

# Renovation of Nijkerker bridge - Innovative procurement and intensive collaboration lead to optimal approach

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**Abstract.** The Nijkerker bridge (est. 1965) proved to have insufficient structural capacity to carry the current traffic loads. A contemporary way of collaboration between Rijkswaterstaat (the Dutch Highway Agency) and private parties was introduced for this project. After the design phase, renovation of the bridge was chosen instead of demolition and construction of a new bridge. Due to the collaboration between the parties involved, an optimal solution was found to increase the lifespan of the bridge by the demanded 30 years and minimize the traffic hindrance during the renovation of the bridge.

## 1 Introduction

The Nijkerker bridge (figure 1) is the connection between the provinces of Gelderland and Flevoland. The provincial road N301 crosses the waterway, the Nijkerkernauw, to connect the Highway A28 and the provincial road N305. Furthermore, the bridge is part of the Nijkerker lock complex. The bridge and lock were built between 1963 and 1965. The bridge consists of a two-directional traffic lane and a bicycle path in both directions on the outer sides of the bridge deck.

The Nijkerker bridge is composed of 15 spans and has a total length of 300 meters (figure 2). Yearly 35.000 ships pass the bridge under the bascule bridge between pillar 13 and 14. The other 14 spans are 19,5 meters in length and are made up of 12 prestressed prefabricated concrete I-girders (figure 3 and 4). The I-girders are connected by an in-situ casted concrete deck. The total width of the bridge deck is 14 meters. A remarkable

property of the prestressed I-girders is the absence of shear reinforcement. The pillars of the bridge consist of a crossbeam, columns and foundation.



Fig. 1. Nijkerker bridge from above during execution phase

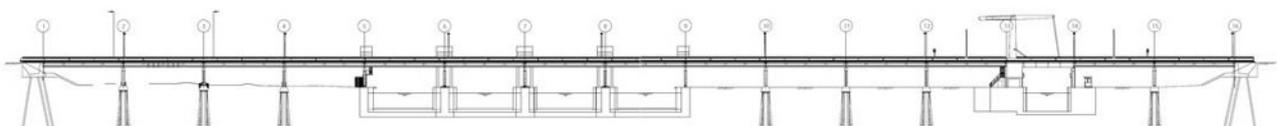
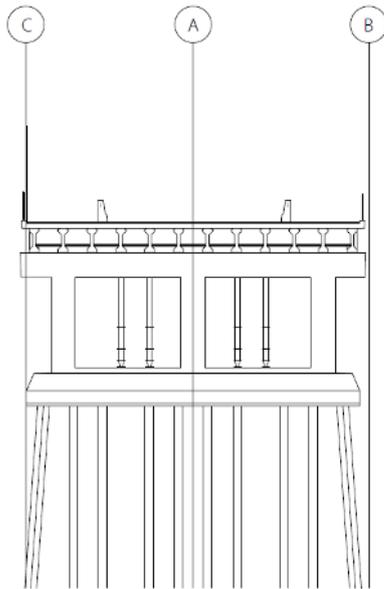
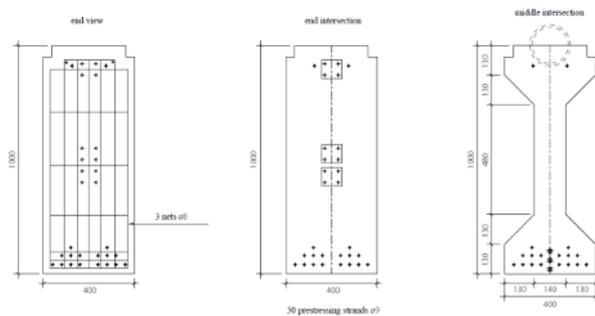


Fig. 2. Longitudinal section existing situation

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**Fig. 3.** Cross section existing situation bridge deck and pillar



**Fig. 4.** Cross section existing situation girders

## 2 Status of the bridge

The bridge was initially designed for a traffic non-compatible for highway loads. The traffic load and intensity has increased significantly since the 1960s. Inspections and research carried out before the start of the project revealed various damage to the structure. The pillars exhibited concrete damage due to chloride-initiated corrosion of the reinforcement [1]. The damage is caused by the intrusion of de-icing salts due to leaking expansion joints. Furthermore, one span (between pillar 2 and 3, see figure 2) was severely damaged as a result of several traffic collisions.

From various inspections, research and structural calculations it was concluded that the bridge did not have sufficient structural residual capacity for the desired lifespan. Before the project started, various (temporary) measures had been implemented for this purpose by Rijkswaterstaat. The pillars were strengthened with steel props, the traffic load was restricted, some severely damaged I-girders were replaced in the span between pillar 2 and 3. In addition, barriers were placed on the bridge deck to avoid the possibility of heavy vehicles on the structurally weaker sides of the bridge deck. Furthermore, a height

restriction was placed to prevent further collisions with the span between pillar 2 and 3.

## 3 Project approach

### 3.1. Procurement

Rijkswaterstaat choose for a non-typical approach, called ‘project DOEN’ (literally: ‘Project DO IT’), compared to other projects. Rijkswaterstaat did not compose a complete program of requirements, but merely a minimal description of the demands and the reasons behind those demands. Furthermore, Project DOEN is a unique project intended to facilitate the cooperation between Rijkswaterstaat and private parties. This project offers an opportunity to deviate from the existing rules and procedures to work with a common goal: ‘fair money for fair work’ and ‘maximum customer value’.

The procurement phase consisted of several stages by which the goal for Rijkswaterstaat was to find the best suitable contracting partner. After several stages, the pre-award was awarded to the combination ‘NU’ which was a combination of the two contractors: Mourik and BESIX. The combination NU was selected among other things on cooperation competences, action plan and analysis of customer demands.

The assignment for the Nijkerker bridge was to realize a (structural) safe bridge connection with a life span of 25 till 30 years without any restriction of the traffic load. The (new or renovated) bridge had to be fully operational for traffic, without any restrictions, in the third quarter of 2018. The bascule bridge and the lock are not part of the project.

### 3.2. Renovation or rebuilding?

Mourik, BESIX and Rijkswaterstaat started working together as one team before the design, price and contract were defined. During that stage different solutions were possible. The solutions included rebuilding the bridge, renovation of the bridge and several combinations of rebuilding and renovation.

There has been intensive collaboration from the beginning of the design stage with Vogel (concrete maintenance and engineering) and ABT (structural engineering). Various possible solutions have been optimised during the design stage. Furthermore, the costs, execution time and the hindrance of the possible solutions have been identified. Minimising the hindrance for road users was one of the most important criteria.

### 3.3. Structural capacity of the bridge

The bridge has been assessed to see if it conformed to the level ‘operation’ conform the national Rijkswaterstaat guideline RBK 1.1 [2]. It was concluded that the bridge did not satisfy the structural demands because the structural capacity was insufficient to bear the (traffic) loads in accordance with the Eurocode NEN-EN 1991-2. An overview of the unity checks from the structural assessment by Rijkswaterstaat are given in

table 1. If the unity check is larger than 1.0 the construction cannot resist the load and should be strengthened or redesigned.

**Table 1.** Existing bridge parts and their capacity unity checks

Pillars		Unity check
Beams	bending moment capacity	1.5
	moment at support capacity	1.6
Columns	breaking load capacity	2.1
Foundation	moment at support capacity	1.9

Fields		Unity check
Prestressed girders	bending moment capacity	1.3
	shear force capacity	1.6

Bridge deck		Unity check
	bending moment capacity	2.0
	bascule bridge - shear force capacity	1.3

Given the high exceedance of the unity checks, it was not expected in advance of the project that renovation of the bridge was possible and suitable. Because of knowledge and experience of various specialised parties, renovation of the bridge was investigated as a serious solution and several additional researches and examinations were executed.

### 3.4. Additional research

Since it was uncertain whether the bearing capacity of the foundation was sufficient, additional geotechnical research was executed with positive results. The supports and the girders have been examined for concrete damage, chloride intrusion and the suitability and necessity for the application of cathodic protection. The occurring traffic vibrations were monitored to show that the installation of (concrete) reinforcements would be possible with continuing traffic on the bridge.

By means of bond strength tests it has been shown that increasing the moment capacity with externally applied carbon fibre reinforced polymer strips (CFRP; adhesive reinforcement) was feasible. The possible presence of reinforcement corrosion in the bridge deck has been mapped out by performing potential measurements. This showed that the existing damage to the bridge deck was far more limited than had been assumed in advance. In combination with more advanced

structural calculations, it has been shown that the bridge deck could be fully preserved.

From the aforementioned studies, in combination with the renovation execution methods to be applied, the important conclusion was ultimately drawn that renovation of the bridge was technically possible.

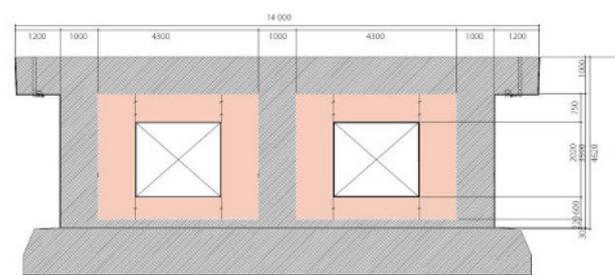
### 3.5. Final choice: renovation

Limiting hindrance to traffic during construction on the bridge was the most important criterion in the final choice between the various solution alternatives. The other criteria related to the duration of the execution concerning the opening date, risk profile, sustainability and costs for execution and maintenance. For the further elaboration of the design, the execution method and price, the customer has decided for the renovation of the Nijkerker bridge.

## 4 Execution phase

### 4.1. Strengthening pillars

The constructive strengthening of the pillars consists of installing concrete walls by which an opening of 2.0 by 2.3 meter is maintained (figure 5). The columns and lower and upper beams provide the load transfer from the bridge deck to the foundation. The reinforcement structure is anchored with reinforcing rods to the existing structure. After placing the formwork, the reinforcement is provided with self-compacting concrete. The advantages of this reinforcement measure include the preservation of building-historical value, the positive ecological effect for flora & fauna, and social safety. For the sake of practicability, the advantage is that the temporary jack post constructions could be removed after sufficient curing (figure 6).



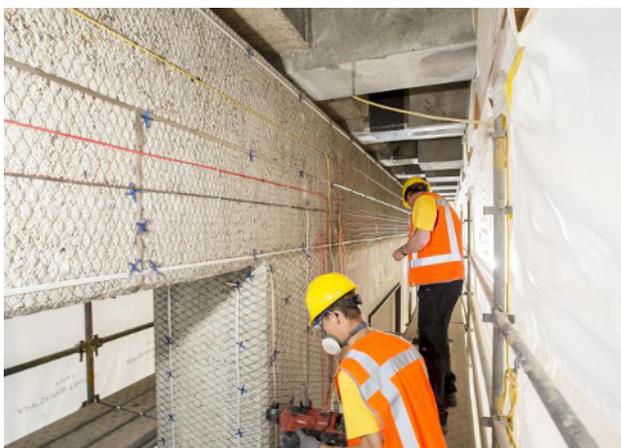
**Fig. 5.** View of the strengthening pillars with poured columns and lower and upper beams. The coloured parts refer to the new concrete strengthening



**Fig. 6.** Pillar during execution with the (temporary) jack posts to be removed.

To prevent concrete damage due to corrosion of the existing reinforcement and to safeguard the constructive bond between existing and new concrete, the pillars are provided with an impressed current cathodic protection system which was designed according to the Dutch Recommendation [3]. For this protection technique, titanium strips have been fitted between the existing pillar and the new columns and lower and upper beams at the inner surfaces of the pillar. Titanium nets have been placed on the external concrete surfaces of the existing pillar (figure 7). The existing reinforcement is checked for electrical continuity and connected to the negative pole (cathode).

Subsequently, a low voltage of approximately 5 volts is applied between the reinforcement to be protected (cathode) and the titanium strips and nets (anode). As a result, the reinforcement receives a protective current that prevents corrosion and detachment between existing concrete and the reinforcement. The CP-system of the pillars is finished with a 25 mm layer of shotcrete. The support points are provided with a coating.



**Fig. 7.** Application of cathodic protection to preserve the concrete pillars

## 4.2. Strengthening girders – moment capacity

The moment capacity of the prestressed I-girders under the bridge deck has been increased by applying carbon fibre (CFRP: carbon fibre reinforced polymer) strips. The design of the CFRP is based on the German DAfStb guideline 'Verstärken von Betonbauteilen mit geklebter Bewehrung' (Reinforcement of concrete members with glued reinforcement) [4], which can also be applied to prestressed structures. This directive also forms the basis for the new edition of the Eurocode 2, which includes the use of carbon adhesive reinforcement.

Depending on the span, the beams are provided with 2 or 4 strips over the entire span (figure 8). The strips are glued with epoxy and anchored at the beginning and end of the strips by means of carbon fibre sheets and CFRP fabrics. Applying carbon strengthening reinforcement on prestressed girders on this scale, while traffic continues to use the bridge, is unique in the Netherlands.



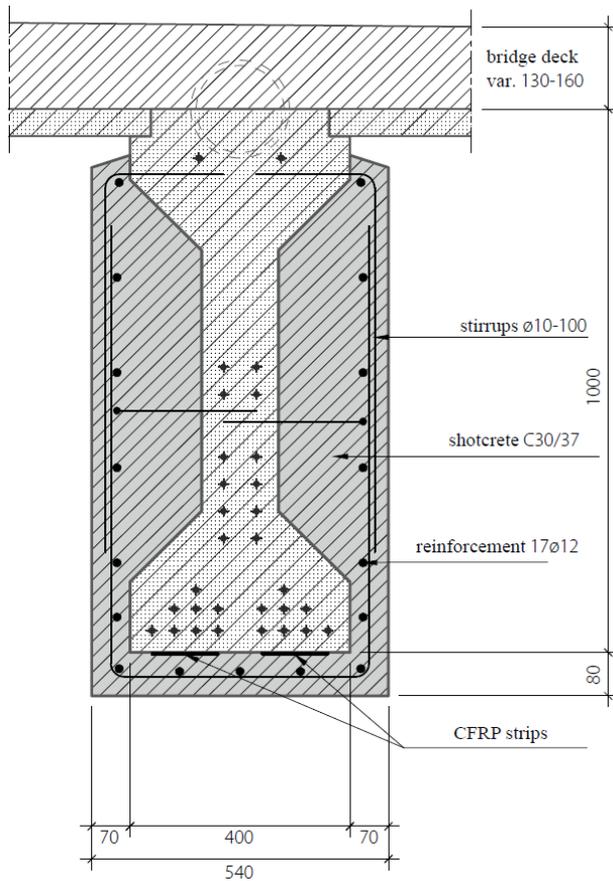
**Fig. 8.** Application of CFRP strips to the prestressed girders

## 4.3. Strengthening girders – shear capacity

The shear capacity of the I-girders has been increased by thickening the beams all around with a reinforced shotcrete shell and steel reinforcement stirrups. The reinforcement is only applied where the shear capacity had been exceeded. Close to the support, no shear force is exceeded due to direct transfer to the support. The strengthening is installed 470 mm from the bearing over a length of 6.2 metres.

Since the strengthening does not extend above the support, it was not necessary to jack up the bridge deck construction. The girders are fitted at the top with L-shaped stirrups and at the bottom the bracket is closed by a U-shape with a diameter of 10mm (figure 9 and 10).

The advantages of using shotcrete are the good adhesion and compaction, easy formwork and the transportability of the concrete across the construction site from the silo to the processing location.



**Fig. 9.** Strengthening shear capacity



**Fig. 10.** Span after application of carbon strengthening strips and shear strengthening

#### 4.4. Bridge deck approach

The road layout, consisting of two bicycle paths on the outer sides and a 7-meter traffic lane in the middle of the bridge, will be preserved. The current barriers are preserved as a separation between the traffic lanes and the bicycle paths. Additional calculations have shown that no constructive reinforcement was necessary for the existing bridge deck.

The bicycle paths have been provided with new asphalt and the drainage has been improved. The bridge deck under the cycle paths has been repaired where

necessary and provided with cathodic protection in the form of sacrificial anodes to extend the life of the concrete repairs. For the removal of inferior concrete parts, a hydrodemolition robot was used by which the concrete is removed with high pressure while the reinforcement steel is kept intact and vibrations to the construction are prevented (figure 11). The expansion joints have been replaced by renovation joints.

One out of the total of 14 concrete spans has been completely replaced by a new bridge section. This bridge section suffered significant collision damage. It has been decided to replace the girders of this field with box girders and to increase the clearance height so that it will be 4.5 meter (figure 12). As a result, the height restriction of the underlying road has been lifted and the height portals have been removed.



**Fig. 11.** Deployment of hydrodemolition robot



**Fig. 12.** Replacement of 1 span by a new bridge section

## 5 Final remarks

The described execution of the constructive strengthening and protection works mainly took place under the bridge and were carried out while traffic on the bridge was unobstructed. As a result, the hinderance for passenger cars, freight and agricultural traffic was limited to a minimum.

The bridge was closed to traffic only for a regular weekend in May 2018 and a long weekend in June 2018 to replace the expansion joints and to place the new bridge section. The construction of the entire bridge started in September 2017. The opening took place at the end of August 2018.

Project Renovation Nijkerker bridge is a unique project in which the technical knowledge from the market parties and Rijkswaterstaat has been combined through the form of cooperation. The design process ensured that technical solutions could be devised by deploying the knowledge and experience of various professionals. In this way, a working and feasible design has been developed, with the result that the bridge is spared and the environment is spared a lot of hinderance.

The form of cooperation offers many advantages for the future. The applied technical solutions for the renovation and the execution period with minimal hinderance are promising, especially in view of the maintenance task that the Netherlands will face in the coming decades.

## References

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