UPDATE: NTSB INVESTIGATION INTO BOSTON I-90 TUNNEL ACCIDENT

The National Transportation Safety Board continues investigating the circumstances of the July 10th ceiling collapse of the Interstate 90 (I-90) connector tunnel in Boston, Massachusetts. A portion of the ceiling located in the tunnel's east portal became detached from the roof of the tunnel and collapsed onto a passing automobile, killing the passenger and injuring the driver.

The NTSB investigation remains focused on those issues surrounding the failure of the epoxy anchors in this section of the tunnel. Other agencies, including the Massachusetts Attorney General's Office, the Department of Justice United States Attorney's Office and the Department of Transportation's Office of the Inspector General are also conducting investigations.

The NTSB's investigation has branched into two primary areas of interest. The first deals with the engineering aspects of the suspended ceiling. Here, investigators are looking at such things as how the use of this particular ceiling design evolved, as well as how it was installed and what quality control programs were used during construction. The other aspect of the Board's investigation is concentrating on those issues associated with construction management and oversight of the ceiling system.

Engineering Issues

Evolution of the Ceiling Design:

The various firms associated with the design and evolution of the ceiling system as used in the connector tunnel have been identified thus far as: 1) Bechtel/Parsons Brinckerhoff (BPB), 2) Gannett Fleming, 3) HDR Engineering Inc. and 4) Howard/Needles/Tammen/Bergendoff (HNTB). To date, we have conducted general interviews with two of these firms, and additional meetings are scheduled to take place in November. The progression of the ceiling design appears to be related to the construction sequence of the tunnel project. The sequence of construction related to our investigation involves three projects. The first project was the section of I-90 connector tunnel where the accident occurred. This segment is about 250 long and is referred to in our investigation as the D-Street portal. The second project was the Ted Williams tunnel which is the submerged tunnel connecting downtown Boston to Logan airport. The third project was the remainder of the I-90 connector tunnel, which essentially attaches to the west side of the D-Street portal and continues in a westerly direction to Interstate 93 (I-93) near downtown Boston. The D-Street portal was the first segment to be constructed. This was done to allow street access for the businesses located above the tunnel and to provide a temporary ramp for traffic access to the airport once the Ted Williams tunnel was completed. Initially, the

D-Street portal was left unfinished (i.e. no ceiling system) and completion of the interior components was scheduled to take place when the remainder of the I-90 connector tunnel was finished out. At that time the plan was to use a common ceiling system in each of the three projects. This ceiling system utilized laminated panels consisting of metal sheets with a porcelain coating and was used in the Ted Williams Tunnel. Because this type of system is considered to be "light weight", it was installed exclusively with epoxy hangers. However, the installation of this type of ceiling system was found to be not only labor intensive but also expensive to install and maintain. This prompted consideration of another more "cost effective" ceiling system and attention was given to another type of suspended ceiling that was being installed in the I-93 tunnel (also a part of the Big Dig). Within the I-93 tunnel, pre-cast concrete panels were assembled into modules, which were subsequently affixed, to the steel girders that comprised the roof of the tunnel. This system allowed for a cost-effective ceiling that was easy to manufacture and install. However, the weight of this ceiling system was substantially more than the one installed in the Ted Williams tunnel. To compensate for the increased weight, the third portion of the project (the remainder of the I-90 connector tunnel) was constructed with steel uni-channels cast into the concrete roof of the tunnel. These uni-channels allowed for a more traditional "nut and bolt" assembly to secure the ceiling system to the roof of the tunnel. However, because the D-Street portal had been constructed without uni-channels, a decision was made to install the ceiling using epoxy anchors similar to those in the Ted Williams tunnel.

<u>Ceiling Module Redundancy:</u>

The Management Consultant directed the Design Consultant to use a "one hanger out" design per Design Policy Memorandum No. 107 dated March 13, 1997. A "one hanger out" design refers to a scenario in which each modular ceiling unit is designed for a failure mode wherein the failure of any one support hanger assembly will not result in the collapse of that modular unit. A "one hanger out" design provides little or no redundancy and the hangers are the only structural members supporting the ceiling system (the system relies solely on loads in tension). No redundancy was built into the ceiling design in the event the hangers failed. The NTSB has researched other tunnels throughout the country and has found that significant redundancy is built into the ceiling design so that in the event of hanger failures, the panels are self-supported. The FHWA is developing a computer model of the ceiling to be used in a finite element analysis of various load scenarios. With NTSB direction, assessments will be made in regard to the number and locations of hanger failures that would result in the failure and subsequent collapse of a ceiling module.

Anchor Proof Testing:

A testing procedure had been developed to provide a quality control aspect and integrity check of the epoxy anchors. Through this process, once each anchor had been installed it was reportedly tested for pullout strength. ConAm Testing has been identified as the company used to conduct these tests. Investigators have interviewed one of the ConAm personnel who performed these tests. Based on the interview, the tester's description of the testing procedure differs from what has been found in the construction contract. The interview also revealed that on occasion, some pullout tests were conducted after the ceiling modules had been installed. To accomplish this, the already connected support hanger had to be removed, which would have resulted in an increase in the load distribution to the remaining hangers supporting the module. Investigators are currently evaluating whether the proof loads used in the tests were adequate.

Ceiling Module Installation:

Modern Continental Construction (MCC) has been identified as the contractor responsible for the installation of the epoxy anchors and they also performed the installation of the ceiling modules. The FBI and State Police have interviewed a number of workers who, at the time were employed by MCC and involved in various aspects of the installation. NTSB investigators have reviewed these interviews and have noted potential problems in the procedures used during installation. To get a better understanding of these installation details, NTSB investigators are scheduling follow-up interviews with workers.

Materials Lab Testing:

Core samples have been taken from the roof in the westbound tunnel, away the accident location (the accident was in the eastbound tunnel). The examination and documentation of these initial core samples has been completed. Additional core samples from other areas within the tunnel, including samples from the accident location, have been sought, but are awaiting an analysis of the safety implications of their removal.

There have been two types of examinations of the twenty anchor holes where the collapse occurred. Initially, an optical bore scope examination was performed. This was followed by a more sophisticated laser scanning which generated digital images of the interior condition of the anchor holes.

The downward displacement of all of the anchors in the east, and westbound tunnels, as well as the HOV tunnel has been documented. All of the tunnels had a substantial number of displaced anchors, and some of the anchors in the westbound tunnel had extreme displacement (greater than 1 inch).

Under NTSB direction, the FHWA has installed fixtures to perform sustained load (aka creep) tests of the epoxy anchors in the westbound tunnel (this tunnel remains closed to traffic). The initial testing was comprised of six anchors and utilized a range of loads.

Under NTSB direction and with the cooperation of the FHWA, a test plan has been developed for the installation of new anchors in a test slab. This will allow for a comparison of properly installed anchors to anchors that have been intentionally installed with voids in the epoxy and other defect conditions. The test slab has been poured and an initial set of anchors should be installed within the next week.

A series of tests have been completed to observe the circumstances leading to the formation of voids in simulated core drilled holes. In these tests, clear acrylic cylinders having the same inside dimensions as the anchor holes were filled with a caulk compound. Threaded nylon rods were then inserted into each cylinder. During the process, various techniques were employed that altered not only how the caulk was injected but also how the rods were inserted.

We are still working to determine the type of epoxy used in the ceiling. A chemical analysis has been performed on epoxy taken from the failure area. Results from this analysis have been compared with analyses of the fast set and standard set epoxies produced by the manufacturer.

In some instances, epoxy samples taken from locations outside of the accident area have exhibited a dark brown discoloration. An analysis has been performed of the darker brown epoxy material.

The NTSB has solicited the National Institute of Standards and Technology (NIST) to perform visco-elastic characterization of the epoxy materials, which would help us to understand the long-term creep behavior of the material

Construction Management and Oversight:

The state hired Bechtel/Parsons Brinckerhoff (BPB) to be the program manager. NTSB investigators are still researching the relationship between the state, FHWA and BPB's roll as program manager.

In regard to the construction projects associated with the ceiling collapse the contract required a Quality Assurance Program. Through this program, each contractor involved with the project was required to develop a Quality Control Program and submit it to the program manager for approval. NTSB investigators are researching the specifics of any such programs for the ceiling installation.

NTSB investigators have not found any records indicating that tunnel inspections were done of the ceiling system from the time it was opened to traffic (January 18, 2003) to the day of the collapse. We are researching AASHTO and FHWA guidelines on tunnel construction and to see if there are any required inspection schedules. The required inspection schedule for bridges is typically every two years.