

### Scope

This Guidance Note gives advice on the practices and problems that can arise in straightening or flattening the kind of steel used in bridgework. 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 bald statement is included because experience has shown that the end result is almost invariably unacceptable: visually: edges are damaged and made irregular and the hammer impact marks are highly visible and very hard to disguise.

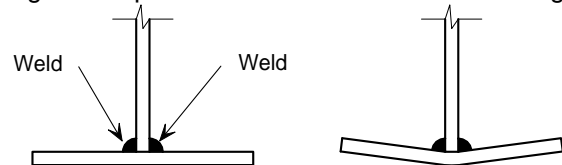
There is a possible mechanical effect as well, caused by the very local surface distortions at the impact locations which leads to some surface hardening. This effect is very difficult to detect and quantify, but it is never beneficial in the case of bridgework and can be positively detrimental in fatigue-prone areas.

### Flame straightening

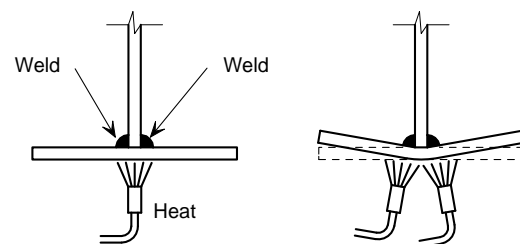
This is a commonly used way of preventing or rectifying the unavoidable distortions that occur throughout the fabrication processes. Used in a controlled way it is very effective. See Figures 1 to 3 for typical applications.

The use of additional, controlled heating during the production of fabricated steelwork is part of the specialist expertise of the fabricator. Some quite useful and practical papers have been written from time to time 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 the note which may help understanding of the mechanisms involved. As far as the designer is concerned, the advice is to leave it to the fabricator to develop his own procedures and not be too concerned about the exact details, provided the requirements of clause 6.5.3 of EN 1090-2 are observed.

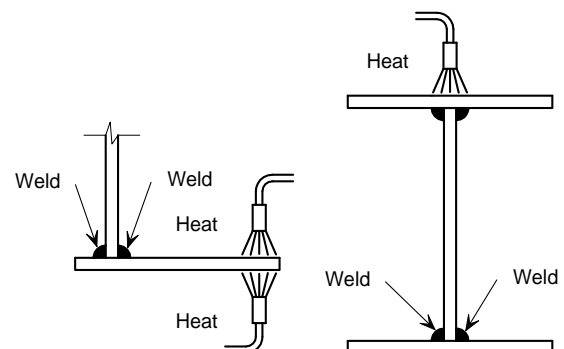
It is therefore necessary to exercise control of the nature of the heating process, level of temperature and time of heating up, time at high temperature and rate of cooling.



**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, which use an acetylene fuel, burn at a temperature which can cut steel and hence will damage the surface of the element. They should not be used for this work, even if they have a 'preheating mode', because there is the risk of opening the wrong valve and causing serious damage. Other means of heating, such as radiant or contact ceramic electrical heaters are not usually used because of the expense in setting up the

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equipment, the running costs and the relatively slow heating up rate.

### *Heating temperature*

This is one of the most critical items to be controlled. Before the introduction of EN 1090-2 the usual method simply limited the temperature to 650°C and prohibited accelerated cooling, but 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 and what is not 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.

It is surprisingly difficult to control the temperature accurately. If over-heating is suspected, it is desirable to be able to check it! Most of the temperature measuring devices in fabrication shops are for measuring pre-heating temperatures, i.e. up to a maximum of 200°C. Digital surface temperature measuring instruments are available which cover a range up to 750°C and others can be obtained which read over 1000°C. The other practical way of controlling the temperature is by colour, or, to be more precise, by the lack of colour! It so happens that steel begins to glow as the temperature rises but unfortunately the first perceptible indication is at about the normal maximum (i.e. 650°C). Hence, if there is a visible reddening, the temperature is almost certainly at or over 650°C. The problem is compounded out of doors when the perception is somewhat

masked by the incident light. If a temperature-colour chart is used for reference, it must be used within the stipulated constraint of *very subdued light*.

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 must be verified by a procedure trial before being used on bridge steelwork.

### **Mechanical forming and restraint**

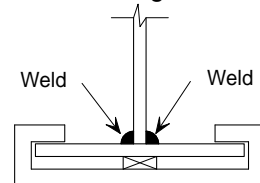
The other way of straightening or rectifying unwanted twists, bows or other distortions, is by the application of sufficient external force to restrain the element or to distort it permanently to the desired shape.

#### *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 will still contain locked-in (*residual*) stresses which, if it is subject to further heating or even shaking (*for example, while being transported significant distances*) can result in some change of shape. The fabricator cannot avoid this; he can do something about it, but he will not achieve perfection.

#### *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.



Strongbacks at close centres

**Figure 4 1** *Mechanical restraint*

As with heat straightening, there are no absolute rules about what is permitted or not

permitted and this is another part of the fabricator's expertise. Indeed, it is quite common to 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

For advice where the material is subject to significant strain, such as when forming a flange on a bent-plate stiffener, reference should be made to GN 5.04. As a guide to what is significant and what is not, reference can also be made to the literature of those firms who provide a service of rolling sections to curved shapes. It will be seen that the sort of mechanical straightening envisaged by this clause is most unlikely to have an effect on the material properties.

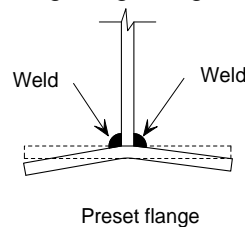
What is more important is to be aware of the potential for damage to or even fracture of weldments in the straightening process. This is most likely when outstands, flanges and stiffeners, are forced back into shape; indeed the welded attachment is more likely to break than the stiffener to bend. For this reason the last stage of any straightening procedure must be a complete visual re-check of *all* the local and adjacent welds. Where the distortions had been severe, (say two to three times the allowable tolerance or more) it would be prudent to require NDT for surface-breaking defects on *all* adjacent welds and sub-surface checks, if possible, in the region of greatest strain.

Where the correction required is significant, the work can also affect the adjacent plate-work, 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 so that the subsequent application of heat from the welding process, working in the opposite sense on cooling, produces the desired shape without any further work. A common use of such is the pre-setting of flanges of plated girders (see

Figure 5). However most fabricators do not have equipment suitable for doing this over long flange lengths.



**Figure 5** *Mechanical presetting*

#### **References and further reading**

1. EN 1090-2:2008+A1:2011 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:

2. Practical design against weld distortion in fabricated beams, Irwin & May, Proceedings Instn Civ Engrs, Part 2, 1989, Vol 87, Sep, 317-341.
3. Basic Welding Data, No. 17: Welding Problems. Welding and Metal Fabrication, Aug/Sep 1990.
4. Heat treatment of Welded Steel Structures, Croft DN, Abington Publ, 1996, Chapter 1.