Title: Corrugated Steel Pipe Reinforcement with UHPC pouring with a Sliding Concrete Formwork

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Abstract

Corrugated steel Pipes are made with steel and a lot of them become rusty after some decades and their reinforcement are one of the challenges of each country with a huge highway network. Different solutions for their reparation already existing: changed the tube; used sprayed concrete; added precast elements of reinforce concrete. All these solutions have an impact on the road traffic or reduce the section by 7.9in (20cm) to 23.6in (60cm) of the tube. In this project, the pipe under the highway A81 is used for large wildlife passage and waterflow. The shape of the tube is ovoid, the width is 3.28Yrd (3m) and the length 52.4Yrd (48m). The innovative solution proposal was to use a sliding formwork filled by UHPC to reduce the thickness of the concrete put on the pipe to limit the reduction of the section. The concrete formwork had a length of 3.28Yrd (3m), and the unmolding timeline was 18 hours after the casting. Furthermore, the formulation of the UHPC was adapted to fulfill with the specific requested performances. The construction jobsite was organized on 2 stages: one with the preparation on the field and the platform for the formulation of the UHPC and another one with the most critical one, the casting of the formwork with the UHPC. The 59Yrd^3 (45m^3)) where pump directly after the production and a critical point was to fill each side with the same flow rate to avoid a lake of pressure in the formwork.

Keywords:

Corrugated Steel Pipe, Reinforcement, UHPC, Formwork,

1. **Subject of the Project**:

Corrugated steel pipes are made with steel and a lot of them become rusty after some decade and their reinforcement are one of the challenges of each country with a huge highway network. A lot of them are old, rusty and need reinforcement. In this project, the pipe under the highway A81 is used for large wildlife passage and waterflow. The shape of the tube is ovoid, the width is 3.28Yrd (3m) and the length 52,4Yrd (48m). The usual technique for their reinforcement reduces the size of the tube by 7.9in (20cm) to 23.6in (60cm) and it can be a problem if they must guarantee a certain length for hydraulic flow.

Those techniques are:

- Sprayed concrete
- PRV element
- reinforced concrete with tube formwork

For this jobsite GTM construction company decided to develop a new reinforcement solution based on UHPC. They would like to use a similar system as reinforced concrete with a sliding formwork but without a huge reduction of the section of the tube. It was an innovation in France.

2. **Jobsite Preparation**

Three months of preparation allowed GTM to design a tailored response for his customer. First challenge, in France, UHPC is not delivered like ready-mix concrete with a truck so you should mix it in the jobsite. They organize the size of the needed UHPC workshop, the adapted pump to the production rate, how to develop a waterproof formwork for UHPC (UHPC create much more hydrostatic pressure than usual concrete), and the works team. At the same time, they calculated the reinforcement of the tube with a thickness of only 1.97in (50mm) of UHPC with a compression strength of 21.8Ksi (150MPa). All documents have been validated by the construction site supervisor and a certified laboratory.

The jobsite was organized in different stages, at first, preparation of the draining tube, secondly reinforcement of the lower part (height of 23.6in (60cm) of UHPC) of the tube with usual formwork and finally the reinforcement of the tube with the sliding formwork.

The first stage with the UHPC, allow the team to understand the comportment of this new material and how they can deal with. It helped to test the equipment (pump, mixer, mold) to estimate the critical point and the guideline for the hardest part of the reinforcement. The mixing procedure was determined with the Vicat producer to fit well with the property of this jobsite. UHPC requires a certain amount of mixing time (15 minutes), that why, they rented two mixers to double the production rate. They launched each production with a delay of 7 minutes. The UHPC is composed of 338 lb/yrd^3 (200kg/m^3) of steel fiber, but it doesn't affect the flow of the UHPC. The aim with the flow test was 30.7In (780mm), the formulation has enough stability with this fluidity to be pump with a screw pump directly inside the formwork.

The construction teams deal with some waterproofing issues of the mold and the higher pressure in the mold compared to usual concrete, but it was an important stage to avoid problems after with the sliding formwork.

The 2nd stage requested some adjustment, on the field, to certify the production of one element on each day. Two shift teams were planned, one for removed the formwork in the morning, ensure the waterproofing point of the sliding formwork and the other one, for the production on the UHPC with the good production ratio and filled the mold.

Despite the huge temperature of this summer 2022 (over 95°F (35°C)), the UHPC keep a good retention of his fluidity (without ice or cold water inside the formulation) and the low temperature inside the tube permit to reduce the temperature of the UHPC after pouring the mold. The strength development during the jobsite was adjusted to reach at 24h a compression of 9.4Ksi (65MPa) to ensure a good unmolding and avoid cracks.

3. Sustainability:

A least, 105Yrd^3 (80 m^3) had been used for the jobsite, 10.5Yrd^3 (8m^3) (10.5Yrd^3) for the formulation of the 59Yrd^3 (45m^3) of UHPC and the rest of the water for cleaning equipment and the jobsite requirement. The water was treated to be conform with the legal parameters of pH and suspended matters. Some of these waters were used to wash the tools and another part rejected into the natural environment after all the tests required.

All the mold used on the site where build in reusable material to guarantee its reuse in other jobsite and to ensure a low impact on the environment. All waste were separated to simplify the recycling stage. For example, all the kraft bags for the fibers were recycling with a specific partner. The wooden pallets used have all been recovered to be reused in production.

At the beginning of the project, the gain of CO2 emissions compared to a sprayed UHPC concrete was supposed to be around -15%. But finally, with all the optimization of energy, the recycling water and equipment, the CO2 emissions has been reduced by around 40%.

Figure 1: General view of the ended reinforced Corrugated Steel Pipe