Steel Bridge Group

Guidance Note

Bearing stiffeners

No. 2.04

Scope

This Guidance Note gives information about practical detailing for bearing stiffeners for plate girder bridges without longitudinal stiffeners. The support positions of box girders usually require plated diaphragms; diaphragms and their stiffeners are outside the scope of this Note.

General

This Note describes first the general design requirements for stiffeners, then explains the practicalities of certain details and finally shows what the consequences of these practical considerations are on the design details.

Design requirements

Although bearing stiffeners are not explicitly required by EN 1993-1-5, the requirements for resistance to transverse forces at supports makes them inevitable in most cases. Figure 5.1 of EN 1993-1-5 illustrates end supports with rigid and non-rigid end posts as well as no end posts; arrangements at intermediate supports of continuous girders are not illustrated.

Detailing of stiffeners is covered in EN 1993-1-5, 9.3.1 and 9.3.2, which presume double-sided stiffeners; it is not stated that the stiffeners should be symmetric about the web but when the arrangement is not symmetrical, the designer must take into account the effect of the resulting eccentricity.

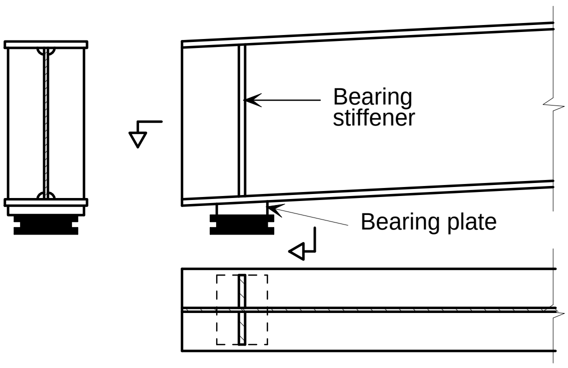

Figure 1 *Arrangement at a support bearing*

The usual support arrangement is for the bridge girder to be placed with the bottom flange seated on top of the bearing (see Figure 1). A tapered bearing plate, sometimes known as either a ‘sole plate’ or a ‘seating plate’, is nearly always required between the upper surface of the bearing and the underside of the flange so that the bearing remains truly horizontal. With this arrangement the load path for the transfer of the bearing reaction to the girder is through the thickness of the bottom flange plate and into the effective section of the stiffener acting with a portion of the web plate on each side of the stiffener. The axial force in the stiffener will be at a maximum immediately above the bearing and is dissipated over the length of the stiffener as load is shed into the web.

The bottom edge of the bearing stiffener should be closely fitted to the bottom flange so that the transfer of load at the ultimate limit state may be assumed to be in direct bearing between the parent metal of the stiffener and the upper surface of the bottom flange. It is not economical to provide a bearing fit between web and flange in a fabricated girder, so the web should not be specified to be fitted locally and should not be included in the bearing area. (The flatness tolerance for plates is such that small ripples up to 3 mm deep can be formed during rolling; considerable extra work would be needed to match the web to the flange where there are such ripples.)

As there is no residual axial force in the stiffener where its top edge meets the underside of the top flange, there is usually no need for the top edge of the stiffener to be closely fitted to the flange.

Edges which are required to be fitted should be clearly indicated on the drawings.

As well as being required to carry the axial force from the bearing reaction, the stiffener must also resist bending moments arising from eccentricity of the axial force (relative to the centroid of the stiffener section), flexure of the end frame, and horizontal loading. It is in order to resist these forces that the stiffener should be adequately connected to the top flange (as well as to the bottom), although this does not mean that it has to be fitted. Attachment to the top flange of a deck-type bridge also provides torsional restraint to the flange plate (see comment in GN 2.05).

Eccentricity of the axial force can arise from a number of causes, including thermal expansion/contraction, bearing misalignment, beam rotation under load, substructure movement and shrinkage/creep of composite decks.

On long continuous decks, the range of movement remote from the fixed bearing can be significant. In such a case, the eccentricity of the bearing reaction to the stiffener centroid can lead to large bending moments in the effective stiffener section. This is usually accommodated either by using multi-leg stiffeners, or by mounting the bearing 'inverted' (if of the sliding type) so that the bearing remains fixed in position relative to the superstructure steelwork. The movement is then relative to the substructure, which can more easily accommodate eccentric loading. However, when the bearing is mounted inverted, the sliding surface will be facing upwards instead of downwards, and it is therefore desirable to specify that the bearings are shrouded to prevent the ingress of harmful debris.

Multi-leg stiffeners may also be necessary on haunched girders where there is a change of direction of the bottom flange either side of the bearing. It is advisable to design the connection between such stiffeners and the flange to resist the tensile force due to the change of direction of the flange plate, ignoring the bearing reaction. This will cater for situations where the load path from the bearing does not spread to the stiffener as a result of extreme thermal movement and during jacking for bearing replacement.

Practicalities of fabrication

For the designer, the main consideration is the type of welds that should be specified at the three edges of the stiffener that are connected to the girder. These connections are:

- stiffener to web
- stiffener to flange adjacent to the bearing
- stiffener to flange remote from the bearing.

The connection to the web will normally be the first edge welded. Fillet welds should be sufficient in most cases. Full penetration butt welds are unlikely to be necessary and are undesirable; the cruciform detail (stiffeners on either side of the web) creates restraint during welding and can result in lamellar tearing.

The connection to the bottom flange is normally the most heavily loaded part of the stiffener. The stiffener can be ‘fitted’ to the flange such that there is very little gap between the end of the stiffener and the flange before welding, and this is a normal feature of the fabrication process. Where the stiffener is fitted, the majority of the load is transmitted in direct bearing, so a full penetration butt weld is unlikely to be necessary for ULS loads.

The requirements in EN 1090-2 for surfaces finished for full contact bearing are given as functional tolerances in Table D.2.7. Two classes of functional tolerance are given and class 1 is usually specified. However, SHW 1800 (Ref 4) adopts the tolerance for fitted web stiffeners that was given in the MPS (Ref 5); clause 1811.1 specifies that the maximum gap shall not exceed 0.25 mm over at least 60% of the fitted area. Although it is not stated clearly in the SHW, it should be presumed that this is an essential tolerance and thus is required to support CE marking.

The fatigue detail categories in EN 1993-1-9 do not include the case of a fitted stiffener transferring compressive forces. It is recommended that the previous practice (according to BS 5400-10) is used - assume that all the fatigue range of force is transferred through the weld throat area. The EN 1993-1-9 detail category for this is 36 (Table 8.5). This recommendation might lead designers to choose a butt weld detail in preference to fillet welds. However, it is advantageous to avoid a full penetration butt weld, because shrinkage strains (vertically) will distort the transverse profile of the flange (see Figure 2) and cause misfit of the bearing. Where the bearing stiffener is thick, it might be helpful to specify a partial penetration weld, as this will reduce the area over which fitting is to be achieved and the amount of weld metal to be deposited.

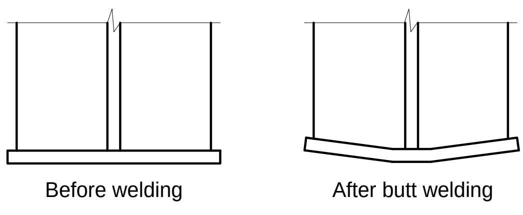

Figure 2 *Distortion due to butt welding (exaggerated)*

To provide proper fitting at the stiffener to top flange connection as well as at the bottom flange is difficult, because it requires a tight fit between two nominally parallel faces. A fillet weld connection to the top flange will normally be adequate structurally. Where gaps occur at the top flange as a result of fitting to the bottom flange, the size of the fillet welds may need to be increased (see Figure 3).

If bearing stiffeners are skew to the web, it may be more difficult to fit them to the bottom flange, because (as noted above) plates may have a small ripple due to rolling; this ripple is too small to have any structural significance but may cause problems in achieving the close fit if the flange is wide and the skew is large.

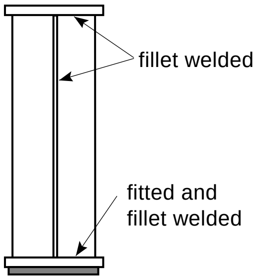

Figure 3 *Connection of a bearing stiffener*

Cope holes may be used to clear root fillets or web/flange welds, as for intermediate stiffeners (see GN 2.05), although this may detract significantly from the bearing area at the bottom flange and is best avoided there.

Skew stiffeners also complicate the welding detail at the connection to the web. If the skew is any more than 30° the fillet in the acute angle (which is then less than 60°) will not achieve full root penetration. EN 1993-1-8 gives a method for calculating the throat thickness in this situation. (The necessary reduction in the throat at acute and obtuse angles must not be overlooked by designers*).* Specifying the weld throat, rather than the leg length, is a better way of ensuring that sufficient weld is provided.

When the bearing reaction is very eccentric from the web (for example above a knuckle bearing which is providing torsional restraint to the main girder), Tee stiffeners may be specified, but this does add considerably to the task of welding and to the difficulty of the application of protective treatment. Designers will also need to ensure that the shape of Tee stiffeners achieve compliance with the limits of BS EN 1993-1-5, clause 9.2(8). In many cases a closed-box section stiffener may well be a better alternative.

Where there are multiple stiffeners, it is inevitable that some pieces will have to be welded once other pieces have been attached. To ensure adequate welding, there must be access for the operative to lay the weld, access for visual inspection and NDT, and, in the case of unacceptable defects, access to remove the defects and to repair. *As an approximate guide*, the clear line of sight to the root of a fillet weld should make an angle to the face of the web of preferably no more than 30°, and in all cases no more than 35°. See Figure 4. This would allow access for a gloved hand holding an electrode and a line of sight for a welder wearing a mask. For a partial penetration weld the line of sight should be no more than 20° to the web (but better still, avoid partial penetration welds in these circumstances).

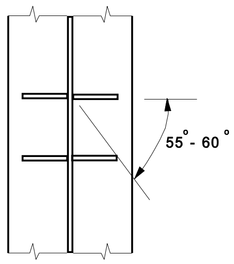

Figure 4 *Double leg bearing stiffener*

Where stiffeners of the closed-box type are specified, they may either be pre-assembled before fitting to the web, or they may be built up piece by piece. In either case, it is not possible to lay welds at every corner on each face, because closed spaces are created. The detail chosen by the designer will effectively determine the sequence in which the box must be built up; the constraints inherent in the implied sequence should be considered carefully at the design stage. A typical simple configuration is shown in Figure 5; in this example, the two outstands are welded first and then the closing plate is fillet welded to the tips of the outstands.

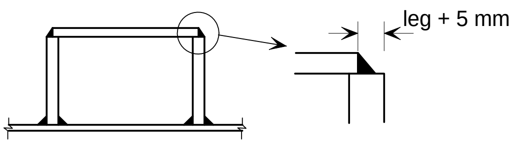

Figure 5 *Attachment of typical box-section stiffener*

Support at bearings

Careful consideration has to be given to the load path between the girder and the bearing itself. There are normally two interfaces to be considered:

a) bottom flange to bearing plate, and
b) bearing plate to bearing.

The top plates of proprietary bearings are usually machined to a flatness better than the tolerance given in EN 1090-2 for bearing surfaces. The design of the bearing normally assumes that load is applied to the top evenly or (for bearings resisting rotation) in a linearly varying fashion, i.e. there are no stress concentrations. High strength epoxies between the underside of the girder and the top of the bearing are also used to achieve a uniform load distribution. The bottom of the bearing plate should therefore also be machined to tolerance class 1 in Table D.2.7 of EN 1090.

The other interface, between bottom flange and bearing plate, needs careful consideration. The top of the bearing plate is often machined, because it is tapered to suit an inclined soffit and horizontal bearing top surface. However, if the bottom flange were machined before fabrication, that would not guarantee a surface within either the functional or essential tolerance limits, because of subsequent distortions due to welding. On the other hand, machining the bottom flange of a completed girder is impractical. In any case, machining the flange removes flange thickness in a highly stressed region and this is likely to incur the penalty of a thicker flange to allow for the loss.

If a good fit is not achieved between the bearing plate and the bottom flange, the load will be transferred unevenly. It may be possible to show that, no matter where the load is transferred at this interface, the spread of load‡ through the plates on either side of the interface is sufficient to ensure that the bearing and the web or stiffener forming part of the effective bearing stiffener are not overstressed. However, in most situations this will not be the case, so this interface will often need to achieve a tolerance equivalent to a machined surface; this can be achieved by grinding the bearing plate or bottom flange of the girder, to ensure even bearing. This tolerance only has to be achieved over that part of the interface defined by a cruciform area equal to the width of stiffeners or web plus 45° spread through bottom flange.

Through-thickness performance

Where large transverse loads are carried through the web (usually as a result of diaphragm action, crosshead details or a configuration that induces high transverse restraint forces caused by welding shrinkage during fabrication), the web may have to be fabricated with material with guaranteed through thickness properties. See GN 2.09 and GN 3.02.

Summary for design

Fillet or partial penetration butt welds, rather than full penetration butt welds, should be specified for the stiffener to bottom flange connection. For design to EN 1993, the designer should ensure that the following are adequate (further clarification is provided in Section 8.3.2 of P356, Ref 3):

- cross sectional resistance of the full effective section (at bottom flange level) to carry full axial force plus moment
- buckling resistance of full effective section,
- fatigue resistance for the stress range due to forces carried through welds between flange and stiffener, based on the section determined by spread from the bearing and ignoring direct bearing
- resistance of welds (in shear) between stiffener and girder web, to transfer the forces between the stiffener and the web
- resistance of the welds between the stiffener and the top flange, to carry lateral forces (restraint forces, wind forces, etc.).

References

1 EN 1993 Eurocode 3. Design of steel structures
EN 1993-1-5 Plated structural elements
EN 1993-1-9 Fatigue
2. EN 1090-2 Execution of steel structures and aluminium structures. Technical requirements for steel structures.
3. Composite Highway Bridge Design (P356), SCI, 2010.
4 Manual of Contract Documents for Highway Works, Volume 1, Specification for Highway Works, Series 1800, Highways Agency, 2014
5. Steel Bridge Group: Model project specification for the execution of steelwork in bridge structures, (P382), SCI, 2009.

‡ EN 1993-1-5 clause 3.2.3 sets the spread angle through a flange as 45 degrees.