ENAC / PROJET DE MASTER 2017
SECTION GENIE CIVIL

The use of high strength steel in bridge decks

Auteur(e)s : Pierre Lorne

Encadrement : Prof. Dr. Alain Nussbaumer [1] / Prof. Dr. José Oliveira Pedro [2]

[1] Resilient Steel Structures Laboratory (RESSLab), EPFL / [2] Instituto de Engenharia de Estruturas, Território e Construção, IST, Portugal

1. Objectives

The objective is to use the high resistance of HSS in **composite steel-concrete bridges**, in order to have lighter and more economical bridge decks. **Three solutions** of a composite road bridge are designed, based on the **Eurocodes**:

- A: with two welded I-section girders in S355 steel.
- B: with two welded I-section girders in S690 steel.
- C: with girders in S690 steel using tubular profiles for the flanges.

A **comparative analysis** of the benefits associated with the three solutions is carried out.

2. Longitudinal and cross-sectional geometry

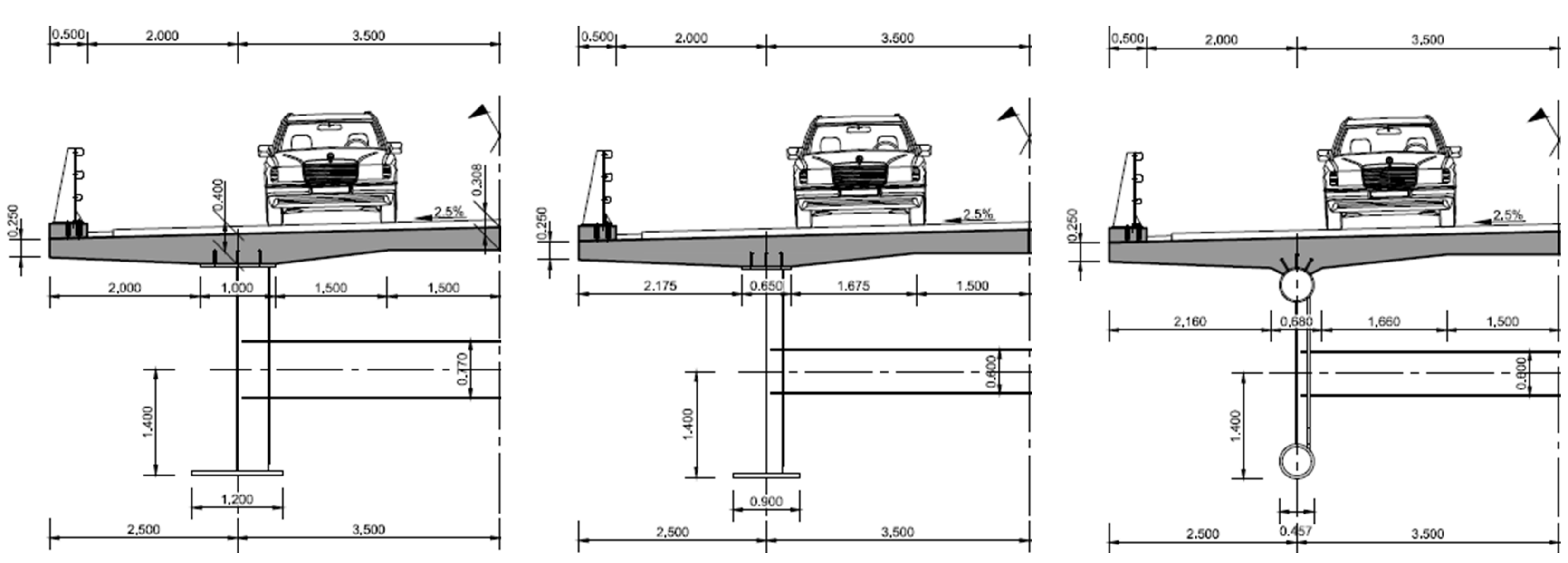

Figure 1. Cross-section of solutions A, B and C

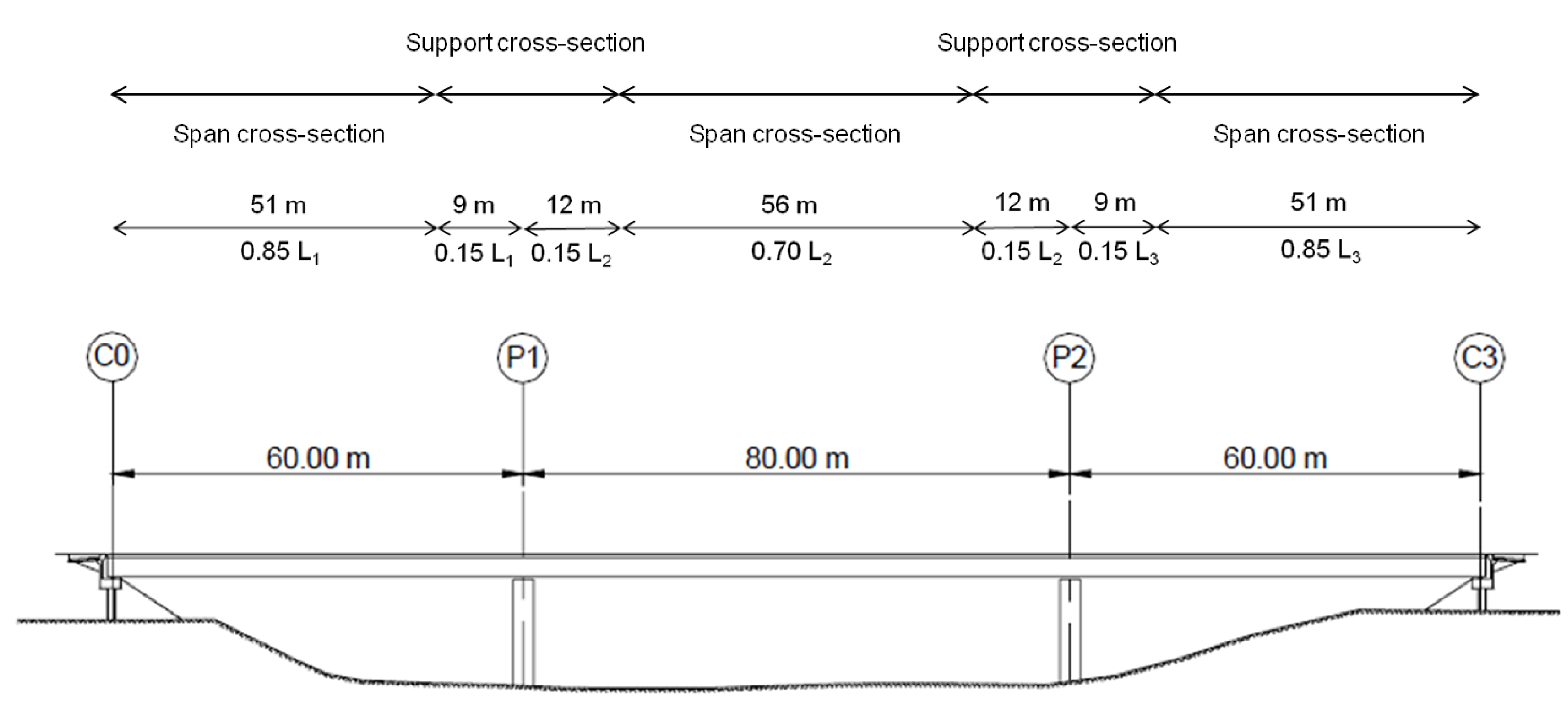

Figure 2. Elevation of the bridge, with the distinction between span and support zones

3. Actions on the structure

Several actions are considered. The structural permanent loads include the **weight of the girders** and the **weight of the reinforced concrete slab**. The bridge equipment regroups the **weight of the barriers** and the **asphalt layer**. The variable actions are made of the **temperature variations** and the **traffic actions**, using the LM1 at ULS and the FLM3 at ULS for fatigue. The effects of **shrinkage** are also considered.

4. Ultimate Limit State

For I-welded girders as in solutions A and B, the connection between the web and the flange is assumed to be a hinge. In solution C, because of the **tubular flanges**, the connection can be fixed and **new formulas** are developed for the limit between the **cross-section classes 3 and 4 of the web**, depending on the stress ratio ψ:

- 1 > ψ > -1: $\frac{h_w}{t_w} \le \bar{\lambda}_p \cdot \frac{1}{1.052} \cdot \sqrt{\frac{k_\sigma \cdot E_a}{235}} \cdot \varepsilon$
- -1 > ψ : $\frac{h_w}{t_w} \le \frac{156}{2} * \varepsilon * (1-\psi) * \sqrt{-\psi}$

The verification of the **bending resistance** depends on the cross-section class: with the plastic resistance when in class 1 and with the elastic resistance for all other classes. In that case, the **design stresses** in the elements of the composite girder are compared with the **design yield strength** of these elements.

The **shear forces** are checked with the **minimum value** of the **shear plastic** and the **shear buckling** resistance. Only the web **participation** is considered. In solution C, a comparison is made for a **hinged or a fixed connection** between the web and the flanges, between the **Eurocode** and **Basler's model** (which considers that the flanges do not contribute to the resistance).

5. Stability

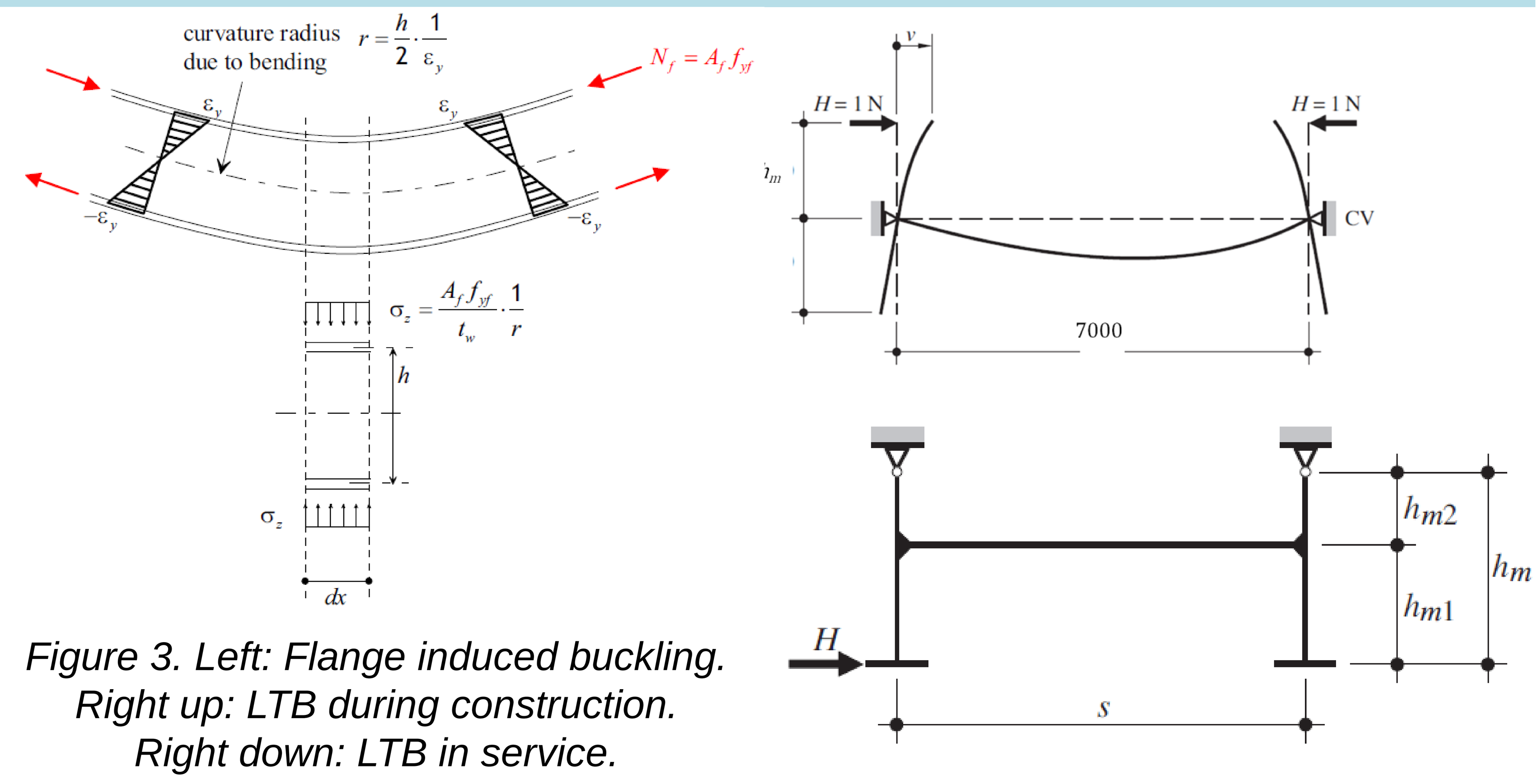

Figure 3. Left: Flange induced buckling.
Right up: LTB during construction.
Right down: LTB in service.

The web must be thick enough against **flange induced buckling**. In solutions B and C, the formula from the Eurocode must be adapted, accounting for the **non-symmetry of the composite girder** and the **reserve in resistance** at ULS.

The **compression flange** must be justified against **lateral-torsional buckling** (LTB) with the **simplified check method**, or the **general check method** if it is necessary to perform the critical load calculations as exactly as possible.

6. Fatigue assessment

The **change in thickness** of the lower flange between the support and span zones, and the **transverse weld** of the vertical T-shaped stiffener web on the lower steel flange, are verified at **ULS for fatigue**. The second detail is the most critical.

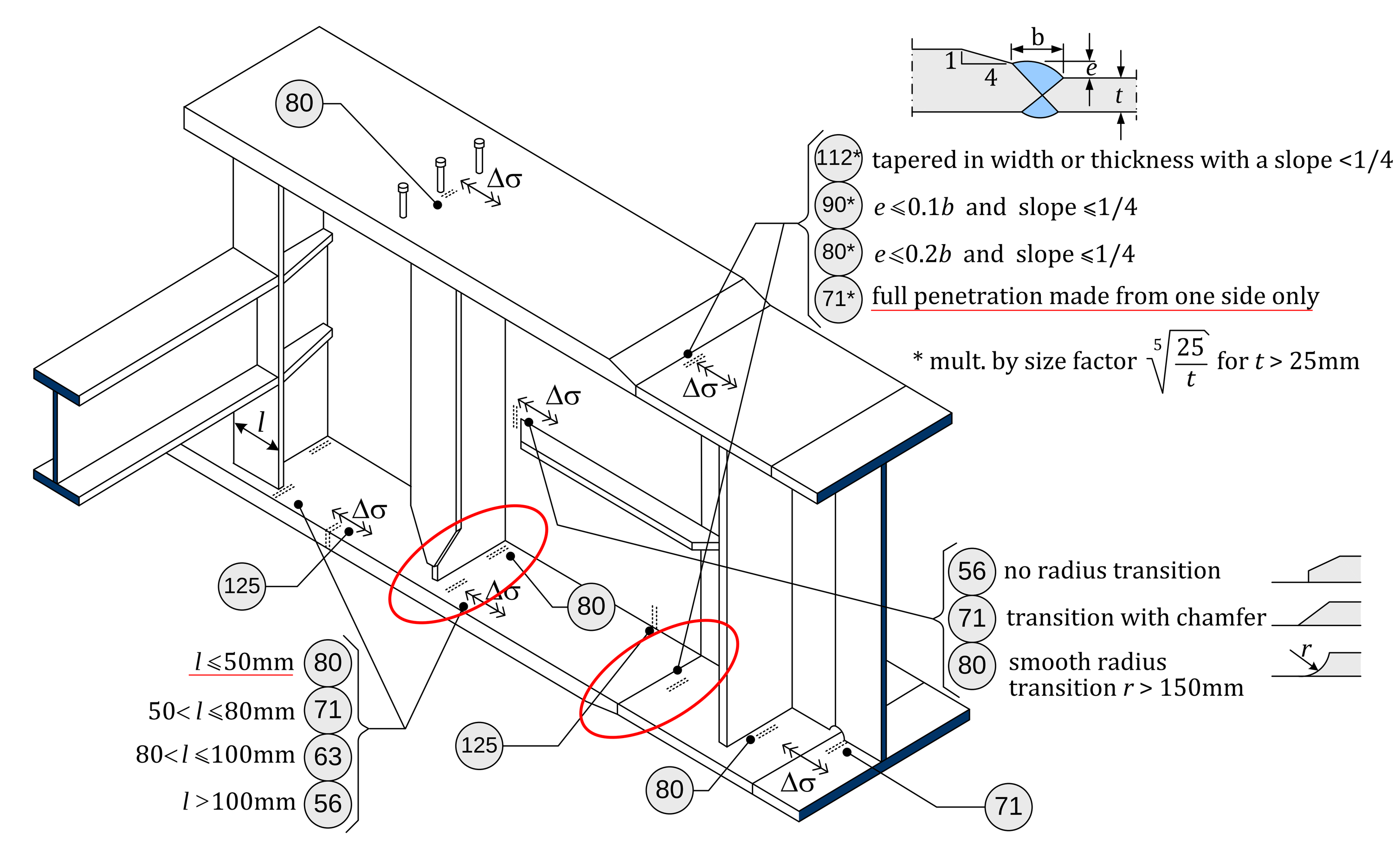

Figure 4. Typical FAT detail categories

7. Conclusions

In solutions B and C, compared to solution A:

- The **weight of the girders** is reduced by respectively 27% and 30%.
- There is more **reserve in resistance at ULS**.
- The verification against the **flange induced buckling** is improved.
- **Tubular profiles** improve the **resistance against LTB**.
- **Fatigue** becomes the decisive criterion in solutions B and C.
- The **execution** of solution C is more difficult.