Selection and Grading of W-Beam End Treatments

CATEGORY: Design

ISSUE: Guardrail end treatments have generally been tested for crashworthiness on flat ground under specific impact conditions. However, many of the sites where these terminals are actually installed differ considerably from the crash-tested conditions. What steps can roadway designers and field inspectors take to ensure optimal terminal performance under less than ideal field conditions?

OBJECTIVES: Provide guidelines that:

- Can be used for terminal selection during design,
- Enable field personnel to recognize site conditions that can lead to unsatisfactory terminal performance, and
- Identify appropriate on-site adjustments that can optimize terminal performance.

METHODOLOGY: The importance of an adequate length of barrier in relation to the proper selection of terminal type will be explained. Additionally, the reasoning behind minimal grading requirements and the frequent need to shield secondary hazards will be summarized. Examples will be given where appropriate.

GENERAL: Three major concerns are addressed in this document: terminal selection and barrier length of need, grading at and around the terminal, and identifying and shielding secondary hazards.

Terminal selection and barrier length of need:

There are three primary W-beam terminal designs in use at present: buried-in-backslope (Type 12), non energy-absorbing (Type 21), and energy-absorbing (Type 38).

Non-Energy Absorbing Terminal (Type 21)

Energy Absorbing Terminal (Type 38)

Figure 1: Pickup Truck Trajectories by Terminal Type

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have been lengthened to shield the entire slope. The energy absorbing terminal can, however, slow any vehicle impacting at a shallow angle and is far preferable here than a non-energy absorbing design.

The "runout" area is the most difficult space to define and is discussed below under shielding secondary hazards.

Grading is easier to visualize with a buried-in-backslope terminal because the only area of concern is the terrain leading up to it, which must be traversable and contain no fixed object hazards. However, there are other "grading" concerns of which to be aware: the backslope itself must be sufficiently steep to prevent a vehicle from climbing over the rail, the barrier flare rate must be appropriate for the roadway design speed and traffic volume, the height of the rail must remain constant in relation to the roadway edge at least until the guardrail crosses the ditch flow-line, and a W-beam rubrail must be added if the distance from the bottom of the primary rail and the ground exceeds about 17 inches. Note that if the backslope is relatively flat, a vehicle can ride up the slope and bypass the terminal. When this condition exists at a site, the designer must ensure that the hazard remains shielded by assessing the available clear runout distance behind the rail and the barrier length-of-need. The terminal depicted in **Photograph D** satisfies the conditions noted above. Although the slope could be overridden, there is ample recovery area beyond the terminal itself.

D

Shielding secondary hazards:

The installation shown in **Photograph E** is an energy absorbing design so a vehicle impacting end-on would likely be stopped safely before reaching the concrete barrier. However, any angled hits at the end would result in significant intrusion behind the rail and into the rock outcropping. The guardrail should have been extend to shield the secondary hazard.

E

If the terminal shown in **Photograph F** had been a non-energy absorbing design, the vehicle that struck it would most likely have continued forward into the cross-drainage structure.

F

The installation shown in **Photograph G** illustrates a common concern. The primary purpose of the barrier is to shield the bridge ends, but the trees lining the roadway also present a hazardous condition to motorists. If a single tree was directly behind the terminal, it might be cost-effective to extend the barrier to shield that hazard as well as the bridge ends. However, barrier extension becomes impractical when the secondary hazard is more or less continuous along the entire road. In this case, a good field check to determine if shielding secondary hazards may be practical is to observe whether or not the area behind the terminal is at least as clear and unobstructed as the unshielded area immediately upstream of the terminal. If the area immediately behind and beyond the terminal is clearly more hazardous than the unshielded upstream area, extending the barrier a greater distance may be warranted. In the photograph, it appears that the tree line is indeed continuous and that shielding them would not be cost-effective.

G

EXPECTED RESULTS:

Provides designers with guidance for selecting appropriate terminal type based on site conditions, and provides inspectors with information that can be used to optimize the effectiveness of field installations.

Non energy-absorbing designs do not significantly reduce vehicle speed in a near end-on hit. They are best specified when there is a long, clear, traversable area behind them parallel to the guardrail installation, such as one often found in a flat freeway median. Crash-testing has shown this runout distance can exceed 150 feet. Therefore, barrier installations less than 150 feet in advance of any shielded object should be introduced with an energy-absorbing terminal design.

Energy-absorbing terminals have been shown to stop an impacting pick-up truck in about 50 feet when struck end-on and thus are best suited to locations that do not have much traversable area behind the barrier installation. Figure 1 on the proceeding page shows the relative trajectories of the heavy passenger vehicle impacting both terminal types head-on and at high speed (62 mph).

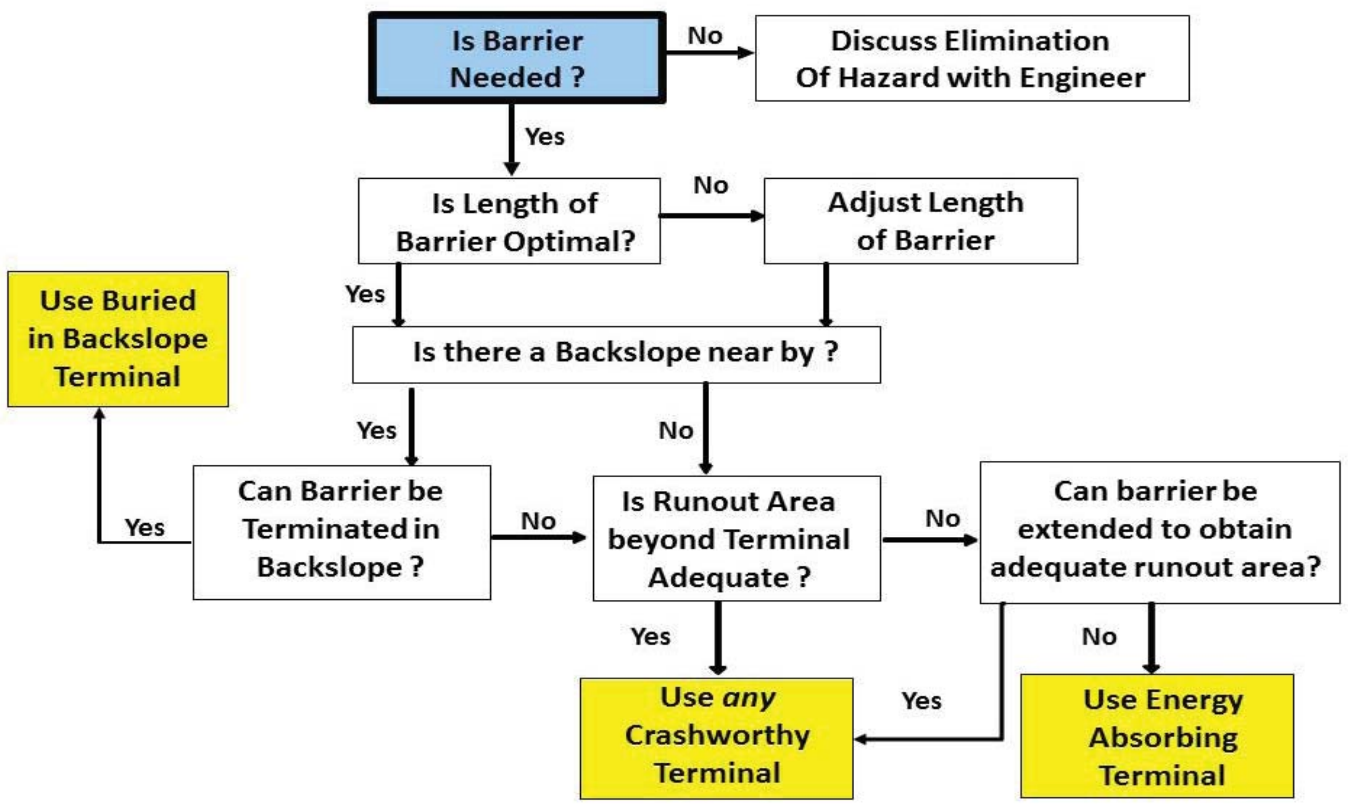

Figure 2: Terminal Selection Flowchart

Figure 2 is a suggested flowchart that can be used by a designer to select the most appropriate terminal for a specific location. Note that the starting point is to verify that a barrier is actually needed. If so, then the correct length of need should be confirmed. If the total length of barrier is less than about 150 feet, an energy-absorbing terminal should be selected for the reasons previously stated. When an appropriate backslope exists near the end of the barrier, the buried-in-backslope terminal should be considered. When no suitable backslope exists, either a non-energy absorbing (Type 21) or an energy absorbing (Type 38) maybe appropriate. However, an energy-absorbing design should be specified when the area beyond the terminal is not traversable or contains fixed object hazards.

Grading:

As seen in Figure 3, there are three grading areas of concern around barrier terminals: advance, adjacent, and run-out. A terminal struck by a stable vehicle, i.e., a vehicle that has its suspension neither compressed nor extended and has minimal roll, pitch, and yaw angles, will result in the best terminal performance possible. The "advance area" consists of the space traversed by an errant motorist before the terminal is struck. If a terminal "platform" was constructed, it must be smoothly blended into the existing roadside embankment so a motorist has an opportunity to return to the roadway without striking the terminal or losing control of the vehicle by dropping off the edge of a steep platform before impact. The "platform" in **Photograph A** creates a significantly greater hazard than previously existed and could easily cause a rollover before a vehicle even reaches the terminal. Many grading platforms can be eliminated either by extending the barrier a short distance to a flatter location and/or by specifying a non-flared end treatment.

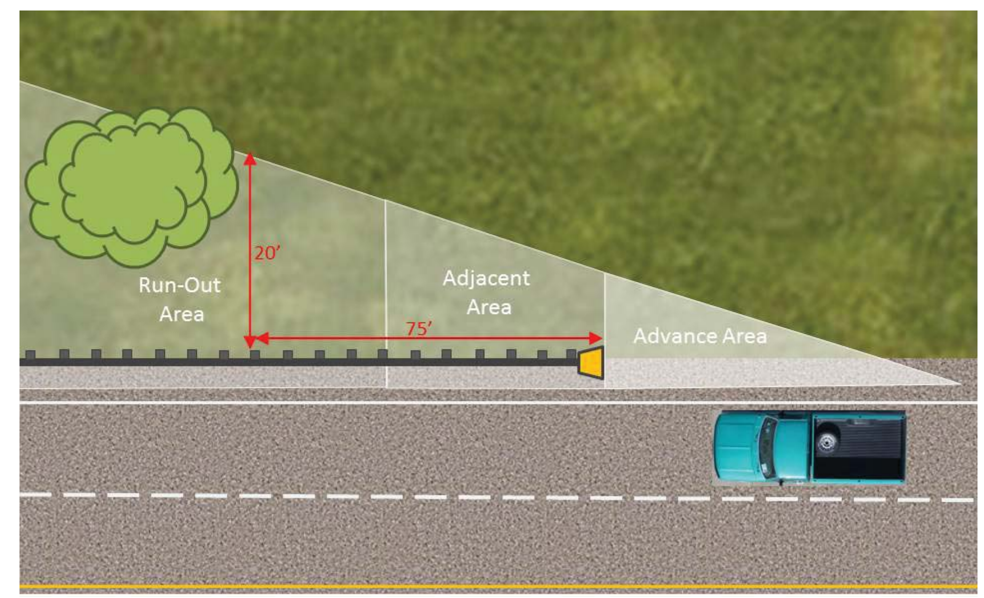

Figure 3: Terminal Grading Areas

Impacting a terminal, even when it is installed on flat ground, induces some instability in most vehicles. When the area immediately behind a terminal (i.e., the "adjacent area") is steep or non-traversable, a vehicle can overturn after breaking through the terminal. A minimal traversable area behind the terminal is an essential part of good barrier design. A field check should be made to determine if a runout area exists. A minimal traversable area 20-feet wide and 75-feet long is necessary. However, this minimal distance was based on the final resting position of the small car during crash testing. A heavier vehicle at a higher speed will travel a greater distance behind and beyond the terminal. **Photograph B** shows excellent adjacent area grading as well as a significant run-out distance beyond the terminal and parallel to the roadway. Although the terminal shown in **Photograph C** is an energy absorbing design, any impact into the end will most likely end with a vehicle striking the utility pole.. In many situations, it simply may not be practical to shield every hazard. This barrier was installed primarily to shield the slope along the curve and is effective for that purpose, but it should

A

B

C