PART 6

Central Artery/Tunnel Project: Boston's Engineering Marvel – Where We Are Now

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This article is the sixth and final paper in the series of articles on Boston, Massachusetts' mammoth Central Artery Tunnel Project. This multi-billion dollar project is the largest highway construction job ever undertaken in the United States. The first five articles discussed the various innovative ways in which precast/prestressed concrete is playing in the successful construction of this project. This concluding article summarizes the major precasting techniques being utilized and outlines the project milestones planned and accomplished so far, which are already having a beneficial impact on the transportation needs of the people of Boston.

A major transportation infrastructure undertaking, billed as "The Big Dig" (Central Artery/Tunnel Project), is transforming traffic operations in and around Boston, Massachusetts. This $14 billion project, the biggest and most complex transportation system ever undertaken in the United States, has worldwide significance.

Precast/prestressed concrete is playing a major role in the construction of the Central Artery/Tunnel Project at many of the interchanges, viaducts and ramps, temporary structures, and even in tunnels, which are all being built while maintaining traffic. The project has brought out the best that precast concrete technology has to offer — in many cases utilizing cutting edge technologies.

Numerous innovative construction techniques are being used in this project, including:

- Precast concrete tunnels jacked under railroad embankments.
- Precast concrete immersed tube tunnels.
- Standardized designs for precast New England Bulb-Tee (NEBT) girders and slab-on-pile structures.
- Standardized temporary structures utilizing precast elements.
- Precast concrete segmental box girders integrated into cast-in-place columns to provide seismically resistant connections.
- Precast concrete segmental boxes cut at a skew to connect on either side of straddle bents.

The purpose of the Central Artery/Tunnel Project is to provide an efficient, uncongested vehicular route for the people of Boston. The city's existing Central Artery, which includes an elevated section of I-93 between Congress Street and Route 1 in Charlestown, is one of the most congested segments of interstate highway in the nation.

Jammed with more than 190,000 vehicles daily — more than twice the capacity it was originally designed to handle when it opened in 1959 — the Central Artery experiences eight hours of congestion each weekday. These conditions were expected to worsen, to the point that by the year 2010, it was estimated that there would be a 15-hour rush period.

Massachusetts transportation officials initiated the current Central Artery/Tunnel Project (see Fig. 1) in August 1986. As planned, major elements of this extensive project include:

- Replacement of a 4.3 mile (6.9 km) segment of the congested Central Artery (I-93) between the Southeast Expressway to the south and Charlestown to the north.
- An improved 1.7 mile (2.7 km) direct connection between Leverett Circle and Charlestown.
- A 3.9 mile (6.3 km) extension of the Massachusetts Turnpike (I-90) to Logan International Airport.

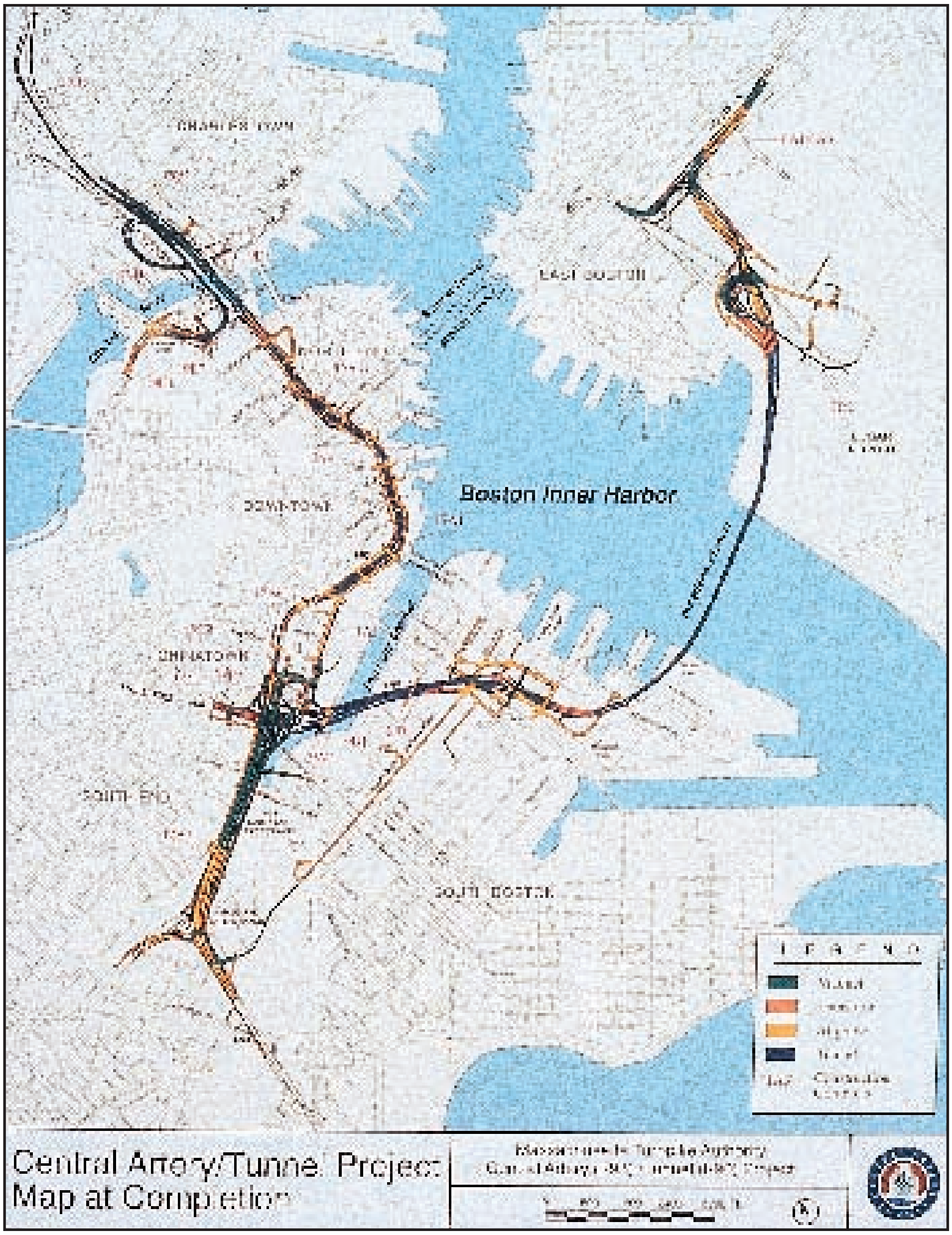

Fig. 1. Overall project map.

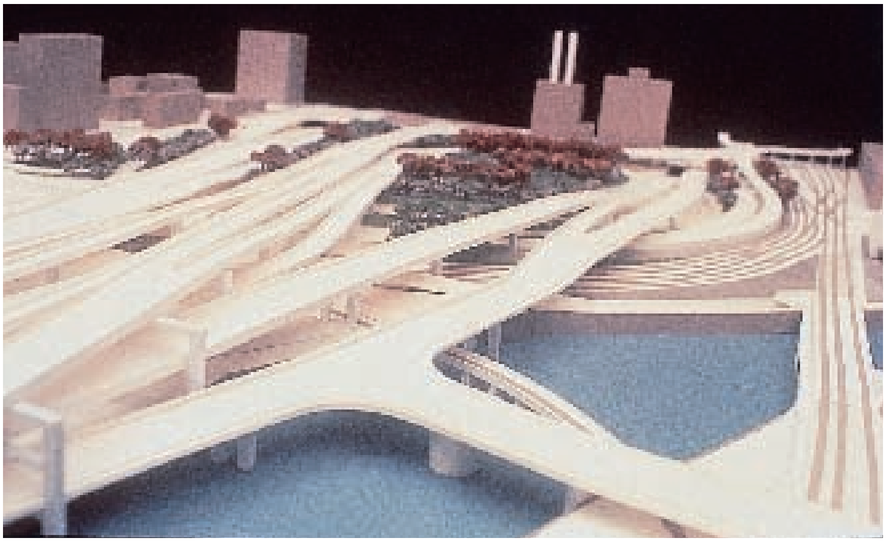

Fig. 2. South Bay Interchange model.

Table 1. Design of the project began in 1986 with major utility relocations initiated in 1991. Major project milestones are listed in table.

Project	Actual/Planned Completion Dates
South Boston Bypass Road, Ted Williams Tunnel and part of Logan Interchange	Late 1995
Leverett Circle Connection to Charlestown	Late 1999
I-90 Eastbound, Westbound, and Ramp L	Mid 2002
Logan Airport Interchange	Mid 2002
I-93 Northbound	Late 2002
East Boston Route 1A Interchange	Mid 2003
I-93 Southbound (two lanes)	Late 2003
I-93 Southbound (all lanes)	Late 2004
I-90/I-93 Interchange (final completion)	Late 2004
Existing Artery Removal and Surface Restoration	2005

- A 1.4 mile (2.3 km) South Boston Bypass Road.

PROJECT MILESTONES

Design of the project began in 1986 with major utility relocations initiated in 1991. Major project milestones, together with actual, planned completion dates, are given in Table 1.

I-90 Extension to Logan Airport

Presently, I-90 (known locally as the Massachusetts Turnpike), extends westwards to Seattle, Washington. In Boston, it terminates at the intersection with I-93 near the Fort Point Channel.

One of the crucial parts of the overall project has been the extension of I-90 to Logan Airport. This will improve access to the airport as well as provide a relief valve to the overloaded Sumner and Callahan Tunnels.

This extension of I-90 includes a major four-level interchange with I-93; crossing under a busy railroad corridor with jacked tunnels; going under Fort Point Channel and over the Massachusetts Bay Transportation Authority (MBTA) Red Line tunnel with concrete immersed tube tunnels; running through South Boston in a depressed roadway section; crossing under the busy shipping lanes accessing Boston Harbor; providing access to the various airport terminals via an interchange; and connecting to the Sumner and Callahan Tunnels and Route 1A via another interchange.

Fig. 3. Precast segmental erection.

The complicated four-level all-directional interchange with I-93 (see Fig. 2) is being built in stages while maintaining the traffic flow of an existing three-level interchange and then demolishing the existing structures in stages. This is being accomplished by using temporary structures and previously built structures as detours. Most of this interchange uses precast concrete technology with many innovations (see Figs. 3 and 4). For further details, see the July-August 2000, PCI JOURNAL.

I-90 needed to be depressed through South Boston due to impacts to Gillette's main manufacturing facility, and needed to cross under Amtrak and MBTA commuter railroad tracks near South Station. The tracks make a 90-degree sweep in the project area.

Crossing under the tracks is accomplished by a technology called "tunnel jacking." Precast concrete tunnels are first constructed in a pit and pushed with large capacity jacks into previously frozen ground (see Fig. 5). There are three 78 ft (24 m) wide, 38 ft (12 m) high tunnels of varying lengths from 167 to 350 ft (51 to 107 m), which have been precast and pushed under the tracks. Tunnel jacking for I-90 is complete.

Crossing the shallow Fort Point Channel is accomplished by immersing precast concrete tunnels (see Fig. 6) of unusual trapezoidal shapes to match the main line section and incoming ramps. Lengths vary from 280 to 417 ft (85 to 127 m), widths vary from a minimum of 66 to 164 ft (20 to 50 m), heights vary from a minimum of 26 to 31 ft (7.9 to 9.4 m), and they weigh as much as 50,000 tons (45,400 t).

The tubes are precast in a dry dock along the I-90 alignment adjoining the

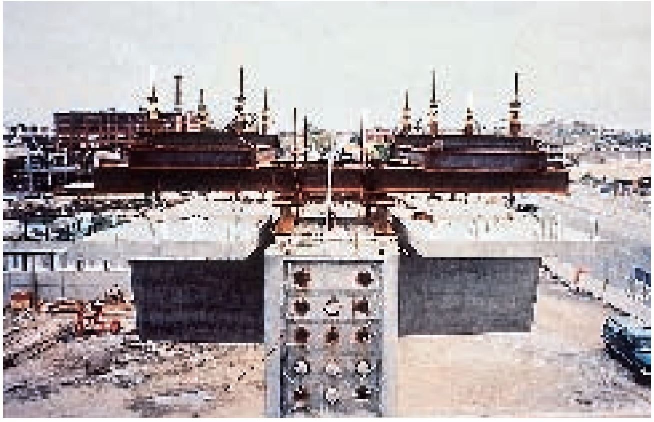

Fig. 4. Precast segments connection to straddle pier.

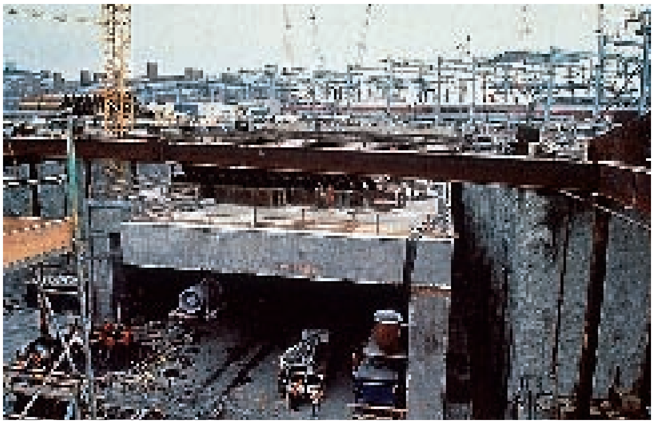

Fig. 5. Precast tunnel jacking.

Fort Point Channel, and then floated out into the channel. Four of the six tubes have been completed and two have already been installed. The two installed tube sections comprise the lower portion of a ventilation structure. Both the tunnel sections and ventilation building were cast together in dry dock and then floated. This was done to avoid underwater work for the ventilation building after placement of the tubes.

The ventilation building is currently under construction. Four of the tubes are being placed over underwater drilled shafts so as not to stress the 100-year-old Red Line transit tubes which are located close to the bottom of the new tunnels — within 4.9 ft (1.5 m). Two of the constructed tubes are in the channel awaiting placement. The last two tubes are under construction in the dry dock.

I-90 traverses through South Boston as a depressed highway and connects to the previously completed and operating Ted Williams Tunnel, which is an immersed steel tube tunnel under the ocean at the entrance to Boston Harbor (see Fig. 7).

Exiting the tunnel in East Boston towards Logan Airport, a semi-circular interchange, which is under construction (see Fig. 8), provides access to the airport terminals and connects to another interchange (East Boston Route 1A). Construction of the East Boston Route 1A Interchange recently began and will eventually connect I-90 back to the Sumner and Callahan Tunnels and Route 1A.

I-93 Reconstruction

Most of I-93 up to the North End will be relocated into tunnels. After rehabil-

Fig. 6. Precast immersed tube tunnel under construction.

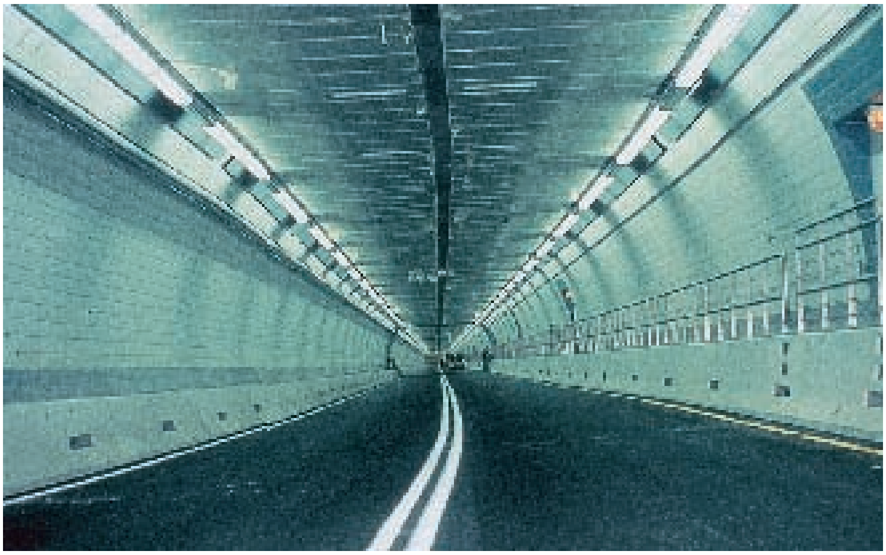

Fig. 7. Ted Williams Tunnel under Boston Harbor.

itation, the existing Dewey Square Tunnel will be serving southbound traffic only. At the I-90 interchange, the northbound roadway splits off and runs through its own alignment under Atlantic Avenue and below the Red Line at South Station before rejoining the southbound main line. North of South Station, the northbound and southbound roadways come together and run parallel with four or more lanes of traffic under the present elevated Central Artery viaducts in downtown Boston.

The new tunnels are being built while maintaining traffic on the elevated viaducts and surface roadways. The northbound roadway is presently 50 percent complete. Finishes for the northbound and southbound tunnels will include precast concrete walls and ceiling panels (see Fig. 9), which are now being installed.

The southbound roadway is partially complete. After both northbound and southbound tunnels are in service, the elevated Central Artery will be razed and a park-lined boulevard will be developed along the alignment.

At Boston's North End, the tunnels emerge into daylight at Causeway Street before proceeding to a cable-stayed bridge over the Charles River. The bridge, named the Leonard B. Zakim Bunker Hill Bridge, is the first of its kind in the United States (see Fig. 10). It is also the widest cable-stayed bridge in the world.

The bridge is asymmetric, both transversely and longitudinally, with inverted Y-shaped towers. The main span is 745 ft (230 m) with back spans of 250 and 420 ft (75 and 130 m). It is a hybrid structure with concrete back spans and composite precast slabs on steel superstructure in the main span. The back spans of the bridge are complete and the main span is 80 percent finished.

North of the Charles River, the cable-stayed bridge merges into a

Fig. 8. Logan Airport Interchange under construction.

complicated three-level interchange that accommodates I-93 as well as a connection to the Tobin Bridge (Route 1) and ramps from Leverett Circle. The interchange utilizes mostly precast segmental box girders, built using span-by-span and balanced cantilever construction techniques.

Span-by-span erection is used in fairly straight sections, with balanced cantilever erection used for the curved ramps over the railroad tracks serving North Station (see Fig. 11).

The northbound and southbound Leverett Circle ramps, after spanning over the North Station platforms and the Charles River, merge into the above interchange.

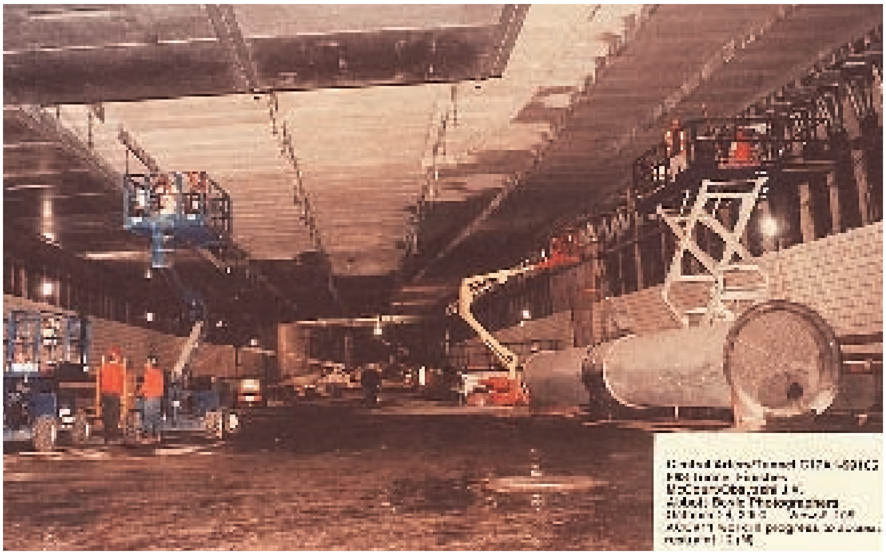
Fig. 9. Precast concrete walls and ceiling being installed.

Temporary Bridges

Because of the need to maintain traffic during construction, as well as the congested urban environment through which the project is constructed, many temporary bridge structures are needed. Early in the process, for a few structures, we proceeded with proprietary products that tended to increase costs. However, since many temporary structures totaling approximately $120 million were necessary, we changed strategies to reduce this cost.

Rather than limiting ourselves to one type of structure, we developed four types — all simple spans — and produced standard drawings to facilitate adaptability in most locations. The concrete alternates included box beams, full depth precast slabs, and Inverset units. This alternative concept has also fostered increased competition and reduced costs.

After the completion of this project, these temporary structures will become the property of the Massachusetts Highway Department for use in replacing secondary and rural bridges. For more information, see November-December 2000, PCI JOURNAL.


Fig. 10. Leonard B. Zakim Bunker Hill Bridge under construction.

Fig. 11. Segmental concrete construction over North Station tracks.

Fig. 12. New England bulb-tee girder construction.

Transition Bridges

When ramps or viaducts were located close to the ground, rather than using concrete or steel box girders, we utilized comparatively shorter spans and a correspondingly shallower superstructure. This improved access for inspection purposes, enhanced aesthetics, and alleviated the traditionally humid conditions below these structures. Rather than allowing individual section designers to develop their own types of structures, the project engineers decided to develop cohesive standards.

Two types of structures were standardized: For spans from 75 to 110 ft (23 to 34 m), NEBTs with composite decks (see Fig. 12), and for very short spans up to 25 ft (7.6 m) (see Fig. 13), precast slabs on piles. The bulb-tee solution was developed for simple spans up to four-span continuous structures.

Section designers used the standard drawings by first calling out beam types from tables, supplemented by general plan, elevation, and other details that could not be anticipated.

The precast slab-on-pile standards included full depth precast slabs on precast pier caps supported on precast square piles. Most of these structures have been constructed and are now in service. For further details, see January-February 2001, PCI JOURNAL.

Miscellaneous Structures

Not every aspect of this project uses new or innovative technologies. Wherever possible, and appropriate, conventional concepts have been utilized. For example, at the Broadway (see Fig. 14) and Dorchester Avenue Bridges, precast side-by-side boxes were used with composite deck slabs.

For the 800 ft (245 m) long Broadway Bridge, built over railroad tracks, the structure is made continuous for superimposed dead and live loads.

Additionally, at Spectacle Island, where an old landfill was used for much of the project's excavated tunnel material, a berthing facility was needed. The resulting pier, necessary to dock boats and ferries once the island is landscaped and transformed to recreational use, utilized a totally precast solution featuring double tees on precast piles and caps. Refer to September-October 2000, PCI JOURNAL.

PRECAST CONCRETE SHOPPING LIST

The Central Artery/Tunnel Project incorporates hundreds of millions of dollars worth of precast concrete components. The sheer scope of the different segments and volume of casting is staggering. Table 2 summarizes the types of precast components used in some of the interchanges.

CONCLUDING REMARKS

The Central Artery/Tunnel Project has been at the forefront of adapting the latest technologies, innovative new concepts, and new techniques as situations allowed — or demanded — while also respecting conventional methods. The recently opened sections

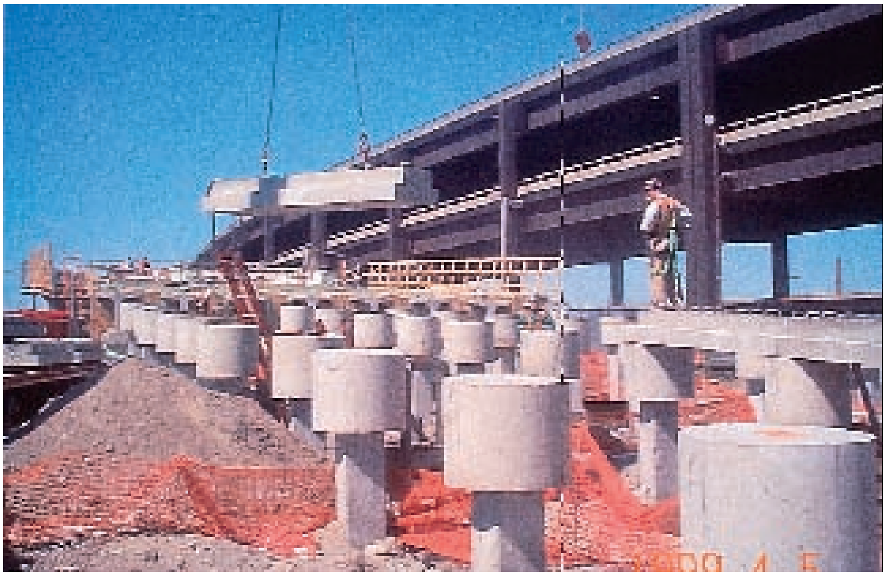

Fig. 13. Slab-on-pile erection.

Fig. 14. Aerial view of Broadway Bridge.

of highway are already improving the transportation efficiency of the people of Boston.

This series of articles, of which this is the concluding paper, owes much to the ingenuity of designers, contractors, and precasters working together to make this massive undertaking a success. The authors wish to once again thank them all.

The authors would also like to thank the PCI JOURNAL editors for publishing this series of articles, as well as the many PCI members for their continued interest and support.

At this time of writing, the Boston Central Artery/Tunnel Project continues to make rapid progress. Approximately 67 percent of construction is now complete.

Table 2. Summary of precast components in some of the interchanges.

Location	Quantity
I-90/I-93 South Bay Interchange	12,000 linear ft (3660 m) of 12-in. (305 mm) piles 51,700 linear ft (15,760 m) of 14-in. (355 mm) piles 47,000 linear ft (14,330 m) of 16-in. (405 mm) piles 594,000 sq ft (55,185 m^2) of segmental box pieces 71,400 sq ft (6630 m^2) of NEBT 130,000 sq ft (12,080 m^2) of box beams 98,900 sq ft (9190 m^2) of curtain walls 43,900 sq ft (4080 m^2) of slab on piles
Massachusetts Avenue Interchange	125,900 linear ft (38,375 m) of AASHTO-PCI girders 5600 sq ft (520 m^2) of box beams 67,700 sq ft (6290 m^2) of curtain walls
I-90 Logan Airport Interchange	13,100 linear ft (3990 m) of 12-in. (305 mm) piles 64,400 linear ft (19,630 m) of 16-in. (405 mm) piles 25,000 sq ft (2230 m^2) of precast slabs 140 precast caps 28,400 sq ft (2640 m^2) of curtain walls 42,200 sq ft (3920 m^2) of segmental concrete box pieces
Leonard B. Zakim Bunker Hill Bridge	104,400 sq ft (9700 m^2) of precast slabs
I-93 Interchange	7000 linear ft (2130 m) of 16-in. (405 mm) piles 11,700 sq ft (1090 m^2) of box beams 503,600 sq ft (46,785 m^2) of segmental boxes 12,800 sq ft (1190 m^2) of slab on piles 17,500 sq ft (1625 square m) of curtain walls