Simplified Method to Analyse Casting Sequences of Composite Bridge Slabs

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Summary

This paper presents a simplified procedure to analyse the effects of construction sequences of slabs in steel-concrete composite bridge decks. The procedure allows accounting for shrinkage and casting sequence effects. The time-dependent behaviour of the concrete is also included to capture the stress relaxation that mitigates the effects of the fast thermal shrinkage. Main features related to modelling of early-age concrete behaviour and tensile creep are discussed. The proposed simplified method is applied to evaluate the stresses in the slab of a realistic three-span composite bridge deck by considering different casting sequences. The comparison between the results obtained with the proposed method and those given by a step-by-step procedure shows the accuracy of the simplified method that can be considered a useful tool for practical applications.

Keywords: analysis, casting sequences, composite bridge decks, cracking, creep, early-age shrinkage, modular ratio method, simplified method.

1. Introduction

In steel-concrete composite bridge decks, the slab is usually constructed by fractionating the concreting. Various techniques may be used depending on specific needs at the construction site, easy of execution, and availability of special formworks. The resisting structure undergoes changes as the concrete setting and hardening proceed and the fresh concrete and the formwork weight produces stresses in slab sections where the concrete has just started to harden.

EN1994-2 states in principle the need of taking into account concrete early age behaviour and construction sequences in the analyses; evaluating the stress state of the slab is thus a very complex task that must be solved by considering properly also the concrete creep that, despite construction phases occupy a very short time interval compared to the bridge lifespan, mitigates the effects of loads and shrinkage.

The aim of this paper is to propose a practical method to evaluate the slab stress state due to the construction stages. The procedure is based on the modular ratio approach suggested by EN1994-1-1 and allows to capture the effects of the repeated concreting as well as those due to the shrinkage components (thermal endogenous and drying).

2. Simplified method for time-dependent analysis of casting sequences

The simplified analysis method consists in the execution of a series of pseudo-elastic analyses, carried out by considering different structural models, and in the superposition of the relevant results. To analyse the deck evolution and the effects produced by each slab segment it is necessary to consider N+1 models where N is the number of castings; in particular, the initial model (Model 0) is constituted by the steel component without concrete slab; in the j-th model, j segments are constituted by steel-concrete composite elements (first j segments according to the slab concreting sequence) while the other segments are constituted by the steel component only. Since the segments

https://doi.org/10.2749/222137813808627325
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have different ages, different modular ratios must be considered to properly evaluate the creep effects. The procedure can be simplified when the casting is regular and repetitive by adopting a unique modular ratios obtained by averaging the real loading times t_{wj} and the ages of the segments.

3. Case study

The accuracy of the proposed method is analyzed with reference to a three span composite bridge deck. Three different casting sequences are considered, namely: continuous casting, optimised alternated casting and continuous casting with post-connected slab.

Fig. 1 shows the comparison between the stress values along the bridge axis obtained with the proposed simplified procedures, and with a step-by-step analysis performed with an accurate finite element model. Only the cases of continuous casting and of optimised alternated casting are shown.

The results obtained at the intermediate phase are characterised by a very good level of accuracy except for the last segments for which the stresses are overestimated. The errors are due to the thermal shrinkage component and are explainable by considering that the temperature reduction is gradually applied in the accurate step-by-step analysis whereas the total cooling is applied instantaneously in the proposed procedures. At time 30 days, the discrepancies observed for the last slab segments are no longer evident as the creep relaxation mitigates the effects of the instantaneous cooling.

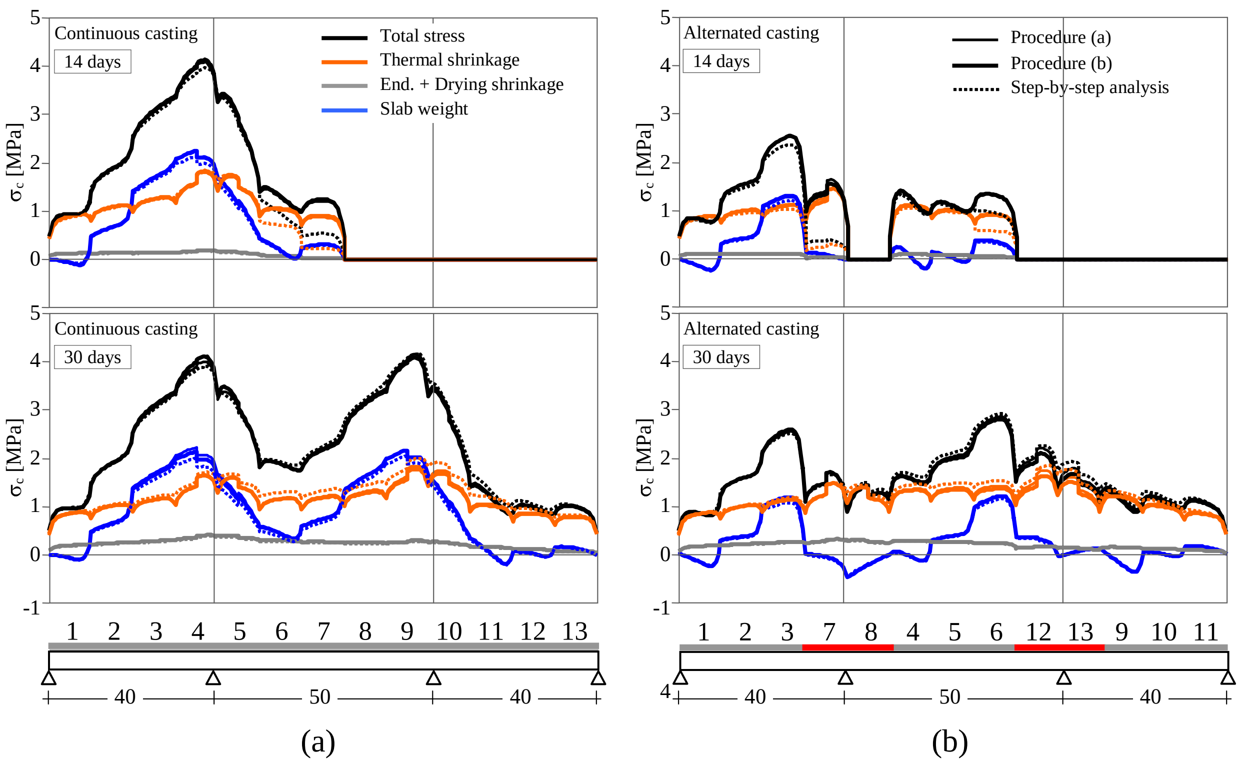

Fig. 1: Comparison between simplified and step-by-step analyses: stresses in the slab (a) continuous casting; (b) alternated casting

4. Conclusions

A practical procedure to evaluate the slab stress state due to the construction stages and to the early age shrinkage is presented. It is based on the application of the modular ratio approach suggested by the EN1994-1-1 and on the superposition of results obtained with a set of models.

The application to a case study demonstrate the capability of the proposed method to capture the stresses for a generic sequence of slab concreting not only at a final stage but even at intermediate concreting stages in which major discrepancies are attained only for few segments.