# Title: UHPC Used to Repair Bridge Pylons after Delayed Ettringite Formation

**Jean-Michel Odin -** Deputy Director of the Bridges & Geotechnics Division, Arcadis, Villeurbanne, FR, Email: jeanmichel.odin@arcadis.com

**Jerome Frecon** – Department Manager, Vicat, Isle d'Abeau, FR, Email: jerome.frecon@vicat.fr

**Anthony Flaus** – Technical Manager (corresponding author), Vicat, Isle d'Abeau, FR, Email : anthony.flaus@vicat.fr

**Abstract:**

The Bourgogne bridge crosses the "Saône" river in France since 1992. The deck is supported by cable stays and two lyre shape pylons. Only 6 years after commissioning, an important number of cracks appeared on both pylon bases (dimensions 7,65-yard x 2,18-yard x 13,38-yard). After several years of investigations, it was concluded the pathology was linked to a Delayed Ettrin gite Formation (DEF) which only affected the pylons' bases. The expansion of the pylons' bases was monitored for 15 years until the experts agreed that there was no further evolution. Three solutions have been designed to repair the pylons' bases: cracks injection and carbon fiber strengthening, PT strengthening with reinforced concrete protection and finally a 3,94-in thick reinforced UHPC shell. The UHPC solution has been selected to ensure a waterproofing effect and long-term protection of the existing rebars. The choice was made to cast in place the UHPC to enhance the pylon's base capacity. The first challenge was to produce the UHPC near to the pylons without impacting the road traffic on the bridge: a dedicated floating platform has been developed to facilitate the production. Secondly, specific care was taken to the "flow" criteria of the UHPC formula to ensure a good steel coating despite the high density of steel fibers. The third challenge was linked to complex pouring operations due to the reduced space inside the cofferdam, the small concrete cover and the required specific construction joint geometry to prevent water ingress.

**Keyword:**

Bridge, UHPC, Ettringite, Shell, Waterproofing, Reinforcement.

## 1. Subject of the Project:

Only 6 years after commissioning, an important number of cracks appeared on both pylon bases (dimensions 7,65-yard x 2,18-yard x 13,38-yard). A certified laboratory was selected to investigate the reason of this pathology. It determined that a too high temperature during the early age of the concrete caused the DEF reaction. Legal proceedings were initiated but the judge declared that no one was guilty. The department of "Saône et Loire" request to follow the evolution of the expansion of the pylons' bases. In 2015, the department decided to repair the bridge to ensure its safety.

## 2. DEF Evolution:

The DEF reaction creates ettringite inside the concrete and this crystal have a higher size compared to the raw elements used. The cracks width, on the bridge pylon, were of 0.04 to 0.12in (1mm to 3mm) and they were multidirectional.

A study done in a laboratory determined that the temperature inside the center of the pylon elements during the construction should be as follows:

- Maximal temperature 174°F and above 158°F until 6 days in the pylon base
- Maximal temperature 174°F for the pylon basement and above 158°F until 3 days but no DEF for this element

The maximal peak of temperature is a parameter that we need to pay attention to in building construction, but it seems, in this case, that the critical parameter should be the time above 158°F for the DEF reaction.

Some core drilling was removed from the pylon base to determine the residual expansion of the element. The process involved separating the sample inside two groups, one stored inside water and another one cover with aluminum paper to avoid the migration of the water inside.

The entire sample inside the water expanded by 0.1 to 0.3% after 420 days for both pylons.

Furthermore, the laboratory has been made a concrete from the old formulation and an expansion test was carried out on it. The concrete expanded by 0.9% during this test.

The expansion of the pylons' bases was monitored for 15 years until the experts agreed that there was no further evolution.

## 3. Feasible Solutions:

Three solutions have been designed to repair the bridge:

- Cracks injection and carbon fiber strengthening on pylons' bases external facing 3.3M$ (3.2Meuros)
- PT strengthening with reinforced concrete protection on pylons' bases 4.33M$ (4.2Meuros)
- Reinforced UHPC shell on pylons' bases 3.3M$ (3.2Meuros)

The UHPC solution has been selected because of its advantages:

- Waterproofing effect (post-tensile strength)
- Long-term protection of the existing rebars
- Pylon base strengthening thanks to very high capacity of UHPC (39,7ksi (150MPa) of compression)
- Low thickness around the steel bar 1.57in around (4cm)
- High abrasive protection
- Less steel bars than usual reinforced concrete

## 4. Job Site Organization:

The choice was made to cast in place the UHPC to enhance the pylon's base capacity.

Due to the huge size of the lower part of the pylon (length 3.3yd / width 13.01yd / height 6.56yd), it was not realistic to fill up all the shell in one time because of the huge UHPC pressure

on the basement of the formwork. Only horizontal construction joint with a special shape were authorized to prevent water ingress. The contractor decided to separate the height in six parts to reduce the pressure and ensure the feasibility of the preparation of the UHPC. Each step represented almost 6.6yd$^3$ (5m$^3$) of UHPC.

One of the challenges was to produce the UHPC near to the pylons without impacting the road traffic on the bridge: a dedicated floating platform has been developed to facilitate the production. The contractor equipped it with a crane, a mixer to reduce time transportation between the production site and the worksite. The area around the pylon was dewatered using sheet piles to create a safety zone for the workers, but the space was limited to reduce the impact on the river traffic. A scaffolding system was built all around the pylons' bases to facilitate the different operations.

One of the difficulties was to avoid bars from the formwork inside the shell of UHPC to ensure a good waterproofing capacity of the shell. The company stabilized the formwork with struts that can be moved using a chain hoist before each stage of pouring.

The total thickness of the UHPC was 3.93in (10cm). The concrete cover was 1.57in (4cm), so it was a very tight space between the formwork and the first layer of rebars to cast in place the UHPC.

The UHPC must have the same flow as a self-leveling concrete to ensure a good coating and a smooth facing surface after unmolding the UHPC to avoid any future problem. The flow range of the UHPC was 27,5 – 29,5in (700 - 750mm) and despite the 661 lb. (300kg) of steel fibers inside, to guarantee the waterproofing effect, (high post-cracking strength) the filling step was not so complicated.

To improve the filling time, the contractor kept the UHPC in 2 different dumpsters on each side of the pylon. This configuration helped to the gravity strength increased the speed of the flow and helped on the lining and facing of the UHPC.

This Bridge reinforcement requested around 70.6 yd$^3$ (54 m$^3$) of UHPC.

**Figure 1: General view: pylon base repairing works**