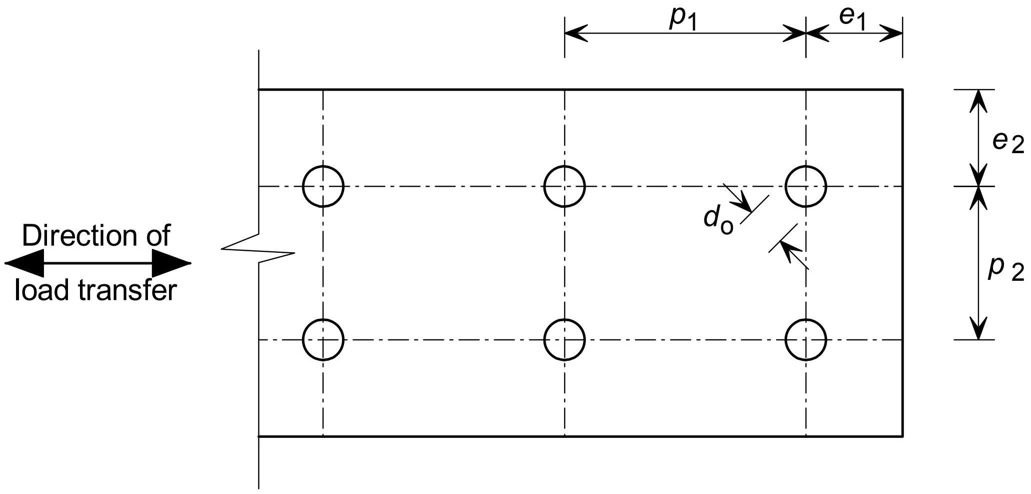

Figure 8.1: End distance, edge distance and spacings for fasteners and spot welds

(6) 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 tests.

(7) 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.

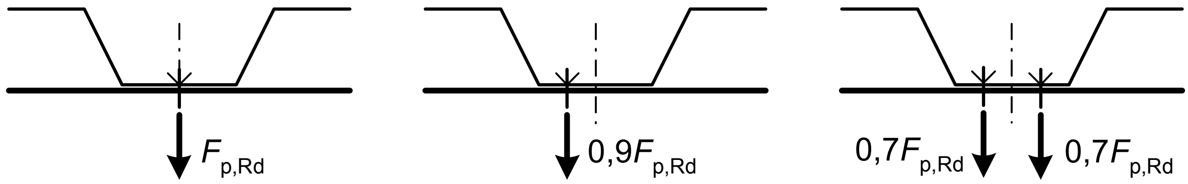

Figure 8.2: Reduction of pull through resistance due to the position of fasteners

(8) For a fastener loaded in combined shear and tension, 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:

$$\frac{F_{t,Ed}}{\min(F_{p,Rd}, F_{o,Rd})} + \frac{F_{v,Ed}}{\min(F_{b,Rd}, F_{n,Rd})} \leq 1 \qquad \text{... (8.2)}$$

(9) 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.

(10) 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.

(11) For long joints a reduction factor β_{Lf} should be taken into account according to EN 1993-1-8, 3.8.

(12) The design rules for blind rivets are valid only if the diameter of the hole is not more than 0,1 mm larger than the diameter of the rivet.

(13) 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.

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 $F_{b,Rd} \leq f_u e_1 t / (1{,}2\, \gamma_{M2})$ In which α is given by the following: - if $t = t_1$: $\alpha = 3{,}6\sqrt{t/d}$ but $\alpha \leq 2{,}1$ - if $t_1 \geq 2{,}5\, t$: $\alpha = 2{,}1$ - 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 *[1)] and $F_{v,Rd} = F_{v,Rk} / \gamma_{M2}$
Conditions: [4)] $F_{v,Rd} \geq 1{,}2\, F_{b,Rd} / (n_f\, \beta_{Lf})$ or $F_{v,Rd} \geq 1{,}2\, F_{n,Rd}$
Rivets loaded in tension: [2)]
Pull-through resistance: Pull-through resistance $F_{p,Rd}$ to be determined by testing *[1)]. Pull-out resistance: Not relevant for rivets. Tension resistance: Tension resistance $F_{t,Rd}$ to be determined by testing *[1)]
Conditions: $F_{t,Rd} \geq \Sigma F_{p,Rd}$
Range of validity: [3)]
$e_1 \geq 1{,}5\, d$ $p_1 \geq 3\, d$ $2{,}6 \text{ mm} \leq d \leq 6{,}4 \text{ mm}$ $e_2 \geq 1{,}5\, d$ $p_2 \geq 3\, d$ $f_u \leq 550 \text{ N/mm}^2$
[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. [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.

NOTE:*[1)] The National Annex may give further information on shear resistance of blind rivets loaded in shear and pull-through resistance and tension resistance of blind rivets loaded in tension.

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 $t_1 \ge 2{,}5\,t$ and $t < 1{,}0$ mm: $\alpha = 3{,}2\sqrt{t/d}$ but $\alpha \le 2{,}1$
- if $t_1 \ge 2{,}5\,t$ and $t \ge 1{,}0$ mm: $\alpha = 2{,}1$
- 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 *[2)]

$F_{v,Rd} = F_{v,Rk} / \gamma_{M2}$

Conditions: [4)] $F_{v,Rd} \ge 1{,}2\,F_{b,Rd}$ or $\Sigma F_{v,Rd} \ge 1{,}2\,F_{n,Rd}$

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 *[2)].

Conditions: [4)] $F_{t,Rd} \ge \Sigma F_{p,Rd}$ or $F_{t,Rd} \ge F_{o,Rd}$

Range of validity: [3)]

Generally: $e_1 \ge 3\,d$ $p_1 \ge 3\,d$ $3{,}0\text{ mm} \le d \le 8{,}0\text{ mm}$

$e_2 \ge 1{,}5\,d$ $p_2 \ge 3\,d$

For tension: $0{,}5\text{ mm} \le t \le 1{,}5\text{ mm}$ and $t_1 \ge 0{,}9\text{ mm}$

$f_u \le 550\text{ N/mm}^2$

[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.
[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.

NOTE:*[2)] The National Annex may give further information on shear resistance of self-tapping AC› screws ‹AC loaded in shear and tension resistance of self-tapping AC› screws ‹AC loaded in tension.

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 *[3)] $F_{v,Rd} = F_{v,Rk} / \gamma_{M2}$
Conditions: [3)] $F_{v,Rd} \geq 1{,}5\, \Sigma F_{b,Rd}$ or $\Sigma F_{v,Rd} \geq 1{,}5\, F_{n,Rd}$
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 *[3)] Tension resistance: Tension resistance $F_{t,Rd}$ to be determined by testing *[3)]
Conditions: [3)] $F_{o,Rd} \geq \Sigma F_{p,Rd}$ or $F_{t,Rd} \geq F_{o,Rd}$
Range of validity: [2)]
Generally: $e_1 \geq 4{,}5\, d$ — $3{,}7$ mm $\leq d \leq 6{,}0$ 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 $f_u \leq 550$ N/mm^2 For tension: $0{,}5$ mm $\leq t \leq 1{,}5$ 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. [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.

NOTE:*[3)] The National Annex may give further information on shear resistance of cartrige fired pins loaded in shear and pull-out resistance and tension resistance of cartridge fired pins loaded in tension.

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 $0{,}75 \text{ mm} \le t \le 1{,}25 \text{ mm}$; $k_t = 1{,}0$ 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 $F_{n,Rd} \le A_{net} f_u / \gamma_{M2}$

with:

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

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

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] $F_{v,Rd} \ge 1{,}2\, \Sigma\, F_{b,Rd}$ or $\Sigma F_{v,Rd} \ge 1{,}2\, F_{n,Rd}$

Bolts loaded in tension:

Pull-through resistance: Pull-through resistance $F_{p,Rd}$ to be determined by testing *[4].

Pull-out resistance: Not relevant for bolts.

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

Conditions: [3] $F_{t,Rd} \ge \Sigma F_{p,Rd}$

Range of validity: [1]

$e_1 \ge 1{,}0\, d_o$	$p_1 \ge 3\, d_o$	AC⟩ $0{,}75 \text{ mm} \le t < 3 \text{ mm}$ ⟨AC	Minimum bolt size:	M 6
$e_2 \ge 1{,}5\, d_o$	$p_2 \ge 3\, d_o$		Strength grades:	4.6 - 10.9
$f_u \le 550 \text{ N/mm}^2$				

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

[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.

NOTE:*[4] The National Annex may give further information on pull-through resistance of bolts loaded in tension.

8.4 Spot welds

(1) 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.

(2) Spot welds may be either resistance welded or fusion welded.

(3) The design resistance $F_{v,Rd}$ of a spot weld loaded in shear should be determined using table 8.5.

(4) In table 8.5 the meanings of the symbols should be taken as follows:

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 [mm];

and the end and edge distances e_1 and e_2 and the spacings p_1 and p_2 are as defined in 8.3(5).

(5) The partial factor γ_M for calculating the design resistances of spot welds should be taken as γ_{M2}.

NOTE: The National Annex may chose the value of γ_{M2}. The value $\gamma_{M2} = 1,25$ is recommended.

Table 8.5: Design resistances for spot welds

Spot welds loaded in shear:						
Tearing and bearing resistance:						
- if $t \le t_1 \le 2,5\,t$:						
$F_{tb,Rd} = 2,7\sqrt{t}\,d_s f_u / \gamma_{M2}$ [with t in mm]						
- if $t_1 > 2,5\,t$:						
$F_{tb,Rd} = 2,7\sqrt{t}\,d_s f_u / \gamma_{M2}$ 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 $\Sigma F_{v,Rd} \ge 1,25\,F_{n,Rd}$						
Range of validity:						
$2\,d_s \le$	e_1	$\le 6\,d_s$		$3\,d_s \le$	p_1	$\le 8\,d_s$
e_2	$\le$	$4\,d_s$		$3\,d_s \le$	p_2	$\le 6\,d_s$

(6) 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 ... (8.3a)

- for resistance welding: $d_s = 5\sqrt{t}$ [with t in mm] ...(8.3b)

(7) 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.

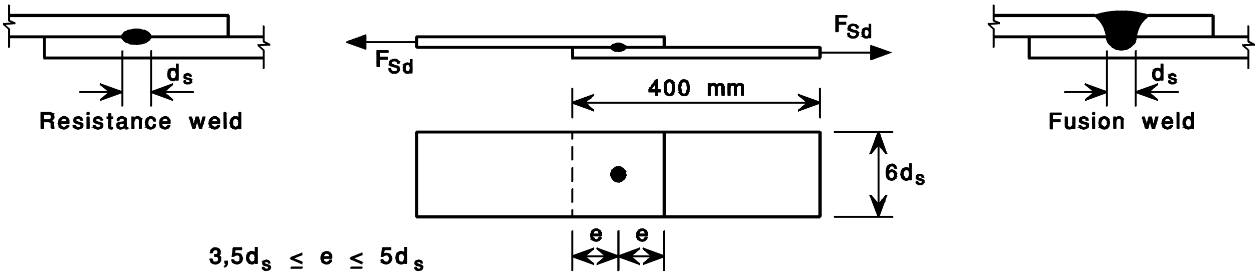

Figure 8.3: Test specimen for shear tests of spot welds

8.5 Lap welds

8.5.1 General

(1) This clause 8.5 should 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 should be designed using EN 1993-1-8.

(2) The weld size should be chosen such that the resistance of the connection is governed by the thickness of the connected part or sheet, rather than the weld.

(3) 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.

(4) The partial factor γ_M for calculating the design resistances of lap welds should be taken as γ_{M2}.

NOTE: The National Annex may give a choice of γ_{M2}. The value $\gamma_{M2} = 1{,}25$ is recommended.

8.5.2 Fillet welds

(1) The design resistance $F_{w.Rd}$ of a fillet-welded connection should be determined from the following:

- for a side fillet that is one of a pair of side fillets:

$$F_{w,Rd} = t L_{w,s} (0{,}9 - 0{,}45 L_{w,s} / b) f_u / \gamma_{M2} \quad \text{if } L_{w,s} \leq b \qquad \text{... (8.4a)}$$

$$F_{w,Rd} = 0{,}45 t b f_u / \gamma_{M2} \quad \text{if } L_{w,s} > b \qquad \text{... (8.4b)}$$

- for an end fillet:

$$F_{w,Rd} = t L_{w,e} (1 - 0{,}3 L_{w,e} / b) f_u / \gamma_{M2} \quad \text{[for one weld and if } L_{w,s} \leq b\text{]} \qquad \text{... (8.4c)}$$

where:

b is the width of the connected part or sheet, see figure 8.4;

$L_{w,e}$ is the effective length of the end fillet weld, see figure 8.4;

$L_{w,s}$ is the effective length of a side fillet weld, see figure 8.4.

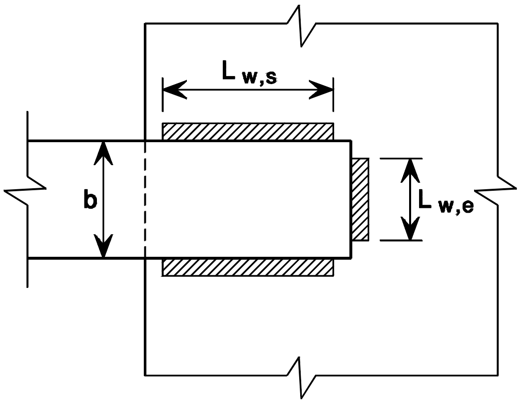

Figure 8.4: Fillet welded lap connection

(2) 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.

(3) 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.

(4) Fillet welds with effective lengths less than 8 times the thickness of the thinner connected part should not be designed to transmit any forces.

8.5.3 Arc spot welds

(1) Arc spot welds should not be designed to transmit any forces other than in shear.

(2) Arc spot welds should not be used through connected parts or sheets with a total thickness Σt of more than 4 mm.

(3) Arc spot welds should have an interface diameter d_s of not less than 10 mm.

(4) If the connected part or sheet is less than 0,7 mm thick, a weld washer should be used, see figure 8.5.

(5) Arc spot welds should have adequate end and edge distances as given in the following:

(i) The minimum distance measured parallel to the direction of force transfer, from the centreline 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:

if $f_u / f_y < 1{,}15$

AC⟩ $$e_{min} = 1{,}8 \frac{F_{w,Rd}}{t\, f_u / \gamma_{M2}}$$ ⟨AC

if $f_u / f_y \geq 1{,}15$

AC⟩ $$e_{min} = 2{,}1 \frac{F_{w,Rd}}{t\, f_u / \gamma_{M2}}$$ ⟨AC

(ii) 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 $1{,}5 d_w$ where d_w is the visible diameter of the arc spot weld.

(iii) 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 $1{,}0\, d_w$.

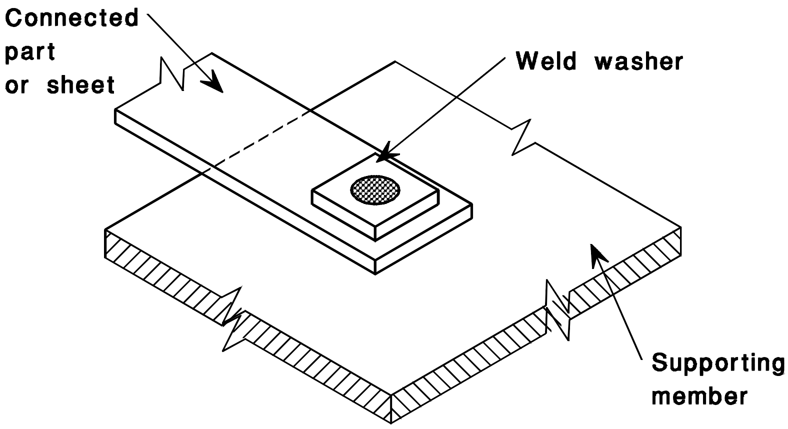

Figure 8.5: Arc spot weld with weld washer

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

$$F_{w,Rd} = (\pi/4)\, d_s^2 \times 0{,}625 f_{uw} / \gamma_{M2} \qquad \text{... (8.5a)}$$

where:

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

but $F_{w,Rd}$ should not be taken as more than the resistance given by the following:

- if $d_p / \Sigma t \leq 18\,(420 / f_u)^{0,5}$:

$$F_{w,Rd} = 1{,}5\, d_p \Sigma t\; f_u / \gamma_{M2} \qquad \text{... (8.5b)}$$

- if $18\,(420 / f_u)^{0,5} < d_p / \Sigma t < 30\,(420 / f_u)^{0,5}$:

$$F_{w,Rd} = 27\,(420 / f_u)^{0,5}\; (\Sigma t)^2\; f_u / \gamma_{M2} \qquad \text{... (8.5c)}$$

- if $d_p / \Sigma t \geq 30\,(420 / f_u)^{0,5}$:

$$F_{w,Rd} = 0{,}9\, d_p \Sigma t\, f_u / \gamma_{M2} \qquad \text{... (8.5d)}$$

with d_p according to (8).

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

$$d_s = 0{,}7 d_w - 1{,}5\, \Sigma t \quad \text{but} \quad d_s \geq 0{,}55\, d_w \qquad \text{... (8.6)}$$

where:

d_w is the visible diameter of the arc spot weld, see figure 8.6.

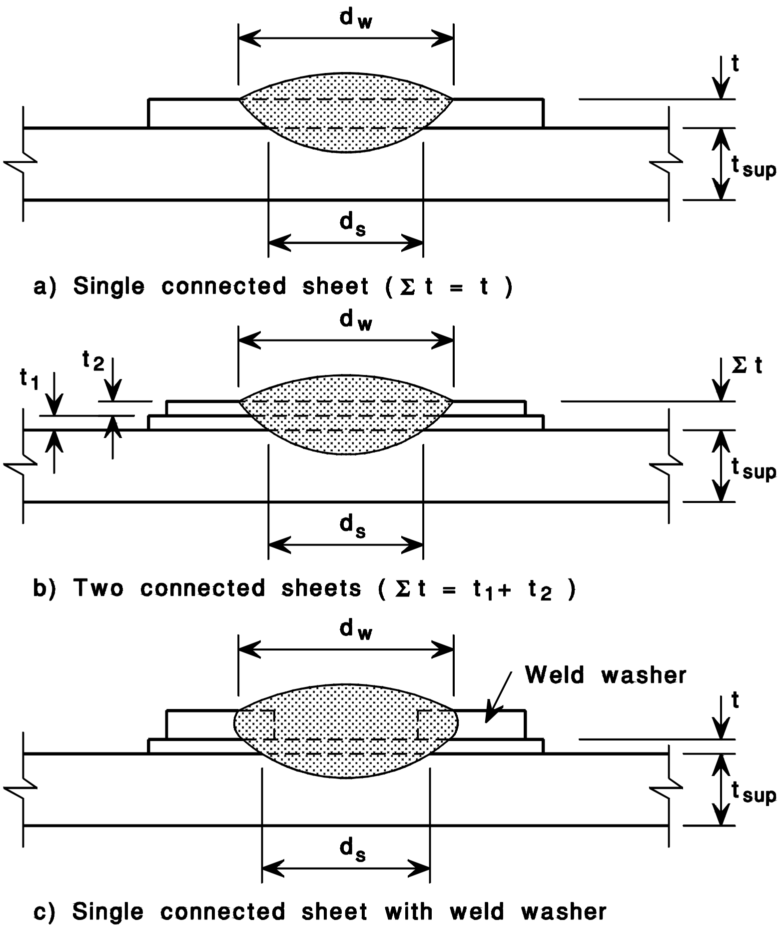

Figure 8.6: Arc spot welds

(8) 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:

$$d_p = d_w - t \qquad \text{... (8.7a)}$$

- for multiple connected sheets or parts of total thickness Σt:

$$d_p = d_w - 2\,\Sigma t \qquad \text{... (8.7b)}$$

(9) The design shear resistance $F_{w,Rd}$ of an elongated arc spot weld should be determined from:

$$F_{w,Rd} = [\,(\pi/4)\,d_s^2 + L_w\,d_s\,] \times 0{,}625 f_{uw} / \gamma_{M2} \qquad \text{... (8.8a)}$$

but $F_{w,Rd}$ should not be taken as more than the peripheral resistance given by:

$$F_{w,Rd} = (\,0{,}5\,L_w + 1{,}67\,d_p\,)\,\Sigma t f_u / \gamma_{M2} \qquad \text{... (8.8b)}$$

where:

L_w is the length of the elongated arc spot weld, measured as shown in figure 8.7.