ABSTRACT

The Winthrop Road Bridge over Interstate 95 in Hallowell, Maine, is a 2-lane, 4-span continuous steel superstructure that required replacement due to inadequate flexural strength and insufficient vertical clearance. After conducting user cost analyses, it was determined that closing the bridge and using accelerated bridge construction (ABC) was the most economical construction method. Incorporating precast deck panels, precast pier cap extensions, precast approach slabs, and ultra-high performance concrete (UHPC) deck closure pours into the design allowed for a successful superstructure replacement in a 45-day closure.

PROJECT BACKGROUND

The Winthrop Road Bridge is a 2-lane, 4-span continuous steel structure supported on three reinforced concrete hammerhead style piers that carries traffic over I-95 in Hallowell, Maine. The bridge is owned by the Maine Turnpike Authority (MTA), one of Maine’s largest transportation agencies. Carrying about 6,500 cars per day, the 60-year-old bridge is a crucial connector between the rural part of town and downtown Hallowell. The bridge also serves as one of two connections between the residential areas in Winthrop and downtown Augusta. The route is used daily by commuters traveling to the state capital, including many employees of the Maine Department of Transportation.

The scope of the project included replacing the existing superstructure, increasing the vertical clearance, and performing substructure repairs. Due to limited cross-section geometry, closing the bridge and detouring traffic was the only efficient method for replacement. During the road closure, traffic was primarily detoured to Western Avenue, the other connection between Winthrop and Augusta. Western Avenue, a heavily commercialized area with multiple signalized intersections, was already near capacity during rush hour. Detouring many of the 6,500 cars to Western Avenue was expected to significantly impact traffic flow through the area. VHB performed several user cost analyses to capture the value of these impacts to the traveling public. The user cost analyses considered many factors, including anticipated delay times, duration of construction, number of passenger vehicles versus trucks that travel the route, and the Historical Consumer Price Index for All Urban Consumers (CPI-U). Based on those results and through discussions with the MTA and the Maine Department of Transportation, it was determined that the Winthrop Road Superstructure Replacement was an ideal candidate for accelerated bridge construction (ABC) to minimize traffic impacts.

The MTA required assurances built into the design, specifications, and construction methods since it was its first project using ABC techniques. Prior MTA projects with similar scopes of work were typically provided with a 150-day maximum roadway closure window to complete the work using conventional construction methods and materials. To minimize disruption to travelers, MTA wanted to shorten the roadway closure to a maximum of 55 days. VHB looked at several options to achieve the 55-day roadway closure goal, including the use of prefabricated bridge units (PBUs), a lateral slide installation, or the use of full-depth precast concrete deck panels on new steel girders. After reviewing the pros and cons of each alternative, VHB and MTA determined that the use of full-depth precast concrete deck panels would be the most cost-effective configuration for completing the superstructure replacement within the desired 55-day roadway closure. Additionally, the contractor was given a daily incentive if the bridge was opened in less than 55 days and corresponding disincentives if the closure extended beyond 55 days. The value of the incentives and disincentives was based, in part, on the user cost analyses that VHB completed during the preliminary phase of the project.
ACCELERATED BRIDGE COMPONENTS

To achieve substantial completion within the allowable 55-day closure, VHB designed and detailed several ABC elements and specified special materials such as precast pier cap extensions, full-depth precast concrete deck panels, UHPC deck closure pours, and precast approach slabs.

Precast Pier Caps

One of MTA's project requirements was to increase the vertical clearance of the existing bridge. The clearance over the highway was 14'-11", and MTA required the new structure to achieve a minimum vertical clearance of 15'-6". The new superstructure design could only decrease the depth of the superstructure by a few inches, so it became necessary to raise the entire superstructure. The substructure consisted of three reinforced concrete hammerhead piers founded on spread footings. These substructure units were found to be in good condition, and re-use of these piers proved to be instrumental in the short duration closure for the bridge replacement.

For the Winthrop Road Bridge, the use of precast pier cap extensions reduced the project schedule by as much as three weeks. On past similar conventional construction projects, the pier cap work typically required nearly a month to complete. Using conventional cast-in-place concrete, each of the three piers would have taken a week to 10 days to prepare the existing caps, form and place reinforcing steel, cast concrete, and allow the concrete to cure. For Winthrop Road, this element took only four days of the total closure window. Each precast pier cap extension was cast off-site and delivered to the project on the same evening it was to be installed. Each night, one of the precast pier cap extensions was placed using a crane in a temporary lane closure. On the fourth night, high-strength grout was placed at all the pier cap extensions to complete the work.

The pier cap extensions not only increased the vertical clearance beneath the bridge, but also added required strength to support the new superstructure and current HL-93 live loads.
The existing pedestals were removed from the pier caps and the top of the cap was scarified. Dowel reinforcing bars were then drilled and grouted into the top of the existing pier cap to ensure that the new precast caps would act compositely with the existing pier cap. The precast pier caps were cast with a trapezoidal void on the underside so that they could accept the doweled reinforcing bars. The drilled and grouted dowel bars had to be carefully laid out and installed so that they would not interfere with the bottom leg of the shear stirrups within the precast cap. Galvanized shim plates were detailed to set the correct elevation of the precast cap, however, the contractor was able set the cap without the shim plates. One precast pier cap could be placed in a single day using a crane in a temporary lane closure. On the fourth day, high-strength grout was placed at all pier cap extensions to complete the work.

**Full-Depth Precast Deck Panels**

Precast deck panels were used to shorten the duration of the deck construction to just eight days. The contractor was able to set a total of 56 full-depth precast concrete panels in three nights. The UHPC joints were poured over two nights, and it took three days for the UHPC to reach the required compressive strength of 14,500 psi, allowing the contractor to use construction equipment on the bridge deck.

The precast deck panels were detailed with unique features, including negative moment reinforcing, blind beam haunch voids, leveling bolts, precast bridge curbs with embedded bridge railing anchorages, and slightly skewed reinforcing bars. The deck was designed to act compositely with the continuous bridge girders, requiring the placement of negative moment reinforcing over the piers. Figure 2 shows several different precast panels labeled A, B, C, D, E1, and E2. Panel A was detailed to have the reinforcing required in a positive moment region; panel B was detailed to have the reinforcing required in a negative moment region; and panel C was detailed as a transition panel between the two regions. Panels D, E1, and E2 were all specialty panels to minimize the final closure pour between the deck and the abutment curtain wall at each end of the bridge.
The full-depth precast panels also included the innovative detail integration of blind beam haunch voids and stub shear studs within the voids. This detail allowed the contractor to shop-install the shear studs to the girders and allowed the bottom mat of reinforcement in the panels to be placed uniformly without any interference between the shear studs and the deck rebar. At the time of design, the AASHTO LRFD Bridge Design Specifications did not provide guidance for UHPC beam haunches and stub shear stud connectors. To obtain more information on the implementation of blind pocket and shear stud size and spacing, VHB designers reached out to the FHWA, in particular the research of Ben Graybeal (1).
Leveling bolt assemblies were detailed along the beam haunch voids and along the longitudinal joint along
the center girder. The shear studs on the girders were detailed to provide adequate transverse clearance
between the center studs to eliminate any conflict with the leveling bolts. The contractor set the leveling
bolts to the appropriate height prior to lifting the panels into place. After the panel was set, the leveling bolts
were used for additional minor vertical adjustments. In cases where more than 1/2" of adjustment was
required, the panel was removed and reset after the leveling bolts were adjusted. The threaded ends of the
leveling bolts were specified to be coated with a bond breaker so that after the UHPC was cured, the
leveling bolts could be extracted and the holes filled
with non-shrink grout.

The bridge curbs and railing anchorages were cast
monolithically with the deck panel, eliminating this
sequence of construction in the field and allowing
the contractor to immediately erect the bridge railing
as soon as the UHPC joints reached the required
compressive strength of 14,500 psi. During the
shop-drawing review phase prior to the construction
of the precast panels, the fabricator proposed
skewing the transverse and longitudinal
reinforcement slightly to ensure the rebar extending
into the UHPC joints would not interfere with each
other, avoiding potential constructability issues
when setting the panels. The precast fabricator
submitted detailed 3D shop drawings of the panels
that greatly streamlined the review process and
ensured proper fit-up during construction. The
panels were cast face-down to ensure a smooth
finish, and the fabricator used custom reusable steel
forms.

![Figure 4: Skewed reinforcing bars in precast deck panel](image)
(Superior Concrete, LLC, Auburn, ME)

![Figure 5: Conceptual view of precast deck panel](image)
(Superior Concrete, LLC, Auburn, ME)

The decision to use UHPC was the result of extensive product research. Traditional precast deck panels
are longitudinally post-tensioned after the joints are filled, however the post-tensioning process is
cumbersome and would have added time to the construction schedule. This project required a superior
product for the transverse and longitudinal joints between the panels due to the tensile forces the bridge
deck would experience under live load. Research conducted by Graybeal (2) shows that UHPC can create full tension development strength with a significantly shorter embedment length, even with straight bar extensions and non-contact lap splices. Non-contact lap splices greatly reduced the need for field bending reinforcing due to fit up and provided the contractor additional tolerances when setting the panels.

![Image of Transverse UHPC joint detail](image)

**Figure 6: Transverse UHPC joint detail**

**Photo 5: Precast deck panel transverse and longitudinal joints**

**Precast Deck Panel and UHPC Mock-up**

The MTA required a trial mock-up of the deck panel, blind pocket, and UHPC joint prior to construction. The goal of this mock-up was to avoid any unintentional problems occurring in the field during construction, familiarize the contractor with the detailing and products they would encounter in the field, and assure the MTA that the construction techniques would result in a satisfactory final product. The UHPC was the biggest unknown for the MTA and the contractor. After the UHPC joints were cast and cured, the MTA required the joints be saw-cut full depth so that they could be inspected to determine if there were consolidation issues or if cold joints had formed between the panel surface and joints.

The mock-up proved well worth the time and expense. The UHPC was more flowable than expected and was able to leak between unsealed gaps in the formwork, which proved to be important when setting that actual formwork over the roadway. After the joints were saw-cut, it was observed that consolidation was not an issue and only minor cold joints formed between the batches of UHPC. The cold joints were determined not to be a concern since there would be a minimum of two mixers on site during construction, providing a continuous pour of UHPC and avoiding cold joints in the process. Additionally, after the mock-up, the contractor fabricated more temporary bulkheads than originally planned so that they could quickly close a section if they encountered issues with the continuous supply of UHPC.

![Image of Mock-up placement of UHPC](image)

**Photo 6: Mock-up placement of UHPC**

**UHPC Placement**

With the knowledge gained from the mock-up, the contractor paid extra attention to sealing the formwork. It was crucial that the forms were sealed so that the UHPC would not leak onto traffic below the bridge. The lessons learned from the mock-up paid off, and there were no noticeable leaks in the formwork during the field placement of the UHPC. The UHPC was placed over two nights. Two portable batch mixers were onsite to provide a continuous supply of UHPC. A series of bulkheads were placed between the joints to
ensure consolidation and eliminate horizontal cold joints in the UHPC as it began to set. After the joint region was filled, timber forms were secured above the joint and 5-gallon buckets with holes drilled in the bottom were secured over the detailed grout ports along the blind beam haunch voids. This setup provided pressure heads at the high point within a joint region and ensured consolidation of the UHPC within the voids and joints.

Precast Approach Slabs
The use of precast approach slabs allowed the contractor to reduce the approach work duration by approximately one week with a relatively simple procedure. The approach slabs were cast in three panels at a shippable width and detailed with a shear key between each panel. The contractor prepared the subgrade at the approach as if they were going to form a cast-in-place approach slab; they then set the precast slab and injected grout through the detailed grout ports and shear keys. Upon completion of this sequence, the contractor immediately began backfilling above the approach slab to prepare for the final roadway subbase.

LESSONS LEARNED
This project was a success and achieved many of the goals established during the planning stages of design. Recommendations and lessons learned include:

- A mock-up of the UHPC placement is extremely beneficial and recommended if the contractor does not have significant prior experience with the product.
- Provide an adequate bond breaker on the precast deck panel leveling bolts. Several bolts had to be cut from the panels, but this was not a significant issue because the bridge deck was to be covered with a bituminous wearing surface.
- Incorporating a slight skew (1% - 2%) in the precast deck panel transverse and longitudinal rebar is a simple way to ensure there will be no conflict between panels.
- The bridge has been open to traffic and in service for two years with no signs of distress or leakage at the UHPC joints.

SUMMARY
With the implementation of ABC techniques, research, and coordination with manufacturers and the contractor, the Winthrop Road Bridge was constructed in 45 days and open to traffic 10 days ahead of schedule and 105 days faster than a conventional superstructure replacement over the Turnpike. The reduced closure window resulted in a cost premium of approximately 33% compared to similar superstructure replacements constructed with conventional construction techniques.
PROJECT TEAM

MTA – Owner

VHB – Lead Engineer and Designer

CPM Constructors – Contractor

Superior Concrete – Precast Concrete Fabricator

Lafarge – UHPC Provider

REFERENCES
