, the bearing resistance may be verified separately for the bolt load components parallel and normal to the end.



11. Dimensionamento

Resistência Cisalhamento e ou Tração EC3 pt. 1.8

Tension resistance [2)]	$F_{t,Rd} = \frac{k_2 \, f_{ub} \, A_s}{\gamma_{M2}}$ where $k_2 = 0,63$ for countersunk bolt, otherwise $k_2 = 0,9$.	$F_{t,Rd} = \frac{0,6 \, f_{ur} \, A_0}{\gamma_{M2}}$
Punching shear resistance	$B_{p,Rd} = 0,6 \, \pi \, d_m \, t_p \, f_u / \gamma_{M2}$	No check needed
Combined shear and tension	$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1,4 \, F_{t,Rd}} \le 1,0$	

For countersunk bolt: (rosca inversa)

- the bearing resistance $F_{b,Rd}$ should be based on a plate thickness t equal to the thickness of the connected plate minus half the depth of the countersinking.
- for the determination of the tension resistance $F_{t,Rd}$ the angle and depth of countersinking should conform with 2.8 Reference Standards: Group 4, otherwise the tension resistance $F_{t,Rd}$ should be adjusted accordingly.

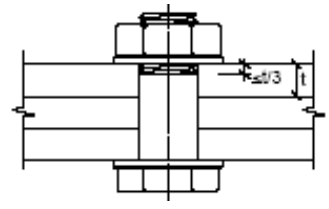
11. Dimensionamento

- **M12 and M14 bolts may also be used in 2 mm clearance holes provided that the bolt group resistance based on bearing is ≥ bolt group resistance based on bolt shear.**

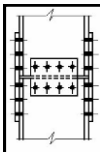
- **In addition for class 4.8, 5.8, 6.8, 8.8 and 10.9 bolts, the shear resistance $F_{v,Rd}$ should be taken as 0,85 x value given in Table 3.4**

11. Dimensionamento

- **Fit bolts**
  - Should be designed as bolts in normal holes
  - Fit bolt thread should not be included in the shear plane
  - Length of the threaded portion of a fit bolt included in the bearing length ≤ 1/3 plate thickness



- Hole tolerance → 2.8 Ref. Standards: Group 7

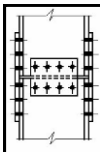


PGECIV

11. Dimensionamento

- In single lap joints with only one bolt row the bolts should be provided with washers under both the head and the nut
- The bearing resistance $F_{b,Rd}$ for each bolt should be limited to:

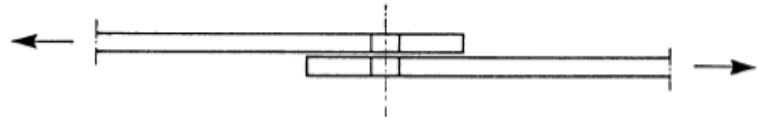
$$F_{b,Rd} \leq 1,5 f_u d t / \gamma_{M2}$$



PGECIV

11. Dimensionamento

- Single rivets should not be used in single lap joints.

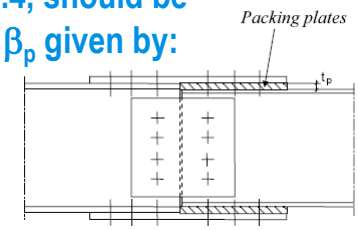


- In the case of class 8.8 or 10.9 bolts, hardened washers should be used for single lap joints with only one bolt or one row of bolts

11. Dimensionamento

- Where bolts or rivets transmitting load in shear and bearing pass through packing of total thickness t_p > 1/3 of the nominal diameter - the shear resistance $F_{v,Rd}$ calculated as specified in Table 3.4, should be multiplying by a reduction factor β_p given by:

$$\beta_p = \frac{9d}{8d + 3t_p} \quad \text{but } \beta_p \leq 1$$

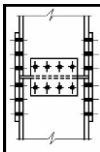


- For double shear connections with packing on both sides of the splice, t_p should be taken as the thickness of the thicker packing

11. Dimensionamento

- Aços Ingleses

Grade	Espessura t <	Tensão de Escoamento Fy (MPa)
43	16	275
	40	265
	100	245
50	16	355
	63	340
	100	325
55	16	450
	25	430
	40	415



11. Dimensionamento

Resistência ao Atrito EC3 pt. 1.8

The design slip resistance of a preloaded class 8.8 or 10.9 bolt should be taken as:

$$F_{s,Rd} = \frac{k_s \, n \, \mu}{\gamma_{M3}} F_{p,C} \qquad \text{... (3.6)}$$

where:

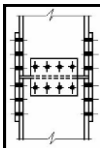
k_s is given in Table 3.6

n is the number of the friction surfaces

μ is the slip factor obtained either by specific tests for the friction surface in accordance with 2.8 Reference Standards: Group 7 or when relevant as given in Table 3.7.

For class 8.8 and 10.9 bolts conforming with 2.8 Reference Standards: Group 4, with controlled tightening in conformity with 2.8 Reference Standards: Group 7, the preloading force $F_{p,C}$ to be used in equation (3.6) should be taken as:

$$F_{p,C} = 0{,}7 \, f_{ub} \, A_s \qquad \text{... (3.7)}$$

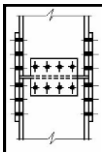


11. Dimensionamento

Resistência ao Atrito EC3 pt. 1.8

Table 3.6: Values of k_s

Description	k_s
Bolts in normal holes.	1,0
Bolts in either oversized holes or short slotted holes with the axis of the slot perpendicular to the direction of load transfer.	0,85
Bolts in long slotted holes with the axis of the slot perpendicular to the direction of load transfer.	0,7
Bolts in short slotted holes with the axis of the slot parallel to the direction of load transfer.	0,76
Bolts in long slotted holes with the axis of the slot parallel to the direction of load transfer.	0,63



11. Dimensionamento

- **Resistência ao Atrito EC3 pt. 1.8**

Table 3.7: Slip factor, μ, for pre-loaded bolts

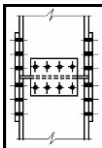
Class of friction surfaces (see 2.8 Reference Standard: Group 7)	Slip factor μ
A	0,5
B	0,4
C	0,3
D	0,2

NOTE 1: The requirements for testing and inspection are given in 2.8 Reference Standards: Group 7.

NOTE 2: The classification of any other surface treatment should be based on test specimens representative of the surfaces used in the structure using the procedure set out in 2.8 Reference Standards: Group 7.

NOTE 3: The definitions of the class of friction surface are given in 2.8 Reference Standards: Group 7.

NOTE 4: With painted surface treatments account should made for any loss of pre-load which occur over time.



11. Dimensionamento

- **Resistência ao Atrito (Cisalhamento) + Tração EC3 pt. 1.8**

If a slip-resistant connection is subjected to an applied tensile force, $F_{t,Ed}$ or $F_{t,Ed,serv}$, in addition to the shear force, $F_{v,Ed}$ or $F_{v,Ed,serv}$, tending to produce slip, the design slip resistance per bolt should be taken as follows:

for a category B connection:
$$F_{s,Rd,serv} = \frac{k_s \, n \, \mu \, (F_{p,C} - 0{,}8 F_{t,Ed,serv})}{\gamma_{M3}} \quad \text{... (3.8a)}$$

for a category C connection:
$$F_{s,Rd} = \frac{k_s \, n \, \mu \, (F_{p,C} - 0{,}8 F_{t,Ed})}{\gamma_{M3}} \quad \text{... (3.8b)}$$

If, in a moment connection, a contact force on the compression side counterbalances the applied tensile force no reduction in slip resistance is required.

11. Dimensionamento

- Slip Coeficient Tests

- ∄Transferência de Pré-tensão por furação desencontrada
- Aperto normal → rotação da porca
- Assume-se P_{pret}=70%Pu
- 20 a 30% de variação
- 3 testes para 2 metades de junta p/ cada um
- Menor valor
  Valor característico

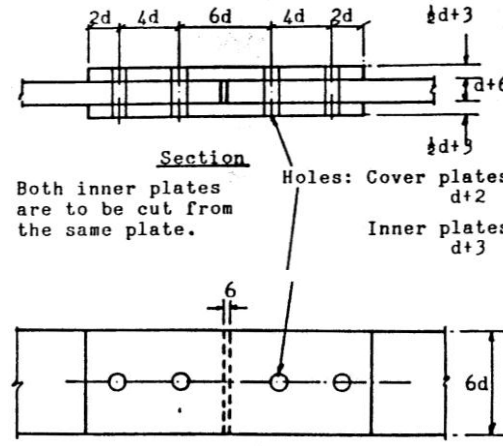


FIGURE 5.16 TEST SPECIMEN DETAILS FOR SLIP COEFFICIENT TESTS.

11. Dimensionamento

- Atrito → pressão de contacto → arruela
- Anel (rugosidade) → escoar sob compressão → superfícies polidas
- atrito ↔ pressão de contacto
- μ ↓ com furos alargados → área de contato menor

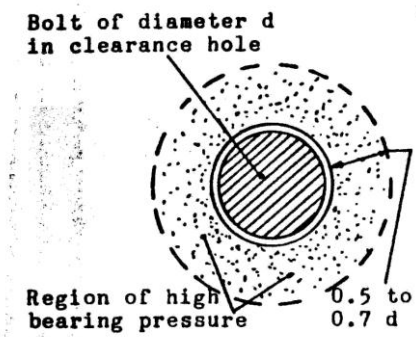


FIGURE 5.17 DISTRIBUTION OF BEARING PRESSURE AT THE FAYING SURFACE IN A FRICTION CONNECTION.

12. Exemplo 1

Check the resistance of the bolted connection of a tie, shown in Figure 2WE2-1, loaded in tension by the factored force F_{Sd} =150 kN. The steel is Grade S355. The bolts M16, Grade 5.6, are the not preloaded. The shear plane passes through the unthreaded portion of the bolts. The material partial safety factors are $\gamma_{M2} = 1,10$ and $\gamma_{Mb} = 1,25$.

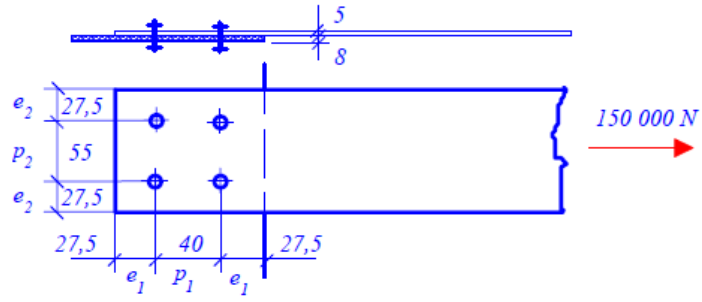


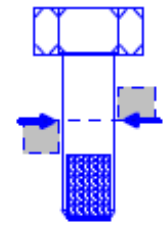
Figure 1WE2-1

12. Exemplo 1

The bolt spacing is satisfying the design rules

$$1,5\ d_0 = 1,5 * 17 = 25,5 \le e_2$$
$$3,0\ d_0 = 3,0 * 17 = 51,0 \le p_2 .$$

The force per bolt is $F_{v.Sd} = \frac{150\ 000}{4} = 37\ 500\ N$.



The shear resistance per a bolt M 16 (at one shear plane) is

$$F_{v.Rd} = \frac{0,6\ f_{ub}\ A}{\gamma_{Mb}} = \frac{0,6 * 500 * \frac{\pi * 16^2}{4}}{1,25} = 48,2 * 10^3\ N > 37\ 500\ N$$

12. Exemplo 1

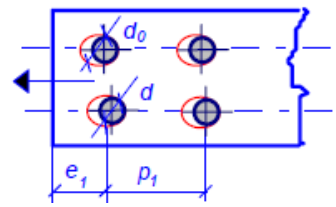
The factor of the bearing resistance is

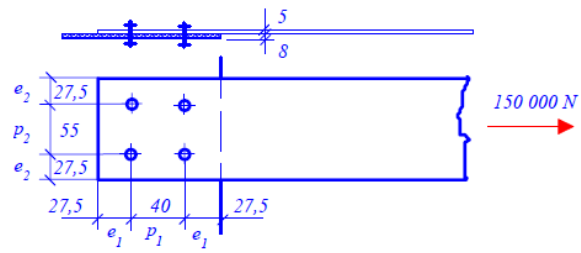
$$\alpha = \frac{e_1}{3\,d_0} = \frac{27,5}{3*17} = 0,539 \text{ (limit)},$$

$$\alpha = \frac{p_1}{3\,d_0} - \frac{1}{4} = \frac{50}{3*17} - \frac{1}{4} = 0,73,$$

$$\alpha = \frac{f_{ub}}{f_u} = \frac{500}{510} = 0,98,$$

$$\alpha = 1,0.$$





12. Exemplo 1

The bearing resistance per bolt in the plate *5 mm* is

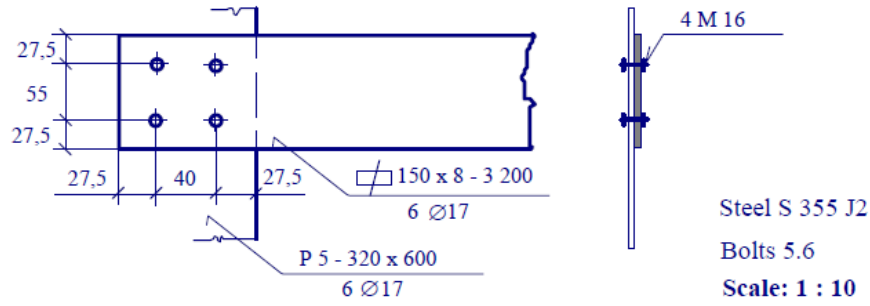
$$F_{b,Rd} = \frac{2,5\,\alpha\,f_u\,d\,t}{\gamma_{Mb}} = \frac{2,5*0,539*510*16*5}{1,25} = 43,9*10^3\ N > F_{v,Sd} = 37,5\ kN$$

The resistance of the member net section is

$$N_{u,Rd} = 0,9\frac{A_{net}\,f_u}{\gamma_{M2}} = 0,9\frac{5*(110-2*17)*510}{1,10} = 158,6*10^3\ N > 150\ kN$$

The connection resistance is satisfactory.

12. Exemplo 1



13. Exemplo 2

Check the bolted connection of the tension member of two equal-leg angles, shown in Figure 1WE2-2. The connection is subject to the factored force $F_{Sd} = 140\ kN$. Plate is P 15. The steel Grade S275. The fully threaded bolts M 20, Grade 8.8, are in holes $22\ mm$. The material partial safety factors are $\gamma_{M0} = 1,0$, $\gamma_{M2} = 1,10$ and $\gamma_{Mb} = 1,25$.

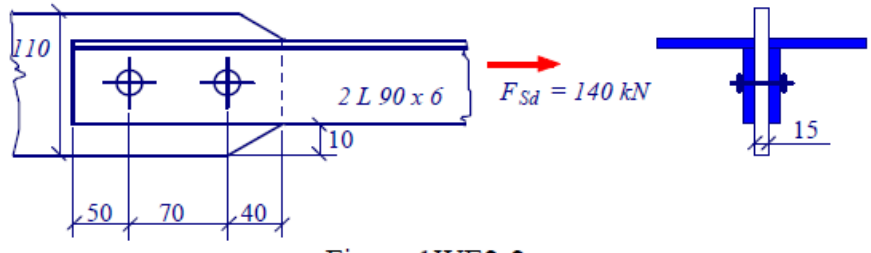


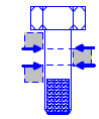
Figure 1WE2-2

13. Exemplo 2

Shear resistance

The design shear resistance per two bolts with two shear plane, if the shear is not passing through threaded part of the bolt, is

$$F_{v,Rd} = 2\,n\frac{0,6\,f_{ub}\,A_s}{\gamma_{Mb}} = 2*2*\frac{0,6*800*245}{1,25} = 376,3*10^3\,N > 140\,kN$$



Bearing resistance

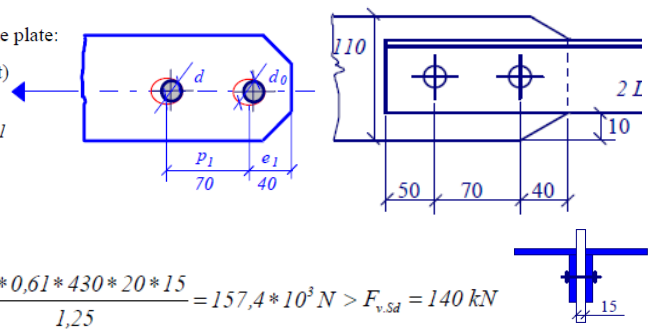
The bolt bearing resistance of the plate:

$$\alpha = \frac{e_1}{3d_0} = \frac{40}{3*22} = \underline{0,61} \quad \text{(limit)}$$

$$\alpha = \frac{p_1}{3\,d_0} - \frac{1}{4} = \frac{70}{3*22} - \frac{1}{4} = 0,81$$

$$\alpha = \frac{f_{ub}}{f_u} = \frac{800}{430} = 1,86$$

$$\alpha = 1,0$$



$$F_{b.Rd} = \frac{2,5\,\alpha\,f_u\,d\,t}{\gamma_{Mb}} = \frac{2,5*0,61*430*20*15}{1,25} = 157,4*10^3\,N > F_{v.Sd} = 140\,kN$$

The bolts shear resistance is satisfactory

13. Exemplo 2

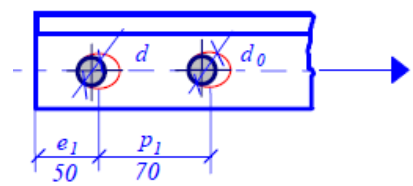
The bolt bearing resistance of the angles:

$$\alpha = \frac{e_1}{3\,d_0} = \frac{50}{3*22} = \underline{0,76} \quad \text{(limit)}$$

$$\alpha = \frac{p_1}{3\,d_0} - \frac{1}{4} = \frac{70}{3*22} - \frac{1}{4} = 0,81$$

$$\alpha = \frac{f_{ub}}{f_u} = \frac{800}{430} = 1,86$$

$$\alpha = 1,0$$



$$F_{b.Rd} = \frac{2,5\,\alpha\,f_u\,d\,t}{\gamma_{Mb}} = \frac{2,5*0,76*430*20*2*6}{1,25} = 156,8*10^3\,N > F_{v.Sd} = 140\,kN$$

The bolts resistance is satisfactory

13. Exemplo 2

Section resistance

The reduction factors for the angles connected by one leg (linear transition) is

$$\beta_2 = 0,4 + \frac{0,7 - 0,4}{5\,d_0 - 2,5\,d_0}(p_1 - 2,5\,d_0) = 0,4 + \frac{0,3}{5 * 22 - 2,5 * 22}(70 - 2,5 * 22) = 0,482\,.$$

The resistance at the net section with two bolts in the force direction is

$$N_{u.Rd} = \frac{\beta_2\, A_{net}\, f_u}{\gamma_{M2}} = \frac{0,482 * (1050 - 22 * 6) * 430}{1,10} = 173,0 * 10^3\ N > 140 / 2\ kN\,.$$

The member resistance in tension is

$$N_{pl.Rd} = \frac{A\, f_y}{\gamma_{M0}} = \frac{2 * 1050 * 275}{1,0} = 577,5 * 10^3\ N > F_{v.Sd} = 140\ kN\,.$$

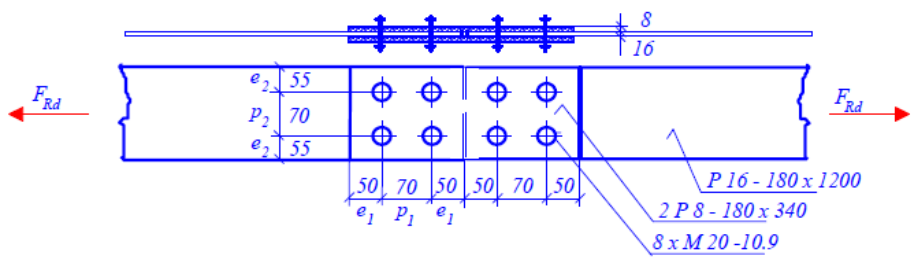
The net area of the connection plate is

$$N_{pl.Rd} = \frac{0,9\, A_{net}\, f_y}{\gamma_{M2}} = \frac{0,9 * 15 * (120 - 22) * 275}{1,10} = 330,7 * 10^3 N > 140\ kN\,.$$

The section resistance in connection is satisfactory

14. Exemplo 3

Evaluate resistance of the bolted connection of a tie, shown in Figure 1WE2-3, with the slip on the ultimate limit state. The steel is Grade S235. The bolts M 20, Grade 10.9, are preloaded (the bolt net area $A_s = 245\ mm^2$) in holes $\varnothing\ 22$. The material partial safety factors are $\gamma_{Ms.ult} = 1,10$, $\gamma_{M2} = 1,10$ and $\gamma_{Mb} = 1,25$.



14. Exemplo 3

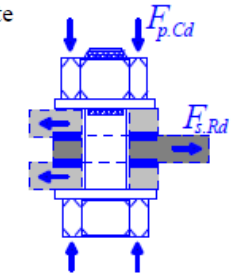
Slip resistance

The design preloading force (net section of the bolt $A_s = 245\ mm^2$) is

$$F_{p.Cd} = 0{,}7\ f_{ub}\ A_s = 0{,}7 * 1\,000 * 245 = 171{,}5 * 10^3\ N\ .$$

The slip factor is for surface blasted with shot $\mu = 0{,}5$ (Class A surface). There are two slip surfaces, as shown in Fig. 5.6.2. The design slip resistance of one bolt under the ultimate limit state (Connection Category C):

$$F_{s.Rd} = \frac{k_s\ n\ \mu}{\gamma_{Ms.ult}} F_{p.Cd} = \frac{1{,}0 * 2 * 0{,}50}{1{,}10}\ 171{,}5 = 155{,}9\ kN\ .$$



14. Exemplo 3

Bearing resistance

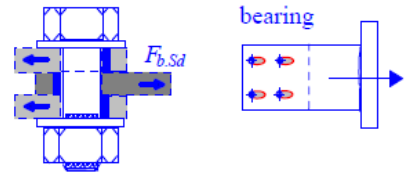
The bearing resistance is derived for the plate *16 mm*:

$$\alpha = \frac{e_1}{3\ d_0} = \frac{50}{3 * 22} = \underline{0{,}758}\ \text{(limit)}$$

$$\alpha = \frac{p_1}{3\ d_0} - \frac{1}{4} = \frac{70}{3 * 22} - \frac{1}{4} = 0{,}811\ ,$$

$$\alpha = \frac{f_{ub}}{f_u} = \frac{1\,000}{360} = 2{,}778\ ,$$

$$\alpha = 0{,}508\ ,$$



$$F_{b.Rd} = \frac{2{,}5\ \alpha\ f_u\ dt}{\gamma_{Mb}} = \frac{2{,}5 * 0{,}758 * 360 * 20 * 16}{1{,}25} = 174{,}6 * 10^3\ N$$

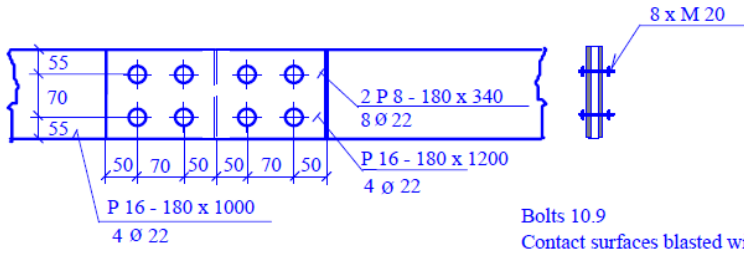
Net section

The design resistance of net cross section is

$$N_{net.Rd} = 0{,}9\ \frac{A_{net}\ f_u}{\gamma_{M2}} = 0{,}9 * \frac{16 * (180 - 2 * 22) * 360}{1{,}10} = 640{,}9 * 10^3\ N$$

14. Exemplo 3

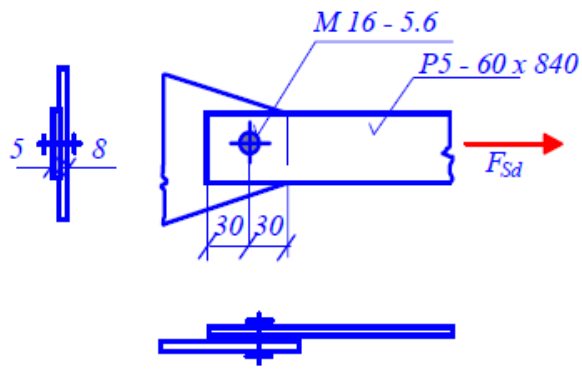
The connection resistance is $4 * 155,9 = 623,6\ kN$

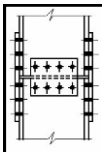


Bolts 10.9
Contact surfaces blasted with shot, no painting
Steel S 235 J2

15. Exemplo 4

Check the resistance of the single lap connection. The connection is subject to the factored force $F_{Sd} = 45\ kN$, shown in Figure 1WE2-4. The steel is Grade S355. The non-preloaded bolt M16 is Grade 5.6 in hole $\varnothing 17\ mm$. The shear passes through the untreated portion of the bolt. The material partial safety factors are $\gamma_{M2} = 1,10$, $\gamma_{Mb} = 1,25$.





15. Exemplo 4

The design shear resistance of one bolt M 16 of one shear plane is

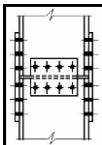
$$F_{v,Rd} = \frac{0,6\ f_{ub}\ A}{\gamma_{Mb}} = \frac{0,6 * 500 * \frac{\pi * 16^2}{4}}{1,25} = 48,3 * 10^3\ N > 45\ kN$$

The design bearing resistance of one bolt for plate $5\ mm$ is calculated for the smallest α

$$\alpha = \frac{e_1}{3\ d_0} = \frac{30}{3 * 17} = \underline{0,588}\ \text{(limit)};\ \alpha = \frac{f_{bu}}{f_u} = \frac{500}{510} = 0,980\ ;\ \alpha = 1,0$$

as

$$F_{b,Rd} = \frac{2,5\ \alpha\ f_u\ d\ t}{\gamma_{Mb}} = \frac{2,5 * 0,588 * 510 * 16 * 5}{1,25} = 48,0 * 10^3\ N > 45\ kN\ .$$



15. Exemplo 4

The bearing resistance of single lap joint with one bolt is

$$F_{b,Rd} \le \frac{1,5\ f_u\ d\ t}{\gamma_{Mb}} = \frac{1,5 * 510 * 16 * 5}{1,25} = 49,0 * 10^3\ N > 45\ kN\ .$$

The net section resistance is

$$N_{u,Rd} = 0,9\ \frac{A_{net}\ f_u}{\gamma_{M2}} = 0,9 * \frac{(5 * 60 - 5 * 17) * 510}{1,10} = 89,7 * 10^3\ N > 45\ kN$$

The connection is satisfactory

Note:
The connections with single bolt are used for structural purposes in special cases only, e.g. for the transmission electric towers and less important structures. In this type of connection is the washer positioned under the bolt nut as well as bolt head due to the shear and bending of the bolt.