STEEL INDUSTRY GUIDANCE NOTES

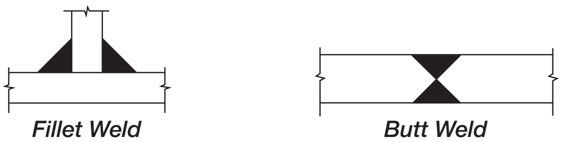
Welding is a key fabrication process, yet little understood outside the workshop.

Welding is a key fabrication process generally completed in the workshop, and often a mystery to design engineers. The confidence in Steelwork Contractors is entirely justified – they fabricate steelwork by welding each and every day, and most welding is entirely orthodox.

This note provides background to the welding process, and gives simple advice on weld design and specification for the designer.

1. The science of welding

Welding involves an electric arc, the parent material and a consumable. Welding does not 'stick' one component to another, as some think, but the parent material is melted to some depth (known as penetration). The molten parent material and the molten metal from the consumable combine in the weld pool to forms the joint. Typical arrangements are fillet welds and butt welds, as shown below.



Key to the process is to prevent unwanted impurities entering the molten weld pool, and this is achieved by welding within a protective gas and/or by providing a protective covering (known as 'slag') which covers the metal as it solidifies on cooling.

The consumable is composed or a metal alloy with additional components either as a coating on the outside of the metal alloy or held in a tubular core within the electrode. A considerable amount of science goes in to their development and some are better suited for welding in certain positions while others have been developed to maximise the rate of welding.

2. Avoiding hydrogen

Hydrogen introduced into the weld pool during the welding process can lead to cold cracking (sometimes this is delayed until after the welding is complete) in the heat affected zone (HAZ) or sometimes in the weld itself.

Hydrogen can be picked up from any contamination, from the parent metal, from the consumable and from the atmosphere. It is therefore important to minimise the introduction of Hydrogen in the weld pool. Furthermore, the risk of cold cracking is increased if the weld cools quickly.

For these reasons, Steelwork Contractors prepare Welding Procedure Specifications (WPS), which describe how the weld is to be made (e.g. the WPS describes the equipment settings, type of consumable, cooling rates etc). A WPS is based on a trial weld, which has been thoroughly tested, and has a Welding Procedure Approval Record (WPAR). The logic is that as long as the production weld closely follows (within specified limits) the WPAR, the production weld will be satisfactory.

Joints in thick material, parent metal with a high carbon equivalent (CE) and increased hydrogen pick-up are circumstances that merit the development of an appropriate WPS

3. The skill of welding

A steady hand is needed but so are many other skills. Welders are qualified for different types of welding, and in different positions. For example welding overhead is more difficult, since the molten weld pool naturally drops under gravity.

4. Inspection and testing

Where to test, when to test and how much to test? For orthodox structures, the testing regime laid out in the National Structural Steelwork Specification (NSSS) is recommended. Developed by agreement with clients, designers, Steelwork Contractors and welding experts, the NSSS represents best practice. The NSSS gives full details of the testing to be undertaken.

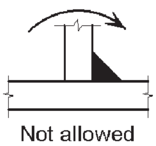
5. Imperfection or defect?

Even with the use of qualified welders and the use of an appropriate WPS, imperfections will occur. The important point is that imperfections are not necessarily defects that need repair. Again, use of the NSSS is recommended, as it sets out criteria against which imperfections can be assessed, and indicates what corrective action should be taken. Cracks, for example are never permitted and some geometrical imperfections may not need repair.

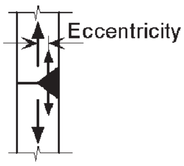
6. Weld design

Weld design is covered in Sections 6.7, 6.8 and 6.9 of BS 5950-1:2000. The key points to note in design are:

- UK practice is to specify fillet welds in terms of their leg length, (standard sizes are 6, 8, 10, 12, 15mm). However, their design is based on the throat thickness
- Single fillet welds should not be subject to a bending moment about their longitudinal axis that would open the root of the weld.



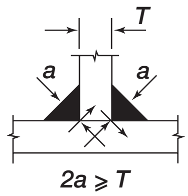
- For fillet welds that do not go round a corner, the effective length for design should be taken as the actual length, less a distance equal to twice the leg length.
- Advantage may be taken of the fact that welds subject to transverse loads have an increased resistance compared to welds subject to longitudinal loads. The increase in resistance is up to 25%.
- Single sided partial penetration butt welds (see the figure below) should not be used to resist tension or compression in the parts joined unless suitably restrained. Furthermore, the eccentricity of the load should be allowed for.



- The resistance of a butt weld should be calculated based on the strength of the parent metal

7. Full strength welds

If a full strength weld is required, butt welds are not always necessary. In S275 steel, a full strength 'T' connection (see the figure below) can be made with two symmetric fillet welds, where the sum of the throat thicknesses is at least equal to the thickness of the connected part. This rule does not apply to S355 material.



8. Good practice

Good practice is to only specify the weld size actually needed, not to increase the specified size to 'have some extra capacity'. Fillet welds are preferred to butt welds, which are more expensive, take more time and demand more expertise.

If a 6mm fillet weld is given a unit cost of 1, the following table gives a basic idea of how welding costs increase:

6mm fillet weld	1
10mm fillet weld	3
Butt weld in 15mm plate	4
Butt weld in 20mm plate	12
Butt weld in 40mm plate	20

(These figures do not include costs of preparing the plate or testing, both of which will be increased for butt welds)

Key Points

1. Specify fillet welds rather than butt weld, and only specify the size demanded by design
2. Use the NSSS, which provides a testing regime and acceptance criteria
3. Think about reasonable access for welding
4. Note that thicker joints, higher hydrogen scales (in the consumable electrode) and higher carbon equivalents in the parent material may mean that special attention is required for the welding
5. Expect the Steelwork contractor to have appropriate WPS and appropriately qualified welders for the work being undertaken. These should cover the joint type, welding process, welding position and material thickness
6. Site welding should be to the same quality as shop welding
7. If full strength joints are essential, consider fillet welds rather than butt welds

Further sources of Information

1. **National Structural Steelwork Specification for Building Construction, BCSA & SCI, Publication No. 203/02, 4th Edition. 2003.**
2. **Commentary on the National Structural Steelwork Specification for Building Construction, BCSA & SCI, Publication No. 209/03, 4th Edition 2003**
3. **Guide to Site Welding. SCI, 2002**
4. **Steel Bridges, BCSA, Publication No. 34/02, 2002**
5. **Steel Building, BCSA, Publication No. 35/03, 2003**
6. **Welding for Designers. New Steel Construction. Sept/Oct 2002**