Central Artery/Tunnel Project: Standard Temporary Bridges

Keith Donington, P.E.
Senior Bridge Engineer
Parsons Brinckerhoff Quade & Douglas, Inc.
Boston, Massachusetts

Precast, prestressed concrete is used at many locations for a multitude of functions throughout the multi-billion dollar Central Artery/Tunnel Project in Boston, Massachusetts. One major aspect of this project is the need for temporary bridge structures to keep traffic flowing smoothly during this long construction period. This article describes four superstucture design choices which can be used for these temporary bridges.

Ted Wisniewski, P.E.
Structural Engineer
Parsons Brinckerhoff Quade & Douglas, Inc.
Tampa, Florida

Vijay Chandra, P.E.
Senior Vice President
Parsons Brinckerhoff Quade & Douglas, Inc.
New York, New York

There are a significant number of temporary bridge structures on the Central Artery/Tunnel (CA/T) Project, Boston, Massachusetts, that are needed to maintain traffic during the construction of this immense urban highway project. The project's standard temporary bridges offer contractors four superstructure choices: precast box beam, precast deck slab, Inverset, and Exodermic.

These standard designs were developed to encourage competition among fabricators and are detailed to facilitate reuse, either on this project or during future state bridge replacement projects. Previous project policy had been for section design consultants (SDC) to provide custom, 100 percent complete sets of bid documents for one particular structure type. However, as a cost saving initiative, the Massachusetts Highway Department (MHD) and the Federal Highway Administration's local office requested that their management consultant, Bechtel/Parsons Brinckerhoff (B/PB), develop the standard design concept for temporary bridges.

The standard design concept involves the following features:

- Develop bid documents for four different superstructure types to provide competition and thus reduce costs.

- Provide a standardized substructure applicable to all four superstructure types.
- SDCs produce bid documents showing span layouts and highway geometry identifying where the standard designs are applicable, providing supplementary designs for conditions not conforming to the standards, such as transition spans tying with existing structures.
- B/PB drawings provide tables of beam and slab elements for various span ranges and beam spacings, as well as corresponding typical details for bridge bearings, steel bents, and foundations.
- Design simple spans and details with reuse in mind. The span lengths range from 50 to 110 ft (15.2 to 33.5 m), while bridge widths range from approximately 22 to 52 ft (6.7 to 15.8 m) curb to curb.
- Contractors and suppliers produce shop drawings based on the most economical superstructure alternative, utilizing the tabular information and standardized details provided on B/PB's standard drawings (essentially a detailing exercise).

The superstructure types selected for standard designs were chosen not only for reasons of economy and speed of erection, but for their ability to be reused; either re-erected as other temporary CA/T bridges or stockpiled for potential permanent reuse by the MHD for future short-span bridge replacement projects throughout the state. Standard designs were also developed for one- and two-column bents, using double steel girder cross beams and pipe columns supported on drilled shafts.

The standard design concept with "ready to go" plans has led to cost savings as a result of competitive bidding of superstructure types and reduced consultant fees for producing construction plans and specifications. The potential exists for additional savings due to the reuse of units after their removal.

DESIGN OPTIONS

In this article, four standard design options are described:

- Precast box beam option
- Precast deck slab option
- Inverset option
- Exodermic option

Some pertinent details regarding the design of the precast elements of these design options are given below.

Precast Box Beam Option (see Fig. 1)

Initially, several precast beam types were evaluated for selection as standard designs. The box beam section was chosen because it offers the ad-

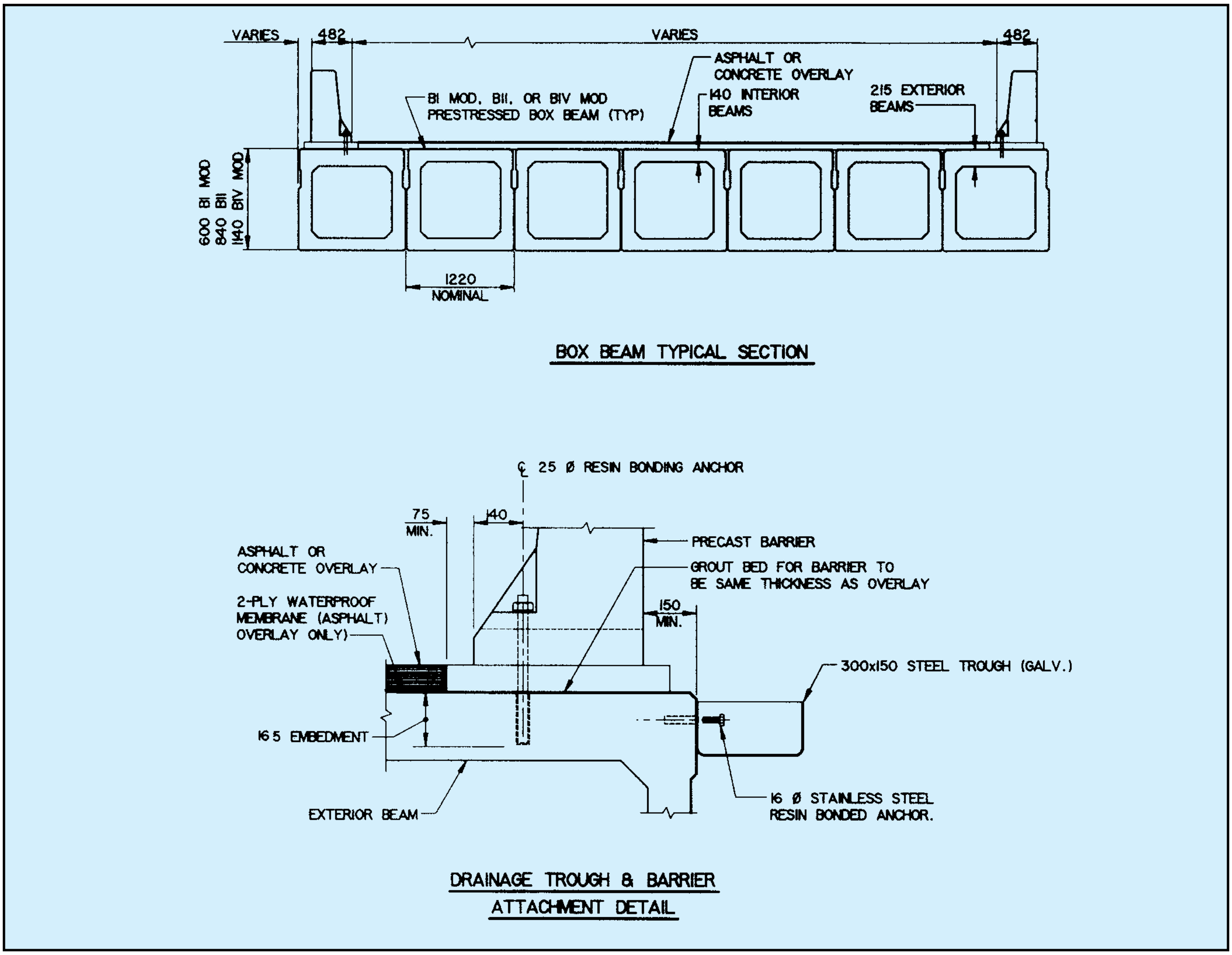

Fig. 1. Typical section of box beam and drainage detail.

vantage of accommodating an array of span ranges. Its symmetrical section is also very stable, lending itself to subsequent dismantling and reuse. Furthermore, butted box beam construction is common in Massachusetts.

The following three standard box sections cover the full range of span lengths:

- BI 48 MOD for 50 to 70 ft (15.2 to 21.3 m) spans
- BII 48 for 70 to 90 ft (21.3 to 27.4 m) spans
- BIV 48 MOD for 90 to 100 ft (27.4 to 30.5 m) spans

Two designs were necessary for each beam type to limit the difference in span range to 10 ft (3.0 m) for a given beam, resulting in a total of six beam designs using straight prestressing strands. This helped keep final stresses within the allowable range while economizing on strands.

In addition, designs met the MHD's strand debonding limit of 25 percent of the total number of strands. The beams were also designed for up to a 3 in. (75 mm) concrete or asphalt overlay for the dual purpose of maintaining a smooth riding surface and allowing the overlay to make up the final roadway geometry.

Each beam contains a 2 ft (0.60 m) solid concrete end zone and several 8 in. (200 mm) thick diaphragms where the transverse post-tensioning is located. As opposed to using post-tensioned (PT) strands, 1 in. (25 mm) diameter hot dipped galvanized PT bars were selected.

By using coupled PT bars with an anchor plate, the nut and bars can be dismantled easily and safely. The jacking force was limited to 50 percent to enable the bars to be reused while still maintaining more than twice the transverse post-tensioning force required by MHD standards.

Precast Deck Slab Option (see Fig. 2)

Precast 7.5 in. (190 mm) thick deck panels were chosen as one of the four options for the temporary bridge design standards. With this system, 8 ft (2.4 m) wide precast reinforced concrete deck panels are placed transversely across standard rolled steel girders. The panel length varies with the width of the bridge. The panels

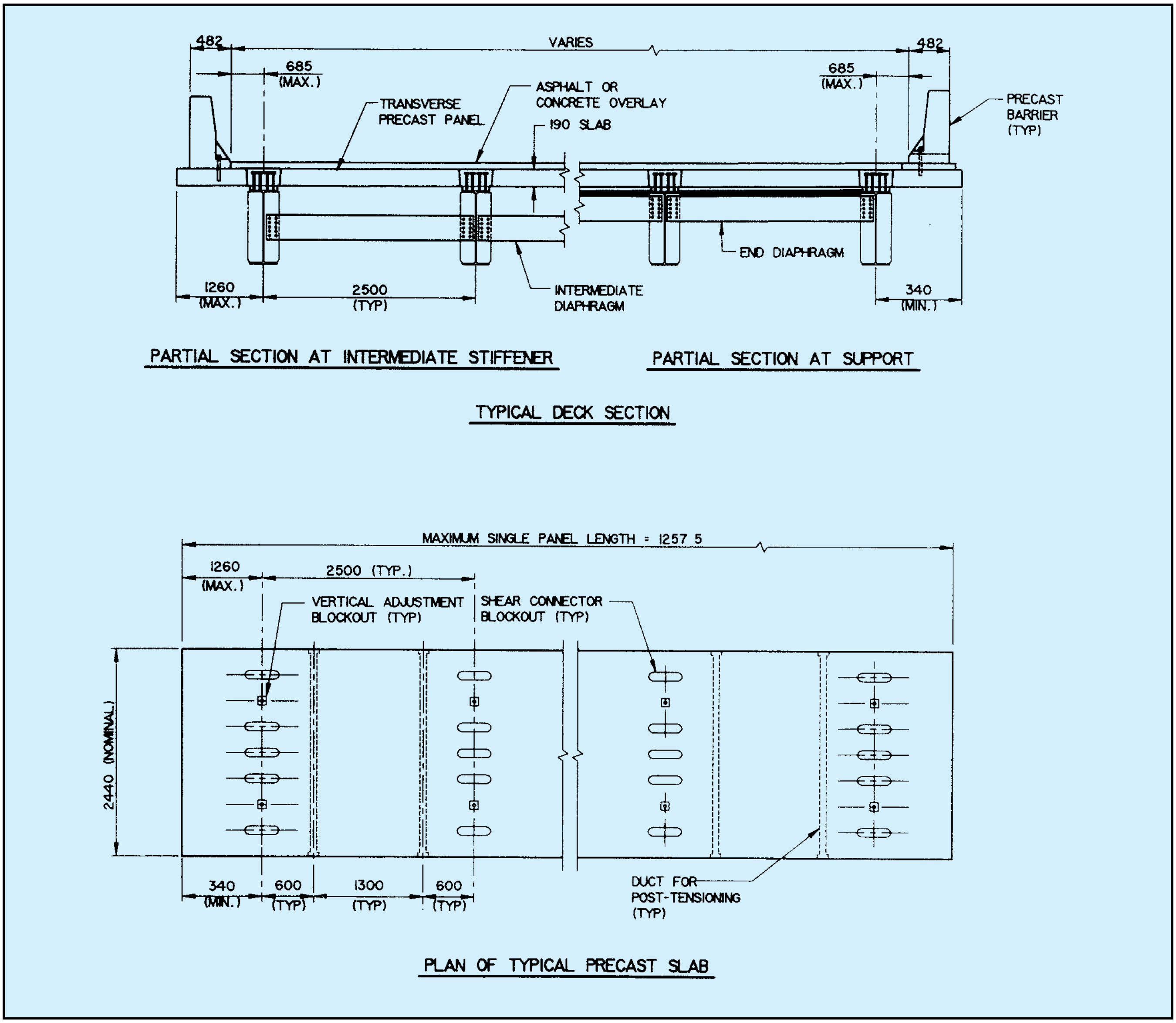

Fig. 2. Typical deck section and plan of precast slab.

have a keyway cast along their entire length that is later filled with non-shrink grout to form 1.5 in. (38 mm) wide transverse joints.

As the panels are placed over the beams, they can be adjusted readily to the correct elevations by using two leveling bolts that have been cast into the deck directly over each steel girder. Enough space is left between the girder and the deck slab to maintain a 1 in. (25 mm) minimum haunch.

When all the units are in their final position, the transverse joints are filled with non-shrink grout and the deck slab units are longitudinally post-tensioned together through two corrugated polyethylene ducts that have been cast in the slab between each girder. Three 0.6 in. (15 mm) diameter strands comprise each tendon that is stressed to a final minimum post-tensioning force of 47.5 tons (43 t) after all losses. After post-tensioning has been completed, the ducts are grouted.

Composite action between the concrete deck slab and steel girder is achieved with 1 in. (25 mm) diameter headed shear connectors that are welded to the top flange of the girder. The shear studs are located in five 5 in. wide x 16 in. long (125 x 400 mm) pockets that have been cast into the slab units at approximately 1 ft (0.30 m) intervals over each girder.

After the panels are in position and post-tensioned, the shear connectors (four per pocket) are welded in the blockouts by means of specialized welding equipment. When all the shear studs are welded in place, the haunches are formed. The haunches and shear connector blockouts are then filled with pourable non-shrink grout.

Girder spacing is fixed at 8.25 ft (2.5 m) as dictated by the slab design with a minimum of three girders per panel. The variable bridge widths are accommodated by varying the width of the overhang from a minimum of 1.125 ft (0.34 m) to a maximum of 4.125 ft (1.25 m). Handling constraints require the maximum allowable deck panel length to be set at 41.25 in. (12.6 m).

To attain deck widths up to 56 ft (17 m) out to out, it was necessary to divide the deck into two panels of constant width with a longitudinal joint centered between two girders. Cast-in-place closure pours at the piers

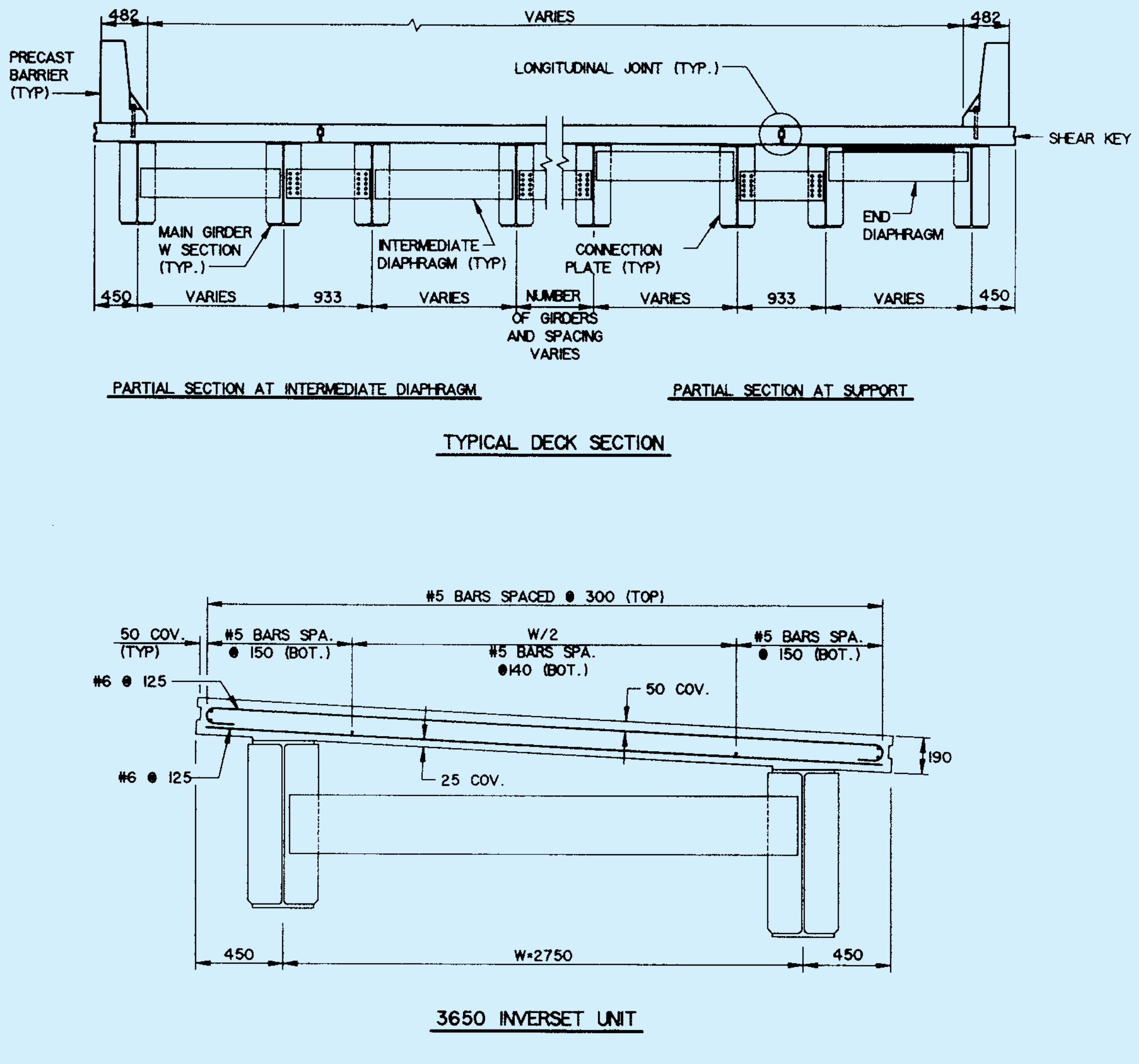

Fig. 3. Typical deck section and Inverset unit.

allow variable bridge lengths when the length is not a multiple of the 8 ft (2.4 m) slab units. The closure pours may vary from a minimum of 2 ft (0.6 m) to a maximum of 8 ft (2.4 m), namely, one panel width.

Transverse post-tensioning is not required in the design for service loads. Transverse prestressing, however, is required to prevent tensile stresses during handling and erection. The amount and location of this prestressing is determined by the deck panel fabricator.

Inverset Option (see Figs. 3 and 4)

The Inverset bridge system utilizes a simple but innovative concept in the manufacturing process. The beams are prestressed using a unique upside down casting technique. When the units are cast upside down (with the wet deck concrete on the bottom), the dead load of the superstructure will reverse bend the steel beams that will compositely support the concrete deck.

Since the "sag" of the beam is permanently cast into the deck, it becomes a camber upon placing the unit right side up. When the finished units are turned right side up, composite action between the steel beams and concrete deck occurs. This process prestresses the steel beams and precompresses the concrete deck.

The Inverset bridge system is a precast modular system that readily lends itself to temporary bridge construction as well as removal and reusability. The design standards utilize combinations of only three standard unit widths of 8, 10, and 12 ft (2.4, 3.0, and 3.7 m) to achieve the prescribed deck width range of approximately 22 to 52 ft (6.7 to 15.8 m) curb to curb. The unit span lengths range from 50 to 110 ft (15.2 to 33.5 m) in 10 ft (3.0 m) increments. Therefore, seven lengths by three widths equals 21 individual unit standard designs.

One design criterion specifies that steel beams be standard rolled sections instead of the more commonly used welded plate girder. For span lengths of 90 ft (27.4 m) or greater, this requires a steel cover plate to be welded on the bottom of the bottom flange to increase the section capacity. As an alternative, however, the standard drawings included the design of a heavier standard section with no required cover plate.

Exodermic Option

The Exodermic bridge deck uses a concrete filled steel grid. The grid can either be filled with cast-in-place concrete or precast with pockets for shear steel attachments to supporting steel stringers. What is unique about the deck is that it combines reinforced concrete compositely with the steel grid. The deck is composed of a 4.5 in. (115 mm) reinforced concrete slab on top of the steel grid bonded compositely through partial embedment of tertiary bars and vertical steel shear studs welded to them.

This creates a system (when under positive bending moments) that utilizes both the compressive strength of the concrete and the tensile strength of the steel. In negative bending, the top layer of rebar is put into tension and the grid main bearing bars and concrete over the girder handle the compressive forces. The result is a bridge deck that typically weighs 50 to 65 percent of a similar depth conventional concrete deck. With a precast deck slab, erection time can also be minimized.

Fig. 4. Underside of bridge showing precast modular Inverset system.

PRECAST TRAFFIC BARRIER

All four superstructure design options use the same temporary traffic barrier, namely, a crashworthy design consisting of 10 ft (3.0 m) long precast concrete sections that are bolted to the deck. Since the roadway alignment on the bridge may be curved, the distance from the exterior edge of the exterior beam to the barrier anchor bolt varies. This does not allow for placement of preset inserts since it is impossible to predetermine their siting.

Apart from Exodermic, where the barriers are attached to the deck by through bolting, the other three superstructure options utilize field drilled holes made in the deck slab, with anchor bolts epoxied in place. The depth of field drilled holes need to be at least 6.5 in. (165 mm) deep to achieve full strength of the structure. These three options have a 7.5 to 8.5 in. (190 to 215 mm) thick deck to accommodate the 6.5 in. (165 mm) deep hole.

The box beams (see Fig. 1), however, contain only a 5.5 in. (140 mm) thick top slab; therefore, attaching an anchor plate and nut for a thin bolted attachment is not feasible since the box is a closed system. The solution was to increase the thickness of the top slab of the exterior beams by 2 in. (50 mm) so that the epoxied anchor system could be used without penalizing the interior box beams with additional dead load.

CONCLUSION

Several ongoing contracts in the CA/T Project are utilizing the standard temporary bridges. In Contract C19B1, the contractor has selected the precast box beam superstructure being fabricated by Northeast Concrete Products of Plainville, Massachusetts.

In two other contracts (C19E7 and C17A1), the same contractor has selected the Inverset option with the Fort Miller Company of New York serving as the fabricator. Precast deck slab units were fabricated for an earlier portion of Contract C17A1 by Bayshore Concrete Products Maine in Auburn, Maine.

It is believed that standardized designs have already resulted in major cost savings to the client—from competitive bidding among superstructure alternatives to final design fees. The amount of additional savings will depend upon the degree of recycling that occurs on later contracts of the CA/T Project and during other state bridge projects in the future.

CREDITS

Client: Massachusetts Turnpike Authority, Boston, Massachusetts

Management Consultant:
Bechtel/Parsons Brinckerhoff, Boston, Massachusetts

Final Design: Parsons Brinckerhoff, Boston, Massachusetts and Tampa, Florida