UHPFRC application in the Isabey-Darnley pedestrian bridge

Authors & Affiliation:

Jean-Philippe Charron, Research Center on Concrete Infras. (CRIB), Polytechnique Montreal
Clélia Desmettre, Research Center on Concrete Infras. (CRIB), Polytechnique Montreal
Étienne Cantin-Bellemare, City of Montreal

1. Project overview

The Isabey-Darnley pedestrian bridge is located in Montreal (Quebec, Canada) over Highway 520 close to the International Airport. This new structure replaces the former reinforced concrete pedestrian bridge that was built in 1967, which suffered of early concrete spalling and rebar corrosion after only 40 years of service. The bridge allows pedestrians to cross the 9 lanes of the highway safely. In this area, the average annual daily traffic of the highway is 30 000. The objectives of this project were to design an aesthetically pleasing footbridge that was durable and cost effective, while minimizing impact on highway traffic during construction.

Construction of this 61 m long footbridge of 3 span supported by steel Pony-Warren truss was completed in December 2016. The deck slab is made of ultra-high-performance fiber reinforced concrete (UHPFRC) precast elements. The development of UHPFRC precast deck slabs for bridges is part of a 10-year research project involving Polytechnique Montreal, the City of Montreal and other partners.

2. Design and specifications of the precast slabs and field-cast joints

The design of the precast slabs and field-cast joints were made considering the loads of the CSA-S6-2013 Canadian Highway Bridge Design Code for loads (dead, live, snow, ice, handling and exceptional loads). Detailed information on the mechanical constitutive laws, structural design equations, durability requirements and quality control methods were taken from the 2013 recommendations of the French Association of Civil Engineering for UHPFRC structures. The design values for UHPFRC tensile properties were obtained considering the variability of the UHPFRC mixture (characteristic law). Then a security factor (-25 %) and a global orientation factor (- 20 %), to take into account disparity in fiber orientation due to the casting method, were applied. Finite-element analysis with Atena 3D software were also performed to confirm the satisfactory structural behavior of the precast slabs and joints (deflection and crack opening in service, rebar yielding and failure mode at ultimate).

The final design comprises 11 precast slabs of 75 mm thick from 2 to 6 m long linked by 125 mm wide UHPFRC field-cast joints (100 mm rebar splices for 10M) (Figure 1). The precast slab includes curbs which serve as a security cladding for pedestrians, favor water drainage and strengthen the 75 mm-thick slab. The critical load combination for the precast slabs occurred during the construction process (handling and installation), whereas the field-cast joints were the critical part at the serviceability and ultimate limit states. After connection on site, the continuous slabs required very low positive and negative bending reinforcements and crack control reinforcement. The mechanical and durability properties of UHPFRC led to reductions of 64 %

and 91 % of concrete and rebar volumes, respectively, in the UHPFRC slab in comparison to a conventional reinforced concrete slab.

Technical specifications for the UHPFRC slabs and joints aimed to maximize flexural and shear strength of thin slab, minimize rebar splicing in the joint, and guarantee exceptional durability (crack widths inferior to 0.1 mm in slabs and joints in service condition). Composition requirements were water-to-binder ratio inferior to 0.25, 8 % minimum content of silica fume in the binder and 4 %-vol. of steel fibers. Mechanical properties specified were a minimum tensile strength of 10.5 MPa, a minimum compressive strength of 100 MPa and some specifications to ensure a hardening behavior in the tensile pre-peak phase. The UHPFRC tensile behavior was verified by four-points bending tests on 400 x 100 x 50 mm^3 prisms with the application of the Swiss Standard SIA 2052 inverse analysis. Durability performance criteria for freeze-thaw resistance, scaling and chloride permeability were also specified and a 7-day water curing was required for the slabs and field-cast joints. The UHPFRC selected for the project was the King Material UP-F4 having nominal compressive strength of 120 MPa and ultimate tensile strength of 11.5 MPa.

Figure 1. UHPFRC precast slab and field-cast joint geometry

3. Construction time and costs

The installation of the steel structure took 12 hours. The installation of the precast slabs of the Isabey-Darnley pedestrian bridge was achieved in two phases of 8 hours, while three periods of 8 hours were required for the casting of the UHPFRC field-cast joints under winter conditions. As a comparison, the construction period required for the cast-in-place reinforced concrete slab of the Barr pedestrian bridge built 1 km away over the same highway was 19 days.

The cost of the precast UHPFRC slabs of the Isabey-Darnley bridge was twice the one of the cast-in-place slab of the Barr bridge. The impact of the UHPFRC utilization on the global project cost was an increase of 5%. Considering the expected life cycle costs of the Isabey-Darnley bridge (less maintenance and repair activities, extended durability of the slab), the use of UHPFRC of this application is an economical choice.

4. Conclusions and perspectives

The fabrication and installation of the UHPFRC slabs were carried out without problems and the result was very satisfactory. Following this successful project, the City of Montreal is interested in using UHPFRC in the future for new and existing bridges to obtain very durable structures.