



# Engineering Ethics: The Big Dig Tunnel Ceiling Collapse

An Online Continuing Education Course for Engineers

**Course Number: ET-1036**

**Credit: 1 Hour / 1 PDH / 1 CPD**

# Engineering Ethics: The Big Dig Tunnel Ceiling Collapse

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## Prologue

“About 11:01 p.m. eastern daylight time on Monday, July 10, 2006, a 1991 Buick passenger car occupied by a 46-year-old driver and his 38-year-old wife was traveling eastbound in the Interstate 90 connector tunnel in Boston, Massachusetts, en route to Logan International Airport.

As the car approached the end of the Interstate 90 connector tunnel, a section of the tunnel’s suspended concrete ceiling became detached from the tunnel roof and fell onto the vehicle. Concrete panels from the ceiling crushed the right side of the vehicle roof as the car came to rest against the north wall of the tunnel. A total of about 26 tons of concrete and associated suspension hardware fell onto the vehicle and the roadway. The driver’s wife, occupying the right-front seat, was fatally injured; the driver was able to escape with minor injuries.”<sup>i</sup>

## Introduction

The family of the victim killed in the Big Dig ceiling collapse eventually received a total settlement of \$28 million. Of that, \$18 million came from 15 defendants. Bechtel/Parsons Brinckerhoff (B/PB), Modern Continental Co. (Modern), Gannett Fleming Inc. (Gannett) and the Massachusetts Turnpike Authority (MTA) were the main defendants in the 15 party lawsuit. The family also received \$6 million from Power Fasteners (Powers) and \$4 million from Newman Associates, the bolt distributor.<sup>ii</sup>

Criminal charges were also pursued against several of the entities. To avoid the criminal charges, B/PB and several other companies paid \$458 million to the State of Massachusetts.<sup>iii</sup> The manslaughter charge against Powers was dropped after it agreed to pay \$16 million to the city and state.<sup>iv</sup>

The National Transportation Safety Board investigated the incident and released its results in the report, *Ceiling Collapse in the Interstate 90 Connector Tunnel, Boston, Massachusetts, July 10, 2006*. Some key findings from the document were<sup>v</sup>:

1. The wrong epoxy formulation was used for the adhesive anchors. Over time the ceiling support anchors pulled free and a portion of the ceiling collapsed.
2. The project management and section design companies failed to identify the risks in the use of the adhesive and account for potential anchor creep in the design, specifications, and approval process for the epoxy anchors used in the tunnel.

3. The construction industry had a poor understanding of epoxy formulation and creep in adhesive anchoring systems.
4. The epoxy manufacturer failed to provide the project with sufficiently complete, accurate, and detailed information about the suitability of its product for sustaining long-term tensile loads.
5. The project Management Company, epoxy manufacturer, and Construction Company didn't properly identify the cause of anchor creep in other portions of the project.
6. The project management and construction companies failed to monitor anchor performance after earlier discovering anchor creep problems in other portions of the project.
7. The Massachusetts Turnpike Authority failed to implement a timely tunnel inspection program that would likely have revealed the ongoing anchor creep in time to correct the deficiencies before an accident occurred.

### **Course Objectives**

This course will draw from the NTSB report and other sources to familiarize the reader with the errors that led to the collapse. The course will discuss the roles and responsibilities of the engineers involved in the accident as they relate to public safety, structural design and project management.

### **ASCE Code of Ethics, Canon 1:**

Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties.

- a. Engineers shall recognize that the lives, safety, health and welfare of the general public are dependent upon engineering judgments, decisions and practices incorporated into structures, machines, products, processes and devices.
- b. Engineers shall approve or seal only those design documents, reviewed or prepared by them, which are determined to be safe for public health and welfare in conformity with accepted engineering standards.



The car is barely visible under the wreckage of the collapsed ceiling. *Source: Massachusetts State Police via NTSB.*

### **The Central Artery/Tunnel Project (Big Dig)**

The Central Artery expressway opened in Boston in 1959. It effectively split the city in two and disrupted cross-town traffic. It was designed to carry 75,000 cars per day, but eventually carried 200,000 cars a day, resulting in massive traffic congestion.<sup>vi</sup> The Central Artery/Tunnel Project (CA/T), known as the Big Dig, was a 14-year construction project initiated to relieve the city's massive transportation problems.

The objectives of the Big Dig were:

- To replace the elevated Central Artery with an underground expressway,
- Replace the existing bridge over the Charles River at the northern end of the project with two new bridges,
- Extend the Massachusetts Turnpike (I-90) from its former terminus south of downtown Boston. The extension provided access to Logan Airport via the Ted Williams Tunnel (TWT), which carried traffic under South Boston and the Boston Harbor.
- Construct an interchange for Interstates 90 and 93.

The project was initiated in 1991 and the roadways were constructed and opened in phases. The entire system was opened to traffic in 2003 and completed in 2006. The new system was designed to handle 245,000 vehicles per day.

The Big Dig generated considerable controversy. Construction ran five years behind schedule and cost billions more than projected. While initially projected to cost \$2.6 billion<sup>vii</sup>, it was completed at an actual cost estimated to be in excess of \$14.6 billion<sup>viii</sup> to \$24 billion<sup>ix</sup>.

The project was owned, managed, and operated by the Massachusetts Transportation Authority (MTA). The MTA hired B/PB, a joint venture formed between Bechtel Corporation and Parsons Brinckerhoff Quade & Douglas, as the project manager. B/PB was contracted to provide the following services<sup>x</sup>:

- Preliminary design
- Final design coordination and review
- Construction coordination and monitoring by inspectors and resident engineers
- Cost estimate preparation and actual cost reporting to project owners
- Right of way and other property acquisition
- Computer-aided design record-keeping
- Utility engineering and coordination
- Internal quality assurance
- Construction safety programs
- Construction contract administration as owners' authorized representative
- Standard drawings for the program
- Geotechnical engineering services
- Environmental services
- Engineering materials testing

As segments were completed, more management responsibility was handed over to the MTA.

In 1997, an agreement was entered into whereby key personnel of B/PB, the MTA, and MassHighway would work together as an “integrated project organization.” Under this structure, the staffs worked as a single organization under the direction of the MTA, which had authority to act on any matter relating to the management and administration of the CA/T project. The stated goal of the change in management structure was to streamline project management and improve cost effectiveness.”<sup>xi</sup>

### **The D Street Portal and the Central Artery/Tunnel Project<sup>xii</sup>**

The collapse occurred in the D Street portal, a 200-foot-long section of the I-90 connector tunnel. The site was just west of the TWT, which directs I-90 traffic to Boston's Logan Airport.

Three tunnels are contained in the portal: a two-lane westbound tunnel, a two-lane eastbound tunnel, and a one-lane eastbound high occupancy vehicle (HOV) lane tunnel. The collapse was in the two-lane eastbound tunnel.

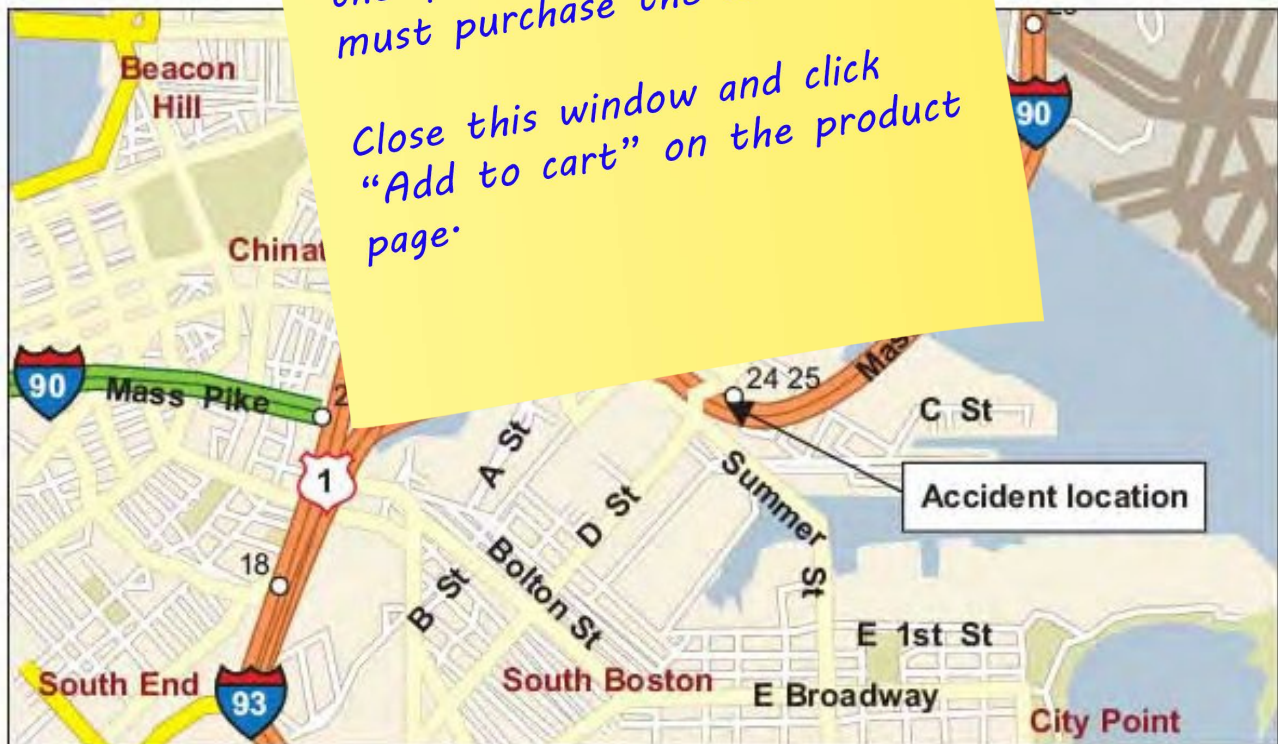
The portal was constructed in 1993, in one of the first stages of the Central Artery/Tunnel Project (CA/T) construction sequence, and was opened to traffic in phases. The section containing the accident site was opened on December 14, 2000. All bores of the portal were finally opened when the entire connector tunnel opened in January 2005.

The early construction of the portal permitted the construction of a temporary aboveground ramp to direct traffic from D Street to the TWT. This allowed Boston traffic to access the airport via the tunnel underneath Boston Harbor before the entire I-90 connector was complete. A parking deck was to be constructed above the portal, so a heavily reinforced concrete of five to seven feet thick was used for the tunnel roof.

The west tunnel approach was a cut-and-cover tunnel, a design by HDR engineering and construction management by Kiewit/Perini/Atkins.

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Location of accident site. (Source: NTSB.)