# AD 399: Design of partial penetration butt welds in accordance with BS EN 1993-1-8

Partial penetration butt welds are covered by Clause 4.7.2, which directs the designer to 'use the method for a deep penetration fillet weld" given in clause 4.5.2(3).

Clause 4.5.2(3) really concerns only the definition of the throat, and leaves the designer unsure of how the design resistance is to be calculated.

Partial penetration welds are considered to be less ductile than full penetration welds and therefore many design Standards require that they are to be treated in the same way as fillet welds. This is the principle behind the advice in clause 4.7.2. Unless rotation is suitably restrained, eccentricity must be taken into account when calculating the stress in the weld. Examples of details where eccentricity is introduced in partial penetration butt welds are shown in Figure 4.9 of BS EN 1993-1-8.

Eccentricity need not be considered if the weld is used as part of a weld group around the perimeter of a structural hollow section (clause 4.12(3)). It is reasonable to assume that there is no eccenticity if the welded element is part of a member which itself cannot rotate at the joint – for example if a partial penetration weld is used to connect the flange of a beam to an end plate.

In the numerical example which follows, it is assumed that rotation cannot take place.

## Throat

The throat of a partial penetration butt weld is the distance from the root to the external face of the weld, as described in clause 4.5.2(1). Examples are shown in figure 1.

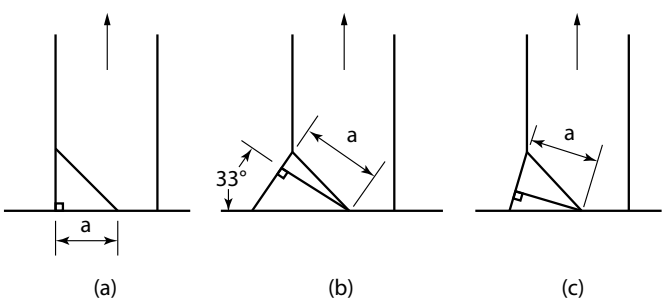


*Figure 1: Throat (a) of partial penetration welds*

Common practice is to either (a) assume the penetration (and hence the design throat) is less than the preparation, or (b) to conduct weld procedure trials to demonstrate what penetration can consistently be achieved. The first approach was encouraged by the 1990 version of BS 5950, where clause 6.6.6.2 specified a reduction of 3 mm for V and bevel welds. Clause 6.9.2 of the 2000 version of BS 5950 specifies no reduction but refers to the depth of penetration, which may be more or less than the preparation.

## Design resistance

It is recommended the the directional method of clause 4.5.3.2(6) is used when calculating the resistance of a partial penetration butt weld. Assuming there is no longitudinal stress, the direct stress must be resolved into a perpendicular stress on the throat, $\sigma\perp$ and a shear stress on the throat, $\tau\perp$. Expression 4.1 of BS EN 1993-1-8 requires that the combination of perpendicular stresses are verified and also limits the perpendicular stress. With no longitudinal stress on the weld throat, the verifications become:

$$(\sigma\perp^2 + 3\tau\perp^2)^{0.5} \leq \frac{f_u}{\beta_W \gamma_{M2}} \quad \text{and} \quad \sigma\perp \leq \frac{0.9 f_u}{\gamma_{M2}}$$

In case (b) of figure 1, assuming the applied force is 2000 N/mm, and the throat is 9 mm, the components of force become:

$\sigma\perp = 2000\ \text{Cos}(33)/9 = 186\ \text{N/mm}^2$ and $\tau\perp = 2000\ \text{Sin}(33)/9 = 121\ \text{N/mm}^2$

The combined check of shear and perpendicular stress, with $\beta_w = 0.9$ for S355 (taken from Table 4.1) becomes:

$(186^2 + 3(121)^2)^{0.5} = 280\ \text{N/mm}^2$. The limit is $\dfrac{470}{0.9 \times 1.25} = 418\ \text{N/mm}^2$

The perpendicular stress $\sigma\perp$ is 186 N/mm²; the limit is $\dfrac{0.9 \times 470}{1.25} = 338\ \text{N/mm}^2$

Of course, if a standard fillet weld is verified by the same process, using an angle to the throat of 45°, it can be demonstrated that the resistances are those quoted in the Blue Book[1] for a transverse weld.

Reference

1 Steel building design: Design data. In accordance with Eurocodes and UK National Annexes (P363). SCI, Reprinted 2015.

Contact: **Abdul Malik**
Tel: **01344636525**
Email: **advisory@steel-sci.com**