

Development of the northeast extreme tee (NEXT) beam for accelerated bridge construction

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Adjacent-box-beam bridge systems have typically been the solution of choice for medium-span bridges in the northeast United States. However, the system does have limitations and has not worked well for all types of bridge replacements. In addition to the difficulty of accommodating utilities across the width of the bridge, the box beam is more difficult to produce because it involves multiple steps. Field construction also has had issues with grouting procedures involving the shear keys.

The idea for the northeast extreme tee (NEXT) beam occurred after one of the authors visited a precast concrete plant in September 2006 and noticed a precast concrete section that was developed for high-level railroad platforms (**Fig. 1**). This high-level-platform section, which was relatively short, had attributes that would work well for a medium-span highway bridge. Rotondo Precast in Rehoboth, Mass., developed the high-level-platform shape and provided the drawings of the section with some modifications to help with the early analysis.

Some quick calculations and parameters were set to determine the feasibility of modifying this shape and moving it into the highway bridge market. Upon evaluation, the authors felt that this new section could provide the needed solutions for areas where box beams or deck slabs did not work well. The new section was proposed in concept to the

Editor's quick points

- Adjacent box beams have uses, and limitations, for the highway bridge market.
- The northeast extreme tee (NEXT) beam provides solutions for applications where box beams or deck slabs do not work as well.
- Highlights of an actual use of the NEXT beam in the field are presented.



Figure 1. A high-level railroad platform slab inspired the model for the northeast extreme tee beam.

bridge technical committee of PCI Northeast, which approved the development of the new beam. The committee kept costs in mind while establishing the basic parameters for the new beam.

Several parameters were set as guidelines for the beam development. The section would be designed for bridge spans from about 45 ft to 90 ft (14 m to 27 m). Section depths were set to vary from 24 in. to 36 in. (610 mm to 914 mm) so that it would not compete with the northeast bulb-tee beam, which starts at a depth of 39 in. (1 m). Widths were to vary from 8 ft to 12 ft (2.4 m to 3.7 m) using magnetic side rails.

These rails were developed to assist fabricators by allowing quick adjustment of forms. They consist of flexible steel panels that are attached to the steel base form through the use of high-power magnets (instead of bolting or welding). A single form can allow variation in the beam by adjusting the depth with fillers and the width with adjustable

side forms. This form reduced the up-front cost of purchasing several form shapes. The new section is easier to fabricate, and it requires fewer pieces to construct a typical bridge. A weight limit was set at about 120 kip (534 kN) to accommodate shipment.

The top flange thickness was set at a constant 4 in. (100 mm) and would act as a stay-in-place form, eliminating the need for deck forming. The bridge would have an 8-in.-thick (200 mm) deck placed on top of the section in the field. Joint details and parapet details are also simpler, which should accelerate the construction of the bridge and reduce construction costs. **Figure 2** shows how the new beam would complement the existing beam sections available in the northeast.

Beam-section development

Before the development of a new beam section, the committee studied the key features of a beam that would ad-

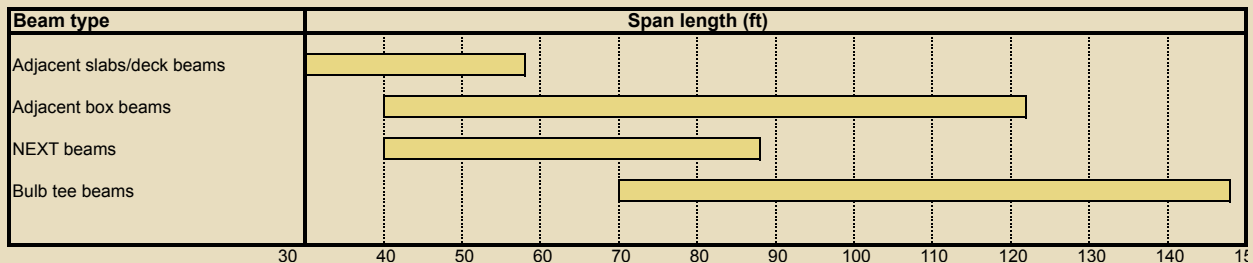


Figure 2. This chart shows common span ranges for prestressed concrete beams. Note: This chart is for information purposes and should not be construed to represent specific limits. Minimum spans are based on common bridges, and short spans can be used for all beams. (For example, a bulb-tee bridge can have a 40-ft span [12.1 m], but this is not common.) Maximum spans are approximated based on previous and current studies. The maximum span length will vary depending on several factors, such as number of beams, size of parapets and sidewalks, and concrete strength. NEXT = northeast extreme tee. 1 ft = 0.305 m.

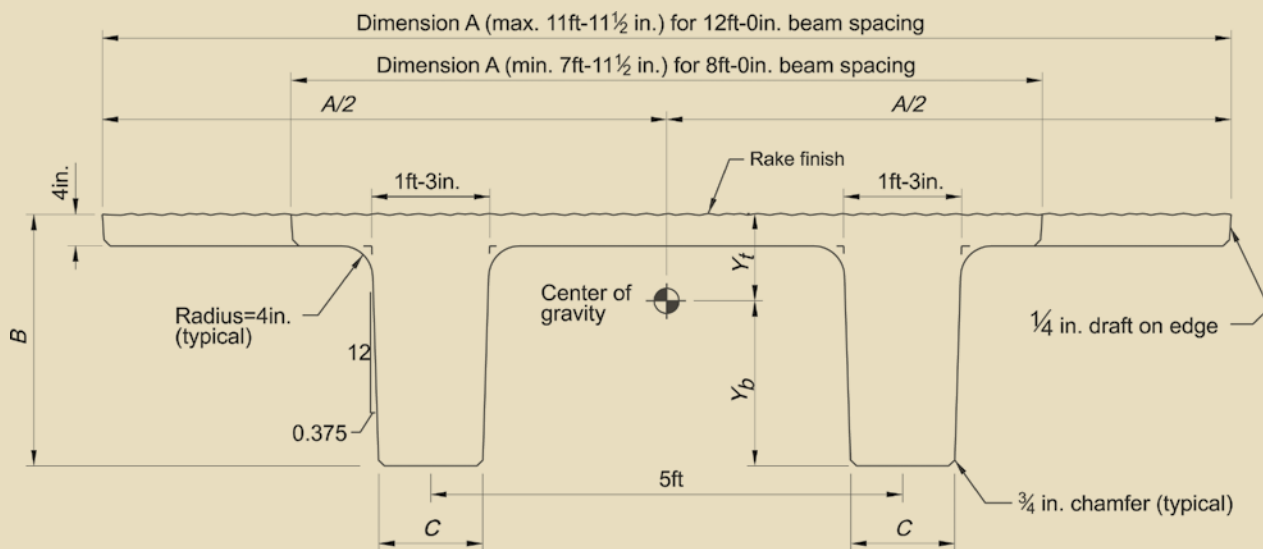


Figure 3. This drawing illustrates the final beam dimensions. Note: A = beam width; B = beam depth; C = stem base width; Y_b = distance from bottom of beam to center of gravity; Y_t = distance from top of beam to center of gravity. 1 in. = 25.4 mm; 1 ft = 0.305 m.

dress the goals of the new section. The following sections discuss the features that were studied and the conclusions reached by the committee. **Figure 3** shows the final beam section. **Table 1** shows the NEXT beam section properties.

General approach

Double-tee sections have been used for years in parking structures and on bridges. In some cases, the double-tees

were installed without topping, using the top flange as the vehicle-contact area. The PCI Northeast bridge technical committee determined that the top flange would need to be about 8 in. (200 mm) thick to accommodate truck loads and to provide adequate concrete cover.

Because of shipping and handling concerns, the committee set a weight limit of 120 kip (534 kN) for the beam because it would be easy to obtain trucking permits at this

Table 1. NEXT beam section properties

Beam designation	Beam width A , in.	Beam depth B , in.	Base stem width C , in.	Area, in. ²	I , in. ⁴	Y_b , in.	y_t , in.	s_b , in. ³	s_t , in. ³	Weight, lb/ft
Minimum-width beams										
NEXT 36	95.50	36.00	13.00	1287	160,240	21.77	14.23	11,261	7361	1341
NEXT 32	95.50	32.00	13.25	1182	115,813	19.51	12.49	9272	5936	1231
NEXT 28	95.50	28.00	13.50	1075	79,901	17.24	10.76	7426	4635	1120
NEXT 24	95.50	24.00	13.75	966	51,823	14.95	9.05	5726	3466	1006
Maximum-width beams										
NEXT 36	143.50	36.00	13.00	1479	185,525	23.36	12.64	14,678	7942	1541
NEXT 32	143.50	32.00	13.25	1374	134,258	20.98	11.02	12,183	6399	1431
NEXT 28	143.50	28.00	13.50	1267	92,661	18.57	9.43	9826	4990	1320
NEXT 24	143.50	24.00	13.75	1158	60,045	16.12	7.88	7620	3725	1206

Note: I = moment of inertia; NEXT = northeast extreme tee; s_b = section modulus of bottom fiber; s_t = section modulus of top fiber; y_t = distance from top of beam to center of gravity; Y_b = distance from bottom of beam to center of gravity. 1 in. = 25.4 mm; 1 ft = 0.305 m; 1 lb = 4.448 kN.

level. A 90-ft-long (27.4 m) section would weigh about 160 kip (712 kN) with an 8-in.-thick (200 mm) flange, which might be problematic. Another concern with a full-thickness top flange is the transverse connection between adjacent beams. Connections used in untopped parking-structure double-tees could be damaged due to the rigors of heavyweight truck loading. Several departments of transportation (DOTs) have developed high-capacity connection details, but the PCI Northeast bridge technical committee was concerned about the durability of these connections over time.

For these reasons, the section was developed with a thin top flange that would act as formwork for field installation of a full-depth cast-in-place concrete deck. Precast concrete partial-depth deck forms are commonly used for interior bays of stringer bridges; however, the deck overhangs still need to be formed using cantilever brackets. A double-tee top flange is able to support the overhang loads as well as the interior bays. This will greatly reduce the construction time on-site because little forming is required in the field.

It would be possible to migrate the design to a full-thickness top flange in the future. Subsequent to the development of the initial beam standards, the PCI Northeast bridge technical committee moved forward with the development of a full-thickness top-flange section. This section will most likely be used for short-span secondary roads with low truck volumes.

Utilities

Another reason for the development of a double-tee section was the need to accommodate under-bridge utilities. Many streets in the northeast United States have underground utilities. In many cases, the utilities are hung from the fascia beams and parapets, which is not a desirable approach because the utilities are more exposed to potential damage and are unsightly. The NEXT beam is able to support several utilities between the stems and eliminate the need for parapet attachments.

Variable bridge widths

The notion of a typical bridge in the northeast United States is not realistic. The highway system in the Northeast is old, and many of the roadways were developed before the introduction of the automobile in the early 1900s. Many roadways were constructed with limited right-of-way and little room for expansion. In many cases, new bridges must be constructed to specific widths in order to fit within the tight confines of the geometric constraints.

For a precast concrete adjacent-beam system to be viable in these conditions, there is a need for a section that can accommodate a variety of different bridge widths. Many

previous short-span bridges in the Northeast were constructed with precast concrete adjacent box beams. These bridges had to be widened beyond what was required to accommodate the standard beam width (3 ft and 4 ft [0.9 m and 1.2 m]), which at times was problematic.

The simple top flange of precast concrete double-tee beams can accommodate any beam width. Recent developments in precast concrete beam forming techniques make adjusting steel forms easy. Magnetically attached side forms can be adjusted to produce a top flange of any width. In addition, these side forms can be made somewhat flexible. Therefore, curved flange edges can also be produced for bridges on curves. With this approach, designers can specify precise beam dimensions that can produce site-specific bridge beams without significant added cost. To facilitate beam shipping, the maximum beam width was limited to 12 ft (3.7 m). Sections wider than this can be shipped in the northeast United States; however, special permits and escorts are required, which increases shipping costs.

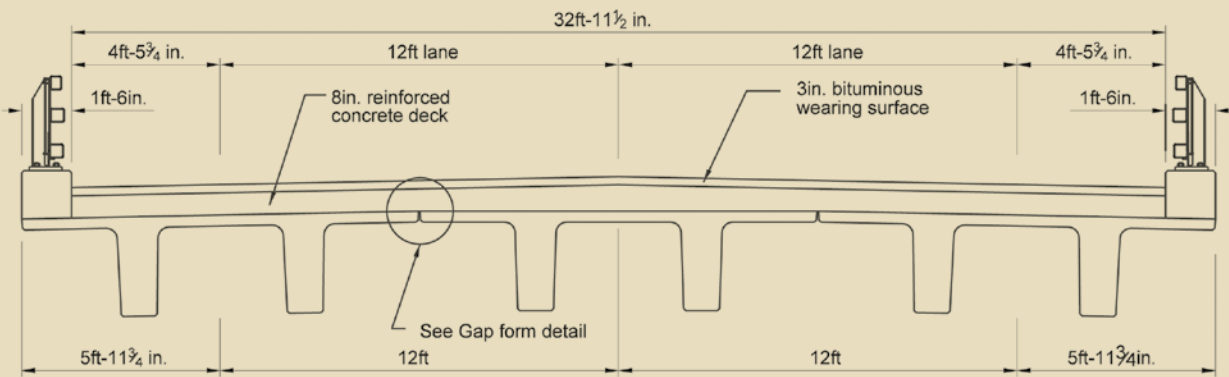
The minimum beam width is limited by the size and location of the beam stems. The stem spacing is fixed in standard double-tee formwork. The next section discusses the development of the stem size and spacing, which ultimately defined the minimum beam width.

Stem spacing and dimensions

The spacing of the stems needed to be studied to accommodate a significant variable top-flange width. The spacing and size of the stems was standardized to reduce the cost of fabrication. With this approach, the fabricators could produce a range of beam sizes with one set of formwork.

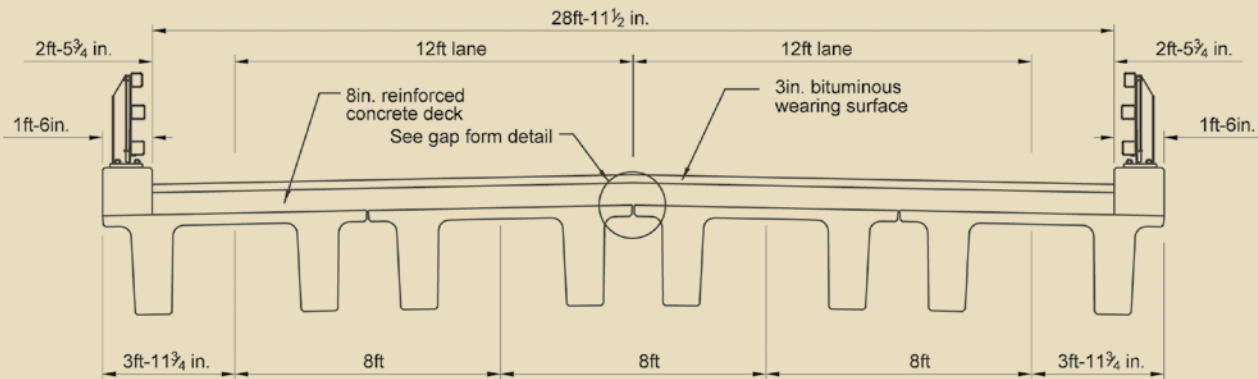
The PCI Northeast bridge technical committee wanted the beam section to be as narrow as 8 ft (2.4 m). With 6 ft (1.8 m) stem spacing, an 8-ft-wide (2.4 m) section would essentially be an inverted U-beam without a top-flange overhang and a narrow gap between stems at the beam joint. The committee had concerns that this section would have an adverse effect on the cast-in-place concrete deck performance. There were also concerns that the tight stem spacing between beams would lead to high shear stress in the slab that could lead to cracking.

Because of this, the committee set the minimum stem spacing to about 3 ft (0.9 m). If stem spacing of 6 ft (1.8 m) was used, the minimum beam width was limited to 9 ft (2.7 m). The spacing was set to a maximum of 5 ft (1.5 m) to accommodate the desired 8-ft-wide (2.4 m) section. An added benefit to this design is the even stem spacing across the bridge width for most designs. **Figure 4** shows details of the use of the maximum and minimum widths of NEXT beams in a typical bridge cross section.



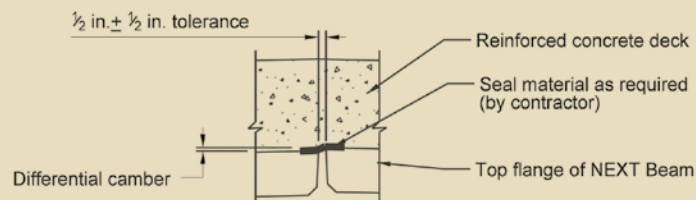
Bridge section with maximum width beams

Trial maximum span design - NEXT 36 x 144in.
Maximum span = approximately 74 ft ($f_c = 8$ ksi)



Bridge section with minimum width beams

Trial maximum span design - NEXT 36 x 96in.
Maximum span = approximately 85 ft ($f_c = 8$ ksi)



Gap form detail

Figure 4. These drawings show typical bridge sections that use northeast extreme tee (NEXT) beams. Note: The bituminous wearing surface would be installed over a membrane waterproofing system. A high-performance concrete wearing surface or a high-performance concrete deck without a wearing surface could also be used. f_c = specified compressive strength of concrete. 1 in. = 25.4 mm; 1 ft = 0.305 m; 1 ksi = 6.895 MPa.

Many bridges in the northeast United States have limited or substandard vertical clearances. For the span lengths being considered, the committee limited the beam depth to 36 in. (914 mm). A maximum stem depth was required to standardize the formwork. Shallower beams could be achieved by inserting blockouts in the bottoms of the stem forms. Production of deeper sections would require new forms, costly modifications to the top-flange forms, and possible overstressing of the fabrication-bed abutments.

The initial width of the bottom of the stem was set at 11 in. (275 mm). This width was set after looking into a number

of factors that included typical strand spacing, the anticipated size of shear reinforcement, and the desired concrete cover. An 11-in.-wide (275 mm) stem had enough room to accommodate four columns of strand and a no. 4 (13 mm) shear stirrup.

The slope of the sides of the stem has an effect on the fabrication process. Vertical side faces are possible; however, fabrication is more complicated and expensive. To remove a beam from the forms with vertical stems, a forming system comprising complicated collapsible formwork is required. The PCI Northeast bridge technical committee

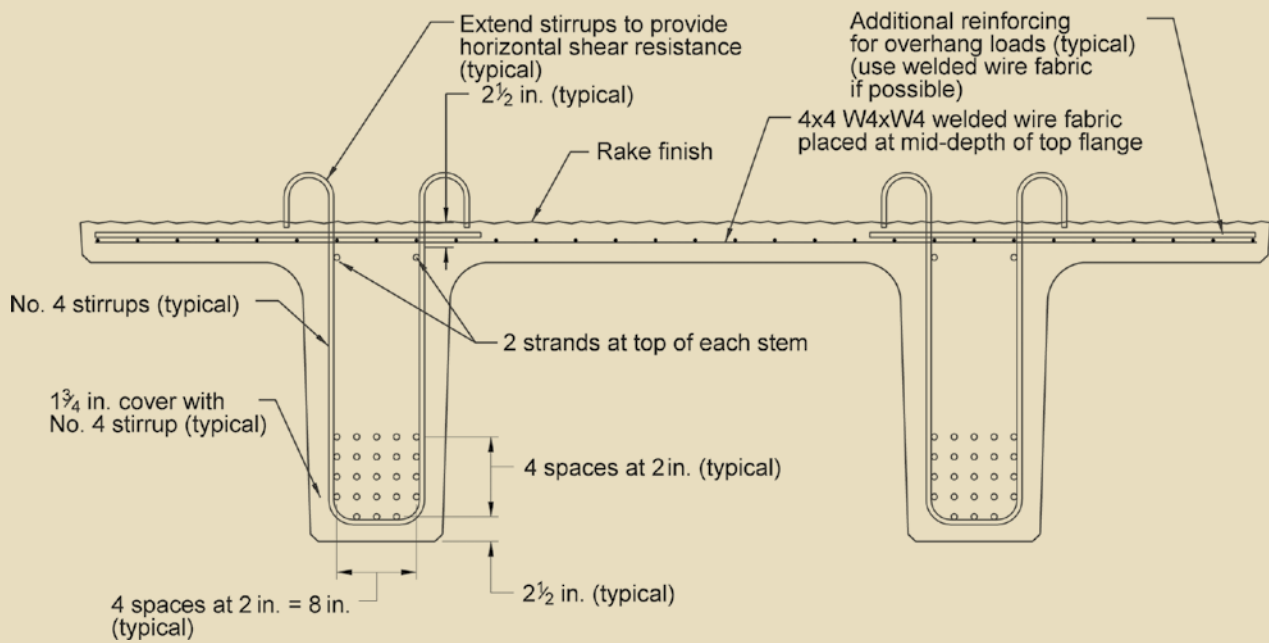


Figure 5. The typical reinforcement details show the concentric mid-depth reinforcement that is desirable to allow the flange to resist both positive and negative moments. Note: no. 4 = 13M; 1 in. = 25.4 mm.

opted for sloping sides on the stems, similar to conventional double-tees. The amount of slope of the stems has an effect on the removal of the beams from the form. After consultation with formwork manufacturers and fabricators, a slope of 0.375 in./ft (31 mm/m) was chosen. This allows for easy removal of the beams from the forms.

Top-flange design

As stated, the top flange was not intended to be the structural slab for the bridge. The intent was to use the top flange as formwork for a cast-in-place concrete deck. The flange needs to resist both positive and negative bending moments; therefore, concentric mid-depth reinforcement is desirable. **Figure 5** depicts typical beam reinforcement.

By using the top flange for deck formwork, there is a potential to make better use of precast concrete curbs and parapets. One of the major difficulties with precast concrete curbs and parapets is the need to make a significant connection at the base. Several precast concrete systems have been crash tested. These systems involve the use of bolts to resist the truck impact forces. Many DOTs do not have approved precast concrete railings. Therefore, DOTs are limited to the use of cast-in-place concrete parapets. The overhang flange of the NEXT beam can be used to support a precast concrete curb or parapet before deck concrete placement.

The main reinforcement of the curb or parapet can be extended horizontally into the deck pour and lapped with

the transverse deck reinforcement. This type of connection is essentially the same as a conventional cast-in-place concrete connection. In place of a horizontal construction joint, a vertical construction joint is used. The precast concrete curb or parapet also acts as a side form for the deck pour.

Because this connection is essentially the same as a cast-in-place concrete connection, crash testing of the system should not be required. Designers should be able to convert standard cast-in-place concrete curbs and parapets to precast concrete using this approach. **Figure 6** shows a typical installation of a precast concrete curb and its connection to the cast-in-place concrete deck. Other standard parapets could be used with similar details.

Precast concrete decks were not considered for the NEXT beam at this time. In theory, a precast concrete deck could be used because the stems of the NEXT beam are similar to stringer beams.

For interior beams, standard welded-wire reinforcement resists the bending moments due to the casting of fresh concrete. Additional reinforcement may be required for the fascia beam cantilevers if a precast concrete parapet is used. In this case, the welded-wire reinforcement can be supplemented with additional mild-steel reinforcement placed near the top of the flange.

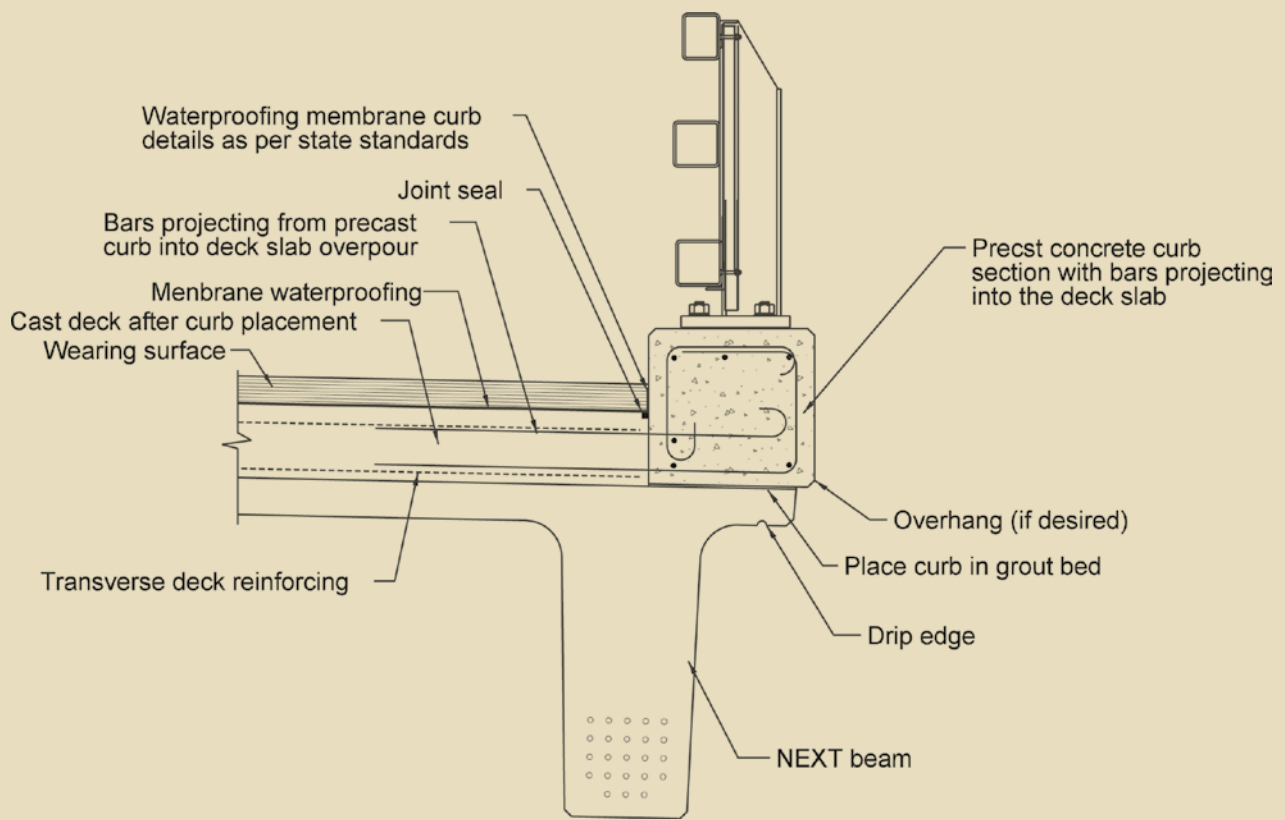


Figure 6. This drawing shows a typical installation of a precast concrete curb and its connection to the cast-in-place concrete deck. Note: NEXT = northeast extreme tee.

Diaphragms

Diaphragms are typically used with stringer bridges. The primary purpose of diaphragms is to provide better live-load distribution and lateral support of the top flange so that lateral torsional buckling of the flange is prevented. Double-tee beams are extremely stable and resistant to lateral buckling. The top flange combined with the concrete deck provides significant live-load transfer among beam stems. Therefore, the committee did not use intermediate diaphragms in its design, which is consistent with the design of parking-structure double-tees. End diaphragms are used to support the unstiffened slab edge at the supports.

Debonding versus draping

To control the cost of the NEXT beam, the strands were debonded instead of draped. Draping requires hold-downs or pushdowns in the forming system, and the hold-down forces must be resisted by footings under the formwork. Draping not only complicates fabrication, it also increases the cost of the form setup. By limiting the beam design to debonding only, it may be possible for fabricators to build self-stressing fabrication beds. The elimination of draping leads to some loss of efficiency in the section; however, the committee thought that this would be offset by the lower cost of production.

The decision to eliminate strand draping does not eliminate the potential to make the section more efficient. The width of the stems increases the potential to design a beam with a combination of pretensioning and post-tensioning. This approach would significantly increase the span length capabilities of the beams. The added cost for the post-tensioning is significant; therefore, it would only be used where structure thickness requirements were critical.

Potential use with integral abutments

Integral-abutment designs require a significant connection between the beams and the abutment stems. This connection is difficult when precast concrete adjacent-butted beams are used without a cast-in-place concrete slab. The NEXT beam has a full-depth cast-in-place concrete slab; therefore, the connection to the abutment is simplified. Longitudinal reinforcement in the slab can be extended into the integral abutment closure pour to resist negative bending moments. Reinforcement or strand extensions can be extended beyond the beam end to resist positive bending moments.

First project



Members of the Precast/Prestressed Concrete Institute Northeast bridge technical committee view the first northeast extreme tee beams at Dailey Precast.

The first northeast extreme tee beam (NEXT) beam was awarded in Maine and installed in the summer of 2010. The project consists of complete replacement of the New Bridge located on Route 103 over the York River in the town of York, Maine. The new seven-span, 510-ft-long (155 m) prestressed concrete bridge (55 ft - 80 ft - 80 ft - 80 ft - 80 ft - 80 ft - 55 ft [17 m - 24 m - 24 m - 24 m - 24 m - 24 m - 17 m]) replaces the existing 17-span steel-girder bridge.

The design challenges required developing a new bridge configuration that maintains the existing profile and navigational clearances while avoiding conflicts with existing substructure locations.

The Maine Department of Transportation required an integral bridge design using the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*. Project-specific details were developed at the abutments to accommodate the design movements. Diaphragms are located only at the beam ends at the abutments and piers. No intermediate diaphragms were used. The NEXT beam follows the cross slope of the road, and pier caps are formed to match beam cross slopes. The NEXT beam provides about 4 in. (100

mm) of additional navigational clearance compared with a traditional bulb-tee design.

The NEXT beam typical road cross section consists of four butted NEXT F 36-in.-deep (1 m) beams with a 9 ft 4½ in.-wide (2.9 m) flange and weighing 1412 lb/ft (2100 kg/m) each. The 28 NEXT beams were designed with a concrete strength of 9000 psi (62 MPa) and 7500 psi (52 MPa) at release. The out-to-out width of the bridge is 38 ft 2 in. (11.6 m), which consists of two 11-ft-wide (3.4 m) lanes, 4-ft-wide (1.2 m) shoulders, and a 5-ft-wide (1.5 m) sidewalk. A 7-in.-thick (175 mm) composite slab with a 3-in.-thick (75 mm) asphalt wearing course will be placed in the field.

Project: York County, New Bridge over York River Bridge No. 3202

Owner: Maine Department of Transportation, Augusta, Maine

Contractor: CPM Constructors, Freeport, Maine

Designer: Vanasse Hangen Brustlin Inc., Bedford, N.H.

Precaster: Dailey Precast, Shaftsbury, Vt.



Speed of construction

The NEXT beam offers significant advantages over typical stringer-beam bridges. The top flange of the beam is designed to support the weight of the cast-in-place concrete deck. There is no installation or stripping of formwork required in the field. No intermediate diaphragms are included in the NEXT beam, which eliminates a time-consuming construction process. Although end diaphragms are proposed to support the free edge of the deck at the supports, it is possible to install these diaphragms during a secondary concrete placement in the precast concrete plant. All of these features should lead to a fast construction process.

Trial designs

Trial designs were completed to ensure that the beam met the goals set by the committee. The bridge technical committee of PCI Northeast comprises seven different DOTs, each with different standards for features such as concrete strength, parapet style, and overlays. To make the trial designs useful, the committee selected the following design parameters that were representative of the majority of the states on the committee:

- a two-lane, four-beam bridge
- parapets consisting of concrete curbing that supports a steel-railing system
- an 8-in.-thick (200 mm), reinforced cast-in-place concrete slab
- a 3-in.-thick (75 mm) bituminous concrete wearing surface
- three different designs of concrete strength:
 - 8 ksi (55 MPa) at release and 10 ksi (69 MPa) final
 - 6 ksi (41 MPa) at release and 8 ksi (55 MPa) final
 - 4 ksi (28 MPa) at release and 6 ksi (41 MPa) final
- debonding up to 25% of strand
- American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*¹ designs with full allowable tension stresses
- straight strand only
- no utility loads
- an interior beam design

The determination of a live-load distribution factor for the trial designs was not straightforward. The AASHTO LRFD specifications have live-load distribution factors for double-tees; however, the factors are based on the use of adjacent double-tees that are connected using transverse post-tensioning, which is essentially a hinged joint. The proposed use of the NEXT beam includes a composite cast-in-place concrete slab. Therefore, the most appropriate live-load distribution factor was to treat each stem as a stringer beam.

This corresponds to the AASHTO LRFD specifications' distribution factor for cross-section type K in Table 4.6.2.2.1-1. This factor is based on a precast concrete stringer supporting a concrete deck. Because the NEXT beam has a concrete deck, it will behave in a similar fashion to a stringer bridge. Designers may choose to treat the beam as a channel beam with a concrete overlay (cross-section type H in AASHTO LRFD specifications Table 4.6.2.2.1-1). It is the opinion of the committee that the minimum stem spacing of 3 ft (0.9 m) is sufficient to warrant the use of the type K distribution factor.

Preliminary beam designs revealed an issue with the initial beam section. The width of the stems limited the amount of prestressing strand that could be placed in the section, which limited the maximum span lengths. The width of the stems was increased from 11 in. to 13 in. (275 mm to 330 mm), which allowed for the addition of one more column of strand. The additional stem width and strand pattern had a favorable impact on the maximum span length of each section. Therefore, the bottom of the stem width was finalized at 13 in.

The maximum span length for the largest NEXT beam is about 87 ft (26.5 m). This is within the original limit set by the PCI Northeast bridge technical committee. This span limit is based on the narrowest beam width of 8 ft (2.4 m).

Effect of slab overpour thickness

There was discussion about using the top flange as the bottom portion of the deck slab similar to that of a partial-depth precast concrete deck slab. This would reduce the concrete overpour thickness to about 4 in. (100 mm), as opposed to 8 in. (200 mm) in the original concept. To do this, the top flange required a special design because the overhang portion between beams would be discontinuous at midbay.

A welded-tie connection could be employed, though the PCI Northeast bridge technical committee was not aware of any research of designs that could verify this type of design. Even with this concern, committee members were curious about the effect of reducing the thickness of the slab overpour. Trial beam runs were made for this approach.

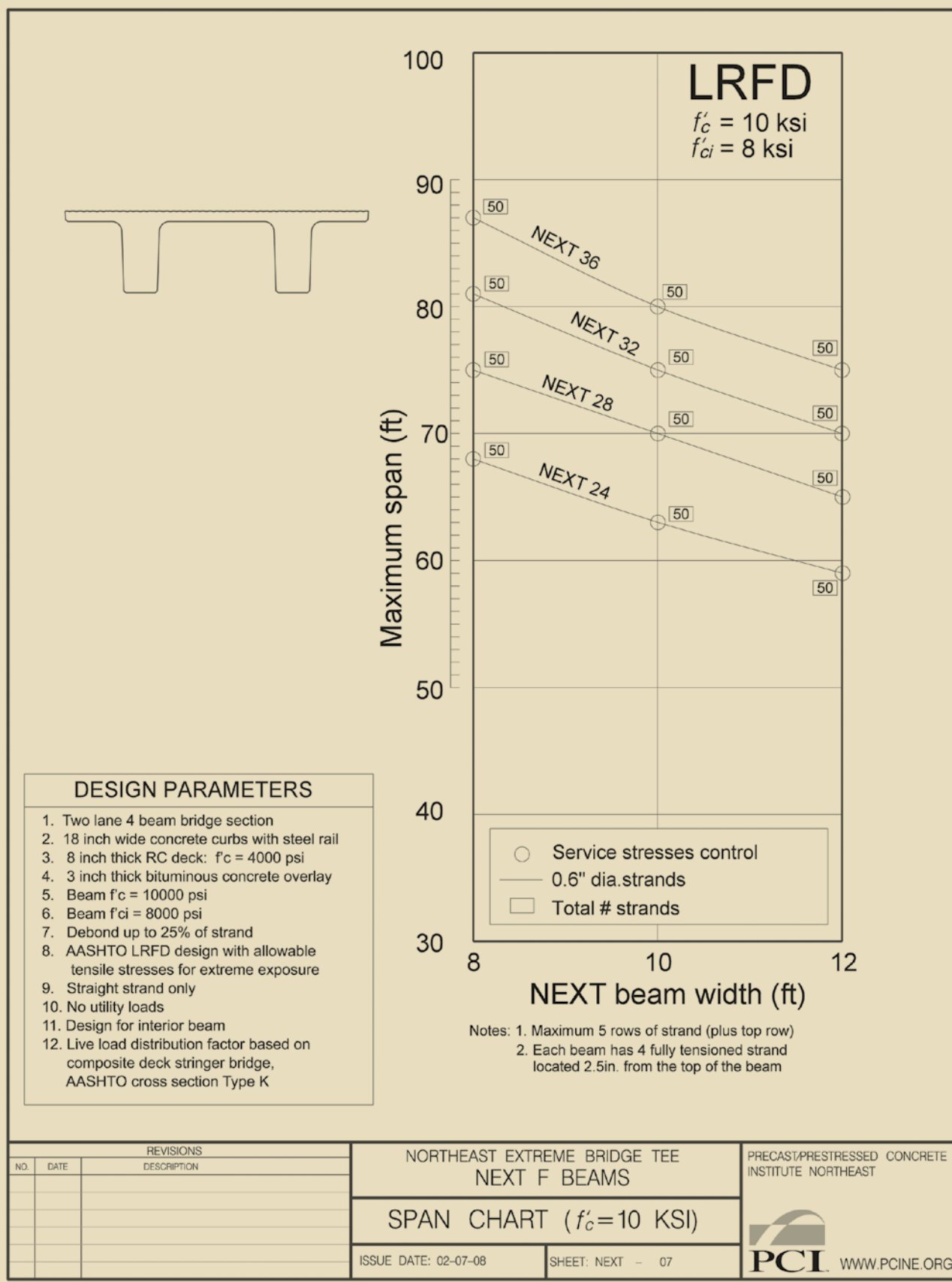
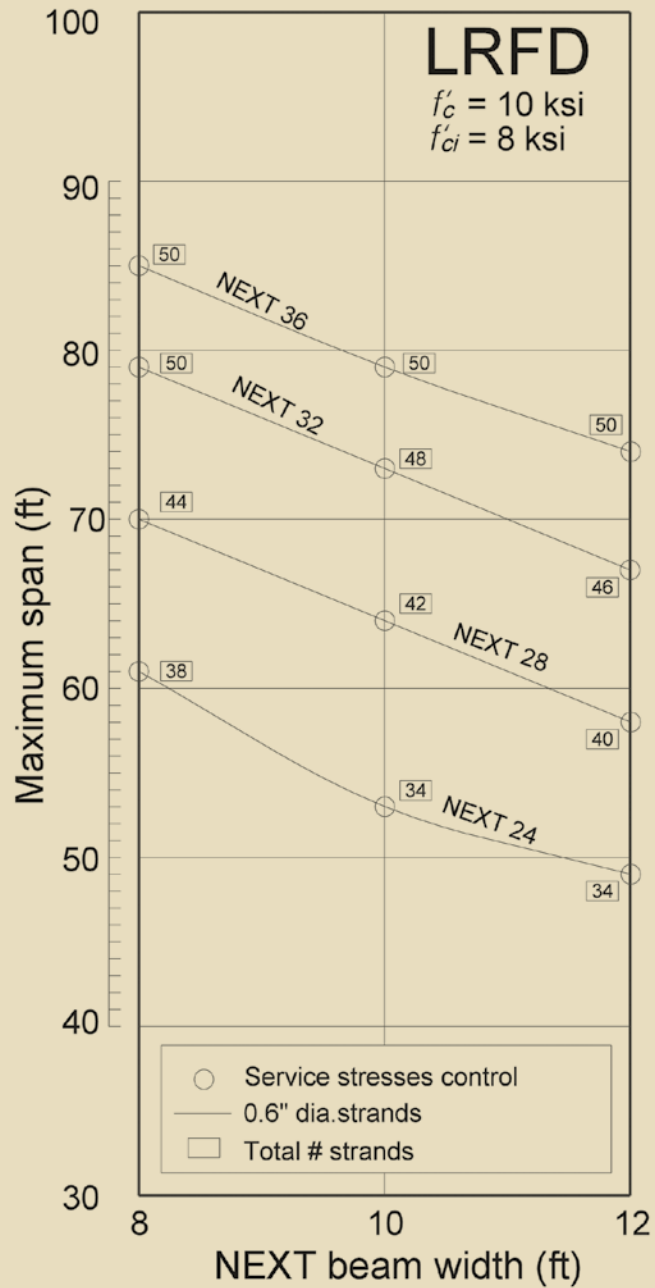
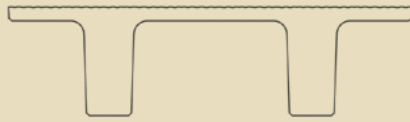


Figure 7. This design chart shows spans of the northeast extreme tee (NEXT) with concrete design strengths of 8 ksi (55 MPa) at release and 10 ksi (69 MPa) final. Note: f'_c = specified compressive strength of concrete; f'_{ci} = specified compressive strength of concrete at release. 1" = 1 in. = 25.4 mm; 1 ft = 0.305 m; 1 psi = 6.895 kPa; 1 ksi = 6.895 MPa.



DESIGN PARAMETERS

1. Two lane 4 beam bridge section
2. 18 inch wide concrete curbs with steel rail
3. 8 inch thick RC deck: $f'_c = 4000$ psi
4. 3 inch thick bituminous concrete overlay
5. Beam $f'_c = 8000$ psi
6. Beam $f'_{ci} = 6000$ psi
7. Debond up to 25% of strand
8. AASHTO LRFD design with allowable tensile stresses for extreme exposure
9. Straight strand only
10. No utility loads
11. Design for interior beam
12. Live load distribution factor based on composite deck stringer bridge, AASHTO cross section Type K

- Notes: 1. Maximum 5 rows of strand (plus top row)
 2. Each beam has 4 fully tensioned strand located 2.5in. from the top of the beam

REVISIONS			NORTHEAST EXTREME BRIDGE TEE NEXT F BEAMS		PRECAST/PRESTRESSED CONCRETE INSTITUTE NORTHEAST	
NO.	DATE	DESCRIPTION				
			SPAN CHART ($f'_c = 8$ KSI)		WWW.PCINE.ORG	
			ISSUE DATE: 02-07-08	SHEET: NEXT - 08		

Figure 8. This design chart shows spans of the northeast extreme tee (NEXT) with concrete design strengths of 6 ksi (41 MPa) at release and 8 ksi (55 MPa) final. Note: f'_c = specified compressive strength of concrete; f'_{ci} = specified compressive strength of concrete at release. 1 ft = 0.305 m; 1 psi = 6.895 kPa; 1 ksi = 6.895 MPa.

It was found that the reduction in overpour thickness had little effect on the maximum span length. There was an increase in dead-load stresses in the beams with thicker overpours, but there was also a reduction in live-load stresses due to the increased composite section properties with the thicker overpour. This option was abandoned because of the issues with the joints between the beams and the limited change in span capacity. In lieu of this, the PCI Northeast bridge technical committee decided to pursue a full-depth top flange.

Once the first trial runs were complete, the PCI Northeast bridge technical committee developed a series of beam tables for use in preliminary designs. The same parameters were used as in the previous trial runs. The final beam design charts are included in **Fig. 7** through **9**. The charts include the approximate maximum span length of each section and the approximate number of strands for each section.

With these design charts, a designer can determine a preliminary beam depth for a particular span length and beam spacing. These design charts are only intended for preliminary designs. Design parameters for a specific bridge will vary for each project. Therefore, the beam chosen would need to be verified with detailed calculations.

Construction sequence with NEXT beams

The following construction sequence is proposed. The sequence is based on the parameters developed by the committee:

1. Construct the foundations and substructures. The bridge seats should be cast to match the cross slope of the final roadway.
2. Erect the NEXT beams. The beams should be installed to the spacing shown on the plans with ½-in.-thick (13 mm) nominal joints between the beams.
3. Form the deck ends and side faces, and place deck reinforcement (precast concrete curbs or parapets set in grout beds can be used in place of side forms).
4. Cast the bridge deck and end diaphragms. It may be possible to pour the end diaphragms in the fabrication shop before shipping.
5. Complete the parapets.
6. Install a wearing surface if required by the owner agency (bituminous overlay with waterproofing membrane or concrete overlay).

During construction, equipment is normally prohibited from the tops of the beams before deck placement. It may

be possible to drive small vehicles across the beams after placement. Designers may want to check the top flange for these loads and either allow or prohibit them during construction.

The weight of the screed would not normally be accounted for in the design of the beam flange overhang in the Northeast. This is because the weight of the screed is somewhat unknown to the designer. Contractors typically place the screed rails over the fascia beam. Therefore, the overhang design is not normally an issue. If contractors use the overhang, they need to check the overhang and possibly place additional reinforcement in the overhang to support the screed.

Figure 10 depicts a completed NEXT beam bridge constructed on a precast concrete integral abutment with a precast concrete open rail parapet.

Future work

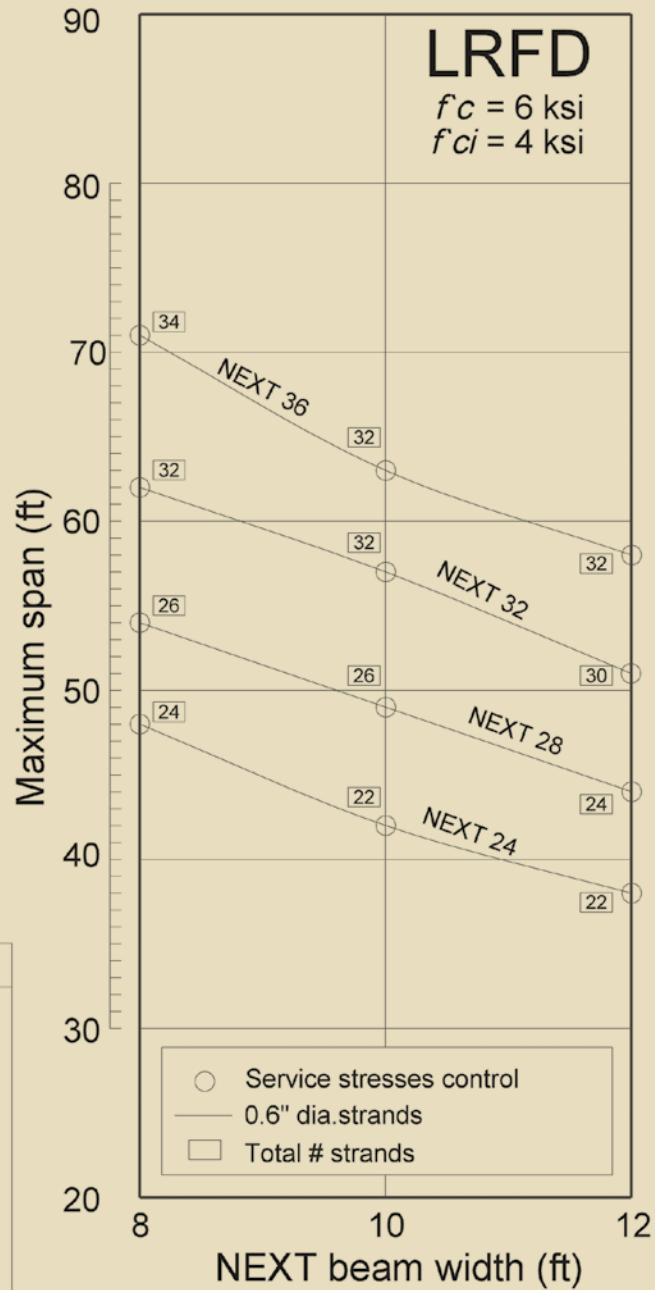
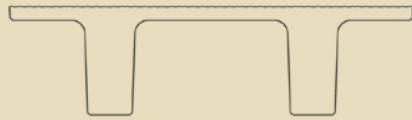
Full-depth top-flange option

The PCI Northeast bridge technical committee initially started with a beam design based on a full-thickness concrete slab overpour. There was always a desire by the PCI Northeast bridge technical committee to develop a fully precast concrete butted-beam section without an overpour. This design consists of a full-thickness (8 in. [200 mm]) top flange that acts as the structural slab for the bridge. The sections are butted and the longitudinal joint is connected using headed reinforcing bars combined with a grouted shear key. This connection is based on preliminary findings of several ongoing research projects. Once connected, the entire bridge can be covered with a waterproofing membrane and a bituminous concrete overlay or a concrete overlay.

The development of the full-depth deck sections was completed in January 2010. Span charts indicate that the untopped beam will be capable of span lengths that are similar to the topped section. The weights of the full-depth sections are high, but the PCI Northeast bridge technical committee felt that the section would be an attractive option for short-span local bridges and low-volume roads. Details for the full-depth top-flange option are available at the PCI Northeast website.²

Use of lightweight concrete for the full-depth NEXT beam

The shipping and handling weight of the NEXT beam was a concern for the PCI Northeast bridge technical committee. The reason for the large weight is that each piece is essentially two stringers tied together. Therefore, it is about twice the weight of a similar stringer beam of the same span length. The committee also developed span charts for



- DESIGN PARAMETERS**
- Two lane 4 beam bridge section
 - 18 inch wide concrete curbs with steel rail
 - 8 inch thick RC deck: $f'c = 4000 \text{ psi}$
 - 3 inch thick bituminous concrete overlay
 - Beam $f'c = 6000 \text{ psi}$
 - Beam $f'ci = 4000 \text{ psi}$
 - Debond up to 25% of strand
 - AASHTO LRFD design with allowable tensile stresses for extreme exposure
 - Straight strand only
 - No utility loads
 - Design for interior beam
 - Live load distribution factor based on composite deck stringer bridge, AASHTO cross section Type K

Notes: 1. Maximum 5 rows of strand (plus top row)
 2. Each beam has 4 fully tensioned strand located 2.5in. from the top of the beam

REVISIONS		
NO.	DATE	DESCRIPTION

NORTHEAST EXTREME BRIDGE TEE
 NEXT F BEAMS
 SPAN CHART ($f'c = 6 \text{ KSI}$)
 ISSUE DATE: 02-07-08 SHEET: NEXT - 09

PRECAST/PRESTRESSED CONCRETE
 INSTITUTE NORTHEAST

WWW.PCINE.ORG

Figure 9. This design chart shows spans of the northeast extreme tee (NEXT) beam with concrete design strengths of 4 ksi (28 MPa) at release and 6 ksi (41 MPa) final. Note: $f'c$ = specified compressive strength of concrete; $f'ci$ = specified compressive strength of concrete at release LRFD = load- and resistance-factor design; 1" = 1 in. = 25.4 mm; 1 ft = 0.305 m; 1 psi = 6.895 kPa; 1 ksi = 6.895 MPa.

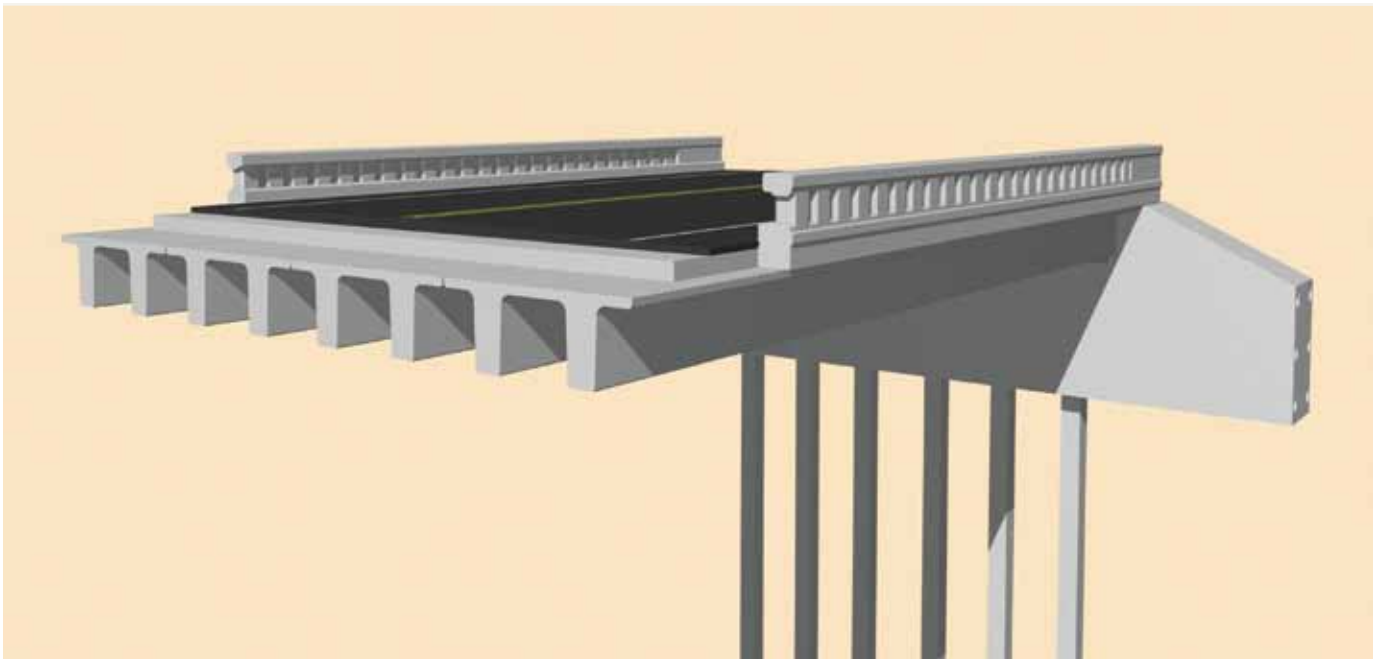


Figure 10. This illustration depicts a completed northeast extreme tee beam bridge constructed on a precast concrete integral abutment with a precast concrete open-rail parapet.

lightweight concrete for the full-depth, top-flange option. The lightweight concrete has the potential to significantly reduce shipping and handling weights, which would correspond to a reduction in cost and an increase in potential span lengths.

Pilot projects

The development process has been completed and standards have been approved and issued by the PCI Northeast bridge technical committee. They can be found at the Precast/Prestressed Concrete Institute Northeast Covering New England and New York website at www.pcine.org.² Each state is looking into locations where the new section can be used, and projects have already been identified for Massachusetts, New York, Vermont, and Maine. The commitment from the states indicates that the NEXT beam will become a useful section for the region. For an update on the NEXT beam's pilot project and uses, see the sidebar "First Project."

Summary

- The development of the NEXT beam is an example of an owner-industry committee collaborating to produce a product that is both owner and fabricator friendly. It has the potential to be used for most short- to moderate-span bridges in the region, which are currently being constructed with adjacent precast concrete box beams.
- The NEXT beam has the ability to support under-bridge utilities. The current use of adjacent-box-beam systems for short-span bridges cannot accommodate

under-bridge utilities. The utilities are often hung from brackets attached to the bridge parapets.

- The NEXT beam was developed for ease of fabrication. It has only straight strands (no draping), which should reduce the cost of forms and simplify fabrication. The elimination of strand draping has an effect on the efficiency of the section, but the production savings will most likely offset the loss of efficiency. If a designer wants to push the limits of a particular section, there is the potential for designing a beam with a combination of pretensioning and post-tensioning.
- The performance of a full-depth structural slab on top of the beam is similar to the performance of beams with thinner concrete slabs. The cast-in-place concrete deck provides a durable bridge that is easy to build. The NEXT beam will support the fresh-concrete overpour, eliminating time-consuming and costly deck forming in the field. The top flange can be used to support the beam overhangs, which are often the most difficult portion of the bridge deck to form. The result of this approach is that overall construction time for the NEXT beams should be significantly shorter than typical decked stringer bridges, such as spread box beams and bulb-tees.
- The use of the NEXT beam top flange as a deck form will greatly reduce construction time of typical bridges. Intermediate diaphragms are not required, which further reduces construction time. End diaphragms are proposed, which can be precast as a secondary concrete placement in the plant before installation.

- Initial pricing from fabricators indicates that a NEXT beam bridge will be significantly less expensive than a precast concrete adjacent box-beam bridge.

Acknowledgments

The NEXT beam was developed for the purpose of promoting a greater degree of uniformity among DOTs, engineers, and industry of the Northeast with respect to planning, designing, fabricating, and constructing highway bridges with the Federal Highway Administration's philosophy of accelerated bridge construction. We would like to acknowledge the PCI Northeast Bridge Technical Committee for its dedication and recommendations in developing the new section. PCI Northeast Bridge Technical Committee members are Rita Seraderian of the Precast/Prestressed Concrete Institute Northeast; Michael P. Culmo and Andrew Benkert of CME Associates Inc.; Eric Calderwood of Calderwood Engineering Etc.; Vartan Sahakian of Commonwealth Engineering and Consulting; Joseph Carrara and Ernie Brod of J. P. Carrara and Sons; Eric Schaffrick and Lee Edwards of Dailey Precast; Darren Conboy of Jacobs Edwards Engineering; Michael Kane of Kane Engineering; Ed Barwicki of Lin Associates; Robert Bulger and Nate Benoit of the Maine DOT; Alex Bardow, Maura Sullivan, and Edmund Newton of the Massachusetts Highway Department; Duane Carpenter, Matthew Royce, and Michael Twiss of the New York State DOT; Jason Tremblay and David Scott of the New Hampshire DOT; Mike Savella of the Rhode Island DOT; Chris Fowler of Rotondo Precast; and George W. Colgrove III of Baker Engineering, formerly of the Vermont Agency of Transportation.

Also special thanks to Reid Castrodale of Carolina Stalite Co. for his help in developing the lightweight span charts for the NEXT D standards.

References

1. American Association of State Highway and Transportation Officials (AASHTO). 2007. *AASHTO LRFD Bridge Design Specifications*. 4th ed. Washington, DC: AASHTO.
2. Precast/Prestressed Concrete Institute Northeast Covering New England & New York. NEXT F Standards: Northeast Extreme Bridge Tee Form Standards. www.pci.org/index.cfm/resources/bridge/Northeast_Extreme_Tee_Beam.

Notation

A = beam width

B = beam depth

C = stem base width

f'_c = specified final compressive strength of concrete

f'_{ci} = specified compressive strength of concrete at release

I = moment of inertia

S_b = section modulus to bottom fiber

S_t = section modulus to top fiber

Y_b = distance from bottom of beam to center of gravity

Y_t = distance from top of beam to center of gravity

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Synopsis

The bridge technical committee of PCI Northeast has recently developed a standard for a new beam called the northeast extreme tee (NEXT) beam. The goals of this new section are to provide a fast construction option for variable-width bridges with spans up to 90 ft (27 m).

The section resembles a standard double-tee except that the stems are wider to handle the moment and shear demand for bridge loads. The top flange of the

beam is thin and is intended to provide formwork for a cast-in-place concrete deck, which is intended to save substantial time during construction. The beam was designed to be easy to fabricate, which will inevitably lead to lower bridge costs. This paper focuses on the committee's work in developing the beam and summarizes the design criteria and how the committee accomplished those goals.

Keywords

Accelerated bridge construction, double-tee, NEXT, northeast extreme tee

Review policy

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

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