National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: September 2, 2011

In reply to refer to: H-11-13 through -17

The Honorable Victor M. Mendez
Administrator
Federal Highway Administration
1200 New Jersey Avenue, SE
Washington, DC 20590

On October 22, 2009, about 10:38 a.m. eastern daylight time, a 2006 Navistar International truck-tractor in combination with a 1994 Mississippi Tank Company MC331 specification cargo tank semitrailer (the combination unit), operated by AmeriGas Propane, L.P., and laden with 9,001 gallons of liquefied petroleum gas, rolled over on a connection ramp after exiting Interstate 69 (I-69) southbound to proceed south on Interstate 465 (I-465), about 10 miles northeast of downtown Indianapolis, Indiana.[1]

The truck driver was negotiating a left curve in the right lane on the connection ramp, which consisted of two southbound lanes, when the combination unit began to encroach upon the left lane, occupied by a 2007 Volvo S40 passenger car. The truck driver responded to the Volvo's presence in the left lane by oversteering clockwise, causing the combination unit to veer to the right and travel onto the paved right shoulder. Moments later, the truck driver steered counterclockwise to redirect and return the combination unit from the right shoulder to the right lane.

The truck driver's excessive, rapid, evasive steering maneuver triggered a sequence of events that caused the cargo tank semitrailer to roll over, decouple from the truck-tractor, penetrate a steel W-beam guardrail, and collide with a bridge footing and concrete pier column supporting the southbound I-465 overpass. The collision entirely displaced the outside bridge pier column from its footing and resulted in a breach at the front of the cargo tank that allowed the liquefied petroleum gas to escape, form a vapor cloud, and ignite. The truck-tractor came to rest on its right side south of the I-465 overpasses, and the decoupled cargo tank semitrailer came to rest on its left side, near the bridge footing supporting the southbound I-465 overpass. The truck driver and the Volvo driver sustained serious injuries in the accident and postaccident fire,

[1] For additional information, see *Rollover of a Truck-Tractor and Cargo Tank Semitrailer Carrying Liquefied Petroleum Gas and Subsequent Fire, Indianapolis, Indiana, October 22, 2009,* Highway Accident Report NTSB/HAR-11/01 (Washington, DC: National Transportation Safety Board, 2011), which is available on the NTSB website at <Uhttp://www.ntsb.gov/U>.

and three occupants of passenger vehicles traveling on I-465 received minor injuries from the postaccident fire.

The National Transportation Safety Board (NTSB) determined that the probable cause of this accident was the excessive, rapid, evasive steering maneuver that the truck driver executed after the combination unit began to encroach upon the occupied left lane. Contributing to the rollover was the driver's quickly steering the combination unit from the right shoulder to the right lane, the reduced cross slope of the paved right shoulder, and the susceptibility of the combination unit to rollover because of its high center of gravity (CG). Mitigating the severity of the accident was the bridge design, including the elements of continuity and redundancy, which prevented the structure from collapsing.

Effect of Cross-Slope Break on Heavy Truck Rollover

The most detrimental effect of cross-slope break traversals is the lateral acceleration generated when a vehicle migrates from the travel lane fully onto the shoulder. If the lateral acceleration is great enough, loss of directional control can occur directly because of the lack of available skid resistance at the tire/road interface or indirectly because of intolerable centrifugal forces that may cause a driver to become apprehensive and take inappropriate actions (hard braking or excessive steer input).

An unpublished 1983 Federal Highway Administration (FHWA) report contained the results of a study that evaluated the dynamic effects of centerline crowns when passing maneuvers were conducted on tangent roadway sections with passenger cars and loaded and empty truck-tractor combinations and single-unit trucks.[2] The simulations produced vehicle dynamic responses of 0.28–0.34 *g* for cross slopes of 2 percent for all vehicle types. The findings indicated that cross slopes should be kept to a minimum on high-speed highways. These results were consistent with simulation-based analyses conducted by the NTSB that revealed a high CG vehicle would be significantly less stable on a shoulder with a −2 percent cross slope than on a travel lane with an 8 percent cross slope. Therefore, the transition from a positive to a negative cross slope as the combination unit moved laterally from the right lane onto the shoulder decreased the speed at which the combination unit involved in this accident could negotiate the curve without rolling over.

The effect of cross-slope breaks on the roll stability of heavy trucks has not been fully evaluated. The results of the limited FHWA study that examined the dynamic response of cross-slope break traversals on highway curves were based on simulations performed with a passenger car, not articulated truck-tractor semitrailers.[3] National Cooperative Highway Research Program Report 505 indicated that the 2001 American Association of State Highway and Transportation Officials (AASHTO) Green Book criteria for cross-slope breaks and vertical clearances appeared to be appropriate for the current truck fleet; however, the report also acknowledged that no further data were found in the literature to address questions on the

[2] J.C. Glennon and others, *HVOSM Studies of Highway Centerline Crowns, Technical Report*, Contract No. DOT-FH-11-9575, unpublished, August 1983.

[3] J.C. Glennon, T.R. Neuman, R.R. McHenry, and B.G. McHenry, *HVOSM Studies of Cross-Slope Breaks on Highway Curves*, DOT-FH-11-9575 (Washington, DC: U.S. Department of Transportation, July 1981).

sensitivity of heavy trucks to cross-slope break traversals. Furthermore, the FHWA confirmed in a September 3, 2010, memorandum that it did not have adequate data to establish an appropriate cross-slope break for heavy trucks.[4] The same assessment was noted during the August 2010 NTSB public hearing, when a question was asked about FHWA research regarding the effect of cross-slope breaks on the safe operation of heavy commercial vehicles. The NTSB concludes that the guidance on cross-slope break in the current AASHTO publication *A Policy on Geometric Design of Highways* does not take into account low-stability heavy trucks that are susceptible to rollover, such as cargo tank motor vehicles with a high CG.

The NTSB believes that more information is needed on heavy truck rollover characteristics relative to cross-slope break traversals. Therefore, the NTSB recommends that the FHWA work with AASHTO to evaluate vehicle design characteristics specific to the rollover thresholds of heavy trucks, including those having cargo tanks, and use the information obtained to develop best practices in highway design that will mitigate the increased rollover risk caused by reduced effective superelevation through changes in cross slope that high CG commercial vehicles experience when they migrate onto the shoulder while negotiating curve sections of high-speed highways. The NTSB is also recommending that AASHTO incorporate the findings of this evaluation in *A Policy on Geometric Design of Highways and Streets*. Further, if the results of the heavy vehicle design evaluation warrant such action, the NTSB recommends that the FHWA work with AASHTO to develop and implement best practices to assist state transportation agencies in identifying existing locations where cross-slope breaks pose a rollover hazard, placing an emphasis on those roadways having high volumes of heavy truck traffic, and develop appropriate strategies for mitigating the hazard. The NTSB further recommends that, until these best practices have been developed and disseminated, the FHWA provide information to state transportation agencies about the safety risks associated with cross-slope breaks and their potential for increasing the rollover propensity of commercial vehicles that have a high CG.

Role of Risk Assessment in Protection of Bridge Pier Columns

Bridges without two specific attributes—redundancy and continuity—are at higher risk of failure due to pier column impacts.[5] *Redundancy* means that alternate load paths are available when a portion of a structure fails. In this accident, one of the outside columns collapsed. However, the I-465 southbound bridge structure was supported by seven columns, so even though the accident removed the outside column, the structure remained standing because six columns were still carrying the load. *Continuity* means that the bridge beams are continuous over the top of the pier columns, allowing the redistribution of loads in the superstructure from one beam to another. In some older bridge structures, the joints are placed over the pier columns, resulting in a superstructure that is not continuous. With such bridge structures, if the bridge pier columns deflect (move in a different direction) as a result of an impact, the beams will also deflect and be more likely to collapse. The bridge in this accident had continuous beams that did not deflect when the outside pier column was removed by the cargo tank semitrailer. Thus,

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[4] Associate Administrator for Safety, Federal Highway Administration, memorandum (regarding design considerations for prevention of cargo tank rollovers) to Directors of Field Services, Division Administrators, and Federal Land Engineers, September 3, 2010, p. 2.

[5] Testimony delivered by the AASHTO Chair of the Technical Committee for Guardrail and Bridge Rail, August 4, 2010, at the NTSB public hearing concerning the Indianapolis rollover accident.

although the right guardrail failed to redirect or prevent the combination unit from impacting the bridge pier column, the ability of the I-465 overpass to remain standing after impact indicates that consideration was taken when the bridge was designed to ensure that the integrity of the structure would be maintained and not compromised if struck by a heavy commercial vehicle. The NTSB therefore concludes that the bridge structure's existing redundancy and continuity prevented the southbound I-465 overpass from collapsing after the cargo tank semitrailer collided with and displaced the outside bridge pier column.

It is not feasible to expect that all inadequate roadside barriers will be replaced or upgraded through planned highway improvements. Accordingly, a risk assessment should be performed to identify high-risk interchanges and prioritize bridges in terms of vulnerability to collapse if struck. The risk assessment would examine key pier protection factors such as the bridge's redundancy, continuity, and distance of bridge pier columns from the edge of the traveled way. It would also take a tiered approach, first looking at locations with no redundancy, no continuity, and bridge pier columns close to the edge of the traveled way. Targeting the most unsafe locations would be more focused and strategic than attempting to retrofit all existing structures that may be vulnerable, or slightly vulnerable, to heavy-vehicle impacts.

The NTSB therefore recommends that the FHWA work with AASHTO to develop guidance for a bridge pier protection program that will allow state transportation agencies to conduct risk-based assessments of bridges located within highway interchanges. At a minimum, the program should consider each structure's redundancy, continuity, and the distance of bridge pier columns from the edge of traveled ways. Additionally, consider traffic volumes, traffic type, and the percentage of commercial vehicles transporting bulk liquid hazardous materials in identifying and prioritizing initiatives for preventing vulnerable bridges at high-risk interchanges from collapsing if struck or otherwise damaged by a heavy vehicle. Once the guidance for a bridge pier protection program has been developed, the NTSB recommends that the FHWA require that it be applied to bridges that are vulnerable to collapse if struck by a heavy vehicle.

Therefore, the National Transportation Safety Board makes the following recommendations to the Federal Highway Administration:

> Work with the American Association of State Highway and Transportation Officials to evaluate vehicle design characteristics specific to the rollover thresholds of heavy trucks, including those having cargo tanks. Use the information obtained to develop best practices in highway design that will mitigate the increased rollover risk caused by reduced effective superelevation through changes in cross slope that high center of gravity commercial vehicles experience when they migrate onto the shoulder while negotiating curve sections of high-speed highways. (H-11-13)

> If the results of the evaluation in Safety Recommendation H-11-13 warrant such action, work with the American Association of State Highway and Transportation Officials to develop and implement best practices to assist state transportation agencies in identifying existing locations where cross-slope breaks pose a rollover hazard, placing an emphasis on those roadways having high volumes of heavy truck traffic, and develop appropriate strategies for mitigating the hazard. (H-11-14)

> Until the best practices in Safety Recommendation H-11-13 and -14 have been developed and disseminated, provide information to state transportation agencies about the safety risks associated with cross-slope breaks and their potential for increasing the rollover propensity of commercial vehicles that have a high center of gravity. (H-11-15)

> Work with the American Association of State Highway and Transportation Officials to develop guidance for a bridge pier protection program that will allow state transportation agencies to conduct risk-based assessments of bridges located within highway interchanges. At a minimum, the program should consider each structure's redundancy, continuity, and the distance of bridge pier columns from the edge of traveled ways. Additionally, consider traffic volumes, traffic type, and the percentage of commercial vehicles transporting bulk liquid hazardous materials in identifying and prioritizing initiatives for preventing vulnerable bridges at high-risk interchanges from collapsing if struck or otherwise damaged by a heavy vehicle. (H-11-16)

> Once the guidance for a bridge pier protection program as described in Safety Recommendation H-11-16 has been developed, require that it be applied to bridges that are vulnerable to collapse if struck by a heavy vehicle. (H-11-17)

The NTSB also issued safety recommendations to the U.S. Department of Transportation, the Federal Motor Carrier Safety Administration, the Pipeline and Hazardous Materials Safety Administration, the National Highway Traffic Safety Administration (NHTSA), and AASHTO. Additionally, this report reclassifies previously issued recommendations to NHTSA and AASHTO.

In response to the recommendations in this letter, please refer to Safety Recommendations H-11-13 through -17. If you would like to submit your response electronically rather than in hard copy, you may send it to the following e-mail address: correspondence@ntsb.gov. If your response includes attachments that exceed 5 megabytes, please e-mail us asking for instructions on how to use our secure mailbox. To avoid confusion, please use only one method of submission (that is, do not submit both an electronic copy and a hard copy of the same response letter).

Chairman HERSMAN, Vice Chairman HART, and Members SUMWALT, ROSEKIND, and WEENER concurred in the issuance of these recommendations.

Original Signed By

By: Deborah A.P. Hersman
Chairman