National Transportation Safety Board

Washington, DC 20594

Highway Accident Brief

Failure of Overhead Electrical Conduit Support System in Lehigh Tunnel and Subsequent Truck-Tractor Crash, I-476, East Penn Township, Pennsylvania, February 21, 2018

Accident Number:	HWY18FH006
Accident Type:	Impact of truck-tractor semitrailer combination vehicle with broken overhead electrical conduit; subsequent crash
Location:	Interstate 476 (I-476; Pennsylvania Turnpike) southbound, Lehigh Tunnel, East Penn Township, Carbon County, Pennsylvania
Date and Time:	February 21, 2018, 6:02 p.m. eastern standard time
Vehicle:	2017 International truck-tractor in combination with 2017 Strick semitrailer
Fatalities:	1
Injuries:	0

Crash Description

On Wednesday, February 21, 2018, about 6:02 p.m., a 70-year-old male was driving a 2017 International truck-tractor in combination with a 2017 Strick semitrailer, operated by Raymour & Flanigan Furniture, Inc., south on Interstate 476 (Pennsylvania Turnpike) in the right lane inside tunnel no. 2 of the Lehigh Tunnel in East Penn Township, Carbon County, Pennsylvania (figure 1). After traveling about 1,000 feet through the 4,379-foot-long tunnel, the truck-tractor struck a 10-foot-long section of electrical conduit whose support system had failed earlier and was hanging by electrical wires at a reduced height of about 8 feet 10 inches above the right lane.[1] The conduit impacted the vehicle's windshield and struck the truck driver. The combination vehicle continued through the tunnel and, after exiting, moved left and crossed onto the median, where it struck the median W-beam guardrail. The impact redirected the vehicle to the right, across the southbound lanes, and onto the right shoulder of the highway, where the truck-tractor collided with the shoulder W-beam guardrail. The combination vehicle came to rest along the right shoulder, about 5,240 feet after striking the electrical conduit. The truck driver died in the crash. No other injuries or damaged vehicles were reported.

[1] An *electrical conduit* is a metal tube that is used to route electrical wiring through the tunnel, supplying power to the tunnel lights, fans, cameras, and substations.

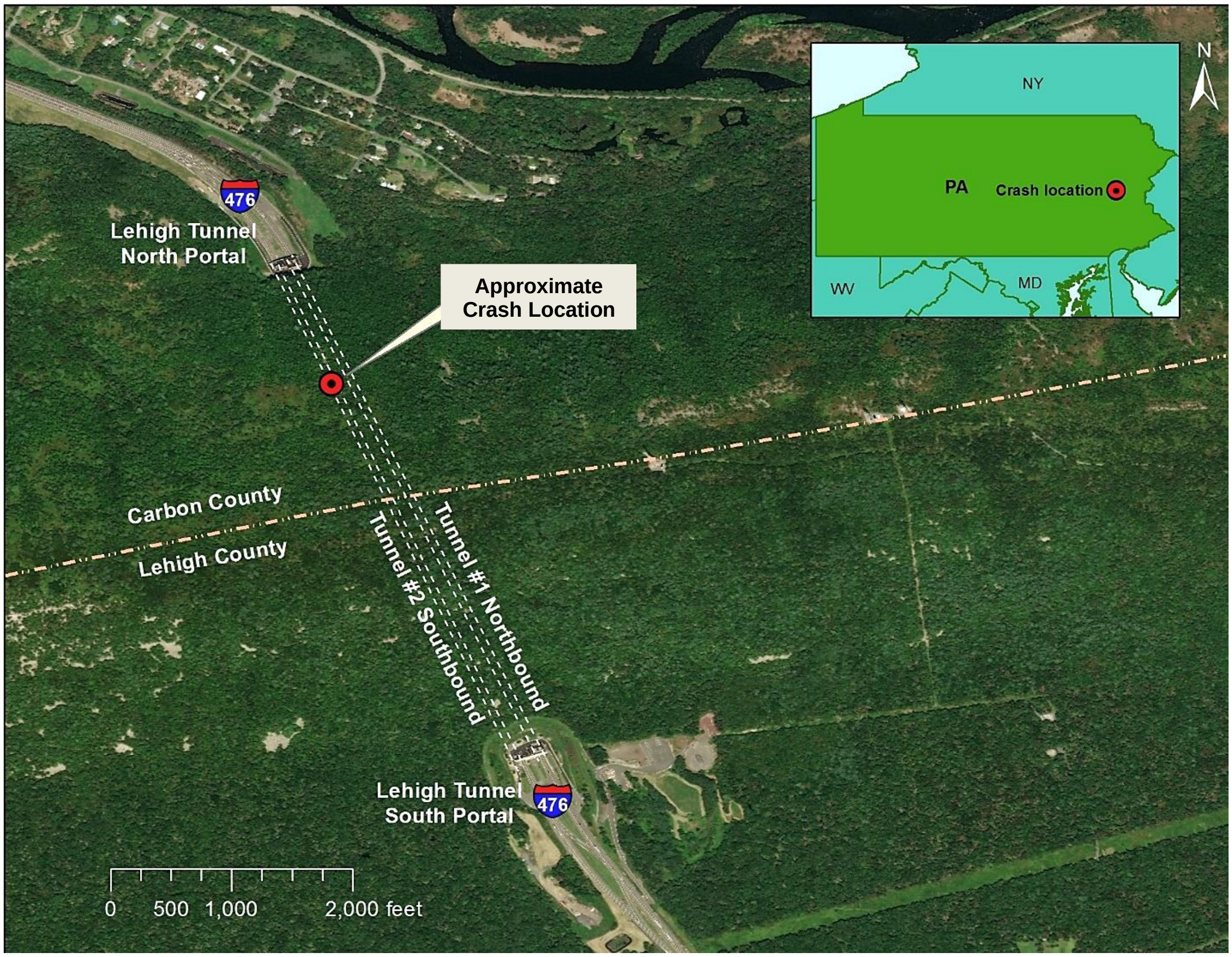

Figure 1. Location of the Lehigh Tunnel (on I-476), East Penn Township, Carbon County, Pennsylvania. The north- and southbound tunnels are indicated by dashed white lines, and the approximate site of the collapse (in southbound tunnel no. 2) is overlaid by a red circle.

Tunnel Information

Overview

The Lehigh Tunnel is a pair of road tunnels between mileposts 70.7 and 71.5 on the Pennsylvania Turnpike that provides north–south passage through the Lehigh Valley. Located about 60 miles northwest of Philadelphia, Pennsylvania, the tunnels geographically cross the county lines of Lehigh and Carbon Counties. Tunnel no. 1 was constructed in 1957 and provides two lanes for northbound traffic. The portal of tunnel no. 1 is rectangular.[2] Tunnel no. 2 (location of impact with conduit) was constructed in 1991 and provides two lanes for southbound traffic. The portal of tunnel no. 2 is oval (figure 2).

[2] A *portal* is the entrance or exit of the tunnel that is exposed to the environment.

Figure 2. North- and southbound portals of the Lehigh Tunnel. (Source: HDR Engineering, Inc., 2016 Tunnel Inspection Report)

The speed limit along I-476 is 65 mph; about 2 miles ahead of the Lehigh Tunnel and inside it, the speed limit is reduced to 55 mph. The traffic lanes inside the tunnels are separated by solid double white pavement markings to prompt motorists to stay in their lane; these double markings also extend between about 1,600 and 2,100 feet at the tunnel entrances and exits. Signs leading up to the tunnels indicate that trucks and buses are to use only the right lane and that all vehicles should turn on their headlights. At the time of the crash, all signage before the tunnel entrances conformed to the Federal Highway Administration's 2009 *Manual on Uniform Traffic Control Devices for Streets and Highways*.

Lehigh Tunnel no. 1 carries two northbound lanes with a roadway width of about 24 feet and a vertical clearance of about 14 feet 11 inches.[3] The tunnel consists of reinforced concrete sidewalls and suspended concrete ceiling slabs with air ducts separating the roadway from the air plenum located above.[4] The concrete ceiling slabs are suspended by ceiling hangers from the tunnel arch and anchored to the tunnel walls at each end. Centrifugal fans are located at both the north and south portals of the tunnel.[5] The concrete side walls and bottoms of the ceiling slabs are

[3] Vertical clearance was measured from the roadway surface to the bottoms of the suspended concrete ceiling slabs.

[4] An *air plenum* in a tunnel is an air compartment or chamber that forms part of the ventilation system.

[5] Centrifugal fans were used to pressurize the air plenum and provide fresh air to the roadway portion of the tunnel below. Air flow could also be reversed for extraction through the same air plenum.

covered with ceramic tiles. The electrical conduits in tunnel no. 1's electrical distribution system rest atop the concrete ceiling slab, not requiring a separate support system (figure 3).[6]

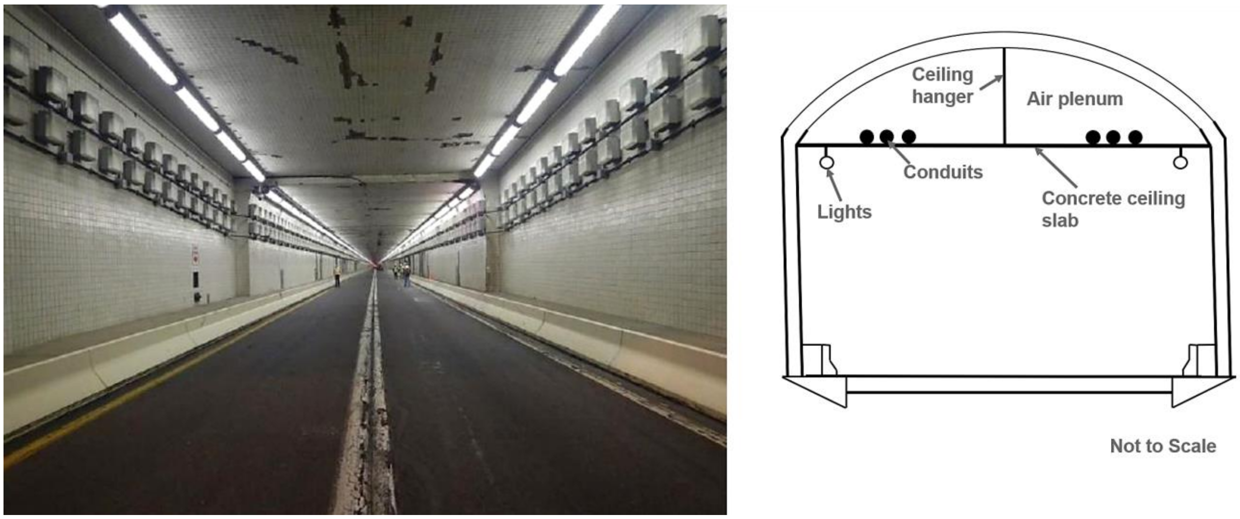

Figure 3. Photo of Lehigh Tunnel no. 1 and detail drawing of its electrical conduits and concrete ceiling slab. (Photo source: HDR Engineering, Inc., 2016 Tunnel Inspection Report)

Lehigh Tunnel no. 2, in which the crash occurred, has two southbound lanes with a roadway width of about 27 feet and a vertical clearance of about 16 feet 6 inches.[7] Unlike tunnel no. 1—in which the electrical distribution system rests atop a concrete ceiling slab—at the time of the crash, tunnel no. 2's electrical conduits were suspended above the center of the roadway and were held in place by transverse horizontal support struts affixed to mechanical anchors at the apex of the tunnel arch (further detail in next section). The tunnel ventilation system consisted of 10 sets of large axial fans, also suspended near the apex of the tunnel arch (figure 4).[8] Before the failure and crash took place, the Pennsylvania Turnpike Commission had already planned and scheduled relocating the electrical distribution system in Lehigh Tunnel no. 2 in response to inspection reports (also see section "Pennsylvania Turnpike Commission Post-Impact Action").

[6] The *electrical distribution system* provides power to the tunnel lights, fans, cameras, and electrical substations.

[7] Vertical clearance was measured from the roadway surface to the bottom of the large axial fans.

[8] The fans were controlled from the portal buildings on the north and south ends of the tunnel, providing longitudinal ventilation in cases of smoke by enabling fresh air to be forced in either direction through the tunnel.

Figure 4. Photo of Lehigh Tunnel no. 2 and detail drawing of its electrical conduit and support system. (Photo source: HDR Engineering, Inc., 2016 Tunnel Inspection Report)

Electrical Conduit and Support System in Lehigh Tunnel No. 2

Configuration. In the area of tunnel no. 2 where the failure occurred, the suspended electrical conduit system consisted of three levels: top, bottom, and side.[9] The top level held about 13 conduits ranging from 1 to 2 inches in diameter; the bottom level held about 9 conduits ranging from 0.75 to 2 inches in diameter; and the side level held 6 conduits ranging from 0.75 to 3 inches in diameter. The conduits, which ran parallel to the roadway, were supported by transverse-oriented support struts attached to mechanical anchors in the tunnel ceiling by $^5/_8$-inch-diameter threaded stainless-steel anchor rods (figure 5). The conduit support struts were typically spaced at about 6-foot intervals throughout the length of the tunnel. Nuts and washers held the struts in place on the anchor rods.

[9] The conduit and support detail was taken from panel no. 112 in the area of impact. The number of conduits and levels of supports decreases from the portal (entrance) toward the center of the tunnel and therefore differs throughout the length of the tunnel.

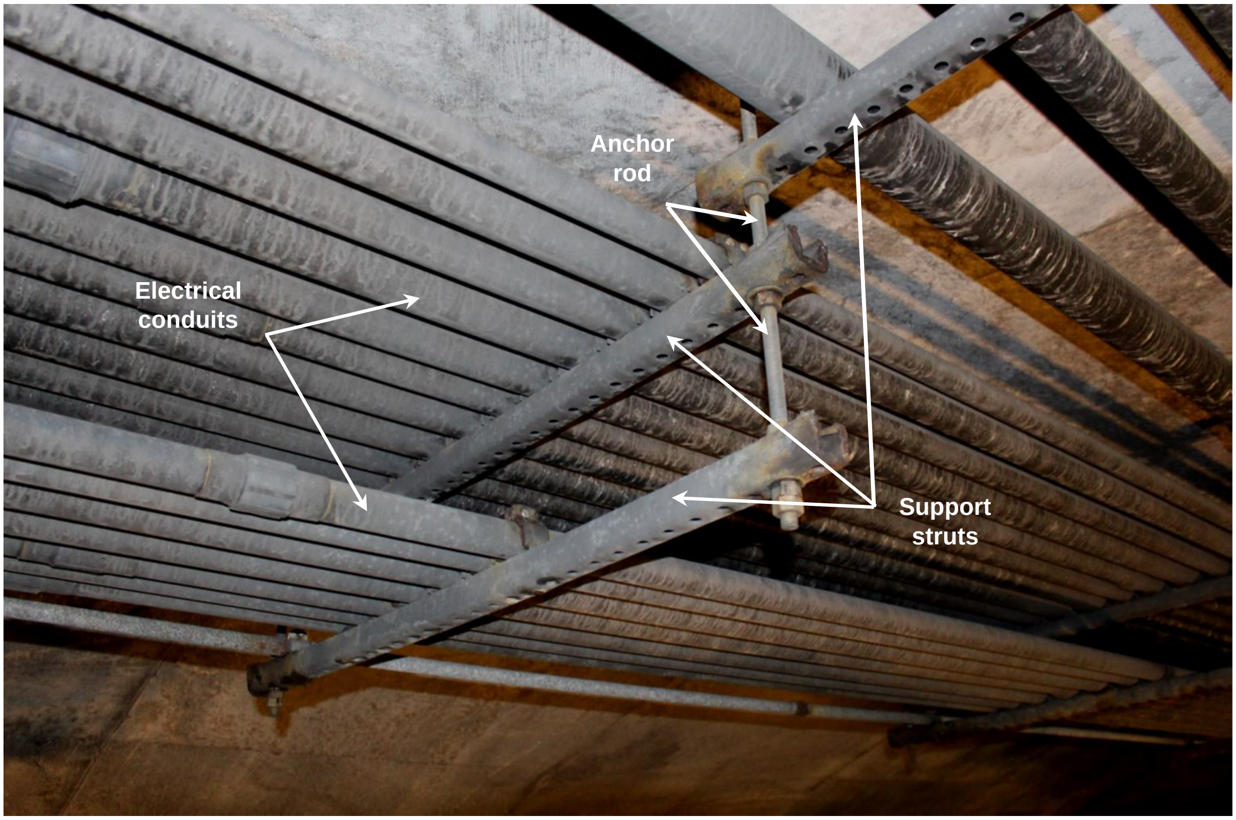

Figure 5. Electrical conduits, support struts, and anchor rod in Lehigh Tunnel no. 2. (Photo taken February 26, 2018, by NTSB investigators)

The struts had an open box-shaped cross-section with holes punched through the bottom of the channel, opposite the open face. As installed, the open face of the channel faced upward. The conduit was held in place on top of the struts by U-shaped pipe straps, where the open end of the straps hooked into small flanges at the open faces of the struts, and the closed end wrapped around the upper side of the conduit. The exterior surfaces of the conduit, straps, and struts were coated with polyvinyl chloride (PVC) as a protective layer against corrosion.

Post-Impact Examination. Investigators from the National Transportation Safety Board (NTSB) and the Federal Highway Administration (FHWA) examined various portions of the electrical conduit and suspension system throughout tunnel no. 2 on February 26, 5 days after the crash. Investigators found corroded, fractured, and missing transverse conduit supports at multiple locations, also photographed by the Pennsylvania State Police on the night of the crash (figure 6).

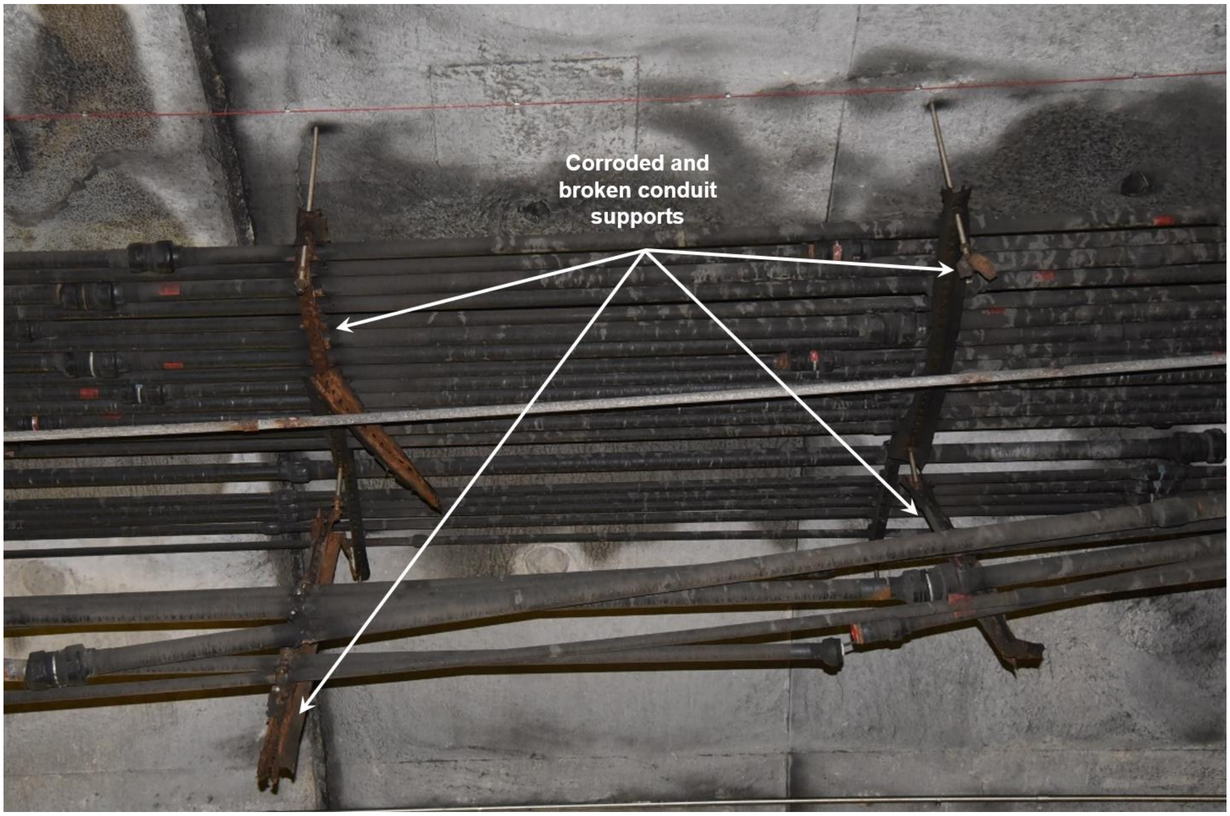

Figure 6. Corroded and broken conduit support struts in the area of the impact. (Source: Pennsylvania State Police; photo taken about 4 hours after the crash)

In the area of impact, nine transverse support struts had failed, for a total collapsed length of about 60 feet. The 10-foot-long section of electrical conduit that struck the truck-tractor's windshield was a portion of the 60-foot-long collapsed section of conduit. Damage to the electrical conduit support system in this section appeared to include both preexisting damage and damage caused by the collision with the truck-tractor. Damage also included detached electrical conduits and wiring that should have been contained inside the electrical conduit but were dangling down to the surface of the roadway. The transverse conduit support struts in and adjacent to the area of the collision were found to be heavily corroded, with most failures occurring inside the horizontal supports near their connections with the threaded vertical anchor rods (figure 7). The anchor rods remained connected to the mechanical anchors in the concrete tunnel liner. None of the mechanical anchors appeared to have been pulled out of the concrete tunnel liner.

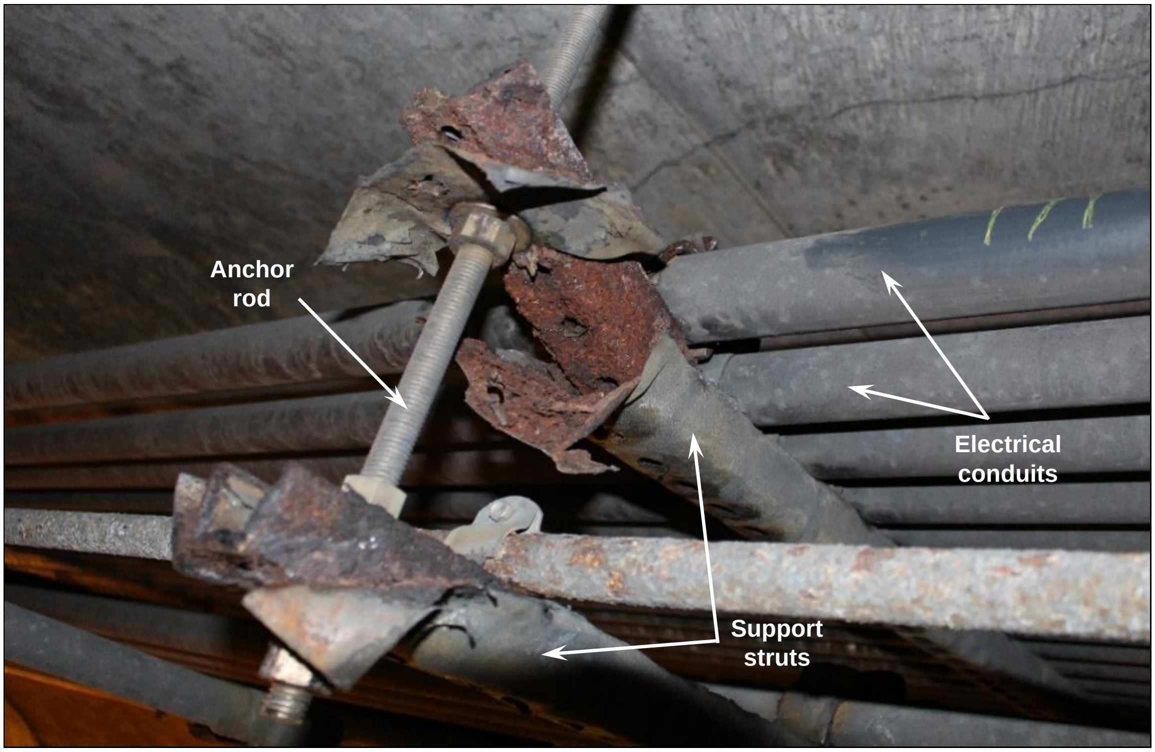

Figure 7. Closeup photo of transverse support struts, which have fractured and failed in areas where their PVC coating separated from the underlying steel surface, leading to corrosion of the steel. (Photo taken February 26, 2018, by NTSB investigators)

Materials Laboratory Examination

Several components of the electrical conduit and conduit support system were examined and analyzed by the NTSB Materials Laboratory. The components included a 4-foot-long section of electrical conduit, five support struts, conduit coupler pieces, pipe straps, and anchor nuts and washers.[10] The examination revealed that the exterior of the pipe straps, support struts, conduit, and conduit coupler pieces had a gray polymer coating that was identified as PVC. Portions of the PVC coating were either missing or separated from the surface, and the underlying metal surfaces were covered with oxides (rust) (figure 8). Many of the exposed metal areas showed section loss from corrosion with missing pieces of underlying metal throughout the components, particularly evident near the anchor point for the support struts.

[10] Investigators cut the 4-foot-long section of electrical conduit from the approximately 10-foot-long section that was found protruding through the top windshield area of the truck-tractor.

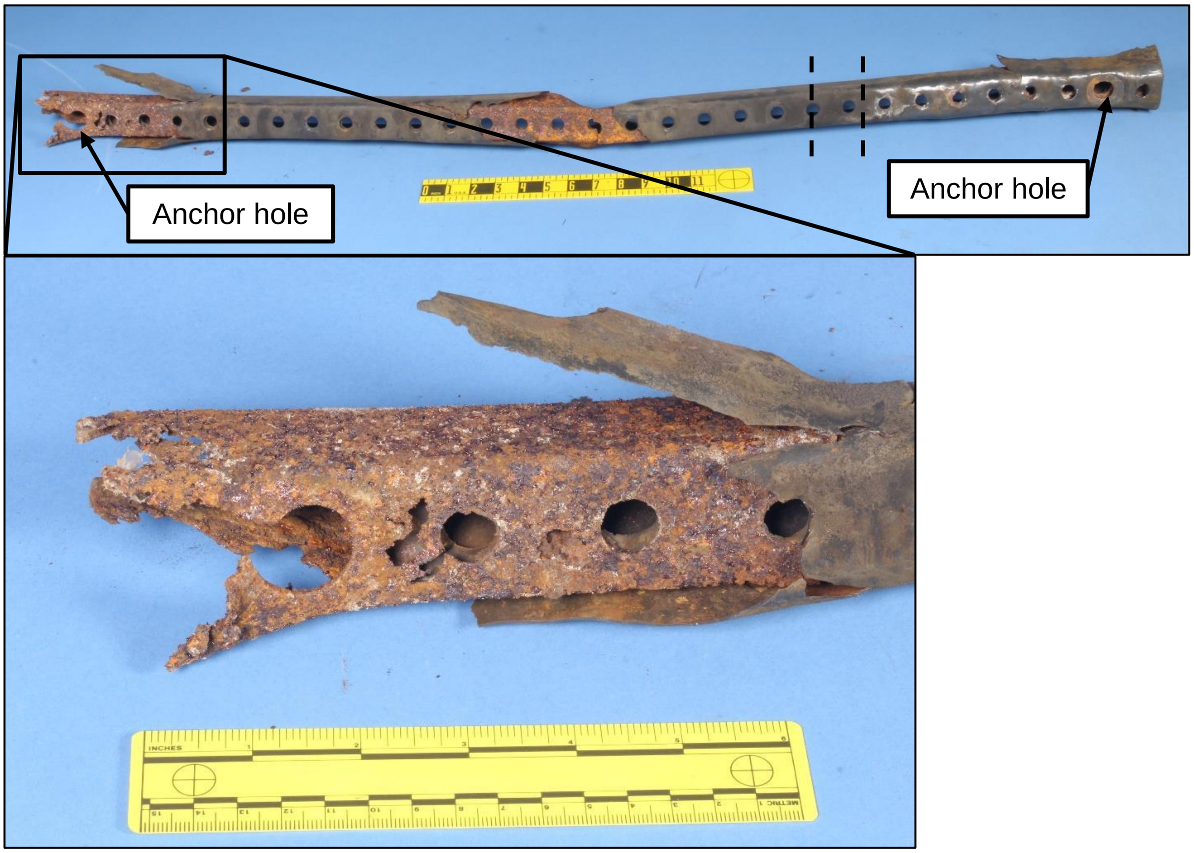

Figure 8. Overall view of a support strut, with a closeup view of the end. The black dashed lines in the upper image indicate the location where investigators made tranverse cuts (also see figure 9). The mid-section of the strut shows an area of corrosion, as well as disbonded and missing PVC coating.

Most of the holes on the bottom of the support struts had a diameter of 0.49 inches. Near the ends of the support struts were larger holes that had been drilled out during the installation process to accommodate the vertical anchor rods. These anchor rod holes, when intact, measured 0.77 inches—more than 0.28 inches in diameter greater than the standard bottom holes.[11] Drilling larger holes in the support struts removed the protective PVC coating and consequently accelerated the corrosion of the struts' underlying steel in the area of the holes. In addition to the compromised PVC coating near the anchor rod holes, the support struts were likely cut from longer sections, resulting in disturbance of the protective PVC coating also at the cut ends. The general pattern of corrosion at the cut ends indicated disbonded/ineffective PVC coating or no PVC coating at all, leading to accelerated corrosion to the exposed metal surfaces in those areas. Other areas where the underlying metal was exposed would also have been susceptible to similar degradation from corrosion. Therefore, the NTSB concludes that the electrical conduit support system in Lehigh Tunnel no. 2 likely failed due to the fracture of extensively corroded PVC-coated steel support struts, allowing the electrical conduit to drop into the path of the oncoming truck-tractor.

[11] Investigators found that many of the anchor rod holes were deformed or fractured along one side of the hole, and therefore were slightly larger than 0.77 inches in diameter.

Galvanic corrosion associated with using stainless-steel anchors in combination with PVC-coated steel supports did not appear to be a factor in the rate of corrosion.[12] The corrosion was generally greatest at the outer ends of the support struts, including the vertical flanges, with lesser corrosion found around the anchor holes.

The underlying steel was susceptible to corrosion from exposure to moisture and salts, and the coating tended to mask the corrosion while simultaneously accelerating it by trapping moisture and other corrosive elements on the steel surface. The transverse cuts that investigators made in the struts (shown by the dashed lines in figure 8) revealed locations where the PVC coating appeared to be visually intact, but on closer examination the coating had partially disbonded from the underlying metal surfaces, which showed rust oxides (figure 9).

Figure 9. Cross-section of strut 16, showing oxidation and PVC disbondment from the metal.

Previous NTSB Tunnel Investigations

The NTSB has previously investigated accidents and crashes across multiple transportation modes involving deteriorated tunnel infrastructure. For example, on January 5, 2005, a CSX train derailed in Glencoe, Kentucky, after colliding with debris from a collapsed section of CSX's Eagle Tunnel no. 3, injuring two people.[13] Previous annual inspections identified the tunnel's deteriorating section and required monitoring during each annual inspection. The NTSB determined that the probable cause of the Glencoe derailment was the collapse of the tunnel due to CSX Transportation's failure to repair the previously identified deteriorating section of the tunnel.

[12] *Galvanic corrosion* (also called *dissimilar metal corrosion*) is corrosion damage that occurs when two (or more) dissimilar metals are coupled in a corrosive electrolyte, such as water. When a galvanic couple forms, one of the metals corrodes faster than it would by itself, while the other corrodes slower than it would alone.

[13] *Railroad Accident Brief, Glencoe, Kentucky, January 5, 2005*, NTSB/RAB-07/02. Washington, DC: National Transportation Safety Board, 2007.

In addition, on July 10, 2006, in Boston, Massachusetts, a section of suspended concrete ceiling inside an Interstate 90 connector tunnel became detached and fell onto a vehicle, resulting in one fatality and one injury.[14] One of the resultant NTSB safety recommendations (H-07-17) asked the FHWA to seek legislation to establish a mandatory tunnel inspection program, similar to the National Bridge Inspection Program. In response to Safety Recommendation H-07-17, the FHWA established the National Tunnel Inspection Program and corresponding manuals and guides for biennial inspections beginning in 2015. Safety Recommendation H-07-17 was classified "Closed—Acceptable Action" on January 11, 2016.

National Tunnel Inspection Standards

Inspection Criteria for Electrical Conduit Support Structures

As part of the National Tunnel Inspection Program, the FHWA developed the *National Tunnel Inspection Standards* (NTIS); the *Tunnel Operations, Maintenance, Inspection, and Evaluation* (*TOMIE*) *Manual*; and the *Specifications for the National Tunnel Inventory* (SNTI).[15] The *TOMIE Manual* provides uniform and consistent guidance related to the operation, maintenance, inspection, and evaluation of tunnels. The NTIS contain the regulatory requirements for the tunnel inventory and inspection program and establish a minimum inspection frequency of 24 months for routine inspections, beginning in 2015. The inspection criteria, as specified in the *TOMIE Manual*, include inspecting miscellaneous structural elements, such as brackets and supports that are mounted against the ceiling or walls. These brackets could be used to support a wide variety of equipment or systems, including but not limited to ventilation fans, closed-circuit television cameras, traffic signs, over-height detection systems, and electrical distribution systems. The inspection criteria state that the brackets and support elements should be "check[ed] for corrosion, dissimilar metals, cracks, buckles and kinks. Dissimilar metals may promote corrosion at accelerated rates when not sufficiently insulated from stray electrical currents. Particular attention should be given to bolts in regions where leakage occurs to evaluate any section loss."

Inspection Findings, Classification, and Required Action

As specified in the NTIS and the *TOMIE Manual*, formal summaries of inspection findings for each element and system, as well as condition state ratings, are used to characterize the condition of tunnel components. The *TOMIE Manual* provides guidance for documenting and reporting tunnel inspection findings. Findings are classified into three levels depending on the severity of the condition, each level having a different reporting requirement and urgency to remediate the finding: (1) critical finding, (2) priority repair, and (3) routine repair.

A critical finding refers to conditions that require immediate action and should be immediately reported to the program manager and the tunnel owner. The *TOMIE Manual* also states that critical findings are to be reported to the FHWA within 24 hours and that the FHWA

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[14] *Ceiling Collapse in the Interstate 90 Connector Tunnel, Boston, Massachusetts, July 10, 2006*, NTSB/HAR-07/02. Washington, DC: National Transportation Safety Board, 2007.

[15] (a) Title 23 *Code of Federal Regulations* 650.501 to 650.517; (b) *Tunnel Operations, Maintenance, Inspection, and Evaluation (TOMIE) Manual*, Federal Highway Administration. Report Number: FHWA-HIF-15-005, July 2015, p. 4–66; (c) *Specifications for the National Tunnel Inventory*, Federal Highway Administration. Report Number: FHWA-HIF-15-006, July 2015.

should be updated regularly until the issue is resolved. Annually, the FHWA should be provided with a summary report of the status of the identified critical findings and the unresolved findings. Priority repair refers to conditions in which further investigation, design, and implementation of interim or long-term repairs should take precedence over other scheduled work. Lastly, routine repair refers to conditions requiring further investigation or remedial work as part of a scheduled maintenance program, scheduled project, or routine facility maintenance.[16]

In addition to the *TOMIE Manual*, the SNTI provide "condition state" ratings from 1 to 4 for tunnel elements, with 1 being "good," 2 "fair," 3 "poor," and 4 "severe." The SNTI definitions for condition state ratings of electrical distribution system elements and condition states are summarized in table 1.[17]

Table 1. Element specification and condition state definitions for electrical distribution systems. (Source: SNTI)

Electrical Distribution System	
Unit of Measure Each	Element Number 10500
Specification	Commentary
Record this element for all electrical distribution systems. The electrical distribution system consists of the electrical equipment, wiring, conduit, and cable used for distributing electrical energy from the utility supply (service entrance) to the line terminals of utilization equipment. The total quantity for electrical distribution system is the sum of all the electrical distribution systems.	The electrical distribution system may include the following subcomponents: Switchgear, Unit Substations, Switchboard, Motor Control Centers, Starters, Transformers, Transfer Switches, Panelboards, Conduits and Raceways, and Electrical Outlets/Receptacles. For this element, a separate electrical distribution system is considered to be one system. Tunnels with twin bores may have separate electrical distribution systems and would be considered as two.

Condition State Definitions

Defect	Condition State 1	Condition State 2	Condition State 3	Condition State 4
System Condition	The system is in good condition – no notable distress.	The system is in fair condition – isolated breakdowns or deterioration.	The system is in poor condition – widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants evaluation to determine the effect on serviceability of the element or tunnel or the evaluation has determined there is an impact on the serviceability of the element or tunnel.

[16] For more detail about the classification levels, see the Tunnel Factors Factual Report in the docket for this investigation.

[17] *Specifications for the National Tunnel Inventory* (see p. 3-94 for Electrical Distribution System Element Number 10500).

Lehigh Tunnel Inspections and Maintenance History

NTSB investigators reviewed previous routine inspections of the Lehigh Tunnel that contractors with the Pennsylvania Turnpike Commission completed in 2012 (prior to the NTIS specification guidance) and 2016. Investigators also reviewed the 2018 routine inspection, which occurred 6 months after the crash. The 2012 inspection of the tunnels was conducted between September and November by contractors from C.S. Davidson. The final report, submitted in August 2013, documented defects and corrosion in the electrical distribution system, noting for example in tunnel no. 2, "multiple areas with corrosion coming through the PVC coating and some conduits are separated."[18] The report also specified the location in tunnel no. 2 of broken conduits, missing conduit covers, conduits needing additional supports, and broken or missing junction box covers. Of note, the report referenced a 2006 routine inspection that also documented the large quantity of broken junction boxes and separation of conduits in the Lehigh Tunnel and noted that no changes had been made since then. The 2012 inspection report classified the defects and corrosion in the electrical distribution system as "priority repair items" and identified specific locations for repairing or replacing components.

In 2015, the Pennsylvania Turnpike Commission began requesting proposals for designing and installing a new electrical distribution system in tunnel no. 2. The work was to include removing the system from directly above the roadway and relocating it closer to the outside edges of the tunnel (also see section "Pennsylvania Turnpike Commission Post-Impact Action").

Finally, the last in-depth inspection of the Lehigh Tunnel precrash took place in 2016 as part of the first biennial inspection required under the NTIS program. HDR Engineering, Inc. conducted the inspection; a brief summary of the noted deficiencies in the electrical distribution system is provided in table 2.

Table 2. Some of the noted deficiencies in the Lehigh Tunnel electrical distribution system in 2016, lifted from HDR Engineering, Inc.'s report. (Note: The routine repair items in tunnel no. 1 pertained to some conduit clamps/supports that were either broken, detached, corroded, or missing in the tunnel and air plenum. An example would be missing anchor bolts for the closed-circuit television mounting supports.)

Area	Location	Deficiency
Priority Repair Items		
Electrical	Tunnel no. 1 and tunnel no. 2	Repair or replace corroded, broken or separated conduits, junction boxes and conduit bodies in the tunnel.
Routine Repair Items		
Electrical	Tunnel no. 1 and tunnel no. 2	Repair or replace the broken, cracked or missing conduit supports in the tunnel.

[18] *In-Depth Inspection of the Lehigh Tunnels 2012–2013, Pennsylvania Turnpike Commission, Field Inspection Dates: September 2012 – November 2012, Appendix E, Electrical Inspection Findings*, C.S. Davidson, Inc.; Final Report Submission Date August 2013.

With respect to tunnel no. 2, the 2016 inspection report noted "missing conduit supports throughout the tunnel," and several photographs showed the condition of the electrical distribution system (figure 10).[19]

Figure 10. Photo showing a section of missing conduit support in Lehigh Tunnel no. 2. (Source: HDR Engineering, Inc., 2016 Tunnel Inspection Report)

NTSB investigators obtained the report of the second biennial inspection that was conducted after the crash.[20] HDR Engineering, Inc. was the contractor this time as well, and its report made the same observations regarding the Lehigh Tunnel's electrical distribution system as did the 2012 and 2016 inspection reports. There was no change to the classifications—the corroded and failing conduit members were classified as both "priority repair items" and "routine repair items"—nor was there a change in the overall rating of the electrical distribution system, deemed to be in Condition State 2 ("fair").

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[19] *2016 In-Depth Inspection of the Lehigh Tunnels, Pennsylvania Turnpike Commission, I-476 Northbound & I-476 Southbound Carbon and Lehigh Counties*, HDR Engineering, Inc.; February 14, 2017.

[20] *2018 Routine Inspection of the Lehigh Tunnels, Pennsylvania Turnpike Commission, I-476 Northbound & Southbound I-476 Carbon and Lehigh Counties*, HDR Engineering, Inc.; February 5, 2019.

Pennsylvania Turnpike Commission Post-Impact Action

In addition to immediately repairing and re-suspending the electrical conduit system in the area of the failure, about a week after the collision, the Pennsylvania Turnpike Commission replaced an additional 16 conduit support struts and one broken anchor rod. The replacement support struts were made from uncoated stainless steel. The Pennsylvania Turnpike Commission assessed the electrical conduit and support system after these repairs were completed on February 28, 2018, and informed the NTSB by e-mail that no additional immediate repairs were needed before the already planned upgrade of the electrical system.

Less than a week before the failure and collision, on February 15, 2018, the chief engineer of the Pennsylvania Turnpike Commission signed a contract for installing a newly designed electrical distribution system in Lehigh Tunnel no. 2 and replacing the electrical distribution system in tunnel no. 1. The construction contract was awarded to Mosites Construction & Development Company, and part of the work for tunnel no. 2 specified placing the new electrical distribution system toward the outside edges of the tunnel as opposed to having it directly above the center of the roadway.[21] The work in tunnel no. 2 began in April 2018 and was completed on October 31, 2018. Figure 11 shows before and after photos of the electrical distribution system replacement in tunnel no. 2.

Figure 11. Before (left) and after (right) replacement of the electrical distribution system in Lehigh Tunnel no. 2, relocated from the top center of the tunnel to the edges. (Source: Pennsylvania Turnpike Commission)

Discussion

NTSB investigators reviewed the *TOMIE Manual*, the SNTI, and the training material for the week-long training course that tunnel inspectors are required to complete before going on site for inspections. Nowhere in any of these documents could investigators find guidance indicating that significant corrosion in overhead electrical distribution systems would constitute either a

[21] The construction award to Mosites was also listed on the Pennsylvania Turnpike Commission's meeting agenda for March 6, 2018.

"critical finding" (in the *TOMIE Manual*) or a "Condition State 4" (in the SNTI).[22] The SNTI do provide guidance with respect to protective coating in preventing or inhibiting steel corrosion; however, that guidance is applicable only to structural tunnel elements.[23] The NTSB concludes that the FHWA's *TOMIE Manual*, its SNTI, and its tunnel inspection training courses did not identify significant corrosion in nonstructural tunnel elements, such as overhead electrical distribution systems, as a critical finding or "Condition State 4" that required immediate action.

Routine tunnel inspections since 2006 revealed numerous conduit support struts that exhibited extensive corrosion, with some support struts missing, some broken, and others being held up only by the conduit that the struts themselves were designed to support. Subsequent inspection reports made clear that no maintenance changes had been made since the previous inspection. Inspections of tunnel no. 2, conducted after the National Tunnel Inspection Program was implemented, documented the deficiencies in the electrical conduit support system as "priority repair items"—conditions in which further investigation, design, and implementation of interim or long-term repairs should take precedence over other scheduled work. Therefore, the NTSB concludes that although the steps taken by the Pennsylvania Turnpike Commission to replace the overhead electrical distribution system in Lehigh Tunnel no. 2 before the crash were consistent with available guidance, the Commission did not sufficiently prioritize repair of the previously documented deficiencies in the system to protect the safety of the motoring public traveling on the roadway below. The NTSB recommends that the FHWA notify tunnel owners of the circumstances of this crash, emphasizing the importance of inspecting, documenting, and promptly repairing significant corrosion in nonstructural tunnel elements located above roadways. The NTSB also recommends that the FHWA revise its *TOMIE Manual*, its SNTI, and its inspection training courses to classify significant corrosion in nonstructural tunnel elements, such as overhead electrical distribution systems, as a critical finding that requires immediate action.

Conclusions

Findings

1. The electrical conduit support system in Lehigh Tunnel no. 2 likely failed due to the fracture of extensively corroded polyvinyl chloride-coated steel support struts, allowing the electrical conduit to drop into the path of the oncoming truck-tractor.

2. The Federal Highway Administration's *Tunnel Operations, Maintenance, Inspection, and Evaluation Manual*; its *Specifications for the National Tunnel Inventory*; and its tunnel inspection training courses did not identify significant corrosion in nonstructural

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[22] *Significant corrosion* in the electrical distribution system could be described as the negative effect on the strength or serviceability of the element, including missing or visibly deformed conduit supports, separated conduit, exposed wiring, and/or conditions that interfere with traffic.

[23] *Structural elements* apply to the structural integrity of the tunnel, including the tunnel liners, roof girders, columns, piles, cross passageways, interior walls, and portals that prevent collapse of the tunnel. *Nonstructural elements*, which include the support mechanisms that carry the electrical distribution system, apply to aspects such as ventilation, lighting, fire suppression, communications, monitoring, traffic signals, emergency response, or other traffic safety components.

tunnel elements, such as overhead electrical distribution systems, as a critical finding or "Condition State 4" that required immediate action.

3. Although the steps taken by the Pennsylvania Turnpike Commission to replace the overhead electrical distribution system in Lehigh Tunnel no. 2 before the crash were consistent with available guidance, the Commission did not sufficiently prioritize repair of the previously documented deficiencies in the system to protect the safety of the motoring public traveling on the roadway below.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the East Penn Township, Pennsylvania, crash was the failure of the electrical conduit support system in Lehigh Tunnel no. 2 due to long-term corrosion, which resulted in displacement of the electrical conduit into the travel path of the truck-tractor. Contributing to the crash was the Federal Highway Administration's insufficient guidance regarding tunnel maintenance and inspection, which did not sufficiently prioritize the repair of significant corrosion in nonstructural tunnel elements located above the roadway, and which led to the Pennsylvania Turnpike Commission's delay in repairing previously documented deficiencies in the support system.

Recommendations

To the Federal Highway Administration:

Notify tunnel owners of the circumstances of this crash, emphasizing the importance of inspecting, documenting, and promptly repairing significant corrosion in nonstructural tunnel elements located above roadways. (H-20-22)

Revise your *Tunnel Operations, Maintenance, Inspection, and Evaluation Manual*; your *Specifications for the National Tunnel Inventory*; and your inspection training courses to classify significant corrosion in nonstructural tunnel elements, such as overhead electrical distribution systems, as a critical finding that requires immediate action. (H-20-23)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Report Date: August 4, 2020

For more details about this crash, visit the NTSB public docket and search for NTSB accident ID HWY18FH006. Accident dockets include such information as police reports, photographs, driver and witness statements, data on previous crashes, highway engineering reports, and timing of traffic signals.
