

## **THE FIRST-EVER NEXT BEAM BRIDGE**

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### **ABSTRACT**

*The replacement of the New Bridge, as it is called, in York, Maine, lived up to its name. The design, fabrication, and construction of the first-ever Northeast Extreme Tee (NEXT) Beam bridge in the United States features innovative project delivery; the first application of Precast/Prestressed Concrete Institute Northeast (PCINE)'s design guidelines; a fabricator willing to take the risk of developing the new forms needed; a contractor who painstakingly erected the new, heavy beams; and an owner who made it all happen. Construction challenges are explored as a new seven-span concrete bridge—the first of its kind—stretches more than 500 feet across the mouth of the York River in historic York, Maine. The York New Bridge is the first bridge to utilize the NEXT Beam which is being embraced in New England and area states including New York, Massachusetts, and Pennsylvania.*

**Keywords:** Accelerated Construction, Construction, Creative/Innovative Solutions and Structures

## INTRODUCTION

The replacement of the New Bridge, as it is called, in York, Maine, lived up to its name. The design, fabrication, and construction of the first-ever NEXT Beam bridge in the United States features innovative project delivery; the first application of PCINE's design guidelines; a fabricator willing to take the risk of developing the new forms needed; a contractor who painstakingly erected the new, heavy beams; and an owner who made it all happen. Construction challenges are explored as a new seven-span concrete bridge—the first of its kind—stretches more than 500 feet across the mouth of the York River in historic York, Maine. The York New Bridge is the first bridge to utilize the Northeast Extreme Tee (NEXT) Beam which is being embraced in New England and area states including New York, Massachusetts, and Pennsylvania.

## OVERVIEW

In the bridge building community, where accelerated construction is becoming more of a necessity than a luxury, the need for alternative streamline fabrication and construction products is growing. The bridge technical committee of PCI Northeast embraced this challenge and developed a solution in the form of the Northeast Extreme Tee, or more simply 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 and provided attributes well suited for the bridge community. The NEXT Beam provides an alternative solution for the 50-to-80 foot bridge span that was primarily dominated by butted box beams as the precast concrete option. A visual comparison of the relative size difference between the NEXT Beams and a typical double tee section can be seen in Figure 1.



Figure 1: NEXT Beam (left) Comparison to Double Tee Beam (right)

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-inch top flange thickness and requires a full depth deck overtop. The section properties of the Type “F” NEXT Beam can be seen in Figure 2. As more interest in the NEXT Beams came about, a Type “D” NEXT Beam was developed with an 8-inch 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 inches so as to not compete with the New England Bulb Tees (NEBT), which have a minimum depth of 39 inches. The width of the NEXT Beam flange may vary from 8-to-12 feet. One of the key fabrication advantages of the NEXT Beams is that the forms for casting the beams 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-inch 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-foot roadway width with a 5-foot sidewalk.

The downside of only having four beams is the resulting weight of each. The maximum standard NEXT Beam (36-inch depth, 12-foot spacing) has a weight of approximately 1500 pounds per lineal foot. The weight of these large NEXT Beams was a concern and the standard beam tables capped the weight limit at 120,000 pounds for transport considerations.

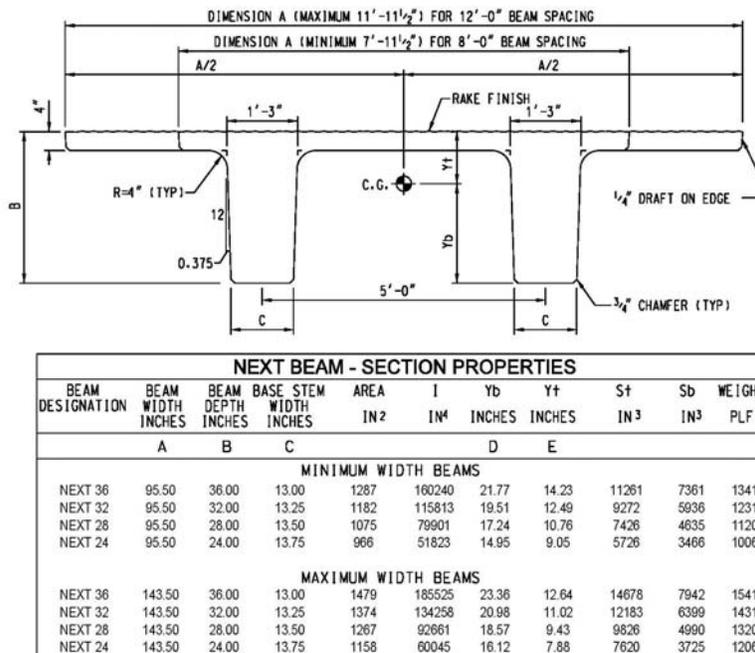


Figure 2: PCINE - NEXT (Type F) Beam Section Properties

**NEW BRIDGE – PRELIMINARY DESIGN**

The New Bridge carries Route 103 over the York River in Historic York, Maine. The original bridge of painted steel girders on treated timber piles was constructed in 1957. The 468-foot-long bridge consisted of sixteen 26-foot spans and a single 52-foot navigational span. The existing bridge had a 24-foot roadway width, which is quite narrow for a major collector. The bridge was scheduled for replacement because it was in poor condition from an unforgiving combination of age and 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. A wider road width was also necessary to better accommodate both vehicular and pedestrian traffic. During construction, the bridge needed to be shut down and traffic detoured to minimize the impacts to 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 for this project.

In the preliminary design stage, two different substructure layouts were evaluated along with a number of superstructure alternatives. The different span arrangements considered allowed for minimal superstructure depth while avoiding existing substructure locations. Figure 3 shows the span ranges for the newly developed NEXT Beam. 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.

**PCI Northeast Bridge Beam Sections  
Common Span Ranges**

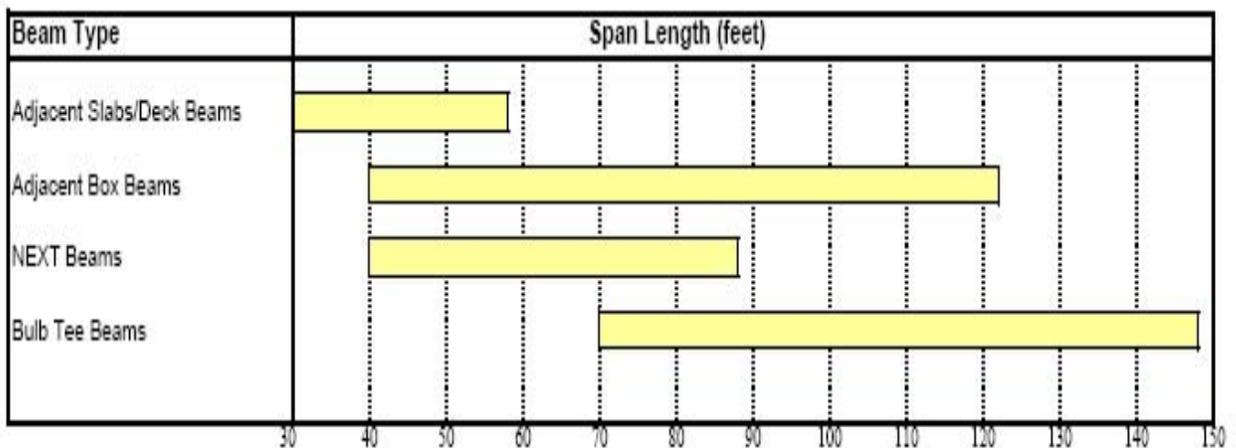


Figure 3: PCINE Span Range Chart

## PRELIMINARY SPAN ARRANGEMENTS & SUPERSTRUCTURE OPTIONS

Original bridge total length = 488'

Alternative #1: 7 spans: 55'-80'-80'-80'-80'-80'-55' total length = 510'  
Four NEXT BEAM 36 precast, prestressed concrete extreme tees per span, continuous integral bridge with 7" composite deck.

Alternative #2: 7 spans: 55'-80'-80'-80'-80'-80'-55' total length = 510'  
Nine NEBT 1000 precast, prestressed butted bulb tees per span, continuous integral bridge with 8" composite deck.

Alternative #3: 5 spans: 104'-104'-90'-104'-104' total length = 506'  
Nine 33"x48" precast, prestressed concrete butted box beams per span, continuous, integral bridge with 5" composite topping.

Alternative #4: 7 spans: 55'-80'-80'-80'-80'-80'-55' total length = 510'  
Six 33"x48" precast, prestressed concrete box beams at approximately 6'3" spacing per span, continuous, integral bridge with 8" composite deck.

Alternative #5: 7 spans: 55'-80'-80'-80'-80'-80'-55' total length = 510'  
Five 39"x48" precast, prestressed concrete box beams at 8' spacing per span, continuous integral bridge with 8" composite deck.

Alternative #6: 7 spans: 55'-80'-80'-80'-80'-80'-55' total length = 510'  
Nine 27"x48" precast, prestressed concrete butted box beams per span, continuous, integral bridge with 5" composite topping.

Right-of-way impacts, profile requirements, environmental impacts, span configurations, cost, and ease and duration of construction were all considered to determine the recommended structure options. At the end of the preliminary design stage Maine Department of Transportation (DOT) and VHB decided to continue the final design with a dual superstructure design of the NEBT 1000 and the NEXT 36 beams as a contractor option. The transverse section of the NEXT 36 beams can be seen in Figure 4.

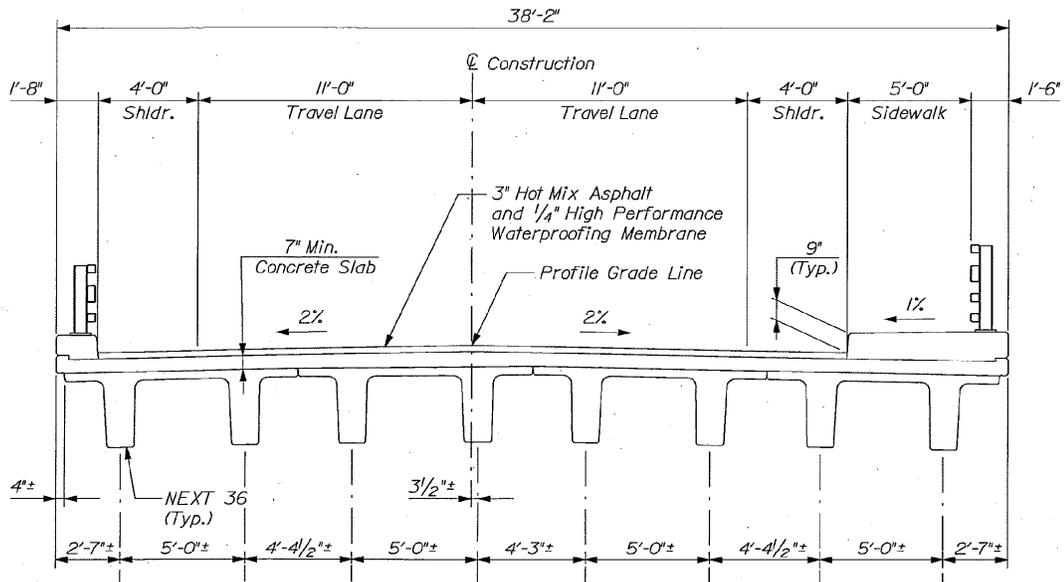
While there was a lot of excitement about the newly developed NEXT beam in the design world, there was also a lot that was unknown in making this design concept a reality. As the first of its kind, the construction costs of the NEXT beam were uncertain. And, not only was cost a concern, but there was also no guarantee that there would even be fabricator and contractor interest.

The New Bridge project site had a number of features that were conducive to the NEXT beam option. The large quantity 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 proper staging area with good marine-mounted crane access for the extremely heavy NEXT beam.

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

It was a pleasant surprise for VHB and MaineDOT when four out of the five contractors bidding on the project, including the low bidder CPM Constructors, chose to bid the NEXT beam option. The overall project was bid at approximately \$5.5 million dollars. The New Bridge portion totaled about \$3.7 million dollars (\$208/SF) including \$950,000 (\$153/SF) for the NEXT Beams. Other bid costs for the NEXT Beams varied from \$322/LF to \$471/LF.

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



TRANSVERSE BRIDGE SECTION - NEXT BEAM OPTION  
 (Looking Up Station)  
 Not to Scale

Figure 4: New Bridge NEXT Beam Transverse Section

## DESIGN ISSUES

### CROSS SLOPE GEOMETRY

One of the first obstacles faced with designing the NEXT beam option was the cross slope geometry. The typical bridge section consists of two 11-foot lanes with 4-foot shoulders and a 5-foot sidewalk on the east side, and a 2-percent crown at the center of the travel lanes. The sidewalk on one side made the centerline of construction different than the centerline of 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 utilized for the strength design of the 80-foot spans, giving the beams a fairly large camber. Add to this the vertical curve of the road and there was quite a bit of camber to balance out. With prestressed members, 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

Determining deflection of a prestressed member is based on theoretical assumptions. There are many factors that go into the deflection of a member, such as the number and size of strands, the relaxation of strands, creep and shrinkage of the concrete, elastic shortening, etc. Because the NEXT beam hadn't 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 theoretical deflections.

### CONTINUITY

The New Bridge NEXT Beams were designed as simple spans and detailed to be continuous under live load. This was accomplished by pouring each simple span separately, then pouring a wide closure pour 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 pour 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 (AASHTO) debonding requirements. Per AASHTO, exterior strands cannot be debonded. Since the NEXT Beam has two stems, there is double the amount of exterior strands, which limits the number of

strands that may be debonded. The NEXT Beam strand layout can be seen in Figure 5. All strands are prestressed, no longitudinal or transverse post-tensioning is required for the NEXT Beams.

The NEXT Beam has all straight strands in its template; no draped strands. This is beneficial on the fabrication side as it provides a much safer working environment.

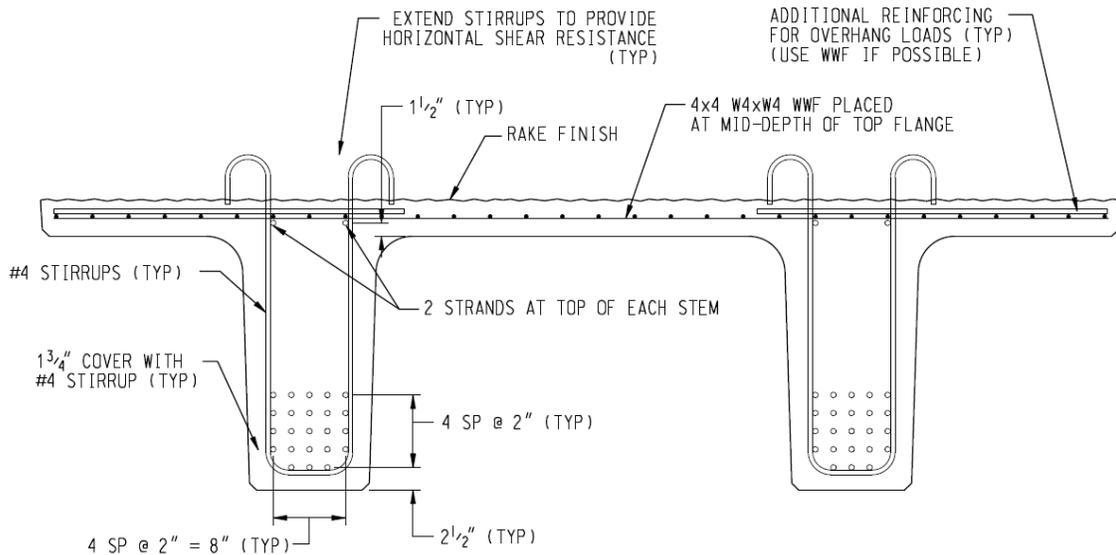


Figure 5: PCINE Typical NEXT Beam Reinforcing

The New Bridge pushed the limits of this newly designed beam by nearly maximizing the strand capacity for the 80-foot spans. Although there was enough strength capacity, there was no room to modify strand location to help with camber and deflection issues. The shorter 55-foot end spans had fewer strands required and therefore provided flexibility in strand placement, finding the necessary balance between strength and camber.

#### MILD REINFORCING DETAILS

As PCINE was developing the NEXT Beam standard details, a W4xW4 mesh was selected for the top flange reinforcement. The thin top flange of the NEXT Beam is intended only for use as a deck form and the welded wire mesh is used to support the wet concrete only. The welded wire mesh was the most appropriate since it provides the most flexibility with the required cover in the 4-inch-thick top flange and is easy to install. VHB's 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 #4 longitudinal bars to the top flange above the welded wire mesh. Although the proper cover could be achieved, it left little tolerance. Additionally, the welded wire mesh 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-inch top flange.

Another element in the standard details that had to be modified for the New Bridge NEXT Beams was the stirrups. PCINE originally detailed the stirrups with 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. The fabricated stirrups can be seen in Figure 6.



Figure 6: Stirrup Placement

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

Since, a low-maintenance, jointless bridge was desired, integral abutments were chosen for the New Bridge. The full-depth cast-in place concrete slab poured on top of the NEXT Beams helped to simplify the connection to the abutment. Longitudinal reinforcement in the slab extended into the abutment closure pour to help resist the negative moments. The bottom strands were extended out and turned up into the backwall to help resist the positive moments. An inch-and-a-half diameter swedged anchor rods were placed at 4-feet on center connecting the approach slab to the integral abutment cap. To allow for movement in this jointless bridge, the abutment H-piles were encased with 30-inch diameter steel casing with voided annular space between the pile and casing.

## CONSTRUCTABILITY

As the New Bridge was the first project ever to use the NEXT Beam, constructability considerations during the design stage were crucial. Having the road closed and traffic detoured during construction allowed for crane set up 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 provided substantial time savings over a typical girder bridge since 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 setting 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 pours at the piers.

## CONSTRUCTION

### FABRICATION

The fabrication of the NEXT Beams was one of the overarching project unknowns. Fabricating these new beams would require purchasing new forms at the expense of the fabricator. Would the fabricators be willing to take this risk? Would the benefits outweigh the risks? These questions were answered when four out of the five contractors bid the New Bridge using the NEXT Beam for the superstructure. 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 7 shows the new forms created for the NEXT Beam.



Figure 7: NEXT Beam Forms

Daily Precast out of Shaftsbury, Vermont, fabricated the beams. There were a few issues to be worked out during the fabrication stage, including 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. At this point, the decision to turn the stirrups hooks to face outward rather than inward was made.

### BEAM TRANSPORT

Transporting the new beams was the next challenge. Once fabricated, the beams had to travel through three states to their new home along the coast in York, Maine. Transporting the large heavy beams required expensive escorts that had to be incorporated into the cost of the project.



Figure 8 NEXT Beam Transport

### ERECTION

A favorable detour route around the New Bridge allowed for the road to be shut down 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 get the job done. The 55-foot end spans were erected first. A truck-mounted boom crane, located behind the new abutments, lifted the end span beams into place. The interior spans were lifted off a barge that was positioned between the new piers. An 80-foot 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 pours over the piers were completed after all beams were erected to provide a continuous under live load configuration. Figure 9 shows the completed bridge.



Figure 9: Completed New Bridge

## CONSTRUCTION SUCCESS

The construction of the New Bridge was considered as success by all parties—owner, contractor, fabricator, designer, the users, and residents. The speed of the beam placement was remarkable. Because there are only four beams per span and no forms required, erection of the beams moved along quickly. Time was also saved by the fact that no intermediate diaphragms were required—only diaphragms at the beam ends. The contractor estimated a time savings of about one week per span (7 weeks total) for erection of the NEXT Beam superstructure compared to the NEBT superstructure option.

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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