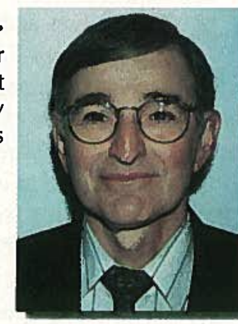
PART 1

Central Artery/Tunnel Project: A Precast Bonanza

by

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

Anthony L. Ricci, P.E.
Chief Bridge Engineer
Central Artery/Tunnel Project
Massachusetts Turnpike Authority
Boston, Massachusetts



This article provides an overview of the monumental efforts of Massachusetts transportation officials, their engineering consultants, and multitudes of construction industry professionals to ease congestion, improve motorist safety, and address issues of environmental quality in the heart of Boston, Massachusetts. The Central Artery/Tunnel Project is the largest highway construction job ever undertaken in the United States, involving many diverse types of precast concrete construction.

A major transportation infrastructure undertaking, billed as "The Big Dig," is transforming traffic operations in and around Boston, Massachusetts. This $13.2 billion project, the biggest and most complex transportation system ever undertaken in the United States, is significant not only in this country, but worldwide. Numerous innovative construction techniques are being used, including:

- Precast tunnels jacked under railroad embankments.
- Deep soil mixing to stabilize land reclaimed from the ocean.
- Precast concrete immersed tube tunnels.
- Standardized designs for precast New England bulb-tee girders and slab-on-pile structures.
- Standardized temporary structures utilizing precast concrete elements.
- Precast segmental box girders integrated into cast-in-place columns to provide seismically resistant connections.
- Precast segmental boxes cut at a skew to connect them on either side of straddle bents.

The project has brought out the best that precast concrete technology has to offer — in many cases utilizing cutting edge techniques — and has been of immeasurable value to New England's precasting industry. Precasters, faced with many complex and daunting challenges, are successfully implementing a range of innovative methodologies to make the Central Artery/Tunnel Project a dream come true.

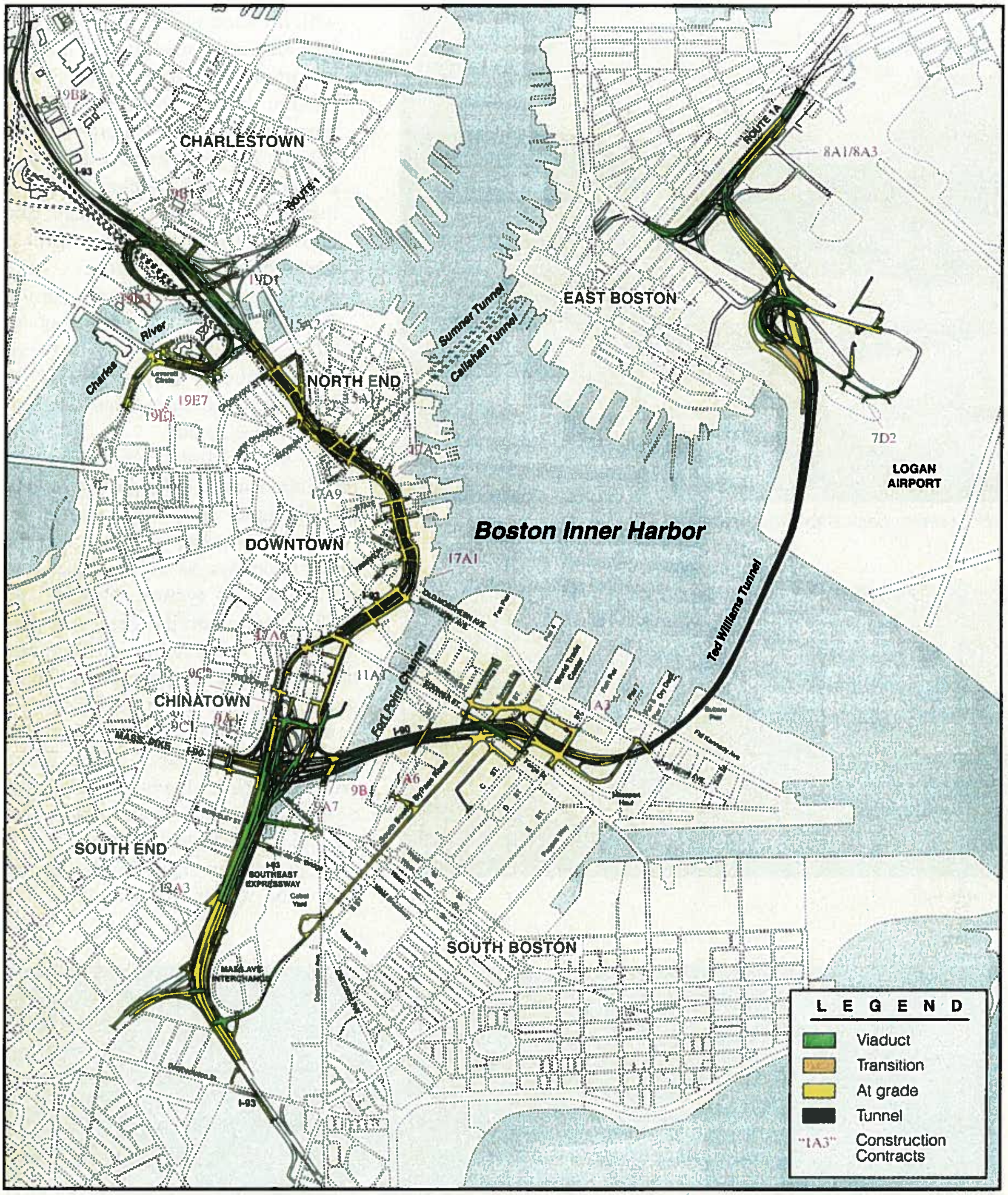


Fig. 1. Central Artery/Tunnel Project, Boston, Massachusetts.

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 Interstate 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 only 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 (7.0 km) segment of the congested Central Artery (Interstate 93) between the Southeast Expressway to the south and Charlestown to the north with a widened eight- to ten-lane underground expressway and a first-of-its-kind asymmetrical, hybrid cable-stayed bridge crossing the Charles River.
- An improved 1.7 mile (2.8 km) direct connection between Leverett Circle and Charlestown with a state-of-the-art bridge over the Charles River.
- A 3.9 mile (6.3 km) extension of the Massachusetts Turnpike (Interstate 90) to Logan International Airport,

Fig. 2. Charles River Crossing deck slab installation.

Fig. 3. Spectacle Island Pier.

which encompasses a new eight-lane, depressed road passing through a commercial district of South Boston; the new four-lane steel immersed tube Ted Williams Tunnel beneath the inner harbor (opened in December 1995); jacked concrete tunnels under railroad tracks; and concrete immersed tube tunnels under the Fort Point Channel.

- A 1.4 mile (2.2 km) South Boston Bypass Road, built in part on an existing railroad right-of-way between the Southeast Expressway/I-93 Frontage Road System and the Seaport Access Road.

The crucial links, which connect these elements, are the project's many interchanges. They move traffic between the interstate roadways and the major highways, as well as connect to the local road system. Most of the multi-level interchanges are being built while maintaining traffic operations on existing interchanges and roadways. Construction within Boston's confined, highly congested corridors poses unique challenges. This is where precast/prestressed concrete is playing a major role in the construction of the Central Artery/Tunnel Project.

Project design began in 1986, utility relocation was initiated in 1991, and

Fig. 4. Broadway Bridge under construction.

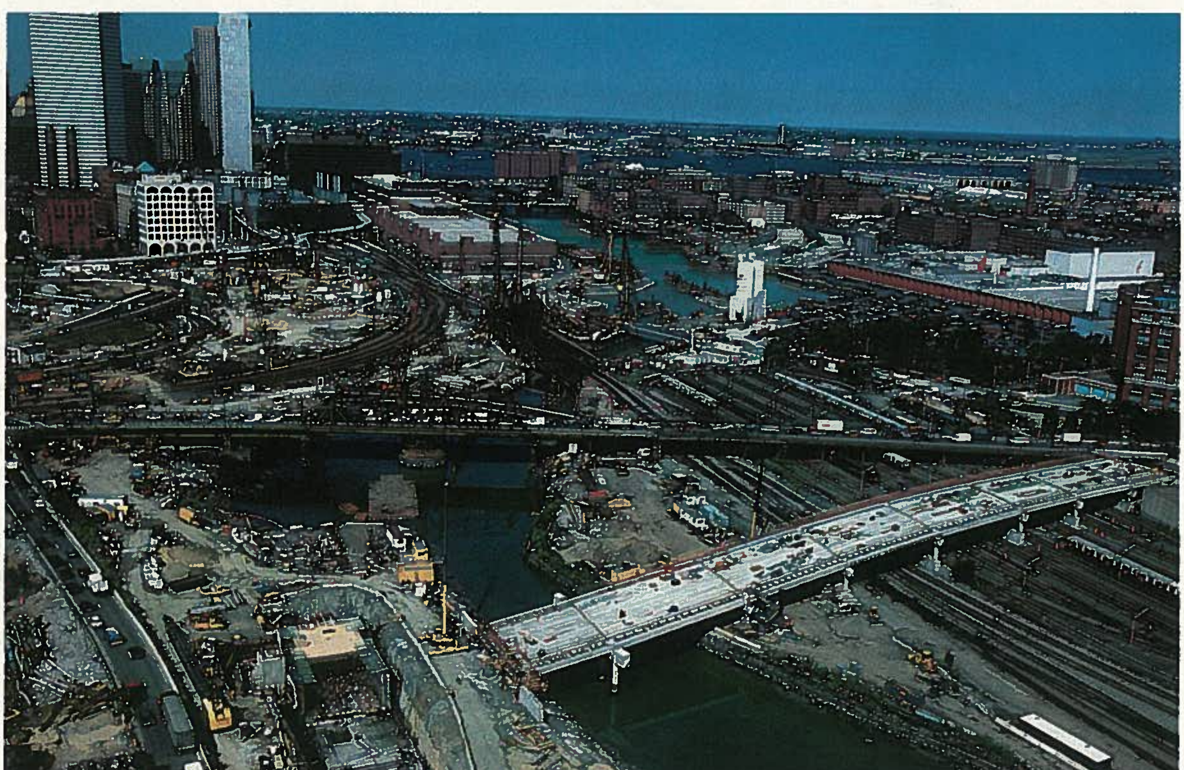


Fig. 5. New England bulb-tee girder installation.

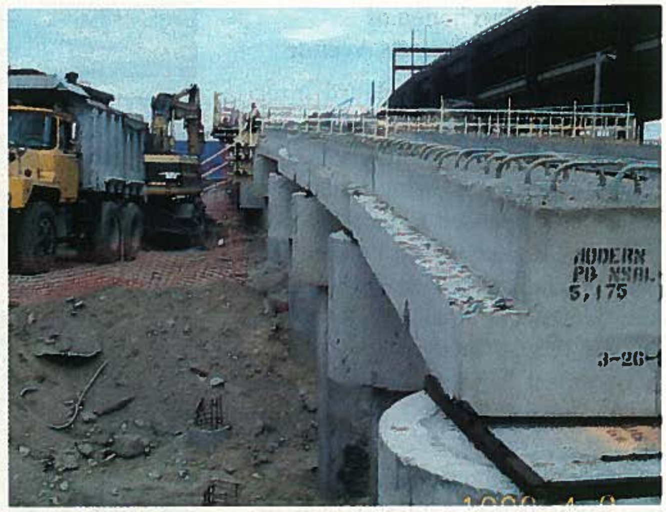


Fig. 6. Slab-on-pile construction.

the first phase (which included the connection from I-93 to Logan International Airport via South Boston and the Ted Williams Tunnel) opened in 1995. The next milestone was the connection of Leverett Circle to Charlestown via the Storrow Drive Bridge over the Charles River, which opened on October 7, 1999. The entire project is scheduled to be completed in 2004.

The Central Artery/Tunnel, the largest highway project in American history located within a metropolis, features:

- One of the most extensive uses of precast segmental concrete bridge construction in one location.
- Widest cable-stayed bridge in the world using a precast decking system.
- First hybrid cable-stayed bridge in the United States.
- First and largest installation of horizontally jacked precast segmented concrete vehicular tunnels in North America.
- Most extensive use of precast segmental concrete immersed tube tunnels in the United States.
- Largest use of the newly developed precast New England bulb tees.
- First adaptation of segmental cutting technology in the world.
- Innovative development of totally precast slab-on-pile structures.

The Big Dig has been instrumental in bringing new techniques and technology to the field of precast concrete construction; however, the project has not forgotten more traditional techniques.

The landmark Charles River cable-stayed bridge has provided a forum for precast technology for the all important deck slabs, which utilize both standard and lightweight concrete (see Fig. 2). Additionally, Spectacle Island, an old landfill utilized to dispose of some of the project's excavated material, is being converted into a public recreational facility. It will be accessible by a totally precast pier utilizing various precast elements such as piles and beams (see Fig. 3). The superstructures of the Dorchester Avenue and Broadway bridges — part of the I-90/I-93 Interchange — are also composed of precast butted boxes (see Fig. 4).

Major strides have also been made to standardize temporary structures (of which there are over $100 million worth) by utilizing precast boxes, precast slabs, and other precast components. This has been a significant step in lowering costs, as has been the design and standardization of precast structures using precast piles, precast New England bulb tees for the transition structure and precast pile caps, precast inverted T-beams and slabs for the slab-on-pile structures (see Figs. 5 and 6).

INTERCHANGE PROJECTS

Two major interchanges built using the latest technology in precast segmental concrete construction form the crucial project links connecting interstate roadways and major highways. These projects are the:

- South Bay Interchange of I-90/I-93/Massachusetts Avenue
- I-93/Route 1 Interchange

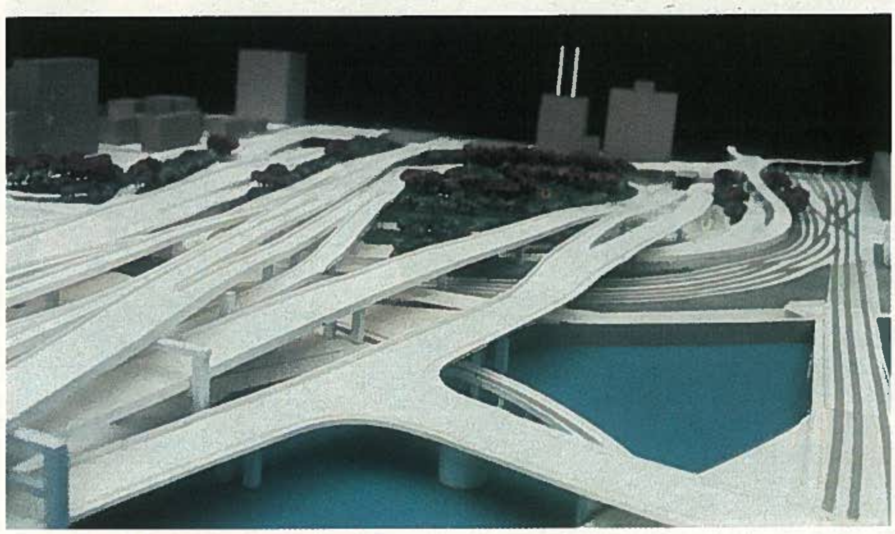


Fig. 7. South Bay Interchange model.

South Bay Interchange of I-90/I-93/Massachusetts Avenue

The existing substandard interchange at the intersection of I-90, I-93 and Massachusetts Avenue, which has limited capacity, is being replaced in stages and expanded to handle a considerably higher traffic volume (see Fig. 7). The massive new multi-level interchange will be all-directional and include the I-90 extension to Logan International Airport through the Fort Point Channel and Ted Williams immersed tube tunnels.

The entire interchange, split into four construction contracts, was designed in both steel trapezoidal and precast segmental concrete box girder alternatives for the viaduct portion. Three of these contracts will be built using precast segmental technology and features precast balanced cantilever and span-by-span construction techniques (see Fig. 8).

The precast segments are being cast in western Massachusetts and transported about 120 miles (193 km) to the site, as needed, and erected. The erection gantry used for the I-93 northbound segment was fabricated in Italy and shipped to Boston. Meanwhile, the existing interchange is being demolished in stages as phases of the new construction are completed.

Many state-of-the-art techniques are being implemented to improve and accelerate construction. Noteworthy features include:

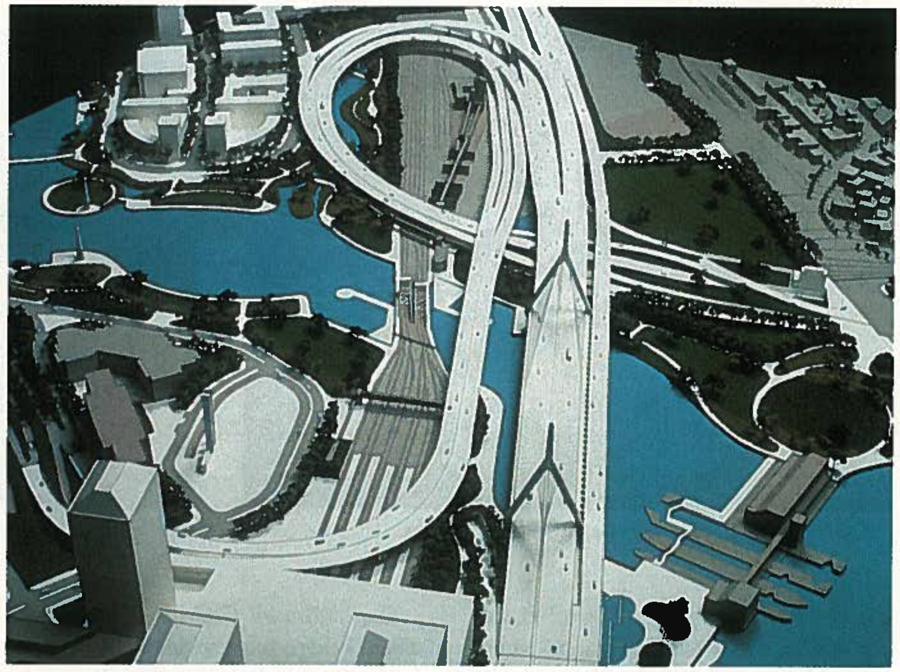


Fig. 9. Overall view of Charles River Crossing.

- Constructing a new four-level interchange while maintaining traffic operations on an existing three-level interchange.
- Supporting viaducts on tunnels in many areas.
- First-time use of concrete segmental box construction in Massachusetts.
- Integrating precast pier segments with cast-in-place piers to achieve seismically resistant connections.
- Precasting and diamond-tipped circular blade cutting pier segments at a skew for integration into pier double column bents.
- Using various erection techniques, including crane, beam and winch, and overhead gantry.

Fig. 8. Segmental concrete construction.

I-93/Route 1 Interchange

The north gateway to Boston through Charlestown begins at the I-93/Route 1 Interchange, which is intertwined with the state-of-the-art Charles River bridge crossings. I-93 dips into the downtown tunnels after crossing the cable-stayed Charles River Bridge from the north. This huge complex interchange, connecting Route 1 with I-93 and Leverett Circle, consists of viaducts, ramps, major bridges and temporary bridges (see Fig. 9). Most of the interchange structures north of the Charles River will be built with precast segmental concrete, using span-by-span and balanced cantilever construction techniques (see Fig. 10).

The precast segments are being cast in an old World War II hangar in Maine and transported to the site daily as needed, due to the scarcity of lay down areas at the site as well as the need to maintain local traffic operations. Two main line and one ramp structure connecting Leverett Circle to I-93 built span-by-span utilizing an overhead gantry, manufactured in Norway (see Fig. 11), are in operation.

Fig. 10. Segmental concrete bridge erection gantry testing.

The gantry will also be used to erect the span-by-span portion of I-93 main line structures. Balanced cantilever construction will be utilized for all the ramps where roadway curvature is too tight for the erection gantry and to minimize impacts to railroad operations. Noteworthy features include:

- A complex multi-level interchange built while maintaining traffic over existing high-level ramps.
- Extremely tight radius of curvature.
- Difficult maintenance of traffic during construction.
- Difficult geotechnical site conditions (the site is on land reclaimed from the ocean).
- Adaptation of span-by-span technology for seismic resistance by utilizing internal post-tensioning for dead loads and external post-tensioning for live loads.

The entire project includes seven buildings that act as a ventilation system, which will be the largest highway tunnel ventilation system in the world.

One of the ventilation buildings features a precast parking structure which serves as a combination vent building/garage. This structure combines functions, as it also will include three upper levels of parking, improvements for a subway rail station and a first level planned for retail and office space.

Because of the unusual site location, some unique elements and methods were used in the parking structure. These included creation of rounded spandrels on one corner to account for an acute intersection angle. Some spandrels measured 11 ft (3.4 m) tall and 30 ft (9.1 m) long, with many faced with brick to help the structure blend with the historic neighborhood. The structure also was erected primarily from one side using a single 300 ton (272 t) crane because of the need to keep open the emergency exit routes from the two subway lines under the structure.

Other applications of precast concrete used on the project include precast finished tunnel wall panels for the full length of the new depressed highway and precast decking on the first hybrid cable-stayed bridge in the United States.

CONCLUDING REMARKS

Boston, at the forefront of the American Revolution over two centuries ago, is now leading another revolution — the development and implementation of new construction technologies in the United States. Precast concrete technology is playing a vital role in this effort.

Whether it is a tunnel jacked under a railroad, an immersed tube tunnel, a segmental concrete bridge, or numerous temporary structures, the Central Artery/Tunnel Project is being built under extremely difficult conditions while maintaining traffic flow through one of America's premier cities. This is in large part due to a direct partnering approach between the project personnel and contractors utilizing many innovative and state-of-the-art construction methods.

Fig. 11. Segmental concrete bridge erection.

ACKNOWLEDGMENTS

Since the Central Artery/Tunnel Project is huge and split into many contracts, it is difficult to mention each organization that has contributed to its success. However, we would like to thank the many final designers and contractors whose efforts are immensely appreciated. They will also be given due credit in subsequent articles highlighting this project.

CREDITS

Owner: Massachusetts Turnpike Authority, Boston, Massachusetts

Oversight: Federal Highway Administration, Washington, D. C.

Managing Consultant: Bechtel/Parsons Brinckerhoff, New York, New York

Precast Concrete Manufacturers:

- I-93 Southbound: Unistress Corporation, Pittsfield, Massachusetts (precast segments); Northeast Concrete Products, Plainville, Massachusetts (other elements)
- I-93 Northbound: Unistress Corporation, Pittsfield, Massachusetts (precast segments); Northeast Concrete Products, Plainville, Massachusetts (other elements)
- I-93/Route 1: Sanford Precast, Sanford, Maine (precast segments); Northeast Concrete Products, Plainville, Massachusetts (other elements)
- Broadway Bridge: Northeast Concrete Products, Plainville, Massachusetts
- Dorchester Avenue Bridge: Northeast Concrete Products, Plainville, Massachusetts
- Spectacle Island Pier: Northeast Concrete Products, Plainville, Massachusetts (piles); Unistress Corporation, Pittsfield, Massachusetts (double tee beams)
- Summer Street Bridge: Northeast Concrete Products, Plainville, Massachusetts
- Parcel 7 Parking Structure: J. P. Carrara & Sons, Inc., Middlebury, Vermont
- Leverett Circle Connector: Northeast Concrete Products, Plainville, Massachusetts
- Temporary Structures: Oldcastle Precast, Inc., Bethlehem, New York (decking); Rotondo Precast, Rehath, Massachusetts (decking); Precast Structures, Inc., Auburn, Maine
- Precast Finished Tunnel Wall Panels: Wm. E. Dailey, Inc., Shaftsbury, Vermont