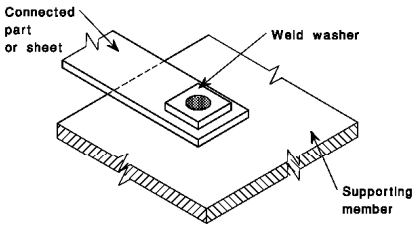
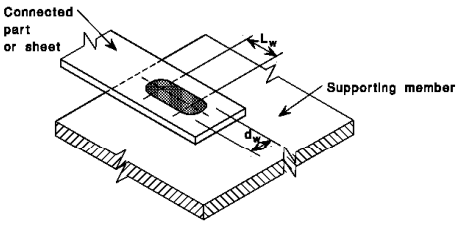




Ligações em Chapa Dobrada – EC3

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

1. Generalidades

- Joints shall be designed on the basis of a realistic assumption of the distribution of internal forces and moments, having regard to relative stiffness within the joint
- This distribution shall correspond with direct load paths through the elements of the joint
- Allowance may be made for the ductility of steel in facilitating the redistribution of internal forces generated within a joint

1. Generalidades

- Accordingly, residual stresses and stresses due to tightening of fasteners and normal accuracy of fit-up need not be considered
- Ease of fabrication and erection shall be taken into account in the design of the details of connections and splices
- Attention shall be paid to the clearances necessary for tightening of fasteners, the requirements of welding procedures, and the need for subsequent inspection, surface treatment and maintenance

2. Interseções

- Members meeting at a joint should normally be arranged so that their centroidal axes intersect at a point
- If there is eccentricity at intersections, the members and connections should be designed to accommodate the moments that result
- In the case of bolted framing of angles and tees, the setting out lines for the bolts may be used instead of the centroidal axes for the purpose of intersection at the joint

3. Lig. sujeitas a impacto, vibração ou fadiga

- Where a connection is subject to impact or vibration, either preloaded bolts, bolts with locking devices or welding should be used. Locking devices should prevent loosening of bolts
- Where a connection that is loaded in shear is subject to reversal of stress (unless such stress is due solely to wind) or where for some special reason slipping of bolts is not acceptable, either preloaded bolts, fitted bolts or welding should be used. Locking devices should be used with bolts.

3. Lig. sujeitas a impacto, vibração ou fadiga

- Other types of fasteners may be used if the fabricator of the fastener may assure the behaviour of the fastener to impact, vibration or load reversal.
- The possible reduction of pre-loading shall be taken into account.

4. Ligações em Pórticos

4.1. Ligações em Pórticos Simples

- In simple framing, the joints between the members shall have nominally pinned connections that:
  - ✓ are capable of transmitting the forces calculated in the global analysis
  - ✓ are able to sustain the resulting rotations
  - ✓ do not develop significant moments adversely affecting members of the structure

4. Ligações em Pórticos

4.2. Ligações em Pórticos Contínuos

- In continuous framing, the joints between the members → transmit the forces and moments calculated in the global analysis
- If elastic global analysis is used, the rigidity of a rigid or semi-rigid joint should not be less than that of the connected member
- In the case of plastic global analysis, the moment resistance of a rigid or semi-rigid joint that is located at, or adjacent to, a plastic hinge location, should not be less than the moment resistance of the cross-section of the connected member (sufficient rotation capacity)

4. Ligações em Pórticos

4.3. Ligações em Pórticos Semi-Contínuos

- In semi-continuous framing, the joints between the members shall be capable of providing a predictable degree of interaction. The rigid or semi-rigid joints shall be capable of resisting the internal moments developed by the joints themselves, in addition to the other internal forces and moments at the joints
- The rigid or semi-rigid joints should have sufficient rigidity to develop the moments calculated in the global analysis, but sufficient flexibility to avoid developing larger moments than they may resist
- If the design value of the moment resistance of a joint is less than that of the connected member, it should be demonstrated that the rotation capacity of the joint is sufficient to allow the necessary redistribution of internal moments and forces to take place.

5. Emendas e Ligações Extremas

5.1. Submetidas à Compressão

- Have at least the same resistance as the cross-section of the member, or an additional bending moment due to the second-order effects within the member, in addition to the internal compressive force N_{Ed} and the internal moments $M_{y,Ed}$ and $M_{z,Ed}$ obtained from the global analysis
- In the absence of a second-order analysis of the member, this additional moment M_{Ed} should be taken as acting about the cross-sectional axis that gives the smallest value of the reduction factor for flexural buckling, see 6.2.2.1(2), with a value determined from:

5. Emendas e Ligações Extremas

5.1. Submetidas à Compressão

$$\Delta M_{Ed} = N_{Ed}\left(\frac{1}{\chi}-1\right)\frac{W_{eff}}{A_{eff}}\sin\frac{\pi a}{l}$$

- where:
  - ✓ A_{eff} is the effective area of the cross-section;
  - ✓ a is the distance from the splice or end connection to the nearer point of contraflexure;
  - ✓ l is the buckling length of the member between points of contraflexure, for buckling about the relevant axis
  - ✓ W_{eff} is the section modulus of the effective cross-section for bending about the relevant axis

5. Emendas e Ligações Extremas

5.1. Submetidas à Compressão

- Splices and end connections should be designed to resist an additional internal shear force

$$\Delta V_{Ed} = \frac{\pi N_{Ed}}{l}\left(\frac{1}{\chi}-1\right)\frac{W_{eff}}{A_{eff}}$$

- Splices and end connections should be designed in such a way that load may be transmitted to the effective portions of the cross-section.
- If the constructional details at the ends of a member are such that the line of action of the internal axial force cannot be clearly identified, a suitable eccentricity should be assumed and the resulting moments should be taken into account in the design of the member, the end connections and the splice, if there is one.

6. Ligações com Parafusos

- See Part 1-8 of EN 1993 → The positions of the fasteners → to provide sufficient room for satisfactory assembly and maintenance
- The shear forces on individual mechanical fasteners in a connection may be assumed to be equal, provided that:
  - ✓ the fasteners have sufficient ductility;
  - ✓ shear is not the critical failure mode
- The resistances of individual mechanical fasteners → determined either by calculation or from the results of tests or the minimum values of resistances of fasteners
- For design by calculation, the resistances of mechanical fasteners subject to static loads should be determined from:
  - ✓ table 8.1 for blind rivets;
  - ✓ table 8.2 for self-tapping screws;
  - ✓ table 8.3 for cartridge fired pins;
  - ✓ table 8.4 for bolts.

6. Ligações com Parafusos

- In tables 8.1 to 8.4 the meanings of the symbols shall be taken as follows:
  - ✓ A is the gross cross-sectional area of a bolt;
  - ✓ A_s is the tensile stress area of a bolt;
  - ✓ A_{net} is the net cross-sectional area of the connected part;
  - ✓ L_f is the reduction factor for long joints according to EN 1993-1-8;
  - ✓ d is the nominal diameter of the fastener;
  - ✓ d_0 is the nominal diameter of the hole;
  - ✓ d_w is the diameter of the washer or the head of the fastener;
  - ✓ e_1 is the end distance from the centre of the fastener to the adjacent end of the connected part, in the direction of load transfer, see figure 8.1;
  - ✓ e_2 is the edge distance from the centre of the fastener to the adjacent edge of the connected part, in the direction perpendicular to the direction of load transfer, see figure 8.1;
  - ✓ f_{ub} is the ultimate tensile strength of the bolt material;

6. Ligações com Parafusos

- ✓ $f_{u,sup}$ is the ultimate tensile strength of the supporting member into which a screw is fixed;
- ✓ n is the number of sheets that are fixed to the supporting member by the same screw or pin;
- ✓ n_f is the number of mechanical fasteners in one connection;
- ✓ p_1 is the spacing centre-to-centre of fasteners in the direction of load transfer, see figure 8.1;
- ✓ p_2 is the spacing centre-to-centre of fasteners in the direction perpendicular to the direction of load transfer, see figure 8.1;
- ✓ t is the thickness of the thinner connected part or sheet;
- ✓ t_1 is the thickness of the thicker connected part or sheet;
- ✓ t_{sup} is the thickness of the supporting member into which a screw or a pin is fixed.

6. Ligações com Parafusos

- The partial factor γ_M for calculating the design resistances of mechanical fasteners shall be taken as: γ_{M2} = 1,25

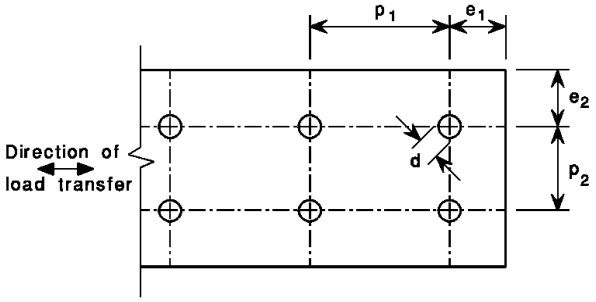


Figure 8.1: End distance, edge distance and spacing for fasteners and spot welds

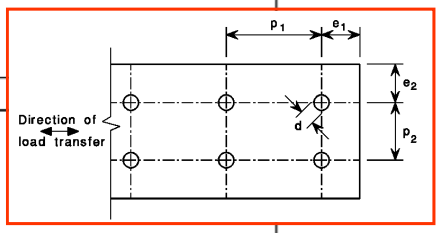
6. Ligações com Parafusos

Table 8.1: Design resistances for blind rivets [1)]

Rivets loaded in shear:
Bearing resistance:
$F_{b,Rd} = \alpha f_u d\, t / \gamma_{M2}$ but $F_{b,Rd} \le f_u e_1\, t / (1{,}2\, \gamma_{M2})$
In which α is given by the following:
- if $t = t_1$: $\alpha = 3{,}6\sqrt{t/d}$ but $\alpha \le 2{,}1$
- if $t_1 \ge 2{,}5\,t$: $\alpha = 2{,}1$
- if $t < t_1 < 2{,}5\,t$: obtain α by linear interpolation.
Net-section resistance:
$F_{n,Rd} = A_{net} f_u / \gamma_{M2}$
Shear resistance:
Shear resistance $F_{v,Rd}$ to be determined by testing or from NA and $F_{v,Rd} = F_{v,Rk} / \gamma_{M2}$
Conditions: [4)] $F_{v,Rd} \ge 1{,}2\, F_{b,Rd} / (n_f \beta_{Lf})$ or $F_{v,Rd} \ge 1{,}2\, F_{n,Rd}$

6. Ligações com Parafusos

Rivets loaded in tension: [2)]
Pull-through resistance: Pull-through resistance $F_{p,Rd}$ to be determined by testing or from NA.
Pull-out resistance: Not relevant for rivets.
Tension resistance: Tension resistance $F_{t,Rd}$ to be determined by testing or from NA
Conditions:
$F_{t,Rd} \ge n F_{p,Rd}$
Range of validity: [3)]
$e_1 \ge 1{,}5\,d$ $p_1 \ge 3\,d$ $2{,}6\text{ mm} \le d \le 6{,}4\text{ mm}$
$e_2 \ge 1{,}5\,d$ $p_2 \ge 3\,d$
$f_u \le 550$ MPa



[1)] In this table it is assumed that the thinnest sheet is next to the preformed head of the blind rivet.

[2)] Blind rivets are not usually used in tension.

[3)] Blind rivets may be used beyond this range of validity if the resistance is determined from the results of tests in accordance with Section 9.

[4)] The required conditions should be fulfilled when deformation capacity of the connection is needed. When these conditions are not fulfilled there should be proved that the needed deformation capacity will be provided by other parts of the structure.

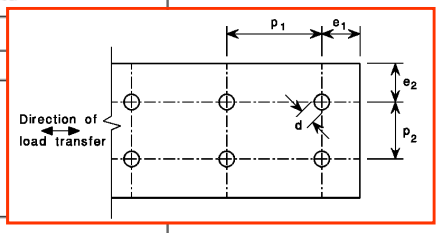
6. Ligações com Parafusos

Table 8.2: Design resistances for self-tapping screws [1)]

Screws loaded in shear:
Bearing resistance: $F_{b,Rd} = \alpha f_u d t / \gamma_{M2}$
In which α is given by the following:
- if $t = t_1$: $\alpha = 3{,}2\sqrt{t/d}$ but $\alpha \le 2{,}1$
- if $t_1 \ge 2{,}5t$ and $t < 1{,}0$ mm: $\alpha = 3{,}2\sqrt{t/d}$ but $\alpha \le 2{,}1$
- if $t_1 \ge 2{,}5t$ and $t \ge 1{,}0$ mm: $\alpha = 2{,}1$
- if $t < t_1 < 2{,}5t$: obtain α by linear interpolation.
Net-section resistance: $F_{n,Rd} = A_{net} f_u / \gamma_{M2}$
Shear resistance: Shear resistance $F_{v,Rd}$ to be determined by testing or from NA and $F_{v,Rd} = F_{v,Rk} / \gamma_{M2}$
Conditions: [4)] $F_{v,Rd} \ge 1{,}2 F_{b,Rd} / (n_f \beta_{Lf})$ or $F_{v,Rd} \ge 1{,}2 F_{n,Rd}$

6. Ligações com Parafusos

Screws loaded in tension:
Pull-through resistance: [2)]
- for static loads: $F_{p,Rd} = d_w t f_u / \gamma_{M2}$
- for screws subject to wind loads and combination of wind loads and static loads: $F_{p,Rd} = 0{,}5 d_w t f_u / \gamma_{M2}$
Pull-out resistance: If $t_{sup}/s < 1$: $F_{o,Rd} = 0{,}45 d t_{sup} f_{u,sup} / \gamma_{M2}$ (s is the thread pitch)
If $t_{sup}/s \ge 1$: $F_{o,Rd} = 0{,}65 d t_{sup} f_{u,sup} / \gamma_{M2}$
Tension resistance: Tension resistance $F_{t,Rd}$ to be determined by testing or from NA.
Conditions: [4)] $F_{t,Rd} \ge n F_{p,Rd}$ or $F_{t,Rd} \ge F_{o,Rd}$
Range of validity: [3)]
Generally: $e_1 \ge 3d$ $p_1 \ge 3d$ 3,0 mm $\le d \le$ 8,0 mm
$e_2 \ge 1{,}5d$ $p_2 \ge 3d$
For tension: 0,5 mm $\le t \le$ 1,5 mm and $t_1 \ge$ 0,9 mm
$f_u \le 550$ MPa



[1)] In this table it is assumed that the thinnest sheet is next to the head of the screw.

[2)] These values assume that the washer has sufficient rigidity to prevent it from being deformed appreciably or pulled over the head of the fastener.

[3)] Self-tapping screws may be used beyond this range of validity if the resistance is determined from the results of tests in accordance with Section 9.

[4)] The required conditions should be fulfilled when deformation capacity of the connection is needed. When these conditions are not fulfilled there should be proved that the needed deformation capacity will be provided by other parts of the structure.

6. Ligações com Parafusos

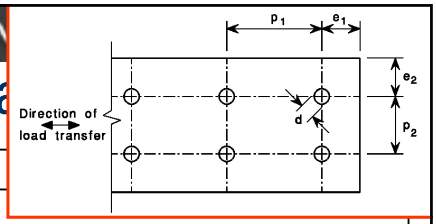
Table 8.3: Design resistances for cartridge fired pins

Pins loaded in shear:
Bearing resistance: $F_{b,Rd} = 3{,}2 f_u d t / \gamma_{M2}$
Net-section resistance: $F_{n,Rd} = A_{net} f_u / \gamma_{M2}$
Shear resistance: Shear resistance $F_{v,Rd}$ to be determined by testing from NA and $F_{v,Rd} = F_{v,Rk} / \gamma_{M2}$
Conditions: [3] $F_{v,Rd} \geq 1{,}5 F_{b,Rd} / (n_f \beta_{Lf})$ or $F_{v,Rd} \geq 1{,}5 F_{n,Rd}$

6. Ligações com Parafusos

Pins loaded in tension:
Pull-through resistance: [1] - for static loads: $F_{p,Rd} = d_w t f_u / \gamma_{M2}$ - for wind loads and combination of wind loads and static loads: $F_{p,Rd} = 0{,}5 d_w t f_u / \gamma_{M2}$
Pull-out resistance: Pull-out resistance $F_{o,Rd}$ to be determined by testing or from NA
Tension resistance: Tension resistance $F_{t,Rd}$ to be determined by testing or from NA
Conditions: [3] $F_{o,Rd} \geq n F_{p,Rd}$ or $F_{t,Rd} \geq F_{o,Rd}$

6. Ligações com Pa



Range of validity: [2]		
Generally:	$e_1 \geq 4{,}5\,d$	$3{,}7\text{ mm} \leq d \leq 6{,}0\text{ mm}$
	$e_2 \geq 4{,}5\,d$	for $d = 3{,}7$ mm: $t_{sup} \geq 4{,}0$ mm
	$p_1 \geq 4{,}5\,d$	for $d = 4{,}5$ mm: $t_{sup} \geq 6{,}0$ mm
	$p_2 \geq 4{,}5\,d$	for $d = 5{,}2$ mm: $t_{sup} \geq 8{,}0$ mm
	$f_u \leq 550$ MPa	
For tension:	$0{,}5\text{ mm} \leq t \leq 1{,}5\text{ mm}$	$t_{sup} \geq 6{,}0$ mm

[1] These values assume that the washer has sufficient rigidity to prevent it from being deformed appreciably or pulled over the head of the fastener.

[2] Cartridge fired pins may be used beyond this range of validity if the resistance is determined from the results of tests in accordance with Section 9.

[3] The required conditions should be fulfilled when deformation capacity of the connection is needed. When these conditions are not fulfilled there should be proved that the needed deformation capacity will be provided by other parts of the structure.

6. Ligações com Parafusos

Table 8.4: Design resistances for bolts

Bolts loaded in shear:

Bearing resistance: [2]

$F_{b,Rd} = 2{,}5\alpha_b\, k_t\, f_u\, d\, t\, / \gamma_{M2}$ with α_b is the smallest of 1,0 or $e_1 / (3d)$ and

$k_t = (0{,}8\, t + 1{,}5) / 2{,}5$ for $0{,}75\text{ mm} \leq t \leq 1{,}25$ mm; $k_t = 1{,}0$ for $t > 1{,}25$ mm

Net-section resistance:

$F_{n,Rd} = (1 + 3\, r\, (d_o / u - 0{,}3))\, A_{net} f_u / \gamma_{M2}$ but $F_{n,Rd} \leq A_{net} f_u / \gamma_{M2}$

with:

r = [number of bolts at the cross-section] / [total number of bolts in the connection]

$u = 2\, e_2$ but $u \leq p_2$

6. Ligações com Parafusos

Shear resistance:

- for strength grades 4.6, 5.6 and 8.8:

$F_{v,Rd} = 0,6 f_{ub} A_s / \gamma_{M2}$

- for strength grades 4.8, 5.8, 6.8 and 10.9:

$F_{v,Rd} = 0,5 f_{ub} A_s / \gamma_{M2}$

Conditions: [3] $F_{v,Rd} \geq 1,2 F_{b,Rd} / (n_f \beta_{Lf})$ or $F_{v,Rd} \geq 1,2 F_{n,Rd}$

Bolts loaded in tension:

Pull-through resistance: Pull-through resistance $F_{p,Rd}$ to be determined by testing or from NA.

Pull-out resistance: Not relevant for bolts.

Tension resistance: $F_{t,Rd} = 0,9 f_{ub} A_s / \gamma_{M2}$

Conditions: [3] $F_{t,Rd} \geq n F_{p,Rd}$

6. Ligações com Parafusos

Range of validity: [1]

$e_1 \geq 1,0 d$ $p_1 \geq 3 d$ 3 mm > $t \geq$ 0,75 mm Minimum bolt size: M 6

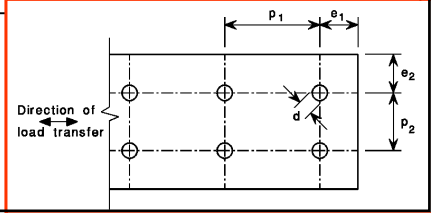
$e_2 \geq 1,5 d$ $p_2 \geq 3 d$ Strength grades: 4.6 - 10.9

$f_u \leq 550$ N/mm^2

[1] Bolts may be used beyond this range of validity if the resistance is determined from the results of tests in accordance with Section 9.

[2] For thickness larger than or equal to 3 mm the rules for bolts in EN 1993-1-8 should be used.

[3] The required conditions should be fulfilled when deformation capacity of the connection is needed. When these conditions are not fulfilled there should be proved that the needed deformation capacity will be provided by other parts of the structure.



6. Ligações com Parafusos

- The resistance of a connection shall preferably be based on tests in accordance with Section 9. Alternatively, the resistance of a connection subject to predominantly static loads may be determined from tables 8.1 to 8.4, provided that the limits on dimensions of fasteners and thicknesses of sheets stated in the tables are satisfied
- If the pull-out resistance $F_{o,Rd}$ of a fastener is smaller than its pull-through resistance $F_{p,Rd}$ the deformation capacity should be determined from the results of tests in accordance with Section 9

6. Ligações com Parafusos

- The pull-through resistances given in tables 8.2 and 8.3 for self-tapping screws and cartridge fired pins should be reduced if the fasteners are not located centrally in the troughs of the sheeting. If attachment is at a quarter point, the design resistance should be reduced to $0,9F_{p,Rd}$ and if there are fasteners at both quarter points, the resistance should be taken as $0,7F_{p,Rd}$ per fastener, see figure 8.2.

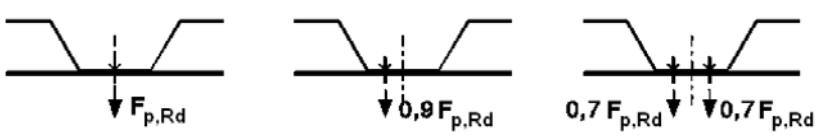


Figure 8.2: Reduction of tension resistance due to the position of fasteners

6. Ligações com Parafusos

- For a fastener loaded in combined shear and tension, if either the shear resistance $F_{v,Rd}$ or the tension resistance $F_{t,Rd}$ have been determined by testing, the resistance to combined shear and tension should also be verified on the basis of tests in accordance with Section 9. Provided that both $F_{t,Rd}$ and $F_{v,Rd}$ are determined by calculation on the basis of tables 8.1 to 8.4, the resistance of the fastener to combined shear and tension may be verified using:

$$\frac{F_{t,Ed}}{\min(F_{p,Rd}, F_{o,Rd})} + \frac{F_{v,Ed}}{\min(F_{b,Rd}, F_{n,Rd})} \leq 1$$

- The gross section distortion may be neglected if the design resistance is obtained from tables 8.1 to 8.4, provided that the fastening is through a flange not more than 150 mm wide.

6. Ligações com Parafusos

- The diameter of holes for screws should be in accordance with the manufacturer's guidelines. These guidelines should be based on following criteria:
  - ✓ the applied torque should be just higher than the threading torque;
  - ✓ the applied torque should be lower than the thread stripping torque or head-shearing torque;
  - ✓ the threading torque should be smaller than 2/3 of the head-shearing torque.
- For long joints a reduction factor Lf should be taken into account according to EN 1993-1-8
- The design rules for blind rivets are valid only if the diameter of the hole is not 0,1 mm larger than the diameter of the rivet.
- For the bolts M12 and M14 with the hole diameters 2 mm larger than the bolt diameter, reference is made to EN 1993-1-8.

6. Ligações com Soldas de Bujão

- Spot welds may be used with as-rolled or galvanized parent material up to 4,0 mm thick, provided that the thinner connected part is not more than 3,0 mm thick
- Spot welds may be either resistance welded or fusion welded
- The design resistance $F_{v,Rd}$ of a spot weld loaded in shear should be determined using table 8.5 where the symbols should be taken as:
  - ✓ A_{net} is the net cross-sectional area of the connected part;
  - ✓ n_w is the number of spot welds in one connection;
  - ✓ t is the thickness of the thinner connected part or sheet [mm];
  - ✓ t_1 is the thickness of the thicker connected part or sheet;
- and the end and edge distances e_1 and e_2 and the spacings p_1 and p_2 are as defined in 8.4(5)
- The partial factor γ_M for calculating the design resistances of spot welds shall be taken as: $\gamma_{M2} = 1,25$

6. Ligações com Soldas de Bujão

Table 8.5: Design resistances for spot welds

Spot welds loaded in shear:
Tearing and bearing resistance: - if $t \le t_1 \le 2,5t$: $F_{tb,Rd} = 2,7\sqrt{t}\, d_s f_u / \gamma_{M2}$ [with t in mm] - if $t_1 > 2,5t$: $F_{tb,Rd} = 2,7\sqrt{t}\, d_s f_u / \gamma_{M2}$ but $F_{tb,Rd} \le 0,7 d_s^2 f_u / \gamma_{M2}$ and $F_{tb,Rd} \le 3,1 t d_s f_u / \gamma_{M2}$ End resistance: $F_{e,Rd} = 1,4 t e_1 f_u / \gamma_{M2}$ Net section resistance: $F_{n,Rd} = A_{net} f_u / \gamma_{M2}$ Shear resistance: $F_{V,Rd} = \frac{\pi}{4} d_s^2 f_u / \gamma_{M2}$
Conditions: $F_{v,Rd} \ge 1,25 F_{tb,Rd}$ or $F_{v,Rd} \ge 1,25 F_{e,Rd}$ or $F_{v,Rd} \ge 1,25 F_{n,Rd} / n_w$
Range of validity:
$2d_s \le e_1 \le 6d_s$ $\quad 3d_s \le p_1 \le 8d_s$ $e_2 \le 4d_s$ $\quad 3d_s \le p_2 \le 6d_s$

6. Ligações com Soldas de Bujão

- The interface diameter *d*s of a spot weld should be determined from the following:
  - ✓ for fusion welding: *d*s = 0,5 *t* + 5 mm
  - ✓ for resistance welding: *d*s = *5* [with *t* in mm]
- The value of *d*s actually produced by the welding procedure should be verified by shear tests in accordance with Section 9, using single-lap test specimens as shown in figure 8.3. The thickness t of the specimen should be the same as that used in practice.

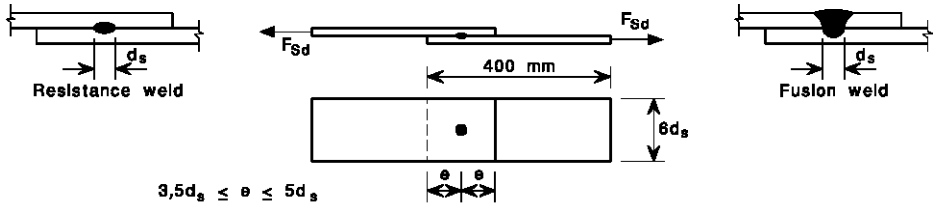


Figure 8.3: Test specimen for shear tests of spot welds

7. Ligações "LAP"

- This clause 8.6 shall be used for the design of arc-welded lap welds where the parent material is 4,0 mm thick or less. For thicker parent material, lap welds shall be designed using EN 1993-1-1.
- The weld size shall be chosen such that the resistance of the connection is governed by the thickness of the connected part or sheet, rather than the weld.
- The requirement in (2) may be assumed to be satisfied if the throat size of the weld is at least equal to the thickness of the connected part or sheet.
- The partial factor γ_M for calculating the design resistances of lap welds shall be taken as: γ_{M2} = 1,25

7. Ligações "LAP"

7.1. Soldas de Filete

- The design resistance $F_{w.Rd}$ of a fillet-welded connection should be determined from the following:
- for a side fillet that comprises one of a pair of side fillets:

$$F_{w,Rd} = t L_{w,s} (0,9 - 0,45 L_{w,s}/b) f_u/\gamma_{M2} \quad \text{if } L_{w,s} \le b$$

$$F_{w,Rd} = 0,45 t b f_u/\gamma_{M2} \quad \text{if } L_{w,s} > b$$

- for an end fillet:

$$F_{w,Rd} = t L_{w,e} (1 - 0,3 L_{w,e}/b) f_u/\gamma_{M2} \quad [\text{for one weld and if } L_{w,s} \le b]$$

where: b is the width of the connected part or sheet;
$L_{w,e}$ is the effective length of the end fillet weld
$L_{w,S}$ is the effective length of a side fillet weld

7. Ligações Cobrejunta

7.1. Soldas de Filete

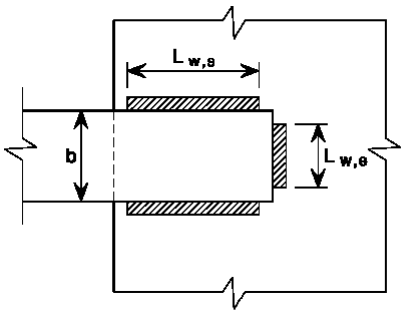


Figure 8.4: Fillet welded lap connection

- If a combination of end fillets and side fillets is used in the same connection, its total resistance should be taken as equal to the sum of the resistances of the end fillets and the side fillets. The position of the centroid and realistic assumption of the distribution of forces should be taken into account.

7. Ligações Cobrejunta

7.1. Soldas de Filete

- If a combination of end fillets and side fillets is used in the same connection, its total resistance should be taken as equal to the sum of the resistances of the end fillets and the side fillets. The position of the centroid and realistic assumption of the distribution of forces should be taken into account.
- The effective length L_w of a fillet weld should be taken as the overall length of the full-size fillet, including end returns. Provided that the weld is full size throughout this length, no reduction in effective length need be made for either the start or termination of the weld.
- Fillet welds with effective lengths less than 8 times the thickness of the thinner connected part should not be designed to transmit any forces.

7. Ligações Cobrejunta

7.2. Arc spot welds

- Arc spot welds shall not be designed to transmit any forces other than in shear.
- Arc spot welds should not be used through connected parts or sheets with a total thickness Σt of more than 4 mm.
- Arc spot welds should have an interface diameter ds of not less than 10 mm.
- If the connected part or sheet is less than 0,7 mm thick, a weld washer should be used, see figure 8.5.
- Arc spot welds should have adequate end and edge distances as given in the following:

7. Ligações Cobrejunta

7.2. Arc spot welds

- ✓ The minimum distance measured parallel to the direction of force transfer, from the centerline of an arc spot weld to the nearest edge of an adjacent weld or to the end of the connected part towards which the force is directed, should not be less than the value of e_{min} given by the following:

$$\text{if } f_u/f_y \le 1{,}15 \qquad e_{min} = 1{,}8\frac{F_{w,Sd}}{t f_u/\gamma_{M2}}$$

$$\text{if } f_u/f_y \ge 1{,}15 \qquad e_{min} = 2{,}1\frac{F_{w,Sd}}{t f_u/\gamma_{M2}}$$

- ✓ The minimum distance from the centreline of a circular arc spot weld to the end or edge of the connected sheet should not be less than 1,5dw where dw is the visible diameter of the arc spot weld.
- ✓ The minimum clear distance between an elongated arc spot weld and the end of the sheet and between the weld and the edge of the sheet should not be less than 1,0 dw.

7. Ligações Cobrejunta

7.2. Arc spot welds

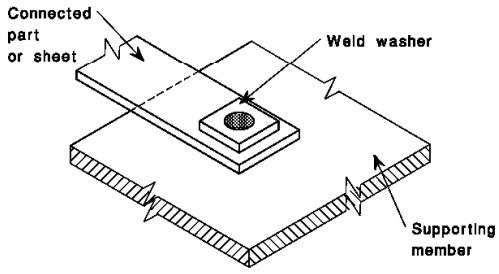


Figure 8.5: Arc spot weld with weld washer

- The design shear resistance $F_{w,Rd}$ of a circular arc spot weld should be determined as follows:

$$F_{w,Rd} = (\pi/4)\, d_s^2 \times 0{,}625 f_{uw}/\gamma_{M2}$$

- f_{uw} is the ultimate tensile strength of the welding electrodes;

7. Ligações Cobrejunta

7.2. Arc spot welds

- if $d_p / \Sigma t \leq 18 (420 / f_u)^{0.5}$:

  $F_{w,Rd} = 1{,}5\, d_p \Sigma t\, f_u / \gamma_{M2}$

- if $18 (420 / f_u)^{0.5} < d_p / \Sigma t < 30 (420 / f_u)^{0.5}$:

  $F_{w,Rd} = 27 (420 / f_u)^{0.5} (\Sigma t)^2 f_u / \gamma_{M2}$

- if $d_p / \Sigma t \geq 30 (420 / f_u)^{0.5}$:

  $F_{w,Rd} = 0{,}9\, d_p \Sigma t\, f_u / \gamma_{M2}$

- The interface diameter d_s of an arc spot weld, see figure 8.6, should be obtained from:

$$d_s = 0{,}7 d_w - 1{,}5 \Sigma t \quad \text{but} \quad d_s \geq 0{,}55\, d_w$$

- where: d_w is the visible diameter of the arc spot weld

7. Ligações Cobrejunta

7.2. Arc spot welds

- The effective peripheral diameter d_p of an arc spot weld should be obtained as follows:
  - ✓ for a single connected sheet or part of thickness t:

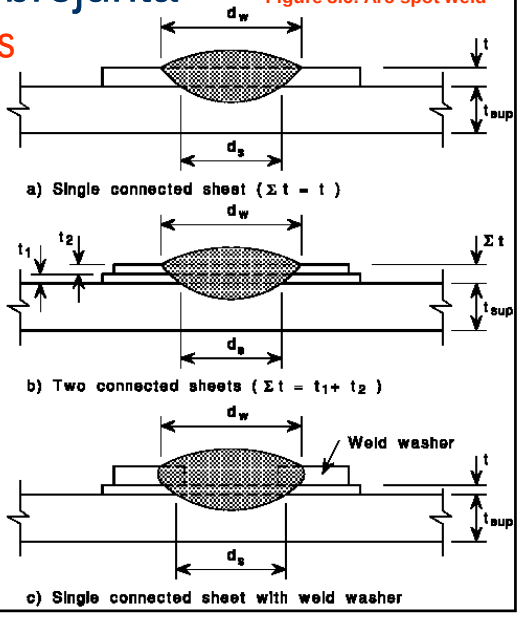
    $d_p = d_w - t$
  - ✓ for multiple connected sheets or parts of total thickness Σt:

    $d_p = d_w - 2 \Sigma t$
- but $F_{w,Rd}$ should not be taken as more than the peripheral resistance given by:

  $F_{w,Rd} = (0{,}5 L_w + 1{,}67 d_p) \Sigma t f_u / \gamma_{M2}$

  where L_w is the length of the elongated arc spot weld

Figure 8.6: Arc spot weld



7. Ligações Cobrejunta

7.2. Arc spot welds

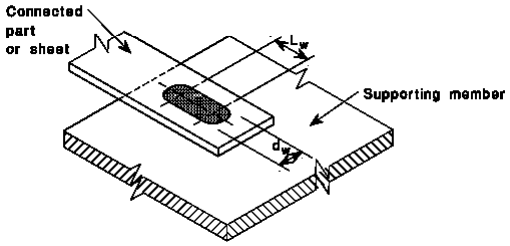


Figure 8.7: Elongated arc spot weld