STRENGTHENING OF THE CHASSE-SUR-RHONE OVERPASS ON THE A7N MOTORWAY

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1. DESCRIPTION OF THE STRUCTURE

Chasse-sur-Rhône Viaduct (designated as VIPP 211 by the motorway owner) is located on Highway A7N in Isère (38), approximately twenty kilometres south of Lyon. This bridge allows the crossing of a residential area in the town of Chasse-sur-Rhône.

Figure 1: general view

Built in 1963, this 300 m long viaduct comprises nine 33.25 m long simply supported spans. Each span is made of precast post-tensioned « I » beams. This type of deck is referred to in French as a VIPP deck type.

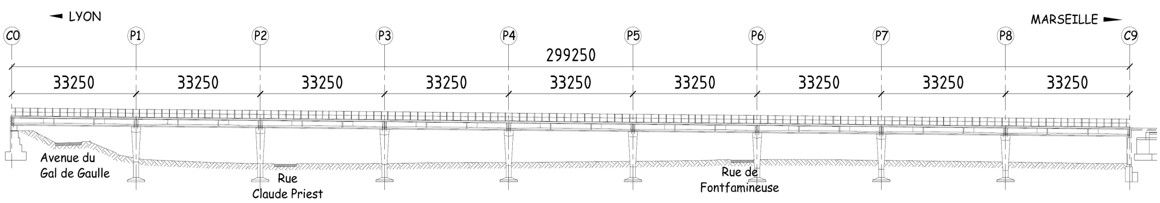

Figure 2: longitudinal cross section of the bridge

Each span comprises eight 32 m long beams post-tensioned by « 12Ø8 » cables. Typical beams are post-tensioned by 10 cables, with four of these anchored into the top slab, and the others at the extremity.

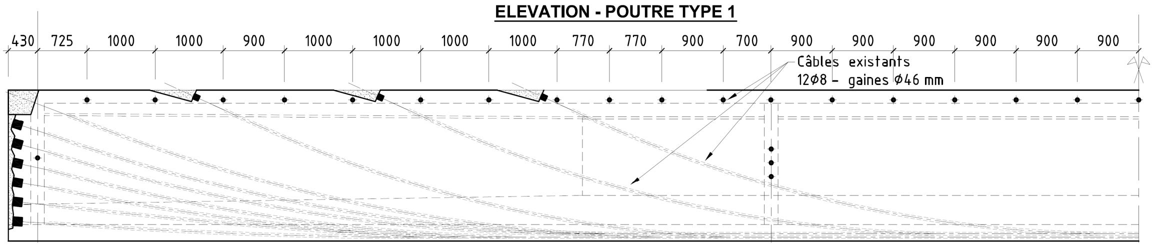

Figure 3: longitudinal cross section of a typical beam – existing post tensioning cables layout

The precast beams are connected transversely by the top slab and diaphragms. Both of them were cast in situ. These transverse elements are also post-tensioned by 12Ø8 cables.
The deck is 27,80m wide and carries two 3-lane roadways. Originally the bridge comprised two independent parallel decks. In 2005 the two decks were connected in order to widen the roadway.

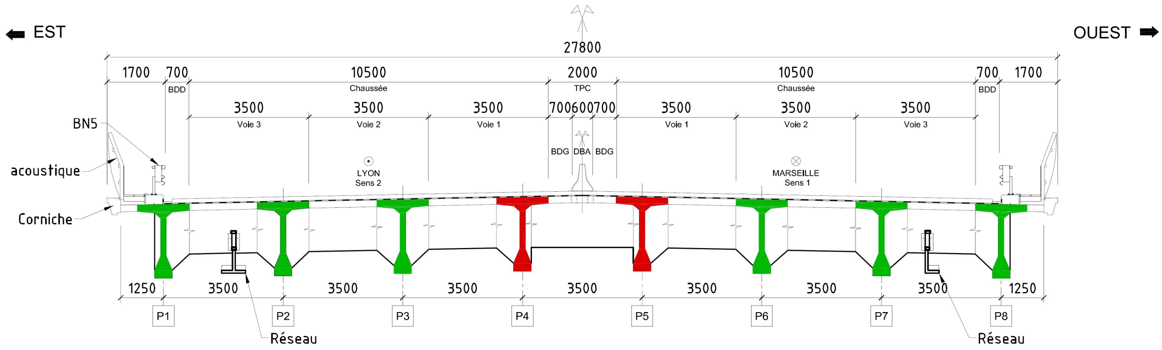

Figure 4: deck cross-section – beams 4 and 5 (in red) have an additional cable, anchored into the top slab.

2. CONTEXT

VIPP 211 is maintained by the toll way company ASF (Vinci Autoroutes). In 2009 a wide site investigation campaign was launched. It was performed by a specialist company, LERM, and comprised in situ measurements as well as laboratory tests.

This allowed assessment of materials and equipment characteristics.

It resulted from this campaign the main following points:

- *Carbonation of concrete has reached the first layer of passive reinforcements,*
- *Presence of chloride ions, in particular in prestressing ducts,*
- *No prestressing wire broken among those investigated,*
- *A residual tension in the prestressing cables of 813 MPa (low but typical of cables of this type and of this time)*
- *Injection defects at the ducts extremities,*
- *Corrosion of anchors and wires at ducts extremities.*

On this basis a contract was awarded to EGIS JMI for the design of the deck strengthening. A technical assistance contract was awarded to ARCADIS in order to supervise the design contract.

The strengthening works were eventually awarded to Freyssinet – Campenon Bernard, under the supervision of ARCADIS. These works comprise:

- *structural strengthening with carbon fibre layers and additional post-tensioning,*
- *impregnating a portion of the prestressing ducts by a corrosion inhibitor,*
- *re-grouting of a portion of the post-tensioning cables,*
- *replacement of neoprene bearings.*

3. STRENGTHENING PHILOSOPHY

This bridge, built during the early 60's, is part of the generation of VIPP type structures built before publication of the French IP1 and SETRA VIPP67 regulations. The calculations made at the time were based on the 1953 official recommendations for prestressed concrete works and the behaviour of prestressed concrete material was then not yet known as well as it is to-day.

At that time, the densities of passive reinforcement in pre-stressed concrete structure were significantly lower than they are nowadays. Some connecting sections between a prefabricated part and a cast in situ had no reinforcement.

In this situation of low reinforcement level a prestressing wire brittle failure, in particular in the poorly grouted area at the extremities, may lead to a structural failure.

The deck strengthening design was guided by investigations results and risk analysis of a prestressing wire failure.

The deck structural assessment was carried out on the basis of several configurations and assumptions in order to evaluate the ductile behaviour of the deck. It showed that BPEL (formal French code for prestressed concrete structural design) requirements were not met.

Pessimistic scenarios of wire failure were established, based on the results of investigations and on potential future damages.

These scenarios lead to the design of longitudinal beams webs and diaphragms strengthening against flexure, shear, and high compression areas near the bearings. The top slab had enough ductility and did not need strengthening.

The wire failure risks are considered higher at the cables ends because of lack of grouting and pollutants ingress from the deck for those cables that are anchored into the top slab.

In order to optimize the cost of the works, it was chosen to combine a « light » reinforcement by carbon fibre sheets and a corrosion inhibitor impregnation treatment of the prestressing ducts most exposed to corrosion (ie those anchored into the top slab). This treatment is followed by a re-grouting with a very thin grout that allows for a re-anchoring of the wires in case of failure. This extends the life of the cables and allows to avoid additional post-tensioning.

The webs extremities being reinforced with carbon fibre strips, the cables anchored at the beams extremities were not treated.

4. MAIN BEAMS STRENGTHENING

The main beams are strengthened against flexure with 3 layers of carbon fibre sheets bonded to the bottom of the beams (Foreva® CFRP patented product of FREYSSINET).

Strengthening against shear is made of 15 cm wide one layer vertical strips of the same material. These strips go around and under the beams. Anchors are placed wherever pull-out forces may occur. To maintain traffic underneath the bridge, mobile platforms are used (fig 6).

At the beams extremities, the shear vertical strengthening is increased to three layers that are anchored with stainless steel plates. This allows to increase the CFRP working tensile stresses from 417 MPa to 789 MPa at ULS.

Figure 5: anchoring against pull-out forces in vertical strips.

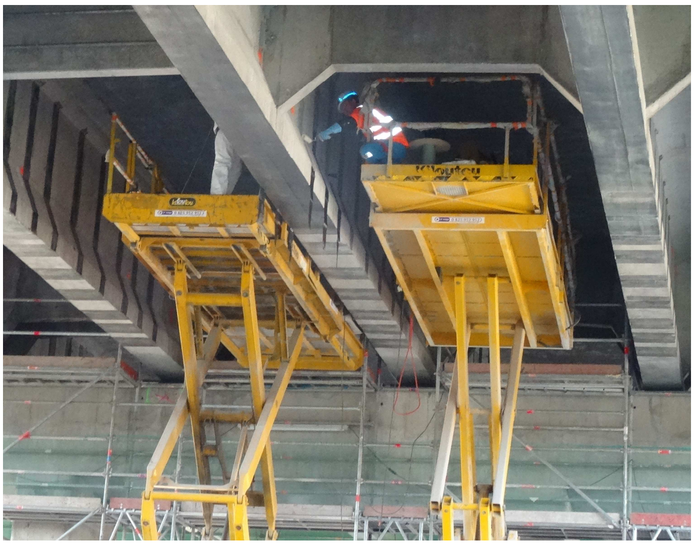

Figure 6: vertical strips installation from mobile platforms.

Figure 7: beam extremity: CFRP sheets anchorage with stainless steel plate

All strengthening works were realized under traffic.

5. DIAPHRAGMS STRENGTHENING

Only the diaphragms located at the beam extremities needed strengthening, because they had not been designed to allow for jacking operations.
Jacking was performed in accordance with FREYSSINET LAO® system. A central hydraulic plant monitors all jacks in order to prevent differential movements and keep them under 0.3mm between two adjacent jacks. A 0.3mm differential movement was indeed considered for structural verifications.

This lead to strengthen end diaphragms with 3 monostrand external cables of the T15S type. The effect of this post-tensioning was analysed with a full span 3D finite elements model. Site measurements have shown that the structure is more flexible than expected, which is favourable.

Monostrand cables are anchored into cast in situ blocks that are also used for jacking. These blocks are connected to the existing structure by prestressing bars Freyssibar Ø 36 mm.

Figure 8: concrete anchorage block at beam extremity

6. CORROSION INHIBITOR IMPREGNATION AND DUCTS REGROUTING WITH MICRO THIN GROUT (FOREVA® ULTRASONS PROCESS)

a. Process description

This process was developed during the 90s by PMD ATEAV SYSTEMS. It is now called Foreva® Ultrasons process by FREYSSINET.

It consists of injecting within prestressing ducts filled with cement grout a corrosion inhibitor in the objective of halting the progression of the corrosion phenomenon of the prestressing cables. The sheaths are then re-grouted with a micro thin grout specifically developed.

The impregnation of existing grout by the corrosion inhibitor is carried out by the use of a high power cyclic ultrasonic pump and results in saturating of inhibitor the material surrounding the prestressing cables.

Using a powerful cyclic pump creates alternatively high and low pressure at an ultrasonic frequency. The action of ultrasound induces cavitation condition in vapour phase of the inhibitor. The energy thus released allows to open the macro pores of the mortar in contact with the prestressing strands, favouring the penetration of the inhibitor. Injected to saturation, the inhibitor acts on the outer layer of the steel prestressing cables so as to interrupt the corrosion process.
Recording the time required to gradually saturate the cables allows to draw an accurate map of grout voids. A targeted re-grouting with a micro-cement from the same injectors is then an easy and reliable operation.

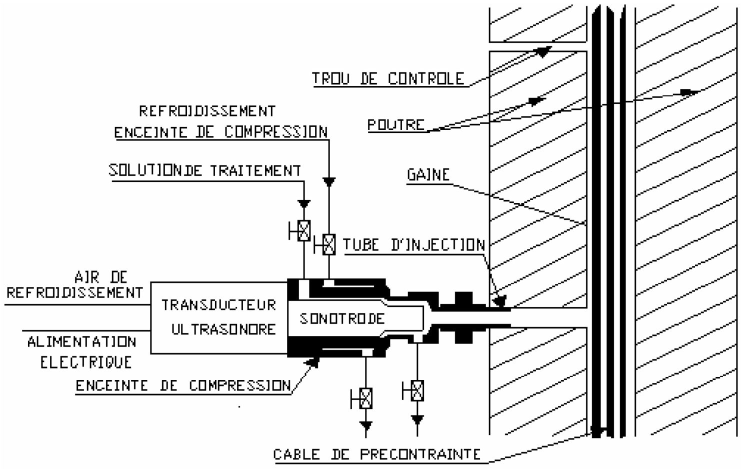

Figure 9: general principles of the corrosion inhibitor impregnation

b. Main steps :

The most significant risk of p.t. cables corrosion is that of pitting induced by chlorides. The corrosion inhibitor used is active even in case of presence of high chloride levels. In the case of VIPP 211, it was chosen to systematically treat all areas where total chloride rate is greater than 0.1% of the cement mass, i.e. 0.053% of the total mass of grout. The operations necessary for the full completion of the prestressing cables corrosion inhibiting, from voids mapping to re-grouting, are the following:

1. *Identification of cables,*
2. *Grout sampling,*
3. *Measurements of chlorides in grout samples,*
4. *Drilling injection and control holes,*
5. *Injection / impregnation of the corrosion inhibitor with the cyclic ultrasonic pump, with the inhibitor pH monitoring.*
6. *Re-injection of micro-cement grout in accordance with voids mapping.*

c. Implementation of the process :

The implementation of the process is carried out in two distinct phases. It requires at first preliminary work to define the contaminated areas and to know the degree of injection (presence of voids) of existing cables ducts. The preparatory works involve taking samples of the existing grout without damaging the prestressing cables (steps 1 to 3).

To achieve this, it is necessary to perform the following basic tasks:

- *Identification of existing cables through radar auscultation,*
- *Drilling down to the pre-stress sheath,*
- *Piercing of the sheath, and sampling of grout, as close as possible to anchor heads,*
- *Analysis of the cement grout (chloride content),*
- *Further drilling on all cables where the anchor head presented a chloride pollution (drilling is carried out every 0.50 m approximately along the cable over a distance equal to 2 m, and extended if necessary) and new analysis are made until along each cable at least one chloride rate measurement below the processing threshold is found,*
- *Mapping of chlorides content,*
- *Visual evaluation of wires degree of corrosion and of sheaths filling.*

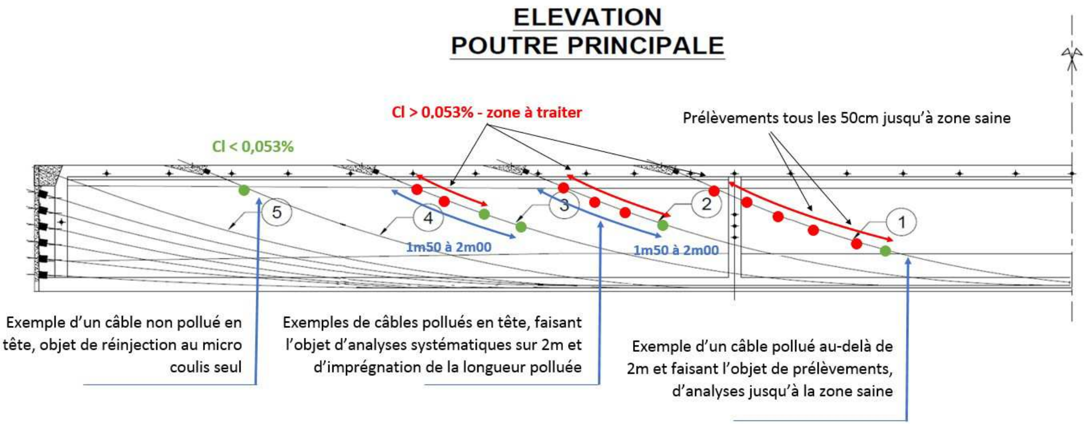

Figure 10: chloride content mapping example

Figure 11 : injectors along the cables layout

Figure 12 : corrosion inhibitor ultrasonic transducer

Once the complete mapping of the cable is performed, the corrosion inhibitor impregnation works and additional injection of micro-cement grout may start (steps 4 to 6).
Processing is carried out with the following steps:

- *Sealing of injectors located every 0.50 m,*
- *Airtightness testing by blowing compressed air from each injector individually,*
- *Airtightness testing from one injector to another in order to characterize the filling state of the sheaths,*
- *Implementation of the transducer,*
- *Injecting the corrosion inhibitor at a pressure of approximately 4 bars in polluted zones,*
- *Monitoring the impregnation of the inhibitor (progression, duration and volume),*
- *Micro grout re-injection through the same injectors,*
- *Removing injectors and plugging holes.*

Figure 13: corrosion inhibitor impregnation workstation on platform

Impregnation is considered sufficient when the inhibiting solution percolates at the adjacent injectors which act as vents. Impregnation duration varies from 30 min to 2 h, depending upon cement grout filling of the ducts. Polluted anchor heads are systematically impregnated over a period of 2 hours.

An impregnation control is carried out a posteriori by sampling. The corrosion inhibitor being made basically of nitrite, nitrite presence check on cement grout samples is performed prior to impregnation.

7. OTHER WORKS

The deck is jacked over each support to allow replacement of all neoprene bridge bearings. As a result of the jacking operation the deck is raised by 6cm, in order to isolate the neoprene bearings located at the edges from water stagnating on the piers upper face. The works were performed at night on 3 weekends (Saturday night to Sunday), with total traffic interruption.
The works included also repairs of spalled areas and exposed steel (local patches, cracks injections and rebar passivating) as well as application of a pore-filling product (type LHM) on the deck lateral faces that are directly exposed to the aggressive environment.

8. MAIN ACTORS

Owner: ASF DOIE

Owner advisor (design): ARCADIS

Designer: EGIS JMI

Construction supervisor: ARCADIS

Material control: CONCRETE

Health and Safety Coordinator: BUREAU VERITAS

Contractor: FREYSSINET – CAMPENON BERNARD REGIONS JOINT VENTURE

Main subcontractors:

- *Detailed design and construction methods : FREYSSINET – BE ARLAUD*
- *Inhibitor ultrasonic impregnation : PMD ATEAV SYSTEMS*
- *Cement grout chloride content measurement : IN SITU*
- *Hydro-scouring : THP*
- *Scaffoldings : ARNHOLDT*

9. MAIN QUANTITIES

TFC reinforcing sheets: 5 500 m²

Additional pt. : 3 100 kg

New neoprene pads: 144 units

Inhibitor ultrasonic impregnation and re-grouting: 450 cables

Chloride content measurement: more than 1 500 units