MONITORING OF FIRST RECYCLABLE BRIDGE IN THE WORLD

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MONITORING OF FIRST RECYCLABLE BRIDGE IN THE WORLD

BY CHRIS FIELDING

Adapted from original paper by DIPL. ING. R.P.E.M. JANSEN / DIPL. ING. K. LÖFFLER

Summary

The Dutch Government Entity for Infrastructure, Rijkswaterstaat, has the ambition to work using recyclable (circular) bridge construction techniques. This means that the traditional methods of bridge construction are no longer applicable. These new systems are fast to erect, decrease waste, and minimize the CO_2 footprint of the bridge.

The whole process from design to execution and subsequent demolition is different. All steps are completed using minimal quantities of primary raw materials, but these must also be reusable in the future.

Background

In many areas, a bridge is designed by architects in combination with the needs of the client. When the architectural design is finished, the engineers step in to make the design a reality, focusing on functional construction methods. This often results in an executable bridge with a design life of 75 to 100 years. In service, bridges often have a lifespan of 30 to 50 years, especially bridges where maintenance is inadequate.

The recyclable bridge is built with a different approach. The engineers design a bridge that is reusable, reaching that goal by using concrete blocks that can be connected, similar to Lego® blocks (Fig. 1). The architect is brought into the process later and creates a design around the basic structure. With this approach, the construction team is leading the process with sustainable ideas that can be implemented.

Concrete and steel production generate high amounts of CO_2. If we can reduce this by minimizing the quantities used, while at the same time making it reusable, our objective can be achieved. This prompted the idea of using precast and modular principles.

The bridge was designed to span between 49 and 82 ft (15 and 25 m), with a width between 25 and 49 ft (7.5 and 15 m). The deck is constructed using 40 concrete elements of two different shapes: end blocks and intermediate blocks. The 40 blocks are tensioned together longitudinally and laterally.

Fig. 1—Recyclable bridge design.

Concrete Blocks

The concrete blocks are made of two different shapes: a 'head' block and an 'intermediate' one. The intermediate blocks are hollow to reduce material use and cast using reusable formwork. The head blocks are more robust to accommodate load transfer to the bearings and transferring load from post-tensioning (PT). The blocks are installed behind each other and tensioned together to create a girder (Fig. 2).

The girders in the pilot project have a length of 66 ft (20 m). In total, five were produced to provide a bridge width of 25 ft (7.5 m). The post-tensioned girders were then transported to the jobsite. At the jobsite, the five girders are positioned and tensioned in the perpendicular direction. To have a good load transfer, all the connections between the blocks are made with shear keys.

Post-tensioning

The concrete blocks are made as a Lego®-like system and can only be functional if they are tensioned together in two directions. In a regular post-tensioned bridge (precast or in-place), the post-tensioning bond is placed or grouted

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after tensioning. These bonded systems are not reusable; therefore, an alternative solution was needed.

A major step was to move from a bonded to an unbonded post-tensioned system. All parties involved agreed to progress from traditional principles to develop this idea. With an unbonded post-tensioned solution, reusable blocks become a possibility.

Longitudinal Post-tensioning

The regular unbonded systems are made with single strands that are sheathed and filled with PT coating. Strand systems are anchored in the anchor body with wedges. Unfortunately, wedges cause damage to the surface of the strand during each individual stressing step (Fig. 3). This causes a local inhomogeneous stress distribution and might reduce the global performance of the system.

Restressing of these systems is therefore only accepted under limited conditions. In the longitudinal direction, the solution was found using a proprietary European-approved tendon (Fig. 4). The system is a pre-manufactured tendon based on up to 84 wires 0.28 in. in diameter (Ø7 mm), Grade Y1670 and Y1770, providing total prestressing forces of up to Pm0 = 4.123 kN (950 lb) according to EN 1992-1-1. In this project, tendons with 66 wires 0.28 in. in diameter (Ø7 mm) in a grade of Y1770 were installed. The wires are anchored in the steel body of the anchorage by cold-formed button heads. The basic body with its outer thread is connected

Table 1—Measurement table

Type	Purpose	Sampling rate
Camera	To photograph the vehicle during a dynamic measurement cycle	Each traffic movement
Vehicle detector	To identify the speed and direction of traffic, record a photo, and trigger dynamic measurement recordings	Continuous
DYNA Force® sensor	To measure force in the Wire EX Tendons	Every 15 minutes
Displacement transducer	To measure vertical deflection (bending) of the deck at the abutments, quarter, and midpoints	20 Hz during traffic Every 15 minutes
Crack sensors	To measure bird gapping between blocks	20 Hz during traffic Every 15 minutes
Temperature sensor	To measure temperature at abutment and midspan, both top and bottom	Every 15 minutes

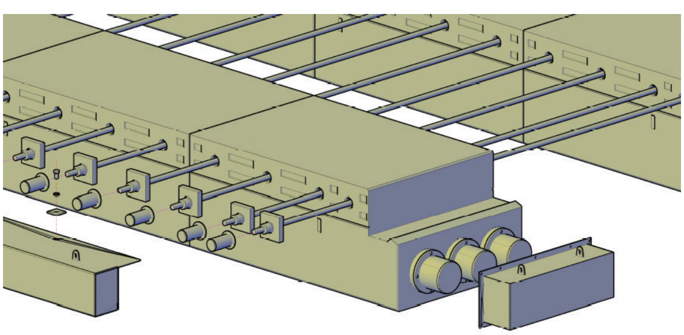

Fig. 2(a)—Concrete block diagram.

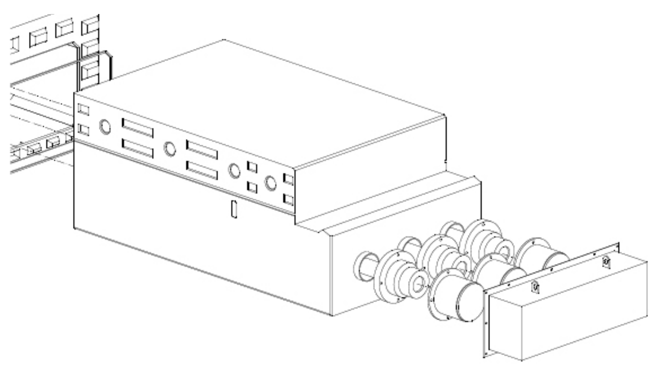

Fig. 2(c)—Head/end block.

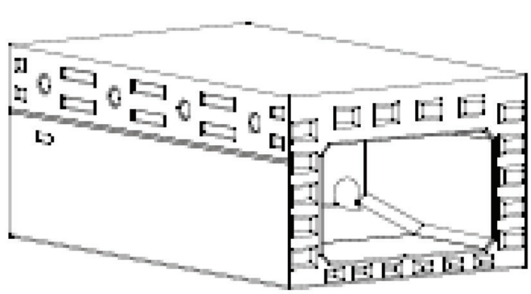

Fig. 2(b)—Intermediate block.

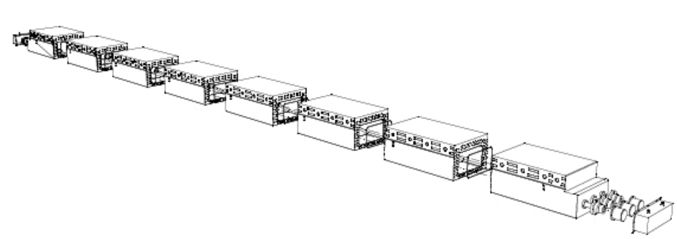

Fig. 2(d)—Post-tensioning girders.

tightly with the smooth polyethylene (PE) sheathing of the tendon. The ring space between the wires and the PE sheath is wax injected at the manufacturing plant.

For stressing, a tensioning sleeve is attached on the basic body and the system stressed by a high-grade tensioning spindle. Finally, the bearing nut is screwed on the tensioning sleeve anchors, securing the applied prestressing force permanently.

The components of the system transfer the loads by threaded parts. This method allows the tendon to be restressed, de-stressed, and exchanged without demolition of the tendon at any time, if required. Tendons can also be extended with a unique coupler, rendering a fully adjustable length.

Perpendicular Post-tensioning

As this is also an unbonded system, within the range of stress bars, hot-rolled prestressing thread bar (WR), Grade Y1050, was used (Fig. 5 and 6). The bars were pre-assembled in the production facility. The corrosion protection used was a double layer of protective tape to minimize the risk of damage during execution. In addition, a protective duct was used for locating each bar on the bridge.

At the anchor zone, a transition tube was welded on the anchor plate, with a seal moved over the duct. By doing this, the total system is closed and protected. After tensioning, the anchor plate and nut were covered with a steel cap and filled with grease. Because the bar system is fully threaded, it is possible to connect a coupler at the end and connect the next one. This allows the bars to be adjusted to different lengths when needed.

Fig. 3—Gripper indentations on multistrand system.

Installation: Monitoring Design and Validation

The installation of the bridge was no different from the installation of a regular precast post-tensioned bridge. The girders were installed, and the perpendicular PT bars pushed in and tensioned. Having used innovative materials and unbonded PT systems, assessing the performance of the bridge was critical to verify the design. Our Lifespan Management team devised a monitoring regime to measure

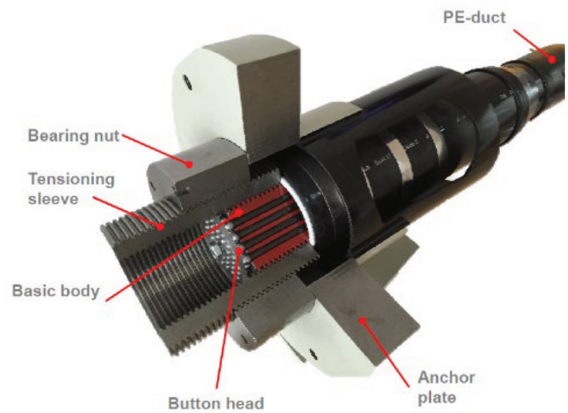

Fig. 4—DYWIDAG Wire EX tendon with tensioning sleeve.

Fig. 5—Hot-rolled prestressing Thread bar (WR), Grade Y1050.

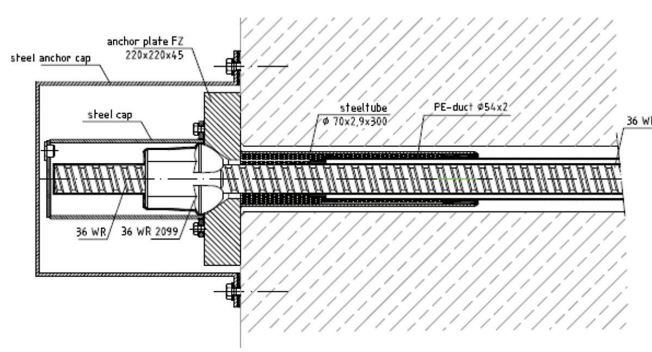

Fig. 6—Steel anchor plate and cap diagram.

short- to medium-term performance and dynamic behavior during traffic movements. In addition to sensors, we also built a reference frame below the bridge to act as a stable benchmark—necessary for measuring high-speed bridge displacement.

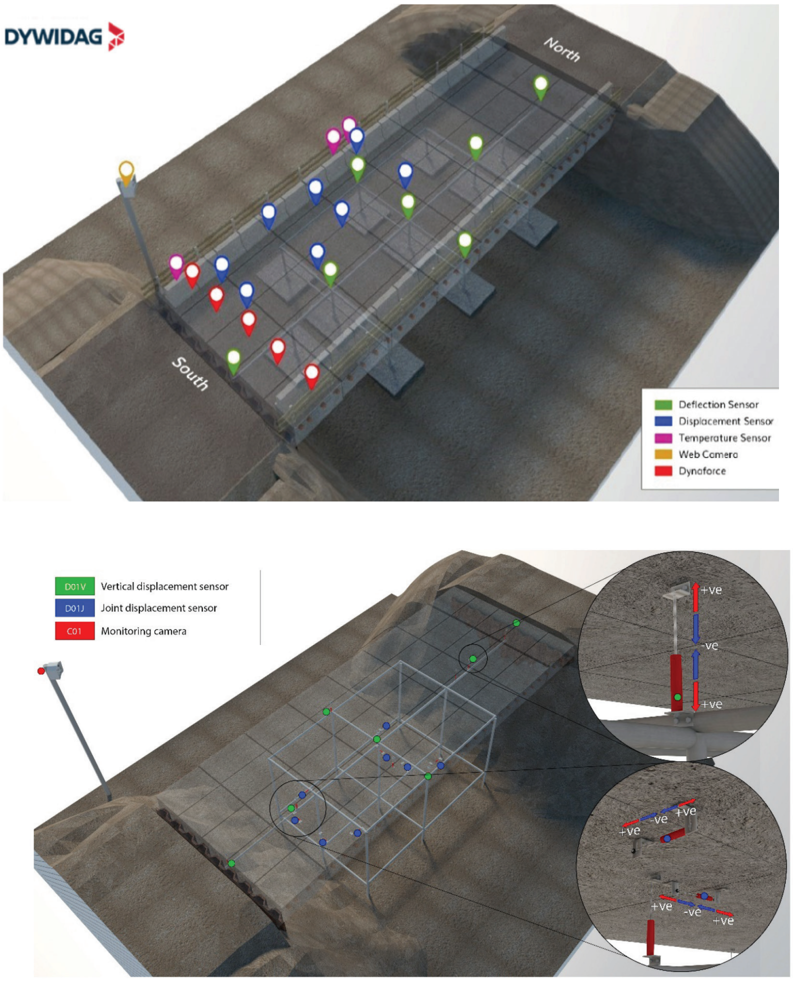

Fig. 7(a)—DYWIDAG Infrastructure Intelligence 3D Image sensor layout.

Fig. 7(b)—DYWIDAG Infrastructure Intelligence dashboard.

Monitoring System Design Considerations

To fulfill the requirements of the measurement table, we selected the most appropriate monitoring system to provide reliable, accurate, and meaningful data. Many factors were considered during monitoring system configuration.

Instrumentation: Resolution, repeatability, range, environment suitability, compatibility with other measurement devices, and cost.

Data acquisition and reporting: Data logger programming, communications, data transformation calculations, system calibration, baselining, and data presentation protocols. Once the design was approved, it was circulated to the relevant internal departments for execution through our 'Designed Document' workflow system.

Automated Readings

The heavy investment in our data management and presentation system allows processing and display of any sensor type from any data source (Fig. 7). In addition, all data is hosted in the cloud with dual redundancy and security protocols surpassing BS EN ISO 27001 standards.

To ensure data from the structure could be contextualized quickly, a comprehensive range of charting options is available. Technicians, engineers, managers, asset owners, and consultants all have differing requirements from the data, so the team is able to collaborate to define individual client needs.