As a result of the different welding procedures required for sheet steel, the specification of the American Welding Society for Welding Sheet Steel in Structures (Ref. 9.4) should be closely followed and has been referenced in AS/NZS 4600. The fact that a welder may have satisfactorily passed a test for structural steel welding does not necessarily mean that he can produce sound welds on sheet steel.

9.2 Fusion Welds

9.2.1 Butt Welds

In AS/NZS 4600, both the nominal tensile and compressive capacity, and the nominal shear capacity are specified for a butt weld. The nominal tensile or compressive capacity (N_w) is based on the yield strength used in design for the lower strength base steel and is given by

$$N_w = l_w t_t f_y \quad (9.1)$$

where l_w is the length of the full size of the weld, and t_t is the design throat thickness of the weld. A capacity reduction factor of 0.90 is specified and is the same as for a member.

The nominal shear capacity (V_w) is the lesser of the shear on the weld metal given by Eq. (9.2) and the shear on the base metal given by Eq. (9.3).

$$V_w = l_w t_t (0.6 f_{uw}) \quad (9.2)$$

$$V_w = l_w t_t \left[\frac{f_y}{\sqrt{3}} \right] \quad (9.3)$$

where f_{uw} is the nominal tensile strength of the weld metal. A capacity reduction factor of 0.8 is used with Eq. (9.2), and a capacity reduction factor of 0.9 is used with Eq. (9.3) since it applies to the base metal. Eq. (9.2) applies to the weld metal and therefore has a lower capacity reduction factor than Eq. (9.3).

9.2.2 Fillet Welds subject to Transverse Loading

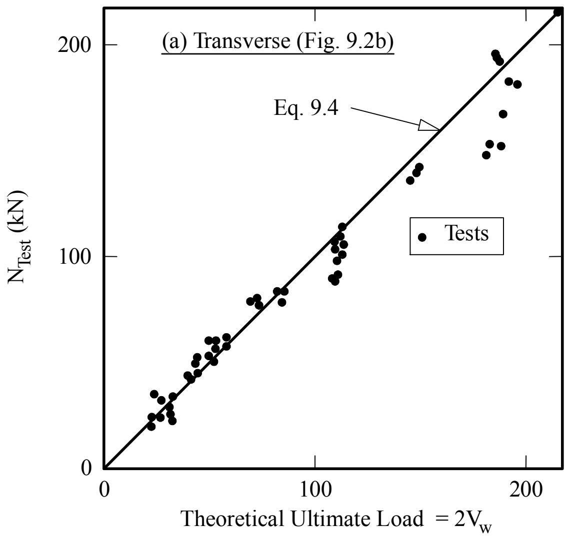
The Cornell test data for fillet welds, deposited from covered electrodes, was produced for the type of double lap joints shown in Fig. 9.2(b). These joints failed by tearing of the connected sheets along or close to the contour of the welds, or by secondary weld shear. Based on these tests, Eq. (9.4) was proposed to predict the connection strength.

$$V_w = t l_w f_u \quad (9.4)$$

where t is the sheet thickness, l_w is the length of weld perpendicular to the loading direction and f_u is the tensile strength of the sheet. The results of these tests are shown in Fig. 9.3(a) for all failure modes where they are compared with the prediction of Eq. (9.4). The values on the abscissa of Fig. 9.3(a) are $2V_w$ since the joints tested were double lap joints. A capacity reduction factor (ø) of 0.60 is specified for fillet welds subject to transverse loading. In Clause 5.2.3.3 of AS/NZS 4600, the lesser of $t_1 l_w f_{u1}$ and $t_2 l_w f_{u2}$ is used to check both sheets connected by a fillet weld where t_1, f_{u1} are for Sheet 1 and t_2, f_{u2} are for Sheet 2.

A series of tests was performed more recently at Institute TNO (Ref. 9.2) to determine the effect of single lap joints and the welding process on the strength of fillet weld connections. The joints tested are shown in Fig. 9.2(a) and were fabricated by the TIG process for uncoated sheet, and covered electrodes for galvanised sheet. The failure modes observed were inclination failure, as shown in Fig. 9.2(a), combined with weld shear, weld tearing and plate tearing. The mean test strengths (N_m) were found to be a function of the ratio of the weld length to sheet width in addition to the parameters in Eq. (9.2), and are given by:

$$N_m = t l_w f_u \left(1 - 0.3 \frac{l_w}{b} \right) \quad (9.5)$$



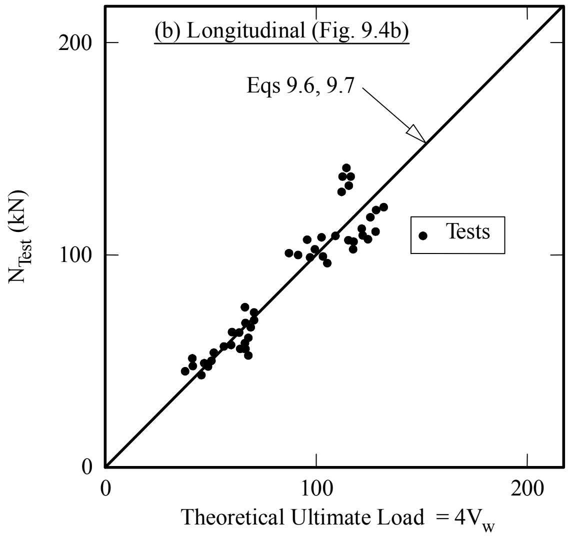


Fig. 9.3 Fillet weld tests (Cornell)

Hence for the single lap joint, the ratio l_w / b appears to be important.

The results for galvanised sheet were found to not be significantly lower than those for uncoated sheet except that the deviation was found to be higher as a result of the difficulty encountered in making a sound weld.

9.2.3 Fillet Welds subject to Longitudinal Loading

The Cornell test data for fillet welds, deposited from covered electrodes, was produced for the type of double lap joints shown in Fig. 9.4(b). These joints failed by tensile tearing across the connected sheet or by weld shear or tearing along the sheet parallel to the contour of the weld, as shown in Fig. 9.4(b). Based on these tests, the following equations were found to predict the connection strength.

$$V_w = t\, l_w \left(1 - 0.01\frac{l_w}{t}\right) f_u \qquad \text{for} \quad \frac{l_w}{t} < 25 \qquad (9.6)$$

$$V_w = 0.75\, t\, l_w\, f_u \qquad \text{for} \quad \frac{l_w}{t} \geq 25 \qquad (9.7)$$

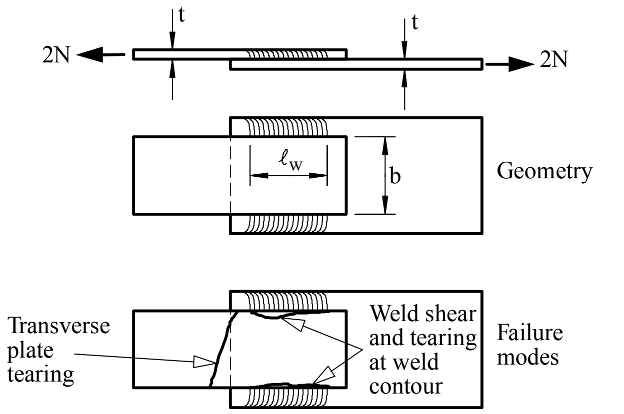
V_w is the strength of a single weld. The results of all tests are shown in Fig. 9.3(b) compared with the predictions of Eqs (9.6) and (9.7) where the least value has been used. The values on the abscissa of Fig. 9.3(b) are $4V_w$ since the joints tested were double lap joints with fillet welds on each side of each sheet.

Capacity reduction factors of 0.60 and 0.55 are specified for Eqs (9.6) and (9.7) respectively. In Clause 5.2.3.2 of AS/NZS 4600, the lesser of $t_1\, l_w\, f_{u1}$ and $t_2\, l_w\, f_{u2}$ is used to check both sheets connected by a fillet weld where t_1, f_{u1} are for Sheet 1 and t_2, f_{u2} are for Sheet 2. A capacity reduction factor of 0.55 was validated for all cases for fillet welds for G450 steel to AS 1397 in Ref. 9.3.

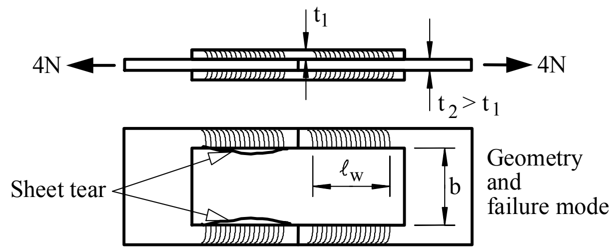
A series of tests was performed more recently at Institute TNO (Ref. 9.2) to determine the effect of single lap joint geometry and welding process on the strength of fillet weld connections subject to longitudinal loading. The type of joints tested are shown in Fig. 9.4(a) and were manufactured by the TIG process for uncoated sheet, and covered electrodes for galvanised sheet. The failure modes observed were tearing at the contour of the weld and weld shear accompanied by out-of-plane distortion and weld peeling for short length welds. For longer welds, plate tearing occurred. The mean test strengths (N_m) were found to be a function of the weld length (l_w) and sheet width (b) as given by:

$$N_m = 2t\, l_w \left(0.95 - 0.45\frac{l_w}{b}\right) f_u \tag{9.8}$$

$$N_m = 0.95\, t\, b\, f_u \tag{9.9}$$



(a) Single lap joint (TNO tests)



(b) Double lap joint (Cornell tests)

Fig. 9.4 Fillet welds subject to longitudinal loading

The lesser of the values of Eq. (9.8) for weld failure and Eq. (9.9) for plate failure should be used. As for the transverse fillet welds, there was no significant difference between the values for the uncoated and galvanised sheet.

9.2.4 Combined Longitudinal and Transverse Fillet Welds

Tests were performed at Institute TNO (Ref. 9.2) to ascertain whether combined longitudinal and transverse fillet welds interacted adversely or beneficially. The test series showed that similar failure modes to those for longitudinal and transverse fillet welds were observed. Also, the deformation capacity of the individual welds allowed full co-operation so that the strengths of the transverse and longitudinal welds can be simply added. In fact, the combined welds were better than the sum of the two but the additional benefits have not been quantified.

9.2.5 Flare Welds

Flare welds are of two common types. These are flare-bevel welds as shown in Fig. 9.1(e) and in cross-section in Fig. 9.5(a), and flare V-welds as shown in cross-section in Fig. 9.5(b).

As for fillet welds, the flare welds may be loaded transversely or longitudinally, and their modes of failure are similar to fillet welds described in Sections 9.2.2 and 9.2.3. The primary mode of failure is sheet tearing along the weld contour.

For transverse flare-bevel welds, the nominal shear capacity in Clause 5.2.6.2 of AS/NZS 4600 is the same as for a fillet weld subject to transverse loading (Eq. (9.4)) except that it is factored by *5/6 = 0.833.*

Design of Cold-Formed Steel Structures
(To Australian/New Zealand Standard AS/NZS 4600:2005)

by

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