Bond in concrete and its consequences on the structural level

Conventional vs. memory steel reinforcement

Graduate

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Introduction: Many existing reinforced concrete structures around the world will need to be rehabilitated in the future. Depending on the structure, an increase of the ultimate limit state or an improvement of the serviceability will be required. This may be due to increased service loads, new code requirements or poor original design.
There are several non-prestressed systems available to improve the ultimate limit state, but only a few prestressed systems with certain disadvantages to improve the serviceability limit state. However, prestressed solutions would often be the most suitable option to reduce deformations and partially close cracks in the existing structure again.
A newer prestressing system that can overcome many of the mentioned difficulties is the memory steel reinforcement. It consists of an iron-based shape memory alloy (Fe-SMA) that can build up prestress through an activation process. An ongoing research project aims to combine Ultra-High-Performance Fibre-Reinforced Concrete (UHPFRC), another innovative material that is gaining popularity in rehabilitation projects, with memory steel reinforcement. The goal is to develop a new system for strengthening and prestressing the concrete deck of existing bridges.

Approach / Technology: The strengthening system, consisting of UHPFRC and memory steel reinforcement, was tested in activation and pull-out tests (Figure 1). Various measurement techniques such as Distributed Fibre Optical Sensing (DFOS) and Digital Image Correlation (DIC) were used to determine the required information. This obtained data will be used in the future to develop a new design guideline for this strengthening system. Furthermore, nonlinear finite element modelling calculations were carried out to gain a better understanding of the interaction between the UHPFRC and the memory steel reinforcement. Analytical ultimate and serviceability limit state calculations of this strengthening system were also performed on an example bridge to demonstrate the potential of the new strengthening system.

Result: During the activation tests, cracks appeared on the surface of the UHPFRC due to the uneven heating of the specimens when activating the memory steel reinforcement. As a result, the test setup of the later pull-out tests had to be modified. The memory steel inside the UHPFRC body got no longer activated. Otherwise, the pull-out tests were completed mostly successful within the planned timeframe. Innovative solutions were always found for problems that arose during the tests. The analysed measurement results showed to be of good quality (Figure 2).
The material model of the UHPFRC and the bond models of the conventional steel and the memory steel reinforcement were determined by nonlinear finite element calculations. These models can be used in further analyses.
The cross-section calculations carried out on the example bridge demonstrated the effectiveness of the UHPFRC and memory steel strengthening system. Individual construction stages were considered and it was shown that large reductions in stresses, strains and deformations can be achieved (Figure 3).

Fig. 1: Test setup of the activation tests and pull-out tests with long embedment length
Own presentment

Fig. 2: Postprocessing of the fibre optical strain measurements of a pull-out test with long embedment length
Own presentment

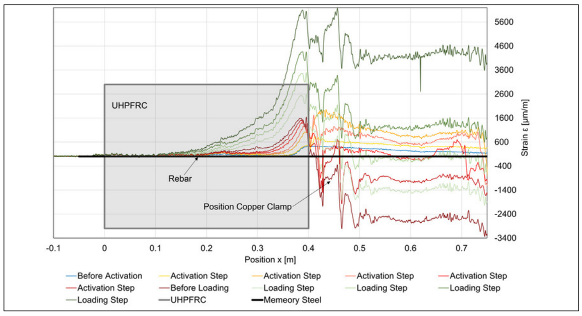

Fig. 3: The construction stages of the UHPFRC and memory steel strengthening system during the rehabilitation
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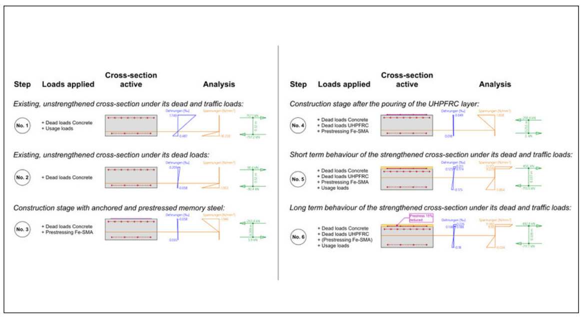

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