

**THE COMMONWEALTH OF MASSACHUSETTS'  
SAFETY REVIEW OF THE CENTRAL  
ARTERY/TUNNEL PROJECT WAS  
COMPREHENSIVE, BUT FHWA'S OVERSIGHT  
APPROACH HAS SHORTCOMINGS**

*Federal Highway Administration*

*Report Number: MH-2010-050*

*Date Issued: April 20, 2010*



# Memorandum

**U.S. Department of  
Transportation**  
Office of the Secretary  
of Transportation  
Office of Inspector General

Subject: **ACTION:** The Commonwealth of Massachusetts'  
Safety Review of the Central Artery/Tunnel  
Project Was Comprehensive, but FHWA's  
Oversight Approach Has Shortcomings  
Report No. MH-2010-050

Date: April 20, 2010

From: Joseph W. Comé   
Assistant Inspector General  
for Surface and Maritime Program Audits

Reply to  
Attn. of: JA-40

To: Federal Highway Administrator

Following the July 2006 incident in Boston's Central Artery/Tunnel (CA/T) Project—in which concrete ceiling panels fell and killed a motorist—the Commonwealth of Massachusetts initiated an independent “Stem to Stern” safety review of the Boston Metropolitan Highway System, including the CA/T Project. The review, completed in August 2008, was performed in two phases: Phase I identified immediate risks to public safety, while Phase II served as an evaluation of all safety risks.<sup>1</sup>

The National Transportation Safety Board Reauthorization Act of 2006<sup>2</sup> directed the Office of Inspector General (OIG) to provide independent oversight of safety review activities performed by the Federal Highway Administration (FHWA) and the Commonwealth, as they pertained to the CA/T Project. Our broad objective was to assure Congress, the Secretary of Transportation, and the public that the safety review was comprehensive and performed in a rigorous and complete manner. In August 2007, we reported that the Phase I review was generally comprehensive, but that timely and thorough follow-up was necessary to fully

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<sup>1</sup> Phase I was a 90-day review to assess conditions that posed immediate safety risks and was completed in November 2006. Phase II was a longer, more comprehensive review to assess conditions that pose longer-term safety risks and was completed in August 2008.

<sup>2</sup> Pub. L. No. 109-443, § 11 (2006).

address immediate safety risks.<sup>3</sup> For this report, we assessed (1) the Commonwealth's Phase II review including actions taken to address identified safety risks and (2) FHWA's oversight of the Commonwealth's actions to address unresolved safety issues.

To conduct our work, we evaluated Phase II safety review activities, including the findings and recommendations of the Phase II safety review report and information FHWA provided on its approach to monitoring the Commonwealth's actions to address unresolved safety risks. To assist us in performing our audit, we contracted with the U.S. Army Corps of Engineers (Corps), which became OIG's subject matter expert for this audit. We conducted this performance audit in accordance with Generally Accepted Government Auditing Standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objective. Exhibit A provides more details on our scope and methodology.

## **RESULTS IN BRIEF**

The Commonwealth's Phase II safety review was comprehensive and rigorous, and included independent verification of recommended repairs. At this time, actions to address many safety risks identified in the review have been taken, although several risks have not been fully evaluated or remain unresolved. First, testing of adhesive anchors that support ceiling panels in the Ted Williams Tunnel (TWT) has not been completed. While these anchors are distinct from those that failed and caused the July 2006 ceiling collapse, the safety review concluded that additional testing was necessary to fully assess the risk. Second, measures to improve the CA/T Project's preparedness for a tunnel fire have not been implemented. Third, calculations assessing the structural integrity of concrete viaducts have not been verified for accuracy.<sup>4</sup>

While FHWA has taken action to oversee the Commonwealth's efforts to resolve safety risks, its approach has shortcomings. We attribute the shortcomings in FHWA's oversight to three factors. First, FHWA's definition of a safety risk requiring independent field verification is less stringent than the one used during the safety review. Second, FHWA is not consistently following its protocol for conducting independent field verifications. Third, FHWA's working list for

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<sup>3</sup> OIG Report Number MH-2007-063, "Initial Assessment of the Central Artery/Tunnel Project Stem to Stern Safety Review," August 16, 2007. OIG reports and testimonies are available on our website: [www.oig.dot.gov](http://www.oig.dot.gov).

<sup>4</sup> Concrete viaducts are a type of bridge. In this case, they connect sections of the CA/T Project to one another.

monitoring the Commonwealth's actions omits some potentially significant activities.

We are making a series of recommendations to FHWA to strengthen its oversight of the Commonwealth's actions to address unresolved safety risks. In commenting on a draft of this report, FHWA concurred or concurred in part with our recommendations. FHWA's comments also reflected disagreement with our position pertaining to independent field verifications. In a meeting between OIG and FHWA officials to discuss the field verification issue and FHWA's other comments to our draft report, the Federal Highway Administrator expressed his commitment to ensuring the safety of the CA/T Project and his interest in coming to a reasonable resolution on this issue. A complete discussion of FHWA's comments to our draft report and our response begins on page 9.

## **BACKGROUND**

Construction of the CA/T Project began in late 1991, and the first link—the four-lane Ted Williams Tunnel under the Boston harbor—was finished in December 1995. The entire project was declared substantially complete in January 2006. It was one of the most technically difficult and challenging infrastructure projects ever undertaken in the United States. Numerous problems plagued the project's construction, and significant lapses in quality assurance were encountered. Examples include massive water leaks in project tunnels, one at the rate of more than 300 gallons per minute, and the use of approximately 5,000 truckloads of concrete that did not meet project specifications. The July 2006 incident was attributed to 26 tons of concrete panels being improperly secured to the tunnel ceiling. In October 2000, due to constantly rising costs, Congress limited Federal aid for CA/T construction to \$8.5 billion<sup>5</sup>—\$6.3 billion less than the estimated costs for the project.

To conduct the safety review, the Commonwealth engaged Wiss, Janney, Elstner Associates, Inc. (WJE), a forensic engineering firm with significant experience investigating infrastructure accidents. In June 2008, WJE completed its independent field verifications of actions taken by the Commonwealth to address unresolved safety risks. In August 2008, WJE provided the Phase II report to the Commonwealth and later provided several addenda.

WJE identified and recorded “reportable conditions” that could pose safety risks and classified them using a scale to identify the urgency with which follow-up activities should be performed (see table 1). The two highest categories of risk

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<sup>5</sup> Department of Transportation Appropriations Act of 2001, Pub. L. No. 106-346, § 340(b) (2000).

include “immediate or dangerous” conditions that warrant immediate follow-up activities and those with “remediation recommended as soon as possible.”

**Table 1. WJE's Categories of Reportable Conditions**

<b>Category</b>	<b>Required Activities</b>
IC	Immediate or dangerous conditions; such conditions were to be immediately reported to the Massachusetts Turnpike Authority for remediation.
R1	Remediation recommended as soon as possible
R2	Remediation recommended in coordination with near-term maintenance and capital improvement programs
MR	Monitoring recommended; remediation should be considered if condition worsens.
PII	Phase II follow-up work recommended to confirm or resolve concern
NA	No follow-up work under the safety review.

Source: Wiss, Janney, Elstner Associates, Inc.

Our August 2007 report noted that follow-up was necessary to fully address certain reportable conditions, such as performing an analysis of the safety of adhesive anchors supporting ceiling panels in the TWT. FHWA’s then-Acting Deputy Administrator concurred with our report’s recommendation to ensure that the Commonwealth completes the analyses of all safety risks—especially those that posed immediate risks—in a timely, independent, and thorough manner, since many key safety studies were limited or deferred, and to ensure that the Commonwealth promptly resolves such risks.

## **PHASE II SAFETY REVIEW WAS COMPREHENSIVE, BUT SOME SAFETY RISKS REMAIN UNRESOLVED**

The Commonwealth’s Phase II safety review was comprehensive and rigorous. WJE assigned the appropriate engineering specialists to examine each major component of the CA/T Project,<sup>6</sup> and WJE’s assessments were technically competent. WJE examined plans and design calculations, performed additional calculations and field inspections, and independently verified the completion of many repairs. Further, the Commonwealth addressed many of the safety risks WJE identified in the review. However, at the conclusion of the Phase II safety review, several risks had not been fully evaluated and resolved.

<sup>6</sup> Major components include tunnel structures, bridge structures, life safety systems, and ventilation systems.

First, the adhesive anchors supporting ceiling panels in the TWT have not been fully tested (see figure 1). WJE conducted limited testing of the adhesive anchors to evaluate their performance during a tunnel fire, and recommended that additional testing be performed to determine the anchors' capacity and whether they needed to be replaced.<sup>7</sup> Based on our audit work conducted up through August 2009, the Commonwealth proposed performing additional tests on samples of adhesive anchors, but the sample sizes were too small to produce reliable results for the more than 25,000 anchors in the TWT.<sup>8</sup> According to the expert opinions of Corps engineers and our statistician, decisions made on how to address this higher priority safety risk should be based on statistically valid results, which will require the Commonwealth to develop and implement a sampling plan that produces results representative of the population of TWT adhesive anchors. Nevertheless, we want to clearly state that WJE's Phase II report does not indicate that the TWT adhesive anchors pose an immediate risk to the traveling public.

In its formal comments to our draft report, dated March 16, 2010, FHWA states that the Commonwealth awarded a contract for testing the adhesive anchors in September 2009 and that its experts believe the testing methodology will yield levels of confidence that are valid and reliable and provide adequate support for decisions on further remediation activities, if required. FHWA also states that the testing will be completed before May 2010 and that it will oversee the evaluation of the results, and any recommendations resulting from the testing.

**Figure 1. TWT Adhesive Anchor Supporting Ceiling Panels**



Source: U.S. Army Corps of Engineers/U.S. Department of Transportation Office of Inspector General

<sup>7</sup> WJE stated in the Phase II report, "If anchor performance is shown to be inadequate, some or all existing anchors should be replaced with mechanical anchors or bypassed using supplemental hangers mechanically anchored to the tunnel roof. Depending on the outcome of the recommended testing, additional ceiling system retrofits may be necessary to mitigate the risk of progressive ceiling collapse during a tunnel fire." WJE Stem to Stern Safety Review Phase II Report, August 2008, volume 3, Tunnel Finishes, page 26.

<sup>8</sup> The Commonwealth has proposed one type of test on a sample of 60 adhesive anchors and a second type of test on a sample of 10 adhesive anchors.

Second, measures to improve the CA/T Project's preparedness for a tunnel fire have not been implemented. The CA/T Project's tunnels were built to design standards that were applicable at the time of construction. However, the safety review's evaluation of the effects of a 20 to 30 megawatt tunnel fire, which is approximate to the intensity of a one-truck fire, demonstrated the need to update emergency response procedures for motorists with health or mobility impairments. The safety review concluded that such motorists could be at greater risk in descending sections of the CA/T Project tunnels.

Further, as stated in our August 2007 report, based on the current body of knowledge and the possibility of such an event, our fire experts expressed concern about the potential impact of a high-temperature tunnel fire. Consequently, FHWA funded a fire modeling study on 70 megawatt fires in tunnels that matched the shape and size of portions of some tunnels in the CA/T Project. Its April 2009 final report demonstrated that changes are necessary to improve motorists' ability to evacuate the tunnels—a finding consistent with the results of WJE's safety review. Given that the CA/T Project includes over 80 lane-miles of tunnels and is the largest public works project in the country, the Commonwealth should use these findings to safeguard motorists in case of a tunnel fire. The findings could also be used to improve the safety of motorists using tunnels nationwide.

Finally, WJE's calculations assessing the structural integrity of concrete viaducts have not been verified for accuracy. Requiring a detailed review of such calculations by a second engineer is a common practice for quality assurance purposes. Inaccurate calculations could lead to mistaken conclusions about the safety of those structures.

## **FHWA'S APPROACH TO OVERSEEING THE RESOLUTION OF SAFETY RISKS HAS SHORTCOMINGS**

While FHWA has taken action to oversee the Commonwealth's efforts to resolve safety risks, it has not implemented an adequate approach overall to overseeing the Commonwealth's actions. At the conclusion of the Phase I safety review, the then-Acting Deputy Federal Highway Administrator made a commitment to ensure that the Commonwealth completes the analysis of all safety risks in a timely, independent, and thorough manner, and to ensure that the Commonwealth promptly resolves such risks. Further, FHWA is responsible for monitoring the efficient and effective use of Federal-aid highway funds according to statute,<sup>9</sup> and states in policy that it will fulfill this responsibility.<sup>10</sup> The benefits of closely monitoring CA/T Project activities were highlighted in the case of the Leverett

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<sup>9</sup> 23 U.S.C. §106 (2006).

<sup>10</sup> FHWA's "Policy on Stewardship and Oversight of the Federal Highway Programs," June 22, 2001.

Bridge, after WJE identified a cracked pier cap beam on the bridge during the safety review.<sup>11</sup> In response to timely FHWA and OIG oversight activities, WJE performed additional analyses that demonstrated the need to post a weight limit on the bridge. The results of WJE's analyses also prompted the Commonwealth to expedite plans to repair the cracked beam to better ensure the continued safety of motorists using the bridge.

The following examples demonstrate the need for FHWA to more actively oversee the resolution of the CA/T Project's safety risks:

- FHWA has not fully verified the testing of adhesive anchors in the TWT, which is necessary to oversee the Commonwealth's actions to address this unresolved safety risk, designated by WJE as needing resolution as soon as possible. While the anchors in the TWT are distinct from those that failed in July 2006, WJE identified multiple occurrences in which anchors were not fully embedded in the concrete ceiling of the TWT tunnel.<sup>12</sup> Without a sufficient number of anchors adequately embedded, a ceiling panel could fall.
- FHWA has not defined how it will oversee the Commonwealth's efforts to improve facilities and modify emergency response procedures to resolve the significant safety risks associated with a tunnel fire. Physical improvements to the tunnels emergency exit features—such as steps, railings, and access doors—may be required; the Boston Fire Department's emergency response procedures must also be updated.
- FHWA has not confirmed the completion of a quality assurance review of calculations assessing the structural integrity of concrete viaducts. The lack of evidence that an independent review of such calculations has been performed poses a potentially significant safety risk because they are used in computer models for determining what loads the viaducts can safely sustain.

We attribute FHWA's shortcomings in overseeing unresolved safety risks to three factors. First, FHWA's definition of a safety risk requiring independent field verification is less stringent than WJE's—which calls for independent field verification of all reportable conditions in the two highest categories of risk. In contrast, FHWA is selectively conducting independent field verifications among a

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<sup>11</sup> The pier cap beam, in this case, was a concrete beam supporting the deck of the Leverett Bridge, the portion of the bridge that carries traffic.

<sup>12</sup> WJE noted two separate reports on tests that measured embedment depth ultrasonically of 83 anchors and found that 72 anchors had less than the recommended depth of 5.5 inches. WJE Stem to Stern Safety Review Phase II Report, August 2008, volume 3, Tunnel Finishes, page 5.



group of conditions it has labeled as “structural” and “engineering issues” that does not include all of the conditions classified by WJE as immediate or dangerous and in need of resolution as soon as possible. For example, the Commonwealth plans to address a safety risk posed by a disabled water valve that firefighters may need in an emergency by adding an instructional sign—not by fixing the valve as recommended by WJE. This reportable condition, classified by WJE as needing resolution as soon as possible, merits independent field verification, but it is excluded from FHWA’s select group of conditions undergoing independent field verification.

Second, FHWA is not consistently following its protocol for conducting independent field verifications. For example, WJE concluded that concrete that had begun to detach from the underside of viaducts needed resolution as soon as possible because the concrete was at risk of falling. However, despite labeling this reportable condition an “engineering issue” needing independent field verification, FHWA is relying on the Commonwealth to confirm that repairs are completed. This approach is inconsistent with performing independent field verification because the Commonwealth cannot truly conduct an independent assessment of whether necessary repairs were completed when it performed the repairs. Our concern is that some higher priority reportable conditions have remained unresolved for up to 3 years. Without performing independent field verifications, FHWA lacks assurance that identified safety risks have been fully resolved and have not become more dangerous since they were originally identified.

Third, FHWA’s working list for monitoring the Commonwealth’s actions omits some potentially significant activities, reducing FHWA’s effectiveness in determining whether all higher priority safety risks are fully resolved. For example, the working list omits the need to complete facility improvements and implement modifications to emergency response procedures to safeguard motorists during tunnel fires. It also lacks milestone dates that are important for monitoring the Commonwealth’s progress in addressing unresolved safety risks. Maintaining a complete working list is critical given that the Commonwealth’s ongoing evaluations could identify additional safety risks.

## **CONCLUSIONS**

In constructing Boston’s underground expressway, the CA/T Project faced numerous technical and environmental challenges. Although the Commonwealth’s Stem to Stern Safety Review was comprehensive and identified safety risks, some actions to address safety risks are still needed. Until FHWA takes a more active role in overseeing the project’s safety, it cannot provide adequate assurance that the Commonwealth has successfully resolved these risks. By asserting a more active role, FHWA could follow through on its commitment

to monitor the resolution of safety risks, as well as meet the agency's obligation to oversee the efficient and effective use of Federal-aid highway funds.

## **RECOMMENDATIONS**

To strengthen its oversight of the Commonwealth of Massachusetts' actions to address unresolved safety risks, we recommend that the Federal Highway Administrator establish a rigorous methodology to evaluate whether all safety risks are resolved, and specifically:

1. Verify that the Commonwealth implements a statistical sampling plan for testing the safety of the adhesive anchors in the TWT that produces adequate support for decisions on remediation activities, and oversee the testing and evaluation of the results.
2. Verify that the Commonwealth implements the necessary modifications to safeguard motorists in case of a tunnel fire, taking into account the findings of WJE's safety review and the results of FHWA's fire modeling study.
3. Verify that a quality assurance review of calculations assessing the structural integrity of CA/T Project concrete viaducts is completed.
4. Conduct independent field verification of actions taken since June 2008, when WJE completed its field verifications, to evaluate and resolve higher priority safety risks, including those classified by WJE in the two highest categories.
5. Maintain a complete and accurate working list of all unresolved higher priority safety risks that includes those classified by WJE in the two highest categories as well as milestone dates for monitoring the Commonwealth's progress in addressing unresolved safety risks.

## **AGENCY COMMENTS AND OFFICE OF INSPECTOR GENERAL RESPONSE**

We provided a draft of this report to FHWA for review and comment on January 7, 2010. FHWA provided us with formal comments on March 16, 2010. These comments are included as an appendix to this report. FHWA concurred with recommendations 2, 3, and 5 and partially concurred with recommendations 1 and 4. However, in general, FHWA disagreed with our conclusion that its oversight approach has shortcomings. It provided a range of information on actions it has taken to ensure that safety risks associated with the CA/T Project have been resolved, particularly those posing an immediate safety risk. We recognize the numerous actions FHWA has taken since the tunnel collapse in July 2006. Regarding the TWT adhesive anchors, specifically, we

want to clearly state that WJE's Phase II report does not indicate that there is an immediate risk to the traveling public. A determination of the ultimate risk, though, is contingent upon the Commonwealth completing the testing of such anchors, an action recommended by WJE in order to address questions about the anchors' long-term performance. We are pleased FHWA has responded that it will oversee the testing and evaluation of the results. The testing is to be completed before May 2010. However, we are concerned by FHWA's overall response because it does not address many of the specific issues raised in our report. For example, we reported that FHWA is not consistently following its protocol for conducting independent field verifications. FHWA labeled a reportable condition as needing independent field verification under its protocol, but such verification was not performed. FHWA does not identify specific steps it plans to take to address this issue, but rather asserts that it conducts appropriate verification. Thus, we are requesting additional information for several recommendations where FHWA is unclear or silent about actions it plans to take in response to our recommendations.

Regarding recommendation 1 (concur in part), FHWA states that the testing methodology being implemented includes a step approach that its experts say will yield levels of confidence that are valid and reliable and provide adequate support for decisions on further remediation activities, if required. FHWA also states that it will oversee the testing and evaluation of the results. To ensure that actions taken or planned are well supported and fully responsive, we are requesting documentation of the methodology used for (1) the random selection of adhesive anchors for all testing activities and (2) the analysis of the test results, including the criteria used for determining pass or fail. We will also need to review the documentation created by FHWA's experts in concurring with the testing plan. FHWA has targeted July 30, 2010, for the completion of its oversight of this effort.

Regarding recommendation 2 (concur), FHWA transmitted the results of its fire modeling research to the Commonwealth in November 2009 and states that it will oversee modifications to emergency response plans. However, FHWA does not reference overseeing facility improvements, a critical component to safeguarding motorists in case of a tunnel fire up to 70 megawatts, as indicated by FHWA's fire modeling study. FHWA also states that it will review and endorse the Commonwealth's plan, but does not reference whether it will verify the implementation of necessary modifications, as specified in the recommendation. Accordingly, to ensure that actions taken or planned are well supported and fully responsive, we are requesting documentation from FHWA on these items. FHWA has targeted August 31, 2010, for completion of its activities related to this recommendation.

Regarding recommendation 3 (concur), FHWA considers its actions complete because WJE certified the content of the entire report by placing professional engineers' seals on the cover page of WJE's Phase II report. FHWA further stated that the original design calculations for CA/T Project structures were checked. Nevertheless, as part of our review, we identified an apparent internal control deficiency in the review the certifying engineers performed, calling into question the completeness of WJE's actions. We found no evidence that a second WJE reviewer verified WJE's set of calculations assessing the structural integrity of concrete viaducts. Second reviewers document the completion of specific reviews by initialing each set of calculations, which was missing in this case. Requiring a second engineer to conduct a detailed review of such calculations is a common practice for quality assurance; and it should occur in addition to the entire report's certification. In contrast, all other critical calculations WJE published in its Phase II report and addenda were initialed by a second reviewer. These included calculations produced by WJE for tunnels, the Zakim and Leverett Bridges, steel viaducts and incomplete tendon grouting. Additionally, contrary to FHWA's assertion, the quality assurance measures applied to the CA/T Project's original design calculations do not have bearing because the intent of the safety review was to conduct an independent review. Given that WJE is accountable for its own quality assurance, the only way to adequately address this issue is for WJE to apply the same engineering standard to the concrete viaduct calculations that it applied to all the other calculations. Therefore, we are requesting that FHWA reconsider its response to this recommendation and take specific actions to verify that a quality assurance review of the concrete viaduct calculations has been performed. We also ask that FHWA provide a completion date for its activities related to this recommendation.

Regarding recommendation 4 (concur in part), FHWA considers its actions complete because its protocol developed specifically for the CA/T Project provides additional, targeted levels of review and oversight above customary requirements. According to its response, FHWA also conducts appropriate verification, including field verification on necessary action items and will continue to do so until all items, regardless of the risk they impose, are completed and verified.

We take issue with FHWA's assertion that it is providing appropriate verification, and stand behind our findings and related recommendations. We determined that the Phase II safety review was comprehensive and rigorous, but not complete because some safety risks remained unresolved, as stated in this report. In carrying out the safety review, WJE established the precedent that reportable conditions in the two highest categories of risk would undergo independent field verifications to provide assurance that they were fully resolved. Even though the Phase II report has been issued and WJE is no longer under contract with the

Commonwealth, we concluded that FHWA needed to continue this practice to provide the same level of assurance. FHWA disagreed and established a protocol of conducting independent field verifications on a more selective basis—a deviation from WJE's approach. In our view, a "trust but verify" approach is still required.

Further, we found that FHWA is not conducting verifications in compliance with its stated protocol. For example, we reported that FHWA is not conducting independent field verification of repairs to concrete that had begun to detach from the underside of viaducts, despite labeling this as a condition needing independent field verification. FHWA's response does not address this deficiency. There are numerous other examples of problems in the implementation of FHWA's protocol that raise concerns. For example, according to FHWA's protocol, it performs field verifications prior to the repair, while the repair is in progress, or at the completion of the repair. However, in reviewing FHWA's documentation, we encountered difficulty determining whether FHWA had observed repairs or not. Specifically, we found that entries documenting field verifications for the majority of the reportable conditions in FHWA's working list had either incomplete or missing data pertaining to the dates of inspections, the amount of repair work completed, and the results of the inspector's assessment.

If FHWA is to achieve its stated goal of providing unequivocal assurance that all necessary actions are taken with regard to safety, it should perform independent field verification of all actions taken to resolve higher priority safety risks, including those WJE classified in the two highest categories. As such, we are requesting that FHWA reconsider its response and provide a completion date for oversight activities in line with our recommendation.

Regarding recommendation 5 (concur), FHWA considers its actions complete because it has and will continue to maintain a complete and accurate working list of all higher priority safety issues. However, FHWA does not respond to the omission identified in the report, which is that its working list does not clearly reference the need to complete facility improvements and implement modifications to emergency response procedures, taking into account the results of FHWA's fire modeling study. We also found that FHWA's working list lacked milestone dates that are important for monitoring the Commonwealth's progress in addressing unresolved safety risks. Accordingly, to ensure that actions taken or planned are well supported and fully responsive, we are requesting that FHWA provide a complete and accurate working list of all unresolved higher priority safety risks that has milestone dates, as recommended in our report. We also request that FHWA provide a completion date for its activities related to this recommendation.

In conclusion, we stand behind our findings and recommendations that point to opportunities for FHWA to improve its oversight of the CA/T Project. Until all unresolved safety risks are mitigated by the Commonwealth, and FHWA conducts independent field verification of unresolved safety risks, including those WJE classified in the two highest categories, we will continue to press on FHWA to take the necessary steps to ensure the long-term safety of motorists using the CA/T Project.

### **ACTION REQUIRED**

FHWA's planned actions and target action dates for recommendations 1 and 2 are responsive. We consider these recommendations open pending completion of appropriate corrective actions. In accordance with DOT Order 8000.1C, we request that FHWA provide within 30 days of this report additional clarifying information for recommendations 3, 4, and 5. We appreciate the cooperation and assistance provided by FHWA representatives during our audit. If you have any questions concerning this report, please call me at (202) 366-5630.

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## **EXHIBIT A. SCOPE AND METHODOLOGY**

To accomplish our broad objective of ensuring that Phase II of the safety review was comprehensive and performed in a rigorous and complete manner, we assessed the findings and recommendations of the Phase II report, evaluated the Commonwealth's efforts in response to safety risks described in our August 2007 report, and identified and analyzed outstanding significant safety risks. We conducted this performance audit from June 2008 through August 2009, in accordance with Generally Accepted Government Auditing Standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. This report concludes our audit work related to the safety review.

Our focus was centered mainly on significant and time-sensitive safety risks classified as dangerous conditions that warrant immediate follow-up activities and those for which remediation was recommended as soon as possible. We assessed work plans, monitored field reviews, and analyzed the findings and recommendations of WJE's August 2008 Phase II report and reviewed subsequent documents as appropriate. Specifically, we monitored the progress of the Phase II safety review effort to ensure that activities adhered to the work plan and complied with established engineering standards and protocols. We also identified safety risks that were not appropriately addressed.

We evaluated WJE's August 2008 Phase II report and its addenda to ensure that remediation plans were developed to correct identified risks. We also reviewed FHWA's proposed monitoring plan for tracking the successful remediation of remaining time-sensitive safety risks. In consultation with the OIG statistician, we reviewed the Commonwealth's proposed plan for testing adhesive anchors securing ceiling panels in one of the CA/T Project's tunnels. We reviewed the plan to determine whether it would produce results representative of the larger population of adhesive anchors in the TWT.

Because of the complexity of this audit, we obtained the technical assistance of the Corps. The Corps independently monitored the safety review and regularly briefed OIG engineers on the status of Phase II. OIG engineers also performed some site visits along with the Corps during Phase II. Technical reviews were performed using criteria from the American Association of State Highway and Transportation Officials, FHWA, the National Fire Protection Association, and the American Concrete Institute, in addition to others. After reviewing information that the Corps provided, our engineers shared their concerns with the Commonwealth.

### **Exhibit A. Scope and Methodology**

**EXHIBIT B. MAJOR CONTRIBUTORS TO THIS REPORT**

<b><u>Name</u></b>	<b><u>Title</u></b>
Eric Mader	Program Director
Jay Swartzbaugh	Project Manager
Rodolfo Pérez	Engineer Advisor
Anne-Marie Joseph	Senior Engineer
Christopher Minovich	Senior Auditor
Adam Tabaka	Analyst
Petra Swartzlander	Statistician



## APPENDIX. AGENCY COMMENTS



# Memorandum

Subject: **INFORMATION:** Federal Highway Administration (FHWA)  
Response to Office of Inspector General (OIG) Draft Report  
on the Central Artery/Tunnel Project (CA/T)

Date: March 16, 2010

From: Victor M. Mendez  
Administrator

Reply to  
Attn. of: HDA-MA/HAIM

To: Calvin L. Scovel III  
Inspector General

The FHWA implemented a thorough and far-reaching oversight approach for ensuring all safety risks associated with the Central Artery/Tunnel (CA/T) were identified and prioritized, and that swift and appropriate action was taken to mitigate all significant risks. At this time, all of the highest priority safety concerns have been identified, resolved, and closed. This conclusion is based upon independent analysis and review by multiple groups of experts, including experts from the Commonwealth of Massachusetts, independent third party structural forensic engineering consultants, and a special expert advisory panel convened specifically to provide additional oversight for the CA/T. Any remaining issues have been documented, analyzed and evaluated for follow-up action and are not considered an immediate risk to public safety.

The FHWA expanded its direct safety oversight of the Commonwealth's efforts in response to the ceiling panel collapse in 2006. We carefully reviewed actions by the Commonwealth of Massachusetts, which enlisted the assistance of independent engineering expertise to perform a comprehensive review of the CA/T. The Agency developed specific protocols that provide additional, targeted levels of review and oversight that go above and beyond customary requirements. These risk-based protocols call for significantly increased levels of oversight, which are being implemented according to plan. Furthermore, FHWA continues to provide careful monitoring to ensure effective long-term safety oversight of the CA/T.

### **Independent Experts Conclude All Immediate Stem to Stern Safety Issues Are Resolved**

Every safety concern identified as posing an immediate risk to the public's safety (categorized as immediate concern) have been resolved, verified, and closed. Remedial actions were taken by the



Commonwealth of Massachusetts and verified by the independent national structural forensics engineering experts at the consulting firm of Wiss, Janney, Elstner Associates, Inc (WJE). These actions received additional verification by FHWA's structural experts and the Commonwealth's Special Advisory Panel comprised of national engineering experts affiliated with the National Science Foundation's Transportation Research Board, the Massachusetts Institute of Technology, Loyola University, and the Port Authority of New York/New Jersey.

### **FHWA's Stem to Stern Oversight Protocols Defined Unprecedented Oversight**

In order to provide unequivocal assurance that all necessary actions are taken with regard to safety, FHWA developed project-specific protocols that add additional, targeted levels of review and oversight that exceed its standard requirements, due to the special challenges posed by the CA/T. While FHWA's approach to safety is intended to provide risk-based oversight of States' actions, we designed the Stem to Stern protocols for the CA/T to include more direct review due to the extreme complexity of the CA/T project. For Stem to Stern, this included multiple layers of both field and document-based verification. The FHWA and the other experts involved in this process field-verified repairs for structural or engineering integrity and other critical safety issues. As work proceeded, FHWA determined the most appropriate approach for its oversight of each identified issue based on the protocols and its assessment of actions taken, together with the consideration of the nature of review implemented by the other independent experts involved in oversight. Based on this work, and based on professional engineering judgment and evaluations of national structural experts, FHWA determined where its own field reviews were necessary and appropriate to ensure rigorous review and documentation of actions taken. The protocols and FHWA's implementation offered needed flexibility within a risk-based multi-level oversight environment. They enabled FHWA to apply its resources in a way that address the most important concerns and best protect public safety. The protocols were not intended, as implied in the OIG draft report, to rigidly define items specifically requiring direct field verification by FHWA. Many of the repairs where the OIG draft is critical of FHWA for not conducting independent field verification are typically rectified by routine maintenance, such as checking replacement of cracked light covers or ensuring adequate cleanup of construction materials. While FHWA verifies all items WJE identified, from the highest priority safety concerns to items requiring routine monitoring or repairs, as intended by the Stem to Stern protocols, it carefully prioritized and focused its work on those items of the greatest concern to public safety.

### **Anchor Testing Methodology Supported by National Experts**

All ceiling panel anchors in the section of the tunnel where fast set epoxy was used and where the ceiling panel fell have been replaced. The FHWA, working with national, Federal, and State experts, completed vigorous assessments of methods to effectively monitor the condition of the entire tunnel ceiling over the longer term. The WJE's forensic structural engineering experts underscored the overall satisfactory performance and the appropriateness of this monitoring. As an additional precaution, WJE recommended further anchor testing of the Ted Williams Tunnel (TWT) where standard epoxy had been used. While the integrity of these ceiling anchors was not a factor in the 2006 incident, FHWA agreed that some additional testing, to ensure the effectiveness of this similar anchoring system, was prudent. It is important to understand, however, that this testing is destructive. In order to evaluate the effectiveness of ceiling panel anchors, they are deliberately pulled to the breaking point. This process disrupts traffic flow with lane and tunnel closures, and can in fact *cause* damage to the tunnel structure. For these reasons it is critical to identify a level of testing that is sufficient to ensure public safety, while minimizing the damage it may cause and the need for extended lane closures.

The ceiling anchor testing methodology, developed by national structural engineering experts, includes a phased or step approach intended to accomplish this balance. The approach, endorsed by FHWA and the other engineering experts involved with overseeing these efforts, determined that destructive testing of 60 ceiling panel anchors would provide sufficient assurance as to the integrity of this anchor methodology. This approach is based on careful deliberation and thorough analysis of all factors involved with the CA/T. We recognize that the OIG draft report maintains that the sample sizes for testing the safety of the adhesive anchors in the TWT were too small (i.e. 300 ceiling panel anchors should be destructively tested), but that was based on a simple statistical assertion. The OIG's assertion is not supported by the combined engineering expertise of WJE and the Commonwealth's Special Advisory Panel. While the stepwise approach allows for expanded testing, based on careful analysis and monitoring of each test as it occurs, mandating the destructive testing of an additional 240 ceiling panel anchors is not offset by any potential gain in public safety, nor the additional damage to the tunnel structure, nor the tunnel closures and safety hazards this additional testing would pose to the public. The FHWA, supported by independent expertise, agrees that the approach now underway will yield levels of confidence that are valid and reliable while minimizing the impact of this inherently destructive and disruptive testing methodology.

### **Independent Experts Support FHWA's Position on CA/T Fire Modeling**

In its final Stem to Stern Safety Review report, the independent Special Advisory Panel concurred with the findings of the WJE team and endorsed its recommendations with regard to fire safety. It also concurred with the simulation models used to assess the performance of CA/T tunnels during fires. The independent Special Advisory Panel noted that a 60 megawatt benchmark standard as advocated by the OIG would be "inappropriate and misleading."

The CA/T was constructed to meet or exceed the National Fire Protection Association (NFPA) standards. The standard in place at the time the tunnel was designed called for the tunnel to be able to accommodate a 20 megawatt fire. During the Stem to Stern process, the Life Safety Systems for the CA/T were evaluated against fires up to an intensity of 30 megawatts, more than 50 percent higher than the tunnel's design standard. This evaluation found that the CA/T life safety elements were faithful to the basis of design and consistent with the NFPA 502 standard, *Standard for Road Tunnels, Bridges, and Other Limited Access Highways*. The OIG draft report advocates evaluation against a 60 megawatt fire, or more than three times the design standard at the time the tunnel was designed. Neither FHWA, nor the experts involved with CA/T oversight, see potential benefit to be derived from evaluating CA/T against a protocol that so far exceeds the standards to which it, and any tunnel in the country was constructed.

Independent of the CA/T project itself, FHWA is pursuing the development of future national tunnel design and inspection standards that will establish Federal tunnel inspection and oversight requirements comparable to FHWA's national bridge inspection standards. They will be released this year. These are consensus-based standards being developed in concert with the industry, academia, and technical experts. Fire tunnel modeling is a part of national and international initiatives to address tunnel life safety issues. The FHWA has sponsored initial research into the implications of fires as strong as 70 megawatts, and recommended that owners of all highway tunnels review established evacuation and emergency response protocols in light of the study. The Boston Fire Department and the CA/T officials have already demonstrated a fast (less than 5 minutes) response time. They are also reviewing procedures and processes to further enhance the effectiveness of their life safety systems.

### **Concrete Viaducts' Structural Integrity Calculations Independently Verified**

The OIG draft report is inaccurate in its assertion that WJE's calculations assessing the structural integrity of concrete viaducts have not been verified for accuracy. The original design of the concrete viaducts in all instances had been independently reviewed and checked by the original design firm. The WJE performed an added layer of verification by conducting structural calculations in accordance with standard engineering practices and documented the results in its final report. We have attached the WJE final report cover page and the page containing the Structural Engineers and Professional Engineers seals, certifying the content in the entire report was developed and reviewed by licensed Structural and Professional Engineers from WJE according to standard engineering practices. The seals of approval signify that the Stem to Stern final report was reviewed or prepared under the engineer's supervisory control and determined to be safe for public health and welfare in conformity with accepted engineering standards. Subsequently, FHWA verified in August 2008, that the quality assurance review of calculations assessing the structural integrity of CA/T Project concrete viaducts was completed.

### **OIG Recommendations and FHWA Responses**

**Recommendation 1:** Verify that the Commonwealth implements a statistical sampling plan for testing the safety of the adhesive anchors in the TWT that produces adequate support for decisions on remediation activities, and oversee the testing and evaluation of the results.

**Response:** Concur in part. The Commonwealth, in concert with the best available engineering expertise, has identified and is implementing a testing plan that will provide assurance that the ceiling panel anchors function as intended. While the specific number of tests is not the same as that OIG asserts is necessary for its statistical analysis, the Commonwealth is proceeding in accord with the review by independent engineering experts who specialize in structural and civil engineering fields. These independent experts agree that its approach will provide support for assessing the viability of the ceiling anchoring systems and making a determination for any additional remediation actions, if necessary, while balancing the competing concerns over destructive testing and traffic flow. The Commonwealth has also implemented additional measures, which provide another layer of protection for public safety. Specifically, the Commonwealth is conducting inspections and regularly monitoring the TWT ceiling in accordance with their Policy Directive for Tunnel Inspection and Testing Program. This is an ongoing measure that was implemented until the anchor testing and evaluation are completed. The FHWA has been actively working on this issue with independent, Federal, and State experts to vigorously assess methods to effectively test and monitor the condition of the entire TWT ceiling over the long term.

The FHWA has maintained an ongoing dialogue with these experts and the OIG on this issue over an extended period of time. It has carefully considered the OIG staff's point of view, based primarily on its statistical analysis that solely looked at the total number of anchors, and balanced this against the applied engineering expertise of third party experts participating in various aspects of the project oversight. The FHWA concluded that the more limited number of destructive tests, combined with a careful and methodical non-destructive inspection program, carried out over the long term provides an equivalent or superior outcome, with less risk of damage to the structure from destructive testing, and less disruption to the public since anchor testing and replacement require lane and tunnel closures on this heavily traveled Interstate link to Boston's Logan International Airport.

## **Appendix. Agency Comments**

Recognizing the potential for unanticipated issues, the testing methodology being implemented includes a testing protocol that provides for a phased or step approach. In general, our step approach will enable structural experts to review the results of the anchor tests as they occur, using engineering judgment and evaluations to determine how many additional anchors must be tested to arrive at an acceptable sampling confidence level while minimizing additional risks associated with this testing methodology. The FHWA's experts have said the step approach will yield levels of confidence that are valid and reliable and provide adequate support for decisions on further remediation activities, if required.

Milestones: Complete and thorough deliberations involving OIG and other stakeholders occurred to ensure that the best and most appropriate testing approach would be implemented. The FHWA's oversight responsibility required assurance that testing would not unnecessarily disrupt the structural integrity of the CA/T. In the interest of ensuring public safety, monitoring and inspection of the TWT were ongoing throughout the entire deliberative process. While these extended deliberations among FHWA, the engineering experts, and OIG delayed implementation of the testing program, the Commonwealth awarded the anchor testing and retrofit contract on September 30, 2009. The contract is scheduled to be completed on April 27, 2010. The FHWA will oversee the testing and evaluation of the results, and any recommendations resulting from the testing will be added to the close out actions by July 30, 2010.

**Recommendation 2:** Verify that the Commonwealth implements the necessary modifications to safeguard motorists in case of a tunnel fire, taking into account the findings of WJE's safety review and the results of FHWA's fire modeling study.

**Response:** Concur. The WJE and its fire safety expert, Schirmer Engineering, concluded in the Phase I and Phase II reports that, "...The design of life safety systems was mostly consistent with the CA/T Project design criteria and the governing standard for tunnels, *NFPA 502: Standard for Road Tunnels, Bridges, and Other Limited Access Highways*. The systems were found to be conservative, with features that protect the public, workers, and emergency responders in a majority of incident scenarios. These systems utilize robust and redundant hardware components that are powered by equally robust and redundant power systems."

The emergency response recommendations are included in our tracking list. All issues identified in the Phase I and II reports are being tracked to completion using our working list with progress discussed and monitored at monthly meetings with the Massachusetts Department of Transportation (MassDOT). In addition, FHWA created 15 new General Recommendations related to the life safety and fire modeling findings to track MassDOT's completion of the issues and has previously provided the updated listing containing these items to the OIG. These items are cited in the Commonwealth's CA/T Project close out actions, including completion dates.

Milestones: The FHWA transmitted the results of the fire modeling pilot research to the Commonwealth in November 2009. The MassDOT, in conjunction with the Boston Fire Department, are reviewing the findings and will revise the emergency response plan by June 30, 2010. We plan to review and endorse the revised plan or request modifications by August 31, 2010.

**Recommendation 3:** Verify that a quality assurance review of calculations assessing the structural integrity of CA/T Project concrete viaducts is completed.

## Appendix. Agency Comments

**Response:** Concur. The WJE performed structural calculations when required to assess reportable conditions that were found during the safety review. These calculations were independently checked in accordance with standard engineering practices by WJE. The State and FHWA have conducted a quality assurance check of these calculations. For example, FHWA engineers performed a quality assurance check on the calculations related to the Leverett Bridge concrete pier crack repair plan in October 2008. We will continue to perform quality assurance checks of these design calculations as structural issues arise during completion of the remaining issues.

The original design calculations completed for the structures on the CA/T Project were checked by independent checkers and quality assurance checks were conducted by the State and FHWA structural engineers in accordance with standard engineering practice. In addition, WJE verified calculations of the original CA/T Project designs for the concrete viaduct structures.

Milestones: The FHWA verified that a quality assurance review of calculations assessing the structural integrity of CA/T Project concrete viaducts was completed in August 2008. We consider this action complete and the recommendation should be closed.

**Recommendation 4:** Conduct independent field verification of actions taken since June 2008, when WJE completed its field verifications, to evaluate and resolve higher priority safety risks, including those classified by WJE in the two highest categories.

**Response:** Concur in part. The FHWA's protocol developed specifically for the CA/T Project provides additional, targeted levels of review and oversight above customary requirements. This protocol is in addition to FHWA's regular oversight responsibilities and provided guidance regarding additional levels of review, including field verification where deemed appropriate, as described in the discussion above. To date, 100 percent of the highest priority reportable conditions identified by WJE have been mitigated to remove any immediate safety concerns and have been verified by FHWA in accordance with our protocol.

As for the remaining items in the second highest category, approximately 85 percent have been completed. None of the remaining 15 percent pose an immediate safety concern. Some of these involve highly complex issues and will require additional study and a longer timeframe to address; however, action is in progress to address these issues. All issues are tracked and monitored via our working list, and are included in the Commonwealth's close out actions. Target dates are included and will be tracked until final completion.

Milestones: The FHWA conducts appropriate verification, including field verification on necessary action items and will continue to do so until all items, regardless of the risk they imposed are completed and verified. However, since 100 percent of the highest priority reportable conditions identified by WJE have been mitigated to remove any immediate safety concerns and have been verified by FHWA in accordance with our protocol, we consider this recommendation closed.

**Recommendation 5:** Maintain a complete and accurate working list of all unresolved higher priority safety risks that includes those classified by WJE in the two highest categories as well as milestone dates for monitoring the Commonwealth's progress in addressing unresolved safety risks.

**Response:** Concur. The FHWA has and will continue to maintain a complete and accurate working list of all higher priority safety issues. As stated above, all of the highest priority safety issues have been addressed and mitigated to remove any immediate concerns. To the extent that any additional issues are identified based on ongoing or recently completed analyses, the FHWA will work with the Commonwealth to ensure that such items are appropriately prioritized and tracked through closeout. The FHWA fully intends to track each and every issue, regardless of priority, through completion.

Milestones: Inasmuch as all of the higher priority issues have been identified, prioritized, tracked and addressed, action on this recommendation is considered complete, and this recommendation should be closed. Nonetheless, FHWA intends to track all items, regardless of priority, through completion. On January 25, 2010, the Commonwealth submitted a revised close out plan for all the remaining items, and we will continue to oversee these efforts.

\* \* \*

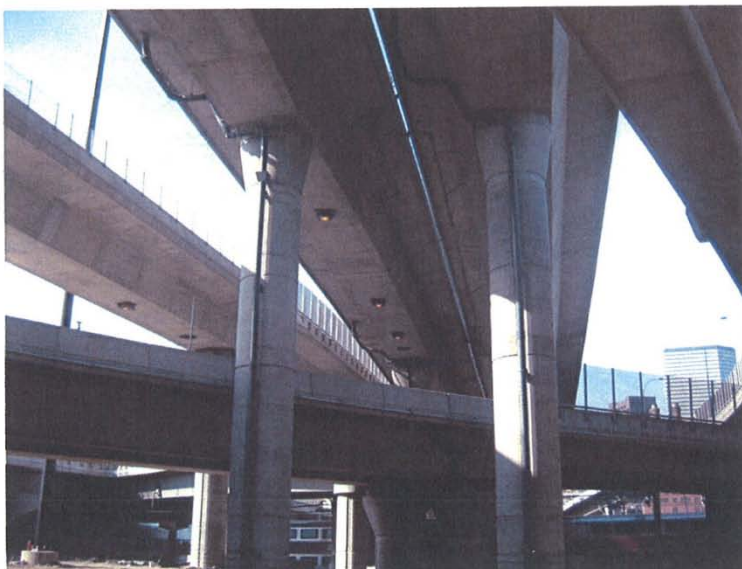
If you have any questions or comments regarding this response, please contact Lucy Garliauskas, Division Administrator, Massachusetts, at 617-494-3567, or John McVann, Director of Project Delivery, at 617-494-2521.



**METROPOLITAN HIGHWAY SYSTEM  
Stem to Stern Safety Review – Phase II**

**Volume II-5 – Concrete Viaducts**

**Commonwealth of Massachusetts**



**Final Report**  
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*Prepared for:*  
**Commonwealth of Massachusetts  
Executive Office of Transportation**

*Prepared by:*  
**Wiss, Janney, Elstner Associates, Inc.**

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**Commonwealth of Massachusetts**

Douglas D. Crampton  
Team Leader

Gary J. Klein  
Project Manager  
Licensed Structural Engineer  
Illinois 4082  
Temporary Permit Massachusetts 2006-119-PE



William J. Nugent  
President  
Licensed Professional Engineer  
Massachusetts 45590



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*Prepared for:*  
**Commonwealth of Massachusetts  
Executive Office of Transportation**

*Prepared by:*  
**Wiss, Janney, Elstner Associates, Inc.**  
330 Pfingsten Road  
Northbrook, Illinois 60062  
847.272.7400 tel | 847.291.9599 fax