Widening of the bridge over Zijkanaal C in highway A9 near Haarlem

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Summary

In 2008 the bridge over Zijkanaal C had to be widened at both sides to accommodate an additional (rush hour) driving lane. The design was confined with a number of conditions which made straightforward widening of the deck unfeasible. Primary reasons were large forces due to restrained deformations in combination with a lack of reinforcement in the original girders. Furthermore differential deflections due to traffic between old and new during construction were too large for hardening concrete. (Partly) closure of the bridge for a couple of days was not tolerable. An innovative method has therefore been used to couple the extension to the original deck requiring closure of the bridge for heavy traffic for no more than 12 hours. The calculations of the long term forces are based on Trost method [1] adapted to be used with a ordinary FE model.

Keywords: Bridges, creep, shrinkage, Trosts-method, post-tensioning, widening, rapid construction, drilling.

1. Introduction

In the early 1970's the bridge over Zijkanaal C in highway A9 near Haarlem was build. The bridge consists of a bascule bridge and 12 approach spans. Increased traffic required an additional rush hour lane per direction. The bridge was widened with one normal and one edge pre-tensioned girder along a deck, see Fig. 1.

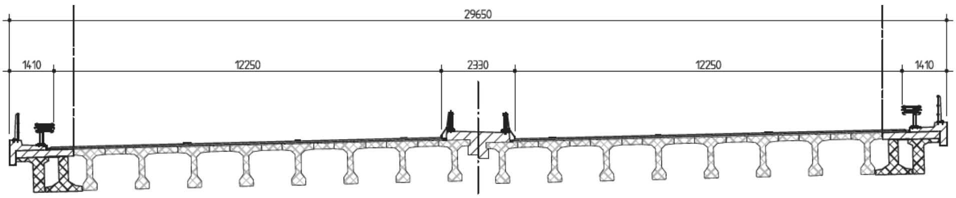

Fig. 1: Cross section with new girders

Usually starter bars would have been glued-in the top flange of the old beams, to be lapped with the reinforcement in the new cast in-situ deck slab. In this case such was not possible due to the lack of transverse reinforcement in the original deck beams. Another issue was the initially very short available period of 28 days between production of the new girders and their connection to the old deck slab. This resulted in large calculated forces between the old deck and the extension due to restrained creep and shrinkage deformation. Analysis showed that coupling was just possible after 180 days.

Calculations made of the original deck structure showed that the deformations due to traffic loads were too large for hardening concrete. Closure for such a period certainly was not an option.

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2. Solution for widening

Based on afore mentioned issues the best solution seemed extending the existing transverse post-tensioning bar-tendons, and to post-tensioning the extension of the deck against the existing structure. The new deck area could then be completed prior to connecting it to the old deck leaving a joint of a couple of cm's in between to be filled with a rapid hardening mortar before being post-tensioned. To avoid differential deflections between old and new parts the bridge was closed during this operation for heavy traffic. After about 12 hours the deck could be reopened for all traffic.

The demolition of the old edge was done carefully to avoid damage to the transverse post-tensioning bar-tendons. All bars survived this demolition, and about 80% of the bar-tendons remained undamaged, and could be extended. Because almost every single bar was necessary most damaged bars had to be replaced. Due to the lack of reinforcement in the old prefabricated girders it was decided to anchor the replacement strands into the second girder from the edge. This required holes of 2,7 m long 'horizontally' drilled through the 1st and 2nd girder and the cast in-situ part in between. The bond anchor consists of an ordinary strand which has been 'twisted' open to improve bonding. The capacity of this bond anchor was proved by testing.

2.1 Calculations

Three different design situations have been analysed using different FE models. The first model was used for the original situation without the extension, to get a reference for the forces and deflections in the original deck structure. It also showed rather large deformations could be expected due to traffic load, which later on were confirmed by measurements. The second FE model was used for the complete deck under short term loads like traffic. The third FE model for the complete deck was used to calculate the long term force distribution in the deck due to shrinkage and creep. Due to the young age at which the new precast girders would be coupled to the old structure it was expected that restrained deformation would play a major role.

Use has been made of Trosts method for the long term (force) distribution in the structure due to changes in loading over time $F(\infty) = F(0) + \Delta F/(1 + \chi \cdot \varphi)$, in which F(0) = initial effect and $\Delta F/(1 + \chi \cdot \varphi)$ = effect of changes in time. The forces from the restraint deformations not only led to more pre-tensioning in the new girders, but also effected the reinforcement in the deck extension.

The tensile force in the strands will introduce splitting forces on the deck slab. The total post-tensioning force of 2 strands replacing a bar tendon was kept equal to the force approximately present in the bar tendon to reduce the risk of splitting.

2.2 Tests and construction

No data was available about adhesive anchoring of strands dia. 15,7 mm in deep (2,7 m) drilled holes. First workability was tested in cooperation with the subcontractor for the post tensioning system. Several horizontal transparent tubes were filled with adhesive and strand using different working methods. After hardening the filled tubes where cut in pieces to investigate the degree of filling of the opened strand. To further test the method and the bond achieved several deep holes were drilled into the abutment of the bridge, and strands were glued-in with the selected method. After hardening of the adhesive these strands were tested by applying a pulling force.

Construction started with the removal of the old curbs and edges of the deck. This was followed by inspections of the bar-tendons in the existing deck, testing of the tread of the tendons, and test loading up to 250 kN. Before installation of the prefabricated girders for the extension on the widened abutments and piers the required holes were drilled in the deck. The (lost) formwork and reinforcement of the new deck slab was installed. The existing anchors which could be extended were prolonged, and the necessary strand anchors were glued-in. Finally the deck slab of the extension was casted.

The closure of the final gap between old and new deck was done in a weekend when the new deck had gained sufficient strength. In the period when no heavy traffic was allowed first the gap was filled with rapid hardening mortar. After a couple of hours this mortar had developed sufficient strength to allow post-tensioning of the bars and strands.