

# Interstate 90 Connector Tunnel ceiling collapse



**Sean Brady highlights potential similarities between the recent Sasago road tunnel collapse in Japan and the catastrophic failure of part of Boston's I-90 Connector Tunnel in 2006.**

On 2 December 2012, concrete ceiling panels fell from the roof of a 4.7km-long road tunnel west of Tokyo, Japan. The ceiling panels were suspended above the tunnel roadway and the falling panels crushed three vehicles and resulted in nine fatalities. The tunnel reopened in late December, and while a number of publications speculate that the cause of the failure may be associated with a failed support bracket or concrete anchor, the findings of an official investigation are yet to be released at the time of writing.

This collapse was a stark reminder of the failure of ceiling panels in the Interstate 90 (I-90) Connector Tunnel in Boston, Massachusetts, in 2006, and a number of the key findings from this failure are discussed here<sup>1</sup>.

The I-90 Connector Tunnel was constructed as part of the CA/T project in Boston, also known as the "Big Dig". The project was regarded as one of the most costly and complex public infrastructure projects in the US, and it was completed in 2006 at a final project cost in excess of US\$14 billion. In essence, the project was undertaken to improve traffic flow in Boston by providing 259km of highway lanes, including 8km of tunnel, six interchanges and 200 bridges. It spanned a 20 year period and was project managed by Bechtel/Parsons Brinckerhoff (B/PB).

The incident site in the I-90 Connector Tunnel, known as the D Street portal, was opened to traffic in December 2000, and consisted of approximately 800m of cut-and-cover tunnel. The D Street portal ceiling was installed by Modern Continental Construction Company in 1999 and 2000,

with the failed section being installed in November 1999. The suspended ceiling consisted of concrete ceiling panels and associated steel support framework, and it was suspended from the tunnel roof by stainless steel anchors held in place with epoxy adhesive. Notably, the specification produced by the tunnel ceiling designer, Gannett Fleming, did not contain criteria with respect to the long term performance of the anchoring system (Figure 1).

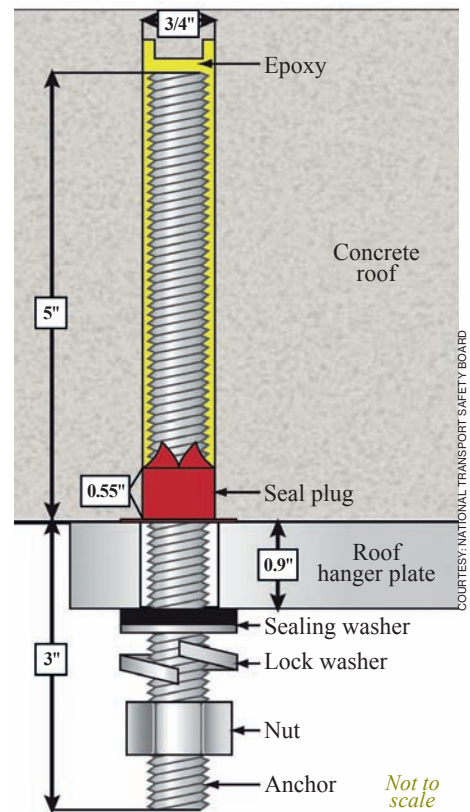
The incident occurred at approximately 23:00h on Monday the 10 July, 2006, more than six years after the D Street portal opened to traffic. A car travelling eastbound in the tunnel was struck by about 24t of falling ceiling panels and steel framework that detached from the tunnel roof. The right hand side of the car was crushed, with the driver suffering minor injuries and the passenger, the driver's wife, being fatally injured (Figure 2).

An investigation into the collapse was commenced by the National Transportation Safety Board (NTSB), who established that all 20 epoxied anchors that connected the ceiling panel's M1 support beam had pulled free from the tunnel roof. Further, an examination of the hardened epoxy, which was still attached to the failed anchors, suggested that a number of the anchors had been pulled some distance out of the tunnel roof (displaced) prior to the incident occurring.

Following the collapse, an inspection of the remaining 634 anchors in the D Street tunnel found that 161 of them had measurable displacement consistent with them being gradually pulled out by the weight of the concrete ceiling panels (Figure 3). Given this evidence, the NTSB concluded "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"<sup>1</sup>.

With respect to the installation of the tunnel ceiling, the NTSB found that all of these anchors had been subject to, and passed, a short term proof load test prior to being put into service. It was also ascertained that the design loads on each anchor "were well below the expected average ultimate

**Figure 1**  
Typical adhesive anchor and roof hanger plate assembly



load capacity published by the anchor supplier"<sup>1</sup>. The NTSB also established that, while all of the anchors may not have been installed in a manner that would result in maximum 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"<sup>1</sup>.

The NTSB investigation focused on why the epoxy failure occurred and discovered ambiguities associated with the type and specification of epoxy supplied. The epoxy used in the construction was NRC-1000 Gold epoxy. This was available in Standard Set or Fast Set versions. Based on tests on epoxy samples, the NTSB concluded that only Fast Set epoxy had been used in the D Street portal. Further tests confirmed that while the Standard Set and Fast Set epoxies



← **Figure 2**  
Approximately 24t of concrete ceiling panels crush a vehicle resulting in a fatality



→ **Figure 3**  
Displaced hanger plates

had similar performance under short term loading, they were dramatically different under long term loading situations, with Fast Set epoxy exhibiting significant displacement when subject to constant loading. Based on these findings, the NTSB concluded that “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”<sup>1</sup>.

The NTSB then set out to identify why the ceiling installer, Modern Continental, utilised an inappropriate formulation for its application. Fundamentally, they found “no evidence that Modern Continental was offered a choice or made a conscious decision to use one epoxy formulation over another”<sup>1</sup> and concluded that “Modern Continental 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”<sup>1</sup>.

A review of the supplier’s records indicated significant ambiguity associated with the epoxy supplied. The NTSB found that in 1997, prior to the D Street tunnel installation, Powers, the epoxy supplier, undertook creep testing on the Standard Set epoxy and found that it met the required standards. Then in February 2000, following installation of the D Street tunnel ceiling, an evaluation report issued by Powers noted that the Fast Set epoxy was only permitted for short-term loading scenarios – a situation that was quite different to what it would experience in the tunnel. In a detailed review of Powers’ documentation, the NTSB learned that “the Power-Fast Fast Set epoxy had been tested for creep performance in 1995 and 1996 and had failed to meet the standard”<sup>1</sup>, thus potentially explaining the recommendation for short term applications only. Ultimately, the NTSB found that “the information that was provided by Powers

regarding its Power-Fast epoxy was inadequate and misleading, with the result that Modern Continental 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 susceptible to creep under sustained tension loading”<sup>1</sup>. However, it also concluded that “Gannett Fleming 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”<sup>1</sup>.

So once the Fast Set epoxy had been put into service, was there an opportunity to detect the potential for a catastrophic failure prior to July 2006? The NTSB found two such opportunities.

In September 1999, seven years before the failure, and approximately two months after installation, a Modern Continental employee working in an adjacent tunnel on the Big Dig, the HOV tunnel, noticed that a number of anchors had started to pull out of the roof. Further inspections over the next two weeks showed this displacement was increasing. B/PB initially suspected these displacements were a result of improper installation by Modern Continental, and it was agreed between B/PB and Modern Continental to replace the displaced anchors and subject them to further short term load testing. Crucially, despite concerns being voiced by various individuals involved, the reason for the displacement was not identified. Two years later, in another portion of the I-90 Connector Tunnel, it was found that additional anchors had begun to pull out after having been proof tested just two months previously. As before, these anchors were replaced and the cause of displacement remained unknown. The NTSB concluded that “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 organisations 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”<sup>1</sup>.

A further issue cited by the NTSB as a missed opportunity, was that of inspections. Although an inspection manual had been published by B/PB in 2003, no ceiling inspections were undertaken between 2003 and the collapse. The NTSB concluded that had the Massachusetts Turnpike Authority “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”<sup>1</sup>.

Like many catastrophic structural collapses in the past decade, a series of errors, oversights, omissions and poor communication (combined with missed opportunities to identify the potential for failure) culminated in loss of life, loss of functionality, and undermined the integrity of a key piece of transport infrastructure.

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#### REFERENCES:

- 1) National Transport Safety Board (2007) Highway Accident Report, Ceiling Collapse in the Interstate 90 Connector Tunnel, Boston, Massachusetts, July 10, 2006 [Online] Available at: [www.nts.gov/doclib/reports/2007/HAR0702.pdf](http://www.nts.gov/doclib/reports/2007/HAR0702.pdf) (Accessed: March 2013)