Interface stresses in concrete bridge deck overlays subjected to differential shrinkage

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ABSTRACT

Concrete overlays on bridge decks are expected to be more durable as compared with the more common asphalt solution. Besides stresses due to traffic load and temperature variations at service, the overlays are exposed to stresses due to long term shrinkage. Of interest is to evaluate the concrete overlay due to the shrinkage induced stresses at the composite interface. Three strategies have been employed to gain knowledge on the stresses; 1) use of non-destructive test systems via field observations, 2) a numerical study on a concrete composite slab tested in laboratory, 3) recordings of realistic shrinkage and climate data on a reference bridge using vibrating strain gauges and humidity probes in the newly cast concrete overlay. The data were used as input data for a linear elastic finite element model. This article demonstrates this last phase of the work.

Keywords: Concrete bridge overlay, shrinkage, full scale recording, FEM, shear stresses

1. INTRODUCTION

The bonded concrete overlay technique has several important areas of application; retrofitting of concrete structures, repair in general and road and pavement applications. One important factor with respect to serviceability and durability of concrete overlay solutions is restrained shrinkage [1] [2]. Failure modes expected in case of differential shrinkage are de-bonding and cracking; which one that is more prone than the other is difficult to predict though it depends on e. g. the stiffness of the structural system. Aspects of importance are; time-dependent material characteristics, climate conditions, workmanship and structural properties of the whole system.

Main purpose of this paper is to analyse interface load effects on a concrete composite bridge deck due to shrinkage. Addressed questions are 1) how does ambient climate conditions effect internal concrete climate, 2) what is the magnitude of interface stresses due to recorded in-situ shrinkage, 3) which type of defect appears first - vertical or horizontal cracks.

2. METHOD

As mentioned earlier, as a part of a PhD project, realistic shrinkage and climate data have been studied on a reference bridge using vibrating strain gauges and humidity probes in the newly cast concrete overlay, see [3]. Material properties were documented on reference specimens stored in laboratory. The data were used as input data for a linear elastic finite element model.

The bridge of which measurements and analysis were performed on is a two hinges beam-frame reinforced concrete bridge with wing walls oriented parallel to its longitudinal direction, Fig 1. Shrinkage strain, climate data etc. on site were recorded in the cover and beside the bridge (non-loaded dummy samples) by use of 12 vibrating strain gauges and 12 humidity probes equipped with wire-less on line documentation facilities, provided by Roctest Ltd and Vema Venturi AB, Fig 2a. Strain and climate readings of reference concrete samples on site and in laboratory at LTU were recorded with similar principles as concrete cover readings, details are given in [3].

Finite element modelling was done by the use of ATENA Science software package. One fourth of the bridge was modelled due to an assumed double symmetric load situation due to shrinkage, thus neglecting that the whole overlay as such was cast at two occasions with four weeks in difference, Fig 2b. All elements modelling the concrete are 8-noded linear 3D solid “brick” or hexahedron, isoparametric elements integrated by Gauss integration at 8 points.

3. RESULTS

Fig 3 shows typical climate history (*T* and *RH*) in the concrete overlay (a) and example of shrinkage strain readings in laboratory (b) and at the site (c). While the laboratory stored specimens show contraction the site readings show a mix of expansion and contraction - a reason that has been difficult to explain. Fig 3d shows typical interface shear stress from FE.

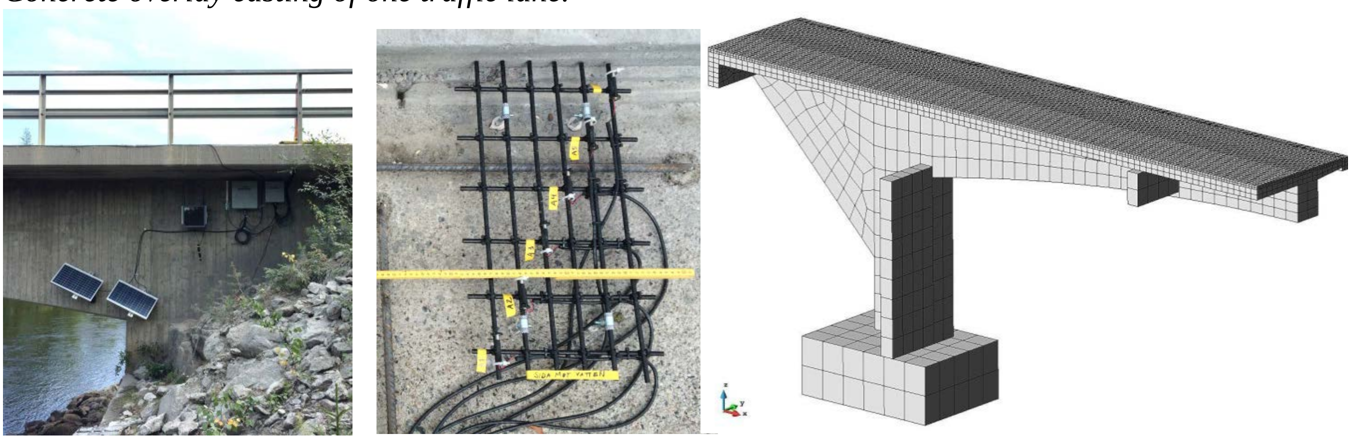
4. DISCUSSION AND CONCLUSIONS

All strain values are small in general compared to what was expected but could be explained to an extremely favourable humid climate at the time of curing and months afterwards during autumn. Moreover, a more or less constant access of evaporating water from the river might be a factor reducing the shrinkage even further. Next spring may give a higher shrinkage of the cover – this will be evaluated in future work. The work will end up in recommendations and guidelines to support future design and executions, see discussions in e.g. [4].

The following comments and conclusions on the study so far can be identified:

- No surface cracks were found up to late autumn (some four months after casting)
- Strain and climate readings from the bridge could be documented wireless during more than 300 days without any larger interruptions and other possible problems.
- Small shrinkage values are obtained due to favorable, humid, climate conditions.
- Small interface stresses were obtained in FE analyses based on autogenous shrinkage strain from in-situ placed specimens.
- The results will be a base for further development of FE model as well as for establishing recommendations/guidelines.

Fig 1. Studied bridge with a span of 25 m and a total length of 37.5 m, bridge deck width: 6.9 m. Concrete overlay casting of one traffic lane.



a) b)

Fig 2. a) Parts of test setup on site: head unit for web/energy/storage service and grid with 6 vibrating wire gauges b) Finite element ATENA model. 1/4th of the geometry, 25 000 elements.

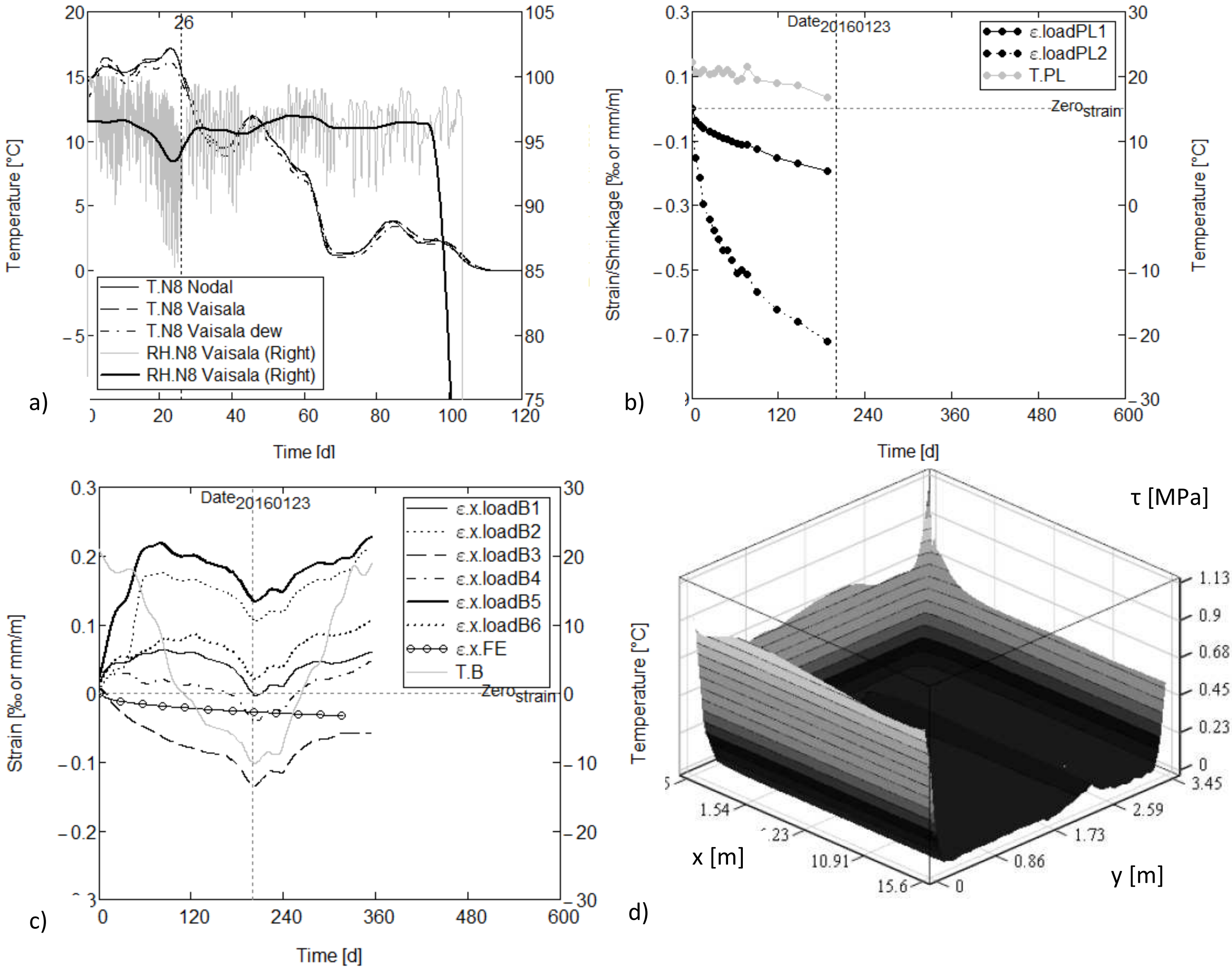


Fig 3.a) Climate data (first 118 d) b) Example of shrinkage - indoor specimens c) example longitudinal overlay strain (first 300 d) d) FEM interface shear stress [MPa,] outer1/4 part

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