Ultra-High Performance Concrete Connections

every day counts
An Innovation Partnership with States

PROJECT CASE STUDY

Rapid Rehabilitation of a Mississippi River Crossing

Project Background

The Franklin Avenue Bridge is an open-spandrel concrete arch bridge that is currently listed on the National Register of Historic Places and is a City of Minneapolis Landmark. When it opened in 1923, the bridge's 400-foot central arch spanning the Mississippi River was the longest reinforced concrete arch in the world.

In the early 1970s, a major renovation changed many of the bridge's ornamental details, eliminated overlooks, and added a new, wider deck. In 2007, a structural investigation revealed that the bridge was structurally sound but in need of rehabilitation. Many concrete elements, especially those located near expansion joints, were deteriorating and warranted extensive repair, including concrete repair on the substructure and full deck and spandrel cap beam replacement.

Project Approach

An accelerated bridge construction (ABC) approach using prefabricated bridge elements and systems (precast deck panels, spandrel cap beams, and ornamental railings) was selected after considering the needs of users at the bridge's location in downtown Minneapolis, where it connects two major pedestrian and bike corridors neighboring the University of Minnesota. Offsite prefabrication of the panels meant significantly less bridge closure time and need for detours. It also allowed closure to be timed for the summer months when many university students would be out of town.

The Franklin Avenue Bridge is a historic crossing in downtown Minneapolis, MN, heavily used by drivers, pedestrians, and cyclists. Hennepin County used UHPC connections between precast deck panels to help accelerate the bridge's rehabilitation in 2016.

This case study presents the experience of Hennepin County, Minnesota, in using field-cast ultra-high performance concrete (UHPC) connections between prefabricated bridge elements to rehabilitate the historic Franklin Avenue Bridge.

Officially named the F.W. Cappelen Memorial Bridge in honor of its designer, the 1,000-foot span's recent rehabilitation was the second-largest project in the United States to date to employ field-cast UHPC connections between precast bridge deck panels.

Using precast panels allowed construction crews to remove and replace the entire deck within a 17-week timeframe, and using UHPC for the connections simplified the construction activities and increased the quality of the completed structure.

What is UHPC?

Ultra-high performance concrete, or UHPC, is a steel-fiber reinforced, portland cement-based material that has superior mechanical and durability properties compared to conventional concrete. Its fresh properties, oftentimes including self-consolidation, allow it to be an ideal match for field construction with prefabricated components.

Hennepin County advertised the design-bid-build project in the fall of 2014, specifying placement of UHPC for connecting the precast panels to improve both construction aspects and durability of the finished product. Below-deck concrete rehabilitation work and fabrication of precast bridge deck panels and spandrel cap beams began in the spring of 2015. The 350 deck panels were cast at a location upriver, and then floated via barge to the bridge for placement once the bridge was closed to traffic in May 2016.

Deck panel placement was completed within tight tolerances on a 2 percent transverse grade. The deck reinforcement was typical to conventional deck design, but included short, straight rebar lap splices in the connections. Using UHPC allowed for shorter lap lengths between panel reinforcement, with the largest connection being 9 inches wide.

Joining the panels with UHPC achieved a full-moment connection by bonding to the exposed aggregate deck panel key-ways and splicing the reinforcing bars. The contractor understood that attaining an exposed aggregate finish with a minimum 1/4" amplitude was necessary to facilitate interface bond and avoid the potential for leakage.

The UHPC connections were placed during July 2016. The UHPC mix was combined with chilled water, a superplasticizer liquid, and steel fibers onsite using two horizontal shaft mixers. The contractor added ice to the water to keep the mix temperature below 80°F. The contractor also used soaker hoses in the formwork overnight, and a hand-held sprayer just prior to the pour, to ensure that the connection interfaces had a saturated surface dry (SSD) condition.

Forming accommodated removal of the top form to check that an SSD condition was met. Five-gallon buckets with a hole in the bottom were used as "chimneys" at the high points of the connections. This allowed the UHPC to flow into the connections after the top form was placed to ensure they were completely filled.

The UHPC connections were overfilled by 1/4", which allowed for removing air pockets and any other anomalies through surface grinding. A total of 350 cubic yards of field-cast UHPC was used to connect the precast panels.

The contractor planned for a pouring sequence that avoided driving buggies on UHPC that had been placed within 48 hours (while the compressive strength was less than 10,000 psi) to reduce the potential for cracking. Other heavy construction vehicles were prohibited. The pouring sequence was planned with sufficient labor and equipment so that the UHPC remained fluid until each connection was filled.

Fully cured connections were ground flush with surrounding deck panels through the use of typical construction equipment.

Go to *http://bit.ly/UHPC_EDC4* to watch a video with more information on UHPC and scenes from the Franklin Avenue Bridge project and others.

Why use UHPC with Prefabricated Bridge Elements?

There are more than 150 bridges in service across the United States and Canada using UHPC. The majority use UHPC for connections between prefabricated bridge elements.

Field casting of UHPC connections between prefabricated components results in a strong connection and addresses both owners' and industry's desire to improve upon the durability, fabrication, and construction aspects associated with prefabricated bridge elements as compared to connections using conventional materials. It makes construction easier, is cost effective, and produces a higher quality product than otherwise possible with conventional construction methods.

The deck surface was finished by installing a polyester polymer concrete (PPC) overlay. Prior to applying the PPC, the deck was flooded with methacrylate to seal all connections and the surface of the precast deck panels. The restored bridge opened to traffic on Sept. 1, 2016.

Lessons Learned

Accelerated Bridge Construction

- Conduct extensive planning and development of contingencies with the contractor significantly ahead of the ABC implementation phase.
- A detailed, realistic, critical path method (CPM) schedule needs to be developed during the design process so that proper expectations are communicated early in the project development.
- Consideration for the safety, fatigue, and work-life balance of the construction project staff needs to outweigh the drive for speed when formulating these projects.

Precast Panels and UHPC

- Connection preparation is critical, including 1/4" amplitude exposed aggregate finish on connection interfaces.
- SSD all connection surfaces early and just prior to pour. One of the most effective ways to ensure an SSD condition is met is to design the formwork to provide access, such as a removable top form.
- Bulkhead locations should be accurately located on the deck panel forms prior to the panel concrete pour. At each of these locations, a vertical recessed groove should be pre-formed into the panel UHPC key-way during the panel pour. The pre-formed groove will then accommodate a bulkhead form during the UHPC pour process.
- At bulkheads or construction joints between UHPC pours, the previous pour must be roughed prior to placing new UHPC. If not, a cold joint will be formed, creating potential for leakage at the bulkhead interface.
- Mix temperature is critical (never to exceed 85°F). Maintaining a mix temperature below 80°F is preferred. On this project, chilled water and ice were critical in lowering the mix temperature. The contractor was encouraged to provide the ice, although this was not spelled out in the specification.
- A small percentage of the connections in an isolated area were observed to leak following a heavy rainstorm and prior to the methacrylate installation. This was attributed to the mix temperature at placement being 80-90°F and also to possibly driving buggies over the connections before they attained the needed strength. As evidenced by the large majority of the bridge deck, leak-free performance can be obtained if the construction is completed according to plan.
- Detailed as-built surveying of reinforcement prior to casting panels is essential to avoid reinforcement conflicts when panels are installed.
- The contractor must design forms/ties so that reinforcement conflicts are not created by their choice of forms.
- The fit of panels to transverse beams, especially at sliding joints, needs to be well designed. Construction tolerances need to consider shims or other practical adjustment methods.

Available Resources

EDC-4 Ultra-High Performance Concrete Connections for Prefabricated Bridge Elements
https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/uhpc.cfm

Design and Construction of Field-Cast UHPC Connections (FHWA-HRT-14-084)
http://www.fhwa.dot.gov/publications/research/infrastructure/structures/14084/14084.pdf

Ultra-High Performance Concrete: A State-of-the-Art Report for the Bridge Community (FHWA-HRT-13-060)
https://www.fhwa.dot.gov/publications/research/infrastructure/structures/hpc/13060/13060.pdf

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