The first NEXT beam bridge

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- The design, fabrication, and construction of the first northeast extreme tee (NEXT) beam bridge in the United States features innovative project delivery and the first application of PCI Northeast's design guidelines.

- Construction challenges are explored for the new seven-span concrete bridge that stretches more than 500 ft (150 m) across the mouth of the York River in York, Maine.

The New Bridge, as it is called, in York, Maine, was the first northeast extreme tee (NEXT) beam bridge to be designed, fabricated, and constructed in the United States. The project featured innovative project delivery, the first application of PCI Northeast's design guidelines, development of new forms needed, and careful erection of the new, heavy beams. The New Bridge's seven spans stretch more than 500 ft (150 m) across the mouth of the York River in York, Maine. The challenges faced in the development and construction of this project are explored in this paper.

Overview

Accelerated construction for bridges is becoming more of a necessity than a luxury, and the need for alternative streamlined fabrication and construction products is growing. The bridge technical committee of PCI Northeast developed a solution in the form of the NEXT beam.

Inception of the NEXT beam

Inspiration for this new beam came from a high-level railroad platform slab that resembled a typical double-tee section but was more robust, with attributes well suited for bridges. The NEXT beam provides an alternative for the 50 to 80 ft (15 to 24 m) bridge span that was primarily dominated by butted box beams as the precast concrete option. **Figure 1** shows a transverse section of the New Bridge.

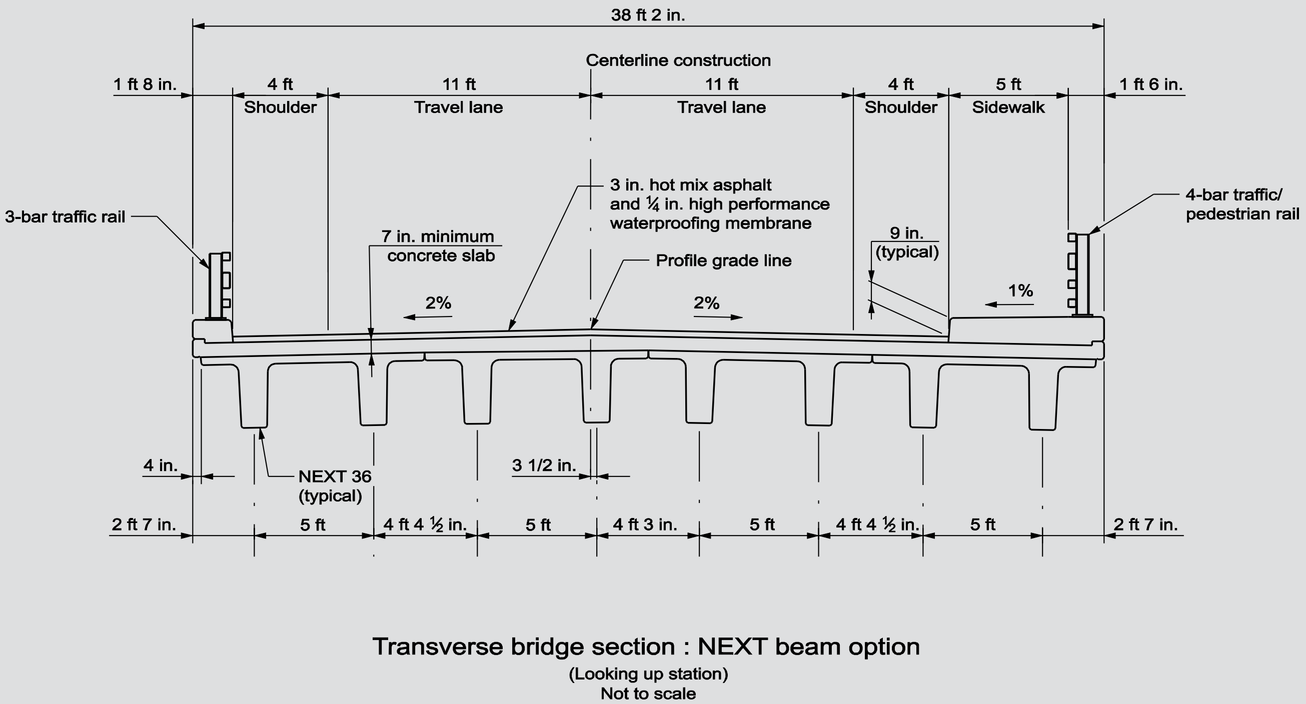

Figure 1. New Bridge NEXT beam transverse section. Note: 1 in. = 25.4 mm; 1 ft = 0.305 m.

Development and standardization

During the development process, design guidelines were set to create standardization. In the beginning of development, the focus was on the type F NEXT beam, which has a 4 in. (100 mm) top flange thickness and requires a full-depth deck topping (Fig. 1). As interest in the NEXT beams grew, a type D NEXT beam was developed with an 8 in. (200 mm) flange thickness that serves as a full-depth deck. The shallow depths of the standard NEXT beams were set to vary from 24 to 36 in. (600 to 910 mm) so as not to compete with the New England bulb tee (NEBT) beams, which have a minimum depth of 39 in. (1000 mm). The width of the NEXT beam flange may vary from 8 to 12 ft (2.4 to 3.7 m). One of the key advantages of NEXT beams in fabrication is that the forms can be easily manipulated to accommodate the different member sizes. Magnetic side forms can be adjusted to create top flange widths at any increment. Shallower beams can easily be cast by blocking up the bottom of the stem forms.

A 4 in. (100 mm) top flange thickness was developed to serve as a stay-in-place form for the deck, which drastically shortens construction time by eliminating the need to create, install, and strip forms. The wide out-to-out distance provided by the top flange allows for a minimal number of beams. In the case of the New Bridge, a cross section of only four NEXT beams was required for a 30 ft (9.1 m) wide roadway with a 5 ft (1.5 m) sidewalk.

The downside of having only four beams is the resulting weight of each. The maximum standard NEXT 36 beam (36 in. [910 mm] depth at 12 ft [3.7 m] spacing) has a weight of approximately 1500 lb/ft (2200 kg/m). The weight of these large NEXT beams was a concern; the standard beam tables limited the weight to 120 kip (54 tonnes) for transport.

New Bridge: Preliminary design

The New Bridge carries Route 103 over the York River in York, Maine. The original bridge of painted steel girders on treated timber piles was constructed in 1957. The 468 ft (143 m) long bridge consisted of sixteen 26 ft (7.9 m) spans and a single 52 ft (16 m) navigation span. The existing bridge had a 24 ft (7.3 m) wide roadway, which is quite narrow for a major collector. The bridge was scheduled for replacement because it was in poor condition due to the harsh coastal environment.

The proposed New Bridge required a shallow superstructure to maintain existing navigational clearances without greatly modifying the profile of the bridge. An increased road width was also necessary to better accommodate both vehicular and pedestrian traffic. During construction, the bridge needed to be closed and traffic detoured to minimize the effects on the historic and environmentally sensitive site. This would allow for the new structure to be on the same alignment as the existing structure; therefore, accelerated bridge construction was critical.

In the preliminary design stage, two different substructure layouts were evaluated along with a number of super-

Table 1. Continuous, integral bridge alternatives considered in the design of the New Bridge

Design alternative	Number of spans*	Total length, ft	Beam type	Number of beams per span	Beam spacing, ft	Composite deck thickness, in.
1	7	510	Precast, prestressed concrete NEXT 36 beam	4	4.0	7
2	7	510	Precast, prestressed concrete NEBT 1000 beam	9	4.0	8
3	5	506	33 in. × 48 in. precast, prestressed concrete box beams	9	4.0	5
4	7	510	33 in. × 48 in. precast, prestressed concrete box beams	6	6.25	8
5	7	510	39 in. × 48 in. precast, prestressed concrete box beams	5	8	8
6	7	510	27 in. × 48 in. precast, prestressed concrete box beams	9	4.0	5

*Seven-span alternatives consisted of span lengths of 55, 80, 80, 80, 80, 80, and 55 ft, while the five-span alternative consisted of span lengths of 104, 104, 90, 104, and 104 ft. Note: 1 in. = 25.4 mm; 1 ft = 0.305 m.

structure alternatives. The different span arrangements considered allowed for minimal superstructure depth while avoiding existing substructure locations. The substructure consists of integral abutments on steel H piles and concrete-filled, coated steel pipe pile bents with concrete caps at the piers. Cost, durability, constructability, and environmental impacts were contributing factors in determining the chosen substructure type.

Preliminary span arrangements and superstructure options

Table 1 lists six alternatives considered in the design of the New Bridge that would replace the original 488 ft (149 m) long bridge. Right-of-way limits, profile requirements, environmental impacts, span configurations, cost, and ease and duration of construction were considered to determine the recommended structure options. At the end of the preliminary design stage, it was decided to continue the final design with a dual superstructure design of the NEBT 1000 beams (where 1000 represents the depth of the beams in millimeters) and the NEXT 36 beams (where 36 represents the depth of the beams in inches) as a contractor option. **Figure 2** shows the transverse section of the NEXT 36 beams.

While there was interest in the newly developed NEXT beam, there was also a lot that was unknown in making this design concept a reality. Construction costs of the NEXT beam were uncertain because it was the first of its kind. In addition, there was no guarantee that there would be any interest on the part of fabricators and contractors.

The New Bridge project site had a number of features that favored the NEXT beam. The large number of beams required for the project would help to offset and justify the additional cost of purchasing forms for the new beam. In addition, the bridge site provides a proper staging area with good access for a marine-mounted crane for the extremely heavy NEXT beam.

The decision to move forward with the dual-design superstructure was stimulated by a desire to continually innovate and improve bridge design and construction practice in the state of Maine. Getting these new NEXT beams into construction would be a plus, but at the same time, providing the commonly used NEBT beams option would ensure a cost-efficient structure. The close proximity to the ocean, allowing easy access for a barge, enabled fabricators along the East Coast to be competitive in bidding the NEBT beam option.

Four of the five contractors bidding on the project chose to bid the NEXT beam option. The overall project lowest bid was approximately \$5.5 million. The New Bridge portion totaled about \$3.7 million (\$208/ft^2 [\$2240/m^2]) including \$950,000 (\$53/ft^2 [\$570/m^2]) for the NEXT beams. Other bids included costs for the NEXT beams that varied from \$36/ft^2 to \$50/ft^2 (\$390/m^2 to 540/m^2).

Giving the contractor the option of choosing a superstructure allowed for real-cost comparison between the NEXT and NEBT beams for future projects with similar site conditions. There was no significant material cost savings of the NEXT beam superstructure (beams and deck) compared with the NEBT beam superstructure (beams and deck) for this project. However, the NEXT beam superstructure resulted in project cost savings by reducing erection and construction time.

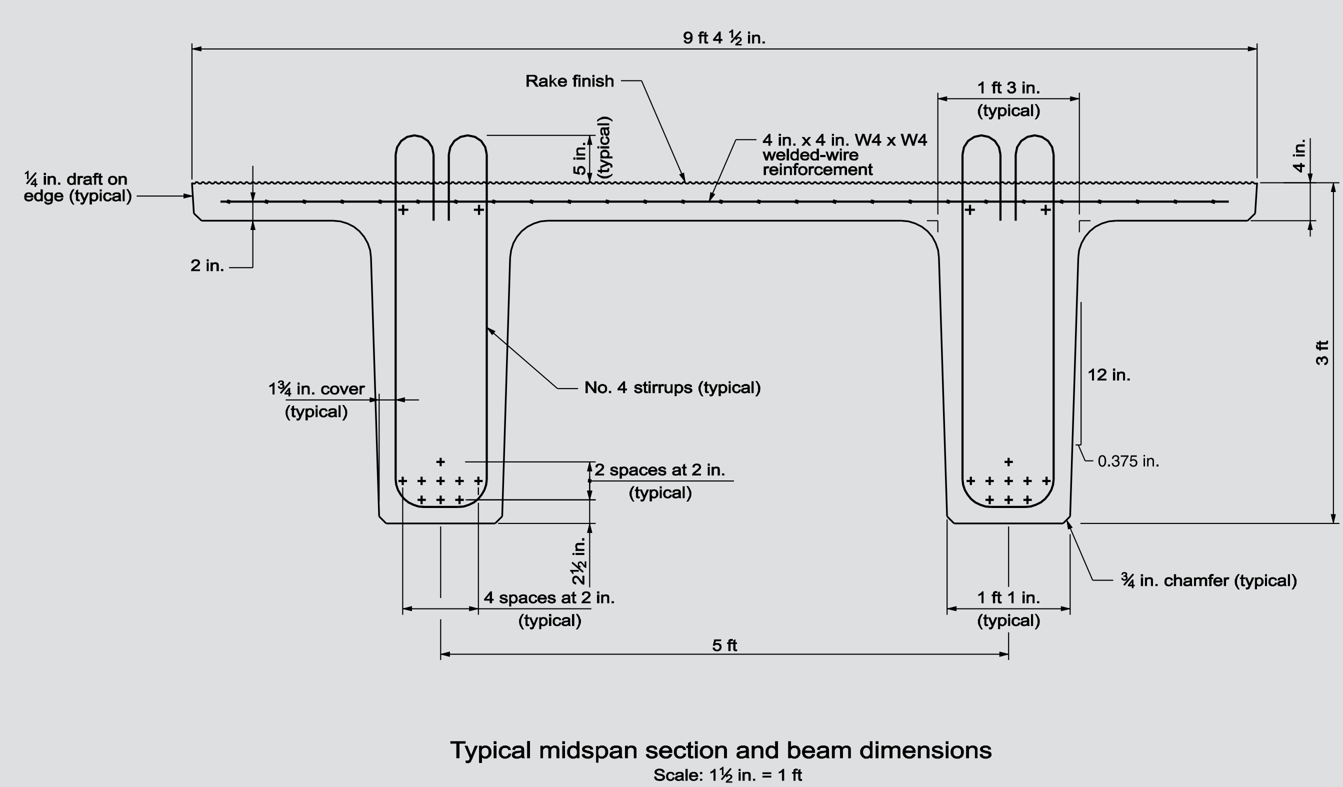

Figure 2. New Bridge NEXT beam reinforcing. Note: W4 × W4 = MW26 × MW26; 1 in. = 25.4 mm; 1 ft = 0.305 m.

Design considerations

Cross-slope geometry

One of the first obstacles encountered in designing the NEXT beam bridge was the cross-slope geometry. The typical bridge section consists of 11 ft (3.4 m) lanes with 4 ft (1.2 m) shoulders, a 5 ft (1.5 m) sidewalk on the east side, and a 2% crown at the center of the travel lanes. The sidewalk on one side made the centerline of construction different from the centerline of the superstructure. A best-fit beam width was determined to accommodate the offset centerline of construction and the cross slope of the road. This resulted in having a thicker deck over one of the interior girders, which had to be accounted for in design.

Camber

Designing the beams for camber proved to be more of a challenge than originally anticipated. All strand locations were used for the strength design of the 80 ft (24 m) spans, giving the beams a large camber. Add to this the vertical curve of the road, and there was quite a bit of camber to balance. With prestressed members, the majority of the camber in the beams is controlled by the strands, which is driven by the strength required for design. Without a haunch, not matching the vertical curve geometry can add more deck concrete in butted construction. Multiple design iterations were performed to balance the anticipated upward camber and downward deflection due to the deck concrete.

Deflection

Many factors affect the deflection of a member, such as the number and size of strands, the relaxation of strands, creep and shrinkage of the concrete, and elastic shortening. Because the NEXT beam had not been used before, PCI multipliers were used to determine the deflection. The design of the member has to be efficient but at the same time conservative enough to handle potential deviations from the calculated deflections.

Continuity

The New Bridge NEXT beams were designed as simple spans and also as continuous under live load. This was accomplished by placing each simple span separately, then placing a wide closure strip over the piers to provide a monolithic deck in the final condition. Strands were extended from the bottom row of the beams and bent up into the closure strip to help control positive moments at the piers from long-term creep effects.

Strand details

Symmetry is required between the stems of the beam for stability, limiting the number of strands to increments of two. This is more difficult when trying to meet required strength and limit excessive camber. The NEXT beam can also be troublesome in relation to the American Association of State Highway and Transportation Officials

Figure 3. Stirrup placement.

(AASHTO) debonding requirements in *AASHTO LRFD Bridge Design Specifications*[1] section 5.11.4.3. According to AASHTO, exterior strands cannot be debonded. Because the NEXT beam has two stems, there are twice as many exterior strands, which limits the number of strands that may be debonded. Figure 2 shows the strand layout. All strands are prestressed, and no longitudinal or transverse posttensioning is required for the NEXT beams.

The NEXT beam has all straight strands in its template, with no draped strands. This is beneficial for fabrication because it provides a safer working environment and is a preference in the Northeast region.

The New Bridge design of the beam nearly maximized the strand capacity for the 80 ft (24 m) spans. Although there was enough strength capacity, there was no room to modify strand location to adjust camber and deflection. The shorter 55 ft (17 m) end spans required fewer strands and therefore provided flexibility in strand placement to give the necessary balance between strength and camber.

Mild steel reinforcing details

A W4 × W4 (MW26 × MW26) welded-wire reinforcement was selected for the top flange reinforcement as the standard detail. The thin top flange of the NEXT beam is intended only for use as a deck form, and the welded-wire reinforcement is used to support the fresh concrete only. The welded-wire reinforcement was the most appropriate because it provides the most flexibility with the required cover in the 4 in. (100 mm) thick top flange and is easy to install. The design of the NEXT beam for the New Bridge required additional top flange reinforcement to control the tensile stress at the beam ends. This was accomplished by adding no. 4 (13M) longitudinal bars to the top flange above the welded-wire reinforcement. Although the proper cover could be achieved, it left little tolerance. In addition, the welded-wire reinforcement needed to be cut and spliced to accommodate the shear stirrups and lifting devices. This was difficult to do with the limited available cover in the 4 in. top flange.

Another element in the standard details that had to be modified for the New Bridge NEXT beams was the stirrups. The stirrups were originally 180-degree hairpin hooks facing inward, and the vertical legs fit the narrowest width at the base of the tapered stem. This resulted in increasing cover to the stirrup legs toward the top of the beam. During the shop drawing process, these hairpin hooks on the stirrups were rotated out for ease of fabrication. **Figure 3** shows the fabricated stirrups.

After the beams were fabricated, intermittent tensile cracks were observed at the stem-to-flange transition. In the future, designers should consider revising the stirrups to

Figure 4. NEXT beam forms.

taper the legs to match the stem taper and add longitudinal reinforcing in the upper stems, which will help to reduce the tensile cracks at the stem-to-flange transition. Another alternative is to add composite mesh reinforcing along the side of the stems at each end.

Integral abutment

Because a low-maintenance, jointless bridge was desired, integral abutments were chosen for the New Bridge. The full-depth cast-in-place concrete slab placed on top of the NEXT beams helped to simplify the connection to the abutment. Longitudinal reinforcement in the slab extended into the abutment closure strip, and the bottom strands were extended out and turned up into the back wall to help create the integral connection. To allow for movement in this jointless bridge, the abutment H piles were encased with 30 in. (760 mm) diameter steel casing with voided annular space between the pile and casing in the uppermost region of the piles.

Constructability

Constructability considerations were crucial during design. Having the road closed and traffic detoured during construction allowed for crane setup behind the abutments, enabling easier beam placement. Also, there are no overhead utilities at the site to limit the maneuvering of the cranes and equipment. The NEXT beam bridge provided substantial time savings over a typical girder bridge because no deck forms needed to be placed and stripped.

The beams were designed as simple spans for construction as well as continuous for the completed structure. This allowed the contractor the option of placing deck sections at the middle spans by driving construction vehicles out over the newly constructed, fully composite, end spans using temporary traffic plates or other suitable means to cross the closure strips at the piers.

Construction

Fabrication

The fabrication of the NEXT beams was one of the overarching project unknowns. Fabricating these new beams required the development of new forms at the expense of the fabricator. The fact that four of the five bidding contractors used the NEXT beam for their proposed bid indicates that the contractors determined that the benefits outweighed the risks associated with this new design. One set of forms could be used for all sizes of the NEXT beams. Blocking could be added to the stem bottoms for the shallower girders, and adjustable rails at the top could be moved easily to accommodate varying flange widths. **Figure 4** shows the new forms created for the NEXT beam.

A problem addressed during fabrication was the lifting inserts. The location of the inserts affected the end-of-beam tensile stress in the top flange and therefore could not be placed too far from the ends. Also, with the size and weight of the beams, finding a standard insert that could support the load and avoid the strands was difficult.

Beam transport

Transporting the new beams was another challenge. Once fabricated, the beams had to travel through three states to the bridge site. Transporting the large heavy beams required expensive police escorts that had to be incorporated into the cost of the project.

Erection

A favorable detour route around the New Bridge allowed the road to be closed and traffic temporarily rerouted during construction. This greatly reduced the overall time of construction. With the road shut down, the contractor had time and space to complete the project. The 55 ft (17 m) end spans were erected first. A truck-mounted boom crane, located behind the new abutments, lifted the end-span beams into place (**Fig. 5**). The interior spans were lifted off a barge that was positioned between the new piers. An 80 ft (24 m) temporary bridge at the north end of the bridge was constructed and used for access to the barge in shallower water.

The simple span design allowed construction equipment on the newly constructed spans to place the deck systematically. The closure strips over the piers were completed after all beams were erected to provide continuity under a live load configuration. **Figure 6** shows the completed bridge.

Figure 5. NEXT beam transport.

Figure 6. New Bridge in York, Maine.

Construction success

The construction of the New Bridge was considered a success. The speed of the beam placement was remarkable. Because there are only four beams per span and no forms required, erection was rapid. Time was also saved because no intermediate diaphragms were required—only diaphragms at the beam ends. There was an estimated time savings of about one week per span (seven weeks total) for erection of the NEXT beam superstructure compared with the NEBT beam superstructure.

The success of the NEXT beams at the New Bridge has led to other NEXT beam projects in Maine, New York, and elsewhere. The future is optimistic for the application of this innovative bridge beam.

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Reference

1. AASHTO (American Association of State Highway and Transportation Officials). 2008. *AASHTO LRFD Bridge Design Specifications, 4rd Edition—2008 Interim Revisions*. 4rd ed. Washington, DC: AASHTO.

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Abstract

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Keywords

Accelerated construction, debond, NEBT beam, NEXT beam.

Review policy

This paper was reviewed in accordance with the Precast/Prestressed Concrete Institute's peer-review process.

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