Reinforcement of the beams of Saint-Nazaire – Saint-Brévin Bridge

Francis LANQUETTE
Civil Engineer
Setec TPI
Paris, FRANCE
francis.lanquette@tpi.setec.fr

Francis Lanquette, born 1982, received his civil engineering degree from the Mines de Nancy engineering school.
He has been working at Setec for 7 years on bridge and tunnel projects.

Summary

A number of beams (out of a total of 120) of the access bridges of the Saint-Nazaire – Saint-Brévin Bridge had some defaults affecting the prestress tendons of the precast concrete beams. Consequently, the owner decided to reinforce the South access decks, from the abutment to the main bridge, which is a steel cable stayed-bridge. The aim of the reinforcement was to increase the prestress and to confer more ductility to the beams. The chosen solution consisted in reinforcing the beams with reinforced concrete cast on the lower part of existing beams. A comprehensive study of the influence of prestress tendon failure was made, modeling failures at various positions and taking into account an increasing number of broken tendons. Moreover, this study showed the underlying lack of resistance of the beams with regards to shear stress, shear stress reinforcement was thus designed using carbon fibers. The finite-element software Pythagore developed by Setec tpi allowed us to construct an original model composed of beam and slab elements. With this model a non-linear analysis was performed simulating the deterioration of prestress, progressively deactivating parts of the tendons.

Keywords: prestress, failure, reinforcement, non-linear, beams, corrosion, composite

1. Introduction

The Saint-Nazaire bridge is located on the departmental road 213, in the French department of Loire Atlantique. With a total length of 3 356 m, it is the longest French bridge. It is composed of a 720 m central cable-stayed bridge, 22 access spans for a length of 1 115 m to the north, and 30 access spans of 1 521 m to the south. The decks of these access bridges are made of precast concrete beams. The bridge was built between 1972 and 1975. The Conseil General de Loire Atlantique is responsible for its management and its maintenance since 1995.

2. Description of the South access bridge

Each bridge has a 50,70 m long span, and is made of four precast and prestress concrete beams. These beams are 2,80 m high and 3,00 m wide (the slab is integrated with the beams). The heel of the beams is 0,80 wide. Between the beams, a 0,50 m wide slab is cast to interlock the beams, in addition to bracings at the extremities of each side of the deck. Each beam is longitudinally pre-stressed by ten tendons, made of 20 to 28 flat wires. The deck is not transversally prestressed.

3. Design of the structural reinforcement

3.1 Objectives of the reinforcement

Although the bridge did not present risks of short-term instability, the discovery of a highly damaged beam highlighted the necessity of structural reinforcement of the whole south access bridge, more exposed to sea sprays that the north access bridge. The design of the reinforcement

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must allow the maintenance of the bridges current functions, taking into account the probable evolution of the observed damages. The principle of the reinforcement must be universal: the design must be adapted to every part of the beams, those in good condition and those that are degraded.

3.2 Principle of the reinforcement

The model of the bridge has been constructed with the Pythagore software, which is developed internally by Setec tpi. The failure cases were simulated in order to have a wider range of results as possible, for 6 cross sections along the beam. For each section, 7 combinations of failure were identified as maximizing the effects on the bending moment and the shear. Both edge beams and central beams have been studied. The first step of the design consisted in finding the maximal quantity of additional prestress that could be supported by the beams, in order to be able to support as many tendons failures as possible in one section. The second step of the design dealt with the bridge stability under ULS combinations. The ULS stability must be assured with the maximum failure possible (objectives: 70 % for fundamental ULS and 100 % for accidental ULS), with a control of deflexions, in order to limit the overtensions of the remaining tendons.

3.3 Calculations

The webs of the beams were modeled by linear elements (0.80 m wide, 2.82 m high) whose cross sections were meshed in order to affect a non-linear behavior to the concrete (multi-fiber model).

For the SLS, the model allowed the determination of the stresses in the heel during the various stages of the reinforcement, to assure that in each failure case the heel remains compressed, as we can see in the envelope of the inferior fiber stress in an edge beam. With no traffic loads after the tensioning of the additional prestress, we could check that the stresses in the central beams, the most compressed, are acceptable.

For ULS combinations, the multi-fiber model allowed the calculation of the stress in the concrete and in the rebars (existing ones and additional ones), and the overtensions in the existing prestress. The calculation of shear stresses allowed the evaluation of the lack of resistance to shear effort regarding the existing transversal rebars, in order to estimate the quantity of composite reinforcement to apply on the beams.

3.4 General presentation of the reinforcement

On the basis of the described calculations, the following reinforcements were adopted:

- Additional external prestress: 4 tendons 8T15S per beam, placed in HDPE sheath;
- Surface preparation, and application of a corrosion inhibitor under the heel;
- Reinforcement of the heel with ϕ40 rebars cast in concrete sealed to existing beams with transversal rebars;
- Realization of the reinforced concrete pads, integrating the prestress anchorages;
- Realization of the deviator pads supporting the effort of the angular deviation of the tendons;
- Reinforcement regarding shear effort with composite bands surrounding the beam up to the slab;
- Application of a 2-component polymer modified waterproofing coating on the whole surface of the beams (except the slab).

4. Conclusion

Thanks to the calculation performed for the reinforcement of the Saint-Nazaire bridge, an efficient solution could be found to extend the bridge's life. The technical solution we have designed is innovative as it has never been used for a bridge made of precast and prestress beams with such dimensions (height of 2,82 m, length of 50 m). The construction works are now in progress, since July 2010. Thanks to outstanding working platforms, the contractor, Bouygues TP RF, has been able to reinforce one span in 3 months, including all operations.