National Transportation Safety Board
Washington, D.C. 20594

Safety Recommendation

Date: October 4, 2011

In reply refer to: H-11-21 through -25

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

On Friday, March 26, 2010, about 5:14 a.m. central daylight time, near Munfordville, Kentucky, a 1999 Freightliner truck-tractor in combination with a 1998 Strick Corporation 53-foot-long van semitrailer, owned by the motor carrier Hester, Inc., and being driven by a 45-year-old male, was traveling south on Interstate 65 (I-65) near milepost 61.5. The truck departed the left lane of southbound I-65 at a shallow angle and entered the 60-foot-wide depressed earthen median between the southbound and northbound roadways. The truck traveled across the median and struck and overrode the high-tension, four-cable, alternating-post median barrier adjacent to the left shoulder of northbound I-65. It then crossed the left shoulder and entered the travel lanes of northbound I-65.

At that time, a 2000 Dodge 15-passenger van, driven by a 41-year-old male and occupied by 11 passengers, was traveling northbound in the left lane. As the truck crossed in front of the van, its tractor was struck by the van. The van rotated clockwise and became engaged with the truck's trailer; the two vehicles continued across both travel lanes and the right shoulder of northbound I-65. As the truck and van traveled across the right shoulder, the van separated from the truck, struck the cut rock wall beyond the shoulder, and rebounded back into the travel lanes, coming to rest in the left lane of northbound I-65, facing south. The truck's tractor struck the cut rock wall, and the vehicle rolled onto its right side. As the truck came to rest across both northbound lanes, a fire ensued that destroyed the tractor and the sides and roof of the semitrailer.

As a result of the accident and subsequent truck fire, the truck driver, the van driver, and nine van passengers died. Two child passengers in the van, who were using child restraints, sustained minor injuries.[1]

[1] For additional information, see *Truck-Tractor Semitrailer Median Crossover Collision With 15-Passenger Van, Munfordville, Kentucky, March 26, 2010,* Highway Accident Report NTSB/HAR-11/02 (Washington, DC: National Transportation Safety Board, 2011), which is available on the NTSB website at <http://www.ntsb.gov/>.

The National Transportation Safety Board (NTSB) determined that the probable cause of this accident was the truck driver's failure to maintain control of the truck-tractor combination vehicle because he was distracted by use of his cellular telephone. Contributing to the severity of the accident were a median barrier that was not designed to safely contain or redirect the heavy vehicle and the lack of adequate guidance to the states in the form of high-performance median barrier warrants.

One issue that the NTSB identified during its investigation was the need to provide objective warrants, rather than general guidelines, for the application of median barriers. This issue area has elements that concern the Federal Highway Administration (FHWA).

Highway Median Barriers

Roadside design guidance[2] indicates that median barrier applications on divided interstate roads are not normally considered for medians wider than 50 feet.[3] However, because of the severity of cross-median crashes, many states, including Kentucky, have begun installing median barriers in accident-prone locations with median widths up to 75 feet, and accident mitigation analysis and cost/benefit model assessments have supported these decisions.[4] Median barriers are not required on any highway in the National Highway System (NHS). However, if a state determines to install a longitudinal or median barrier along an NHS highway, the barrier must meet Test Level Three (TL-3) standards (at a minimum). TL-3 barriers are designed to redirect passenger cars but are usually inadequate for redirecting commercial motor vehicles (CMV).

The severity of cross-median accidents is a significant factor in a state's decision to install median barriers along divided highways. In 2009, some 2,987 large trucks were involved in fatal accidents; fatalities in accidents involving large trucks made up about 10 percent of all fatalities in motor vehicle accidents that year.[5] Although the overall percentage of fatal accidents involving large trucks appears relatively small, their level of involvement in fatal cross-median crashes is higher than their percentage of registered vehicles or vehicle miles traveled. These numbers are less than exact and almost certainly represent an undercount because cross-median accidents can be difficult to identify using Fatality Analysis Reporting System (FARS) data. Also, there is no single accepted definition of "cross-median crash," which adds to the uncertainty of the accident data.

[2] For the purposes of this discussion and with respect to median barrier information, it should be emphasized that "guidance" and "guidelines" are not synonymous with "warrants." Warrants identify specific metrics, such as accident rate, average daily traffic (ADT), and percentage of heavy vehicle traffic that, if exceeded, indicate a barrier should be placed in that location. Guidance and guidelines refer to less specific and often subjective indications that a barrier should be considered or that additional study may be appropriate.

[3] *Roadside Design Guide*, 3rd ed. (Washington, DC: American Association of State Highway and Transportation Officials, 2006), p. 3–1.

[4] (a) National Cooperative Highway Research Program (NCHRP) Report 633, *The Impact of Shoulder Width and Median Width on Safety* (Washington, DC: Transportation Research Board, 2009). (b) E.T. Donnell and J.M. Mason, "Methodology to Develop Median Barrier Crash Warrant Criteria," *Journal of Transportation Engineering*, American Society of Civil Engineers, vol. 132, no. 4, (April 2006), pp. 269–281.

[5] For information, see <http://www.fmcsa.dot.gov/documents/facts-research/CMV-Facts.pdf> and <http://www.ai.volpe.dot.gov/CarrierResearchResults/HTML/2009Crashfacts/2009LargeTruckandBusCrashFacts.htm>, both accessed June 16, 2011.

Different barrier systems—categorized as rigid, semi-rigid, and flexible—have different characteristics. Flexible median barrier systems have the beneficial quality of being less destructive to vehicles and their occupants than rigid barriers, such as those made of concrete, and they are designed to capture rather than deflect errant vehicles. Although they are less expensive to install than many barrier systems, high-tension cable barriers involve higher maintenance costs because cable hits must be repaired[6] and increased maintenance carries with it an increased exposure risk to maintenance crews. Installation and use of high-tension cable barrier systems have increased throughout the states in recent years.[7] Between 2008 and 2010, Kentucky installed approximately 150 miles of cable barrier on six interstates and two state highways.

Because of the lack of appropriate Federal warrants on barriers, some states have developed their own detailed guidance about when and where median barriers should be used. The recent *The Development of Guidelines for Cable Median Barrier Systems in Texas*[8] is a good example of the kind of work being initiated by the states. FHWA research has shown that cable barrier effectiveness is related to barrier design (for example, cable numbers, heights, and tensioning); configuration of the median (shape, width, slopes, and depth); and lateral position of the barrier within the median.[9] However, no detailed Federal warrants exist for median barrier systems. Only general guidance is provided for median barrier implementation in the 2006 American Association of State Highway and Transportation Officials (AASHTO) *Roadside Design Guide*.

A 2005 Transportation Research Board paper reporting on NCHRP Project 17-14, *Improved Guidelines for Median Safety*, found that 76 percent (28 of 37 responding state transportation departments) used the *Roadside Design Guide*.[10] However, it also reported that 9 of 37 states had design guidelines that differed from the principles established in the *Roadside Design Guide*.

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[6] One state manual on cable barrier maintenance noted that maintenance departments can expect seven hits per mile per year.

[7] Several surveys of state use of cable barrier systems have been conducted, and they show that use of the systems has increased markedly in recent years. The following references contain state survey information: (a) S. Cooner and others, *The Development of Guidelines for Cable Median Barrier Systems in Texas*, Report FHWA/TX-10/0-5609-2 (College Station, Texas: Texas Transportation Institute and the Federal Highway Administration, February 2009). (b) X. Qin and M. Wang, *High-Tension Median Cable Barrier In-Service Performance Evaluation and Cost Effectiveness Analysis*, 89th Annual Transportation Research Board Meeting, January 2010. (c) M. Ray and R. McGinnis, *Guardrail and Median Barrier Crashworthiness*, NCHRP Synthesis 244 (Washington, DC: Transportation Research Board, June 1997).

[8] *The Development of Guidelines for Cable Median Barrier Systems in Texas*, FHWA/TX-10/0-5609-2.

[9] K.S. Opiela, D. Marzougui, and C.D. Kan, *Developing Functional Design and Evaluation Requirements for Cable Median Barriers*, paper prepared for the 2011 Transportation Research Board Annual Meeting Program, p. 2.

[10] E.T. Donnell and W.E. Hughes, *State Transportation Agency Median Design and Safety Practices: Results From a Survey* (2005). (Manuscript submitted for publication and presentation consideration to the 84th Annual Meeting of the Transportation Research Board, National Research Council, Washington, DC).

NTSB Recommendation History on Median Barriers

The NTSB addressed the issue of median barrier warrants in its report on the 1997 Slinger, Wisconsin, accident.[11] On February 12, 1997, a tractor/double-semitrailer combination unit with empty trailers was traveling on a four-lane, limited access highway when it lost control. The truck crossed a 50-foot depressed median and struck a flatbed loaded with lumber; in turn, the flatbed lost control, crossed the median, and was struck by a passenger van and a refrigerator truck. Eight of the nine passenger van occupants were killed. The NTSB concluded that the traffic volumes, speed, and history of median encroachment accidents warranted the installation of an effective median barrier system at the accident location. The NTSB also concluded that the warrant guidance for median barriers provided in the AASHTO *Roadside Design Guide* was inadequate. As a result of the investigation, the NTSB issued Safety Recommendation H-98-12 to the FHWA and a companion Safety Recommendation H-98-24 to AASHTO, as follows:

> Review, with the Federal Highway Administration, the median barrier warrants and revise them as necessary to reflect changes in the factors affecting the probability of cross-median accidents, including changes in the vehicle fleet and the percentage of heavy trucks using the roadways. (H-98-24)

On February 2, 1999, the NTSB classified these recommendations "Open—Acceptable Response." In the subsequent years, several NCHRP projects have focused on median barrier safety.[12] The NTSB reiterated Safety Recommendations H-98-12 and -24 in the report of its investigation of another cross-median accident, which took place near Largo, Maryland, in 2002.[13]

In 2007, the NTSB noted that in chapter 6 of the 2006 revision of the AASHTO *Roadside Design Guide*, the FHWA, in cooperation with AASHTO, had published updated median barrier guidelines. The revised text encourages the states to evaluate the need for a median barrier on freeways where traffic volumes exceed 20,000 vehicles per day for median widths of up to 50 feet, as well as for areas where an accident problem exists.[14] The 2006 *Roadside Design Guide* also notes that an evaluation may be made for high-speed, high-volume divided highways, operating like freeways, where an accident problem has been documented. For states that have not yet developed their own analyses of accident data, the revised *Roadside Design Guide* encourages the use of an accident-based warrant; examples would include the warrant review

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[11] *Multiple Vehicle Crossover Accident, Slinger, Wisconsin, February 12, 1997*, Highway Accident Report NTSB/HAR-98/01 (Washington, DC: National Transportation Safety Board, 1998).

[12] The projects included NCHRP 17-14, *Improved Guidelines for Median Safety*; NCHRP 22-12, *Guidelines for Selection, Installation, and Maintenance of Highway Safety Features;* NCHRP 15-30, *Median Intersection Design for Rural High-Speed Divided Highways*; NCHRP 22-14 (2), *Improved Procedures for Safety-Performance Evaluation of Roadside Features*; NCHRP 22-21, *Median Cross-Section Design for Rural Divided Highways*; and NCHRP 22-22, *Placement of Traffic Barriers on Roadside and Median Slopes*.

[13] *Ford Explorer Sport Collision With Ford Windstar Minivan and Jeep Grand Cherokee on Interstate 95/495 Near Largo, Maryland, February 1, 2002*, Highway Accident Report NTSB/HAR-03/02 (Washington, DC: National Transportation Safety Board, 2003).

[14] In 2004, the FHWA determined that two-thirds of cross-median crashes occurred at locations where the median width was 50 feet or less.

developed by the California Department of Transportation[15] or as documented in research supported by the Pennsylvania Department of Transportation.[16] Based on these revisions to the 2006 *Roadside Design Guide*, and revisions to the testing under the *Manual for Assessing Safety Hardware* (MASH) that addressed changes to the fleet, the NTSB classified Safety Recommendation H-98-12 to the FHWA "Closed–Acceptable Action" on September 17, 2007. Because of the ongoing NCHRP work by AASHTO and policy work by the states, Safety Recommendation H-98-24 to AASHTO remained "Open—Acceptable Response."

The NTSB also addressed high-performance barrier warrants in a recommendation made to AASHTO in 2005, as a result of its investigation of two consecutive cross-median accidents that took place in Fairfield, Connecticut.[17] The NTSB recommended that AASHTO take the following action:

> Establish warrants in the *Roadside Design Guide* regarding the selection and use of high-performance barriers, including 42- and 50-inch-high concrete barriers, that are capable of redirecting heavy trucks. (H-05-31)

Safety Recommendation H-05-31 is classified "Open—Acceptable Response." Although this recommendation is not specific to median barriers, it does recognize the need for warrants particular to the selection and use of high-performance barriers.

Median Barrier Warrants for Heavy Vehicles

The high-tension median cable barrier at the accident location was a Test Level Four (TL-4) design, installed in accordance with TL-3 performance criteria because it was on a 1:4 slope. The implementation of the MASH revised the single-unit truck performance test for TL-4 barriers. The test vehicle weight was increased from 18,000 to 22,000 pounds, and the impact speed was increased from 50 to 56 mph. The changes created a more rigorous test that distinguished the TL-4 from the TL-3 criteria.[18] The design force value for TL-3 and TL-4 barriers under NCHRP Report 350 was 54 kips in the transverse or lateral direction. Under the MASH, the TL-4 transverse design value is 76 kips.[19] A 76,660-pound vehicle traveling at 60 mph[20] with an impact angle of 15° would have an estimated applied force approaching 200 kips. The NTSB concluded that the forces in this accident exceeded the capability of a cable barrier system that was not designed to safely contain or redirect a heavy vehicle such as the accident truck.

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[15] J.B. Borden, *Median Barrier Study Warrant Review*, California Department of Transportation, December 1997.

[16] E.T. Donnell and J.M. Mason (2006).

[17] *Multiple Vehicle Collision on Interstate 95, Fairfield, Connecticut, January 17, 2003,* Highway Accident Report NTSB/HAR-05/03 (Washington, DC: National Transportation Safety Board, 2005).

[18] The TL-5 criteria did not change from the parameters established in the previous standard, NCHRP Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features.*

[19] *Load and Resistance Factor Design Specification*, table A13.2-1.

[20] This force calculation uses a vehicle speed of 60 mph in recognition of the decrease in speed that would have occurred as the truck crossed the median prior to impact with the barrier.

As noted above, some AASHTO member states have conducted research and established policies concerning median barrier systems that are more extensive and detailed than those provided in the median barrier implementation guidelines of the current edition of the *Roadside Design Guide*. A TL-5 median barrier, designed to contain and redirect heavy trucks, would have been needed in the I-65 median to prevent this cross-median crash; however, the rural nature of this area and the lack of *Roadside Design Guide* criteria for the use of high-performance barriers resulted in Kentucky's using a TL-3 barrier system. Consequently, the NTSB concluded that the *Roadside Design Guide* provides inadequate warrants and standards for the selection and installation of median barriers along roadways with high volumes of heavy vehicle traffic. Moreover, the warrants needed by the states to make informed cost/benefit decisions should include quantifiable variables such as median width, accident frequency, accident severity, traffic volume, percentage of heavy traffic, traffic speeds, degree of median cross slope, number of travel lanes, and degree of road curvature. The states also need warrants particularly to address median barrier performance characteristics appropriate to installation sites. Despite state action, AASHTO has not been sufficiently active in reviewing and revising guidance for the use of median barriers, particularly with regard to high-performance barriers. Therefore, the NTSB reclassifies Safety Recommendation H-98-24 to AASHTO "Closed—Superseded," and recommends that the FHWA and AASHTO work together to establish warrants and implementation criteria for the selection and installation of TL-4 and TL-5 median barriers on the NHS. Once they are available, AASHTO should publish these warrants and criteria in the *Roadside Design Guide*.

Accident Rates and Heavy Vehicle Traffic Volume

The 2006 *Roadside Design Guide* recommends installing median barriers on high-speed, fully controlled-access highways where the median is 30 feet wide or less[21] and the ADT count is greater than 20,000 vehicles per day. These criteria were based on evaluations of crossover accidents carried out by California[22] and the Texas Transportation Institute,[23] as well as the judgment of an AASHTO task force. In the early 1990s, California revised its median barrier guidelines to include consideration of accident rates.[24] In 2008, Kentucky drafted *Guidelines for Median Barrier Applications on the Depressed Medians of Fully Controlled-Access Highways*, which incorporated the accident rates developed by California; that is, 0.50 cross-median crashes (of any severity) per mile per year or 0.12 fatal cross-median crashes per mile per year. The *Roadside Design Guide* states that for median widths greater than 50 feet, a barrier is usually only considered under special circumstances, such as at locations with a significant history of cross-median crashes. However, in 2004, the FHWA found that about one-third of cross-median crashes occurred at locations with median widths greater than 50 feet. Procedures to select an appropriate barrier performance level include "high percentage of heavy vehicle traffic" as a

[21] The *Roadside Design Guide* recommends installing barriers on medians with widths of 30 feet and less; for medians with widths between 30 and 50 feet, a median may be recommended, depending on the results of further study.

[22] V.D. Graf and N.C. Wingerd, *Median Barrier Warrants* (Sacramento, California: Traffic Department of the State of California, 1968).

[23] H.E. Ross, *Warrants for Traffic Barriers in Texas*, Research Report 140-8 (College Station, Texas: Texas Transportation Institute, Texas A&M University, 1974).

[24] L.L. Seamons and R.N. Smith, *Past and Current Median Cable Barrier Practices in California*, (Sacramento, California: California Department of Transportation, 1991).

decision factor.[25] However, no metric defines what constitutes a "high percentage."[26] The NTSB concluded that the volume of heavy vehicle traffic should be a factor in median barrier selection. The NTSB recommends that the FHWA and AASHTO work together to identify cross-median crash rates that call for special consideration when selecting median barriers. Once they are available, AASHTO should publish the rates in the *Roadside Design Guide*. The NTSB also recommends that the FHWA and AASHTO work together to define the criteria for median barrier selection, including heavy vehicle traffic volume. Once they are available, AASHTO should publish the criteria in the *Roadside Design Guide*.

High-Tension Cable Barrier Deflection

High-tension cable barriers are being used along highways that have substantial proportions of heavy truck traffic,[27] and one aspect of their placement is consideration of cable deflection from a crash impact. In the Munfordville case, the FHWA acceptance letters to Gibraltar noted that one barrier test installation used posts on 14-foot centers with 350-foot cables, resulting in a deflection of 7.0 feet. An additional TL-4 test, using posts spaced on 30-foot centers, resulted in 9.3 feet of deflection. The Commonwealth of Kentucky installed posts on 10-foot center spacing.

In-service field installations differ considerably from MASH barrier test articles. The FHWA issued an acceptance letter to Gibraltar for the cable barrier system based on a 350-foot test article length, as specified in NCHRP Report 350. With the adoption of the MASH, the test article length has been increased to 600 feet. The cable barrier near Munfordville had an installation length of 9,504 feet (distance between anchor terminal fittings). Such lengths are not uncommon; for instance, Texas policy calls for the maximum run of cable length to be approximately 10,000 feet.[28] The NTSB concluded that, to adequately address cable barrier deflection, the test article evaluations for high-tension cable barrier systems conducted according to the MASH should consider the test length applications used in the field. To ensure that states include dynamic deflection considerations in the selection and installation of cable barrier systems, the NTSB recommends that the FHWA provide to state transportation agencies information from current research, such as NCHRP Project 22-25, *Development of Guidance for the Selection, Use, and Maintenance of Cable Barrier Systems*, about the safety risks associated with the installation of cable barrier systems that differs from the configuration of the system as designed and tested; information should include the risks associated with the dynamic deflection that may occur when installation distances between cable barrier anchorages differ from the 600-foot test length prescribed in the MASH. Because state transportation agencies use FHWA acceptance letters to qualify their selection of median barriers, the NTSB further recommends that the FHWA include, in its product acceptance letters for cable barrier safety devices, cautionary language reflecting current research, such as NCHRP Project 22-25, *Development of Guidance for the Selection, Use, and Maintenance of Cable Barrier Systems*, to warn state transportation agencies of the safety risks associated with the installation of cable barrier systems

[25] *Roadside Design Guide*, p. 6-3.

[26] *Supplemental Guidance on Safe Accommodation of Heavy Vehicles on U.S. Highways* (Washington, DC: Federal Highway Administration, Office of Safety, Office of Safety Design, October 8, 2004).

[27] With respect to I-65, about 35 percent of the traffic consisted of commercial vehicles.

[28] FHWA/TX-10/0-5609-2, p. 2–22.

that differs from the configuration of the system as designed and tested; language should include the risks associated with the dynamic deflection that may occur when installation distances between cable barrier anchorages differ from the 600-foot test length prescribed in the MASH.

As a result of the investigation, the National Transportation Safety Board makes the following safety recommendations to the Federal Highway Administration:

> Work with the American Association of State Highway and Transportation Officials to establish warrants and implementation criteria for the selection and installation of Test Level Four and Test Level Five median barriers on the National Highway System. (H-11-21)
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> Work with the American Association of State Highway and Transportation Officials to identify cross-median crash rates that call for special consideration when selecting median barriers. (H-11-22)
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> Work with the American Association of State Highway and Transportation Officials to define the criteria for median barrier selection, including heavy vehicle traffic volume. (H-11-23)
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> Provide to state transportation agencies information from current research, such as National Cooperative Highway Research Program Project 22-25, *Development of Guidance for the Selection, Use, and Maintenance of Cable Barrier Systems*, about the safety risks associated with the installation of cable barrier systems that differs from the configuration of the system as designed and tested; information should include the risks associated with the dynamic deflection that may occur when installation distances between cable barrier anchorages differ from the 600-foot test length prescribed in the *Manual for Assessing Safety Hardware*. (H-11-24)
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> Include, in your product acceptance letters for cable barrier safety devices, cautionary language reflecting current research, such as National Cooperative Highway Research Program Project 22-25, *Development of Guidance for the Selection, Use, and Maintenance of Cable Barrier Systems*, to warn state transportation agencies of the safety risks associated with the installation of cable barrier systems that differs from the configuration of the system as designed and tested; language should include the risks associated with the dynamic deflection that may occur when installation distances between cable barrier anchorages differ from the 600-foot test length prescribed in the *Manual for Assessing Safety Hardware*. (H-11-25)

The NTSB also issued safety recommendations to the Federal Motor Carrier Safety Administration, the National Highway Traffic Safety Administration, the 50 states and the District of Columbia, the Commonwealth of Kentucky, the American Association of State Highway and Transportation Officials, and the Governors Highway Safety Association.

In response to the recommendations in this letter, please refer to Safety Recommendations H-11-21 through -25. 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 these recommendations.

[Original Signed]

By: Deborah A.P. Hersman
Chairman