

NTSB/HAR-07/02
PB2007-916203
Notation 7901A
Adopted July 10, 2007

Highway Accident Report

Ceiling Collapse in the Interstate 90 Connector Tunnel
Boston, Massachusetts
July 10, 2006



**National
Transportation
Safety Board**

490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

CONCLUSIONS

Findings

1. By July 2006, a significant portion of the adhesive anchors used to support the D Street portal ceilings had displaced to the extent that, without corrective action, several of the ceiling modules in the three portal tunnels were at imminent risk of failure and collapse.
2. Although it is unlikely that all the D Street portal adhesive anchors were installed in a manner that would ensure maximum anchor performance, improper or deficient anchor installation procedures or practices alone would not account for all of the anchor failures that were observed before and after the accident.
3. The anchor loading calculations developed by Gannett Fleming, Inc., for the ceiling in the D Street portal tunnel were consistent with the actual maximum loads sustained in service.
4. Based on published anchor strength test data, the calculated anchor loading for the D Street portal ceiling system, and the limited number of available alternatives, Gannett Fleming, Inc.'s, specification of an adhesive anchoring system to support the ceiling system was not inappropriate.
5. Gannett Fleming, Inc., and Bechtel/Parsons Brinckerhoff failed to account for the fact that polymer adhesives are susceptible to deformation (creep) under sustained load, with the result that they made no provision for ensuring the long-term, safe performance of the ceiling support anchoring system.
6. Modern Continental Construction Company, Inc., was supplied with and used the Fast Set formulation of Power-Fast Epoxy Injection Gel when the company was installing the anchors in the D Street portal, including the anchors that failed in this accident.
7. The source of the anchor displacement that was found in the D Street portal tunnels and that precipitated the ceiling collapse was the poor creep resistance of the Power-Fast Fast Set epoxy used to install the anchors.
8. Modern Continental Construction Company, Inc., was not aware, when its employees installed the adhesive anchors in the D Street portal, that the epoxy being used was susceptible to creep and was therefore unsuitable for this application.

9. Had Gannett Fleming, Inc., in the construction contract for the D Street portal finishes, specified the use of adhesive anchors with adequate creep resistance, a different anchor adhesive could have been chosen, and the accident might have been prevented.
10. Gannett Fleming, Inc., approved the D Street portal anchors without identifying which epoxy formulation was being used, even though the company was provided with information indicating that one version of the Power-Fast epoxy should be used for short-term loading only.
11. The information that was provided by Powers Fasteners, Inc., regarding its Power-Fast epoxy was inadequate and misleading, with the result that Modern Continental Construction Company, Inc., used the Fast Set formulation of the epoxy for the adhesive anchors in the D Street portal even though that formulation had been shown through testing to be subject to creep under sustained tension loading.
12. As shown by the displaced anchors in the D Street portal, the maximum load capacity of an adhesive anchor, which relates to short-term loading, does not indicate that the anchor will be able to support even lighter loads over time, and thus a larger design safety factor cannot compensate for an adhesive material that is susceptible to creep.
13. After unexplained anchor displacement was found in the Interstate 90 connector tunnel in 1999 and 2001, Bechtel/Parsons Brinckerhoff and Modern Continental Construction Company, Inc., 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.
14. Powers Fasteners, Inc.'s, response to the anchor displacements that occurred in 1999 in the high-occupancy tunnel of the D Street portal was deficient in that the company did not identify the source of the failures as creep in the Fast Set epoxy adhesive and took no followup action to ascertain why its product had not performed in accordance with the users' expectations.
15. Had the Massachusetts Turnpike Authority, at regular intervals between November 2003 and July 2006, 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.
16. Because of the potential catastrophic effects of a failure of the D Street portal ceiling system, Bechtel/Parsons Brinckerhoff and Gannett Fleming, Inc., should have required that ultimate load tests be conducted on the adhesive

anchors used to support the ceiling before allowing any of the anchors to be installed.

17. Installing adhesive anchors in overhead applications appears, by the nature of the task, to introduce voids into the adhesive that can reduce the ultimate load capacity of the anchor and thus the overall reliability of the anchoring system.
18. The circumstances of this accident demonstrate a general lack of knowledge and understanding among design and construction engineers and builders of the complex nature of epoxies and similar polymer adhesives, and in particular, the potential for those materials to deform (creep) under sustained tension loads.
19. Protocols or standards for the testing of adhesive anchors in sustained tensile-load applications will provide designers and builders with test methods designed specifically to accurately assess the long-term safety of those anchors.
20. National standards for the design of tunnel finishes, including tunnel suspended ceilings, will provide government entities or other organizations with ready access to information that could be useful in designing tunnel finishes that minimize potential risks to public safety.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the July 10, 2006, ceiling collapse in the D Street portal of the Interstate 90 connector tunnel in Boston, Massachusetts, was the use of an epoxy anchor adhesive with poor creep resistance, that is, an epoxy formulation that was not capable of sustaining long-term loads. Over time, the epoxy deformed and fractured until several ceiling support anchors pulled free and allowed a portion of the ceiling to collapse. Use of an inappropriate epoxy formulation resulted from the failure of Gannett Fleming, Inc., and Bechtel/Parsons Brinckerhoff 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 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. In addition, Powers Fasteners, Inc., failed to provide the Central Artery/Tunnel 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 Fasteners, Inc., 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 Power-Fast Fast Set epoxy, which was known by the company to have poor long-term load characteristics. Also contributing to the accident was the failure of Modern Continental Construction Company, Inc., and Bechtel/Parsons Brinckerhoff, 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 Turnpike Authority 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.

RECOMMENDATIONS

As a result of its investigation of the July 10, 2006, ceiling collapse in the I-90 connector tunnel in Boston, Massachusetts, the National Transportation Safety Board makes the following safety recommendations:

To the Federal Highway Administration:

In cooperation with the American Association of State Highway and Transportation Officials, develop 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. (H-07-15)

Prohibit 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. (H-07-16)

Seek legislation authorizing the Federal Highway Administration to establish a mandatory tunnel inspection program similar to the National Bridge Inspection Program. (H-07-17)

Once provided with legislative authority to establish a mandatory tunnel inspection program as indicated in Safety Recommendation H-07-17, develop and implement a tunnel inspection program that will identify critical inspection elements and specify an appropriate inspection frequency. (H-07-18)

In cooperation with the American Association of State Highway and Transportation Officials, develop specific design, construction, and inspection guidance for tunnel finishes and incorporate that guidance into a tunnel design manual. (H-07-19)

To the American Association of State Highway and Transportation Officials:

Work with the Federal Highway Administration to develop standards and protocols for the testing of adhesive anchors to be used in sustained tensile-load overhead highway applications, and incorporate those standards and protocols into the *AASHTO Construction Quality Assurance Guidelines*. 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. (H-07-20)

Use the circumstances of the July 10, 2006, accident in Boston, Massachusetts, to emphasize to your members through your publications, Web site, and conferences, as appropriate, the risks associated with using adhesive anchors in sustained tensile-load applications where failure of the adhesive would result in a risk to the public. (H-07-21)

In cooperation with the Federal Highway Administration, develop specific design, construction, and inspection guidance for tunnel finishes and incorporate that guidance into a tunnel design manual. (H-07-22)

To the Departments of Transportation of the 50 States and the District of Columbia:

Prohibit 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. (H-07-23)

Review 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. (H-07-24)

To the International Code Council:

Require creep testing for the qualification of all anchor adhesives. (H-07-25)

Disqualify for use in sustained tensile loading any adhesive that has not been tested for creep or that has failed such tests. (H-07-26)

Revise your building codes, qualified materials listings, and product labeling guidelines to clearly address the possibility for creep in polymeric anchor adhesives and to make end users aware of the potential lack of correlation between short- and long-term performance of these adhesives. (H-07-27)

Use your building codes, qualified materials listings, test criteria, or other mechanisms to make end users aware of the strong potential for creating voids in the adhesive during the overhead installation of adhesive anchors and of the need to account for the reduction in effective embedment depth associated with the use of seal plugs in such applications. (H-07-28)

To ICC Evaluation Service, Inc.:

Revise evaluation report ICC ESR-1531 to state explicitly in the text and in the bond strength tables that the Fast Set formulation of Powers Power-Fast epoxy is approved for short-term loads only. (H-07-29)

To Powers Fasteners, Inc.:

Revise the packaging, for all distributors, of your Power-Fast Epoxy Injection Gel Fast Set formulation to state explicitly that this formulation is approved for short-term loads only. (H-07-30)

To Sika Corporation:

Revise your product literature and packaging to state explicitly that Sikadur Injection Gel AnchorFix-3 epoxy is approved for short-term loads only. (H-07-31)

To the American Concrete Institute:

Use your 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. (H-07-32)

To the American Society of Civil Engineers:

Use the circumstances of the July 10, 2006, accident in Boston, Massachusetts, to emphasize to your members through your publications, Web site, and conferences, as appropriate, the need to assess the creep characteristics of adhesive anchors before those anchors are used in sustained tensile-load applications. (H-07-33)

To the Associated General Contractors of America:

Use the circumstances of the July 10, 2006, accident in Boston, Massachusetts, to emphasize to your members through your publications, Web site, and conferences, as appropriate, the need to assess the creep characteristics of adhesive anchors before those anchors are used in sustained tensile-load applications. (H-07-33)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

MARK V. ROSENKER
Chairman

DEBORAH A. P. HERSMAN
Member

ROBERT L. SUMWALT
Vice Chairman

KATHRYN O'LEARY HIGGINS
Member

STEVEN R. CHEALANDER
Member

Adopted: July 10, 2007