Simplified assessment methods for LTB

David Brown of the SCI considers the simplified assessment method for lateral-torsional buckling given in EC3, and finds a useful application in elastic portal frames.

The advantage of using intermediate restraints to the tension flange of a steel member was discussed in the July 2011 edition of New Steel Construction. Provided the intermediate restraints are spaced sufficiently closely, the flexural buckling resistance and the lateral torsional buckling resistance can be increased, compared to a member without intermediate restraints. This approach might be considered to be at one end of a scale of complexity.

An altogether simpler approach is described in BS EN 1993-1-1, which whilst not being attractive for orthodox situations (the results are too conservative), can have useful application in situations not explicitly covered by the Standard, or where the alternatives are complex and time-consuming to apply.

The so-called 'simplified assessment method' is described in clause 6.3.2.4 of BS EN 1993-1-1, and proposes that the compression zone of a member be treated as a Tee-shaped simple strut between points of restraint. The clause proposes that the Tee be taken as the compression flange, plus 1/3 of the compressed part of the web area. The concept is illustrated in Figure 1 and will be familiar to many bridge designers.

This simplified approach has the disadvantage that the contribution from the tension zone is ignored. The tension zone normally contributes to reduce the tendency to buckle. BS EN 1993-1-1 clause 6.3.2.4 states that the member is not susceptible to lateral-torsional buckling if the length L_c of the equivalent compression flange between restraints satisfies the expression:

where: $$\frac{k_c L_c}{i_{f,z}\lambda_1} \le \bar{\lambda}_{c0}\frac{M_{c,Rd}}{M_{y,Ed}}$$

$M_{y,Ed}$ is the maximum design value of the bending moment within the restraint spacing

$M_{c,Rd} = W_y \frac{f_y}{\gamma_{M1}}$ This is the bending resistance of the cross-section, but calculated with γ_{M1} rather than γ_{M0}, which would normally be used for cross-sectional resistance. In the UK, the difference is irrelevant because, according to the UK NA, γ_{M1} and $\gamma_{M0} = 1.0$

k_c is a slenderness correction factor. The UK NA relates this to the C_1 factor that accounts for the shape of the bending moment diagram. The value is given by

$$k_c = \frac{1}{\sqrt{C_1}}$$

$i_{f,z}$ is the radius of gyration of the Tee-shaped equivalent compression flange about the minor axis of the section

$\bar{\lambda}_{c0}$ is a slenderness limit, defined in the UK NA as 0.4 for rolled sections.

$$\lambda_1 = \pi\sqrt{\frac{E}{f_y}} = 93.9\varepsilon$$

Practical application

Consider a 457 × 191 × 67 UKB in S355 steel, with restraints to the compression flange at 5m. The dimensions of the equivalent compression flange, taking 1/6 of the distance between flanges, and ignoring the root radius, are shown in Figure 2.

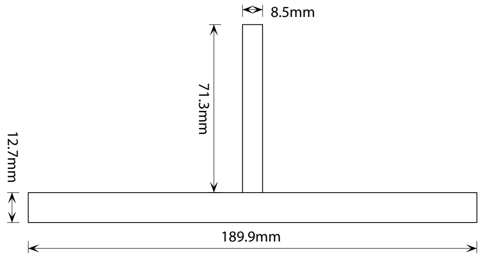


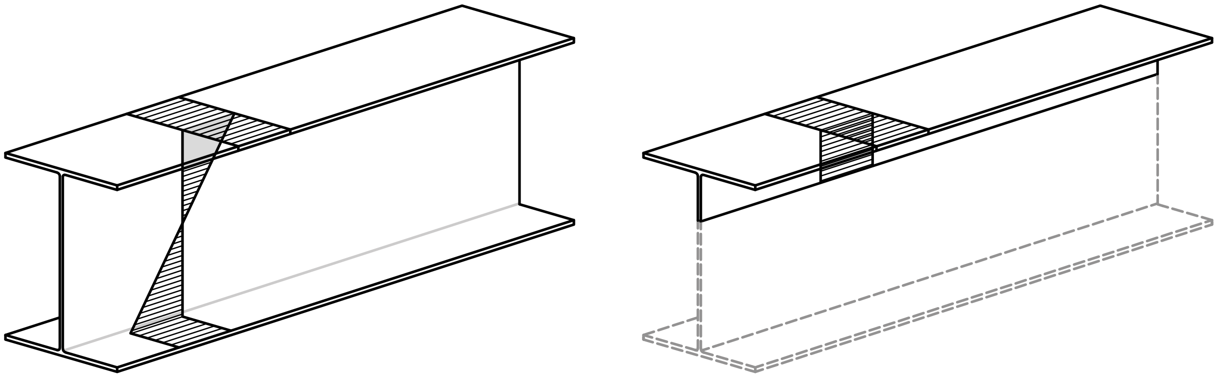
Figure 2: Equivalent compression flange

The calculated properties for the Tee-shaped equivalent compression flange shown in Figure 2 are:

A = 3018 mm^2

I_z = 7.25 × 10^6 mm^4

$i_{f,c}$ = 49 mm



Original Beam

Equivalent compression flange

Figure 1: Principle of simplified assessment method

From the Blue Book, for a 457 × 191 × 67 UKB in S355 steel,
$M_{c,Rd} = 552$ kNm
Assuming a uniform bending moment, then C_1 and $k_1 = 1$

$$\lambda_1 = 93.9 \times \sqrt{\frac{235}{335}} = 76.4$$

The expression given above can then be used to calculate the maximum design moment, $M_{y,Ed}$:

$$\frac{k_c L_c}{i_{f,z} \ddot{e}_1} \leq \bar{\lambda}_{c0} \frac{M_{c,Rd}}{M_{y,Ed}} = \frac{1.0 \times 5000}{49 \times 76.4} \leq 0.4 \frac{552}{M_{y,Ed}}$$

which gives $M_{y,Ed} = 165$ kNm

The buckling resistance moment, Mb,Rd given in the Blue Book for the 457 × 191 × 67 UKB in S355 steel is 257 kNm, which illustrates the conservatism of this simplified method in orthodox situations.

Extending the application of the simplified assessment method

The concept of using a simple strut to assess susceptibility to lateral-torsional buckling may be applied to other situations. The common situation of a haunched beam is not specifically addressed in BS EN 1993-1-1, which is unfortunate, as this is a very common situation in portal frames. BS EN 1993-1-1 does contain checks for a haunched length containing a plastic hinge, which could be used, on the basis that an elastic length must be more stable than one containing a hinge. The checks are, however, laborious to apply, which means the simple strut approach may be attractive.

The development from the haunched member, with a restraint at each end, to a simple Tee-shaped strut, is shown in Figure 3. The middle flange is ignored, and conservatively, it is assumed that the stress at the extreme fibre of the compound section is uniform throughout the Tee. The depth of the tee section depends on the longitudinal location selected. Choosing the deepest section will be the most conservative, so an appropriate rule of thumb is to calculate the cross-sectional properties of the equivalent Tee section at a third of the length from the deepest cross-section.

The interest in the simplified assessment method has arisen from the particular issue described above – how to assess the susceptibility of a haunched length in a portal frame to lateral-torsional buckling. The forthcoming publication on the elastic design of portal frames will include a numerical example of both the simplified assessment method and the use of the rather more involved 'plastic' verification.

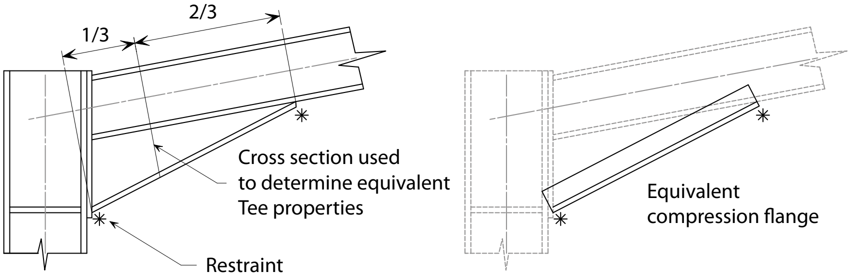


Figure 3: Haunched section and equivalent Tee