

Additional design requirements for overlap joints in structural hollow sections

Christopher Morris of Tata Steel Tubes explains the reasons for an additional design requirement introduced into Eurocode 3 for K and N overlap joints

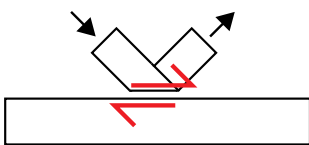


Figure 1 - Shearing force at an overlapped K joint

Introduction

BS EN 1993-1-8:2005 was revised on 28th February 2010 with the implementation of the July 2009 CEN corrigendum. This Corrigendum includes the additional requirement to verify the shear resistance (in the direction of the longitudinal axis of the chord) of the connection between bracing members and chord, for overlapped K- and N-joints in lattice structures of hollow section members. The additional requirement is only applicable to joints with a large overlap. The design situation is illustrated diagrammatically in Figure 1.

Failure modes for hollow section K and N joints

Overlap K- and N-joints should be verified for the range of failure modes given by clause 7.2.2. The particular modes that usually need to be considered are:

- chord face failure (CHS chords)
- effective width/brace failure (RHS chords)

The addition of the following requirement in clause 7.1.2 (6) effectively adds a further failure mode – shear failure in the connection between braces and chord:

If the overlap exceeds $\lambda_{ov,lim} = 60\%$ in case the hidden seam of the overlapped brace is not welded or $\lambda_{ov,lim} = 80\%$ in case the hidden seam of the overlapped brace is welded or if the braces are rectangular sections with $h_i < b_i$ and/or $h_j < h_j$, the connection between the braces and the chord face should be checked for shear.

In addition, the range of validity in Tables 7.1, 7.8, 7.20 and 7.23 now includes the value of $\lambda_{ov,lim}$ as an upper limit for the overlap in K and N joints. However, it is not intended as a maximum overlap limit but that if the overlap exceeds $\lambda_{ov,lim}$ the additional check for shear needs to be made.

Basis for verifying shear resistance

No criteria for this additional failure mode have been included in tables 7.2, 7.10, 7.21 or 7.24. In their absence, the following criteria for adequacy of the shear connection may be used. They are based on research by CIDECT but expressed using EN 1993-1-8 symbols.

Shear check for CHS bracings

When: $60\% < \lambda_{ov} < 100\%$ and overlapped brace hidden seam is NOT welded

or: $80\% < \lambda_{ov} < 100\%$ and overlapped brace hidden seam IS welded

$$N_{i,Ed} \cos \theta_i + N_{j,Ed} \cos \theta_j \leq \frac{\pi}{4} \left[\frac{f_{tj}}{\sqrt{3}} \times \frac{\left[\left(\frac{100 - \lambda_{ov}}{100} \right) 2d_i + d_{eff,i} \right] t_i}{\sin \theta_i} + \frac{f_{tj}}{\sqrt{3}} \times \frac{(2d_j + c_s d_{eff,j}) t_j}{\sin \theta_i} \right] \times \frac{1}{\gamma_{M5}}$$

When: $\lambda_{ov} \geq 100\%$

$$N_{i,Ed} \cos \theta_i + N_{j,Ed} \cos \theta_j \leq \frac{\pi}{4} \times \frac{f_{tj}}{\sqrt{3}} \times \frac{(3d_j + d_{eff,j}) t_j}{\sin \theta_j} \times \frac{1}{\gamma_{M5}}$$

Shear check for RHS bracings

- When: $60\% < \lambda_{ov} < 100\%$ and overlapped brace hidden seam is NOT welded
 or: $80\% < \lambda_{ov} < 100\%$ and overlapped brace hidden seam IS welded
 or: $h_i < b_i$ and $\lambda_{ov} < 100\%$
 or: $h_j < b_j$ and $\lambda_{ov} < 100\%$

$$N_{i,Ed} \cos\theta_i + N_{j,Ed} \cos\theta_j \leq \left[\frac{f_{uj}}{\sqrt{3}} \times \frac{\left[\left(\frac{100 - \lambda_{ov}}{100} \right) 2h_i + b_{eff,i} \right] t_i}{\sin\theta_i} + \frac{f_{uj}}{\sqrt{3}} \times \frac{(2h_j + c_s b_{eff,j}) t_j}{\sin\theta_j} \right] \times \frac{1}{\gamma_{M5}}$$

When: $\lambda_{ov} \geq 100\%$

$$N_{i,Ed} \cos\theta_i + N_{j,Ed} \cos\theta_j \leq \left[\frac{f_{uj}}{\sqrt{3}} \times \frac{(2h_j + b_j + b_{eff,j}) t_j}{\sin\theta_j} \right] \times \frac{1}{\gamma_{M5}}$$

Where c_s is an effective shear area coefficient and all the other symbols are as defined in BS EN 1993-1-8 and subscripts i and j refer to the overlapping and overlapped bracings respectively.

Effective shear area coefficient

Usually, the hidden part of the overlapped brace (toe) is not welded unless the brace vertical components of design forces differ by more than 20%. However, if it is not welded, it cannot contribute to shear resistance. Therefore, welding the hidden toe of the overlapped brace increases the brace shear capacity and is represented by the effective shear area coefficient:

- $c_s = 1$ when the hidden toe is not welded
 $c_s = 2$ when the hidden toe is welded.

If the designer requires the hidden toe welding to provide sufficient shear resistance it is essential to provide this information to the fabricator.

Effective widths of braces

The effective width given as b_{eff} in tables 7.10 and 7.12 (expressed in terms of width of RHS b for overlapping brace member i), can be substituted by d for CHS and subscript j for the overlapped brace - except CHS braces to CHS chords. In which case, the effective diameter for the overlapping brace is given by:

$$d_{eff,i} = \frac{12t_0}{d_0} \times \frac{f_{y0} t_0}{f_{yi} t_i} \times d_i \text{ but } \leq d_i$$

To apply this for the overlapped CHS brace to CHS chord substitute subscript i for j .

The effective widths for the overlapping and overlapped brace thus depend on chord and brace section profiles, as shown in Table 1.

		Brace	
		CHS	RHS
Chord	CHS	Overlapping CHS brace to CHS chord: $d_{\text{eff},i} = \frac{12t_0}{d_0} \times \frac{f_{y0}t_0}{f_{yi}t_i} \times d_i \text{ but } \leq d_i$	—
		Overlapped CHS brace to CHS chord: $d_{\text{eff},j} = \frac{12t_0}{d_0} \times \frac{f_{y0}t_0}{f_{yj}t_j} \times d_j \text{ but } \leq d_j$	—
	RHS	Overlapping CHS brace to RHS chord: $d_{\text{eff},i} = \frac{10t_0}{b_0} \times \frac{f_{y0}t_0}{f_{yi}t_i} \times d_i \text{ but } \leq d_i$	Overlapping RHS brace to RHS chord: $b_{\text{eff},i} = \frac{10t_0}{b_0} \times \frac{f_{y0}t_0}{f_{yi}t_i} \times b_i \text{ but } \leq b_i$
		Overlapped CHS brace to RHS chord: $d_{\text{eff},j} = \frac{10t_0}{b_0} \times \frac{f_{y0}t_0}{f_{yj}t_j} \times d_j \text{ but } \leq d_j$	Overlapped RHS brace to RHS chord: $b_{\text{eff},j} = \frac{10t_0}{b_0} \times \frac{f_{y0}t_0}{f_{yj}t_j} \times b_j \text{ but } \leq b_j$

Table 1 - Effective width equations

Brace ultimate tensile strength

The brace ultimate tensile strength, f_{ui} and f_{uj} for the overlapping and overlapped brace respectively, is given in BS EN 1993-1-1 as:

$$f_u = 510 \text{ N/mm}^2 \quad \text{for S355H, hot finished to BS EN 10210-1}$$

$$f_u = 510 \text{ N/mm}^2 \quad \text{for S355H, cold formed to BS EN 10219-1}$$

However, the UK NA to BS EN 1993-1-1:2005 recommends the use of values from the product standards, which give:

$$f_u = 470 \text{ N/mm}^2 \quad \text{for Celsius 355}^\circ \text{ to EN 10210-1:2006}$$

$$f_u = 470 \text{ N/mm}^2 \quad \text{for Hybox 355}^\circ \text{ to EN 10219-1:2006}$$

References:

Tata Steel, Tubes: Design of welded joints, Celsius 355 and Hybox 355

BSI: EN 1993-1-8:2005 Design of steel structures, design of joints

CIDECT: Design guide for circular hollow section (CHS) joints under predominantly static loading (2nd edition 2008)

CIDECT: Design guide for rectangular hollow section (RHS) joints under predominantly static loading (2nd edition 2009)

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