Analysis of Composite Bridges in Practice – a Holistic Approach

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Summary

Composite structures are often used in bridge engineering. In most cases steel girders are combined with a cast in place concrete slab, but composite systems with precast concrete girders are also widely built. Although often applied in everyday structures, composite structures require challenging design procedures due to the necessity of considering the difference in behaviour of the materials and providing full connection between the structural parts.

These requirements are related to topics like properly considering the actual construction schedule in order to assign different loading components to the respective structural system. Further special needs arise in the simulation of certain loadings such as self weight of wet concrete or temperature differences between the different materials. A third major problem is related to correct simulation of long time behaviour redistributing stresses from the concrete slab to the girders and to dealing with pre-stressing in case of structures with pre-stressed concrete girders.

Consistent analysis procedures considering all these special problems have recently been developed and are presented herein. The solution allows for considering all required effects with sufficient accuracy in comprehensive manner and in accordance with generally accepted theories.

Keywords: composite structure, non-linear stress distribution, non-linear temperature distribution, creep and shrinkage, long-term effects, shear keys

1. Basics

1.1 Introduction

The solution described in this paper is working with an extended beam approach [1] based on establishing a full geometric model of the superstructure cross-section with assigning the actual material parameters and activation time to the individual parts. Different sets of structural elements are defined, modelling on the one hand the individual parts and on the other hand the composite section.

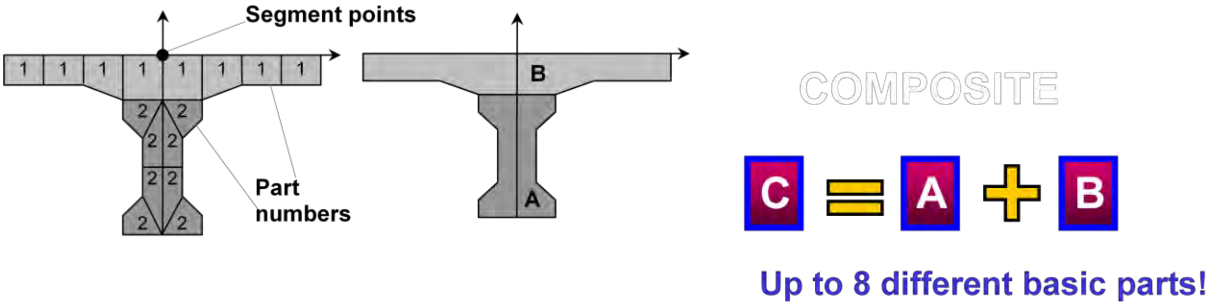

Figure 1 Composite cross-section with cross-section parts

2. Construction schedule

Bridge structures are almost always built in stages, where the different construction parts are erected at different times and the related erection loading is acting on different intermediate structural systems. The final stressing state is generally very much dependent on the erection sequence. This particularly applies to composite structures, where not only additional structural parts are assembled during erection, but already active structural members are successively completed. Using a 4D approach where the time domain is taken properly into account is therefore essential. The erection sequence is thereby described in the (construction) *schedule*.

3. Special loading conditions – self weight, pre-stressing, temperature

Self weight – body loads: The approach with separate sets of elements for representing the individual parts and the composite members allows for handling these problems consistently: body loads can be related to the partial elements with realistic material properties. Wet concrete weight can also be easily defined with allowing the application of self-weight loads on inactive partial elements.

Temperature: Considering the *temperature impact* it is essential to allow for taking into account non-linear conditions where primary and secondary stresses must be distinguished.

Pre-stressing of Composite Girders: Pre-stressing is related to structures where precast concrete girders are combined with a cast in place slab. One possibility is that the individual girders have been pre-stressed with straight strands in the manufacturing process. Another possibility is that the girders contain ducts. The tendons are placed on site and post-tensioned after the composite state is active. “Primary” and “secondary” results must be distinguished and separately stored in order to allow for proper proof checking.

4. Creep and shrinkage

Long-term effects due to creep and shrinkage of the concrete together with the specific structural behaviour make it imperative that appropriate techniques be used in the design and analysis process for considering these effects. The process must take into account all types of quasi-permanent loading and the time, when it is applied on the structure. This includes the computation of the effects due to creep and shrinkage in the time intervals between activating new structural components and applying major new loadings.

5. Assessment of results and proof checks

Special techniques must be used to relate results (internal forces) of partial elements to the composite section and vice versa from the composite element to the cross-section parts. Program options “*Split*” and “*Joined*” have been provided for this purpose. This allows for performing all the required proof checks for SLS conditions as well as for ULS conditions.

6. Shear key design

Shear keys are usually provided to avoid shear deformation between the 2 parts of the composite section. Design forces in the shear keys must be determined in the design procedure in order to determine the required number and strength of the individual keys.

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