Intermediate transverse web stiffeners

No. 2.05

Scope

This Guidance Note gives information about the need for intermediate transverse web stiffeners for plate girder bridges and summarizes the practical detailing aspects.

Stiffeners used as part of a U-frame in half-through construction require additional considerations that are not covered in this Note.

This Note first describes the main purpose of intermediate transverse web stiffeners, then describes their secondary role in the context of intermediate restraints. It then explains the practicalities of certain details and the influence of these details on the design and cost of fabrication.

Primary purpose of intermediate web stiffeners

Where universal beam sections provide adequate bending resistance, they could, in theory, normally be used without any intermediate web stiffeners (in the absence of any need for intermediate systems of restraint to compression flanges). This reflects the inherent stability of webs in such sections and the general ability of the section to sustain significant levels of plastic strain before attainment of ultimate load (i.e. the section classification is generally Class 1 or 2).

The two key factors determining the stability and hence the resistance of webs are: web slenderness (the h_w/t ratio) and the aspect ratio of web panels (the a/h_w ratio) - see Figure 1. Web resistance reduces as these two parameters increase. The transverse bending resistance of the flanges has a secondary influence that is only significant at close stiffener spacing.

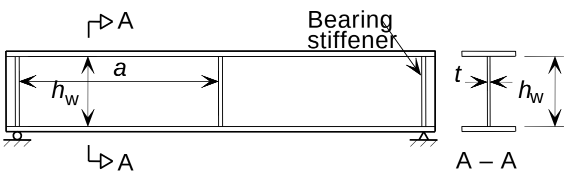


Figure 1 *Web slenderness h_w/t and web panel aspect ratio a/h_w*

Plate girders are generally different from universal beams in relation to web stability. The designer's freedom to proportion the component plates of such girders frequently means that h_w/t ratios can be relatively high. This, coupled with high aspect ratios (a/h_w) for web panels would result in low web resistances in shear and bending; the overall resistance of the girder would therefore be reduced.

From the above, the primary role of intermediate web stiffeners is clear: they serve to divide the web into panels and thereby reduce the web panel aspect ratio. This increases web resistance.

The maximum resistance achievable in a web occurs if its geometric characteristics (h_w/t, a/h_w) are such as to permit the development of full plasticity. Even where this is not possible, shear buckling involves a large post-buckling reserve beyond initial elastic buckling. This is an ultimate condition in which tension bands develop and ultimate failure of the web is by yielding of these bands as they rotate to develop the optimal resistance – see Figure 2. Final collapse involves the flanges pulling into the plane of the web and this mechanism contributes some additional shear resistance (the flange contribution in EN 1993-1-5, cl 5.4) and also develops some force in the stiffeners.

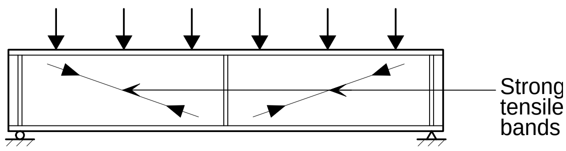


Figure 2 *Development of tensile bands in the girder shown in Figure 1*

On deck-type bridges, intermediate stiffeners are usually avoided on the exposed face of the outer girders for aesthetic reasons. For half-through railway bridges, the intermediate stiffeners are located on the outer face of the girder in order that the gap under the top flange on track side can, if necessary, be used as a refuge.

Secondary roles of intermediate web stiffeners

In addition to their role in determining web panel sizes and being active in the development of tension field action, intermediate web stiffeners are frequently required to play two further roles:

- To permit attachment of bracing between beams/girders.

- To act as load bearing stiffeners to the web at points of stationary concentrated loading on the beam/girder. This is not common in bridges, except for occasional applications during erection when it is necessary to apply concentrated loads to the girders, such as from crane outriggers.

The first of these roles is discussed in the context of detailing below. The second is an aspect that is taken into account in the design verification in EN 1993-1-5, 9.1.4.

Economy in design

The amount of workmanship in stiffener assemblies is disproportionately high compared to the other components in a typical bridge girder. The cost of stiffening work varies considerably among fabricators, depending on their particular investment strategies and the processes used. However it is often the case that selecting a thicker web and reducing the number of stiffeners will lead to a cheaper girder. As automation of stiffener welding develops, this will become a less dominant consideration.

Care needs to be exercised in relation to the proportioning of webs and stiffeners if the most economical girder configuration is to be achieved.

Stiffener layout and detailing

Simple intermediate web stiffeners

A typical arrangement for a simple single intermediate web stiffener is a flat welded onto one face of the web and connected to one flange (see Figure 3).

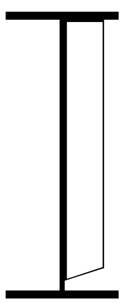


Figure 3 *Simple web stiffener*

Flat stiffeners are usually preferred as they are easily welded onto web plates using all-round fillet welds. They are normally attached after the web has been joined to the flanges (with automatic girder welding they have to be attached afterwards, since they would obstruct the passage of the welding heads).

Traditionally, web stiffeners have had to be attached and welded manually, though robotic equipment is now becoming available that can weld them automatically after they have been positioned and tacked manually.

No more stiffeners should be specified than are actually necessary for structural adequacy - by any method of fabrication they are relatively expensive items.

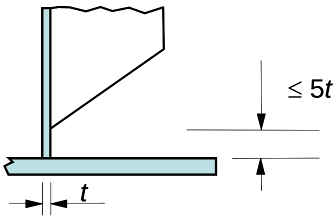
Flat stiffener outstands (width of the flat) are limited by the criterion in EN 1993-1-5 cl 9.2.1(8), to prevent torsional buckling; this limits the outstand to 10.5t_s for S355 steel. Commonly used sizes include:

100 x 10 or 12 mm
150 x 15 mm
200 x 20 mm
250 x 25 mm

At the top flange, attachment of the stiffener to the flange is not strictly necessary for its function as a web stiffener. Where the top flange is composite, the stiffener should be attached, to provide torsional restraint to the flange. Fillet welds are generally sufficient for attachment.

Only the minimum weld required for strength should be specified between any web stiffener and the flange (subject to a practical minimum size of 6 mm). Even fillet welds introduce some local distortion of the flange, though much less than would be introduced by a butt weld. However, with a thick flange (T > 50 mm) it may be the choice of the fabricator to lay a bigger weld than specified to avoid the necessity for local preheat, which can itself lead to distortion. Where bracing is attached to the stiffener, however, moment is attracted out of the slab and into the stiffeners and this may require larger welds between stiffener and flange to provide adequate fatigue life.

At the bottom flange, a clear gap should be left, preferably about 3 times the web thickness, but not more than 5t. This accommodates tolerances in depth of both the web and the stiffener, whilst not being sufficient to lead to fatigue problems at the stiffener end (except possibly where the shear resistance relies heavily on the flange contribution, in which situation stiffener axial force is induced - it is better to attach both ends in such cases). The free corner of the stiffener is often scarfed, which facilitates the application of protective treatment, as shown in Figure 4.



Note. Scarf angle typically 45°

Figure 4 *Detail at stiffener bottom*

The shape of web stiffeners attached to a flange must allow for the fillet weld between web and flange. One way of achieving this is by use of 'cope holes'. These are circular quadrants cut out of the right angle to leave a clear gap (see Figure 5). A radius of at least 40 mm, preferably 50 mm, is needed to allow welds to be returned around the corners and protective treatment to be applied to the inner faces of the hole (although the standard of cleaning can never be as good as on a plane face).

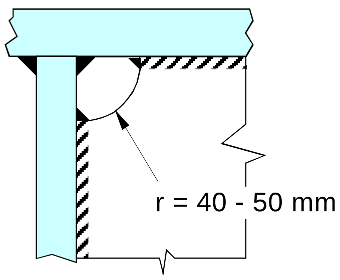


Figure 5 *Cope hole detail*

Alternatively, some fabricators prefer to cut stiffeners square then grind the corner of the plate so that it just clears the weld. The fillet welds to the stiffener can then continue without stop/start, from web to flange (see Figure 6). This avoids creating areas that are difficult to give proper protective treatment, though on bottom flanges it can create corners that trap debris and moisture. Where weathering steel is used, cope holes should be provided in the stiffener at the bottom flange, of at least 50 mm radius, to avoid these moisture traps; this recommendation is given in GN 1.07.

Sniped corners (45° cut across the internal corner) have been used by some designers in this location, but the detail should be avoided, because it is very difficult to return the weld (i.e. in the acute angle, across the thickness of the stiffener) and protective treatment cannot be applied satisfactorily to the inner edge of the stiffener or the weld return.

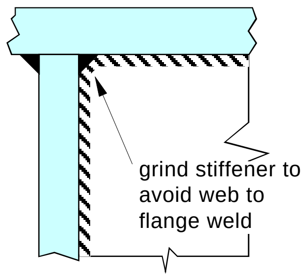


Figure 6 *Alternative stiffener detail at corner*

The weld attaching an intermediate or other web stiffener (i.e. across the flange and around the edge) should not have its toe closer than 10 mm to the edge of the flange for good fatigue detailing, although EN 1993-1-9 does not penalize lesser clearances. It is wise to choose a stiffener width at least 25 mm less than the nominal flange outstand to ensure that this clearance is achieved in practice. If it is necessary to use wider stiffeners, perhaps to suit bracing, they can be scarfed at the ends, or a quadrant notch (similar to the cope hole detail) could be made, as shown in Figure 7, so that the weld is clear of the edge of the flange.

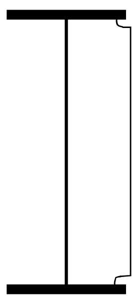


Figure 7 *Stiffener shaped to avoid welding close to edge of flange*

Intermediate stiffeners for the attachment of bracing

Stiffeners for triangulated bracing

Flat stiffeners are well suited to simple and inexpensive attachment of bracing members. However, as noted in GN 2.03, they may need to be shaped to suit attachment details.

Attachment to flanges

The stiffeners are a means of transmitting torsional restraint to the beams and they should therefore be attached to both flanges. Fillet welds are quite adequate for this purpose.

Stiffeners for 'channel' bracing

Again, flat stiffeners are preferred for attaching channel bracing, though they will probably be more substantial than those used with triangulated bracing, since a moment restraint has to be provided and a larger group of bolts is needed to transmit the moment. Stiffeners are sometimes shaped to provide extra space for the bolt group. See GN 2.03.

Treatment of skew

Small degrees of skew of bracing members can easily be accommodated by suitable alignment of the flat stiffener, but it is normally just as easy, and cheaper, to detail orthogonal bracing. Highly skewed bracing should always be avoided, because it introduces difficulties in fabrication as well as being less effective as intermediate bracing. See GN 1.02 for guidance on skew bridges.

Notching for longitudinal stiffeners

Guidance on notching of transverse stiffeners to accommodate longitudinal stiffeners is given in GN 2.02.

Summary of web stiffener layouts

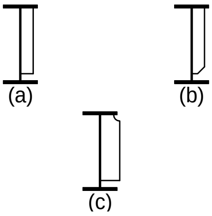
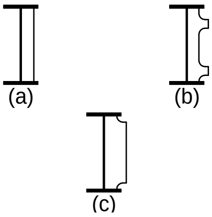
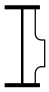
The layout of common arrangements of intermediate web stiffeners, and comments on detailing, are summarized in Table 1. The Table indicates the suitability of different shapes for different purposes.

Each bridge will merit individual consideration as to the most effective and economic arrangement and geometry of stiffeners. The Table should, however, act as a general guide. Further detailed guidance is given in GN 2.03.

Reference

EN 1993-1-5:2006, Eurocode 3 – Design of steel structures: Part 1-5 Plated structural elements.

Table 1 *Typical intermediate web stiffener configurations and detailing advice*

Type		Suitable for:							
		Divid-ing web panels	**Tri-ang'd bracing**	**Single cross-beam**	**Attachment to flanges**	**Shape of stiffener**	**Weld to web**	**Weld to flanges**	**Detail in corners**
1		Yes	No	No	To one flange only Gap 3*t* to 5*t* at unat-tached end.	a)rectangular b)scarfed at free end c)cut back at attached end All from flat $h_s/t_s \geq 10.5$ for S355 steel	Fillet weld As small as possible (6 mm min)	Fillet weld As small as possible (6 mm min) Weld toe at least 10 mm(1) from edge of flange	Circular cope hole (40 mm radius min) or sniped in corner and welded around(2)
2		Yes	Yes	No	To both flanges	As (a) or (c) above, or shaped plate, or (a) or (c) plus gusset	As above	As above. Butt welds and end preparation not neces-sary	As above
3		Yes	No	Yes	To both flanges	Shaped plate, $h_s/t_s \geq 10.5$ for S355 steel outside lapped region	As above	As (2) above	As above

Notes:
1. The 10 mm clearance is required to avoid a reduction in fatigue performance although failure to comply is not specifically penalized in EN 1993-1-9.
2. The stiffener weld overlapping the longitudinal flange/web weld is now a widely accepted detail and is not considered to carry a fatigue penalty.
3. Minimum sizes may need to be increased if there are gaps, for example between one end of a stiffener and the flange where the stiffener is attached at both ends.
4. Welds should normally be continuous and all round the stiffener.