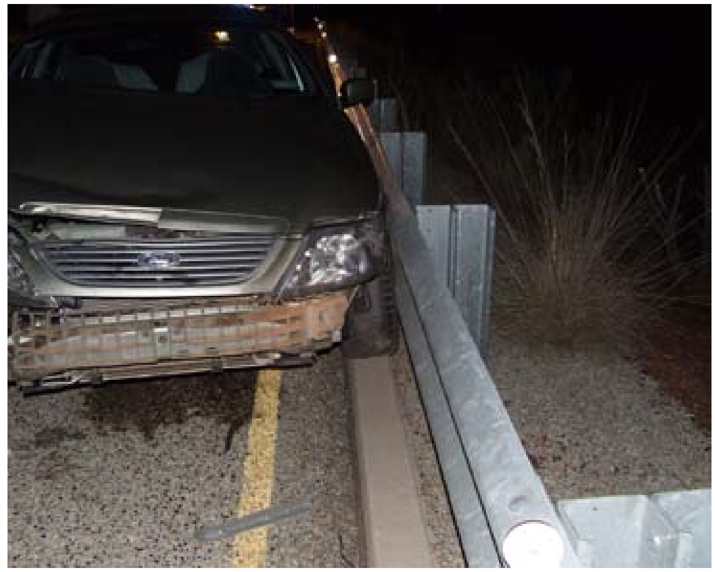
Tech Note #50

# BARRIERS



According to a fact sheet prepared by the University of Massachusetts Traffic Safety Research Program (UMassSAFE), 46 percent of all crash fatalities in the Commonwealth were from lane departure crashes during 2002-2004. While these collisions account for less than 1/5 of all crashes, they do make up nearly 1/2 of all **fatal** crashes. Trees and utility poles are the most common objects hit, accounting for 52 percent of incapacitating injury, single-vehicle lane departure collisions.

Studies show that guardrails along the road edge reduce the number of fatalities and serious injuries resulting from run-off-road crashes by redirecting vehicles in a controlled manner. Hospital stays and charges were considerably less when single vehicle crashes involved a guardrail as opposed to other hazards according to The Crash Outcome Data Evaluation System.

Various solutions can be considered to improve safety and reduce road hazards such as clear zones, treatment of ditch sections and transverse slopes, roadside and median barriers, and impact attenuators. The 2006 AASHTO *Roadside Design Guide* provides standards and recommendations on the design of these.

The *MassHighway Project Development and Design Guidebook* indicates that clear zones or roadside recovery areas should be provided when practical. Where this is not feasible or practical, roadside barriers must be considered when there is a history of run-off-road collisions or when there is a significant potential for such collisions. Barriers should be installed only if the consequences of striking the barrier are less severe than a run-off-road crash.

A roadside barrier is a longitudinal barrier used to shield motorists from natural or manmade obstacles located along the roadway. Barriers may occasionally be used to protect pedestrians and bicyclists from vehicular traffic. A single-faced longitudinal barrier installed either in the median or on the outside of the roadway is referred to as a roadside barrier. A double-faced longitudinal barrier, which is designed to redirect vehicles striking either side of the barrier, is referred to as a median barrier.

The primary purpose of barriers is to prevent a vehicle from leaving the roadway and striking a fixed object or terrain feature that is considered more dangerous than the barrier itself. This is accomplished by containing and redirecting the impacting vehicle.

There are three categories of roadside barriers: flexible, semi-rigid, and rigid. Flexible systems are generally more forgiving since much of the impact energy is dissipated by the deflection of the barrier. Rigid systems are generally more durable, higher in initial cost, and more maintenance-free. Semi-rigid systems provide a combination of these features.

Once it has been decided that a barrier is warranted, the designer must choose the appropriate type by consulting the *Roadside Design Guide* and considering the following factors:

**Performance Capability:** Barriers must be structurally strong enough to contain and redirect vehicles.

**Deflection:** Barriers may require a buffer to account for their flexing during impact.

**Site Conditions:** The slope approaching the barrier and distance from the traveled way may preclude or suggest the use of some types.

**Compatibility:** The barrier must be compatible with the planned end anchor and capable of transition to other barrier systems such as bridge railings.

**Cost:** Standard barrier systems are generally consistent in cost, but high-performance or aesthetically designed railings can cost significantly more.

**Maintenance:** Selections should consider these factors:

- **Routine** -- Amount of routine attention required.
- **Collision** -- Flexible and semi-rigid systems require significantly more maintenance after a collision than rigid ones.
- **Materials Storage** -- Consistency in barrier systems use reduces the needed inventory of spare parts.
- **Simplicity** -- Simple designs cost less and are more likely to be properly installed and maintained.
- **Aesthetics** -- This is an important consideration to ensure visual consistency with the surrounding context and is discussed further in Chapter 13 of the MassHighway *Project Development and Design Guidebook*.
- **Field Experience** -- Performance and maintenance monitoring data of existing systems can identify problems with the opportunity for improvement.

Three barriers commonly used in Massachusetts fall into the flexible, semi-rigid and rigid categories.

## Flexible

These slow an errant vehicle, but sometimes will not completely prevent it from leaving the roadway area. Flexible systems require large "clear zones" beyond the

edge of the traveled roadway. Massachusetts employs a three-strand cable system that uses posts driven into the ground at fixed vertical intervals along the roadside. This system is designed to wrap around the colliding vehicle and redirect it with minimal impact to the vehicle and its occupants. The vehicle's force stretches the cables and the posts bend or break. Because this system requires elasticity to deflect the vehicle, adequate clear space from potential hazards beyond the guardrail is essential.

Cable systems are inexpensive to purchase, simple to install, and relatively inexpensive to repair. Snow removal is simplified and they are unobtrusive forming a visually attractive alternative to heavier guardrail designs.

Disadvantages include damage from vehicular crashes or snowplows and the need for greater offset/deflection space. Flexible systems can deflect vehicles between 8 and 12 feet upon impact. Given these relatively large deflections, cable barrier systems are not usually considered appropriate to shield fixed objects closer than 8 feet offset of the traveled way. To be fully effective, cables must be maintained at the proper tension levels and heights.

Approximately 95 percent of rollover crashes are caused by what is known as "tripping force." This occurs when an errant vehicle slides with lateral motion, often with its wheels dug into soft soils or granular materials. If the vehicle reaches critical sliding velocity and hits a low obstacle, such as slack cable, it is likely to roll over. This is particularly true for sport utility vehicles with their high center of gravity. Lighter vehicles can hit a slack cable system and "trampoline" back into traffic causing multi-vehicle crashes.

Cable systems require abundant clear space beyond the edge of the roadways. Proper tension levels must be maintained for optimum safety. New cables meet the National Cooperative Highway Research Report 350 Test Level 3, which is acceptable for all National Highway System roadways, and MassHighway has recently begun to use them on higher speed and high volume roadways such as Routes 495 and 213.

## Semi-Rigid Systems

Advantages include lower initial cost than rigid systems, familiarity by maintenance personnel, the ability to safely accommodate a wide range of impact conditions, and relatively easy installation. These can be a hazard until repaired and tend to cause snow drifting. Performance for vehicles above 4,400 lbs. is not assured. At high impact locations, frequent maintenance may be required putting work crews in dangerous situations.

* **Blocked-Out W-Beam** -- This system uses a heavy post of either steel or wood with a block out and corrugated steel face (W-beam). Typical post spacing is 6 feet 3 inches on center. This system is more durable than cable and damage from a mild impact only affects a specific area. It may act as a snow fence and induce drifting. This barrier is more expensive than cable but significantly less than concrete. Details are shown in the *MassHighway Construction Standards.*

* **Blocked-Out Thrie Beam** -- Similar to the blocked-out W-beam, it has a deeper corrugated metal face to minimize the possibility of underride or vaulting by impacting vehicles. It is used where superior strength is required but space is too limited for a rigid system. Details are shown in the *MassHighway Construction Standards.*

* **Steel-Backed Timber Rail** -- A heavy wood rail backed with a steel plate and installed on heavy wood posts. It may be used only on low volume roads with design speeds under 55 mph as confirmed by recent crash tests. This rustic appearance may be preferred if funding can support the additional cost. Because only full height straight sections have been crash tested, this system must transition to other approved systems at termini and on sharp curves.

## Rigid Systems

The concrete safety shape barrier is often used in MassHighway projects. The F-shape is preferred over other designs because of its better performance in small vehicle impacts with respect to vertical roll and redirection. These systems have the highest initial cost but require the least maintenance. There is little or no deflection distance required behind the barrier. Light supports, sign supports, etc. may be mounted on top. Details are shown in the *MassHighway Construction Standards*.

## Roadside Barrier Requirements

Once a potential roadside hazard (fixed objects or non-traversable slopes) has been identified, determining barrier warrants involves these steps:

1) Is the hazard within the recovery zone?
2) Can the hazard be removed, relocated or made breakaway?

3) Can the slope be flattened to provide recovery area?
4) Is the barrier less of an obstacle than the hazard it will shield?
5) Is a barrier installation practical, based on engineering judgment?

Barrier installation guidelines are presented below:

### Fixed Object and Non-Traversable Hazards

Warrants for hazards within the roadside recovery zone are found in the AASHTO *Roadside Design Guide* and Exhibit 5-23 of the MassHighway *Project Development and Design Guidebook*.

### Embankments

Generally, a barrier is required to protect slopes steeper than 1:4. A barrier may also be warranted based on speed, traffic volumes, crash history, and cost-effectiveness. Exhibits 5-24 to 5-26 in the *MassHighway Project Development and Design Guidebook* illustrate embankment warrant critieria one of which is reproduced here.

### Bridge Rails or Parapets (overpass)

These require an approach section which will securely attach to the rail or parapet. Barriers should also be installed on the trailing end of the bridge if its end is within the recovery area for opposing traffic.

### Ditches

See the AASHTO *Roadside Design Guide*

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### Traffic Signal Support

Isolated traffic signals within the recovery area on high speed rural facilities may require shielding.

### TERMINALS/END TREATMENTS

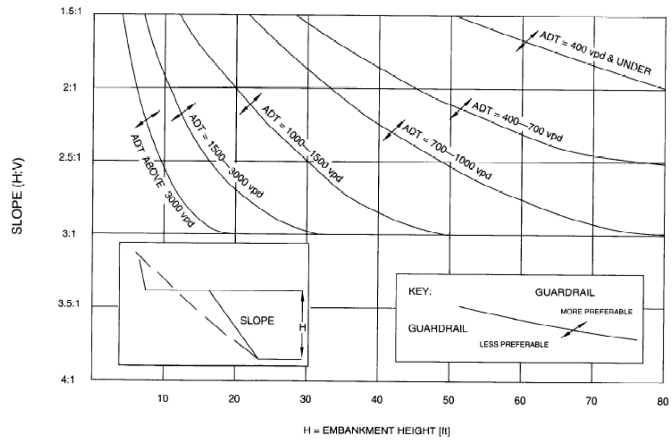
Barrier end terminals are used to reduce severity of impacts by gradually slowing and bringing the vehicle to a stop or by redirecting it around the object of concern. It is important that the vehicle remain in an upright position during and after the collision without entering adjacent lanes of traffic. A terminal can be designed to have full redirection capabilities along its entire length (a non-gating terminal) or to allow controlled penetration along a portion of its length (a gating terminal).

Preferably, the barrier should be flared away from the travel lane and, if feasible, should be terminated outside the recovery area. To be crashworthy, the end treatment should not spear a vehicle, cause a vehicle to vault or roll a vehicle for head-on or angled impacts. Trailing ends must be protected with a crashworthy end treatment if it is within the clear zone of opposing traffic.

Descriptions of standard and special end treatments can be found in the *MassHighway Construction Standards* and the *2006 AASHTO Roadside Design Guide.*

### EXHIBIT 5-25

**EXAMPLE DESIGN CHART FOR EMBANKMENT WARRANTS BASED ON FILL HEIGHT, SLOPE AND TRAFFIC VOLUME**




*H = Embankment Height (ft)*
*Source: Roadside Design Guide, AASHTO, 2002, Chapter 5 Roadside Barriers*


**Sources:**

"Massachusetts Lane Departure Crash and CODES Data Analysis Fact Sheet," Massachusetts Traffic Safety Research Program (MassSAFE), University of Massachusetts, Amherst, MA, 2004.

*MassHighway Construction Standards,* Massachusetts Highway Department, Boston, MA, 1997.

*MassHighway Project Development and Design Guidebook,* Massachusetts Highway Department, Boston, MA, 2006.

*2006 Roadside Design Guide,* American Association of State Highway and Transportation Officials, Washington, DC, 2006.