CHAPTER 9 CONNECTIONS

9.1 Introduction to Welded Connections

Welded connections between thin-walled cold-formed steel sections have become more common in recent years despite the lack of design guidance for sections of this type. Two publications based on work at Cornell University, U.S.A. (Ref. 9.1) and the Institute TNO for Building Materials and Building Structures in Delft, Netherlands (Ref. 9.2) have produced useful test results from which design formulae have been developed. The design rules in AS/NZS 4600 are based on those in the North American Specification (Ref. 1.14) which were developed from the Cornell tests. However, the more recent TNO tests add additional information to the original Cornell work and so the results and design formulae derived in both Refs 9.1 and 9.2 are covered in this chapter even though the design of welded connections in AS/NZS 4600 is based solely on Ref. 9.1. A recent publication by Teh and Hancock (Ref. 9.3) extends the Cornell research to high strength G450 steel to AS 1397-2001.

Sheet steels are normally welded with conventional equipment and electrodes. However, the design of the connections produced is usually different from that for hot-rolled sections and plate for the following reasons:

(a) Stress resisting areas are more difficult to define.
(b) Welds such as the arc spot and seam welds shown in Figs 9.1(c) and 9.1(d) are made through the welded sheet without any preparation.
(c) Galvanising and paint are not normally removed prior to welding.
(d) Failure modes are complex and difficult to categorise.

![Fusion weld types](image_url)

**Fig. 9.1 Fusion weld types**
The usual types of fusion welds used to connect cold-formed steel members are shown in Fig. 9.1, although butt welds may be difficult to produce in thin sheet and are therefore not as common as fillet, spot and seam welds. Arc spot and slot welds are commonly used to attach cold-formed steel decks and panels to their supporting frames. As for conventional structural welding, it is general practice to require that the weld materials should be matched at least to the strength level of the weaker member. Design rules for the five weld types shown in Figs 9.1(a), (b), (c), (d) and (e) are given as Clauses 5.2.2, 5.2.3, 5.2.4, 5.2.5 and 5.2.6 respectively in AS/NZS 4600.

Failure modes in welded sheet steel are often complicated and involve a combination of basic modes, such as sheet tearing and weld shear, as well as a large amount of out-of-plane distortion of the welded sheet. In general, fillet welds in thin sheet steel are such that the leg length on the sheet edge is equal to the sheet thickness and the other leg is often two to three times longer. The throat thickness ($t_w$) (in Fig 9.2(a)) is commonly larger than the thickness ($t$) of the sheet steel and hence ultimate failure is usually found to occur by tearing of the plate adjacent to the weld or along the weld contour. In most cases, yielding is poorly defined and rupture rather than yielding is a more reliable criterion of failure. Hence for the fillet welds tested at Cornell University and Institute TNO, the design formulae are a function of the tensile strength ($f_u$) of the sheet material and not the yield strength ($f_y$). This latter formulation has the added advantage that the yield strength of the cold-formed steel in the heat affected zone does not play a role in the design and hence does not need to be determined. Values for the tensile strength ($f_u$) are given in Table 2.1 of this book and Table 1.5 of AS/NZS 4600 to assist in the design of connections.

![Fig. 9.2 Transverse fillet welds](image-url)
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

\[
N_w = l_w t_t f_y
\]  

(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).

\[
V_w = l_w t_t (0.6 f_{uw})
\]  

(9.2)

\[
V_w = l_w t_t \left[ \frac{f_y}{\sqrt{3}} \right]
\]  

(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.

\[
V_w = t l_w f_u
\]  

(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 (\( \phi \)) 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:

\[
N_m = t l_w f_u \left( 1 - 0.3 \frac{l_w}{b} \right)
\]  

(9.5)
Design of Cold-Formed Steel Structures
(To Australian/New Zealand Standard
AS/NZS 4600:2005)

by

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