Underground Engineering for the Central Artery/Tunnel Project

Even though most of this monumental project will be built below ground, it will also require the integration of a wide range of engineering disciplines.

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This special focus issue of *Civil Engineering Practice* centers on geotechnical engineering and construction planning for the Central Artery/Tunnel (CA/T) Project, the largest transportation project currently underway in the United States. The CA/T Project is also one of the most challenging projects ever undertaken since it makes use of virtually every conceivable type of analysis, design and construction method. Even small parts of the project – such as ventilation buildings – are themselves enormously complicated, with subway interfaces, design of deep ducts, multiple building uses and other complications. Not only are the technical challenges daunting, but the project also winds its way through the heart of downtown Boston, a city well known for its exuberant, often contentious politics – making it a hot issue for many people.

In this issue of *Civil Engineering Practice*, the articles presented focus on some aspects of underground engineering for the project. These articles cover such topics as:

- The geotechnical instrumentation program for the project;
- Protecting historic buildings near the construction;
- Design and construction of a circular cofferdam used in the construction of the project's harbor tunnel;
- Full-scale tiedown test program for the project;
- Design and construction of deep stone columns in marine clay; and,
- Using trenchless technology for sewer/utility construction;

In keeping with the size of this historic project, it is planned that future issues of *Civil*

Engineering Practice will include presentations on additional features of the underground analysis and design, as well as papers describing other aspects of the work.

Project Description

The highway system in the Boston metropolitan area is characterized by two major circumferential highways (Interstate-495, Interstate-95/Route 128) and two major highways (Interstate-90 which runs east-west, Interstate-93 which runs north-south) leading into and through the core city itself. Since Boston's location is on the shoreline, the circumferential highways are in essence only semi-circles, and heavy traffic is funnelled through the present Central Artery. This situation is aggravated by the highway access to the airport, which is mostly through the two existing cross-harbor tunnels, and also requires use of the Central Artery. The Central Artery was built in the 1950s as an elevated structure intended to provide commuter access to downtown Boston. For this reason, the structure literally winds its way through Boston, and numerous access ramps follow each other at short intervals.

The existing six-lane highway was initially planned for 75,000 vehicles/day. However, it currently carries 187,000 vehicles/day, with significant delays. Traffic is projected to increase to 244,000 vehicles/day by 2010 with even greater congestion if no improvements are made. This congestion, and the need to repair the existing structure, led to the present CA/T Project, which includes (see Figure 1):

- A new eight- to ten-lane cut-and-cover tunnel to be constructed beneath the existing viaduct while maintaining traffic above;
- A new cross-harbor tunnel connecting the existing Southeast Expressway and Massachusetts Turnpike (I-90) to Logan Airport and East Boston;
- Several new and reconstructed highway interchanges;
- Many complex tunnel ventilation buildings;
- A new long-span bridge across the Charles River;
- Sophisticated "smart highway" control systems; and,
- Environmental and urban design improvements for the Boston area such as new parks, upgraded mass transit and provisions for air rights buildings above the new tunnels.

Geotechnical Engineering Overview

The project has necessitated an extensive subsurface exploration program that began in 1986 with the collection of existing subsurface data from various sources. These data were then integrated with the overall project planning for the highway alignment and structure placement. From that time on, both geotechnical and subsurface environmental issues were evaluated concurrently. During 1987 and 1988, an initial exploration program of borings and test pits was carried out by the project's Management Consultant (MC) in order to begin assessment of potential site-specific problems along the alignment, and to better define subsurface geologic boundaries. The MC was engaged by the Massachusetts Highway Department (MHD) and has responsibility for carrying out the preliminary design (PD), for managing the final design (FD) effort which is prepared by section designers and for managing the construction.

During this same period, planning was advanced for management of the final design phase of the project. The project was divided into five geographic areas:

- East Boston and Third Harbor Tunnel
- South Bay Interchange
- Central Area – South
- Central Area – North
- Area North of Causeway (ANOC)

An Area Geotechnical Consultant (AGC) was selected (qualifications-based) for each area. The AGCs then worked with the MC while exploration and test programs were carried out for the PD. These efforts resulted in a Geotechnical Data Report (GDR) and a Geotechnical Engineering Report (GER) for each of the design contracts in an AGC's area. These reports were furnished to the Section Design Consultants (SDC) who were also qualifications-selected and were responsible for carrying out the final design and producing bid documents, In

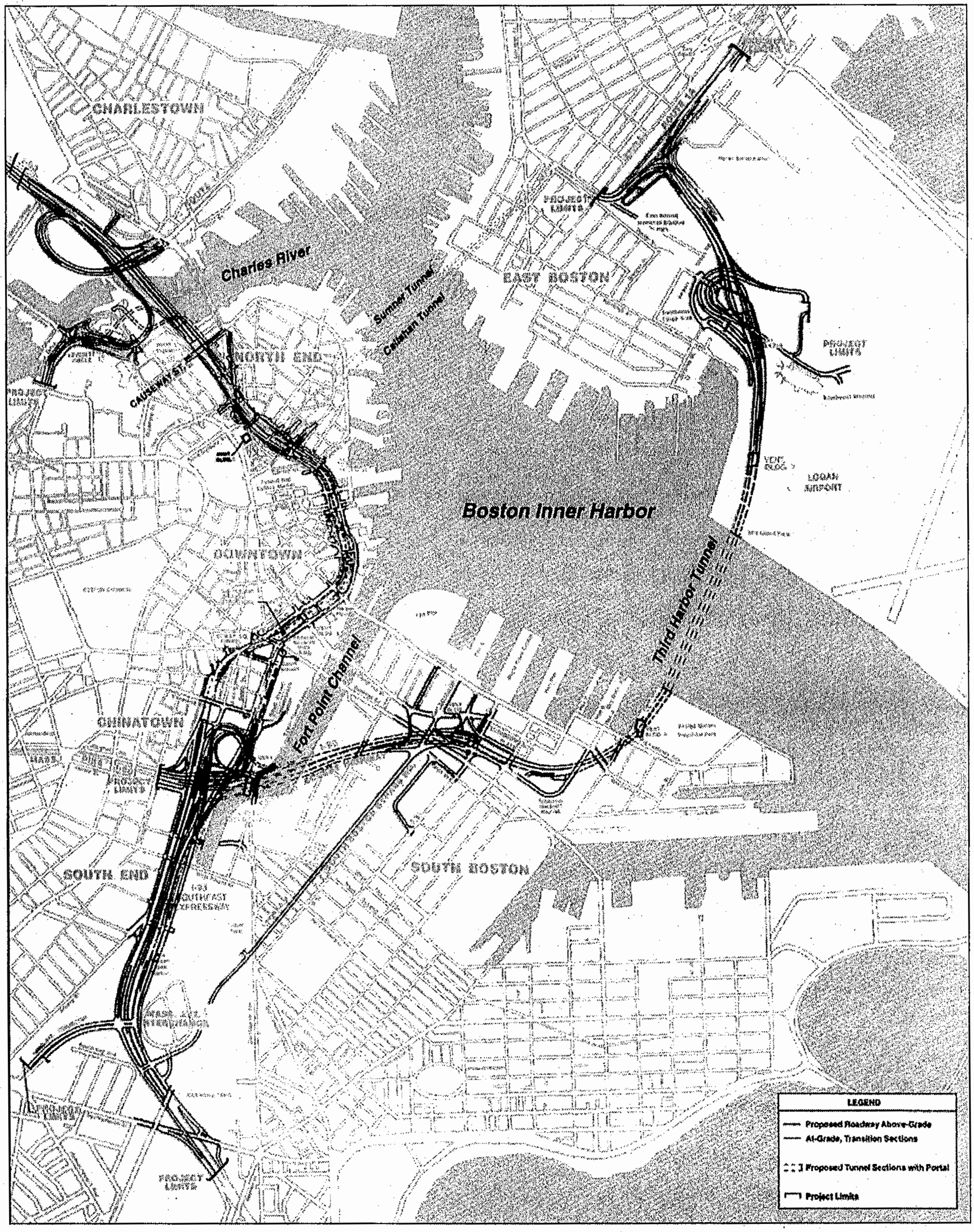

FIGURE 1. Plan of the Central Artery/Tunnel Project.

many cases, the SDCs had geotechnical subconsultants on their teams, and had the option of asking for additional subsurface data, if they deemed it necessary.

To date, the AGC and SDC groups have completed over 4,000 borings and hundreds of test pits. The boring data, as well as selected test data, have been entered into a computerized database management system and its use has been integrated with project design elements and the instrumentation data management system.

The project has provided the opportunity to generate a wealth of data on the Boston underground, as well as to participate in some innovative testing programs. For example, the following three technical areas justified special test programs to evaluate cost-effective alternatives to solving specific local problems:

- Tension Element Test Program
- Caisson Load Test Program
- Soil Stabilization Test Program

Each of these technical areas was a significant issue in one or more of the project areas, and a cost-effective design was deemed important enough to justify a special test program to help contribute to an optimum design/construction scenario.

The data gathered by subsurface exploration efforts have helped support detailed analyses for CA/T structures. Tunnels — both immersed tube and cut-and-cover — were the subject of complex soil-structure interaction analyses that sought, again, to optimize the design and construction process.

Underground urban construction is expensive under the best conditions. However, Boston's old and complex infrastructure, coupled with its less-than-ideal geological/geotechnical setting, demanded a creative and realistic approach to the project. It was critical to minimize the soil deformations and resulting adjacent facility movements. In addition, since the existing elevated artery and associated surface streets must remain operational throughout construction (through the year 2004), traffic studies provided important input to the planning, design and construction sequences.

The Importance of Construction Effects Mitigation

A crucial part of the project is construction mitigation. Due to the project's location and size — as well as the sociological, historic and political impacts — it has been paramount throughout the project to ensure that construction effects are mitigated to the greatest extent possible as it proceeds. In historic Boston, with numerous existing buildings, utilities and other (old and new) facilities, this in no easy task. Supporting the construction management effort is an elaborate program of geotechnical instrumentation (surface and subsurface) that utilizes thousands of field-installed instruments ranging from inexpensive surface settlement monitoring points to expensive and complex vibration monitoring devices. The data from these instruments provide a record of the effects of the construction process, a means to actually "control" the construction process in sensitive areas, and an early warming system to alert both construction contractors and the MC to respond to situations that are developing that may be at variance with design predictions.

Though much of the project will be built below ground, with all of the risks and unknowns of underground construction, the constituent engineering and scientific disciplines are being effectively integrated and coordinated — ranging from the standard civil, structural, mechanical and electrical, through environmental systems and traffic operations, and insurance and risk management. It is truly a team effort on a "mega" scale.

In summary, we are proud of our work and the work of our colleagues who are participating on this massive project. We hope you find this special Journal issue informative and interesting.

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