`

SIBLEY POND DESIGN-BUILD BRIDGE REPLACEMENT PROJECT ROUTE 2, CANAAN/PITTSFIELD, MAINE

G. Keith Donington, PE, Parsons Brinckerhoff, Manchester, NH
Hany L. Riad, PhD, PE, Parsons Brinckerhoff, Boston, MA

ABSTRACT

Due to an innovative design and the very first use of the PCI Northeast Extreme Tee (NEXT D) double T-beam, the Sibley Pond Bridge was opened to traffic in 15 months—more than 10 months ahead of the scheduled date set by the owner.

The 790-foot-long (240-meter-long), two-lane bridge consists of ten 79-foot (24-meter) spans arranged in two five-span continuous units. Fixity is provided at each end through semi-integral abutments, and each of the nine intermediate piers are supported on single rows of four steel pipe piles that flex as the structure expands and contracts around a single expansion joint located in the center.

By maximizing precast, and limiting cast-in-place concrete construction to the pier diaphragms and 8-inch-wide (0.2-meter-wide) closure strips between beam flanges, the four NEXT D beams per span were rapidly erected using a gantry crane that rolled sideways from the old bridge and across the new piers. Mechanical couplers provided continuity connections over the piers. Durability was enhanced by using 10,000 psi, self-consolidating precast concrete, with corrosion inhibitors for both the precast and field-placed concrete.

The technical proposal was judged by the owner as having the highest technical score and the lowest cost.

Keywords: First NEXT D, Innovative, Accelerated Bridge Construction (ABC), Design-Build

INTRODUCTION

Accelerated project delivery, state-of-the-art concepts, utilization of accelerated bridge construction (ABC) techniques, and making every day in the allotted project schedule count, played an important role in the design and construction of the ten-span, 790-foot-long (240-meter-long), two-lane Sibley Pond Bridge (Figures 1 & 2). It is located along Route 2 between the towns of Canaan and Pittsfield and was opened to traffic on November 21, 2011, more than 10 months ahead of the owner's scheduled project completion date of October 2012. The bridge was designed and constructed in 15 months as part of a design-build project. The two five-span continuous structure has semi-integral abutments at each end with only one expansion joint in the middle of the bridge.

Fig. 1 Elevation view of completed bridge

Fig. 2 Bridge open to traffic

The Sibley Pond Bridge also marks the first usage of the Precast/Prestressed Concrete Institute (PCI) Northeast Extreme Tee (NEXT D) type precast/prestressed double T-beam section with full depth integral deck. This section had been newly developed by PCI Northeast in response to the Federal Highway Administration's (FHWA) nationwide initiative for ABC.

The NEXT F section, with its 4-inch (100-millimeter) form deck with cast-in-place (CIP) topping had been pioneered on two previous projects by the owner. However, the newly introduced precast NEXT D beam section with its fully precast/prestressed deck section was considered more advantageous for this design-build project. Potential advantages included opportunities for additional economy, speed of erection, potential for enhanced durability to meet the owner's 100-year life requirement, and achieving the "best value point score" to win the contract for the design-build team.

PROJECT DESCRIPTION

The existing 30-span, 790-foot-long (240-meter-long) cast-in-place concrete bridge along Route 2 over Sibley Pond was built in 1939 and, after more than 70 years of service, it was decided to replace the significantly deteriorated bridge using an expedited design-build procurement process.

The project included the design and construction of a new bridge on Route 2, crossing over the shallow Sibley Pond between Canaan and Pittsfield, Maine. The existing two-lane, 26-foot-wide (8-meter-wide) curb-to-curb bridge, would be removed and replaced with a widened bridge comprised of two 12-foot (3.7-meter) lanes with 6-foot-wide (1.8-meter-wide) shoulders (i.e. 36 feet [11 meters] curb-to-curb). The project also included approximately 500 feet (150 meters) of roadway approach improvements and landscaping. Per the Maine Department of Transportation (MaineDOT) Bridge Design Guide, the bridge was to be designed to AASHTO LRFD Bridge Design Specifications for HL-93 loading for all limit states except for Strength 1. The live load for Strength 1 limit state is the MaineDOT Modified Live Load that consists of the standard HL-93 Live Load with 25% increase in the design truck.

Following a qualifications-based selection process, in April 2010 the design-build team submitted a technical proposal that was judged by the owner to offer the best value and lowest bid for replacing the existing bridge over Sibley Pond. In June 2010, the team received notice to proceed and final design commenced in earnest in September 2010. The new two-lane bridge is 36 feet (11 meters) wide curb-to-curb, 790 feet (240 meters) long, and straddles the town line between Canaan and Pittsfield.

DESIGN CONSIDERATIONS

During the technical proposal phase, the design-build team evaluated several steel and precast concrete girder bridge alternatives and span arrangements. As can be seen from the aerial view below (Figure 3) and the site plan drawing (Figure 4), the replacement bridge was placed on a tangent alignment, partially overlapping the existing bridge at each end near the abutments, but with sufficient width to maintain access to the old bridge during construction. The bridge was laid out with ten equal 79-foot (24-meter) spans so that piles from the new bents would be well clear of those from the existing bridge with its 26-foot (8-meter) spans.

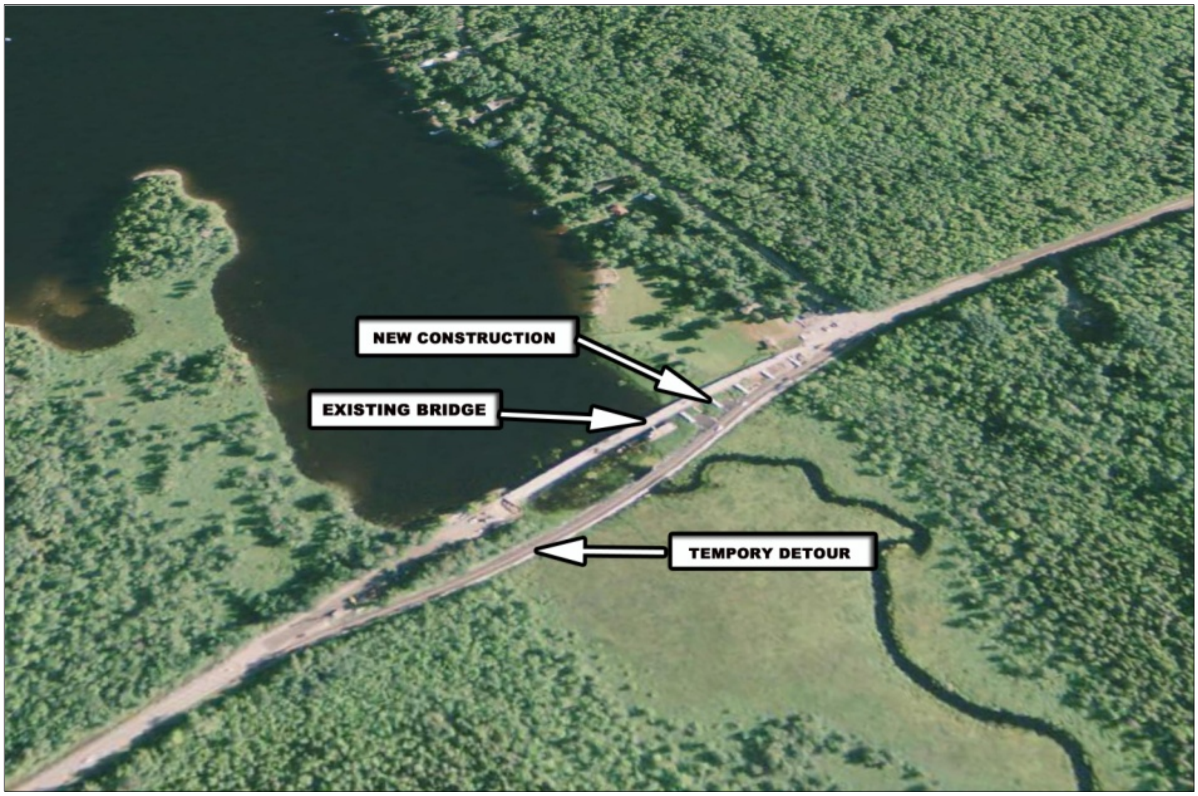

Fig. 3 Aerial view of project site

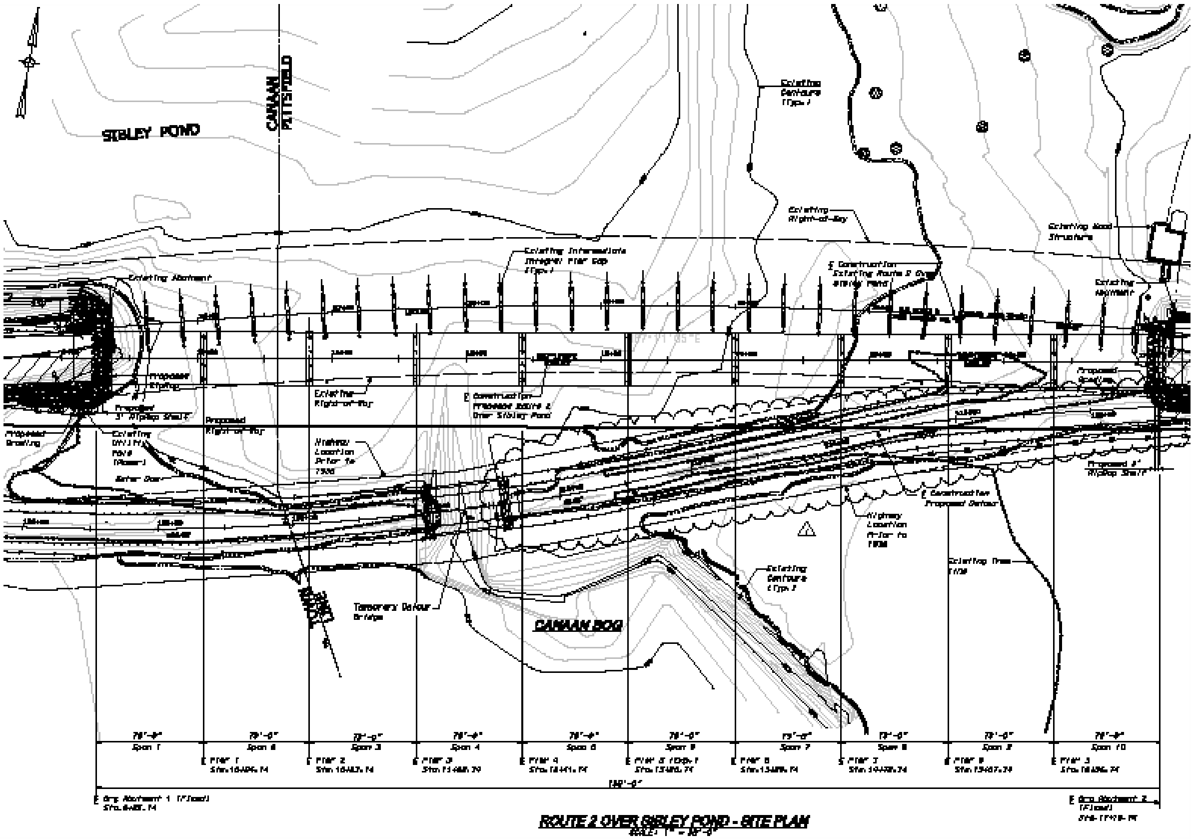

Fig 4 Site plan drawing

Early in the proposal phase, the contractor submitted an alternate technical concept (ATC) to the owner to move Route 2 traffic to the south onto an at-grade detour roadway that followed a former alignment of the route, with a 60-foot (18-meter) span temporary bridge over the pond inlet (Figure 5). The temporary detour roadway enabled traffic to be relocated safely away from the work area, and thus freed up the existing bridge to be used for contractor access, placement of concrete pier caps, and beam delivery and lateral erection of the NEXT D beams using a custom fabricated gantry crane (Figure 6).

Fig. 5 Temporary detour roadway and bridge

Fig. 6 Erection setup

Beam Selection

Thirty-six-inch-deep (0.9-meter-deep) NEXT D beams were selected for the 79-foot (24-meter) spans, that were made continuous for live load by providing continuity reinforcing steel over interior supports. As shown in the typical deck section (Figure 7) and photo below (Figure 8), the bridge cross section is achieved using four 9-foot, 4-inch-wide (2.8-meter-wide) beam units with three 8-inch-wide (0.2-meter-wide) closure pours with overlapping steel studs (Figure 9).

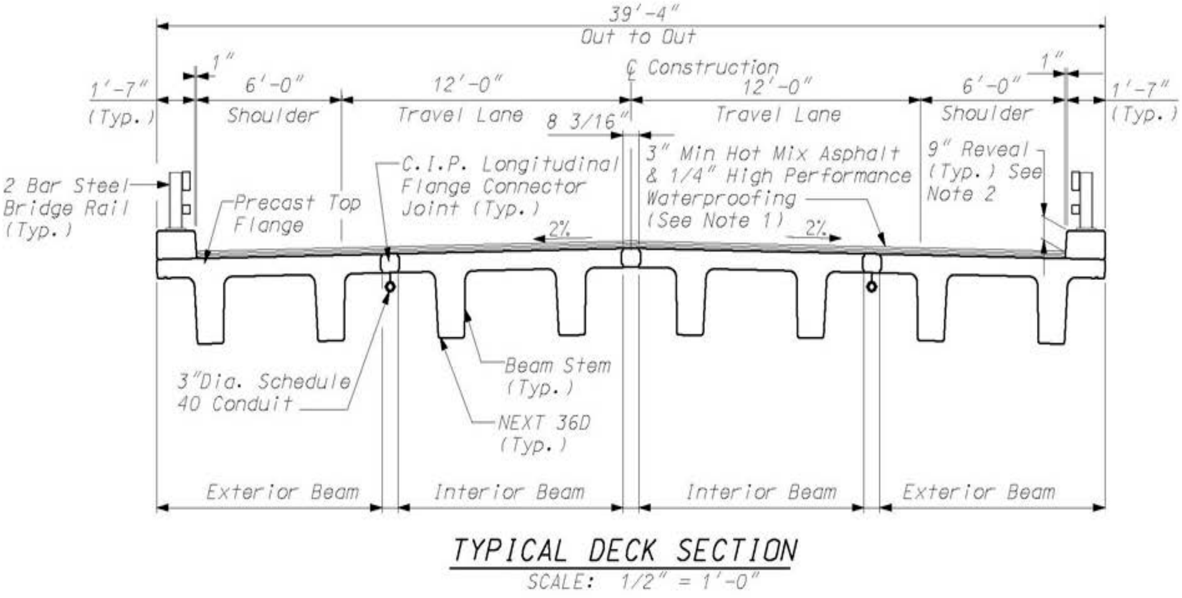

Fig. 7 Typical deck section

Fig. 8 Underside of NEXT D beam span between temporary detour road and existing bridge

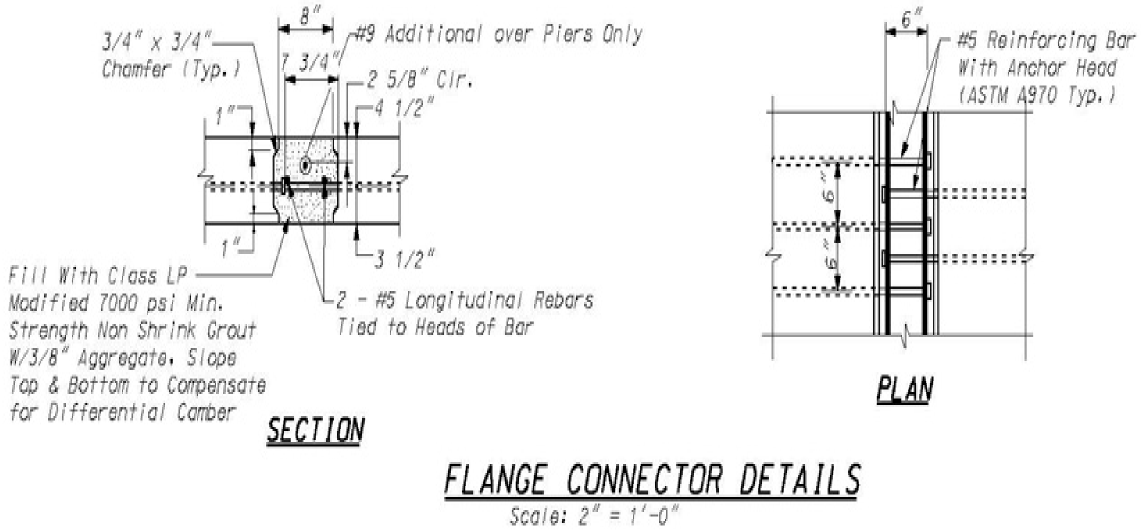

Fig. 9 Flange connector details

The advantage of the D type beam is that it has a full depth integral deck slab cast monolithically with the webs, thereby maximizing precast in-shop work, using the highest quality concrete, and minimizing the use of field-placed concrete to the 8-inch-wide (0.2-meter-wide) longitudinal joints between the beams, curbs to support the steel railings, and continuity closure diaphragms at the piers.

The team determined that a solution using the NEXT D beam would be the most cost effective by maximizing the use of precast, prestressed concrete, thereby enabling the bridge to be built quickly during a single construction season, and satisfying the owner’s 100 year minimum life requirement.

The photos that follow (Figures 10-13) were taken at the precaster’s plant in Middlebury Vermont.

Fig. 10 NEXT D beam in casting bed

Fig. 11 NEXT D beam with steel studs

Fig. 12 NEXT D beam lifted from casting bed

Fig. 13 Completed NEXT D beam

Substructure Selection

The bridge spans over a shallow pond. Glacial till and underlying bedrock are located at relatively shallow depths at the abutments with weaker organic soils, including peat, increasing in depth towards the middle of the pond. To take advantage of these variable soil conditions, and to limit the number of expansion joints, the bridge was configured with "fixity" and longitudinal stability being provided at each end through semi integral abutments supported on double rows of steel H piles driven to rock.

Each of the nine intermediate concrete pier cap piers are supported on single rows of four concrete-filled steel pipe piles driven to bedrock. The beams are supported on elastomeric bearings, and stainless steel dowels pin the continuity diaphragms to the pile caps (Figures 14 & 15). The "lollypop" type piers allow the structure to accommodate thermal, shrinkage and creep movements by flexing around a single expansion joint located at the middle of the bridge, located at the profile crown where the weak soils are at their deepest.

Fig. 14 Elevation view of several pier bents

Fig. 15 Elevation view of fixed pier bents

Pile Driving

The steel pipe piles for piers near the north abutment were driven from the old road during the first winter, before the detour road was opened to traffic (in Spring 2011). The remainder of the piles were driven by leapfrogging the pile driving crane from pier to pier, supported by temporary decking and temporary intermediate steel pile bents as shown in Figure 16.

Fig. 16 Pile driving operation with temporary bent in foreground

Final Design Innovations

Close collaboration between the contractor, the beam designer, the precaster and PCI Northeast took place during the project's early stages to optimize the final design details of these new beam sections to accommodate maximum efficiencies in precasting, erection by a custom built gantry crane, and to achieve the quality necessary for a 100-year service life as specified by the owner. Several innovative details were developed to achieve these objectives, to make the beams continuous for live load over the piers, and to select enhanced materials to achieve maximum durability.

The contractor determined that erecting the beams using a custom fabricated gantry crane running sideways across the old bridge and onto the new piers would be significantly more cost effective than erecting the beams using two cranes supported on temporary pile platforms, as initially indicated during the technical proposal stage. Float mounted erection equipment had been determined to not be feasible due to the pond's shallow depth. To maximize production of the precaster's form bed to three beams per placement, to meet the contractor's beam erection schedule, and to provide the necessary 15-inch (0.4-meter) horizontal clearance to accommodate the rails under the legs of the gantry erection crane, it was necessary to keep the ends of the beams free of all rebar and strand protrusions.

By working together, the following details were developed by the project team: for live load negative moment continuity over the piers, mechanical couplers were detailed to field splice the splice bars between adjacent beams. This required the precaster to align the bars from adjacent beams to tight tolerances. For the positive moment continuity reinforcement in the bottom of the beams, which normally is provided by overlapping extended prestressing strands, a special detail was developed using a steel end plate with ASTM A706 weldable rebar.

As shown in Figure 17, after the gantry rail support system was removed, hooked bars were field welded to the ends of steel plates that had been cast flush to the beam ends.
(Note: during the set up process at the precast plant, the steel plate and rebar assemblies were initially bolted to the bulkheads. The plate assemblies also had holes to allow the strands to pass through them as required. At the time of distressing, the assemblies were unbolted from the bulkheads).

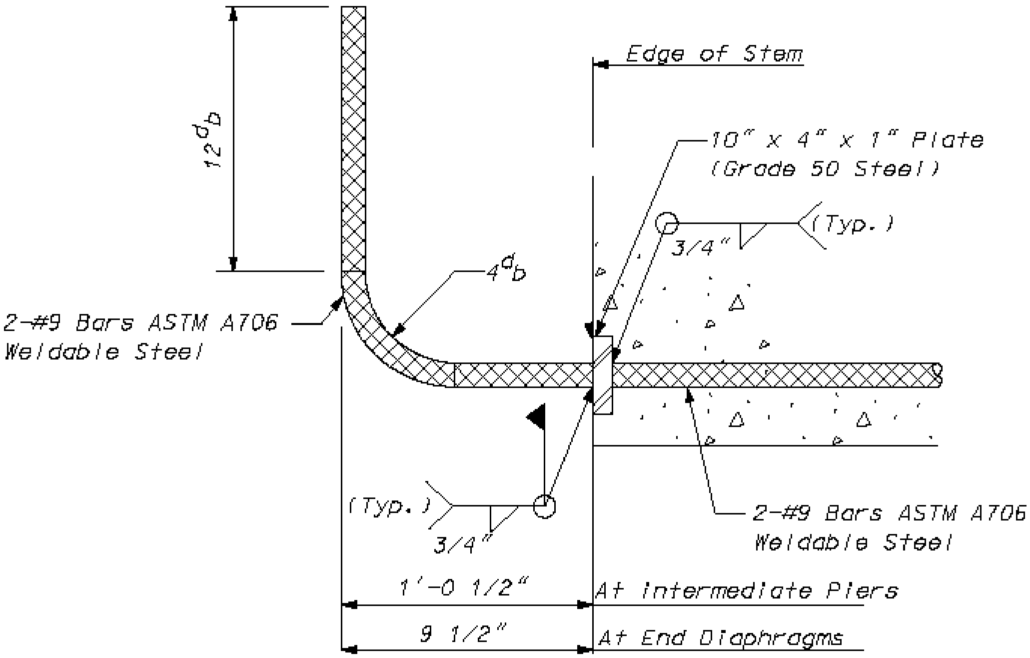

Fig. 17 Beam End detail

Beam Erection Considerations

The ten 79-foot (24-meter) spans of four beams per span were erected by a custom designed/fabricated gantry crane procured by the contractor that lifted the beams from the transporter vehicle parked on the old bridge deck, then rolled sideways across the new piers and lowered the beams onto the bearings. The design specified that for stability, the spans should be erected progressing from the abutments towards the center expansion joint pier.

The project engineer designed the steel gantry crane rail support beams for transfer of the beam from the old bridge deck across the new piers. Steel channels were welded to the top of the steel beams to contain the Hillman rollers attached to the legs of the gantry crane. A detailed structural inspection and analysis was performed for the existing bridge and several deteriorated existing piles were repaired with reinforced concrete collars to ensure structural integrity (Figure 18).

Fig. 18 Existing concrete pile requiring repair

Steel beams were used for support with a combination of short pedestal columns cut from steel H pile sections, and concrete blocks cast to accommodate the differential grades between the adjacent bridges so as to position the gantry legs in a horizontal elevation.

The photos below (Figures 19-22) show a typical beam erection sequence. The 70-ton beams were backed under the four legged gantry crane. Once lifted, the truck and beam dolly were removed from the bridge and a steel beam drop-in section was inserted transversely between the legs to complete the beam rails. The gantry crane was then propelled sideways by synchronized electrical winches located at the piers.

Fig. 19 NEXT beam positioned under gantry crane

Fig. 20 Gantry crane and rail system

Fig. 21 NEXT beam lifted off truck

Fig. 22 Gantry crane moving laterally to place NEXT beam

This gantry crane erection method proved to be very productive. It took only one day to physically move the gantry crane from one span to the next. And the contractor consistently remained ahead of the gantry crane in setting extra rails, pedestals and concrete blocks. After the first spans were erected, the contractor was easily able to set a span of four beams within an eight-hour shift, and achieve an overall turnaround time of two days per span.

DURABILITY CONSIDERATIONS

The use of NEXT D beams maximized precast concrete and limited CIP concrete construction in the superstructure to the longitudinal closure joints (Figures 23 & 24), the continuity diaphragms located at the piers, and the curbs. Long-term durability was enhanced by using high performance/high strength, self-consolidating concrete mix with 5.5 gallons per cubic yard of calcium nitrite corrosion inhibitors in the precast beams. Ten-thousand (10,000) psi strength concrete was consistently achieved by the precaster, although 8,000 psi was specified by design. High performance concrete was also specified for all field-placed concrete, along with calcium nitrite.

Fig. 23 Longitudinal closure joints

Fig. 24 Continuity diaphragm

In addition, as can be seen in Figure 25, by using self-consolidating concrete, the precaster was able to consistently achieve an outstanding quality surface finish without noticeable imperfections.

Fig. 25 NEXT beams stored at precaster

In accordance with the owner’s policy, the use of black rebar was specified, with the exception of MMFX corrosion resistant rebar for exposed concrete curbs and barrier transitions. Increased cover and high performance concrete with DCI calcium nitrite corrosion additive were used to meet the 100-year life requirement.

The roadway deck is protected with a hot machine applied high performance waterproofing membrane system with 3 inches (75 millimeters) of asphalt wearing surface. The steel pipe piles are protected with a shop applied fusion bonded epoxy coating system extending from the top of the pile to 10 feet (3 meters) below the mud line.

Locating the expansion joint in the middle of the bridge and at the high point crest of the roadway vertical curve, results in water rapidly draining away from the joint in both directions, thereby minimizing the potential for future leakage. The ends of the diaphragms at the joint are covered with a sheet membrane. Since a total of only four roadway scuppers are needed to drain the bridge (two along each curb line), the number of penetrations in the NEXT D beams were significantly minimized.

CONCLUSIONS

On first glance, one might think that the Sibley Pond Bridge would be a simple structure to design and construct. However, in actuality, this was a very challenging project that required close collaboration among several parties to succeed. Excellent teamwork by the owner, contractor, precaster, designer and PCI Northeast helped make the job a success.

In addition to the noteworthy project features already discussed, it is also worth mentioning that:

- Several of the PCI standard details for these new beam sections associated with continuity at the piers had to be adapted to maximize erection and fabrication economies and schedule requirements.

- Prior to commencing final design, the project engineer met with the PCI Northeast Bridge Technical Committee to review design concepts and benefit from the experience of committee members in design, fabrication and construction.

- Due to the horizontal curved geometry of the old bridge (the new and existing bridges were not parallel), the design and detailing of the rail support system for the gantry crane was complicated and required extensive analysis of several different support conditions.

- An unusually powerful tropical storm (Irene) washed out numerous roads in Vermont and caused delays in shipping beams from the precaster’s plant in Middlebury, Vermont. However, because the gantry crane erection method was able to complete spans on a two-day cycle, these delays did not prevent the bridge from opening to traffic as planned prior to the Winter 2011/2012 season.

ACKNOWLEDGEMENTS

The authors would like to take this opportunity to thank all the members of the design-build project team who made this paper possible:

- Owner: Maine Department of Transportation, Augusta, ME
- Contractor: The Lane Construction Corp., Bangor, ME
- Engineer/Designer: Parsons Brinckerhoff, Inc.,
  Manchester, NH & Boston, MA
- Precaster: J.P. Carrara & Sons, Inc., Middlebury, VT