PROJECT CASE STUDY

REHABILITATION OF THE PULASKI SKYWAY

ULTRA-HIGH PERFORMANCE CONCRETE CONNECTIONS

Introduction

The Pulaski Skyway is a critical part of the roadway infrastructure in northern New Jersey, and by 2012 it was in need of a new deck. However, because the traffic demands were so high, the structure could not be completely closed during the deck replacement. Furthermore, the New Jersey Department of Transportation (NJDOT) wanted to ensure that no major deck repairs would be required over the next 75 years to avoid future disruptions on this relatively narrow and heavily traveled highway structure.

To meet NJDOT's strict criteria of minimizing traffic disruptions and future deck maintenance, the Skyway deck was replaced with precast concrete deck panels connected with ultra-high performance concrete (UHPC). This system minimized the time needed to construct the deck and maximized the quality of the deck. The choice of UHPC for the panel connections made the connections the strongest and most durable part of the deck, as opposed to the weak link typically associated with connections between precast concrete elements.

Project Background

The 3.5-mile Pulaski Skyway (the Skyway) connects Jersey City, South Kearny, and Newark. The Skyway is an elevated structure composed of a series of bridges that carries US Route 1/9 over the Hackensack and Passaic Rivers, the New Jersey Turnpike, several railroads, and industrial facilities. It serves as an express link for car and bus traffic to and from the Holland Tunnel and destinations farther north on US Route 1/9, transporting more than 67,000 vehicles a day.

Figure 1 - Partial aerial view of the Pulaski Skyway © 2018 WSP USA

Because the bridge was designed and constructed in the 1930s, it did not meet today's standards for live load capacity, ramp geometry, shoulder width, cross slope, horizontal and vertical clearance, and stopping sight distances. The deck slab, constructed in 1932, had reached the end of its useful life. Frequent lane closures were needed to perform deck repairs, and there were reports of spalling concrete falling from the underside of the bridge.

Approach to Rehabilitation

The overall rehabilitation of the 80-year-old Skyway is being carried out in a series of contracts to repair existing steel member defects, replace the existing deck, repair existing concrete substructure members and paint the entire structure. The objectives of the rehabilitation program are to bring the Skyway into a state of good repair, improve the overall condition and safety of the roadway, and provide a 75-year design life with minimal maintenance—all while minimizing traffic disruptions.

To coordinate with other major projects in the region, it was decided to start the rehabilitation program with the deck replacement, and to replace the deck quickly. Through the study of several deck alternatives in 2012 by the project designer, WSP USA (formerly Parsons Brinckerhoff), NJDOT decided to use precast concrete deck panels with UHPC connections to accelerate the deck replacement and create a durable system that would provide the desired design life. The first deck replacement contract began in 2013 with the first lane closures beginning in early 2014.

The Choice of UHPC

UHPC was chosen as the connection material for the precast panels because of its high strength, fast cure time, fluidity during placement, and long-term durability. These unique properties make UHPC an ideal material for connecting precast concrete bridge elements. UHPC connections are extremely durable due to the material's extremely low porosity and discontinuous pore structure. These properties make the connections the strongest parts of the precast deck, and not the typical weak links, in terms of both strength and durability.

In addition, the high compressive and tensile strengths of UHPC (22,000 psi minimum in compression and about 1,000 psi in tension) allow it to fully develop reinforcing bars over very short distances. This leads to simple, narrow connections. Hence the labor and materials necessary to construct the connections are minimized, resulting in significant time savings compared to traditional connection methods and materials. Time savings are further realized by the relatively fast cure time of UHPC—typically only two to four days under ambient conditions.

Finally, UHPC is self-consolidating and highly flowable, which allows it to fill the narrow connections and flow around reinforcing bars and shear studs and through shallow haunches with ease, eliminating most consolidation and air pocket problems.

Deck Structural Features

The deck replacement project used precast concrete deck panels and UHPC connections to have the Skyway operational as quickly and for as long as possible. Precast concrete deck panels allowed for faster construction than cast-in-place concrete since the concrete panels were fabricated offsite, fully cured, and stockpiled until the contractor was ready to install them on the bridge. The shop-fabricated deck panels also provided a higher quality bridge deck than typical field-cast concrete would.

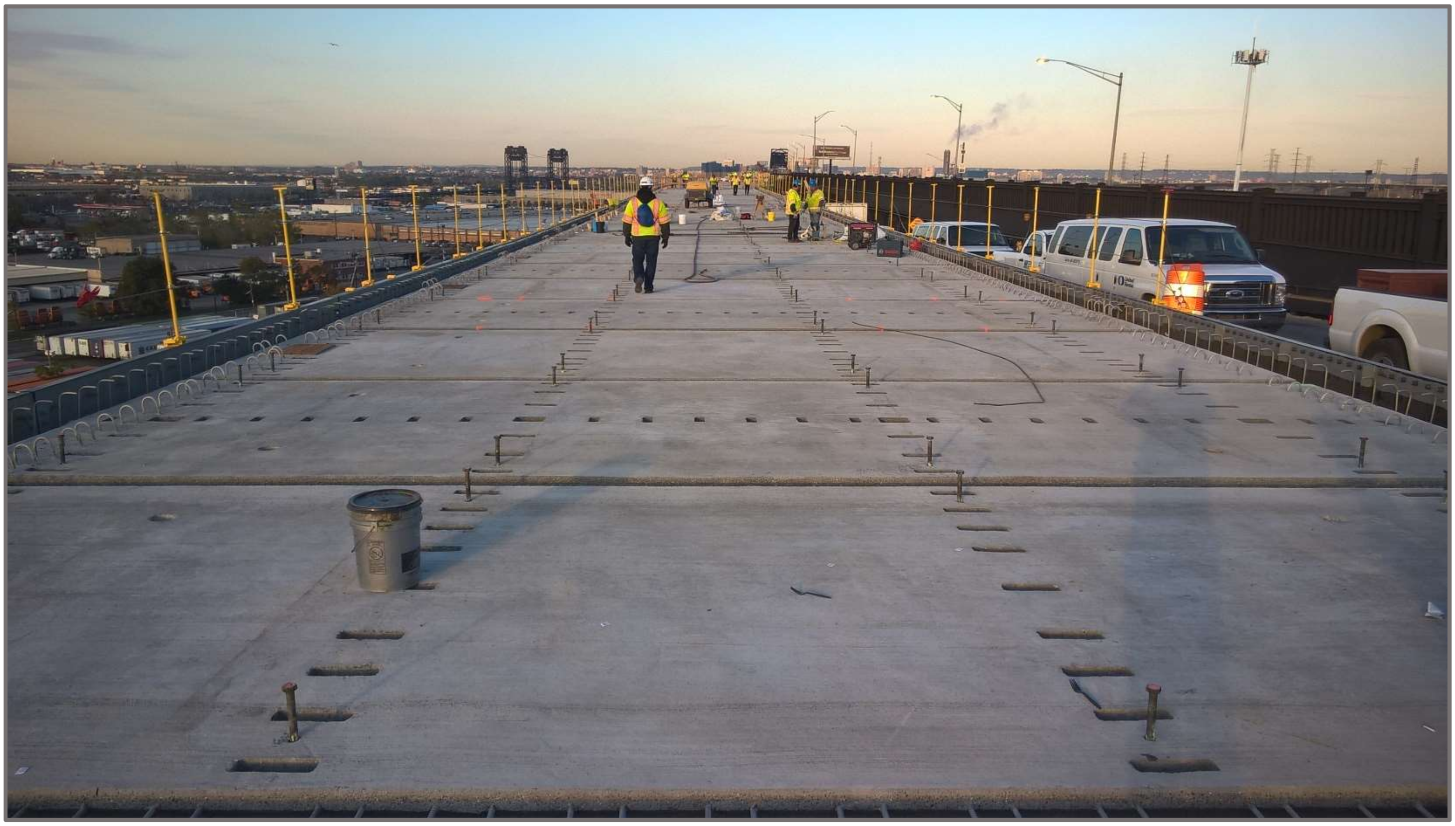

Figure 2 - Precast full-depth concrete deck panels in place prior to UHPC placement © 2018 WSP USA

The precast concrete deck panels included precast full-depth concrete panels and precast composite steel grid panels. In areas where the bridge deck was widened, precast composite steel grid panels were used to reduce the deck weight. These lighter panels consisted of an unfilled steel grid, topped with a composite 4-inch-thick precast reinforced concrete slab. The precast composite steel grid panels reduced the unit weight of the deck by about 20 pounds per square foot, versus the precast full-depth concrete panels, to compensate for the extra weight of the widening. The precast composite steel grid panels were connected using UHPC. The highly flowable nature of UHPC was especially important for these connections, which had more steel since the steel grid extended partially into the connections.

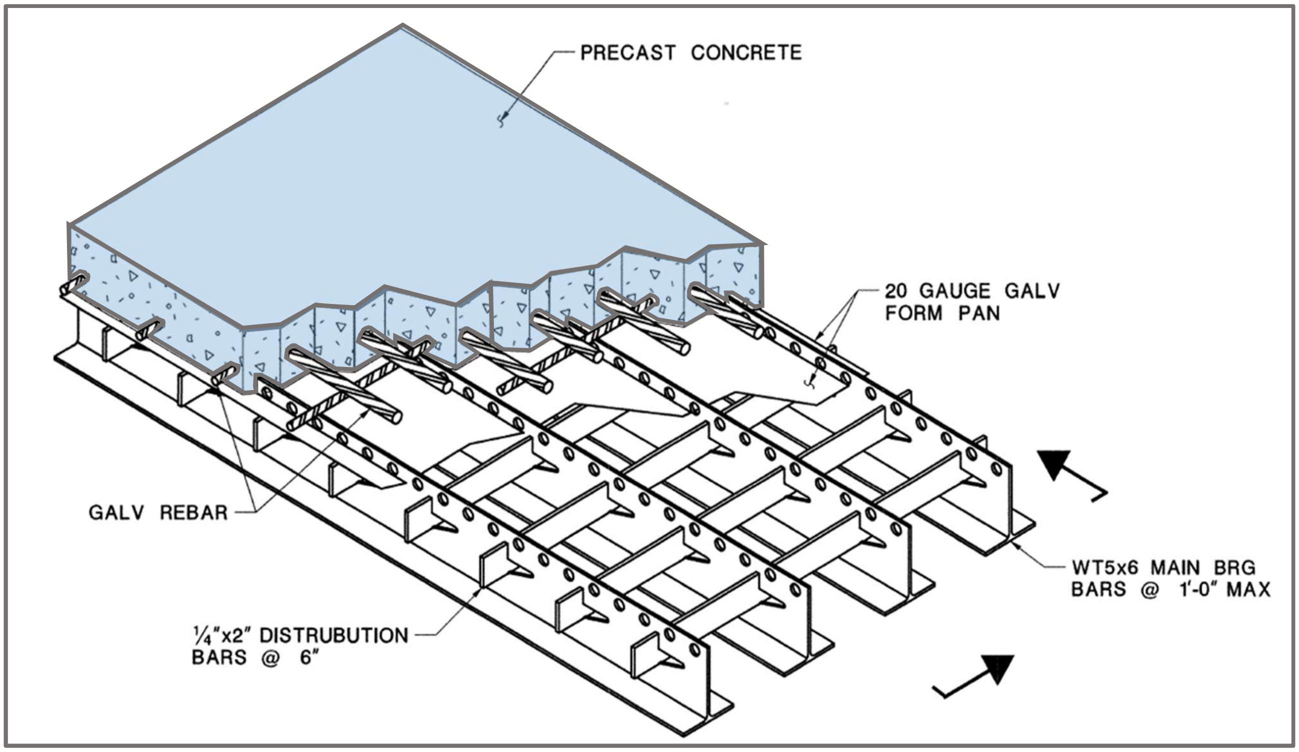

Figure 3 - Isometric cutaway view of precast composite steel grid deck panel
© 2018 WSP USA and the Bridge Grid Flooring Manufacturers Association

Closure pours between precast full-depth concrete deck panels were also made using UHPC. This allowed for very short rebar extensions from the panels, which in turn allowed for very narrow panel connections of 8 inches or less in most instances, while still achieving full rebar development in the connections. The narrow connections maximized the amount of precast material and minimized the amount of site-cast UHPC material, resulting in time and cost savings.

Figure 4 - Transverse connection between precast full-depth concrete deck panels prior to UHPC placement
© 2018 WSP USA

The general contractor (CCA Civil, Inc. for the northbound side, and CCA Civil/Daidone Electric, a Joint Venture for the southbound side), also elected to use UHPC for the haunches and shear connections to the steel framing, which were originally specified to use a different material. The shear connections consist of shear studs that project into full-depth pockets in the precast full-depth concrete deck panels and open pour strips in the precast composite steel grid deck panels above the stringers and floorbeams. Using UHPC for the haunches and shear connections in addition to the deck panel connections allowed the contractor to pour everything in one sequence, which resulted in less formwork and greater time savings. The high degree of flowability of the UHPC enabled haunches as thin as 5/8 inch—which was confirmed by a demonstration pour—and provided flexibility when field adjustments to the deck profile were needed.

Figure 5 - Precast composite steel grid deck panels prior to UHPC placement, showing limited space between northbound deck panels and existing southbound deck on the right side of photograph
© 2018 WSP USA

The bridge deck was replaced in two separate contracts. Under the first contract, the majority of the northbound deck was replaced while the original southbound deck remained open to traffic. After the northbound deck replacement was completed, the second contract replaced the southbound deck and connected the southbound deck panels to the northbound deck panels. Reconstructing the northbound deck while the original southbound deck remained in service limited the amount of space available to extend rebar from the northbound deck panels to splice to the southbound deck panels. Typically, there was only about 10 inches of space available. The high strength of the UHPC was critical to fully developing the transverse rebar lap slices at the median, thereby ensuring that the rebar would be functionally continuous across the full width of the bridge.

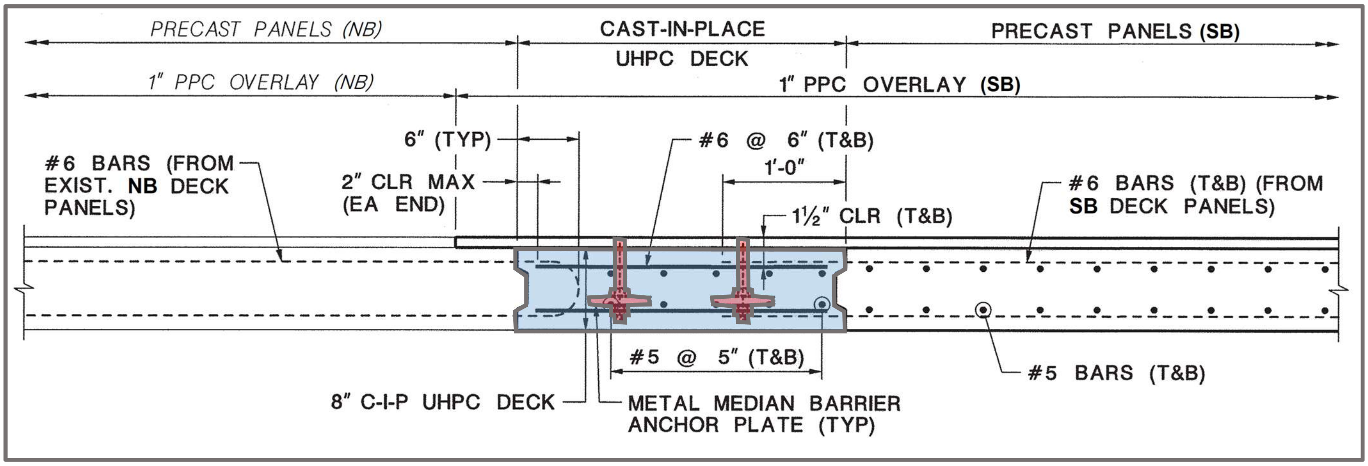

Figure 6 - UHPC median pour between adjacent contracts (northbound on left, southbound on right) © 2018 WSP USA

Specifications and Application

For the construction contract, a performance specification was used for the UHPC. The specification had a 5-year experience requirement for the UHPC supplier since both the contractor and the NJDOT had limited experience with UHPC. The expertise of the supplier was essential, so it was stipulated that the supplier have a representative on site during all batching operations and pours.

Figure 7 - Pouring of UHPC into demonstration deck panel joint © 2018 WSP USA

Per the project specifications, two deck-panel prototypes were cast, and a demonstration of the UHPC pour in the connection between the two panels was performed before any pours on the bridge were allowed. This proved crucial to help the contractor understand the unique aspects of working with UHPC, such as the lower viscosity compared to traditional concrete. Two demonstration pours were performed, since the contractor had some difficulties with the first pour. However, the contractor learned from the first pour how best to work with the UHPC, and the second pour was successful.

The UHPC was mixed on site utilizing high shear mixers with a capacity of one-half cubic meter, which matched the capacity of the dry UHPC mix bags provided by the supplier, thus simplifying the batching process. Keeping the temperature of the UHPC within the correct range is essential for successful placement. Hence during hot summer days, as much as 90 percent of the required water was replaced with ice to keep the UHPC cool. A flow test was performed on each batch before being approved for placement.

Prior to placing the UHPC, the edges of the precast panels along the connections were hydrated to a saturated surface dry condition. This was typically accomplished by spraying the deck panel edges multiple times with water, starting up to 6 hours before UHPC placement and repeated until immediately before UHPC placement. The UHPC was then transported from the mixers to the connection locations. The contractor initially tried pumping the UHPC, and had success doing so during cool weather. However, as the weather warmed up, pumping overheated the UHPC, causing it to lose workability, which led to voids in the pour areas. The NJDOT temporarily disallowed pumping in order to study what was happening, and during that time the contractor discovered that placing the UHPC with motorized buggies was more efficient and thus continued to use buggies for the duration of the project.

Figure 8 - Placing UHPC using motorized buggy © 2018 WSP USA

The UHPC connection pours were overfilled by 1/4 inch and then ground down with a mechanical grinder. This was done to remove any air pockets and to create a uniform surface for bonding to the overlay.

The durability of the entire Skyway deck system was further enhanced by a polyester polymer concrete (PPC) overlay, which fully sealed the deck to prevent infiltration of harmful chlorides.

Summary

The Pulaski Skyway deck replacement is the largest use of UHPC on a single project in North America to date, using over 5,000 cubic yards. Despite some minor setbacks arising from the initial method of transporting the freshly mixed material, UHPC was successfully used to connect nearly one million square feet of deck panels and was placed year-round in a wide variety of temperature conditions typical to northern New Jersey. It is expected that the UHPC will be a major contributor to minimizing or possibly even eliminating any need for deck maintenance over the next 75 years.

Figure 9 - Completed deck replacement © 2018 WSP USA

Lessons Learned

- Formwork for UHPC must be watertight. UHPC is a fluid material, and as such, will ooze out of formwork if not contained in all directions.
- Formwork should be made of a non-absorbent material or plywood coated with a sealing material. However, plywood wrapped in plastic is not generally a good idea. The plastic can detach from the plywood and become embedded in the UHPC, creating a debonded interface that requires full removal and replacement of the connection.
- Transporting freshly mixed UHPC by pumping can be problematic, especially in warmer weather. The heat from the friction of the pump and from the discharge line raises the temperature of the UHPC, which can result in a loss of workability. This will reduce the flowability of the UHPC and can lead to voids in the pour.
- Overfilling and grinding top-formed UHPC is critical. Otherwise, there will be air bubbles trapped in the UHPC beneath a top crust, compromising the bond between the UHPC and any subsequent overlay. The top forms can be installed a minimum of 1/4 inch higher than the adjacent precast elements to provide for an overpour.
- Maintaining a minimum curing temperature of 50°F (60°F preferred) during winter placement of UHPC is critical to avoid having the steel fibers settle toward the bottom and become segregated due to the UHPC staying fluid for too long.

Additional Resources

- EDC-4: Ultra High Performance Concrete Connections for Prefabricated Bridge Elements (UHPC) https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/uhpc.cfm
- TechNote: Design and Construction of Field-Cast UHPC Connections (FHWA-HRT-14-084) https://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

Acknowledgments: Photos and project details for this case study provided courtesy of NJDOT and WSP USA. This document was developed as part of the FHWA Every Day Counts UHPC initiative. It was drafted by Leidos Incorporated and WSP USA, under contract with FHWA in 2018.