October 9, 2024

HIR-24-07

High-Speed Vehicle Collision with Workers in a Highway Work Zone

Woodlawn, MD
March 22, 2023

On Wednesday, March 22, 2023, about 12:36 p.m., six highway workers were struck by a passenger vehicle in a work zone along northbound (inner loop) Interstate 695 near Woodlawn, Maryland.[1] The work zone was a long-term closure of the left shoulder, and all six workers were behind a series of concrete barriers in place to isolate workers from vehicles operating in the travel lanes. The crash occurred when a 2017 Acura TLX, traveling at a vehicle-recorded speed of 121 mph, moved from the right lane, across the two middle lanes and toward the left lane, and struck a 2017 Volkswagen Jetta, which was traveling at a vehicle-recorded speed of 122 mph. The Acura driver lost control, and the vehicle entered the work zone through an opening in the concrete barrier that was intended for work zone access. After striking the center concrete median barrier inside the work zone, the vehicle began to overturn. While overturning, the Acura struck construction materials and equipment and the six workers, who were standing in the work zone. The Volkswagen made a controlled stop in the left lane. All six workers were fatally injured, and the Acura driver was seriously injured.

[1] (a) In this report, all times are eastern time. (b) Visit ntsb.gov to find additional information in the public docket for this NTSB investigation (case no. HWY23FH010). Use the CAROL Query to search safety recommendations and investigations.

Figure 1. Postcrash view of the work zone and the opening in the concrete barriers through which the Acura entered. (Source: Maryland State Police; annotations by NTSB)

Location	Northbound Interstate 695, inner loop, about 0.2 miles north of the Dogwood Road overpass, Woodlawn, Maryland
Date	March 22, 2023
Time	12:36 p.m. eastern daylight time
Involved vehicles	2 (2017 Acura TLX, 2017 Volkswagen Jetta)
Involved people	8
Injuries	6 fatal (highway workers), 1 serious injury (Acura driver), 1 uninjured (Volkswagen driver)
Weather	Dry, clear, and daylight
Roadway information	Limited-access interstate highway, with 4 northbound and 4 southbound 12-foot-wide travel lanes, and 12-foot-wide right and left shoulders. Long-term work zone configuration involved a closure of the left shoulder and isolation of the work area by a continuous linking of prefabricated concrete barriers.

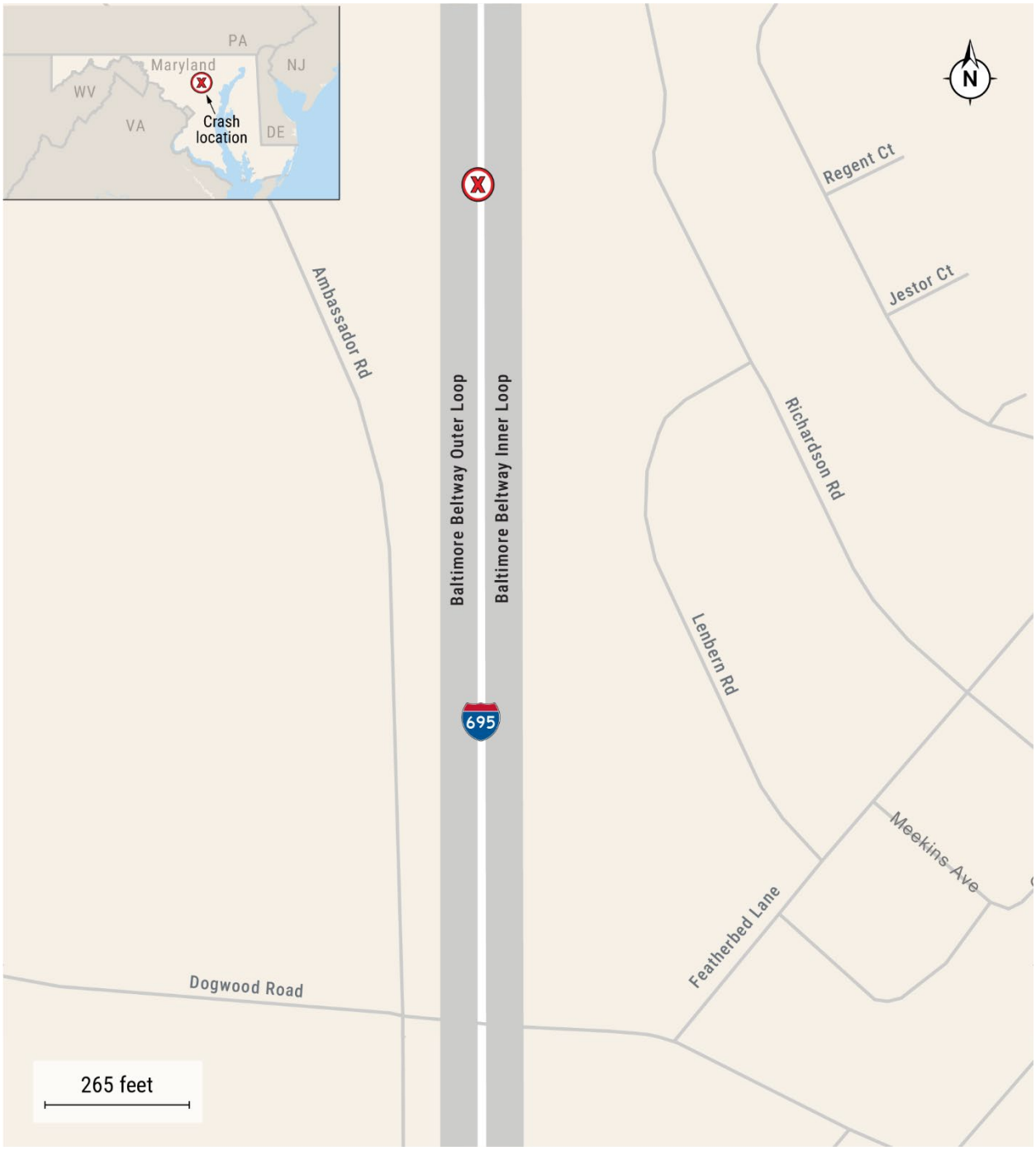

Figure 2. Crash location on I-695.

1 Factual Information

1.1 Background

Interstate 695 (I-695) is a 51.5-mile-long auxiliary interstate highway that encircles the city of Baltimore and is known locally as the Baltimore Beltway. The directional heading for this crash is designated as northbound, and the crash occurred on the inner loop roadway. At this location, the I-695 inner loop comprises four travel lanes, each measuring about 12 feet wide. Left and right paved shoulders exhibited similar 12-foot widths and ran contiguous with the travel lanes. The posted speed limit is 55 mph.

The crash occurred in a highway work zone that had been established for a long-term highway construction project. The entire project covered about 21 miles of the I-695 inner and outer loops between Interstate 70 and Maryland Route 43. The project objective was to manage congestion by designing and upgrading the median (left) shoulders for part-time traffic use. In general, the project called for upgrading the pavement surface and drainage and installing overhead electronic signage to control lane use. At the time of the crash, the phase of work involved trenching and installing precast 48-inch-long polymer concrete drains along the outer edge of the median shoulder. The Maryland State Highway Administration (MDSHA) was the project owner and had oversight responsibility. The primary contractor—Concrete General, Incorporated—was responsible for design and construction in compliance with appropriate requirements and standards.

The work zone configuration involved closing the median (left) shoulder and isolating the work area by a continuous linking of prefabricated concrete barriers. The barrier system is designed to prohibit motor vehicles from entering work areas and protect workers and construction elements from vehicle traffic. The barrier system design, component requirements, and work zone configuration required adherence to several state and federal specifications and standards.[2] Additional requirements and information were referenced on the temporary traffic control plan (TTCP) sheets

[2] Such specifications and standards included, but were not limited to: Maryland Manual on Uniform Traffic Control Devices for Streets and Highways; Maryland SHA Book of Standards for Highways, Incidental Structures and Traffic Control Applications; American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (AASHTO 2016); National Cooperative Highway Research Program (NCHRP) Report 350: Recommended Procedures for the Safety Performance Evaluation of Highway Features; and AASHTO *Policy on Geometric Design of Highways and Streets* (AASHTO 2018). In addition, the barrier required a *Manual for Assessing Safety Hardware* (MASH) Test Level 3 (TL-3) certification, which generally requires impact testing using a passenger vehicle (2,420 lbs) and light truck (5,000 lbs) at a speed of 62 mph and up to a 25° angle.

in the project plan documents. For work zone access and per the project construction plan, the contractor provided openings in the barrier system. The barrier openings were placed at the contractor's discretion as noted in the TTCP.

The crash occurred at the third inner loop opening from the beginning of the work zone. Separation distance between the first five to six openings was about 0.5–0.6 miles. The length of the barrier opening where the crash occurred was estimated to be 149 feet. The upstream end (facing oncoming traffic) of the barrier opening required the installation of a crash-attenuating end-treatment.[3] The work zone area did not intrude into the roadway travel lane, and the posted speed limit was unmodified at 55 mph.

1.2 Event Sequence

The NTSB obtained three videos that showed the events leading up to the crash. The first was obtained from a third party that had recorded the live video feed from a Maryland Department of Transportation (MDOT) camera positioned along I-695 facing northbound. The remaining two videos were from dash cameras from motorists traveling north on I-695. In addition, both involved vehicles were equipped with an event data recorder that recorded data associated with the crash along with precrash information.

Leading up to the crash, the videos showed that two vehicles—a 2017 Acura TLX and a 2017 Volkswagen Jetta—were traveling north on I-695. About 5 seconds before the crash, the Volkswagen—operated by a 20-year-old male—was traveling in the left lane at a vehicle-recorded speed of 122 mph. The Acura—operated by a 54-year-old female—was traveling in the right lane at a vehicle-recorded speed of 121 mph. As the vehicles continued north, the Acura began a leftward lane change across the two middle lanes and toward the left lane.

As the Acura transitioned into the left lane, the vehicle's left rear struck the Volkswagen's right front. That contact redirected the Volkswagen to the left, where the vehicle's left-front tire and lower left-front corner contacted the concrete barrier protecting the work zone. As the Volkswagen engaged with the barrier, the Acura began an impact-induced counterclockwise rotation around the front of the Volkswagen. The Acura lost control, began to rotate, and entered the work zone through the opening in the concrete barrier. The Volkswagen continued north in the left lane and made a controlled stop. Figure 3 depicts the crash sequence and postcrash path of travel.

[3] Per Maryland standards, the end treatment consisted of a two-sided, non-gating, type-E energy-absorbing system certified to MASH TL-3 standards.

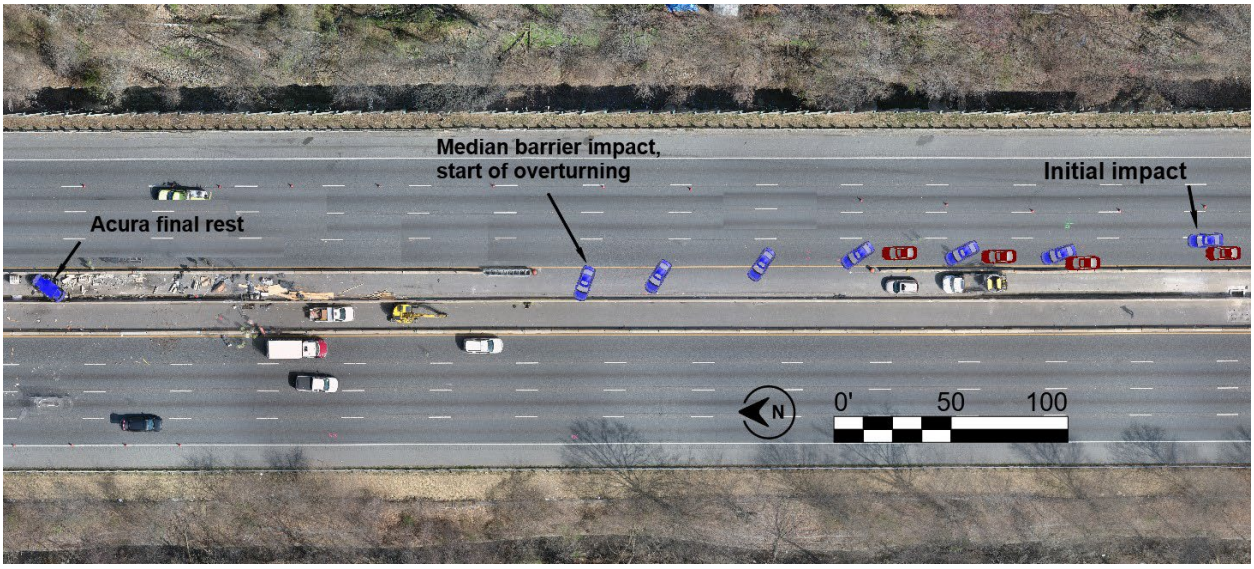

Figure 3. Postimpact travel path for the Acura (shown as the blue vehicle) relative to the physical evidence as overlaid on an orthomosaic image of the scene. (Source image: Maryland State Police; annotations by NTSB)

The front of the Acura struck the center median barrier; the vehicle then began to overturn. As the Acura continued through the work zone, it struck a large metal toolbox and three pallets of prefabricated polymer concrete trench drain, each weighing about 2,240 pounds and spaced about 35 feet apart. Each pallet contained eight sections of drain. The Acura's movement through the work zone broke and displaced the eight sections on the first two pallets and four of the sections on the third pallet. The vehicle's final rest position was about 525 feet from the point of impact with the Volkswagen.

As it overturned, the Acura struck six workers who were standing in the work zone. The final rest position for three of the struck workers was on the ground between the left shoulder edge and the median barrier, near the final rest position of the Acura. The remaining three workers were located on the ground across the median barrier along southbound I-695, northwest of the Acura's final rest position. All six workers sustained fatal injuries. The Acura driver, who was restrained by her seat belt, sustained serious injuries. The Volkswagen driver was restrained by his seat belt and was not injured. The Acura sustained several impacts causing extensive damage to the entire vehicle. The Volkswagen sustained minor contact damage consistent with being struck by the Acura and impacting the concrete barrier.

Figure 4. Postcrash damage to the 2017 Acura TLX (left) and the 2017 Volkswagen Jetta (right).

1.3 Additional Information

1.3.1 Driver information

1.3.1.1 General

Neither driver involved in this crash had any previous crash history in the past 5 years, and their driving records showed no prior traffic violations. According to the Maryland State Police, no evidence indicated that the drivers were acquainted and neither driver was cited for speed contest (that is, racing). The driver of the Volkswagen had no indication of impairment—he was not administered postcrash toxicological testing by law enforcement and did not receive postcrash medical care.

1.3.1.2 Acura driver toxicology and medical history

The Maryland State Police Forensic Sciences Division performed toxicology testing of blood collected from the Acura driver at 5:12 p.m. on the crash date. No alcohol was detected. The blood specimen was reported to be positive for tetrahydrocannabinol (THC) and the THC metabolites hydroxy-THC and carboxy-THC. At the NTSB's request, the Federal Aviation Administration (FAA) Forensic Sciences Laboratory performed toxicological testing of blood remaining from the Maryland State Police test specimen. FAA testing detected delta-9-THC at 5.5 ng/mL, 11-hydroxy-THC at 3.5 ng/mL, and carboxy-delta-9-THC at 73.5 ng/mL. Cyclobenzaprine was detected at a low level.[4] Norcyclobenzaprine (an active metabolite of cyclobenzaprine) was detected at 1 ng/mL.

[4] Cyclobenzaprine is a prescription medication that acts on the central nervous system to produce muscle-relaxing effects to relieve musculoskeletal pain. The drug commonly causes drowsiness.

The Acura driver was admitted to a hospital after the crash. She was alert and oriented when the hospital trauma team initially assessed her. She reported to her hospital providers that she had experienced a seizure while driving which had caused her crash. A neurologist evaluated her during her hospital stay and concluded that it was unclear whether she had a seizure disorder, noting that some symptoms she reported may have been sleep-disorder related. Her medical history also included chronic pain treated with medications. A note from a hospital pain management consultation documented that she held a medical marijuana card and routinely smoked marijuana three times per day.

1.3.2 Work zone procedures and setup

Workers were assigned to specific work areas daily. The work zone location in the median required daily coordination with all personnel working in the area. Space constraints restricted personnel to their assigned areas, including during break periods. The involved workers were in their assigned work area at the time of the crash. The contractors and MDSHA staff conducted the following routine procedures and inspections:

- Contractor management/foremen conducted a daily safety assessment;
- Foremen held a daily pre-work briefing with crews;
- The project superintendent inspected the site daily and held daily conversations with the MDSHA project engineer to discuss work activities;
- The contractor and MDSHA staff conducted daily maintenance of traffic inspections; and
- MDSHA district office quality assurance inspectors visited the site once per week, on average.

The NTSB's review of the daily reports identified no significant issues in the days before the crash. In addition, the project superintendent and all foremen working onsite that day held certifications in Maryland DOT Temporary Traffic Control Manager and Occupational Safety and Health Administration (OSHA) 30-hour safety and health programs. The struck workers and most of the contractor's hourly employees had received the OSHA 10-hour safety and health training.

The NTSB's review of the work zone setup noted the absence of one "Shoulder Closed" sign and multiple "Trucks Entering Highway" signs before and at the work

zone openings.[5] The contractor told the NTSB that the missing "Shoulder Closed" sign had recently been struck by a vehicle and was scheduled for replacement. Although the "Trucks Entering Highway" signs were not present at the time of the crash, the contractor noted that they would be displayed using portable sign stands when the openings were being accessed by vehicles.

Imagery of the crash location after the event showed that a truck-mounted attenuator protection vehicle was parked in the work zone south of the barrier opening but was not positioned to block the opening. MDSHA and the contractor reported that truck (and trailer)–mounted attenuators have specific applications and are used on this project when temporary lane closures are needed. This is consistent with guidelines for the use of truck-mounted attenuators.[6]

1.3.3 Maryland's automated speed enforcement program

Maryland law allows use of the Automated Speed Enforcement (ASE) program to deploy automated speed safety cameras in highway work zones.[7] At the time of the crash, the law stated that cameras must have conspicuous signage and the equipment operator must be present. Violations would occur when drivers exceeded the posted speed by 12 mph or more. However, no cameras were present at the crash location.

MDSHA described several factors when considering ASE deployment, which can include a request from the MDSHA district, a review of the eligible projects, the duration of the project, the type of work zone, and the number of deployments available under the MDSHA ASE contract. MDSHA would also consider locations with high speeding prevalence, as indicated by crash data from police reports (identifying speeding as the cause of the crash), citizen concern, or the observation of MDSHA employees or representatives with traffic expertise.

The crash area had not been identified as having a speeding prevalence prior to this crash. Crash data from the most recent 5-year period (2018–2022) indicated

[5] Maryland's Occupational Safety and Health Office investigation issued MDSHA a citation for failing to post traffic control signs in advance of the openings in the barriers to warn road users that construction vehicles may be transitioning into or out of the work zone.

[6] See the MDSHA *Book of Standards for Highways and Incidental Structures*, as well as the article in *Transportation Research Record 1304*, "Guidelines for the Use of Truck-Mounted Attenuators in Work Zones" (Humphreys and Sullivan 1991). See also the AASHTO *Manual on Assessing Safety Hardware*, Section 2.2.3, "Truck- and Trailer-Mounted Attenuators and Portable Work-Zone Traffic Control Trailers" (AASHTO 2016).

[7] See Maryland Code, "Transportation" (see specifically Title 21, Subtitle 8, Section 21-810, "Work Zone Speed Control Systems").

about 77% of the 536 crashes were classified as either rearend (52%)– or sideswipe (25%)–configuration impacts. About 80 and 85% of the total crashes occurred on dry road surfaces and during clear/cloudy weather, respectively. Fifty percent of the total crashes occurred during daylight hours. Police reports identified speed "too fast for conditions" in 10.3% and "exceeded speed limit" in 0.6% of the crashes. Crashes with "improper lane change" listed as a police-identified probable cause were infrequent at 4%. Generally, the data depicted crash characteristics that were consistent with congestion and heavy traffic, which the construction project was designed to address. Crashes due to speed above the posted limit rarely occurred.

1.4 Postcrash Actions

After the crash, MDSHA planned the following changes to the work zone's temporary traffic control plan:

- Close additional lanes next to the median when workers are present;
- Block access areas with a protection vehicle when the adjacent lane is closed and work is taking place;
- Reduce the speed limit when workers are present by using variable speed limits; and
- Increase the use of ASE systems.

In addition, Maryland's governor announced the creation of a statewide work group to address work zone safety. The group, chaired by the lieutenant governor, was composed of individuals with expertise in transportation, including law enforcement, labor, traffic engineering, highway safety, and workers with direct experience in work zones. Group members were tasked with developing a set of recommendations; in November 2023, they published a report that focused on recommendations for changing driver behavior—which was identified as the cause for most work zone crashes—and improving roadway operations.[8]

In addition, a public survey on work zone safety found that 66% of Marylanders were more likely to slow down if work zone speed camera fines were increased, and 69% of Marylanders supported expanded deployment of ASE cameras to protect roadway workers. In 2024, Maryland enacted legislation aimed at better protecting roadway workers by increasing fines for ASE speed violations, removing the requirement that an ASE equipment operator needs to be present, requiring updated

[8] See the Governor's Work Zone Safety Work Group report "Recommendations to Improve Work Zone Safety in Maryland" (November 17, 2023).

signs and lights when workers are present, and allowing for multiple cameras throughout a work zone.[9]

2 Analysis

Weather and visibility were not factors in this crash. Drivers had no obstructions to their line of sight approaching the crash area. The general roadway configuration, design, and construction did not contribute to the cause of the crash.

Although delta-9-THC, the primary psychoactive substance in cannabis, was detected in the Acura driver's blood after the crash, the measured concentration could not be used to determine when she last used cannabis or whether she was acutely impaired by cannabis effects at the time of the crash, because frequent cannabis users may sometimes have such persistently elevated delta-9-THC (Karschner and others 2009; Odell and others 2015). Aggressive, very-high-speed driving is not a typical result of cannabis effects. However, it is generally plausible that cannabis effects might have impaired the Acura driver's perception, judgment of maneuvering, and/or reactions while driving at high speed (Compton 2017). In addition, her use of the medication cyclobenzaprine also had some potential to impair driving ability (Caron and others 2020). Whether substance effects contributed to the crash could not be determined.

Although the Acura driver reported to her postcrash care providers that she had a history of seizures and experienced a seizure prior to the crash, medical records provided no specific evidence to corroborate this information. She had been treated for chronic pain and may have had other potentially impairing medical issues. The circumstances of the crash were not obviously indicative of a sudden medical event, and it was not possible to clearly attribute her performance or decision-making to a medical condition. Whether a medical condition contributed to the crash could not be determined.

2.1 Work Zone Factors

The work zone configuration met applicable state and federal standards, and MDSHA and the contractor conducted daily inspections, which conveyed no discernible safety issues. Ongoing safety reviews were part of the project process. In addition, onsite workers were trained appropriately.

[9] See the Maryland SafeZones Program page for Maryland laws against speeding in work zones. See also Maryland House Bill 513, known as the Maryland Road Worker Protection Act of 2024, for further information on work zone speed control systems.

Workers can be exposed to many different hazards, including vehicles intruding into the work zone. According to the Centers for Disease Control and Prevention, an average of 89 construction workers died each year in roadway work zones; about half of those deaths were caused by vehicle strikes.[10] In this work zone, positive protection was in place—that is, the workers were behind a concrete barrier system, which provided a high level of protection. The barrier system prevented the Volkswagen from intruding into the work zone during the initial portion of the collision sequence, as designed. In addition, appropriate crash-attenuating end-treatments were present at the work zone access openings in the barrier system.

Although the opening in the concrete barriers allowed the Acura to enter the work zone after losing control, the Acura's excessive speed was the key factor that determined how far the vehicle traveled into the work zone as it overturned, resulting in the worker fatalities. In addition, the Acura's loss of control was initiated by the driver's unsafe high-speed lane change across three lanes and collision with the high-speed Volkswagen. Since the crash, MDSHA planned several changes to the work zone, including closing the adjacent lane when work is taking place and blocking the work zone opening with a protection vehicle.

2.2 Excessive Speed

In the Woodlawn crash, two drivers were operating their vehicles at about double the posted speed limit. Despite both drivers' similar rates of excessive speed, they were not cited for racing, and we found no evidence that they were acquainted. Speeding is one of the most common factors associated with fatal crashes in the United States (NHTSA 2024), and one that the NTSB frequently encounters in our investigations. Speeding increases the chances of being in a crash as well as the severity of the crash. Excessive speed is particularly hazardous for "vulnerable road users"—including pedestrians and highway workers—because they lack an external structure to protect them and are therefore more likely to suffer a serious injury or death when a crash occurs. Pedestrian fatality risk is directly related to vehicle speed (Rosén and Sander 2009).

We have advocated for comprehensive strategies to prevent speeding-related crashes. In a recent crash investigation—North Las Vegas, Nevada—the NTSB issued new safety recommendations to the National Highway Traffic Safety Administration (NHTSA) and passenger vehicle manufacturers to implement intelligent speed

[10] Fatal Injuries at Road Construction Sites Among Construction Workers | Centers for Disease Control and Prevention (July 2018).

assistance (ISA) systems as standard equipment in all new vehicles (NTSB 2023).[11] ISA can (a) alert a driver who is exceeding the speed limit, (b) implement an overridable/easily counteracted deceleration mechanism, or (c) completely prevent a driver from driving above the speed limit. In this crash, an ISA system could have helped the drivers maintain a slower speed, which could have prevented the loss of control that led to the crash and/or reduced the distance traveled by the Acura after the initial collision occurred.

Automated speed enforcement (ASE), also known as speed safety cameras, is another effective technology to help prevent speeding-related crashes. The NTSB has previously recommended that states authorize state and local agencies to use ASE and remove operational and location restrictions on its use (NTSB 2017).[12] Although Maryland had an ASE program in place that allowed for speed safety cameras in work zones, its use was limited, and no speed cameras had been placed in the crash area. After this crash, MDSHA has increased the use of speed safety cameras in work zones. In addition, the change to Maryland law, which increases fines for speed safety camera violations, removes the requirement that an equipment operator needs to be present and allows for multiple cameras throughout a work zone, is also a positive step.

3 Conclusions

3.1 Probable Cause

The National Transportation Safety Board determines that the probable cause of the Woodlawn, Maryland, crash between a passenger vehicle and highway workers in a work zone was the excessive speed of two vehicles and unsafe lane change by the Acura driver, resulting in a collision with the Volkswagen and subsequent loss of control, entry into the work zone, rollover, and collision with the workers.

3.2 Lessons Learned

Speeding is one of the most common factors associated with fatal crashes in the United States and is particularly hazardous for "vulnerable road users"—including pedestrians and highway workers. Vehicle technologies previously recommended by the NTSB, including intelligent speed assistance (ISA), can help drivers maintain safer speeds. In this crash, an ISA system would have helped the drivers maintain a slower

[11] See Safety Recommendations H-23-14 and H-23-20.

[12] See Safety Recommendations H-17-31, H-17-32, and H-17-33.

speed, which could have prevented the loss of control that led to the crash or could have reduced the severity of the crash.

The NTSB has also previously recommended that states authorize state and local agencies to use automated speed enforcement (ASE) and remove operational and location restrictions on its use. Maryland has an automated speed enforcement program in place to allow ASE in work zones. Since the crash, Maryland updated its state law related to the use of ASE systems in highway work zones by increasing fines for violations and allowing systems to be used without an operator present. In addition, changes to work zone procedures implemented by the Maryland State Highway Administration, including using temporary lane closures, protection vehicles, and variable speed limits when workers are present, are likely to increase safety of highway workers.

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NTSB investigators worked with the **Maryland State Police** and **Maryland State Highway Administration** throughout this investigation.

The NTSB is an independent federal agency charged by Congress with investigating every civil aviation accident in the United States and significant events in the other modes of transportation—railroad, transit, highway, marine, pipeline, and commercial space. We determine the probable causes of the accidents and events we investigate and issue safety recommendations aimed at preventing future occurrences. In addition, we conduct transportation safety research studies and offer information and other assistance to family members and survivors for each accident or event we investigate. We also serve as the appellate authority for enforcement actions involving aviation and mariner certificates issued by the Federal Aviation Administration (FAA) and US Coast Guard, and we adjudicate appeals of civil penalty actions taken by the FAA.

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For more detailed background information on this report, visit the NTSB investigations website and search for NTSB accident ID HWY23FH010. Recent publications are available in their entirety on the NTSB website. Other information about available publications also may be obtained from the website or by contacting—

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