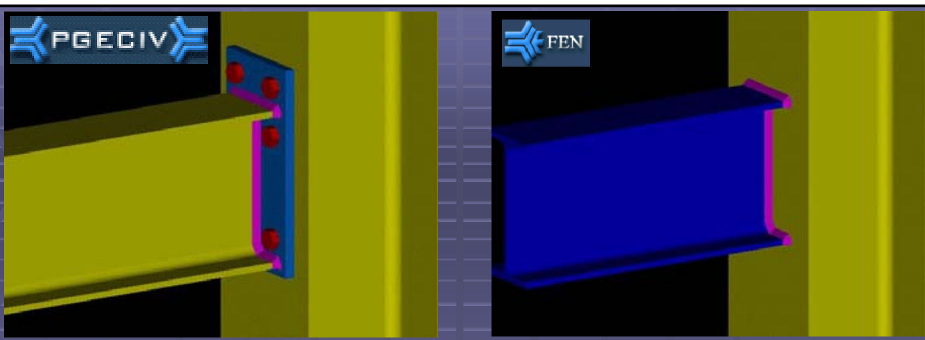


Ligações Aparafusadas

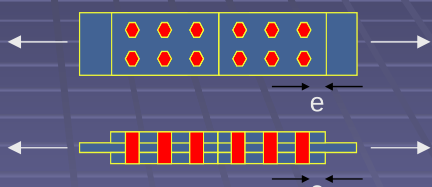
Terceira Parte

Programa de Pós-Graduação em Engenharia Civil
PGECIV - Mestrado Acadêmico
Faculdade de Engenharia – FEN/UERJ
Disciplina: Tópicos Especiais em Projeto (Ligações em Aço e Mistas)
Professor: Luciano Rodrigues Ornelas de Lima

11. Dimensionamento

- Esmagamento da chapa

$$B_r < \begin{cases} \text{esmagamento} \\ 3\,\phi_{br}\,t\,n\,d\,F_u \\ \text{rasgamento} \\ \phi_{br}\,t\,n\,e\,F_u \end{cases}$$



ϕ_{br} = 0,67

d = diâmetro do parafuso

n = nº de parafusos

t = espessura de chapara a ser analisada

F_u = tensão última da placa

e = distância do furo a borda na direção paralela ao esmagamento

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11. Dimensionamento

- Corte no parafuso

$V_r = 0{,}60\ \phi_b\ n\ m\ A_b\ F_u$ **(rosca fora do plano de corte)**

$V_r = 0{,}70\ .\ 0{,}60\ \phi_b\ n\ m\ A_b\ F_u$ **(rosca no plano de corte)**

$\phi_b = 0{,}80$

m = nº de planos de corte

n = nº de parafusos

A_b = área da seção transversal do parafuso (bruta)

F_u = tensão última do parafuso

$$V_{final} < \begin{cases} V_r \\ B_r \end{cases}$$

Se o comprimento da ligação > 1300 mm → $V_{corr} = 0{,}8\ V_{final}$

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11. Dimensionamento

- Resistência ao Cisalhamento Eurocode 3 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.

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.

11. Dimensionamento

- Resistência ao Cisalhamento Eurocode 3 pt. 1.8
- a) Category A: Bearing type:

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.

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

Failure mode	Bolts	Rivets
Shear resistance per shear plane	$F_{v,Rd} = \dfrac{\alpha_v\, f_{ub}\, A}{\gamma_{M2}}$ - 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): $\alpha_v = 0,6$	$F_{v,Rd} = \dfrac{0,6\, f_{ur}\, A_0}{\gamma_{M2}}$

11. Dimensionamento

- Resistência ao Cisalhamento Eurocode 3 pt. 1.8
- a) Category A: Bearing type:

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.

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

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11. Dimensionamento

- 1) Bearing resistance $F_{b,Rd}$ for bolts:
  - ✓bearing resistance in oversized holes is 0,8 x resistance for 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.

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11. Dimensionamento

- 2) Countersunk bolt:
  - ✓Bearing resistance $F_{b,Rd}$ should be based on a plate thickness = thickness of the connected plate – ½ countersinking depth.
  - ✓Tension resistance $F_{t,Rd}$ the angle/depth of countersinking should conform with 2.8 Ref. Standards: Group 4, otherwise tension resistance $F_{t,Rd}$ should be adjusted accordingly.
- 3) When the load on a bolt is not ∥ edge:
  - ✓Bearing resistance may be verified separately for bolt load components ∥ and ⊥ to the end

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11. Dimensionamento

• Design resistances for tension and for shear through the threaded portion of a bolt given in Table 3.4 should only be used for bolts manufactured in conformity with 2.8 Ref. Standard: Group 4.

• For bolts with cut threads, such as anchor bolts or tie rods fabricated from round steel bars where the threads comply with EN1090, the relevant values from Table 3.4 should be used.

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11. Dimensionamento

•Bolts with cut threads where the threads do not comply with EN1090 relevant values from Table 3.4 should be multiplied by a factor of 0,85.

• Shear resistance Fv,Rd given in Table 3.4 should only be used where the bolts are used in holes with nominal clearances not exceeding those for normal holes as specified in 2.8 Ref. Standards: Group 7.

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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 Fv,Rd should be taken as 0,85 x value given in Table 3.4

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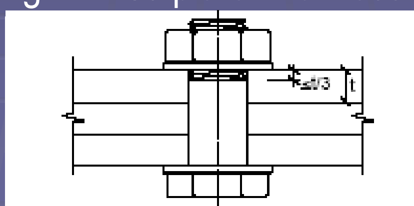
11. Dimensionamento

•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.

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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 Fb,Rd for each bolt should be limited to:

$$F_{b,Rd} \leq 1,5 \, f_u \, d \, t \, / \, \gamma_{M2} \qquad (3.2)$$

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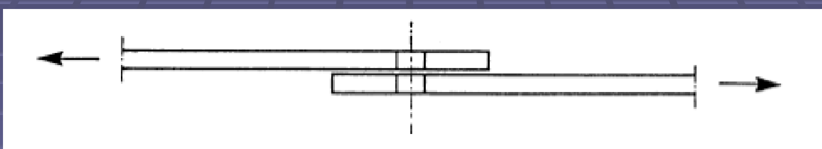
11. Dimensionamento

•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

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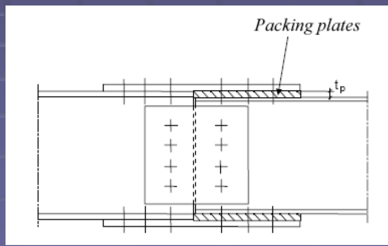
11. Dimensionamento

• Where bolts or rivets transmitting load in shear and bearing pass through packing of total thickness p > 1/3 of the nominal diameter the shear resistance Fv,Rd calculated as specified in Table 3.4, should be multiplying by a reduction factor p given by:

$$\beta_p = \frac{9d}{8d + 3t_p} \quad \text{but } \beta_p \le 1 \qquad (3.3)$$



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

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11. Dimensionamento

• Riveted connections should be designed to transfer shear forces. If tension is present the design tensile force Ft.Ed should not exceed the tension resistance Ft,Rd given in Table 3.4.

• For S235 steel grade the "as driven" value of fur may be taken as 400 N/mm2

• As a general rule, the grip length of a rivet should not exceed 4,5 for hammer riveting and 6,5 for press riveting.

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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

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11. Dimensionamento

- Norma Inglesa BS5950 - Edificações

Bolt capacities

Nom. dia. (mm)	Stress area (mm²)	Tension (kN)	Shear* Single (kN)	Shear* Double (kN)	Bearing† (Grade 43/Grade 50) 6 mm (kN)	8 mm (kN)	10 mm (kN)	12 mm (kN)	15 mm (kN)	20 mm (kN)	25 mm (kN)
4.6 bolts											
12	84.3	16.4	13.5	27	31.3/31.3						
16	157	30.6	25.1	50.2	41.8/41.8	55.7/55.7					
20	245	47.8	39.2	78.4	52.2/52.2	69.6/69.6	87/87				
24	353	68.8	56.5	113.0	62.6/62.6	83.5/83.5	104.4/104.4	125.3/125.3			
30	561	109.4	89.8	179.5	78.3/78.3	104.4/104.4	130.5/130.5	156.6/156.6	195.7/195.7		
8.8 bolts											
12	84.3	37.9	31.6	63.2	33.1/39.6	44.2/52.3	55.2/66	66.2/—			
16	157	70.7	58.9	117.7	44.2/52.8	58.9/70.4	73.6/83	88.3/105.6	110.4/132	147.2/—	
20	245	110.3	91.9	183.7	55.2/66	73.6/88	92/110	110.4/132	133/165	184/220	
24	353	158.9	132.4	264.7	66.2/79.2	88.3/105.6	110.4/132	132.5/158.4	166/198	220.3/264	276/—
30	561	252	210.4	420.7	82.8/99	110.4/132	133/165	166/198	207/247.5	276/330	345/412.5

*Assumes threads in both shear planes.
†Assumes end distance not less than 2d.

Table 5.1 Design data for ordinary bolts to BS 5950: Part 1
Design strengths

Bolt grade	4.6		8.8	
Steel grade	43	50	43	50
Tension p_t	195	195	450	450
Shear p_s	160	160	375	375
Bearing on connected ply p_{bs}	(460)	(550)	460	550
Bearing on bolt p_{bb}	435	435	(970)	(970)

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11. Dimensionamento

- Norma Inglesa BS5400 - Pontes

Table 5.2 Design strenghts of bearing bolts according to BS 5400: Part 3 (ultimate limit state)

Bolt grade		4.6	8.8
Tension	$\frac{\sigma_t}{\gamma_m \gamma_{f3}}$	$\frac{235}{1.2 \times 1.1} = 178$	$\frac{549.5}{1.2 \times 1.1} = 416$
Shear	$\frac{\sigma_q}{\gamma_m \gamma_{f3} \sqrt{2}}$	$\frac{0.85 \times 235}{1.1 \times 1.1 \times \sqrt{2}} = 116.7$	$\frac{0.85 \times 549.5}{1.1 \times 1.1 \times \sqrt{2}} = 273$
Bearing[b] (Grade 43, $L = 2d$, $T \leq 16$ mm)	$\frac{k_1 k_2 k_3 k_4 \sigma_y}{\gamma_m \gamma_{f3}}$	$\frac{0.85 \times 1.97 \times 1.2 \times 1.0 \times 235}{1.05 \times 1.1} = 409\ N/mm^2$	$\frac{0.85 \times 1.97 \times 1.2 \times 1.0 \times 275}{1.05 \times 1.1} = 478\ N/mm^2$

Bolt capacities

Nom. dia. (mm)	*Stress area (mm²)*	*Tension (kN)*	*Shear[a] Single (kN)*	*Shear[a] Double (kN)*	*Bearing[b] (Grade 43/Grade 50 for 8.8 bolts) 6 mm (kN)*	*8 mm (kN)*	*10 mm (kN)*	*12 mm (kN)*	*15 mm (kN)*	*20 mm (kN)*	*25 mm (kN)*
4.6 bolts											
12	84.3	15.0	9.8	19.7	29.4						
16	157	27.9	18.3	36.6	39.2						
20	245	44.6	28.6	57.2	49.0	65.3					
24	353	62.8	41.2	82.4	58.8	78.3	97.9				
30	561	99.9	65.5	130.9	73.4	98.0	122	147			
8.8 bolts											
12	84.3	35.1	23	46.0	34.4/44.4	45.9/—					
16	157	65.3	42.8	85.3	45.9/59.2	61.1/79.0	76.4/98.8	91.8/—			
20	245	102	66.9	133	57.4/74.0	76.4/98.8	95.2/123	114/148	143/—		
24	353	147	96	193	68.8/88.8	91.7/118	114/148	138/178	172/222	221/—	
30	561	233	153	306	86.0/111	115/148	143/185	172/222	214/277	277/360	346/—

[a] Assumes threads in both shear planes.
[b] Enclosed bearing values with an end distance of 2 × d

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11. Dimensionamento

- Atrito

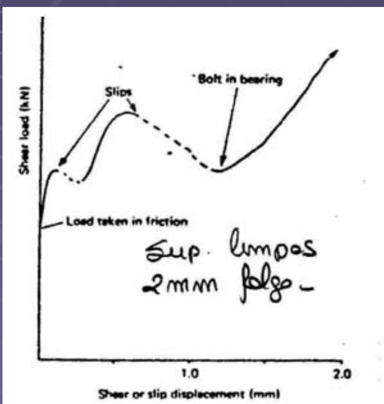

Figure 5.14 Load deformation response of a single, 20 mm diameter, general grade HSFG bolt in double shear

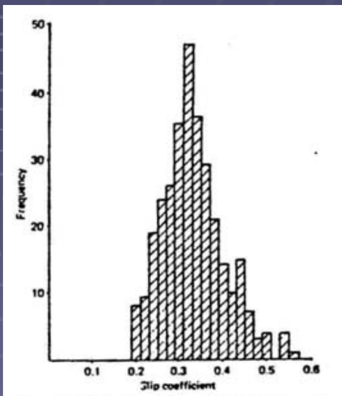

Figure 5.15 Distribution of slip coefficients for clean mill scale

Coeficiente de atrito médio = 0.45?

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11. Dimensionamento

- Valores típicos para os coeficientes de atrito → superfícies de contacto

Table 5.3 Typical average values for coefficients of friction

Clean mill scale	0.33
Grades 43 or 50, grit or shot blasted	0.48
Ditto, after light rusting	0.52
Very high tensile steel, grit blasted	0.33
Red lead paint	0.1 or less
Grit blasted and oiled	0.25
Galvanized	0.22
Galvanized, subsequently wire brushed or grit blasted	0.41
Metal sprayed with zinc	0.46
Metal sprayed with aluminium	0.51
Metal sprayed aluminium on zinc	0.49
Surfaces painted with alkali–zinc silicate coat (50–80 mm)	0.46

Óleos (furação) → Lubrificantes (tintas) → rugosidade da superfície →

Pouca ferrugem → melhora → Interlock

Muita ferrugem → piora → escamação

Solda fria

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11. Dimensionamento

- ∌Transferência de Pré-tensão por furação desencontrada
- Aperto normal → rotação da porca
- Assume-se Ppret=70%Pu
- Porém ∃20 a 30% de variação
- 3 testes para 2 metades de junta p/ cada um
  - ✓Menor valor
  - ✓Valor característico

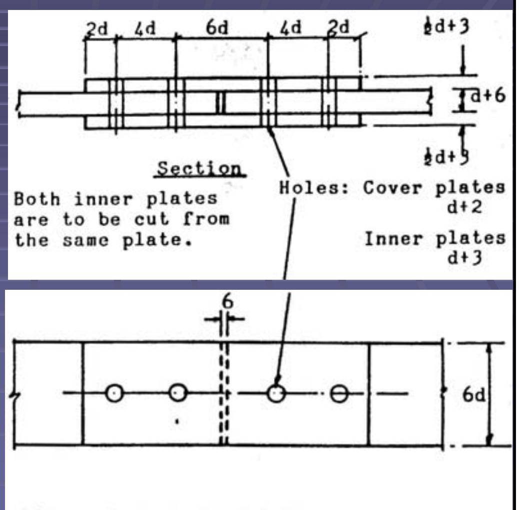

FIGURE 5.16 TEST SPECIMEN DETAILS FOR SLIP COEFFICIENT TESTS.

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11. Dimensionamento

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

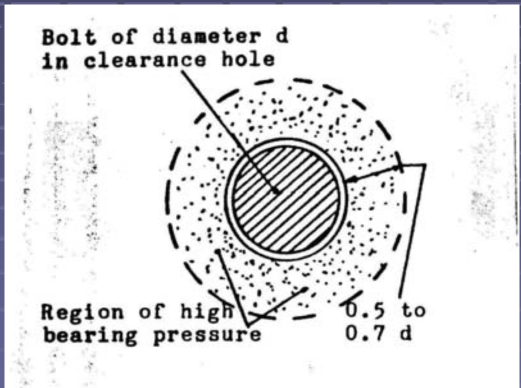

FIGURE 5.17 DISTRIBUTION OF BEARING PRESSURE AT THE FAYING SURFACE IN A FRICTION CONNECTION.

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11. Dimensionamento

- Influência da carga de pré-tensão na resistência ao cisalhamento pós-atrito

- Interação pré-tensão x τult
- ≠ níveis de pré-tensão mesma τult sem rosca no plano de corte
- ≠ pontos de ruína
- Com roscas no plano de corte → limitada
- Antes da estricção ∄ efeito → cisalhamento → Ppret ↓

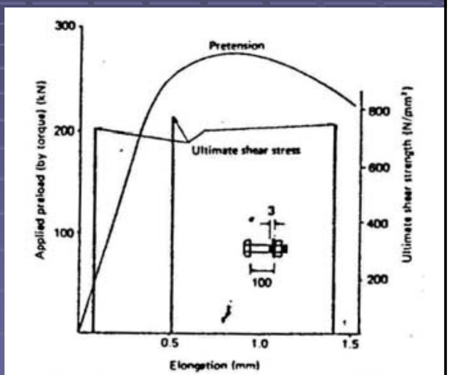

Figure 5.19 Effect of bolt prestrain on shear strength of higher grade HSFG bolts

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11. Dimensionamento

- Relaxação da protenção → carga de atrito
- → espessura placas de junta
- → s de tração nas placas
- Caso 1 → extremidade (interna + solicitada)
- Caso 2 → centro (externa + solicitada)
- Inicialmente a relaxação é pequena devido a redução elástica da espessura devido ao efeito de Poisson
- σ ↑ relaxação ↑

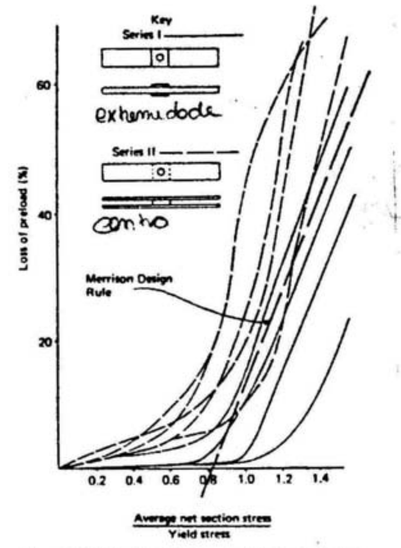

Figure 5.20 Relaxation of bolt preload due to connected plate stresses

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11. Dimensionamento

- Transição → σ < Fy → concentração da tensão de compressão → Pu (70%)
- Redução pode chegar até valores de 40% → última fila de parafusos (máximo de norma)
- No centro → 10%
- Merrison design rule → σ_n/Fy → relaxação do parafuso
- Com atrito o desalinhamento não é mais problema para distribuição de cisalhamento entre parafusos

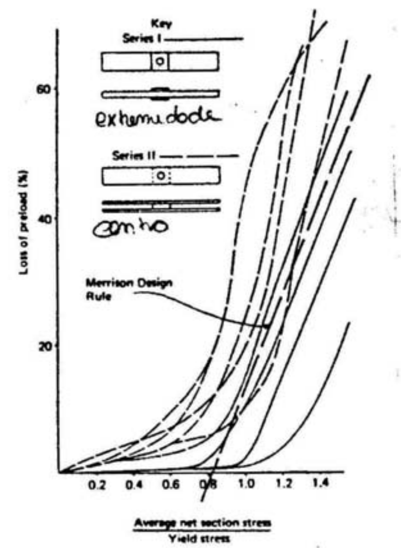

Figure 5.20 Relaxation of bolt preload due to connected plate stresses

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11. Dimensionamento

- Atrito

$V_s = 0{,}53\ c_1\ k_s\ m\ n\ A_b\ F_u$

Classe	Descrição	k_s	c_1 (A325)	c_1 (A490)
A	Sem resíduos, limpo com jato de ar com cobrimento - classe "A"	0,33	0,82	0,78
B	limpo com jato de ar com cobrimento - classe "B"	0,50	0,90	0,85
C	Galvanização por imersão a quente com superfície escovada	0,40	0,90	0,85

ks = coeficiente de atrito médio (tabelado)

c1 = coeficiente que relaciona a carga de protensão e o coeficiente de atrito médio ks a uma probabilidade de escorregamento de 5% para parafusos apertados pelo método da rotação da porca

A e B → m ≥ 0,33 e 0,5

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11. Dimensionamento

- Atrito – Eurocode 3 pt. 1.8
- b) Category B: Slip-resistant at serviceability limit state
  - ✓In this category preloaded bolts should be used.
  - ✓Slip should not occur at the serviceability limit state.
  - ✓Design serviceability shear load ≤ slip resistance
  - ✓Design ultimate shear load ≤ shear resistance
  - ✓Design ultimate shear load ≤ bearing resistance

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11. Dimensionamento

- Atrito – Eurocode 3 pt. 1.8
- c) Category C: Slip-resistant at ultimate limit state
  - ✓In this category preloaded bolts should be used
  - ✓Slip should not occur at the ultimate limit state
  - ✓Design ultimate shear load ≤ slip resistance
  - ✓Design ultimate shear load ≤ bearing resistance
  - ✓In addition for a connection in tension, the design plastic resistance of the net cross-section at bolt holes Nnet,Rd, should be checked, at the ultimate limit state.

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11. Dimensionamento

- Atrito – Eurocode 3 pt. 1.8

Table 3.2: Categories of bolted connections

Category	Criteria	Remarks
Shear connections		
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

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11. Dimensionamento

- Resistência ao Atrito Eurocode 3 pt. 1.8
- Categories B and C:

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): $\alpha_v = 0{,}6$	$F_{v,Rd} = \frac{0{,}6 \, f_{ur} \, A_0}{\gamma_{M2}}$

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11. Dimensionamento

- Resistência ao Atrito Eurocode 3 pt. 1.8
- Categories B and C:

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

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11. Dimensionamento

- Atrito – Eurocode 3 pt. 1.8
- Slip-resistant connections using 8.8 or 10.9 bolts
- Design slip resistance of 8.8 or 10.9 bolts should be:

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

- where:
- ks is given in Table 3.6
- n is the number of the friction surfaces
- m is the slip factor obtained either by specific tests for the friction surface in accordance with 2.8 Reference Standards: Group 7 or given in Table 3.7.

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11. Dimensionamento

- Atrito – Eurocode 3 pt. 1.8
- For class 8.8 and 10.9 bolts conforming with 2.8 Reference Standards: Group 4, with controlled tightening in conformity with 2.8 Ref. Standards: Group 7, the preloading force Fp,C should be taken as:

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

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11. Dimensionamento

- Atrito – Eurocode 3 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

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11. Dimensionamento

- Atrito – Eurocode 3 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.

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11. Dimensionamento

- Atrito - Norma Inglesa BS5950 - Edificações

Table 5.4 Design data for general grade HSFG bolts to BS 5950: Part 1
Basic equations (using notation of BS 5950: Part 1)

Tension	P_t	$0.9P_o$
Slip	P_{SL}	$1.1K_s\mu P_o$
Combined shear and tension		$\frac{F_s}{P_{SL}} + 0.8\frac{F_t}{P_t} \leq 1.0$

Design capacities

Nominal dia. (mm)	16	20	22	24	27	30	36
Proof load (kN)	92.1	144	177	207	234	296	418
Tension capacity (kN)	82.9	129.6	159.3	186.3	210.6	257.4	376.2
Slip capacity (kN)	45.6	71.3	87.6	102.5	115.8	141.6	206.9

Slip capacity in single shear in presence of external tension (kN)

External tension (kN)	16	20	22	24	27	30	36
25	34.6	60.3	76.6	91.5	104.8	130.6	195.9
50	23.6	49.3	65.6	80.5	93.8	119.6	184.9
75	12.6	38.3	54.6	69.5	82.8	108.6	173.9
82.9	9.1/0						
100		27.3	43.6	58.5	71.8	97.6	162.9
125		16.3	32.6	47.5	60.8	86.6	151.9
129.6		14.3/0					
150			21.6	36.5	49.8	75.6	140.9
159.3			17.5/0				
175				25.5	33.8	64.6	129.9
186.3				20.5/0			
200					27.8	53.6	118.9
210.6					23.2/0		
Change in interpolation interval							
250						31.6	96.9
257.4						28.3/0	
300							74.9
350							52.9
376.2							41.4/0

Assumes a coefficient of friction of 0.45.

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11. Dimensionamento

- Atrito - Norma Inglesa BS5400 - Pontes

Table 5.5 Design data for general grade HSFG bolts to BS 5400: Part 3
Basic equations (using notation of BS 5400: Part 3)

Tension $P_T = \frac{\sigma_t A_{et}}{\gamma_m \gamma_{f3}} = \frac{0.7 \times 827}{1.2 \times 1.1} A_{et}$ ≯M24; $\frac{0.7.725}{1.2 \times 1.1} A_{et}$ >M24

Slip $P_{fS} = \frac{F_{v} \cdot \mu}{\gamma_m \gamma_{f3}} = \frac{587.0.45}{1.3 \times 1.1} A_{et}$ ≯M24; $\frac{512 \times 0.45}{1.3 \times 1.1} A_{et}$ >M24

Combined shear and tension $F_{fS} = \frac{(F_v - F_t)\mu}{\gamma_m \gamma_{f3}}$

Design capacities

Nominal diameter (mm)	16	20	22	24	27	30	36
Proof load (kN)	92.1	144	177	207	234	286	418
Tension capacity (kN)	68.9	107.4	132.9	154.8	176.5	215.7	314.1
Slip capacity (kN)	29.0	45.3	56.0	65.2	74.0	90.4	131.6

Slip capacity in presence of external tension (kn)

External tension (kn)	16	20	22	24	27	30	36
25	21.1	37.4	48.1	57.3	66.1	82.5	123.7
50	13.3	29.6	40.2	49.5	58.2	74.6	115.9
68.9	7.3/0						
75		21.7	32.3	41.6	50.3	66.7	108.0
100		13.8	24.4	33.7	42.4	58.8	100.1
107.4		11.5/0					
125			16.5	25.8	34.5	50.9	92.2
132.9			14.0/0				
150				18.0	26.6	43.0	84.4
154.8				16.4/0			
175					18.7	35.1	76.5
176.5					18.2/0		
200						27.2	68.6
Change in interpolation interval						22.2/0	
215.7							
250							52.9
300							37.2
314							32.7/0

Assumes a coefficient of friction of 0.45.

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11. Dimensionamento

- Redução na resistência ao atrito para juntas com furos alongados

Table 5.6 Reduction factors for slip resistance of HSFG bolted joints with non-standard clearance holes

	BS 5950: Part 1	*BS 5400: Part 3*
Oversize hole	0.85	0.85
Short-slotted hole	0.85	0.85
Long-slotted hole loaded perp. to slot	0.85	0.70
Long-slotted hole loaded parallel to slot	0.60	0.70

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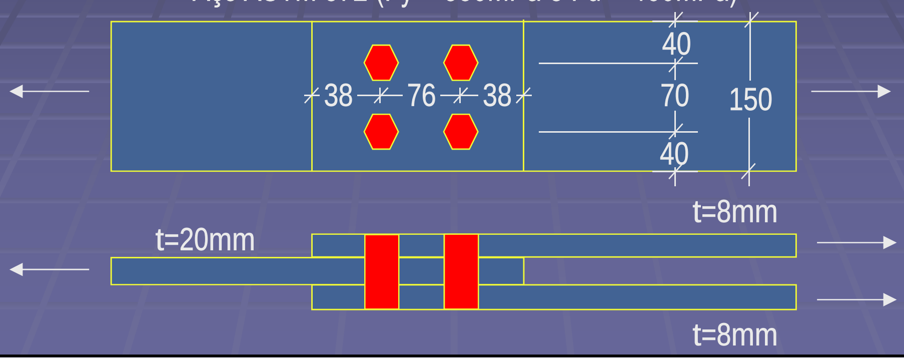
PGECIV FEN

12. Exemplos

1. Determinar a carga axial máxima de projeto P_d suportada pela ligação aparafusada abaixo. Assumir furos padrão, borda cortada a maçarico e rosca fora do plano de corte.

Dados: d = 7/8” com Fu = 825MPa

Aço ASTM 572 (Fy = 350MPa e Fu = 460MPa)



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12. Exemplos

a) Resistência dos parafusos ao corte

$d = 7/8" * 25{,}4mm = 22{,}2mm$

$A_b = \pi d^2 / 4 = \pi(22{,}2)^2 / 4 = 387mm^2$

$V_r = 0{,}60\ \phi b\ n\ m\ A_b\ F_u = 0{,}60\ .\ 0{,}80\ .\ 1\ .\ 2\ .\ 387\ .\ 0{,}825 = 306{,}5kN$

$4\ .\ V_r = 4\ .\ 306{,}5 = 1226kN$

b) Verificação do esmagamento da chapa

menor das espessuras

B_r:

$3\ \phi_{br}\ t\ n\ d\ F_u = 3\ .\ 0{,}67\ .\ (8+8)\ .\ 4\ .\ 22{,}2\ .\ 0{,}460 = 1313{,}7kN$

esmagamento

$\phi_{br}\ t\ n\ e\ F_u = 0{,}67\ .\ (8+8)\ .\ 4\ .\ 38\ .\ 0{,}460 = 749{,}5kN$ ⇐

rasgamento

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12. Exemplos

c) Verificação dos espaçamentos

- Furo à borda
  - ✓ d = 7/8 . 25,4mm = 22,2mm ≈ 24mm ⟶ e > 30 mm (borda cortada a maçarico ⟶ OK)
- Entre furos
  - ✓ L > 2,7 d = 59,94mm
  - ✓ L > 3 d = 66,6mm

  < 76mm ⟶ OK

  - ✓ L < 12 t = 12 . 16 = 192mm
  - ✓ L < 150mm

  > 76mm ⟶ OK

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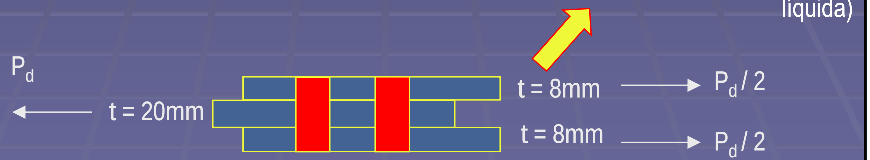
12. Exemplos

d) Verificação da placa à tração

- Área bruta
  - ✓ A_g = 150 . 16 = 2400mm²
- Área líquida (reduz-se 2 furos com diâmetro 24mm)
  - ✓ A_g = (150 – 2 .24) . 16 = 1632mm²
- Resistência
  - ✓ $T_r = \phi \,.\, A_g \,.\, F_y$ = 0,90 . 2400 . 0,350 = 756kN (escoamento da seção bruta)
  - ✓ $T_r = 0{,}85 \,.\, \phi \,.\, A_n \,.\, F_u$ = 0,90 . 1632 . 0,460 = 574,3kN (ruptura da seção líquida)



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12. Exemplos

2. Repetir o exemplo anterior considerando:
   a) Rosca no plano de corte
   b) Ligação por atrito (superfícies limpas → classe “A”)

a) Resistência dos parafusos ao corte

d = 7/8” * 25,4mm = 22,2mm

$A_b = \pi d^2 / 4 = \pi (22{,}2)^2 / 4 = 387\text{mm}^2$

$V_r = 0{,}70 \,.\, 0{,}60\ \phi_b\ n\ m\ A_b\ F_u$ =
= 0,70 . 0,60 . 0,80 . 1 . 2 . 387 . 0,825 = 214,5kN

4 . V_r = 4 . 306,5 = 858,2kN > T_r (logo T_r ainda controla o dimensionamento)

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12. Exemplos

b) Ligação por atrito (superfícies limpas → classe “A”)

$V_s = 0,53 \,.\, c_1 \,.\, k_s \,.\, m \,.\, n \,.\, A_b \,.\, F_u$

onde $c_1 = 0,82$ e $k_s = 0,33$

$V_s = 0,53 \,.0,82 \,.\, 0,33 \,.\, 2 \,.\, 4 \,.\, 387 \,.\, 0,825 = 366,32$ kN (não ponderada → $P_d < 366$kN)