# AD 391: Lateral Torsional Buckling of rectangular plates in accordance with BS EN 1993-1-1

BS EN 1993-1-1 does not explicitly cover LTB of rectangular plates. This AD note provides guidance for calculating the design buckling resistance moment ($M_{b,Rd}$) that can be used for BS EN 1993-1-1. To calculate $M_{b,Rd}$ it is necessary to determine the non-dimensional slenderness $\bar{\lambda}_{LT}$. This AD note gives two methods of calculating $\bar{\lambda}_{LT}$ for a plate. The first method is from first principles, using the formula for the elastic critical moment $M_{cr}$ of a plate; the second is by using the formula for the equivalent slenderness $\lambda_{LT}$ of a plate given in Appendix B, clause B.2.7 of BS 5950-1.

For BS 5950-1, AD note 310 (Staircases with flat stringers) discusses the design of steel stairs with flat plate stringers. It suggests the design of the stringers can be carried out by determining the buckling resistance of the stringer over a buckling length equal to the tread spacing, assuming the stringer is class 3.

**Method 1 to determine $\bar{\lambda}_{LT}$:**
Starting from first principles, the non-dimensional slenderness of a plate can be determined as follows:

The standard moment for the elastic critical moment of an I section is:

$$M_{cr} = C_1 \frac{\pi^2 EI_z}{l^2} \sqrt{\frac{I_w}{I_z} + \frac{l^2 GI_T}{\pi^2 EI_z}}$$

Under uniform moment, $C_1 = 1.0$. For a plate, there is no term involving the warping constant $I_W$ because the section has no flanges and it is assumed axial stresses due to warping are not developed. The formula for a plate therefore reduces to:

$$M_{cr} = \frac{\pi}{l} \sqrt{EI_z GI_T}$$

Making the substitutions $I_z = \dfrac{dt^3}{12}$, $I_T = \dfrac{dt^3}{3}$ and $G = \dfrac{E}{2(1+\nu)}$

where $\nu$ is Poisson's ratio and equals 0.3 for steel.
$t$ and $d$ are the thickness and depth of the plate respectively.

Therefore $$M_{cr} = \frac{dt^3}{6} \frac{\pi E}{l} \sqrt{\frac{1}{2.6}} \qquad \text{(Equation 1)}$$

Assuming a class 3 cross-section, the non-dimensional slenderness is given in BS EN 1993-1-1 (clause 6.3.2.2 (1)) by the formula:

$$\bar{\lambda}_{LT} = \sqrt{\frac{W_{el} f_y}{M_{cr}}} \qquad \text{(Equation 2)}$$

where $W_{el} = d^2t/6$

**Method 2 to determine $\bar{\lambda}_{LT}$:**
Substituting for $M_{cr}$ from equation 1 and $W_{el} = d^2t/6$ into equation 2, leads to:

$$\bar{\lambda}_{LT} = \sqrt{\frac{f_y \times 1.0 \times \sqrt{2.6}}{\pi E} \frac{ld}{t^2}} = \sqrt{\frac{f_y}{\pi^2 E} \frac{1.0\pi \times \sqrt{2.6}}{1} \frac{ld}{t^2}} \approx \sqrt{\frac{f_y}{\pi^2 E}} \times 2.8 \sqrt{\frac{0.667ld}{t^2}}$$

The quantity $\sqrt{\dfrac{\pi^2 E}{f_y}}$ is denoted $\lambda_1$ in BS EN 1993-1-1 and is the slenderness at which the Euler load equals the squash load.

Starting from the formula in BS 5950 -1, clause B.2.7 the equivalent slenderness is given as:

$$\lambda_{LT} = 2.8 \sqrt{\frac{\beta_w ld}{t^2}} \qquad \text{(Equation 3)}$$

For a class 3 section, $\beta_w = 2/3 = 0.667$.

Therefore for design to BS EN 1993-1-1, the non-dimensional slenderness $\bar{\lambda}_{LT}$ of a plate can be stated as:

$$\bar{\lambda}_{LT} = \frac{\lambda_{LT}}{\lambda_1} \qquad \text{(Equation 4)}$$

For $f_y = 275$, $\lambda_1 = \pi \times \sqrt{\dfrac{210000}{275}} = 87$

for $f_y = 355$, $\lambda_1 = 76$

The design buckling resistance $M_{b,Rd}$ can then be calculated from clause 6.3.2.1 (3) (equation 6.55) assuming a class 3 cross-section. The reduction factor $\chi_{LT}$ is calculated from clause 6.3.2.2 (1) (equation 6.56) based on curve d (i.e imperfection factor $\alpha_{LT} = 0.76$ )

The non-dimensional slenderness $\bar{\lambda}_{LT}$ may be determined from equation 2 or 4 above.

Contact: **Richard Henderson**
Tel: **01344 636525**
Email: **advisory@steel-sci.com**