PART 5

Central Artery/Tunnel Project: Standardized Precast, Prestressed Transition Structures

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Precast, prestressed concrete has played a prominent role in the design and construction of Boston's Central Artery/Tunnel Project. The previous four articles have shown the many innovative ways in which precast concrete products have been used in this project. In this Part 5 article, the authors discuss the use of standardized precast, prestressed transition structures, especially the slab-on-pile and the New England bulb-T girder.

The complex Central Artery/Tunnel Project in Boston, Massachusetts — commonly referred to as "The Big Dig" — includes more than 94 main bridge structures with over 45 approaches. Bechtel/Parsons Brinckerhoff, the project's joint venture management consultant, has renamed these approaches "transition structures," and has standardized their design.

Two different precast concrete structures are being utilized as standard approaches to the project's main bridges. These construction techniques use slab-on-pile and New England bulb-T girder designs. Slab-on-pile is used for roadway heights ranging from a minimum of zero feet at grade to a maximum of 10 ft (3.05 m) above finished grade, while New England bulb-T girders are used for structures with a finished roadway grade between 10 and 20 ft (3.05 and 6.10 m) above finished grade.

Above a height of 20 ft (6.10 m), the main structure continues as either a precast segmental concrete box girder bridge or a steel trapezoidal box structure (see Fig. 1). Both slab-on-pile and the New England bulb-T girder structures have been designed to create an illusion of an abutment and

Fig. 1. View of slab-on-pile structure, the New England bulb-T girder structure, and the main steel structure.

wingwall system. After the erection of a section is complete, precast curtain walls are set on precast, prestressed concrete piles to enclose the entire transition structure.

Prior to standardizing the transition structures, precast concrete bridge structures were designed by various engineering firms — each firm completing designs of AASHTO I-girders for their particular contract. However, this experience showed that design and construction costs as well as scheduling could not be controlled effectively. It soon became apparent that the structures needed to be organized and designed as standard structures.

STANDARD PRECAST TRANSITION STRUCTURES

There are a number of reasons why the designers of the project decided to use standard precast transition structures for the bridge approaches. These reasons include inspection access, existing soil conditions, and time/cost benefits.

Inspections

The future inspection of structures is a major concern for the Big Dig's clients, namely, the Massachusetts Turnpike Authority and the Federal Highway Administration. The use of precast concrete superstructures and walls to enclose structures allows inspectors to gain easy access to areas needing close examination (see Fig. 2).

Using the transition structure system also provides for inspection access to the approach structure itself, as well as to the first pile bent or abutment. Wall panels have doors cast into them to provide access to the enclosed structure while also providing an aesthetically pleasing appearance of a retained fill structure.

Fig. 2. Preparation of final deck placement for the New England bulb-T girder transition structure. The height of this structure allows for easy inspection and maintenance in the future.

Soil Conditions

The Central Artery/Tunnel Project is built predominantly on existing historic fill. The city of Boston was much smaller 200 years ago than it is today. To grow, it reclaimed shallow harbor shoreline by continuous, unplanned filling. As a result, there is not a reliable soil base to place additional fill in many parts of the city.

There are also many transition bridge locations throughout the project where the subsurface is so weak (even if it was possible to compact the fill) that existing ground conditions do not permit the placement of additional weight within available time limits. Additionally, at many of these locations hazardous materials are present. Transition structures offered the best solution to reducing costs associated with disposing of hazardous materials.

In many project locations, there are also problems associated with the time required to consolidate supporting soil when using normal fill methods behind abutments. Unfortunately, there was not enough time to completely consolidate the soil of the approaches prior to placing traffic on the structures, as normal fill behind an abutment requires months or years to adequately settle. Therefore, precast concrete transition structures were designed to work around the poor soil conditions encountered in Boston.

Precast, prestressed square piles were driven down to bedrock, and precast superstructures were then placed on top of the piles. By making the transition to the main bridge a bridge itself, instead of a fill section, the need to address inconsistent soil conditions was eliminated.

Time and Cost Benefits

Time was a key consideration during construction of the Big Dig. When it was decided to use structures to transition from existing ground to elevations up to 20 ft (6.10 m), the fastest and most efficient way to accomplish this was by using precast concrete (see Fig. 3). Steel and cast-in-place concrete structures were quickly eliminated from design consideration because of the amount of time necessary to place these structures.

Aesthetics was also a major concern in this project since most of these structures are in full view of commuter traffic. Precast concrete provided the fastest assembly, while also furnishing an aesthetically pleasing appearance.

Fig. 3. Placement of T-shaped cross-beams on pile caps for the slab-on-pile transition structures.

DESIGN SOLUTIONS

Based on the previously discussed reasons for not being able to use standard fill in the approach area, as well as time constraints and the sheer number of necessary approaches, it was quickly determined that a precast concrete solution was the key to controlling project costs and schedules.

The most difficult part of this process was developing a standard design that could be used throughout the project's varied locations and site conditions. This task became the responsibility of the management consultant's design team.

Design Thought Process

The project consists of 45 transition structures. Thirty-five of these structures are being constructed using standard designs: 21 slab-on-pile structures and 14 New England bulb-T girder structures. Other engineering firms, prior to the development of the standard drawings, designed 10 AASHTO I-girder structures. In total, there are 348,000 sq ft (32,330 m^2) of precast transition structures being constructed on the Central Artery/Tunnel Project.

Parsons Brinckerhoff developed the standard drawings for the slab-on-piles, New England bulb-T girders, and precast curtain walls. The designers created structures that could be pieced together using sets of tables and details. These tables and details were placed on a set of standard drawings for use by the project's various section designers.

There are more than 50 design contracts for this project. Section designers are responsible for taking standard drawings and incorporating them into their contract drawings. They are also responsible for creating framing plans and basic geometry.

The section designers also chose the size of New England bulb-T girders from tables and specified them in the framing plans. All other design aspects — from dimensions to reinforcement layout to prestressing strand patterns — are provided by the standard

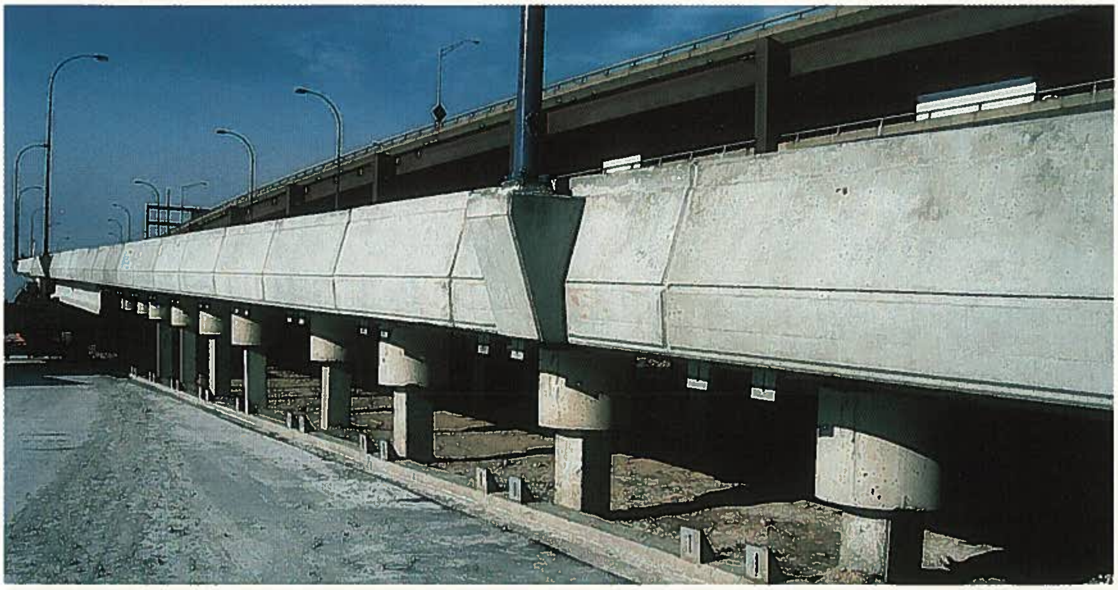

Fig. 4.
Finished slab-on-pile structure. The steel angles that are visible at the base slab and under the barrier are for attaching the precast concrete wall panels.

drawings, which are included in the contract drawings set.

Slab-on-Piles

The slab-on-pile design uses a combination of precast, prestressed 16 in. (406 mm) square piles, precast pile caps, precast cross-beams, and precast panels. The precast piles are spaced at intervals of 12 ft (3.65 m) along the longitudinal direction and at 10 to 20 ft (3.05 to 6.10 m) intervals transverse to the roadway (see Fig. 4).

Circular precast pile caps sit atop each pile to support the precast cross-beams. The pile caps have openings in the base to receive protruding reinforcing steel from the precast, prestressed piles.

Once a pile cap has been placed, it is integrated into the precast, prestressed pile to form a moment resistant connection. The precast cross-beams running parallel to traffic are inverted T-shaped supports for the precast panels. The precast panels are 7 in. (180 mm) thick and sit between the cross-beams.

When all the precast units are in place, a 5 in. (130 mm) thick cast-in-place deck is placed over the entire structure with a 1.5 in. (38 mm) finish overlay for durability and protection. A final step involves placing the precast curtain walls.

New England Bulb-T Girders

The New England bulb-T girder is a new precast, prestressed concrete girder adopted in the New England area a few years ago. For this project, only 47 or 55 in. (1200 or 1400 mm) deep girders are being used — the standard design needed to satisfy all project conditions.

The standard also specifies that the bulb-T girders accommodate a general span length and girder spacing (see Fig. 5). The girders' prestressing strands are laid out in accordance with these specifications, with a maximum overhang dimension to accommodate the curvature of the structures.

The standard design also provides typical diaphragm and end diaphragm details. Section designers are responsible for laying out framing plans for the girders within the limits of the standard drawings, which are detailed as simple, two-span continuous or multiple span continuous structures up to 400 ft (122 m) in length (see Fig. 6).

In addition, the substructures of the New England bulb-T girders consist of concrete pile bents. Each bent has 16 in. (400 mm) precast piles spaced up to 10 ft (3.05 m) apart. These piles are capped with 7.5 ft wide x 3 ft high (2.29 m x 0.91 m) cast-in-place pier caps (see Fig. 7).

Precast Curtain Walls

The precast curtain walls sit on a cast-in-place grade beam, which is supported by 12 in. (305 mm) square precast, prestressed concrete piles. These piles are spaced less than 20 ft (6.10 m) apart. The precast wall panels are 10 ft wide and 8 in. thick (3.05

Fig. 5. The 20 ft (6.10 m) high abutment also acts as a transition pier between the New England bulb-T girders and the main structure.

Fig. 6. Framing of the New England bulb-T girder structure.

m x 203 mm), and can be cast up to 20 ft (6.10 m) high.

Due to the highly visible locations of these walls, their architectural treatment utilizes the natural finish of the precast units to enhance the aesthetics of the wall structure. False tie holes are also added to the forms to create a consistent pattern, with chamfered edges to provide a finished look.

CONSTRUCTION

Once the precast piles are in place, the superstructures can be erected very quickly. The barriers are then cast and the final wearing surface is placed. The only set time necessary during this process is for curing the cast-in-place concrete overlay and barriers.

The construction of all transition structures continues to proceed smoothly. This was apparent from the opening of the Initial Leverett Circle Connector (ILCC), which occurred in the fall of 1999.

This project segment, which included two major expressway ramps north of the city, totaled 428,000 sq ft (39,800 m^2), including 31,700 sq ft

Fig. 7. Pier between the New England bulb-T girder and the slab-on-pile structure. This pier is supported on 12 in. (305 mm) square precast piles.

Fig. 8. Initial Leverett Circle Connector – the New England bulb-T girder structure is utilized to raise the roadway to the main bridge structure.

(2948 m²) of transition structures (see Fig. 8). As demonstrated in other parts of the project, the benefits of using standard designs for precast concrete structures provided significant time savings which, in turn, allowed for an expedited construction schedule.

CONCLUSION

The Central Artery/Tunnel Project includes more than 42 miles (68 km) of permanent bridge structures, including nearly 4 miles (6.4 km) of approach structures. The use of standard, precast transition structures — rather than unique, individually designed bridge approaches — has been a key ingredient for the project's success to date.

Their use has resulted in time savings, both during design and construction; has reduced construction costs; and has enhanced the aesthetics of the final, constructed structure by ensuring consistency throughout historic Boston. Indeed, the entire design-construction team can feel justifiably proud of their accomplishment, which will transform Boston's archaic highways into an efficient, modern transportation system.

CREDITS

Owner: Massachusetts Turnpike Authority

Managing Consultant: Bechtel/Parsons Brinckerhoff

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Contractors:
- J.F. White/Slattery/Interbeton
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Precaster: Northeast Concrete Products