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Long Term Behaviour of Composite Concrete Structures

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Summary

The numerical simulation of the widened Javroz bridge deck demonstrates that it is essential to consider the early age behaviour of the composite deck consisting of new and old concrete layers. Actually, internal stresses mainly due to restraint of thermal shrinkage may decrease the strength of these hybrid structural elements and affect their durability. The most effective measure to limit the early age damage is to decrease the maximum temperature of the new concrete during hydration by a system of cooling pipes.

1. Introduction

The 45 year-old Javroz bridge in Switzerland, a 170m long concrete arch bridge spanning 90m, will be improved to account for future traffic needs. The existing deck slab will be modified by an additional concrete layer and larger cantilever slabs (fig.1). The challenge being to restore a service life comparable to that of a new structure. The long term behaviour and thus the durability of the modified slab must therefore be studied by considering the composite action of the new section consisting of two concrete layers of different ages.
According to [1], the adherence between old and new concrete layers decreases continuously, and the hybrid system may fail after 17 - 20 years of service. This can be explained by the fact that the influence of the early age behaviour of the new concrete is usually disregarded, and the only criterion considered is the short term adhesive strength between the two materials.

2. Description of the domain studied

During the lifespan of hybrid structural elements, three stages can be distinguished (fig.2). First, during *hardening of the new layer*, the effects of cement hydration must be considered to determine the internal stress state mainly due to restraint of thermal shrinkage caused by the old concrete support. These internal stresses are at the origin of cracking of the new concrete layer which may affect strength and durability. To evaluate this effect, the *initial damage coefficient* α can be defined as $\alpha = \left(1 - \dfrac{resid.\ strength}{init.strength}\right)$; small reduction of α (curve $\alpha_2 < \alpha_1$) leads to a significant extension of lifespan. Secondly, during *service life*, effects of temperature variation as well as dynamic and fatigue action due to traffic loading are superimposed to the initial stress state and play a major role in damage propagation. Finally, *failure* of the hybrid system is determined according to ultimate state criteria.

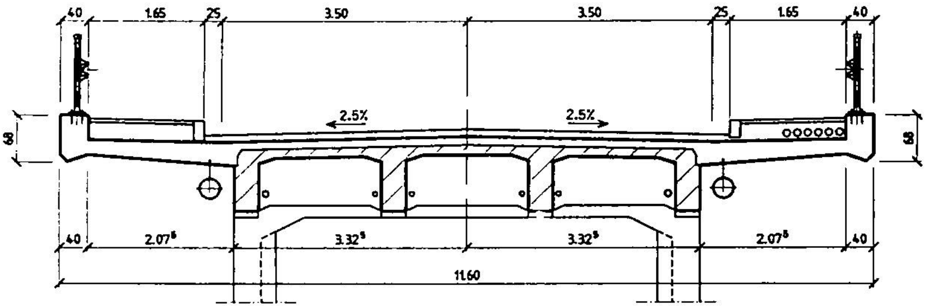

Fig. 1 Cross section of the widened Javroz bridge deck

3. Analysis of early age behaviour of a hybrid concrete bridge deck

The early age behaviour of the modified bridge deck is analysed by a numerical study [2]. The initial stress state and the likelihood of crack formation are determined [3], taking into consideration both the hydration heat release and variable environmental conditions.

For three different construction sequences, the initial state of internal stresses is obtained in terms of parameters such as cement content, temperature of fresh concrete, duration of cure, thickness and modulus of elasticity of the new concrete. The results show that reducing the cement content by 50 kg/m^3 has the same effect of avoiding early age damage of the hybrid deck as pouring of fresh concrete the temperature of which has been lowered by 5°C. The most effective measure is to decrease the maximum temperature of the new concrete during hydration. Numerical simulation shows that a system of pipes for cooling water placed in the new concrete layer allows for sufficient temperature decrease to reduce significantly internal stresses (fig.3). Without specific measures, the coefficient α is 0,75 600 hours after pouring the new concrete. Comparatively, with the use of cooling pipes in the young concrete, this coefficient is reduced to 0,30.

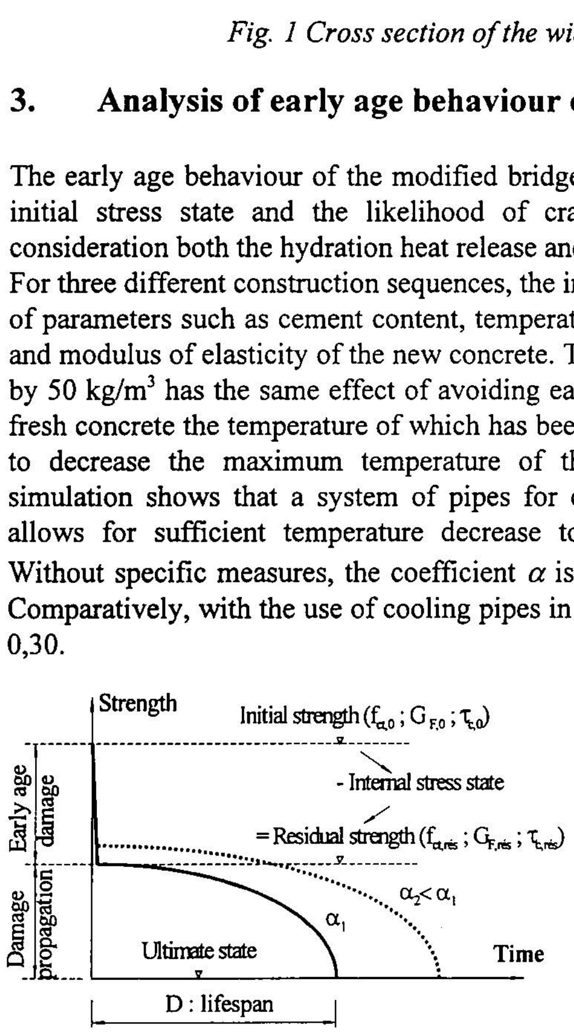

Fig. 2 Damage curve of composite concrete structures

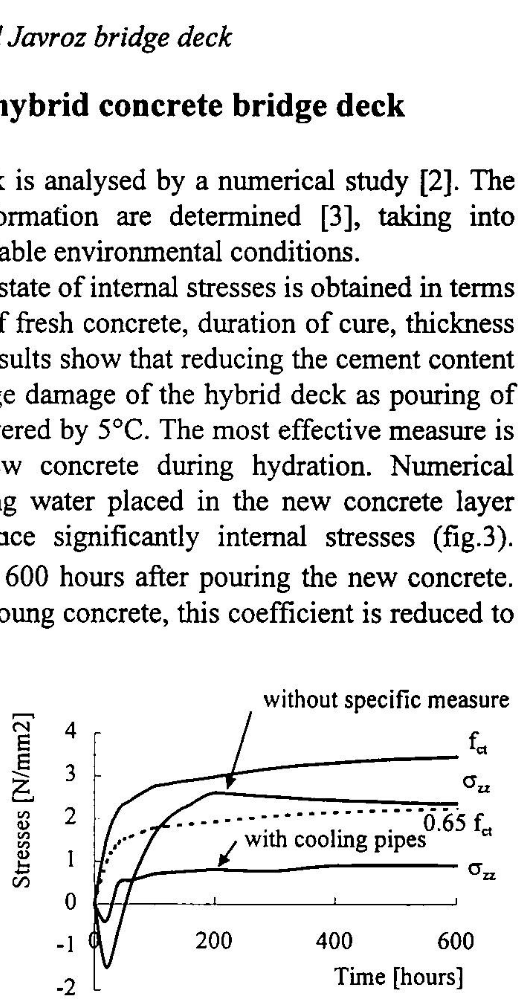

Fig. 3 Evolution of out of plane stress σ_{zz} in the cantilever slab versus tensile strength f_{ct}

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[1] Wittmann F.H., Proceedings of the 2nd Bolomey Workshop on Adherence of Young on Old Concrete, Sion, Aedificatio Publishers, 1994.

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