National Transportation Safety Board
Washington, D.C. 20594

Safety Recommendation

Date: July 21, 2005

In reply refer to: H-05-19 through -22

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The National Transportation Safety Board is an independent Federal agency charged by Congress with investigating transportation accidents, determining their probable cause, and making recommendations to prevent similar accidents from occurring. We are providing the following information to urge your organization to take action on the safety recommendations in this letter. The Safety Board is vitally interested in these recommendations because they are designed to prevent accidents and save lives.

These recommendations, which address the need to better identify areas with a high risk of accidents and implement the necessary roadway improvements, are derived from the Safety Board's investigation of a February 14, 2003, accident involving a motorcoach and a sport utility vehicle[1] and are consistent with the evidence we found and the analysis we performed. As a result of this investigation, the Safety Board has issued 11 new safety recommendations, 4 of which are addressed to the Texas Department of Transportation (TxDOT). Information supporting these recommendations is discussed below. The Safety Board would appreciate a response from you within 90 days addressing the actions you have taken or intend to take to implement our recommendations.

On February 14, 2003, about 9:59 a.m., central standard time, a 1996 Dina Viaggio motorcoach, operated by Central Texas Trails, Inc., and occupied by a driver and 34 passengers, was traveling northbound on Interstate 35 (I-35) near Hewitt, Texas. The weather was overcast with reduced visibility due to fog, haze, and heavy rain. As the motorcoach approached the crest of a hill, the bus driver said he observed brake lights ahead of him and began to brake lightly. The bus driver said that as he moved from the right lane into the left lane, another vehicle ahead of the bus also moved over, so he braked harder and the rear of the bus skidded. The bus driver was unable to maintain control of the bus as it departed the left side of the roadway, crossed the grassy median, entered the southbound lanes, and collided with a 2002 Chevrolet Suburban sport utility vehicle (Suburban) occupied by a driver and two passengers. The right mirror of a southbound 1996 Chevrolet C1500 Z71 pickup truck, occupied by a driver, was also struck by

[1] For more information, read National Transportation Safety Board, *Motorcoach Median Crossover and Collision With Sport Utility Vehicle, Hewitt, Texas, February 14, 2003,* Highway Accident Report NTSB/HAR-05/02 (Washington, DC: NTSB, 2005).

the motorcoach. The motorcoach then overturned on its right side, rotated, and slid to final rest facing south against a concrete embankment on the side of the road. The Suburban rotated 180 degrees, began to climb the embankment, slid back down, and came to rest facing north and against the roof of the bus.

Five motorcoach passengers, the Suburban driver, and one Suburban passenger sustained fatal injuries. The bus driver sustained serious injuries; the remaining passengers on the bus and in the Suburban sustained injuries ranging from minor to serious. The pickup truck driver was not injured.

The National Transportation Safety Board determined that the probable cause of this accident was Texas's decision to set a speed limit on Interstate 35, in the vicinity of the accident, that did not take into account the roadway's limited sight distance or its poor conditions in wet weather; as a result, the bus driver was unable to detect the stopped vehicles as he approached the traffic queue and lost control of the motorcoach due to low pavement friction. Exacerbating the poor roadway conditions were the minimum tread depths on the motorcoach's drive axle tires and differing tread depths on its front and rear tires, both of which were allowed under the *Federal Motor Carrier Safety Regulations* but reduced the friction available to the motorcoach. Contributing to the severity of the accident were the lack of a temporary or permanent median barrier, which might have redirected the motorcoach or reduced the speed at which it crossed the median into the southbound lanes, and the lack of an occupant protection system for the motorcoach passengers.

Before the accident, traffic had backed up to and stopped at a location on the downslope of a hill on I-35. Because of the hill, the stopped traffic was obscured from the sight of approaching motorists. Using an American Association of State Highway and Transportation Officials (AASHTO) formula,[2] the sight distance available to the motorcoach approaching the crest vertical curve was 732 feet. Measurements taken during the on-scene investigation indicated that the sight distance available to the bus driver was 767 feet.[3]

Investigators also calculated the distance required to stop the motorcoach, using the coefficients of friction from the pavement friction tests (which were on wet pavement) in the right lane.[4] Required stopping distances for the motorcoach ranged from 399 to 1,293 feet and for passenger cars from 335 to 962 feet, depending on speed and tire tread. The investigation found that the required motorcoach stopping distance in the right lane exceeds the available sight distance for smooth tires at speeds of 60 mph or greater. For a treaded tire, the required stopping distance is only exceeded at 70 mph or greater. The alignment of the roadway at the accident site, resulting in a vertical curve, combined with the low coefficients of friction on I-35 when the pavement is wet, created a situation in which vehicles may not have been able to avoid hitting traffic stopped on the roadway. I-35 was designed in 1955 with a 60-mph design speed. Since

[2] The AASHTO formula is based on an object height of 2 feet, whereas on-scene testing used a minimum object height of 4 feet to represent a passenger car as the object being sighted by the bus driver, thus accounting for a longer available sight distance. For more information, see AASHTO, *A Policy on Geometric Design of Highways and Streets,* Fourth Edition (Washington, DC: AASHTO, 2002) 271.

[3] The AASHTO formula and this measurement did not take into account weather, which may have reduced the driver's visibility even further.

[4] See NTSB/HAR-05/02, table 11, for the results of these calculations.

that time, the speed limit has been raised to 70 mph, yet the roadway geometry has remained the same, creating a potentially dangerous situation. The 85th percentile speed for traffic flow on I-35 in the vicinity of the accident was 74 mph, 14 mph over the original design speed. Thus, similar vehicles on the roadway may find it difficult to react in time to stop for traffic ahead, particularly in wet weather. The Safety Board concludes that the wet pavement at the accident site, combined with I-35's roadway geometry and speed limit exceeding the design speed, created a situation in which drivers may not have had enough time to react and come to an emergency stop on the interstate or to avoid a collision.

The Safety Board believes that TxDOT should inventory highway locations where poor vertical geometries, combined with low coefficients of friction and speeds greater than the design speed of the roadway, may create a situation in which traffic has inadequate stopping sight distance, and develop and implement a plan for repaving or other roadway improvements. The Safety Board has also recommended that the Federal Highway Administration (FHWA) issue guidance to its field offices describing the inadequate stopping sight distance that could occur when poor vertical geometries exist at locations with low coefficients of friction and speeds greater than the design speed and work with the States to inventory such locations and that, once these locations have been identified, the FHWA should assist the States in developing and implementing a plan for repaving or other roadway improvements. In addition to making formal recommendations, the Safety Board will inform AASHTO of the inadequate stopping sight distance that could occur when poor vertical geometries exist at locations with low coefficients of friction and speeds greater than the design speed and ask that AASHTO encourage its members to rectify similar situations that may exist throughout the country.

Because design and operational criteria have changed over the years, many locations exist nationwide where the stopping distance may exceed the available sight distance. Members of the AASHTO Committee on Design have expressed concern that roadway operating speeds exceeding design speeds could lead to increased liability for the engineer or agency.[5] When these roadways were designed, a safety factor was often incorporated; thus, motorists may feel comfortable traveling at speeds greater than the roadway's design speed in good weather.[6] However, in poor weather, such as existed during this accident, it may be prudent to alert drivers of the condition. NCHRP Report 504 recommends that when a "safety concern exists at a location, appropriate warning or informational signs should be installed to warn or inform drivers of the condition."[7]

While drivers generally reduce their speed in rain by about 6 mph,[8] this may not be enough to compensate for the roadway geometry and wet pavement conditions. Before this accident, the bus driver was already traveling about 10 mph below the posted speed limit of 70

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[5] Kay Fitzpatrick, Paul Carlson, Marcus A. Brewer, Mark D. Wooldridge, and Shaw-Pin Miaou, *Design Speed, Operating Speed, and Posted Speed Practices*, National Cooperative Highway Research Program (NCHRP) Report 504 (Washington, DC: Transportation Research Board, 2003) 16.

[6] Fitzpatrick and others, 80-81.

[7] Fitzpatrick and others, 84.

[8] Lin Zhang and Panos D. Prevedouros, "Motorist Perceptions on the Impact of Rainy Conditions on Driver Behavior and Accident Risk," Transportation Research Board, 2005 Annual Meeting (Washington, DC: Transportation Research Board, 2005).

mph. The investigation found[9] that had the motorcoach been traveling at 50 mph, the required stopping distance for the motorcoach would have been less than the available sight distance, providing the driver with adequate time to react to the stopped traffic ahead. The Safety Board concludes that although the speed limit on I-35 was 70 mph and the design speed was 60 mph, the driver would have had to have been traveling 50 mph or less to avoid the collision or at least to have reduced its severity. Further, the Safety Board concludes that despite the safety factors that are incorporated into roadway design, roadways with speed limits exceeding their design speed can constitute a hazard in wet weather.

Variable speed limit signs are one method of alerting drivers to reduce their speed in response to a potentially hazardous condition during poor weather. These signs display the posted speed limit during good weather, and, when weather conditions deteriorate, the posted speed limit is decreased. Over 1,300 Environmental Sensor Stations have already been deployed nationwide to provide transportation managers with information on current conditions, including atmospheric, pavement, subsurface, and water level.[10] These data can be integrated with National Weather Service data to maximize the benefits from information posted on variable message signs. Road weather data may be used in automated motorist warning systems (such as variable speed limit signs) or sent to traffic management centers so that signs can be changed manually.

The Florida Department of Transportation, for example, installed a motorist warning system consisting of a flashing light mounted on a speed limit sign at an exit ramp where 69 percent of crashes occurred on wet pavement. Vehicle speeds and speed variances, as well as accidents, were reduced.[11] The New Jersey Turnpike Authority uses weather data to determine when to reduce speeds in inclement weather using variable speed limit signs, which have reduced inclement weather accidents.[12] The Washington State Department of Transportation uses speed management through the Snoqualmie Pass to inform motorists of reduced speeds due to inclement weather, including heavy rain and/or standing water on the roadway, thus increasing safety.[13]

Redesigning the roadway to eliminate locations where stopping distance exceeds available sight distance would be ideal; however, the Safety Board understands that roadway redesign can be costly. Variable speed limit signs based on current weather conditions could warn drivers to reduce their speed, thereby reducing their stopping distance below the available sight distance in adverse weather conditions. The Safety Board concludes that when redesigning a roadway for a higher design speed is not feasible, variable speed limit signs can be used as a countermeasure to reduce speeds and increase safety. The Safety Board believes that TxDOT should install variable speed limit signs or implement alternate countermeasures at locations

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[9] NTSB/HAR-05/02, table 11.

[10] Paul Pisano, Brandy Hicks, Rudy Persaud, Lynette Goodwin, and Andy Stern, *An Overview of Federal Highway Administration Road Weather Management Program Activities*, 83rd Annual American Meteorological Society Meeting (Long Beach, CA: AMS, 2003). For further information, see <ams.confex.com/ams/pdfpapers/54831.pdf>.

[11] Lynette Goodwin and Paul Pisano, *Best Practices for Road Weather Management* (Washington, DC: FHWA, July 24, 2002) 8.

[12] Goodwin and Pisano, 26.

[13] Goodwin and Pisano, 50-51.

where wet weather can produce stopping distances that exceed the available sight distance. The Safety Board has also recommended that the FHWA issue guidance recommending the use of variable speed limit signs in wet weather at locations where the operating speed exceeds the design speed and the stopping distance exceeds the available sight distance. In addition, the Safety Board will inform AASHTO of the circumstances of this accident and of the benefits of using variable speed limit signs in wet weather at locations where the operating speed exceeds the design speed and where the stopping distance exceeds the available sight distance.

Roadway friction was another factor considered in this accident investigation. Postaccident testing at 50 mph in the vicinity of the accident site revealed the average friction coefficients in the right lane, right and left wheel paths, of 0.16 and 0.20, respectively, and in the left lane, right and left wheel paths, of 0.36 and 0.47, respectively. TxDOT's Pavement Management Information System (PMIS) showed pavement friction coefficients in the right lane of 0.12 in 2000 and 0.13 in 2002. (These variations can be attributed to differences in the location of the skid trailer.) All of the pavement friction values in the right lane were very low; in fact, they were equivalent to performance on ice. Coefficients of friction on icy surfaces can range from 0.12 to 0.25.[14]

Further, Texas PMIS skid data for fiscal years 1999 and 2000 revealed that 50 percent of the roads in the interstate highway system had coefficients of friction of 0.26 or below; 50 percent of the U.S.-numbered highways in Texas, 0.31 or below; 50 percent of State highway system roads, 0.35 or below; and 50 percent of the farm-to-market roads, 0.41 or below. Coefficients of friction on Texas interstate highways have values that are generally 0.10 to 0.15 units lower than on State highways and farm-to-market roadways because noninterstate roadways are typically surfaced with high macrotexture seal coats. As coefficients of friction decrease, the required stopping distance increases.

The coefficients of friction on I-35 were close to those coefficients of friction found on icy surfaces. TxDOT was aware of the low frictional qualities of I-35 as early as 2000, when the PMIS data indicated a coefficient of friction of 0.12. Despite this, TxDOT had no immediate plans to repave this roadway to increase its frictional qualities because many interstate roadways in Texas have similar coefficients of friction and all of the other factors (distress, ride, and condition) were rated at the highest level (A). The Safety Board concludes that TxDOT's PMIS does not adequately identify roadways where hazardous conditions exist due to low coefficients of friction and does not expeditiously prioritize these locations for rehabilitation, increasing the risk for accidents such as the one that occurred at this location. The Safety Board believes that TxDOT should change its PMIS to increase its emphasis on roadways with low coefficients of friction in determining maintenance priorities.

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[14] (a) J. Stannard Baker, *Traffic Accident Investigation Manual* (Evanston, Illinois: Northwestern University Traffic Institute, 1975). (b) Francis Navin, Michael Macnabb, and Connie Nicoletti, *Vehicle Traction Experiments on Snow and Ice*, SAE 960652 (Warrendale, PA: Society of Automotive Engineers, 1996). (c) A.H. Easton, "Summary of Tests on Motor Vehicles Under Winter Conditions," *Highway Research Board Proceedings, 1961* (Washington, DC: Highway Research Board, 1961) 565-581. (d) M. McBride, "Skid Tests on Nine Vehicles on an Ice Covered Surface," *Accident Reconstruction Journal*, Vol. 4, No. 2 (Overland Park, KS: Criterion Press, 1992). (e) J. Hunter, *Reconstructing Collisions Involving Ice and Slippery Surfaces*, SAE 930896 (Warrendale, PA: Society of Automotive Engineers, 1993).

The investigation also examined another tool your State uses for determining wet weather accident risk, the Wet Weather Accident Reduction Program (WWARP). The Texas WWARP threshold for determining hazardous roadway segments, which requires that five accidents occur within a 1/10-mile (528-foot) segment on an interstate roadway, is fairly short given the high speeds, traffic volumes, number and weight of trucks, and limited number of intersecting roadways found on interstates. By limiting segments to 1/10 mile, TxDOT may fail to identify longer segments of roadway that have equally hazardous roadway conditions in wet weather. The WWARP indicates that more than half (14) of all the district offices in Texas had zero or one location identified as hazardous. The urban district offices of Houston, San Antonio, Dallas, Austin, and Fort Worth, however, had a disproportionately high number of wet weather accident sites identified (410 of the total 467 reported high-accident sites in the State). Because of the threshold the WWARP uses for collecting data, the program is weighted toward identifying locations in high population areas, virtually ignoring other locations that are just as hazardous but in less densely populated areas.

Sixteen percent of the accidents that occurred on I-35 in the vicinity of the accident from 1996 to 2002 were in wet weather. That segment of roadway was exposed to precipitation only 2.35 percent of the period. Thus, although travelers had nearly a seven times greater chance of being in an accident in wet weather than dry weather at the accident location, the WWARP did not identify this area as a high-accident location. The 2000 WWARP report did not indicate that I-35 in the vicinity of this accident had five or more accidents in the 1/10 mile surrounding the accident site.

The data used for the WWARP are 3 years old. Because of the lag time in this data, locations that have pavement friction issues in wet weather may not be identified quickly enough, as pavement quality deteriorates over time. Further, this accident location had low friction values, a “shallow” rutting problem, and poor roadway geometry that may have indicated an increased accident risk. The Safety Board concludes that Texas’s WWARP methodology is not sufficiently refined to measure wet weather accident risk, fails to identify the greater risk of being involved in a wet weather accident on the segment of I-35 in the vicinity of the accident, and, generally, does not identify problems in a timely manner.

In the 5 miles on either side of the accident site, fewer than three accidents per 1/10 mile occurred within a 3-year time frame (under both wet and dry pavement conditions), on average. Yet this location had a higher percentage of wet weather accidents than other similar U.S. highway segments (16 percent versus 13 percent).[15] When accidents occur on an interstate, the results can be severe because of the high speeds and high traffic volumes. In the vicinity of the accident, the poor roadway conditions consisted of low macrotexture pavement depths, a rutting problem, and low skid numbers. These roadway conditions can be an indicator of potential wet weather problems, and, by not taking these conditions or roadway geometry into consideration, Texas’s WWARP may not identify highly dangerous locations. The Safety Board believes that TxDOT should revise and validate its WWARP so that improvement priorities are not disproportionately influenced by the number of accidents that occur but also consider locations

[15] The National Highway Traffic Safety Administration (NHTSA) estimates that, in 2003, approximately 13 percent of all accidents on the interstate highway system occurred in wet weather. For further information, see NHTSA, *Traffic Safety Facts 2003: A Compilation of Motor Vehicle Crash Data From the Fatality Analysis Reporting System and the General Estimates System* (Washington DC: U.S. DOT/NHTSA, 2004) 47.

where surface conditions and roadway geometry lead to very low friction coefficients and dangerous conditions.

Each State has its own method for determining whether a roadway's friction is a factor in wet weather accidents or has fallen to such a level that the roadway needs to be repaved. For instance, the Illinois system for wet weather pavement management is considerably different from the Texas system because it does not rely on the number of accidents to evaluate and remedy locations that may have greater wet weather accident potential, as Texas's WWARP does, but instead relies upon a roadway's friction number. Furthermore, Illinois drivers are exposed to more wet weather (3.8 percent of 2003), yet experience the same percentage of wet weather accidents (16 percent of all accidents occurred in wet weather in 2003) as drivers in Texas.

While the FHWA provides limited guidance and one possible method of identifying and reducing wet weather accidents, no additional guidance on best practices has been developed by the FHWA since the technical advisory *Skid Accident Reduction Program*[16] was published in 1980. Thus, the States develop their own methodologies, which may or may not be adequate. The Safety Board concludes that Federal guidance on identifying and eliminating locations with wet weather accident problems is limited; had more comprehensive guidance existed, Texas may have implemented a more robust WWARP. Therefore, Safety Board has also recommended that the FHWA review State programs that identify and eliminate locations with a high risk of wet weather accidents and develop and issue a best practices guide on wet weather accident reduction.

The National Transportation Safety Board therefore makes the following recommendations to the Texas Department of Transportation:

> Inventory highway locations where poor vertical geometries, combined with low coefficients of friction and speeds greater than the design speed of the roadway, may create a situation in which traffic has inadequate stopping sight distance, and develop and implement a plan for repaving or other roadway improvements. (H-05-19)
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> Install variable speed limit signs or implement alternate countermeasures at locations where wet weather can produce stopping distances that exceed the available sight distance. (H-05-20)
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> Change the Pavement Management Information System to increase its emphasis on roadways with low coefficients of friction in determining maintenance priorities. (H-05-21)
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> Revise and validate your Wet Weather Accident Reduction Program so that improvement priorities are not disproportionately influenced by the number of accidents that occur but also consider locations where surface conditions and

[16] U.S. Department of Transportation, FHWA, *Skid Accident Reduction Program*, Technical Advisory T5040.17 (Washington, DC: FHWA, 1980).

roadway geometry lead to very low friction coefficients and dangerous conditions. (H-05-22)

The Safety Board also issued safety recommendations to the Federal Highway Administration, the National Highway Traffic Safety Administration, and the Federal Motor Carrier Safety Administration. Please refer to Safety Recommendations H-05-19 through -22 in your reply. If you need additional information, you may call (202) 314-6177.

Acting Chairman ROSENKER and Members ENGLEMAN CONNERS, HEALING, and HERSMAN concurred in these recommendations.

Original Signed

By: Mark V. Rosenker
Acting Chairman