U.S. Department of Transportation
Federal Highway Administration

Memorandum

SENT VIA ELECTRONIC MAIL

Subject: INFORMATION: Design Considerations for Prevention of Cargo Tank Rollovers

Date: September 3, 2010

From: Joseph S. Toole
Associate Administrator for Safety

In Reply Refer To: HSSI

To: Directors of Field Services
Division Administrators
Federal Land Engineers

On August 3-4, 2010, NTSB conducted a public hearing to examine factors that lead to the crash involvement of cargo tank vehicles and measures that can be taken to improve their dynamic stability and prevent the subsequent release of hazardous materials. While the public hearing focused on a specific hazardous materials cargo tank rollover crash in Indianapolis, Indiana, on June 22, 2009, (a description of the crash is attached) it was clear that the NTSB was more concerned about various factors that could lead to cargo tank rollovers in general or prevent or mitigate the release of hazardous materials in the case of crash. The purpose of this memorandum is to provide information on the technical issues that were raised and to encourage you to consider these issues in your stewardship, oversight, design, training and other roles working with your partners.

Background

Although crashes involving cargo tank vehicles can be catastrophic in nature, they remain relatively rare and occur at generally unpredictable locations. The FHWA's position is to encourage geometric improvements at identified, predicted or probable problem locations rather than to advocate system-wide reconstruction to geometric standards above and beyond those recommended in the AASHTO Policy on Geometric Design of Highways and Streets (Green Book). The NCHRP Project 17-18(3) developed a series of guides to assist State and local agencies in reducing injuries and fatalities in targeted emphasis areas. Several of these guides provide information relevant to cargo tank rollovers:

- Addressing Run-Off-Road Collisions http://safety.transportation.org/guides.aspx?cid=27
- Reducing Collisions on Horizontal Curves http://safety.transportation.org/guides.aspx?cid=32
- Reducing Collisions Involving Heavy Trucks http://safety.transportation.org/guides.aspx?cid=34

Geometric Design Issues Raised at the Public Hearing

- Cross slope break. The algebraic difference between the cross slope on the superelevated ramp and the shoulder at the Indianapolis crash location exceed the AASHTO Green Book standard of 8 percent. The cross slope break may have made it more difficult for the driver to regain control on the vehicle. It is important to note that the 8 percent cross slope break standard established in the AASHTO Green Book was based on studies of passenger vehicle driver comfort. We do not have adequate research to determine an appropriate cross slope break based on trucks.
- Negative superelevation on the shoulder. The 8-foot wide shoulder was constructed with a negative superelevation. The NTSB has stated that "the reduction of superelevation as the vehicle moved from the right lane onto the shoulder was a significant contributor to this accident."
- Protection for bridge piers. The cargo tank in the Indianapolis crash left the roadway, struck a bridge pier and the liquefied petroleum gas ignited. The exterior column of the seven column pier collapsed, but the structure remained standing. The NTSB is concerned about hazardous material cargo tankers hitting bridge piers. The Load Resistance Factor Design (LRFD) specifications require structures within 30 feet of the edge of the roadway to withstand a 400 kip load or be protected from impact by an embankment, a 54-inch barrier located within 10 feet or a 42-inch barrier located at more than 10 feet from the component being protected. The 2010 update of AASHTO's Roadside Design Guide is considering including similar provisions.

Action

As you design or evaluate projects and work with your partners, consider:

- The extent to which large trucks, and cargo tank vehicles in particular, are forecast to use the facility. If a significant percentage of trucks are forecasted, it may be appropriate to adjust the design specifically to accommodate these trucks.
- All projects on the National Network must accommodate 102-inch wide trucks. In many cases, truck manufacturers are producing only 96-inch wide trucks since some States and localities restrict trucks to 96 inches on their roads. However, 23 CFR Part 658 states that the maximum width limit for commercial motor vehicles on the National Network *and reasonable access routes* is 102 inches, except for Hawaii where it is 2.74 m (108 inches).

Attached is "Supplemental Guidance on Safe Accommodation of Heavy Vehicles on U.S. Highways". This guidance was prepared by the Office of Safety in 2004 in response to NTSB Recommendations H-95-032 and H-95-033 issued as a result of its investigation of a fatal crash involving a tractor-tanker vehicle to raise awareness of the NCHRP reports and to assist in considering and selecting truck barriers. It should also be discussed with appropriate transportation agency officials.

Future Activities
Sometime next year NTSB is expected to issue its Highway Accident Report, which will determine the probable cause and issue safety recommendations intended to prevent future accidents. At that time, in addition to addressing any NTSB recommendations, the Office of Safety will consider the need for providing additional guidance on safety strategies to mitigate rollover of cargo tank vehicles.

2 Attachments

cc: Associate Administrators

Attachment 1

Description of Crash

On Thursday, October 22, 2009, at approximately 10:38 a.m. EDT, a 2006 International truck-tractor with a 1994 Mississippi Tank Company 11,600-gallon cargo tank semitrailer (specification MC331) operated by a 73-year-old male was traveling south on Interstate 69 (I-69) near Indianapolis, IN. As the truck-tractor semitrailer combination unit entered the semi-direct connection ramp in the right lane toward Interstate 465 (I-465) south, it began to encroach on the left lane, which was occupied by a 2007 Volvo passenger car. The driver of the Volvo blew his horn, at which time, the combination unit moved to the right and onto the shoulder, where the right front of the truck-tractor struck the guardrail. The combination unit was continuing partially on the shoulder when its cargo tank semitrailer began to roll to the right. The cargo tank semitrailer then struck the guardrail with its right side as the combination unit went under the I-465 northbound overpass. The cargo tank semitrailer went over the guardrail and slid on its right side into the bridge footing and the pier supporting the I-465 southbound overpass. As these events took place, the truck-tractor separated from the cargo tank semitrailer. The trucktractor rolled onto its right side, caught fire, and came to rest across the semi-direct connection ramp.

The impact of the cargo tank semitrailer caused the outside column of the southbound I-465 overpass pier to completely separate from the bridge, and the front of the cargo tank semitrailer was breached. Following its impact with the bridge footing, the cargo tank semitrailer passed between the piers supporting the I-465 north and southbound overpasses. The cargo tank breach released the tank's contents (liquefied petroleum gas), which caught fire, and a deflagration1 occurred. The ensuing fire involved eight other vehicles on the I-69 semi-direct connection ramp to I-465 and the I-465 overpasses.

As a result of the accident and subsequent fires, the truck-tractor driver and the driver of the 2007 Volvo passenger car received serious injuries. The occupants of three vehicles on the I-465 overpasses received minor injuries.

SUPPLEMENTAL GUIDANCE ON SAFE ACCOMMODATION OF HEAVY VEHICLES ON U.S. HIGHWAYS

Office of Safety, Office of Safety Design
Federal Highway Administration

October 8, 2004

Based on the findings of several in-depth crash investigations involving tractor-trailers/tractor-tankers, the National Transportation Safety Board (NTSB) has recommended that the Federal Highway Administration provide transportation agencies with expanded guidelines addressing the safe accommodation of large trucks on the Nation's highways, both through improved geometric design and through the increased use of barriers capable of containing large trucks. This paper is a synthesis that summarizes and expands upon information found in the American Association of State Highway and Transportation Officials' (AASHTO) Green Book, the AASHTO Roadside Design Guide, NCHRP Report 505, NHTSA crash data, and other documents. It is intended to supplement the guidance provided in these documents by providing additional guidance on the selection and use of traffic barriers designed to contain heavy vehicles at critical locations.

I. **Truck Crashes in Perspective**

Of the reported 43,005 total highway fatalities in 2002, the percentage of those killed in multi-vehicle crashes involving heavy trucks was 11.4 per cent and those killed in single-vehicle heavy truck crashes was 0.7 per cent. Based on data obtained from the National Highway Traffic Safety Administration's Fatality Analysis Reporting System (FARS), 302 deaths were the result of these single vehicle truck crashes, approximately half of which occurred on curved sections of roadways. Of the 302 single vehicle fatalities, 151 were associated with *van-type trailers*, 44 with *cargo tankers*, 35 with *flatbed trailers*, and 19 in which the cargo body was classified as *"dump"*. The remaining fatalities occurred in crashes involving several miscellaneous heavy truck classifications. Of the four major trailer types listed above, the FARS Most Harmful Event was recorded as *overturn* in 125 cases, *guardrail/concrete traffic barrier* in 22 cases, *bridge pier or abutment* in 8 cases, *bridge rail* in 4 cases, and *tree* in 20 cases.

Most large truck crashes are generally attributed to driver error such as drowsiness, inattention, excessive speed, or an attempt to avoid a collision with another vehicle. However, driver error may be aggravated by a combination of factors such as substandard geometric design, poor advance warning signs, driver expectancy violations, or difficult handling characteristics of heavy trucks, especially their low rollover threshold.

Anecdotal evidence indicates that many truck crashes also may occur in weaving areas, on exit ramps or as a result of conflicts with other vehicles entering or exiting a freeway. To minimize such traffic conflicts, the geometric design features of a highway should anticipate and to the extent practicable address the demands placed on the system by heavy vehicles.

II. Geometric Design for Large Trucks

Geometric design criteria for large trucks are addressed in the AASHTO Policy on Geometric Design of Highways and Streets and focus primarily on roadway elements such as gradient (climbing lanes and emergency escape ramps) and turning radii at intersections. A review of the current guidelines with recommendations for possible revisions was the topic of the recent TRB National Cooperative Highway Research Program (NCHRP) Report 505: Review of Truck Characteristics as Factors in Roadway Design. This document presents information to roadway geometric designers on the accommodation of large trucks on the U.S. highway system. It can be read at http://gulliver.trb.org/news/blurb_detail.asp?id=2314. The report is summarized as follows:

"[Chapter 1 of] The report presents an overview of the size and characteristics of the current truck fleet, a review of geometric design issues related to trucks, and recommendations for potential future changes to geometric design policy to better accommodate trucks. The remainder of this report is organized as follows. Chapter 2 summarizes current size and weight limits for U.S. trucks, as well as comparable data for trucks in Canada and Mexico. The size, composition, and characteristics of the U.S. truck fleet are presented in Chapter 3. The current truck design vehicles used in the AASHTO Green Book are reviewed in Chapter 4, and recommendations for changes in these design vehicles are presented. Chapter 5 summarizes the characteristics of trucks that are related to highway geometric design. Chapter 6 reviews highway geometric design criteria and their relationship to truck characteristics. Chapter 7 presents recommendations for potential future changes in geometric design policy to better accommodate trucks."

Since NCHRP Report 505 provides the most recent information on trucks and geometric design, this paper will only address traffic barriers for large trucks.

III. TRAFFIC BARRIERS FOR HEAVY TRUCKS

Crashes of heavy vehicles through or over traffic barriers that result in catastrophic consequences are rare but are of extreme public concern. There are no specific warrants requiring the use of heavy truck barriers to prevent catastrophic crashes in part because the probability of such a crash at any specific location is low and the cost of such barriers is high. Nevertheless, because a large truck crash is always possible, highway designers should identify locations where it may be in the public interest to install effective countermeasures. This next section addresses factors to be considered by designers in identifying such locations, and the final section addresses the selection, design and location of high-performance barriers.

A. Warrants for Heavy-Vehicle Barriers

The AASHTO Roadside Design Guide addresses locations where truck barriers should be considered. Specifically, Section 5.3, PERFORMANCE LEVEL SELECTION FACTORS, states, "Although objective warrants for the use of higher performance traffic barriers do not presently exist, subjective factors most often considered for new construction or safety upgrading include:

- High percentage of heavy vehicles in the traffic stream
- Adverse geometrics, such as sharp curvature, which are often combined with poor sight distance, and
- Severe consequences associated with the penetration of a barrier by a large vehicle."

Although more definitive warrants are desirable, none are currently available. However, the expanded analysis factors listed below provide some additional guidance to a designer attempting to assess the need for a truck barrier at a specific site. To do so, it is suggested that one:

- Assess the likelihood of a heavy truck leaving the roadway at a specific location
- Assess the risk associated with a crash at a specific location
- Assess the importance and relative vulnerability of the feature that is considered for shielding
- Select and locate a barrier if warranted

1. Some factors to consider in assessing the likelihood that heavy trucks/truck tank trailers (HT/TTT) could be a concern at a specific location include:

- Large percentage of heavy trucks in the traffic stream (e.g., along major interstate transportation corridors)
- Location near fuel distribution center (high concentration of trucks carrying hazardous materials)
- Hazardous material routes

2. Geometric factors to consider in assessing the likelihood that a large vehicle may leave the roadway generally include the potential for traffic conflicts and the geometric characteristics of the roadway. These factors include:

- Location in vicinity of truck –passenger car/light vehicle conflict points such as near interchange ramps, merge lanes, or weaving sections of roadway
- Sharp horizontal curvature, particularly on ramps having lower design speeds and compound curves, often combined with limited sight distance
- Long downhill grades, especially when combined with horizontal curvature
- Adverse pavement surfaces such as excessive shoulder wedges or reverse superelevation on shoulders which may increase the likelihood of rollover for tractor-trailers/tankers

3. Factors to consider in assessing the importance and relative vulnerability of the feature considered for shielding include the degree to which severe damage to or loss of the facility would impact the community. For example, crashes at locations likely to have grave consequences, such as extensive loss of life, widespread severe injuries, or total loss of primary services including transportation for the nation or region. Such locations could include:

- High volume highway or occupied facilities sited beneath a bridge or multi-level interchange
- Transit or commuter rail located beneath a structure or adjacent to a highway
- Facilities that, if impacted, could lead to severe loss of life such as certain chemical or nuclear plants
- Highly sensitive environmental areas such as reservoirs
- Critical highway components such as regionally or nationally significant bridges and tunnels

Even with consideration of the additional factors listed above, the determination of risk remains subjective. Ongoing NCHRP studies may provide additional analysis tools in the foreseeable future, but judgment will remain a key element in the decision process. As noted in the Roadside Design Guide, on reconstruction projects the designer has the added advantage of crash history to aid in deciding if a high performance barrier may be warranted at a specific site or along a particular section of roadway.

B. Barrier Selection

A traffic barrier should always be a "last resort" effort to reduce the severity of a crash by containing and redirecting a vehicle that would otherwise have run off a road or bridge. Every effort should first be made to minimize the likelihood of a roadway departure. Good geometric design, combined with signing, delineation, pavement marking and milled rumble strips, prevents many run-off-the-road crashes – but not all. However, once a decision is made to shield a steep slope or other roadside feature or obstacle against large vehicle impacts, it becomes imperative that the barrier selected and its placement are capable of shielding the feature effectively. This section identifies some of the barrier options available.

Under NCHRP Report 350 testing guidelines, there are currently six different test levels for traffic barriers for vehicles. Test levels 1, 2, and 3 require containment and redirection of a compact car (at 20 degrees) and a ¾ ton pickup truck (at 25 degrees) impacting at 50 km/h, 70 km/h or 100 km/h, respectively. Test level 4 requires containment also of an 18,000-lb single unit truck impacting at 15 degrees and 80 km/h. A 32-inch tall concrete safety shape satisfies this requirement. A test level 5 barrier must contain and redirect an 80,000-lb tractor-trailer, also at 15 degrees and 80 km/h; a 42-inch tall concrete barrier meets this requirement. Finally, a test level 6 barrier must contain and redirect an 80,000-lb tractor-tanker. Only one design has been so classified in the U.S. to date – the 90-inch tall Texas Type TT railing shown in Figure 7.6 in the Roadside Design Guide. Note that a lower test level barrier may contain and redirect some large trucks depending on the actual impact conditions (speed and angle) and on the weight and center of gravity location of the truck or trailer.

Currently, many state highway agencies routinely install concrete median barriers that are 42-inches tall (TL-5 design), both to eliminate virtually all crossover crashes and to reduce headlight glare. In addition, a few states have established a policy that new bridge rails will be TL-5 designs.

The FHWA is aware of only four TL-6 designs installed to date - a new bridge rail in Texas, a retrofit bridge rail in Louisiana, a roadside barrier in Maryland, and a median barrier in Utah. Except in the first case, all construction was undertaken as a result of earlier truck crashes. The approximate cost of the TT bridge rail in Texas was recently estimated to be $125 per linear foot. The bid price for the rail alone was $100 per linear foot in Louisiana, but since it was a retrofit design requiring extensive substructure and superstructure modifications, the total project cost was over $4 million dollars. In addition to being relatively expensive, TL-6 traffic barriers can have other disadvantages. Higher traffic barriers have structure at the same height as occupants in passenger cars. Depending on the design of the barrier, impacts by passenger vehicles may result in head injuries that may not have occurred if the impact had been into a lower barrier. Also, since the available TL-6 barrier is tall and essentially solid, it can be massive in appearance both from the drivers view on the bridge and residents view from the surrounding area.

Another design option to consider for large trucks is a vertical-faced concrete barrier. Crash tests show conclusively that vertical-faced barriers create less roll on impacting vehicles and eliminate most “climb” on a barrier. Increased use of this shape at critical locations (such as bridge piers located immediately behind the barrier), combined with additional height (up to 54 inches) could be a cost-effective alternative to addressing heavy truck design issues. Adding a steel rail to the top of existing shaped concrete barriers is another way by which crash performance can be enhanced by reducing vehicle climb and roll towards the barrier in an impact.

IV. Bridge Rails, Transitions and Approach Rail

If a bridge is on a horizontal curvilinear alignment and the primary reason for the use of a higher test level bridge rail is to shield a vulnerable site below such as a school, a rail line, or a major freeway, the approach barrier and its transition to the bridge rail must also be capable of containing the design vehicle. In such cases, it may be desirable to continue the same bridge rail design off the bridge before transitioning to a lesser rail design.

V. Summary

It would be ideal to be able to assess the risk of a catastrophic crash of a heavy truck at any given site with a high degree of accuracy and to then design a barrier capable of containing such a vehicle. Since that is not currently possible, the above information is offered to assist designers evaluating a site for a heavy vehicle barrier.

We will continue working with our industry partners to evaluate and develop, as appropriate, additional barrier selection criteria. This work will be the basis of any update to the Roadside Design Guide. For additional information or questions contact Messrs. Harry Taylor at (202) 366-2175 or Richard Powers (202) 366-1320 in the Office of Safety Design.