STEEL INDUSTRY GUIDANCE NOTES

Curving Steelwork

This SIGNS introduces the processes used to curve steelwork, describes the effects of the process and highlights the design issues that need to be considered. This guidance note does not cover cambering because the effects of the curvature are small, and can be ignored. In most cases, curving of structural members is to a relatively modest radius with small effects. The effects of curving steel are significant at smaller radii, but these sorts of curves are more often used in architectural steelwork rather than primary loadbearing members. In all aspects of curving steelwork, the general advice is to contact the specialists – contact details are given overleaf.

Curving processes

There are two primary processes – cold bending and induction bending. Cold bending is accomplished by passing the steel member back and forth between sets of rolls as shown in Figure 1. The point load applied by the central roller is sufficient to take the steel past its yield point and introduce a permanent set.

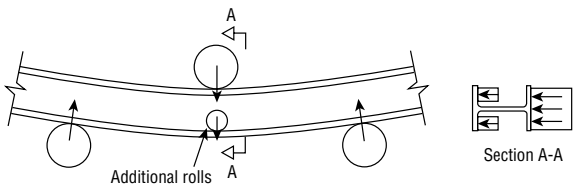

Figure 1 Cold bending

Because the point load is often sufficient to buckle the web, some arrangement of additional rollers is used to support the web, or to apply tension to the web, as shown in Figure 1. The rolls used must suit the section, demanding a different tooling arrangement for each profile. From Figure 1, it is clear that the rolling process cannot extend to the very end of the member – there is always a short straight length. This straight length can often be utilised in the design, or may need to be discarded.

Induction bending is shown diagrammatically in Figure 2. An electric coil, shaped to suit the profile, heats and softens a short section of the member. After the steel has been heated and curved, water or air (or a combination of both) is used to cool the steel. As the member is pushed through the induction coil, the leading end is forced to follow a curve set by a pivot arm.

In general, induction bending is used to curve to small radii relative to the section size.

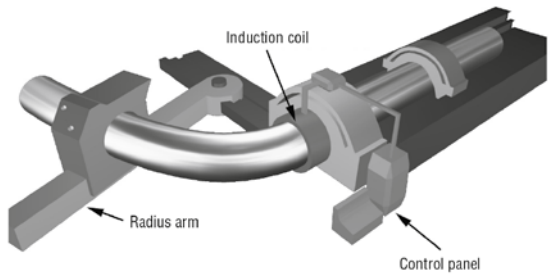

Figure 2 Induction bending

The effects of curving steel

The temperature changes during induction bending can lead to changes in metallurgical properties, but this is dependent on the properties of the straight material. Post-bending heat treatment can usually be undertaken to restore the properties if necessary.

Cold bending obviously takes the material past the first yield point which will strain harden the steel to some degree. Some of the yield plateau will have been used, so in general plastic design is not recommended. The toughness of the steel may also have been changed, particularly at small radii. It is worth emphasising again that at most radii found in structural applications, the changes are modest.

The more important effects of the curving process may be aesthetic, rather than structural. The steel on the "outside" of the curve tends to get stretched (and therefore thinner) whilst the steel on the inside of the curve tends to become thicker. Some distortion of the section geometry is likely. In some cases, for example with thin hollow sections, the bending process can cause visible ripples on the concave face. A section with a thicker wall

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may be more appropriate. Specialist contractors have much experience in this area, and are happy to advise on choice of section.

Many engineers are concerned about the residual stresses left in the steelwork as a result of the curving process. Because the curving induces strains in excess of yield, the residual stresses after the curving process are not additive to the residual stresses in the straight member. The residual stresses can be deduced by subtracting the elastic stress distribution (as the member comes free of the rolls) from the plastic stress distribution (as the member passes through the rolls). The result depends on the ratio of the elastic modulus and plastic modulus. In the major axis, this means that the residual stresses are generally no more than those found in a straight beam – in the minor axis they are larger, but generally are not a design issue as serviceability tends to govern, reducing stress levels.

Design issues – curved steel in elevation

The first modest effect is that as shown in Figure 3, the direct stresses in the member have a radial component. This radial component introduces out-of-plane bending in the flanges, which introduces additional stresses not present in a straight beam.

Using Von Mises expression, a reduced yield stress can be calculated to allow for these additional stresses. The out-of-plane stresses are generally very small.

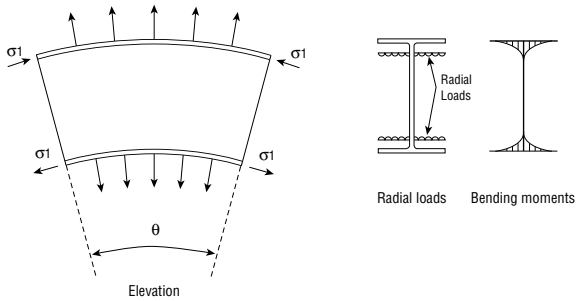

Figure 3 Out-of-plane flange bending

When curved steel is subject to a bending moment, revised calculations are required. If the bending causes compression on the convex face, the member is less stable than a straight member, which must be taken into account. Conversely, although compression on the concave face increases the member stability this beneficial effect is generally ignored.

Design issues – steel curved on plan

Use a hollow section! This is good practical advice, as members curved on plan are often subject to torsion. Open sections will carry torsion, but never as effectively as a hollow section. If an open section is necessary, the direct stresses induced in the member due to the vertical loads cause out-of-plane bending in the flanges and these should be allowed for in design. A simple approach is to consider the flanges acting alone, subject to direct stresses and out-of-plane stresses.

Key Points

- The specialist contractors can be consulted for advice on curving steelwork, including the visual appearance of a curved section.
- For most structural applications, the changes in material properties are modest.
- If bending causes compression on the convex face of a member curved in elevation, the member is less stable than a straight member – the buckling resistance must be reduced
- For members curved on plan, a hollow section is preferred.

Further Sources of Information

Specialist contractors: **The Angle Ring Company Ltd** ***http://www.anglering.com/***
Barnshaws Steel Bending ***http://www.barnshaws.com/***

Design issues: ***Design of Curved Steel,*** **P281, SCI**