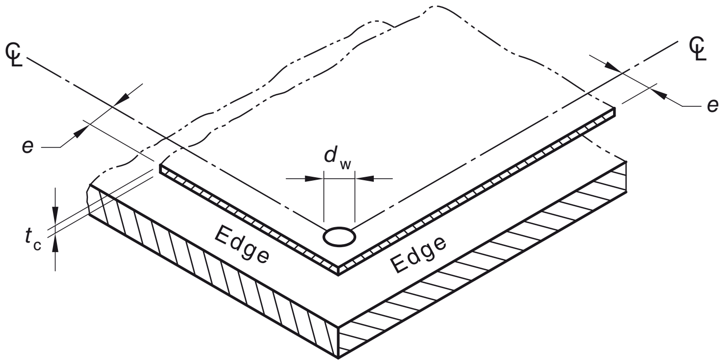
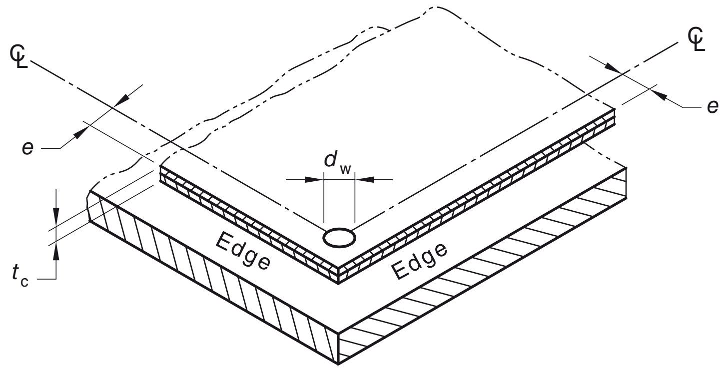



(a) Single sheet




(b) Double sheet

FIGURE 5.2.4(C) EDGE DISTANCE FOR ARC SPOT WELDS

**5.2.4.4** *Tension*

The design tensile force $\left(N_w^*\right)$ on an arc spot weld shall satisfy—

$$N_w^* \leq \phi N_w \qquad \text{. . . 5.2.4.4(1)}$$

The design tensile capacity ($\phi N_w$) of each arc spot weld between sheet and supporting member shall be determined as follows:

$\phi$ = 0.65

$N_w$ = nominal tensile capacity of an arc spot weld

$$= 0.7 t d_a f_u \qquad \text{. . . 5.2.4.4(2)}$$

The following additional limitations for use in Equation 5.2.4.3(2) shall apply:

$e \geq d_w$

$f_{uw} \geq$ 410 MPa

$f_u \leq$ 410 MPa

$t \leq$ 0.7 mm

NOTE: If it can be shown by measurement that a given weld procedure will consistently give a larger average diameter ($d_a$), this larger diameter may be used provided the particular welding procedure used for making those welds is followed.

The effects of any eccentric loading on an arc spot weld subject to uplift tension load, e.g., an arc spot weld on the perimeter of a roof or floor system, shall be evaluated and considered within the design of the weld.

### 5.2.5 Arc seam welds

#### 5.2.5.1 *General*

Arc seam welds (see Figure 5.2.5.1) apply only to the following connections:

(a) Sheet to thicker supporting member welded in the flat position.

(b) Sheet to sheet welded in the horizontal or flat position.

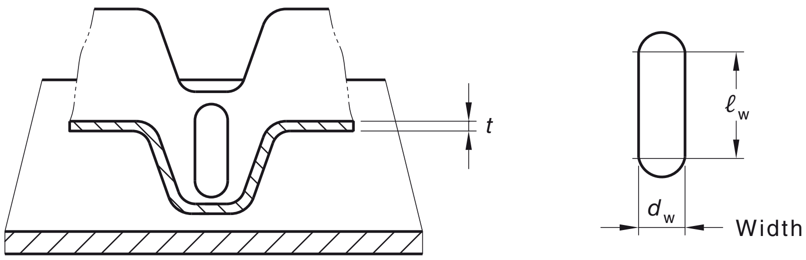



FIGURE 5.2.5.1 ARC SEAM WELD—SHEET TO SUPPORTING MEMBER IN FLAT POSITION

#### 5.2.5.2 *Shear*

The design shear force $\left(V_n^*\right)$ on an arc seam weld shall satisfy—

$$V_n^* \leq \phi V_w \quad \text{. . . 5.2.5.2(1)}$$

where

$\phi$ = capacity reduction factor of an arc seam weld in shear (see Table 1.6.3)

$V_w$ = nominal tensile capacity of an arc spot weld

The design shear capacity ($\phi V_w$) of an arc seam weld shall be the lesser of the following:

(a) $\phi = 0.60$

$$V_w = \left[\frac{\pi d_e^2}{4} + l_w d_e\right] 0.75 f_{uw} \quad \text{. . . 5.2.5.2(2)}$$

(b) $\phi = 0.60$

$$V_w = 2.5 t f_u \left(0.25 l_w + 0.96 d_a\right) \quad \text{. . . 5.2.5.2(3)}$$

where

$d_e$ = effective width of an arc seam weld at fused surfaces

= $0.7 d_w - 1.5 t$ . . . 5.2.5.2(4)

$d_w$ = width of an arc seam weld

$l_w$ = length of the full size of the weld not including the circular ends.

For calculation purposes, $l_w$ shall not exceed $3 d_w$

$t$ = thickness of the thinnest connected part

$d_a$ = average width of arc seam weld

$= d_w - t$ (for single sheet) . . . 5.2.5.2(5)

$= d_w - 2t$ (for double sheet) . . . 5.2.5.2(6)

**5.2.5.3** *Tearout*

The design tearout capacity ($\phi V_w$) of the connected part based on the edge distance ($e$) (see Figure 5.2.5.3) shall be determined as for the arc spot weld specified in Clause 5.2.4.3.

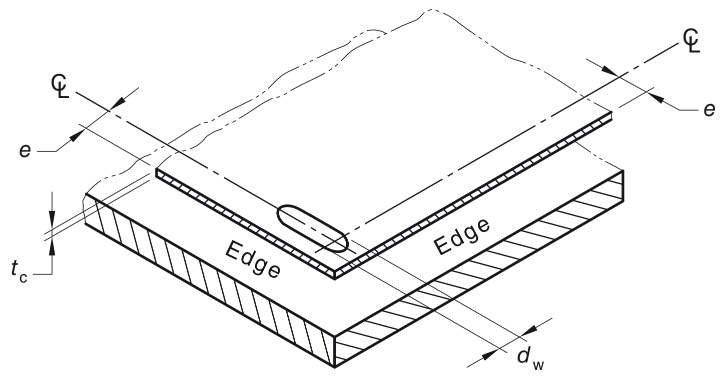



FIGURE 5.2.5.3 EDGE DISTANCE FOR ARC SEAM WELD

### 5.2.6 Flare welds

**5.2.6.1** *General*

Flare welds (see Figure 5.2.6(a), (b) and (c)) apply only to the following connections welded in any position:

(a) Sheet to sheet for flare V-welds.

(b) Sheet to sheet for flare-bevel welds.

(c) Sheet to thicker steel member for flare-bevel welds.

**5.2.6.2** *Shear*

The design shear force $\left(V_w^*\right)$ on a flare weld shall satisfy—

$$V_w^* \le \phi V_w \quad \text{. . . 5.2.6.2(1)}$$

where

$\phi$ = capacity reduction factor of flare welds subject to transverse and longitudinal loading (see Table 1.6.3)

$V_w$ = nominal shear capacity of a flare weld

The design shear capacity $\left(\phi V_w\right)$ of a flare weld shall be the least of the following values:

(a) For flare-bevel welds, subject to transverse loading [see Figure 5.2.6(a)]:

$\phi$ = 0.55

$V_w = 0.833 t l_w f_u$ . . . 5.2.6.2(2)

(b) For flare welds, subject to longitudinal loading [see Figure 5.2.6(b), (c), (d), (e), (f) and (g)]:

(i) For $t \leq t_w < 2t$ or if the lip height is less than $l_w$:

$\phi = 0.55$

$V_w = 0.75 t l_w f_u$ . . . 5.2.6.2(3)

(ii) For $t_w \geq 2t$ and the lip height is greater than or equal to $l_w$:

$\phi = 0.55$

$V_w = 1.5 t l_w f_u$ . . . 5.2.6.2(4)

(c) For longitudinal and transverse loading:

For $t \geq 2.5$ mm:

$\phi = 0.60$

$V_w = 0.75 t_w l_w f_{uw}$ . . . 5.2.6.2(5)

where

$t_w$ = design throat thickness of the weld (see Figure 5.2.6(d), (e), (f) and (g))

= $(5/16)R$ for flare bevel weld filled flush to the surface . . . 5.2.6.2(6)

= $(1/2)R$ or $(3/8)R$ if $R > 12.0$ mm for flare V-weld filled flush to the surface; or . . . 5.2.6.2(7)

= effective throat thickness of flare weld not filled-flush to surface

= $0.707w_1$ or $0.707w_2$, whichever is smaller

$R$ = radius of outside bend surface

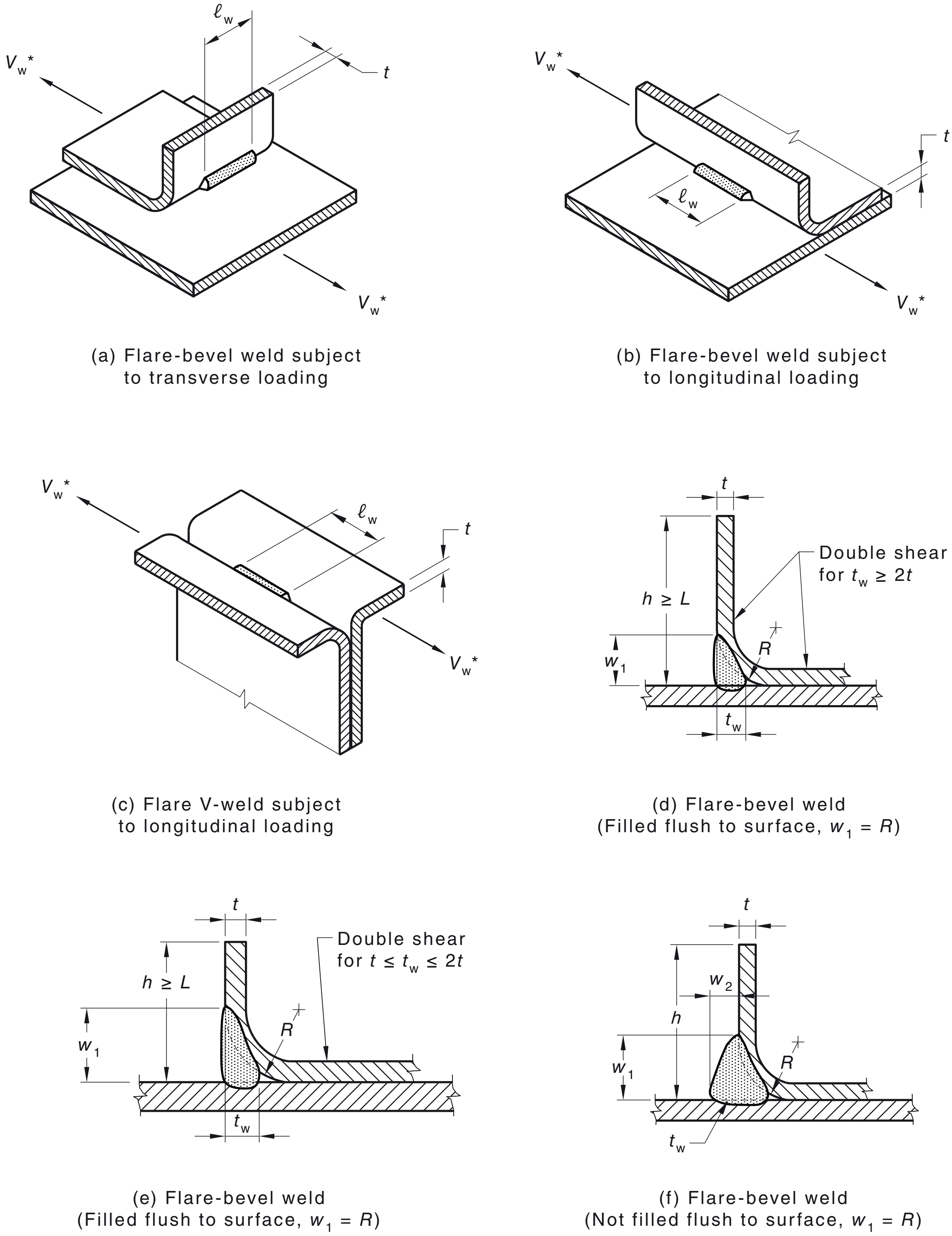
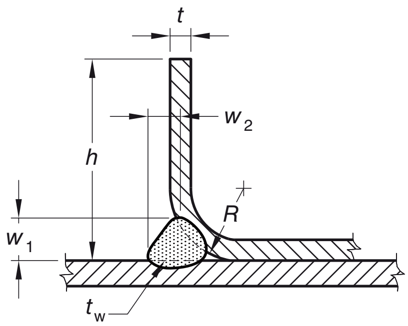



FIGURE 5.2.6 (in part) SHEAR IN FLARE WELDS




(g) Flare-bevel weld
(Not filled flush to surface, $w_1 = R$)

FIGURE 5.2.6 (in part) SHEAR IN FLARE WELDS

### 5.2.7 Resistance welds

The design shear force $\left(V_w^*\right)$ on a resistance weld shall satisfy—

$$V_w^* \leq \phi V_w \qquad \text{. . . 5.2.7(1)}$$

where

$\phi$ = capacity reduction factor of the resistance weld (see Table 1.6.3)

$V_w$ = nominal shear capacity of the resistance weld

The design shear capacity ($\phi V_w$) shall be determined as follows:

(a) For spot welds, the design shear capacity ($\phi V_w$) shall be as follows:

$\phi = 0.65$

$$V_w = 5.51t^{1.47} \text{ (kN)} \quad \text{for } 0.25 \text{ mm} \leq t < 3.56 \text{ mm} \qquad \text{. . . 5.2.7(2)}$$

$$7.6t + 8.57 \text{ (kN)} \quad \text{for } 3.56 \text{ mm} \leq t < 4.57 \text{ mm} \qquad \text{. . . 5.2.7(3)}$$

$t$ = thickness of thinnest outside sheet, in millimetres

(b) For seam welds, the design shear capacity ($\phi V_w$) shall be determined by testing in accordance with Section 8.

## 5.3 BOLTED CONNECTIONS

### 5.3.1 General

This Clause applies to bolted connections for cold-formed steel structural members in which the thickness of a connected part is less than 3 mm. For bolted connections in which the thickness of a connected part is greater than or equal to 3 mm, AS 4100 or NZS 3404, as appropriate, shall be used.

Bolts shall be installed and tightened to achieve the required performance of the connections involved under service conditions.

Standard holes for bolts shall not exceed the sizes given in Table 5.3.1; except that larger holes may be used in column base details or structural systems connected to concrete provided special plate washers as specified in AS 4100 or NZS 3404 are used.

Oversized and slotted holes given in Table 5.3.1 may be used, provided all bolts are loaded in shear and bolt holes conform to the following:

(a) *Slotted holes for Australia* The length of long-slotted holes shall be normal to the direction of the shear hole. Short-slotted holes may have the force either perpendicular or parallel with the hole. Modification factors for the type of bearing connection for oversize and short-slotted holes are given in Table 5.3.4.2(A).

(b) *Purlins and girts for Australia* In situations where lapping or nesting of sections is required, such as purlin and girt applications, it is permissible to have oversized short-slotted holes, provided integral washers are used with the bolt head and nut, all bolts are loaded in shear and the length of slotted holes are normal to the direction of the shear force. The dimension of such oversized-slotted holes shall be—

$(d_f + 6.0)$ mm by $(d_f + 10.0)$ mm

(c) *Z-section purlins and girts for New Zealand* In situations where lapping or nesting is required, such as purlin and girt applications, it is permissible to have short-slotted holes provided all bolts are loaded in shear, washers or backup plates are installed and bolts tightened to achieve the required performance of the connection. The dimension of such short-slotted holes shall be—

$(d_f + 2.0)$ by $(d_f + 10.0)$ mm

Washers and backup plates shall be installed over oversized or short-slotted holes, or long-slotted holes in an outer ply, unless suitable performance is demonstrated by load tests in accordance with Section 8.

In addition, the minimum distance between centres of bolt holes shall provide clearance for bolt heads, nuts, washers and the wrench but shall be not less than 3 times the nominal bolt diameter ($d_f$). Also, the distance from the centre of any standard hole to the end or other boundary of the connecting member shall be not less than $1.5d_f$.

For oversized and slotted holes, the distance between edges of two adjacent holes and the distance measured from the edge of the hole to the end or other boundary of the connecting member in the line of force shall be not less than $[e - (d_h/2)]$, where $e$ is the distance used in Equation 5.3.2(2), and $d_h$ is the diameter of a hole given in Table 5.3.1. The clear distance between edges of two adjacent holes shall be not less than $2d_f$ and the distance between the edge of the hole and the end of the member shall be not less than $d_f$.

When holes are staggered, the area to be deducted shall be the greater of—

(i) the deduction for non-staggered holes; or

(ii) the sum of the areas of all holes in any zig-zag line extending progressively across the member or part of the member, less $\left(\dfrac{s_p^2 t}{4s_g}\right)$ for each gauge space in the chain of holes;

where

$s_p$ = staggered pitch, the distance measured parallel to the direction of the design action in the member, centre-to-centre of holes in consecutive lines [see Figure 5.3.1(A)]

$t$ = thickness of the holed material

$s_g$ = gauge, the distance measured at right angles to the direction of the design action in the member, centre-to-centre of holes in consecutive lines [see Figure 5.3.1(A)]

For sections such as angles with holes in both legs, the gauge shall be taken as the sum of the back marks to each hole, less the leg thickness [see Figure 5.3.1(B)]

**TABLE 5.3.1**

**MAXIMUM SIZE OF BOLT HOLES**

| Nominal bolt diameter ($d_f$) mm | Standard hole diameter ($d_h$) mm | Oversized hole diameter ($d_h$) mm | Short-slotted hole dimensions mm | Long-slotted hole dimensions mm |
|---|---|---|---|---|
| <12 | $d_f + 1.0$ | $d_f + 2.0$ | $(d_f + 1.0)$ by $(d_f + 6.0)$ | $(d_f + 1.0)$ by $2.5d_f$ |
| ≥12 | $d_f + 2.0$ | $d_f + 3.0$ | $(d_f + 2.0)$ by $(d_f + 6.0)$ | $(d_f + 2.0)$ by $2.5d_f$ |

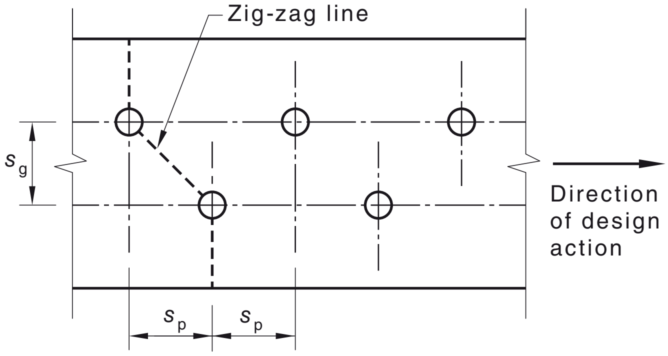



FIGURE 5.3.1(A) STAGGERED HOLES

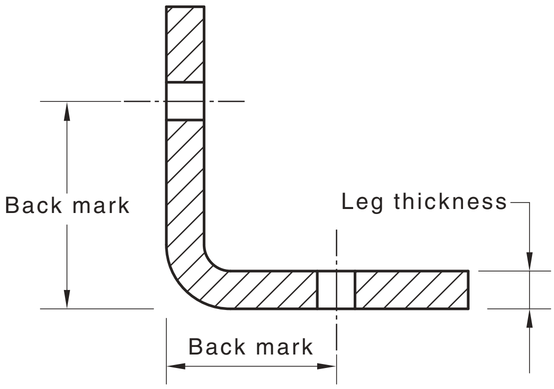



FIGURE 5.3.1(B) ANGLES WITH HOLES IN BOTH LEGS

For bolted connections in shear, the design shear capacity $(\phi V_w)$ is the minimum of the capacities calculated from Clauses 5.3.2 (tearout), 5.3.3 (net section tension), 5.3.4 (bearing), and 5.3.5.1 (bolts in shear).

### 5.3.2 Tearout

A connected part shall have a spacing between bolts and an edge distance from a bolt such that the design shear force $\left(V_{\mathrm{f}}^{*}\right)$ of the connected part satisfies—

$$V_{\mathrm{f}}^{*} \leq \phi V_{\mathrm{f}} \qquad \text{. . . 5.3.2(1)}$$

where

$\phi$ = capacity reduction factor of bolted connection subject to tearout (see Table 1.6.3)

= $0.70 \text{ for } \dfrac{f_{\mathrm{u}}}{f_{\mathrm{y}}} \geq 1.05$

= $0.60 \text{ for } \dfrac{f_{\mathrm{u}}}{f_{\mathrm{y}}} < 1.05$

$V_{\mathrm{f}}$ = nominal shear capacity of the connected part along two parallel lines in the direction of the applied force

= $t e f_{\mathrm{u}}$ . . . 5.3.2(2)

$t$ = thickness of the connected part

$e$ = distance measured in the line of force from the centre of a standard hole to the nearest edge of an adjacent hole or to the end of the connected part

### 5.3.3 Net section tension

The design tensile force $\left(N_{\mathrm{f}}^{*}\right)$ on the net section of the connected part shall satisfy Clause 3.2 and—

$$N_{\mathrm{f}}^{*} \leq \phi N_{\mathrm{f}} \qquad \text{. . . 5.3.3(1)}$$

where

$\phi$ = capacity reduction factor of bolted connection subject to net section tension (see Table 1.6.3)

$N_{\mathrm{f}}$ = nominal tensile capacity of the net section of the connected part

The design tensile capacity ($\phi N_{\mathrm{f}}$) of the connected part shall be determined as follows:

$$N_{\mathrm{f}} = \left[0.9 + \left(\frac{0.1 d_{\mathrm{f}}}{s_{\mathrm{f}}}\right)\right] A_{\mathrm{n}} f_{\mathrm{u}} \qquad \text{. . . 5.3.3(2)}$$

where

$d_{\mathrm{f}}$ = nominal bolt diameter

$s_{\mathrm{f}}$ = spacing of bolts perpendicular to the line of the force; *or*

width of sheet, in the case of a single bolt

$A_{\mathrm{n}}$ = net area of the connected part

### 5.3.4 Bearing

#### 5.3.4.1 *General*

The design bearing capacity ($\phi V_{\mathrm{b}}$) of bolted connections shall be determined in accordance with Clauses 5.3.4.2 and 5.3.4.3. For conditions not specified in this Standard, $\phi V_{\mathrm{b}}$ of bolted connections shall be determined by tests.

**5.3.4.2** *Bearing capacity without considering bolt hole deformation*

When deformation around the bolt holes is not a design consideration, the nominal bearing capacity ($V_b$) of the connected sheet for each loaded bolt shall be determined as follows:

$$V_b = \alpha C d_f t f_u \qquad \ldots 5.3.4.2$$

where

$\phi$ = 0.60

$\alpha$ = modification factor for type of bearing connection given in Table 5.3.4.2(A)

$C$ = bearing factor given in Table 5.3.4.2(B)

$d_f$ = nominal bolt diameter

$t$ = base metal thickness

$f_u$ = tensile strength of sheet

**TABLE 5.3.4.2(A)**

**MODIFICATION FACTOR ($\alpha$) FOR TYPE OF BEARING CONNECTION**

| Type of bearing | $\alpha$ |
|---|---|
| Single shear and outside sheets of double shear connection with washers under both bolt head and nut | 1.00 |
| Single shear and outside sheets of double shear connection without washers under both head and nut, or with only one washer | 0.75 |
| Single shear and outside sheets of double shear connection using oversized or short-slotted holes parallel to the applied load without washers under both bolt head and nut, or with only one washer | 0.70 |
| Single shear and outside sheets of double shear connection using short-slotted holes perpendicular to the applied load without washers under both bolt head and nut, or with only one washer | 0.55 |
| Inside sheet of double shear connection with or without washers | 1.33 |
| Inside sheet of double shear connection using oversized or short slotted holes parallel to the applied load with or without washers | 1.10 |
| Inside sheet of double shear connection using short slotted holes perpendicular to the applied load with or without washers | 0.90 |

**TABLE 5.3.4.2(B)**

**BEARING FACTOR ($C$)**

| Thickness of connected part ($t$) mm | Ratio of fastener diameter to member thickness ($d/t$) | $C$ |
|---|---|---|
| $0.42 \leq t < 4.76$ | $d_f/t < 10$ | 3.0 |
| | $10 \leq d_f/t \leq 22$ | $4 - 0.1(d_f/t)$ |
| | $d_f/t > 22$ | 1.8 |

**5.3.4.3** *Bearing capacity at a bolt hole deformation of 6 mm*

When deformation around a bolt hole is a design consideration, the nominal bearing capacity ($V_b$) shall be determined as follows:

$$V_b = (0.183\, t + 1.53) d_f t f_u \qquad \ldots 5.3.4.3$$