

**Massachusetts Department of Transportation**  
**Review of Roadside Barrier and Maintenance Safety/Emergency Egress Railings**  
**In the Ted Williams Tunnel, I-90 Connector and Thomas P. O'Neill, Jr. Tunnels**  
**April 14, 2011**

**Executive Summary**

This report provides MassDOT's conclusions and recommendations concerning the existing roadside barrier and maintenance safety/emergency egress railing in the Ted Williams Tunnel, I-90 Connector and Thomas P. O'Neill, Jr. Tunnels ("Tunnels").

The report scope includes a review of the roadside barrier and maintenance safety/emergency egress railing for in-service operation and safety performance. The barrier and the railing are reviewed as separate units and as a combined barrier/railing system.

**Summary of Findings**

The Tunnels were built to federal safety requirements and meet all those requirements today. The Tunnels, including the existing roadside barrier and maintenance safety/emergency egress railing, are safe as designed and used.

Barrier

The existing roadside barrier meets construction standards and complies with national crash performance standards for highway barriers and roadside safety elements. Design parameters and standards for the roadway barriers require that passenger compartment integrity be maintained and that barrier/railing hardware or snagged vehicle parts do not endanger vehicle occupants by penetrating the passenger compartment. There are no design standards for elements and roadside hardware in cases where individuals are ejected from motor vehicles or motorcycles.

Railing

The railing mounted on the roadway barrier provides maintenance worker and emergency egress safety as designed. These railings are required by the Massachusetts Building Code and National Fire Prevention Association (NFPA) 502, Standard for Road Tunnels, Bridges, and Other Limited Access Highways.

Barrier/Railing System

The combined barrier/railing system is performing the function of worker safety and fire safety as designed. The combined vehicle barrier and walkway railing is functioning within national crash performance standards for highway barriers and roadside safety elements.

## **Summary of Recommendations**

The following recommendations are made for enhancements that may potentially mitigate certain types of injuries sustained by an ejected occupant of a vehicle or motorcycle rider impacting the maintenance safety/emergency access railing.

1. Remove the railing at all locations where the railing is not specifically needed to meet the emergency egress requirements of NFPA 502.
2. Retrofit existing railing with chain link fence mesh/fabric along outside curves at locations to be determined based on analysis of crash data.
3. Improve existing signage regarding speed limit and geometry of the tunnel.

## **I. Background**

Massachusetts has the lowest statewide fatality rate in the U.S. when measured by fatal accidents per 100 million vehicle miles traveled, including accidents caused by driving under the influence of drugs or alcohol, reckless driving and speeding.

Based on State Police accident data for the Tunnels since 2003, there have been 10 crash fatalities, 493 crashes with personal injury and 1,201 crashes with property damage only occurring inside the Tunnels. The O'Neill Tunnel accounted for a majority of all accidents with the Northbound and Southbound tunnels respectively having 46% and 39% of the total reported. There is no data available that measures fatal accidents involving dismemberment or entanglement with roadside hardware as a percentage of total fatal accidents statewide. Therefore, there is nothing to indicate that there is a higher rate of such fatalities in the Tunnels compared to the rest of the state highway system.

Of the 10 reported crash fatalities in the Tunnels, four involved motorcycles, five involved passenger cars and one involved a pick-up truck. All 10 fatal crashes occurred primarily along curved sections of the Tunnels in the proximity of on and off-ramps. In six of the fatal accidents, ejected occupants struck the tunnel railings. However, excessive speed, loss of control of the vehicle, failure to use safety restraints, and other factors were noted in the initial police reports, suggesting that the handrails were not the cause of the accidents.

Also of note is the fact that there are no safety design standards or crash test standards for roadside safety hardware where individuals coming into contact with the safety hardware are outside of a vehicle passenger compartment.

Each incident resulting in injury or fatality has a unique set of circumstances and multiple contributing factors. Therefore, no single mitigation option will address all incidents or eliminate the possibility of injury or fatality when the events as described above occur.

## **II. Findings and Recommendations**

### **Roadway Barrier**

The roadway barrier is a concrete safety shape barrier, tested and approved in accordance with National Cooperative Highway Research Program Report 350 (NCHRP-350). NCHRP-350 establishes crash performance standards for highway barriers and other roadside and safety elements. All roadside safety elements which have been tested in accordance with the requirements of NCHRP-350 and accepted by the Federal Highway Administration are considered safe and effective. The roadside barrier in the tunnel is an approved NCHRP-350 Test Level 4 barrier and is accepted as a safe roadside barrier.

At Test Level 4, tests are performed on passenger cars, pickup trucks and single unit trucks. The tests require that vehicles hitting the barrier are redirected in a controlled manner and do not rebound into an adjacent lane. Passengers who are restrained in the vehicle must not experience excessive force likely to cause severe or fatal injury and the passenger compartment must not be crushed or penetrated by material such as barrier parts or snagged or loose vehicle parts. Motorcycles are not NCHRP-350 test vehicles for Test Level 4 on barriers because the rider/passenger is neither restrained nor within a defined passenger compartment providing protection.

Accepted concrete safety shapes (both SGM11, the New Jersey Shape and SGM 10 the F Shape) are as shown in the appendix of the AASHTO Roadside Design Guide 2002 edition. The barrier shown in the appendix drawings has an overall height of 32 inches; however as noted in the Roadside Design Guide (RSDG):

“The details of the shape are critical. The distance from the pavement to the break between the upper and lower slopes should be kept at 13 in. or below. Barrier performance under moderate to severe impact is not significantly affected by overlays on the lower sloped face. The overall height of the barrier, however, needs to be maintained at a minimum of 29 in.” (RSDG 2002(2006) Appendix C-13)

Measurements made in the field indicate the overall barrier height is at least 30 inches. This is an accepted level and the barrier is expected to perform safely in accordance with standards established in NCHRP-350.

### **Maintenance/Emergency Walkway Rail**

The walkway railing is attached to the top of the vehicle barrier and is designed to separate pedestrians from the roadway. Potential pedestrians in the Tunnels include maintenance personnel performing routine tasks and occupants from disabled vehicles and emergency response vehicles. In the event of a tunnel emergency, the railing is intended to prevent pedestrians from falling or stepping off the elevated safety walkway, especially in conditions of limited visibility. The railings also protect pedestrians accessing emergency egress routes to tunnel cross-passage doorways, and are therefore required along the elevated walkway leading to the tunnel portals or exits.

The railing is designed to comply with the Massachusetts State Building code and NFPA 502. It is required on walkways that are over 30 inches in height and must support 100 lbs. per linear foot vertical load, 50 lbs. per linear foot horizontal load at the top of rail, and a concentrated load of 200 lbs. in any direction. The handrails are 42 inches in height along the walkway and 50 inches in height in the area directly adjacent to tunnel cross passage emergency egress exits and utility rooms.

The railing for the walkway is performing the function of worker safety and fire safety as designed. There are no reported instances where the railing has failed for this purpose.

### **The Barrier/Railing Combined System**

The combined Barrier/Railing system is performing the function of worker safety and fire safety as designed. There are no reported instances where the railing has failed in this regard. It is also functioning within the requirements of NCHRP 350 pertaining to crash performance standards for highway barriers and other roadside and safety elements.

### **III. Review of Potential Safety Enhancements to the Barrier/Railing System**

Several alternatives to enhance the safety of the tunnel barrier/rail system were considered. These alternatives were considered based on the assumption that safety could be improved by eliminating, modifying or redesigning the handrails thereby reducing the probability of ejected vehicle operator or motorcycle interactions with the handrail posts. Other types of trauma that occur during traffic incidents are not addressed by these alternatives.

Alternatives regarding a reduction in the width of walkway were not considered due to minimum width requirements of NFPA 502. Alternatives requiring drilling into the existing walkway for anchorage were also not considered due to the presence of electrical conduit embedded in the walkway.

Each alternative provides a different level of safety risk to mitigate the interaction of the occupant or rider with railing posts. Additionally, each has different impacts on operations, costs and timeline for implementation. They are presented here for further policy development. The alternatives considered are of a practical nature and should not be considered exhaustive. A recommendation is made based on evaluation and comparison of the mitigation provided and the impacts of implementation.

#### Option 1 - Maintain the Current System

Safety Risk – The current level of safety is maintained for workers and tunnel users.

Cost – The current tunnel operation costs are maintained.

Time – There is no implementation timeline.

Tunnel Operations – There is no effect on current operations.

#### Option 2 - Remove the rail at all locations where not specifically needed to meet the emergency egress requirements of NFPA 502.

In this alternative, the railing would be removed from locations where it is not needed for NFPA 502 compliance. Preliminary assessment is that 14% or 8,000 linear feet of the total 58,000 linear feet of railings are in place to serve only as a maintenance walkway and therefore, do not implicate the emergency egress requirements of NFPA 502.

Safety Risk - This alternative will remove any chance of an ejected vehicle passenger or motorcycle rider impacting the vertical railings in select locations. However, railing elements would still be required at ladder/stair climbing points along the barrier as the ladder/stair is difficult to climb without a handgrip attached to the railing. It would also be necessary to retain railings at doorways of utility rooms and cross passages so that persons passing through the doors are stable and oriented prior to using the elevated walk.

Costs - Costs would be limited to labor costs to remove the rail and partially offset by the salvage value of the stainless steel rails removed.

Time - Implementation timeline would be brief, including traffic management during the unbolting of the rail and grinding residual material to provide a smooth subsurface on top of the concrete barrier.

Tunnel Operation - Certain tunnel maintenance work in these areas would require lane closures, resulting in traffic impacts. Operational issues in these areas would be simplified due to lack of railings such as inspection, access to wall appurtenances such as fire extinguishers and pull stations. Tunnel washing in these areas would be simplified.

### Option 3 - Design a New Railing with Small Openings and Consistent with NCHRP-350/MASH

Safety Risk - This option would reduce the likelihood of ejected vehicle passengers or motorcycle riders' impact with vertical railings, the exception being at breaks for access points. Physical crash tests are required to confirm that the design meets the requirements of NCHRP-350 and MASH. Recently accepted advanced computer modeling techniques provide results that closely approximate actual crash test data and could be relied upon for vehicle/railing interaction. Incidents involving ejected passenger impact with the railing are not easily computer-model tested. Any openings would be designed to reduce or eliminate the potential for injury in these specific types of cases.

Costs- The costs for this option are significant. A new railing must be designed. Simulation testing would be required before manufacture and installation.

Time- The timeline to implement this solution would be significant, depending on design and modeling time as well as time to construct the final design.

Tunnel Operation- The impact on tunnel operations and driver safety would be projected following design of the new railing.

#### Option 4 - Replace open railing with a solid railing with no openings.

Safety - This option may reduce the likelihood of ejected vehicle passengers or motorcycle riders' impact with vertical railings, except at access point breaks in the new railing. It provides protection from traffic to persons on the safety walk by resisting most passenger vehicle impacts.

Costs - The costs are significant. This type of solution, concrete or steel, must be designed first and likely crash tested and then constructed by forming for concrete or installing new prefabricated solid face steel railings or retrofitting existing railing with plate steel. In addition to removing the railing as required in the previous options, dowels and additional connection details into the existing barrier would likely be necessary for new railings.

Time - The implementation timeline would be significant. It would require design followed by a major construction operation with traffic impacts.

Tunnel Operations - Operations would be affected during construction because of the nature of the work. This option also may affect traffic flow and safety in the tunnel after installation. Observations of motorist behavior in tunnels show a "tunnel effect" where operators presented with a high wall above the line of sight tend to brake, reduce speed, and encroach on an adjacent lane. Measures could be considered to reduce lane encroachment and braking. Speed reduction may not be sustained as drivers become familiar with the new barriers. Other impacts would include changes to inspection of walls and wall appurtenances, removal of wall panels for leak repair, fire pull stations location and access, fire extinguisher access and more difficult mechanized tunnel washing behind the solid railing.

#### Option 5 - Retrofit Existing Railing with Chain Link Fence Mesh

Safety - A chain link fence mesh could be fitted against existing railings from just above the walkway surface to the top rail. This option also may reduce the likelihood of ejected vehicle passengers or motorcycle riders coming in contact with vertical railings. Because this is not a solid system, however, it may abrade anything that slides along it. The capacity of the railing system to contain and provide a stable egress path in the event of a tunnel emergency would not be affected.

Costs - Posts for the fence are not required as it can be attached directly to the railing posts. Special anchorage for the tension wire may be required. As the tunnel environment is very corrosive stainless steel mesh would likely be required increasing costs as compared to standard fencing.

Time - The implementation timeline would be moderate as the system must be designed and crash tested. However, no railing need be removed and construction would be limited to installation of the mesh.

Tunnel Operations - Operations and traffic safety, again, may be affected by “tunnel effect” previously discussed in #4. However, because the fence is not solid and light passes through the fencing, the tunnel effect is likely to be less significant. Maintenance of chain link fence will be required, litter removal and tunnel washing will likely become more labor intensive.

Option 6 – Review existing signage and revise/enhance as appropriate

A review of existing signage regarding speed limit and geometry of the tunnel is recommended to determine if any enhancements should be made to the signage in areas of the tunnel where there have been higher incidences of accidents.

#### **IV. Recommendation**

Implement a combined approach consisting of Options 2, 5 and 6:

- 1. Remove the railing at all locations where the railing is not specifically needed to meet the emergency egress requirements of NFPA 502.**
- 2. Retrofit existing railing with chain link fence mesh/fabric along outside curves and other locations to be determined based on analysis of crash data.**
- 3. Review existing signage regarding speed limit and geometry of the tunnel, and revise/enhance as appropriate.**

The above combination of alternatives provides the most practical, cost-effective action to mitigate the interaction of the occupant or rider with railing posts. Further review of accident locations, egress requirements, change in maintenance access policies and discussion with Federal Highway Administration, Massachusetts State Police and Boston Fire Department are required to implement the recommendations.