PROGRESS: 100% - COMPLETED
SWITZERLAND

BRIDGE RENOVATION IN RECORD TIME WITH UHPC

Renovation on the A4 between Küssnacht and Brunnen

Author: Marco Schöpf

The comprehensive overhaul of a 5km stretch of national road was one of the first projects to involve the large-scale use of UHPC in Switzerland.

The use of ultra-high performance concrete (UHPC) replaces sealing and waterproofing processes across the entire surface of a bridge. In doing so, it makes it possible to significantly shorten the construction period by dispensing with weather-dependent work stages such as applying the epoxy resin seal and laying polymer-bitumen membranes (PBMs).

Project data

Employer	Federal Roads Office (FEDRO)
Contractor	ARGE N4 EP KüBru (PORR SUISSE AG, Implenia Schweiz AG, Cellere Bau AG)
Architect	INGE A4SZ (Jauslin Stebler AG, B+S AG, Locher Ingenieure AG)
Project type	Civil engineering
Project scope	Overhaul of a 5km stretch of national road and sections of road with several large bridge structures, renovation of two tunnels and expansion of two tunnel control centres
Order volume	53.9 million francs (49.1 million euros)
Construction start	03/2017
Construction end	07/2019

General information

In early 2017, the ARGE N4 EP KüBru consortium – composed of Implenia Schweiz AG, PORR SUISSE AG and Cellere Bau AG – accepted a contract from the Swiss Federal Roads Office (FEDRO) to overhaul section 2 of the EP KüBru maintenance project on the A4 between Arth and Goldau. PORR was responsible for commercial management of the project.

As this was a pilot project trialling the large-scale use of UHPC without an additional sealing layer, at the start of construction work, all installations and test specimens were produced using a machine-based UHPC installation. The first year of construction focused on renovating the longitudinal beams with UHPC and replacing bearings on the three main bridges at Boli, Mettlen and Linden. The second and third years of construction involved comprehensive renovation work, creation of new bridge parapets, large-scale use of UHFB for reinforcement and sealing purposes and renovation of the safety barrier systems and cable conduit blocks.

Requirements

The 4.8km stretch of the national road that was to be renovated, located between Arth and Goldau and referred to as section 2, included five bridges and two tunnels. The

practicability of the route was significantly restricted during the project due to the altered height and position of the carriageways. As it was not possible for works to continue during the winter months, the construction schedule was divided into three sections over three years with numerous construction stages.

The three bridges at Boli, Mettlen and Linden, which are between 120m and 540m long, were in poor condition with structural deficits and serious corrosion damage to the parapets, cantilever plates and the exterior faces of the lateral longitudinal beams. The required total renovation included removing and reinstalling approx. 4,000m of parapets with in-situ concrete, partially replacing the expansion joints, replacing the bridge bearings and overhauling the longitudinal beams and pier heads. In addition, CFRP fins and shear reinforcement elements were installed in the first span. The cross-beam reinforcements were also exposed and re-installed, UHPC was used on a large scale and two layers of poured asphalt were applied as a binding and covering layer.

The two smaller bridges, Harmettlen and Rigiaa, were renovated with smaller-scale concrete restoration works; the parapets were also replaced and the carriageway was surfaced with a new noise-minimising top layer. As the Harmettlen Bridge crosses the two-track Arth-Goldau railway line, the line had to be closed overnight on numerous occasions to install and remove the protective scaffolding and work platforms.

Due to damage in the portal areas, the Engiberg and Schönegg tunnels required extensive renovation. The existing control centres in both tunnels also had to be expanded.

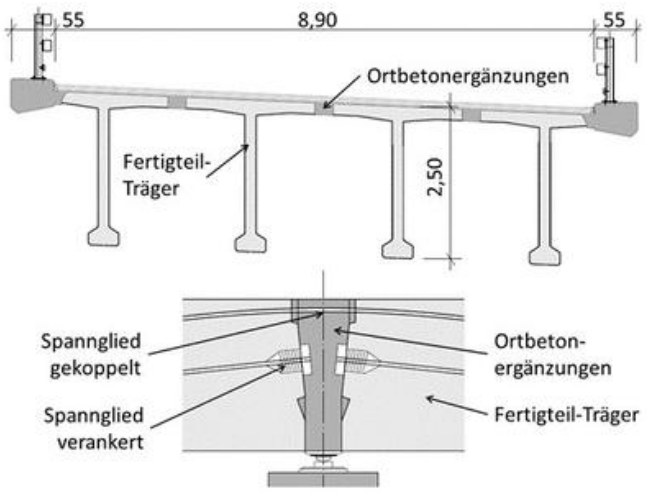
The two overpasses for the Rigi train line and Gotthardstrasse only required small-scale renovation, including localised repairs to the supports and a range of repair work on the undersides of the bridges.

Two column piers were also installed to reinforce the column heads of the Gotthardstrasse overpass.

New cable blocks were installed in certain sections of the route, while drainage ducts were renovated with support sleeves and inliners. This involved a special procedure to repair old, damaged tubing without having to excavate the surrounding area. In addition, the binding course and top surface of the carriageways were renewed and all restraint systems replaced.

UHPC – Pilot project

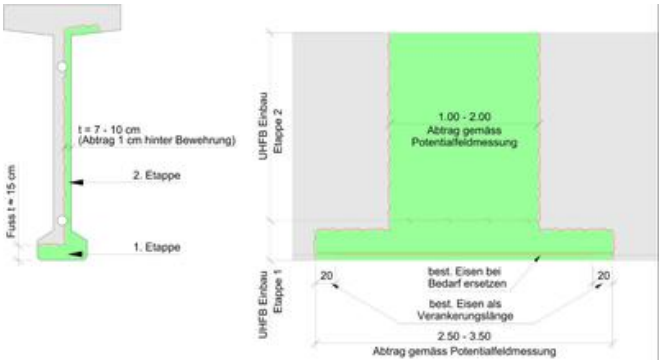
The three large bridges at Boli, Mettlen and Linden have almost identical designs with separate carriageways. They consist of different numbers of spans of different widths. Their construction is based on four pre-stressed longitudinal girders, roughly 2.5 metres in height, which were pre-cast on site. The four joined longitudinal beams were connected with in-situ concrete between the connecting elements, or “flanges”, and transversely between the supporting and longitudinal beams. The parapets were attached on the sides to the outer flanges of the ready-mixed concrete beams as in-situ concrete elements. In the longitudinal direction, the joins create a continuous beam system using pre-stressed cables coupled above the columns and an in-situ concrete cross-beam. The surface of the supporting concrete cross-section corresponds to the surface of the longitudinal beams upon which the seal and surface were installed.



A cross-section and longitudinal section of the three large bridges at Boli, Mettlen and Linden. Source: INGE A4SZ

Renovation of bridge supports

The bridge supports in the poorest condition were renovated with the help of self-compacting UHPC. In addition, the foot section and the mend points in the platform’s concrete were stripped back to approx. 1-2cm behind the reinforcements using high-pressure water jets. The UHPC was introduced directly into the formwork through a bored hole in the carriageway slab. Cathodic protection (CP) was installed to halt the progress of damage in longitudinal beams that had been less badly affected.

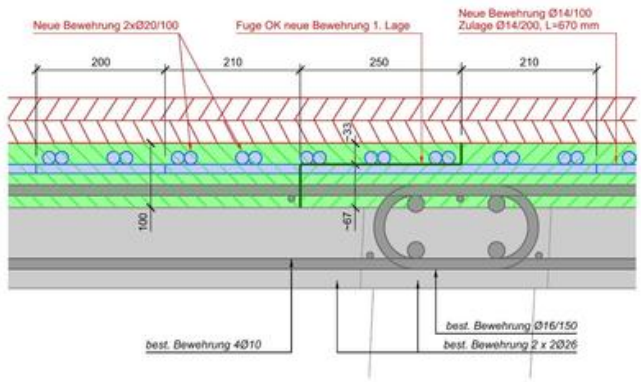


High-pressure water jets were used to strip back the existing concrete to approx. 1-2cm behind the reinforcement. Source: INGE A4SZ

Renovation of the bridge slab

The new bridge construction is composed of a field section and a support section. In the support section of the cross-beams, the existing surface concrete was stripped back by approx. 5cm with a high-pressure water jet and a new 10cm-thick layer of UHPC applied over a length of 10m across the entire section. In this section, strong reinforcements were installed in the longitudinal direction (2 x D=20mm at 10cm intervals).

In the field section, the existing concrete surface was roughened with water jets and secondary reinforcement put in place. In the field area, a 4.5cm layer of reinforcing UHPC was applied extensively.



In the support section of the new bridge slabs, the reinforcement was significantly increased. Source: INGE A4SZ

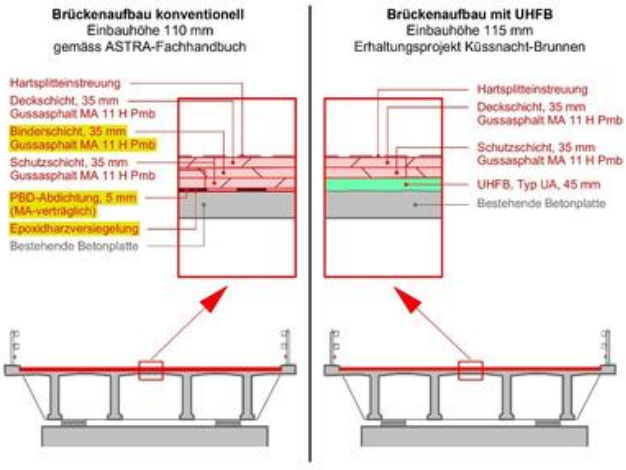
THE USE OF UHPC IN BRIDGE RENOVATION HAS PROVEN EFFECTIVE AND IS A GENUINE WIN-WIN.

Marco Schöpf
Construction Manager, PORR SUISSE AG

The advantages of UHPC

The combination of UHPC to increase the cross-section in the form of the thinnest possible concrete overlay while simultaneously avoiding additional sealing and waterproofing has proven completely effective and represents a genuine win-win. Investigations in the preliminary stages showed that the UHPC inhibits vapour diffusion and is comparable to a polymer-bitumen membrane (PBM). This means that the UHPC can be used to achieve practically the same results as a PBM seal. Dispensing with an epoxy resin seal and PBM waterproofing results in enormous time and cost savings. Less weather-dependent work stages reduce the risk in the execution stage, and expensive protective canopies are not required.

In this specific case, the use of UHPC resulted in additional thickness of 5mm, an increase of just 4.5%, compared to classic, conventional bridge construction methods.



Left: Conventional composition with sealing layer. Right: Composition with UHPC. Source: INGE A4SZ

The Linden Bridge with scaffolding below the sides and new parapets. Source: PORR AG

THE UHPC WAS PRODUCED ON THE CONSTRUCTION SITE ITSELF IN A SPECIFICALLY DEVELOPED MOBILE MIXING FACILITY.

Marco Schöpf
Construction Manager, PORR SUISSE AG

Production, logistics and installation with slipform paver

Ultra-high performance concrete (UHPC) is composed of cement, microsilica, fine sand, additives, steel fibres and water; it was produced on the construction site itself in a specifically developed mobile mixing facility. As the production of UHPC involves long mixing periods, the system was placed on the central reservation between the two carriageways. This ensured that transport distances for the concrete were minimised.

The product was transported on the building site using a hydraulic/pneumatic excavator, which was able to precisely deliver the UHPC ready for application. Daily progress involved covering 550m² to 900m² with 40m³ to 60m³ of UHPC. Applying the UHPC along one side of the tunnel meant that access was always ensured via the logistics lane. The formwork alongside was erected with a special T-square that had to be precisely placed at exactly the correct height.

When temperatures during the day were high, work had to begin at 4am so that application could be completed by around 11am, before temperatures reached their peak. In normal conditions, work began at 6am. A second unit then cured the UHPC by applying a covering of PE film.

When temperatures during the day were high, work to apply the ultra-high performance concrete (UHPC) had to begin as early as 4am. Source: PORR AG

Summary

This pilot project allowed both the companies executing the project and the employer to gather valuable knowledge. Results showed that the large-scale use of UHPC to repair and reinforce structures while simultaneously providing bridge sealing is more than just an alternative to conventional methods.

The UHPC was successfully produced on site in the required quality and was applied without any problems. Thanks to the unconventional and innovative method and the positive cooperation between all parties involved in the project, targets were actually exceeded and the construction period reduced by almost four months. As all milestones were adhered to or exceeded, the agreed system of financial incentives was awarded in full.

Technical data

1,200t
Reinforcement steel used

approx. 1,350m³
UHPC used

Section length	4.8km
Total bridge length	approx. 1,200m of carriageway
Asphalt	approx. 17,000t
Repair mortar used	approx. 480t
Concrete used	approx. 2,200m³