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SAFETY BOARD DETERMINES CAUSE OF BOSTON'S BIG DIG TUNNEL CEILING COLLAPSE LAST YEAR

Washington, DC -- The National Transportation Safety Board today determined that the probable cause of the ceiling collapse in the D Street portal of Interstate 90 connector tunnel in Boston, Massachusetts, was inappropriate use of an epoxy anchor adhesive. Over time, the epoxy deformed and fractured until several ceiling support anchors pulled free and allowed a portion of the ceiling to collapse.

Epoxy is a polymer and its stiffness is time and temperature dependent. If a load is applied suddenly, the epoxy responds like a hard solid. But if the load is then held constant, the molecules within the polymer may begin to rearrange and slide past one another, causing the epoxy to gradually deform in a process called creep. The epoxy used in the tunnel had poor creep resistance.

"This has been a multi-faceted and complicated investigation for the Safety Board. We expended many of our resources to find out what happened and to prevent similar accidents," said NTSB Chairman Mark V. Rosenker. "It is very clear that had this accident occurred at a different time of day it would have been more catastrophic, although one fatality is one too many."

On July 10, 2006, a passenger car was traveling eastbound in the D Street portal of the Interstate 90 (I-90) connector tunnel in Boston, Massachusetts, en route to Logan International Airport. As the car approached the end of the I-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. The passenger was fatally injured and the driver had minor injuries. A total of about 26 tons of concrete and associated suspension hardware fell onto the vehicle and the roadway.

The Board states in its probable cause that the use of an inappropriate epoxy formulation resulted from the failure of Gannett Fleming, Inc., (Gannett Fleming) and Bechtel/Parsons Brinckerhoff (B/BP) to identify potential creep in the anchor adhesive as a critical long-term failure mode and to account for possible anchor creep in the design, specifications, and approval process for the epoxy anchors used in the tunnel. The Board also notes that had Gannett Fleming specified the use of adhesive anchors with adequate creep resistance in the construction contract, a different anchor adhesive could have been chosen, and the accident might have been prevented.

The use of an inappropriate epoxy formulation also resulted from a general lack of understanding and knowledge in the construction community about creep in adhesive anchoring systems. The Board notes that those responsible for overseeing the Central Artery/Tunnel project (CA/T), in design and specifications for the tunnel's ceiling, failed to account for the fact that polymer adhesives are susceptible to deformation (creep) under sustained load. In addition, Powers Fasteners, Inc., (Powers) failed to provide the CA/T project with sufficiently complete, accurate and detailed information about the suitability of the company's Fast Set epoxy for sustaining long-term tensile loads.

Contributing to the accident was the failure of Powers to determine that the anchor displacement that was found in the high-occupancy vehicle tunnel in 1999 was a result of anchor creep due to the use of the company's Fast Set epoxy, which was known by the company to have poor long-term load characteristics. The information that was provided by Powers regarding its Power-Fast epoxy was inadequate and misleading. This resulted in Modern Continental Company (Modern Continental) using the Fast Set formulation of the epoxy for the adhesive anchors in the tunnel even though that formulation had been shown through testing to be subject to creep under sustained tension loading, the Board found.

Also contributing to the accident was the failure of Modern Continental and B/PB, subsequent to the 1999 anchor displacement, to continue to monitor anchor performance in light of the uncertainty as to the cause of the failures. The Massachusetts Highway Department (Masshighway), B/PB, and Modern Continental should have instituted a program to monitor anchor performance to ensure that the actions taken in response to the displacement were effective. Had these organizations taken such action, they likely would have found that anchor creep was occurring, and they might have taken measures that would have prevented this accident.

The Massachusetts Turnpike Authority (MTA) also contributed to the accident by failing 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. The Board concluded that had MTA, at regular intervals, inspected the area above the suspended ceilings in the D Street portal tunnels, the anchor creep that led to this accident would likely have been detected, and action could have been taken that would have prevented this accident.

As a result of its investigation the Safety Board made Safety Recommendations to the Federal Highway Administration, American Association of State Highway and Transportation Officials, Departments of Transportation of the 50 States and the District of Columbia, International Code Council, ICC Evaluation Service, Inc., Powers Fasteners, Inc., Sika Chemical Corporation, American Concrete Institute, American Society of Civil Engineers, and Associated General Contractors of America. These 20 recommendations include:

- Developing standards and protocols for the testing of adhesive anchors to be used in sustained tensile-load overhead highway applications. These standards and protocols should consider site-specific ultimate strength values as well as the creep characteristics of the adhesive over the expected life of the structure;
- Prohibiting the use of adhesive anchors in sustained tensile-load overhead highway applications where failure of the adhesive would result in a risk to the public until testing standards and protocols have been developed and implemented that ensure the safety of these applications;
- Developing specific design, construction, and inspection guidance for tunnel finishes and incorporate that guidance into a tunnel design manual;
- Reviewing the use of adhesive anchors in highway construction within your jurisdiction and identify those sites where failure of the adhesive under sustained load could result in a risk to the public. Once those sites have been identified, implement an inspection and repair program to ensure that such failures do not occur;
- Requiring creep testing for the qualification of all anchor adhesives.
- Disqualifying for use in sustained tensile loading any adhesive that has not been tested for creep or that has failed such tests;
- Using building codes, forums, educational materials, and publications to inform design and construction agencies of the potential for gradual deformation (creep) in anchor adhesives and to make them aware of the possible risks associated with using adhesive anchors in concrete under sustained tensile-load applications.

A synopsis of the Board's report, including the probable cause and recommendations, is available on the Board's website, www.nts.gov, under "[Board Meetings](#)." The Board's full report will be available on the website in several weeks.

NTSB Media Contact: Keith Holloway, (202) 314-6100

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