Design of Soil Steel Composite Bridges, Report 112, Structural Design and Bridges, 2007, 4th ed. 2010

New version of Subsection 5.3

5.3 Adaptation of the design principles to Eurocode 3*

The following adaptations should be implemented when using Eurocode 3 for the design of the culvert. The section properties of the plates used for culverts is almost always in cross-section class 1 or 2, meaning that reduction due to risk for local buckling can be omitted. For notations see **Figure B1.2 – Figure B1.5**. The formulae presented in this section are thus simplified using the assumption that the plates are in cross-section class 2 or lower.

3) Check against flexural buckling of the upper part of the pipe

At the ultimate limit state, a check is made on the maximum loaded section using EN 1993-1-1 expression *(6.61)*. As the plate is presumed not to deflect laterally (*z*-axes), $\chi_{\mathrm{LT}} = 1{,}0$ and $\chi_{\mathrm{z}} = 1{,}0$. Furthermore, the moments $M_{\mathrm{z,Ed}} = \Delta M_{\mathrm{z,Ed}} = 0$ and, as the neutral axis does not change due to local buckling, $\Delta M_{\mathrm{y,Ed}} = 0$.

The expression (*6.61*) in EN 1993-1-1 can thus be simplified to

$$\frac{N_{\mathrm{Ed}}}{\frac{\chi_{\mathrm{y}} N_{\mathrm{Rk}}}{\gamma_{\mathrm{M1}}}} + k_{\mathrm{yy}} \frac{M_{\mathrm{y,Ed}}}{\frac{M_{\mathrm{y,Rk}}}{\gamma_{\mathrm{M1}}}} \leq 1{,}0 \quad \text{(EN1993-1-1, } \mathit{6.61}\text{, and Table 6.7)} \qquad (5.b')$$

$N_{\mathrm{Ed}}, M_{\mathrm{y,Ed}}$ design value for axial force and bending moment, $N_{\mathrm{d,u}}, M_{\mathrm{d,u}}$. Observe that in certain cases the moment capacity should be reduced according to Eq. (b1.h)

$\chi_{\mathrm{y}} = \frac{N_{\mathrm{cr}}}{N_{\mathrm{u}}}$ reduction factor for flexural buckling, see *6.3.1* in EN 1993-1-1

k_{yy} interaction factor according to Table *A.1* and *A.2* in Appendix A in EN 1993-1-1. Note that method 1 is recommended in the Swedish National Annex.

$N_{\mathrm{Rk}} = f_{\mathrm{y}} A$ and $M_{\mathrm{Rk}} = f_{\mathrm{y}} W$ resistance for axial force and bending moment.

$\gamma_{\mathrm{M1}} = \gamma_{\mathrm{n}}$ in compliance with the design methods suggested in this manual. (Using the Swedish Standard $\gamma_{\mathrm{M1}} = 1{,}0$)

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* The notations used in this section are not in the notation list of Report 112. Reference is made to the notations used in the Eurocodes.

The interaction factor k_{yy} can be simplified considerably. For cross-section classes 1 and 2 it is:

$$k_{\text{yy}} = \frac{C_{\text{my}}}{\left(1 - \chi_{\text{y}} \dfrac{N_{\text{Ed}}}{N_{\text{cr,y}}}\right) C_{\text{yy}}} \qquad (5.\text{b}'')$$

where $C_{\text{my}} = C_{\text{my,0}}$ is a correction factor allowing for the distribution of the moment along the arch according to Tables *A.1* and *A.2* in SS-EN 1993-1-1. For simplicity, it can be assumed that $C_{\text{my}} = 1{,}0$. $N_{\text{cr,y}} = N_{\text{cr,el}}$ according to Eq. B5.b.

For cross-section classes 1 and 2 the correction factor C_{yy} is added. As $\bar{\lambda}_0 = 0$ and $\bar{\lambda}_{\text{z}} = 0$, the expression for C_{yy} in Table *A.1* can be simplified to:

$$C_{\text{yy}} = 1 + \left(w_{\text{y}} - 1\right)\left[\left(2 - \frac{1{,}6}{w_{\text{y}}} C_{\text{my}}^2 \bar{\lambda}_y \left(1 + \bar{\lambda}_y\right)\right) \cdot n_{\text{pl}}\right] \qquad (5.b''')$$

and

$$C_{\text{yy}} \geq \frac{W_{\text{el,y}}}{W_{\text{pl,y}}} \qquad (5.\text{b}^{IV})$$

where $w_{\text{y}} = \dfrac{W_{\text{pl,y}}}{W_{\text{el,y}}} \leq 1{,}5$ is the quotient between plastic and elastic section modulus.

The relative slenderness $\bar{\lambda}_{\text{y}}$ is given by

$$\bar{\lambda}_{\text{y}} = \sqrt{\frac{N_{\text{u}}}{N_{\text{cr,el}}}} \qquad (5.\text{b}^{V})$$

where N_{u}, $N_{\text{cr,el}}$ and N_{cr} are given in **Appendix 5**.

Check should be done according to Section 5.2 point *3)* with ξ according to Appendix 5, Eq. (B5.e) testing the relation $\left(\dfrac{N_{\text{d,u}}}{\omega f_{\text{y}} A}\right)^{\alpha_{\text{c}}} \leq 1{,}0$.