PROJECT

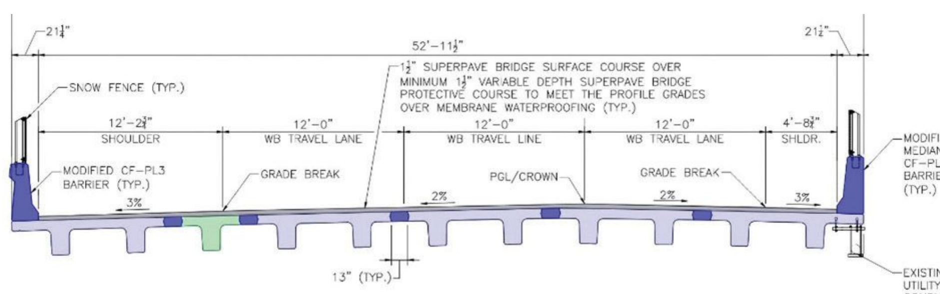
Interstate 90 Acceler-8 Bridge Project

by Preston Huckabee and Fédorah Berlus, Gill Engineering Associates

In 2019, to avoid delaying future scheduled highway reconstruction, the Massachusetts Department of Transportation (MassDOT) took an aggressive approach to accelerating the rehabilitation and replacement of eight bridges carrying Interstate 90 (I-90) in the towns of Southborough and Westborough. Using a combination of design-build (DB) contracting and accelerated bridge construction (ABC), MassDOT was able to complete the procurement, design, and construction of the aptly named Acceler-8 I-90 Bridge Replacement Project in less than two years. After a two-stage procurement process, MassDOT, with assistance from the owner's consultant engineer, selected the winning DB team, which consisted of a contractor, a structural design lead and design manager, and a civil and traffic design lead. This was the same award-winning team that in 2011 replaced 14 bridge superstructures on Interstate 93 just north of Boston, on a project known as the Fast-14. With MassDOT's leadership and the DB team's prior experience, this team was primed for success on Acceler-8.

Construction of the eight bridges was scheduled to be completed over eight weekends in the summer of 2021 using ABC techniques. During each weekend, all traffic was consolidated into one barrel of the roadway (eastbound or westbound), which was temporarily reconfigured to carry two lanes in each direction. This traffic setup was implemented with crossovers and movable barriers.

The base technical concept proposed in the request for proposal called for prefabricated bridge units (PBUs) consisting of steel beams with precast concrete deck as the primary structural element. Although this construction method had been successfully employed for the Fast-14 project, the team decided early in the proposal stage to pursue a more innovative solution using precast, prestressed concrete Northeast Extreme Tee (NEXT) D beams instead of PBUs. Compared with the PBU option, NEXT D beams were more economical because of their lower material and fabrication costs, including reduced handling. PBUs require fabrication in both steel and precast concrete plants, whereas NEXT D beams only require fabrication in a precasting plant. Furthermore, NEXT D beams allow designs of shallower sections, which would improve the clearance beneath the structures. However, there was one wrinkle: to accommodate the existing and proposed abutment layouts, the NEXT D beams had to be designed for skews and spans that exceeded the



The typical bridge cross section consisted of one single-stem and five double-stem Northeast Extreme Tee (NEXT) D beams. The replacement bridges used 28-in.-deep beams, and the new bridges with longer spans used 36-in.-deep beams. All Figures and Photos: Gill Engineering Associates Inc.

profile

ACCELER-8 INTERSTATE 90 BRIDGE REPLACEMENT PROJECT / **SOUTHBOROUGH AND WESTBOROUGH, MASSACHUSETTS**

BRIDGE DESIGN ENGINEER: Gill Engineering Associates Inc., Needham, Mass.

OTHER CONSULTANTS: Owner's (MassDOT's) engineer: CDR Maguire Inc., Milton, Mass.; civil & traffic design lead: Tetra Tech, Marlborough, Mass.; Green International Affiliates Inc., Tewksbury, Mass.; Lamson Engineering Corporation, West Newton, Mass.

PRIME CONTRACTOR: J. F. White Contracting Company, Framingham, Mass.

CONCRETE SUPPLIER: Closure pour mobile mixer: inTerra Innovation Inc., Chelsea, Mass.; on-site ready-mixed: Dauphinais Concrete Inc., Douglas, Mass.

PRECASTER: J. P. Carrara & Sons, Middlebury, Vt.—a PCI-certified producer

Single-stem Northeast Extreme Tee D beam after curing and before end diaphragm placement. Epoxy-coated mild reinforcement extending from the top flanges will become part of the cast-in-place concrete closure pours and end diaphragm.

typical permissible limits; therefore, a design waiver from MassDOT was required for their use. Because MassDOT is open to innovation in all its designs, the agency granted the waiver.

While these bridges are not complex structures by definition, many complex design elements had to be taken into account to facilitate construction. For example, each design considered fabrication and erection tolerances in every design element to ensure proper fit-up during construction.

Six of the eight bridges were superstructure replacements set on the existing rehabilitated abutment stems. The other two bridges were full replacements with new cast-in-place (CIP) concrete abutment stems, wingwalls, and footings founded on micropiles. The six superstructure replacements maintained the existing single-span configurations with 28-in.-deep NEXT D beams, and the full replacements converted existing three-span structures into single spans with 36-in.-deep NEXT D beams. The bridges had varying spans, from 35 ft 6 in. to 70 ft 9 in. between centerline of bearings, but all had identical widths of 56 ft 6 in. to accommodate three 12-ft 0-in. travel lanes, a 12-ft 2-in. right shoulder, a 4-ft 9-in. left shoulder, and two standard MassDOT 42-in.-high concrete F-shape barriers. Each bridge cross section consisted of one single-stem and five double-stem NEXT D beams. The single-stem NEXT D beam allowed the design of identical cross sections and beam layouts by maintaining a constant stem spacing of 5 ft 0 in., which helped reduce some of the fabrication and erection complexities.

In addition to the NEXT D beams, the abutment caps, approach slabs, approach barrier moment slabs, and guardrail transitions were precast to accelerate construction. Before the weekend closures, the preserved bridge abutments were rehabilitated and finished with partial-depth horizontal saw cuts to facilitate the bridge seat demolition and to receive the new precast concrete abutment caps.

A double-stem Northeast Extreme Tee D beam after end diaphragm placement in a secondary pour. Reinforcement for the barrier is visible at the far edge of the deck slab.

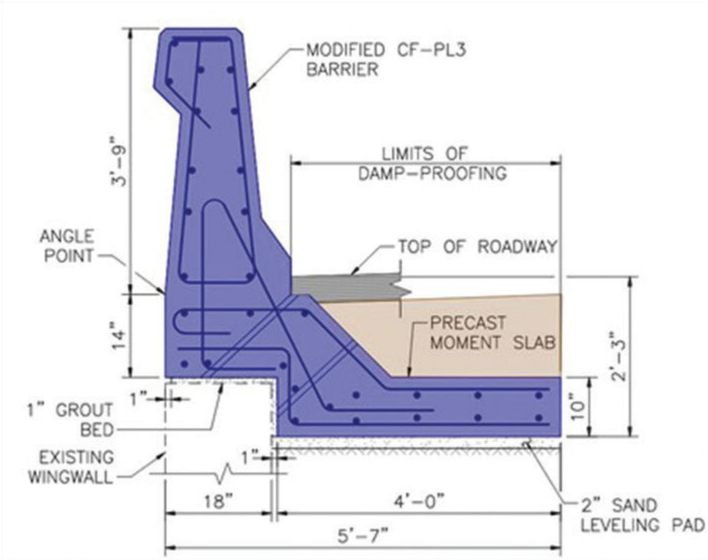
MASSACHUSETTS DEPARTMENT OF TRANSPORTATION, OWNER

OTHER SUPPLIERS: Micropiles: HUB Foundation Co. Inc., Chelmsford, Mass.; erector: Saugus Construction Corporation, Georgetown, Mass.; formwork: Hamilton Form Company, Fort Worth, Tex.

BRIDGE DESCRIPTION: Eight simple-span bridges, each 56 ft 6 in. wide with spans ranging from 35 ft 6 in. to 70 ft 9 in., using precast, prestressed concrete Northeast Extreme Tee (NEXT) D beams on precast concrete abutment caps (superstructure replacements) or cast-in-place concrete abutments, wingwalls, and footings on micropiles (full bridge replacements)

STRUCTURAL COMPONENTS: Five double-stem prestressed concrete NEXT D beams and one single-stem prestressed concrete NEXT D beam per bridge; 28-in.-deep beams used at superstructure replacements, and 36-in.-deep beams used at full bridge replacements, with rapid-hardening, low-permeability cement concrete closure joints; precast concrete abutment caps for superstructure replacement projects; cast-in-place abutment stems, wingwalls, and footings for full structure replacement projects; and precast concrete approach slabs, approach barrier moment slabs, and guardrail transitions.

PROJECT COST: $49 million



Cross section and reinforcement details of the unique precast concrete moment slab developed to support the concrete F-shape barriers on the approaches.

The fabrication form with near-side form removed shows epoxy-coated steel reinforcement in place for the casting of the moment slab. Self-consolidating concrete was used for all precast concrete components.

The micropile foundations, CIP abutment stems, and CIP wingwalls for the bridge replacements were all constructed and backfilled under the existing approach spans in the months before the summer traffic redirection. The superstructures of the bridges were then constructed during the scheduled weekends closures.

Four of the bridges were located on vertical curves, and the other four were located on vertical tangents, with normal roadway crown for the travel lanes consisting of 2% cross slopes that break to 3% slopes at each shoulder. The NEXT D beams were rotated to accommodate the crown and shoulder breaks in the road surface and align with the longitudinal profile grades. The combination of longitudinal and lateral slopes needed to be accommodated in the bearing plates at each support. Tapered plates and shim plates were detailed with built-in tolerances to ensure the bearings would mate properly with the rotated stems.

The design team also paid careful attention to the NEXT D beam camber when calculating the seat elevations to ensure that the beams would sit below the final roadway profile and accommodate the placement of the hot-mix asphalt wearing surface. The team had anecdotal information that camber in NEXT D beams can exceed calculated design values. Without any accurate means to estimate the camber, they set beam seat elevations during the design phase based on typical methods. However, armed with the foreknowledge that increased camber growth was possible, the design team had the beams surveyed after fabrication to evaluate the actual camber. As anticipated, the survey data demonstrated that the camber measured in the plant exceeded the anticipated design camber at erection. Working with the contractor, the DB team revised the seat elevations during construction by lowering the horizontal saw cuts in the rehabilitated abutments and lowering the seat elevations of the CIP abutments to ensure that the final beam position would properly conform to the roadway profiles. After beam placement, significant survey effort was required to ensure that the variable-depth asphalt wearing surface could be properly placed to fill the gap between the end of the deck and the approach roadway, meeting the final roadway profile and providing a smooth ride.

Self-consolidating concrete was used for all precast concrete elements for this project. Epoxy-coated reinforcement was used for all conventionally reinforced concrete sections, and

For each of the bridges with only superstructure replacement, the erection of precast concrete abutment cap sections typically took place midmorning on Saturday during the weekend closure. During each 55-hour weekend closure, all Interstate 90 traffic was consolidated into one barrel of the roadway (eastbound or westbound), which carried two lanes in each direction.

Northeast Extreme Tee D beams were typically placed late on Saturday afternoon during the weekend closure. A single-tee beam is being erected in this photo.

0.6-in.-diameter, 270-ksi, low-relaxation seven-wire prestressing strands were used as the primary reinforcement in the NEXT D beams. The prestressed concrete beam design required a compressive strength of 8000 psi; the 28-day concrete cylinder breaks reached over 11,000 psi.

The single-stem beams were cast two at a time in the same forms used for regular NEXT D beams; this meant that the width of the flanges and any reinforcing bar extensions had to be sized to not interfere with the other single-stem beam being cast at the same time. If two single-stem beams had not been cast at the same time, the fabricator would have been required to balance the prestressing force in the self-stressing form by placing the same prestressing force on the side that was not receiving a concrete placement. Although each bridge had only one single-stem beam, both bridges (eastbound and westbound) at each location were identical, so it was effective to cast both single-stem beams at the same time.

A unique moment slab was developed to support the concrete F-shape barriers on the approaches. The moment slab was detailed with a 10-in. × 4-ft 0-in. slab section and a 19-in.-wide barrier section, making the moment slab only 5 ft 7 in. wide. This relatively narrow detail was successfully achieved by designing the moment slab to key into the top of the existing wing walls and shifting the center of mass lower than the center of rotation. Drill-and-grout doweled connections were not used; instead, a bed of grout was placed between the moment slab and the existing wing walls.

NEXT D beams have a nominal 8-in.-deep top flange that forms were bridge deck. CIP concrete closure pours are placed between the flange edges to finish the deck and complete the bridge. For this project, the closure pours used rapid-hardening, low-permeability cement (calcium sulfoaluminate–based) concrete placed from a mobile volumetric mixer, typically early on Sunday mornings. To open each bridge to traffic, a 1500-psi minimum concrete strength was required in the closure pours. Two hours after placement, the concrete cylinder breaks would typically reach 4000 to 6000 psi, with a low of 3500 psi and a high of 7000 psi. This rapid strength gain ensured that the structures were ready to support traffic on the bare concrete deck surface long in advance of the reopening of each bridge on Monday morning. Concrete barriers, waterproofing, and hot-mix asphalt wearing surface were applied to the bridge decks later, after the weekend bridge closures.

MassDOT allocated eight weekend closures to complete construction. Only six were needed to demolish, replace, and reopen the bridge superstructures to traffic. The final weekends were held in reserve. Bridge demolition and reconstruction took place during the 55-hour weekend closures. Beginning Friday evening, traffic was crossed over the interstate median to the opposite barrel to maintain bidirectional traffic throughout the closure period, and each completed bridge was reopened to traffic by 5:00 a.m. on Monday. The DB team and MassDOT took an all-hands-on-deck approach to the weekend closures, with senior decision makers on site or readily accessible. Any issues that arose were discussed there and then, and solved within the closure period. This approach contributed to the overall success of the project.

The closure pours, visible in this photo as longitudinal stripes in the deck, used rapid-hardening, low-permeability (calcium sulfoaluminate–based) cement concrete. To open each bridge to traffic, a 1500-psi minimum concrete strength was required for the closure pours to ensure that the structures were ready to support traffic on the bare concrete deck. Two hours after placement, the concrete cylinder breaks typically reached 4000 to 6000 psi.

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