9.2.7 Arc Seam Welds

Arc seam welds commonly find application in the narrow troughs of cold-formed steel decks and panels. The geometry of an arc seam weld is shown in Fig. 9.6(d). The observed behaviour of the arc seam welds tested at Cornell was similar to the arc spot welds although no simple shear failures were observed. The major mode of failure was tensile tearing of the sheets along the forward edge of the weld contour plus shearing of the sheets along the sides of the weld. The full set of test results for the arc welds is shown in Fig. 9.8(b). In general, there was considerably less variability than for the arc spot welds shown in Fig. 9.8(a).

Based on the Cornell tests, the following formula has been developed for arc seam welds.

$$V_n = 2.5\, t\, f_u\, (0.25\, l_w + 0.96\, d_a) \tag{9.23}$$

where d_a is the width of the arc seam weld given by Eqs (9.18) and (9.19) with d_w equal to the visible width of the weld. The test results plotted in Fig. 9.8(b) are compared with the prediction of Eq. (9.23). The values on the abscissa of Fig. 9.8(b) are $2V_w$ since the joints tested were double lap joints. A capacity reduction factor of 0.60 is specified in Clause 5.2.5.2(b) for use with Eq. (9.23).

In addition, AS/NZS 4600 includes a formula to check the shear capacity of the weld.

$$V_n = \left[\frac{\pi d_e^2}{4} + l_w d_e\right] 0.75\, f_{uw} \tag{9.24}$$

where f_{uw} is the nominal tensile strength of the weld metal. A capacity reduction factor of 0.60 is specified in Clause 5.2.5.2(a) for use with Eq. (9.24).

The minimum edge distance (emin) shown in Fig 9.6(d) is the same as specified for arc spot welds and bolted connections.

9.3 Resistance Welds

Resistance welds are a type of arc spot weld and as such may fail in shear. Recommended practices for resistance welds are given in Ref. 9.5. The nominal shear capacity (V_w) of resistance spot welds are specified by Equations 5.2.7(2) and (3) of AS/NZS 4600:2005 which replaces the table in AS/NZS 4600:1996. A capacity reduction factor of 0.65 is specified in Clause 5.2.7(a) of AS/NZS 4600. By comparison, the approach developed at the Institute TNO (Ref. 9.2) uses the same design formulae for resistance welds as for arc spot welds but with a different formula for the effective weld diameter as given by Eq. (9.21) from that for arc spot welds given by Eq. (9.20).

9.4 Introduction to Bolted Connections

Bolted connections between cold-formed steel sections require different design formulae from those of hot-rolled construction as a result of the smaller ratio of sheet thickness to bolt diameter in cold-formed design. The design provisions for bolted connections in AS/NZS 4600 are based mainly on those in the AISI Specification (Ref. 1.14). The basis of the American design rules is set out in Ref. 9.6. However, some changes have been made, particularly for oversized and slotted holes, to satisfy Australian and New Zealand practice.

The Australian Standard allows use of bolts, nuts and washers to the following specifications.

AS/NZS 1110.1:2000	ISO Metric Hexagon Bolts and Screws - Product Grades A & B Part 1: Bolts (Grade 8.8 bolts up to 12 mm are available in this standard)
AS/NZS 1111.1:1996	ISO Metric Hexagon Commercial Bolts and Screws - Product Grade C Part 1: Bolts
AS/NZS 1112:1996	ISO Metric Hexagon Nuts
AS/NZS 1252:1996	High Strength Steel Bolts with Associated Nuts and Washers for Structural Engineering

Bolts manufactured according to AS/NZS 1111 are commonly of strength Grade 4.6. This designation means that their nominal tensile strength is 400 MPa and their nominal yield stress is 60 percent of this value, that is, 240 MPa. The standard size range defined in AS 1111 is from M5 to M64 where the numeral denotes their nominal diameter in millimetres.

Bolts manufactured according to AS/NZS 1252 are commonly of strength Grade 8.8. This designation means that their nominal tensile strength is 800 MPa (though 830 MPa may be used for design) and their nominal 0.2 percent proof stress is 80 percent of this value, nominally 640 MPa. The standard size range defined in AS 1252 is M16, M20, M24, M30 and M36. Grade 8.8 is also available in AS 1110 for smaller sizes.

The design rules in AS/NZS 4600 only apply when the thickness of a connected part is less than 3 mm. For connected parts 3 mm or greater, AS 4100 or NZS 3404 should be used.

A selection of bolted connections, where the bolts are principally in shear, is shown in Fig. 9.9. As shown in this figure, the bolts may be located in line with the line of action of the force (Fig. 9.9(b)) or perpendicular to the line of action of the force (Fig. 9.9(c)) or both simultaneously. The connections may be in double shear with a cover plate on each side as shown in Fig. 9.9(d) or in single shear as shown in Fig. 9.9(e). In addition, each bolt may contain washers under the head and nut, under the nut alone or under neither.

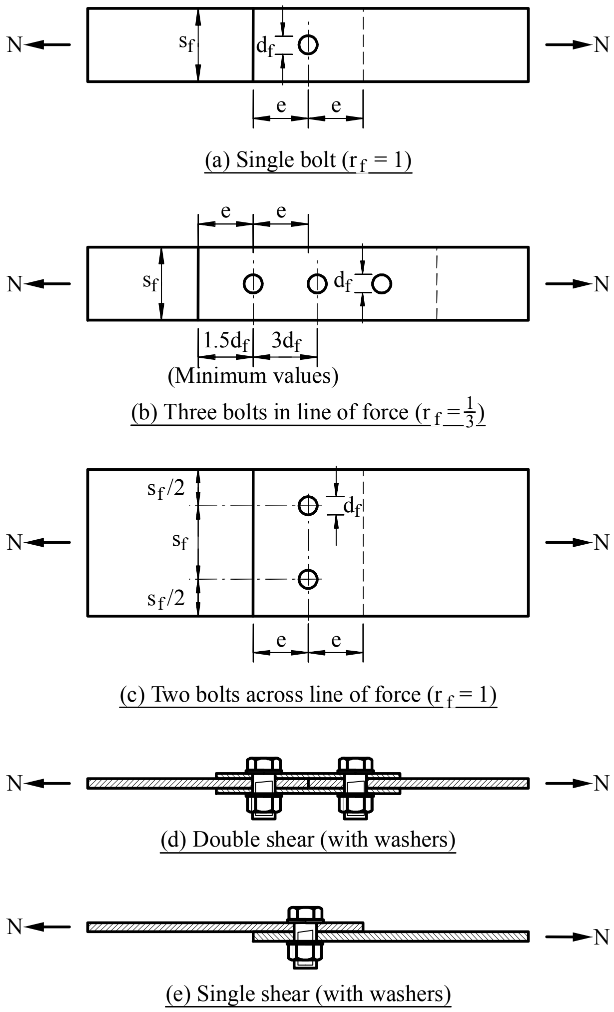
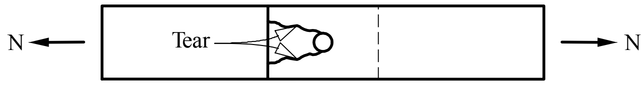


Fig. 9.9 Bolted connection geometry

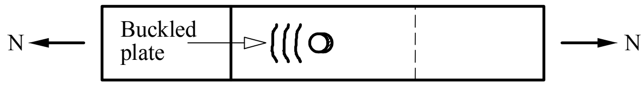
The symbols, e for edge distance or distance to an adjacent bolt hole, s_f for bolt spacing perpendicular to the line of stress, and d_f for bolt diameter are shown for the various bolted connection geometries in Figs 9.9(a), 9.9(b) and 9.9(c). In Table 5.3.1, AS/NZS 4600 defines the diameter of a standard hole (d_h) as 2 mm larger than the bolt diameter (d_f) for bolt diameters 12 mm and larger and 1 mm larger than the bolt diameter for bolts less than 12 mm diameter.

9.5 Design Formulae and Failure Modes for Bolted Connections

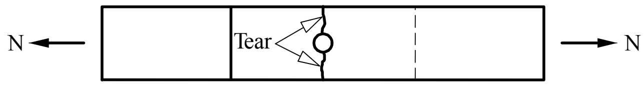
The four principal modes of failure for bolted connections of the types shown in Fig. 9.9 are shown in Fig. 9.10 with photos for G550 sheet steel of the first three types in Fig. 9.11. They have been classified in Ref. 9.6 as Types I, II, III and IV. This classification has been followed in this book.



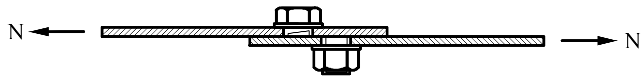
(a) Tearout failure of sheet (Type I)



(b) Bearing failure of sheet material (Type II)

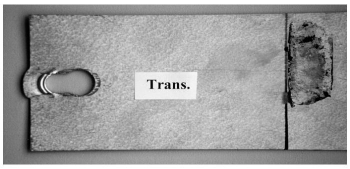


(c) Tension failure of net section (Type III)



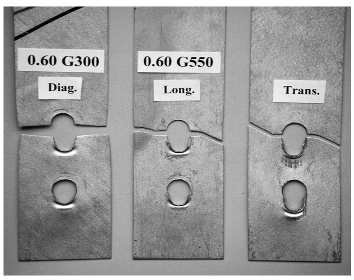
(d) Shear failure of bolt (Type IV)

Fig. 9.10 Failure modes of bolted connections



(a) End Tearout failure

(b) Bearing failure



(c) Net SectionTension failure

Fig. 9.11 Failure modes in G550 steel

Design of Cold-Formed Steel Structures

(To Australian/New Zealand Standard AS/NZS 4600:2005)

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