NEW JERSEY ROUTE 10 BRIDGE OVER THE PASSAIC RIVER SUPERSTRUCTURE REPLACEMENT USING ACCELERATED BRIDGE CONSTRUCTION SYSTEMS

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ABSTRACT

The New Jersey Department of Transportation's Route 10 Bridge over the Passaic River exhibited advanced deterioration of its primary structural components. The bridge was reconstructed to provide a new three-span continuous prestressed concrete superstructure. Due to site constraints and significant commercial/commuter traffic volumes, the reconstruction used Accelerated Bridge Construction (ABC) systems to reduce construction duration and minimize impacts to local communities and businesses. Steel beam prefabricated bridge units with composite concrete decks were initially identified for rapid superstructure replacement. However, those units required one or two maintenance paintings over their service life. The NEXT Beam® prestressed concrete beam (double T) prefabricated bridge unit system was determined to be compatible with the intent of the accelerated construction project, and the change was incorporated early in the final design phase. The use of precast concrete approach slabs and NEXT Beam® prestressed concrete prefabricated bridge units, utilizing High Performance Concrete (HPC) for live load continuity connection and closure pours, greatly reduced the construction schedule compared to standard cast-in-place construction. In the end, the project successfully utilized accelerated bridge construction systems to deliver the project in an expeditious manner and before the start of the busy holiday shopping season.

Keywords: Accelerated, Bridge, Construction, NEXT Beam®, Prestressed, Concrete

INTRODUCTION

The New Jersey Department of Transportation's (NJDOT) Route 10 Bridge over the Passaic River, which links East Hanover Township in Morris County with Livingston Township in Essex County, was showing its age. The structure, more than 80 years old, exhibited advanced deterioration of its primary structural components. The bridge deck was evaluated as being in poor condition (4) in the June 2010 Bridge Re-Evaluation Report, while the superstructure was evaluated as being in satisfactory condition (6) and the substructure being in fair (5) condition. As part of NJDOT's annual Capital Program and planning procedures, the bridge went through a screening process and was added to their list of scheduled bridge rehabilitation projects and then advanced to the design phase initially as a deck replacement project.

EXISTING BRIDGE, SITE CONSTRAINTS, AND OVERALL SCOPE OF RECONSTRUCTION

EXISTING BRIDGE

The Route 10 Bridge over the Passaic River, built circa 1931, is a three-span structure with an overall length of 108′ and an out-to-out width of 64.2′. Route 10 is classified as an urban principal arterial roadway and is generally oriented west to east in the project corridor. The bridge spans the Passaic River, which flows from south to north at the site. The river is the municipal and county border between East Hanover Township in Morris County to the west and Livingston Township in Essex County to the east. The existing roadway configuration consists of a four-lane divided highway, two eastbound and two westbound. The half widths of the roadway across the bridge are each 24.0′, separated by a 2′ wide concrete median Jersey barrier. There are 6′ wide sidewalks with concrete balustrade parapets flanking the roadway on each side of the bridge. There are no shoulders across the bridge, but the approach roadways have 6′ wide shoulders that taper to 0′ at the bridge abutments. The roadway is on a long horizontal tangent alignment and vertically on a 1.3% tangent profile uphill to the east. The highway right-of-way (ROW) width was a uniform 80′ in the vicinity of the bridge. The bridge was evaluated as functionally obsolete due to insufficient curb-to-curb width in consideration of the number of lanes and the traffic volume.

Photo 1 - West approach roadway, eastbound lanes, looking east.

The design and details of the existing bridge are typical for short-span bridges built in New Jersey in the 1930s and 1940s. The superstructure comprises three simply supported 34′ long spans of rolled steel beams that were monolithically concrete encased with the concrete deck. The 9″ thick reinforced concrete deck spans over the steel bridge beams spaced at 6′-6″ centers under the roadway and 5′-2″ under the sidewalks. The top flanges of the roadway stringers were embedded into the slab thickness from 2″ at the centerline stringer to 7″ at the curb line stringer. The deck was in poor condition, exhibiting several large under-deck spalls with exposed, moderately rusted reinforcement and large areas of moderate scaling with efflorescence on the deck underside. The superstructure was in satisfactory condition, exhibiting minor defects, including cracked and loose beam concrete encasement at the beam bottom flanges. The superstructure carries a 2x2 bank of 4″ telephone conduits supported between stringers under the north sidewalk.

Photo 2 - South Elevation

The substructure consists of two unreinforced concrete solid wall piers supported on spread footings founded below the river bed and two full height unreinforced concrete semi-gravity abutments on spread footings founded below the river bed at the water’s edge. The substructure was in fair condition due to large areas of severely scaled and disintegrated concrete and incipient spalls on the north and south ends of both pier seats, the west pier stem, and both abutment back walls. There was no observed scour at the piers or at the abutments.

SITE CONSTRAINTS

Several site constraints influenced the scope of the reconstruction. Route 10 is a busy land service highway providing access to a popular and heavily utilized commercial corridor with numerous small stores, strip malls, box stores and office space with numerous ingress and egress driveways throughout. The existing two-way ADT of 44,710 (2012) vehicles per day with a 58% directional split required that two lanes of traffic be maintained in each direction throughout the reconstruction project. Based on traffic counts, the peak hour volume occurs on Saturdays in this popular shopping corridor, with combined commuter and commercial traffic nearly as high on weekdays but still less than Saturdays. For the timing of the construction project, it was critical that the project was advertised and awarded; and then constructed in less than one construction season. The project also needed to limit traffic impacts during the school year due to a nearby regional high school, and be completed well before the annual holiday shopping season.

Photo 3 - Deteriorated bridge seats at abutments and piers.

Immediately adjacent to the northeast corner of the bridge, there is an Essex County Park encumbered by the New Jersey Department of Environmental Protection's Green Acres program. This parcel is part of the 1,360-acre West Essex Park that stretches for six miles along the Passaic River. The parcel frontage along westbound Route 10 has a municipal well and pump station facility that requires daily access for operations and delivery of treatment materials. There are also delineated wetlands just downstream from the bridge along both banks of the river. Adjacent to the southwest corner of the bridge is a private residence with its sole access from Route 10.

The environmentally sensitive parcels adjacent to the bridge, together with numerous commercial parcel access points on both approaches to the bridge, precluded a temporary bridge and diversionary road along either side of the existing roadway or within the Route 10 ROW. These constraints made maintaining traffic on site (within the existing public ROW), while maintaining access to the adjacent properties, critical to the project's success. This drove the decision to use accelerated construction methods to reduce the impact to the traveling public and the commercial corridor businesses.

Photo 4 - Typical driveways adjacent to bridge within work zone.

Several utilities also influenced staging and layout of the project. A bank of telephone ducts that contain primary fiber optic trunk lines was located under the north sidewalk, between existing bridge beams. Overhead primary electric cables spanned over the bridge near the north fascia line. The local gas company requested a new system interconnect across the bridge to increase redundancy and capacity in its separate systems on each side of the bridge.

SCOPE OF RECONSTRUCTION

The combination of the various site constraints and the details and condition of the existing structure made accelerated bridge construction a challenge. However, due to the high traffic volume through the corridor, limiting the time traffic was impacted was paramount. Traffic was impacted by the detouring of eastbound traffic onto local roads, while maintaining westbound traffic on the highway, first in its normal location and then crossing over westbound traffic onto eastbound lanes, which allowed the bridge to be reconstructed in two primary stages. The primary focus became utilizing accelerated bridge construction systems to reduce construction duration and complete the work before the busy holiday shopping season.

Bridge Design

At the beginning of the preliminary design phase, a Bridge Design Appraisal Statement was prepared to study and confirm the originally screened deck replacement project. Based on the relatively short 34′ spans, and the monolithic steel beam encasement with top flange embedment in the concrete deck, it was determined that removing the deck from the remaining embedded 30″ steel beams, without damaging them, would be too time-consuming and inconsistent with the goal of minimizing construction duration. Thus, it was decided to replace the full superstructure to reduce the construction duration. Originally, steel beam prefabricated bridge units with composite concrete decks were identified for rapid superstructure replacement.

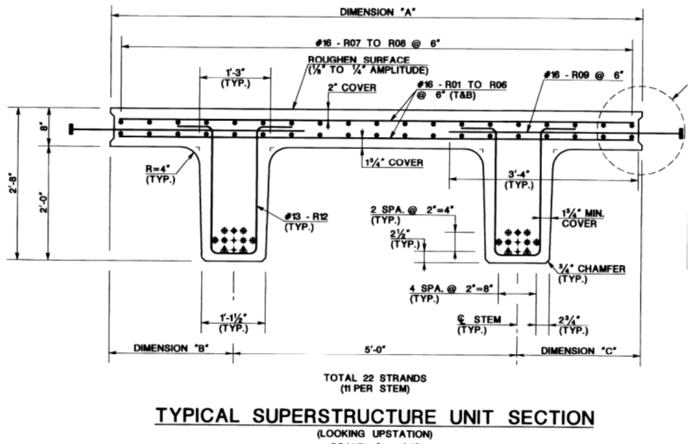

Fig 1. NEXT Beam® Superstructure Units

At the beginning of the final design phase, prestressed concrete beam prefabricated bridge units were also considered for reduced long-term maintenance over the river. The steel beam prefabricated bridge units originally considered would have needed one or two maintenance paintings over their service life. A review of the NEXT Beam® prestressed concrete beam prefabricated bridge unit system determined that the product was compatible with the intent of the accelerated construction project, and the change was incorporated. NEXT Beam® units are precast prestressed concrete double Tee sections that can use a thin top flange as forms for a cast-in-place structural slab, or a full-thickness top flange that functions as the structural deck. On this project, the full-thickness flange section (Type D) was used with high-performance concrete (HPC) closure pours and a high early strength (HES) concrete wearing surface overlay. The NEXT Beam superstructure was designed for live load continuity by means of mechanical rebar connections and an HPC diaphragm pour at pier locations. This was one of the first installations of continuous, Type D NEXT Beam® systems on a NJDOT project.

To address the substandard curb-to-curb width, the project would include a minor widening of the bridge superstructure by 1′ on each side, such that the bridge would no longer be assessed as functionally obsolete.

Early in the final design, a stability check was performed on the existing abutments for loading during the superstructure replacement. The findings indicated that the abutments had a low factor of safety against overturning due to relatively narrow footing widths under the abutments, relative to their height. This was addressed with the installation of 60′ long, inclined ground anchors that were installed through the abutment between existing beam stems just below the bridge seat elevation, spaced at about 6.5′ centers, and penetrating down into underlying soils and bedrock. This work further restricted the ability to accelerate the construction.

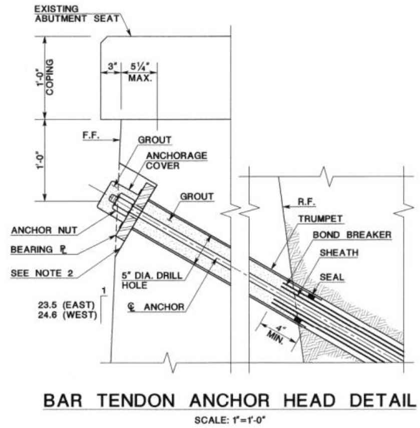

Fig 2. Inclined Ground Anchors

Photo 5 - Ground anchor installation through hole in concrete deck.

The existing bridge details were compatible with accelerated demolition procedures. During Stage 1B, the bridge superstructure was sawcut longitudinally between the bridge beams and lifted out in sections, together with the attached deck section. The fascia stringer, parapet, and sidewalk were removed in one piece.

Photo 6 - Removal of fascia stringer and parapet.

Highway Design

Approach roadway reconstruction was limited on the project to include only that necessary to transition the new slightly widened superstructure to the existing approach roadway width and to replace the existing approach slabs. In order to accelerate construction, prefabricated, precast concrete approach slab panels were used, connected with similar HPC closure pours and HES concrete overlays as on the bridge.

Photo 7 - Precast approach slabs ready for HPC closure pour.

The Bridge Design Appraisal Statement also included a staging study, which determined that due to the lack of space adjacent to the highway's ROW, the adjacent historic parkland, a private residence and multiple commercial property access driveways, a temporary bridge and diversionary roadway was not feasible and staged construction would be necessary within the existing ROW. In reviewing the local roadway network, there was a short, local, generally parallel county roadway (Mount Pleasant Avenue) that could be used for part of the detour. Thus, a staging scheme was developed to maintain westbound Route 10 traffic on the Route 10 roadway while the eastbound Route 10 traffic would be detoured down the adjacent county roadway. Traffic analyses were performed and the scheme was found to function with acceptable levels of service.

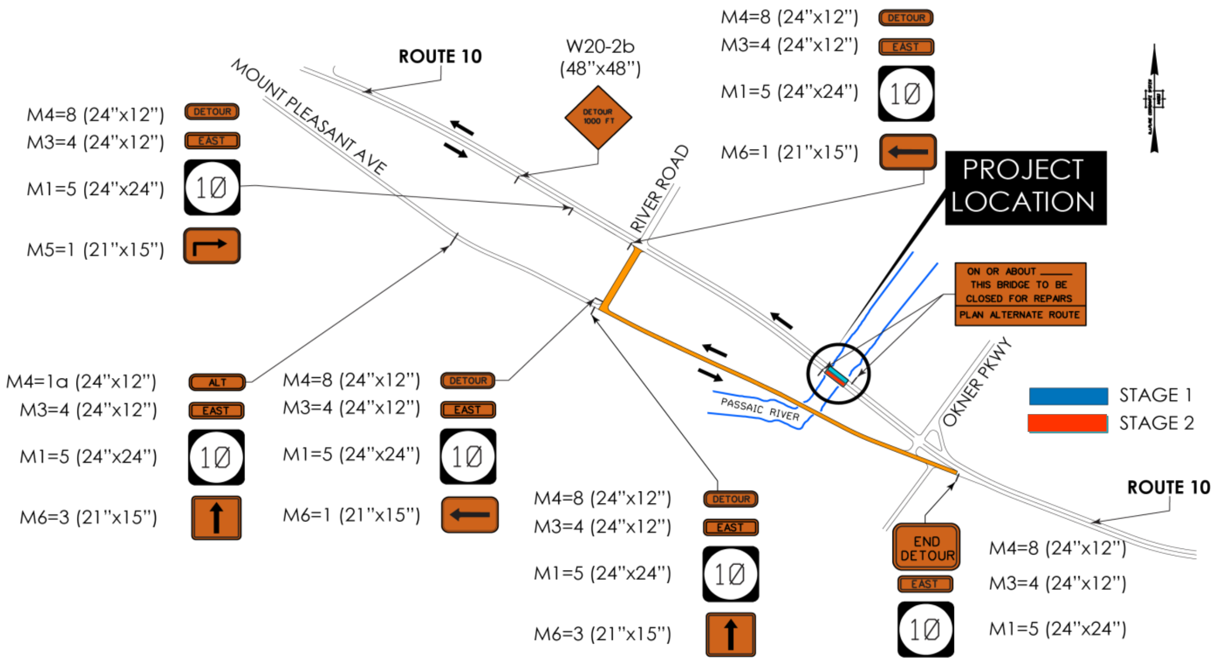

Fig 3. Detour Plan

Construction started with a short preliminary stage to prepare the local roadways for the detoured eastbound Route 10 traffic. The existing two-lane roadway (Mount Pleasant Avenue) was restriped to accommodate two eastbound and one westbound lane, with some minor incidental widening of the roadway. A temporary traffic signal was installed at an existing stop controlled intersection along the route and timing was set to be compatible with the Route 10 mainline signal.

The first primary stage of construction maintained westbound Route 10 traffic in its current location while the south half of the superstructure was reconstructed. Eastbound Route 10 traffic was detoured to Mount Pleasant Avenue and back to Route 10 eastbound, about one quarter mile east of the bridge. In the second primary stage of construction, westbound Route 10 traffic was moved onto the newly constructed south half of the bridge, with short crossovers, while the north half of the structure was reconstructed. Detoured westbound Route 10 traffic remained on Mount Pleasant Avenue. A final short completion stage with Route 10 westbound traffic back on the westbound roadway was required to remove the temporary crossovers, reestablish the concrete median barrier, complete the southerly bridge sidewalk and perform final repaving of the approach roadways. The original two-lane traffic pattern was restored on Mount Pleasant Avenue after two-way traffic was reestablished on the new bridge on Route 10. Bridge staging sections are shown in Figure 4 at the end of this paper.

DESIGN OF ABC SOLUTION FOR SUPERSTRUCTURE

Design of the new three-span continuous superstructure units was in accordance with the AASHTO LRFD Bridge Design Specifications as modified by the NJDOT Design Manual for Bridges and Structures. Live loading consisted of the AASHTO HL-93 vehicle, as well as the NJDOT permit vehicle, whichever governed. The design compressive strength (f'_c) of the concrete was 7,000 psi in order to meet NJDOT's strict requirements for zero tension in the tensile zone. Computer software aided in the computations for design of the NEXT Beam® prestressed beam units and the live load continuity connections.

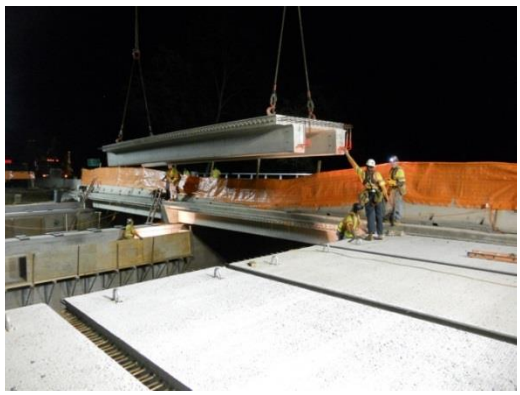

Photo 8 - Installation of prefabricated bridge unit.

NEXT Beam®, Type D beam units were chosen for design based on span length and comparable superstructure depth, as well as their thicker top flange, which would help accelerate construction. The Type D beam units include an 8″ thick reinforced flange which functions as the structural bridge deck, eliminating the need to construct a cast-in-place deck with the associated reinforcement and curing. Another benefit of the Type D beam is the ability to quickly form a continuity connection between the ends of units.

Live Load continuity was provided in order to eliminate deck joints over the piers, where deterioration and leakage typically occurs over time, causing eventual deterioration of the substructure units. Cast-in-place HPC end diaphragms over the piers serve as the connection for live load continuity, whereby the beams act as simple spans for dead loads but as continuous for live load. This connection was designed for a 90-day casting age of the eight prestressed beams, per AASHTO methods. Prestressing strands, extending from the beam ends were supplemented with significant reinforcement extending from the beam top flanges. The extended beam flange reinforcement was coupled by mechanical connectors and short splice bars to make the continuity connection. This approach has been used successfully in the past for precast, prestressed concrete superstructure continuity connections and will extend the service life of the structure through the elimination of deck joints over the piers and the issues associated with their future maintenance.

Photo 9 - Live load continuity pour couplers over pier (between bridge units).

CONSTRUCTION (AND ITS CHALLENGES)

The construction contract was awarded on January 29th, 2014 with the official start date of the contract set as March 8th, 2014. After completing the preliminary set up stage preparing the detour route for the additional traffic from eastbound Route 10, the first primary stage of construction commenced May 10, 2014.

Construction projects seem to be especially susceptible to the phrase, "*Nothing ever goes according to plan.*" Project schedules are always challenged to overcome unforeseen changes. The first challenge was encountered during performance and proof testing of the abutment inclined ground anchors, installed to provide stability to the abutments during construction. One anchor failed, delaying the full demolition of the existing superstructure, since the anchors needed to be installed, fully cured and tested prior to the superstructure removal. Fortunately, the Contractor was able to act quickly and proposed a deadman anchor solution to replace the failed inclined anchor. The Contractor's design and details were reviewed and accepted and the replacement anchor constructed and tested. This delayed the demolition of the bridge superstructure by two weeks.

The list of challenges kept growing. The Contractor completed the required abutment and pier bridge seat reconstruction and was ready to install the NEXT Beam® prefabricated bridge units, but the beams had not aged sufficiently according to the project specifications, based on their casting dates. The beam units needed to have a 90-day age based on AASHTO guidelines prior to casting the concrete end diaphragms over the piers for live load continuity to reduce time-dependent stresses in the connection and in the beam units. In an effort to maintain the accelerated schedule, based on Hatch Mott MacDonald's recommendation, NJDOT granted a 30-day reduction to the specified 90-day casting age of the beams so that the continuity connection could be made at 60 days, consistent with PCI guidelines versus AASHTO. Even with this relaxed requirement, it would still be difficult to maintain the project schedule.

On site guidance was provided to NJDOT and the Contractor to ensure proper assembly of the live load continuity connection. With this guidance and careful inspection by NJDOT, the required couplers and splice bar were properly installed to construct the negative moment connection at each deck bar, an important aspect for the connection to function as intended for live load continuity. The extra time and care required to properly construct all the connections were necessary, but continued to challenge the project schedule.

THE FINISHED PROJECT

Photo 10 - Stage 1 HES concrete overlay on precast approach slabs and NEXT

Despite these challenges during construction, the project was completed per the accelerated schedule and well before the start of the busy holiday shopping season. Specifically, Stage 1 was opened to traffic on August 25th and Stage 2 was opened on October 13th. Lessons learned during the first stage of reconstruction greatly helped to advance the project. Superstructure demolition, ground anchor installation, superstructure erection and continuity pours proceeded quickly with the experience gained in the first stage. Substantial project completion occurred on October 28, 2014. The use of accelerated bridge components and techniques reduced the construction duration by 50% compared to standard cast-in-place construction of the concrete components of the structure.

The finished product was the culmination of design efforts spread over several years, but took less than one construction season to complete. The benefits of using Accelerated Bridge Construction systems are obvious, including reduced construction duration, that carries with it road user cost benefits, lessened impacts to the motoring public, local business impacts, and safety benefits by reducing field/site work, as well as benefits for the owner and local governments. Both NJDOT and the local county and municipal stakeholders were integral in the successful completion of the project. Bridge cross-sections and elevation drawings are shown in Figures 4 & 5 near the end of this document.

Photo 11 – Elevation view of the bridge with new superstructure.

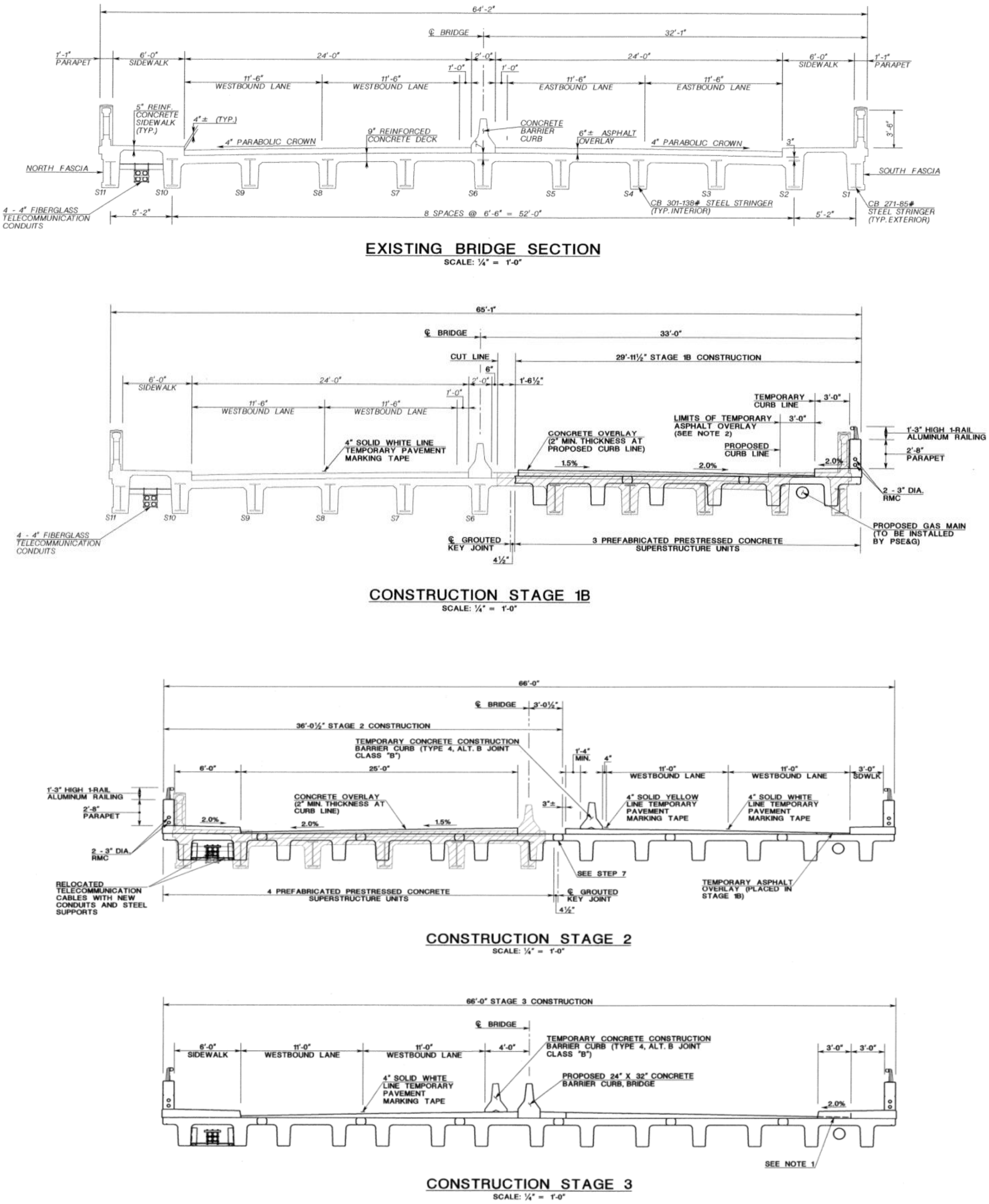

Fig. 4 Bridge Staging Sections

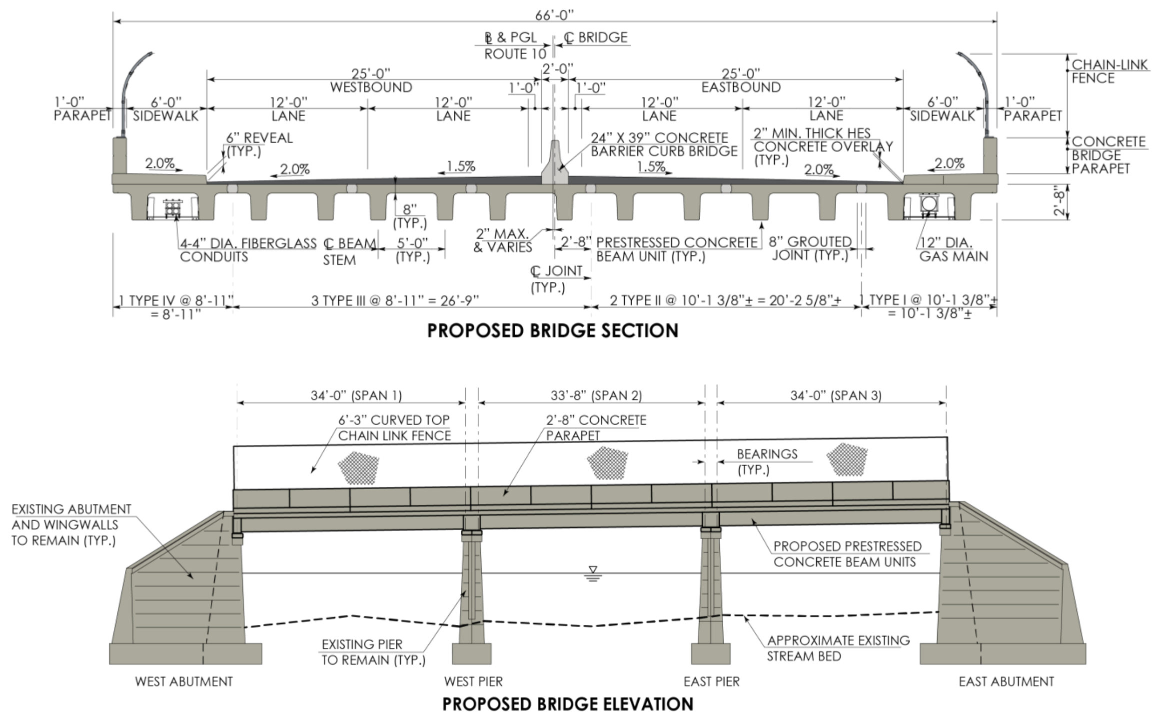

Fig. 5 Proposed Bridge Section and Elevation

CONCLUSION

While site restrictions, including limited ROW width; high traffic volumes; adjacent, environmentally sensitive properties; and the need to install ground anchors for the existing abutments, precluded full realization of accelerated bridge construction benefits, precast components and methods used in accelerated bridge construction were utilized as much as possible to reduce the construction duration. Precast concrete approach slabs and NEXT Beam® prestressed concrete prefabricated bridge units, both with HPC closure pours, greatly reduced the construction schedule compared to standard cast-in-place construction. These components allowed for accelerated completion of this three-stage bridge reconstruction project on a high-volume commercial corridor.

In selecting prefabricated bridge units, it is important to consider the time-dependent effects of prestressed concrete beam units made continuous for live load in the overall construction schedule. The construction contract procurement and construction contract execution/notice-to-proceed also need to be carefully timed relative to the construction schedule and the desired construction completion date. Time-dependent effects on beam geometry and stresses must be considered, as well as the benefits of live load continuity pours versus the extra construction time associated with those pours.

Careful coordination with the owner and the contractor is required to implement the proper ABC techniques suited for a specific project. On the Route 10 Bridge Reconstruction project, a balance was struck between the need to quickly complete the reconstruction and to provide a durable structure with reduced maintenance needs. The use of precast, prestressed, concrete NEXT Beams® and approach slabs met those needs on this project.

In the end, the project successfully utilized accelerated bridge construction components and techniques to deliver the project in an expeditious manner. The collaboration between NJDOT and the design team, led by Hatch Mott MacDonald, and further collaboration with the construction inspection team and the Contractor, resulted in a successful project that overcame administrative and technical challenges.

NOTE: The original version of this paper was presented (conference proceedings and presentation) at the National Accelerated Bridge Construction (ABC) Conference in Miami, Florida in December 2014 that was sponsored by the Accelerated Bridge Construction - University Transportation Center (ABC-UTC), Florida International University. This version published by PCI contains some additional information.

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