# Straightening and flattening

## Scope

This Guidance Note gives advice on the practices and problems that can arise in straightening or flattening the kind of steel used in bridgeworks. It covers both the preparation stages, when making components which are then assembled into structural elements, and attempting to rectify distortions in the finished elements arising from welding or damage due to careless handling.

In some designs, steel is cold-formed to produce a desired shape without the use of welding. This process is covered by GN 5.04.

## Hammering

*Hammering is not permitted*. This bold statement is included because experience has shown that the end result is, almost invariably, unacceptable. Plate edges can become damaged and made irregular and the hammer impact marks are highly visible and difficult to disguise.

There is also a risk of changing the mechanical properties of the steel, caused by the very local surface distortions at the point of impact. This can lead to surface hardening which is very difficult to detect and quantify, and can be detrimental to the structural integrity of the bridge, particularly in fatigue-prone areas.

## Flame straightening

Distortion can occur during the welding process, particularly with large fillet or butt welds. The fabricator will put in place procedures, such as preheat, balanced welding and additional camber, to limit distortion. However, in certain situations, distortion will be unavoidable. Heating the plate in localized areas is an effective and commonly used method of rectifying distortions that occur throughout the fabrication processes. Figures 1 to 3 give some typical applications of flame straightening.

The use of additional, controlled heating during the production of fabricated steelwork is part of the specialist expertise of the fabricator. Some useful and practical papers have been written on the subject, but most of the authors recognize that they are at best a guide to some basic physical effects, and that there is usually a need for some trial-and-error before the optimum result can be achieved. Some references are included at the end of this Guidance Note which may help to understand the theories behind some of the flame straightening techniques that are used. Where flame straightening is required, it should be carried out by a competent fabricator in accordance with clause 6.5.3 of BS EN 1090-2.

To avoid permanently changing the properties of the steel, it is therefore necessary to control of the nature of the heating process, level of temperature and time of heating up, time at high temperature and rate of cooling.

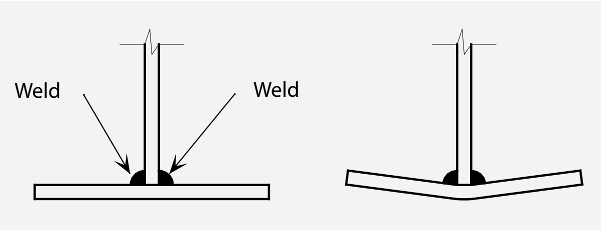


Figure 1 Flange peaking due to welding

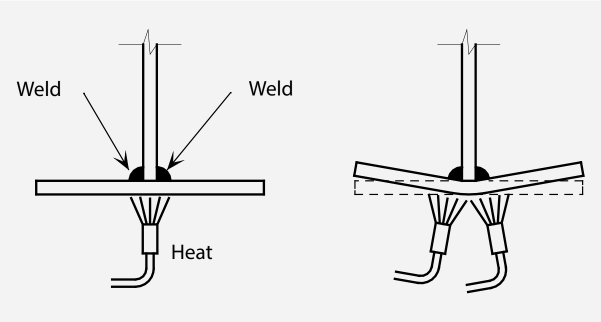


Figure 2 Heating to avoid or remove peaking

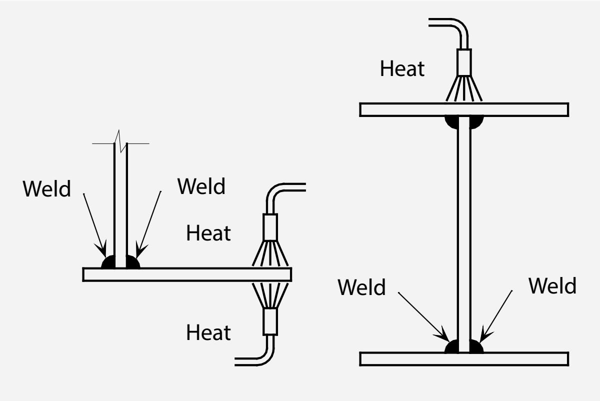


Figure 3 Compensation heating to avoid residual curvature

### Heating processes

Unless there is some particular reason for doing otherwise, the heating should be carried out by an oxygen/propane blowtorch fitted with the appropriate nozzle for the application. Nozzles are available in a range of sizes, for use on material from thin sheet steel to thicknesses of 100 mm and more.

Burning torches, using acetylene fuel, burn at a temperature which can cut steel and hence cause damage to the material. They should not be used for this work, even if they have a 'preheating mode', because there is the risk of misuse and causing serious damage. Other means of heating, such as radiant or contact ceramic electrical heaters are not usually used because they are expensive to run and slow to heat up to the required temperature.

### Heating temperature

This is one of the most critical items to be controlled. Before the introduction of BS EN 1090-2 the usual method simply limited the temperature to 650°C and prohibited accelerated cooling, but BS EN 1090-2 requires that a procedure is developed with evidence of mechanical tests and more control over the process.

With the wide range of structural steels now available, many for special applications which are themselves manufactured by strictly controlled regimes of thermal and mechanical rolling, it is not possible to give simple rules of what is acceptable. What matters is the whole life heat history of the material. Even the 650°C limit will have an effect if it is sustained for many hours: this is the basis of stress-relieving. Conversely, going quickly to some temperature between 650°C and 850°C and then letting it cool in still air will be unlikely to affect the properties of most commonly used bridge steels. Holding at these higher temperatures for extended periods (half an hour or more) will begin to affect the strength and/or toughness of most steels, and going over 900-950°C is likely to affect most steels in some way. Those steels which are produced by the thermomechanical routes are more likely to be affected and the advice of the manufacturer should always be sought if in doubt.

As the steel is heated, it needs to be monitored and controlled. Most digital surface temperature measuring instruments cover a range up to 750°C. If required, there are instruments available that will measure over 1000°C.

However, a fabricator, highly skilled in heat straightening, will be able to the control the temperature of the steel by the changing colour, particularly with the use of temperature-colour charts. As the steel approaches 650°C, it starts to change colour. When it starts to glow, it is probably at about the normal maximum (i.e. 650°C). Extra care must be taken outside when different light conditions can obscure the appearance of the steel as it is heated. In these situations, it may not appear as it is shown on the temperature-colour charts if used for reference.

### Accelerated cooling

Water and air jets are commonly used in shipyards to assist rapid cooling, but they can have a highly detrimental effect on the material properties, particularly on the surface. Any accelerated cooling techniques must be verified by a procedural trials before being used on bridge steelwork.

## Mechanical forming and restraint

The other way of straightening or rectifying unwanted twists, bows or other distortions, is by the application of sufficient external force to restrain the element or to distort it permanently to the desired shape.

### Restraint

The best way of avoiding the problem of distortions is to carry out the assembly and welding of elements in jigs or fitments which are themselves sufficiently stiff and rigid to restrain the fabrication throughout the whole process and to hold it in shape until it has cooled to ambient temperature. However, this is neither practical in all circumstances nor entirely effective for all the parts of a complex element. In addition, the resulting fabrication may still contain locked-in (residual) stresses which, if subjected to further heating or even vibration, for example, during transportation, can result in some change of shape. Although the fabricator can put controls in place to minimize these effects, they cannot be completely avoided or predicted.

### Mechanical straightening

Straightening can be carried out locally with relatively small hydraulic jacks, or in large presses, bending machines or rollers for whole sections or large elements.

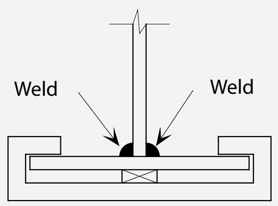


Figure 4 Mechanical restraint

As with heat straightening, mechanical straightening relies on the expertise and experience of the fabricator. In some cases the fabricator will use a combination of heating and external force, both controlled, to achieve the required result.

This acceptable use of mechanical straightening or forming applies to situations where there are relatively small strains involved which have little or no effect on the mechanical properties of the material itself.

There are differences between mechanical straightening and cold forming where the material is subjected to significant strain, such as when forming a flange on a bent-plate stiffener. For further advice on cold forming, reference should be made to GN 5.04. Whereas cold forming can alter the local material properties, this is less likely with mechanical straightening where the bend radii and strains are less severe. However, with mechanical straightening, care should be taken to avoid damage to weldments. This is most likely to occur when outstands, flanges and stiffeners, are forced back into shape. It is important, therefore, to carried out visual and NDT testing of the welds after the straightening has been completed.

Where the correction required is significant, the work can also affect the adjacent platework, causing bows in stiffeners and buckles in webs. Hence these dimensional checks must be repeated after all straightening is complete.

### Presetting

In some applications, the element, or part of it, is pre-set by mechanical forming such that the subsequent application of heat from the welding process, brings the plate back to the desired shape without any further work. A common use of this technique is the pre-setting of flanges of plated girders (see Figure 5).

However, this requires large pieces of equipment so most fabricators opt to place greater control on the welding process and straighten the flanges, post fabrication if required.

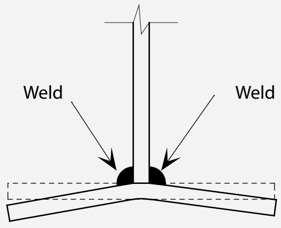


Figure 5 Mechanical presetting

## References and further reading

[1] BS EN 1090-2:2018+A1:2024 Execution of steel structures and aluminium structures. Part 2, Technical requirements for steel structures.

A number of published papers and specific chapters of books deal with the problem of distortions arising from welding. The following is a selection:

1. Practical design against weld distortion in fabricated beams, Irwin & May, Proceedings of the Institution of Civil Engineers, Vol 87, Issue 3, Part 2, Sept 1989, pp317-341.
2. Heat Treatment of Welded Steel Structures, Croft DN, Woodhead Publishing, 1996.