CHAPTER 12

GUIDE RAIL, MEDIAN BARRIER AND ROADSIDE SAFETY DEVICES

12.0 INTRODUCTION

Highways should be designed through judicious arrangement and balance of geometric features to preclude or minimize the need for roadside or median barrier. To provide for maximum roadside safety, a thorough study during the early stages of design is necessary to recognize and eliminate, where practical, those items and conditions which require barrier and impact attenuating devices.

While every reasonable effort should be made to keep a motorist on the roadway, the highway design engineer should acknowledge the fact that this goal will never be fully realized. Motorists continue to run off the road for many reasons, including driver error in the form of excessive speed, falling asleep, reckless or inattentive driving, or driving under the influence of alcohol or other drugs. A driver may also leave the road deliberately to avoid a collision with another motor vehicle or with objects on the road.

The consistent application of geometric design standards for roads and streets provides motorists with a high degree of safety. Design features such as horizontal and vertical curvature, pavement and shoulder width, and signing and pavement markings each play an important role towards achieving the desired level of safety. Roadside safety features, such as breakaway supports, bridge railings and impact attenuating devices provide an extra margin of safety to motorists who inadvertently leave the roadway. Most appurtenances are installed based on an analysis of their benefits to the motorists. In some instances, however, it may not be immediately obvious that the benefits to be gained from a specific safety design feature or treatment equal or exceed the additional costs. The design engineer must decide how and where limited funds should be spent to achieve the greatest overall benefits.

Railing systems mounted on bridges require a high level of protection be afforded to motorists. Select railing system Test Levels in accordance with the criteria of Section 12.10.

Policy and/or guidelines presented in this chapter, relative to clear zone, are applicable to all projects including new location, reconstruction and 3R projects. For resurfacing, restoration and rehabilitation (3R) projects, where major upgrading to horizontal or vertical alignment is not practical, clear zone widths less than those indicated in Table 12.1 may be suitable for attainment or retention. The cost of full reconstruction for these facilities will often not be justified. The designer must do specific site investigation and crash history analysis to determine a cost effective design by selectively upgrading the roadway and roadside to optimize the clear zone widths. Consideration must be given to the location and type of obstruction, existing roadway geometry and right-of-way widths, the ability to improve existing roadway geometry, signing and pavement marking and/or to require additional right-of-way, and the costs and benefits involved.

The following information and criteria are a guide and should be supplemented with sound engineering judgment. For additional guidelines, refer to the Standard Drawings for typical guide rail and median barrier placement and installation details. Also refer to the AASHTO Roadside Design Guide for additional source references.

12.1 THE CLEAR ZONE CONCEPT

Clear zone is defined as the total roadside border area, starting at the edge of traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a non-recoverable slope, and/or a clear run-out area. The width of the clear zone is influenced by the traffic volume, the design speed and embankment slope.

Table 12.1 can be used to determine the clear zone width recommended for selected traffic volumes, design speeds and embankment slopes. Clear zone widths shown in Table 12.1 represent values that are extrapolated from the curves in the AASHTO Roadside Design Guide and are a general approximation since they are based on limited empirical data.

TABLE 12.1 (METRIC)
CLEAR ZONE WIDTH
(in meters from edge of through traveled way)

DESIGN SPEED	DESIGN ADT	FORESLOPE			BACKSLOPE		
		1V:6H OR FLATTER	1V:5H TO 1V:4H	1V:3H	1V:3H	1V:5H TO 1V:4H	1V:6H OR FLATTER
60 km/h or less	Under 750	2.0	2.0	**	2.0	2.0	2.0
	750 - 1500	3.0	3.5	**	3.0	3.0	3.0
	1500 - 6000	3.5	4.5	**	3.5	3.5	3.5
	Over 6000	4.5	5.0	**	4.5	4.5	4.5
70-80 km/h	Under 750	3.0	3.5	**	2.5	2.5	3.0
	750 - 1500	4.5	5.0	**	3.0	3.5	4.5
	1500 - 6000	5.0	6.0	**	3.5	4.5	5.0
	Over 6000	6.0	7.5	**	4.5	5.5	6.0
90 km/h	Under 750	3.5	4.5	**	2.5	3.0	3.0
	750 - 1500	5.0	6.0	**	3.0	4.5	5.0
	1500 - 6000	6.0	7.5	**	4.5	5.0	6.0
	Over 6000	6.5	8.0	**	5.0	6.0	6.5
100 km/h	Under 750	5.0	6.0	**	3.0	3.5	4.5
	750 - 1500	6.0	8.0	**	3.5	5.0	6.0
	1500 - 6000	8.0	9.0	**	4.5	5.5	7.5
	Over 6000	9.0	9.0	**	6.0	7.5	8.0
110 km/h	Under 750	5.5	6.0	**	3.0	4.5	4.5
	750 - 1500	7.5	8.5	**	3.5	5.5	6.0
	1500 - 6000	8.5	9.0	**	5.0	6.5	8.0
	Over 6000	9.0	9.0	**	6.5	8.0	8.5

** Since recovery is less likely on the unshielded, traversable 1V:3H slopes, consider removal of fixed objects present beyond the toe of these slopes. Determination of the width of the recovery area provided, if any, at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through traveled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of slope.

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TABLE 12.1 (ENGLISH)
CLEAR ZONE WIDTH
(in feet from edge of through traveled way)

DESIGN SPEED	DESIGN ADT	FORESLOPE			BACKSLOPE		
		1V:6H OR FLATTER	**1V:5H TO 1V:4H**	**1V:3H**	**1V:3H**	**1V:5H TO 1V:4H**	**1V:6H OR FLATTER**
40 mph or less	Under 750	7	7	**	7	7	7
	750 - 1500	10	12	**	10	10	10
	1500 - 6000	12	14	**	12	12	12
	Over 6000	14	16	**	14	14	14
45-50 mph	Under 750	10	12	**	8	8	10
	750 - 1500	14	16	**	10	12	14
	1500 - 6000	16	20	**	12	14	16
	Over 6000	20	24	**	14	18	20
55 mph	Under 750	12	14	**	8	10	10
	750 - 1500	16	20	**	10	14	16
	1500 - 6000	20	24	**	14	16	20
	Over 6000	22	26	**	16	20	22
60 mph	Under 750	16	20	**	10	12	14
	750 - 1500	20	26	**	12	16	20
	1500 - 6000	26	30	**	14	18	24
	Over 6000	30	30	**	20	24	26
65-70 mph	Under 750	18	20	**	10	14	14
	750 - 1500	24	28	**	12	18	20
	1500 - 6000	28	30	**	16	22	26
	Over 6000	30	30	**	22	26	28

** Since recovery is less likely on the unshielded, traversable 1V:3H slopes, consider removal of fixed objects present beyond the toe of these slopes. Determination of the width of the recovery area provided, if any, at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through traveled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of slope.

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When obstructions exist behind curbs, a minimum horizontal clearance of 0.5 m (1.5 ft) should be provided beyond the face of curbs to the obstructions. This offset may be considered the minimum allowable horizontal clearance (or operational offset), but **IT SHOULD NOT BE CONSTRUED AS AN ACCEPTABLE CLEAR ZONE DISTANCE**. Since curbs do not have a significant redirectional capability, obstructions behind a curb should be located at or beyond the minimum clear-zone distances shown in Table 12.1. In many instances, it will not be practical to obtain the recommended clear zone distances on existing facilities. On new construction where minimum recommended clear zones cannot be provided, fixed objects should be located as far from traffic as practical on a project-by-project basis, but in no case closer than 0.5 m (1.5 ft) from the face of the curb.

The designer must keep in mind site-specific conditions, design speeds, rural versus urban locations, and practicality. The numbers in Table 12.1 suggest only the approximate values to be considered and not a precise distance to be held as absolute.

The designer may choose to modify the clear zone width obtained from Table 12.1 for horizontal curvature by using the horizontal curve adjustment factors in Table 12.2. These modifications are normally considered only where crash histories indicate a need, or a specific site investigation shows a definitive crash potential. This potential could be significantly lessened by increasing the clear zone width, provided such increases are cost-effective. Horizontal curves, particularly for high-speed facilities, are usually superelevated to increase safety and to provide a more comfortable ride.

For relatively flat and level roadsides, the clear zone concept is simple to apply. Application is more complex when the roadway is in a fill or cut section where roadside slopes may be either positive, negative, or variable, or where a ditch exists near the traveled way. For additional clear zone information refer to the 2004 AASHTO Green Book and the AASHTO Roadside Design Guide.

A. Foreslopes. Foreslopes parallel to the flow of traffic may be identified as recoverable, non-recoverable, or critical. Recoverable foreslopes are 1V:4H or flatter. If such slopes are relatively smooth and traversable, the suggested clear zone width may be taken directly from Table 12.1. Motorists who encroach on recoverable foreslopes can generally stop their vehicles or slow them enough to return to the roadway safely.

A non-recoverable foreslope is defined as one that is traversable, but from which most vehicles are unable to stop or to return to the roadway easily. Vehicles traversing such slopes typically can be expected to reach the bottom. Foreslopes between 1V:3H and 1V:4H generally fall into this category. Since a high percentage of encroaching vehicles may reach the toe of these slopes, the clear zone distance cannot logically end on the slope. Fixed obstacles are normally not constructed along such slopes and a clear runout area at the base is desirable. Figure 12.1 provides an example of parallel embankment slope design thru recoverable and non-recoverable slopes. The basic philosophy behind the recovery area is that a vehicle can traverse a 1V:3H slope but is not likely to recover (control steering) and therefore, recovery may be expected to occur beyond the toe of slope. Determination of the width of the clear zone distance at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs and crash history.

A critical foreslope is one which a vehicle is likely to overturn. Foreslopes steeper than 1V:3H generally fall into this category. If a foreslope steeper than 1V:3H begins closer to the through traveled way than the suggested clear zone width for that specific roadway, a roadside barrier might be required (Table 12.5) if the slope cannot readily be flattened.

B. Transverse Slopes. Common obstacles on roadsides are transverse slopes created by median crossovers, berms, driveways or intersecting side roads. These are generally more critical to errant motorists than foreslopes or backslopes because they are typically struck head-on by run-off-the-road vehicles. Transverse slopes of 1V:6H or flatter are suggested for high-speed roadways, particularly for that section of the transverse slope that is located immediately adjacent to traffic. This slope can then be transitioned to a steeper slope as the distance from the through traveled way increases.

Transverse slopes of 1V:10H are desirable; however, their practicality may be limited by width restrictions and the maintenance problems associated with the long tapered ends of pipes or culverts. Transverse slopes steeper than 1V:6H may be considered for urban areas or for low-speed facilities.

TABLE 12.2 (METRIC)
HORIZONTAL CURVE ADJUSTMENTS
K_{cz} (CURVE CORRECTION FACTOR)

RADIUS (m)	DESIGN SPEED (km/h)					
	60	70	80	90	100	110
900	1.1	1.1	1.1	1.2	1.2	1.2
700	1.1	1.1	1.2	1.2	1.2	1.3
600	1.1	1.2	1.2	1.2	1.3	1.4
500	1.1	1.2	1.2	1.3	1.3	1.4
450	1.2	1.2	1.3	1.3	1.4	1.5
400	1.2	1.2	1.3	1.3	1.4	—
350	1.2	1.2	1.3	1.4	1.5	—
300	1.2	1.3	1.4	1.5	1.5	—
250	1.3	1.3	1.4	1.5	—	—
200	1.3	1.4	1.5	—	—	—
150	1.4	1.5	—	—	—	—
100	1.5	—	—	—	—	—

$CZ_c = (L_c)\ (K_{cz})$

Where: CZ_c = CLEAR ZONE WIDTH ON OUTSIDE OF CURVATURE (m)
L_c = CLEAR ZONE WIDTH (m), TABLE 12.1
K_{cz} = CURVE CORRECTION FACTOR

Note: THE CLEAR ZONE CORRECTION FACTOR IS APPLIED TO THE OUTSIDE OF CURVES ONLY. CURVES WITH A RADIUS GREATER THAN 900 m DO NOT REQUIRE AN ADJUSTED CLEAR ZONE WIDTH.

TABLE 12.2 (ENGLISH)
HORIZONTAL CURVE ADJUSTMENTS
K_{cz} (CURVE CORRECTION FACTOR)

RADIUS (ft)	DESIGN SPEED (mph)						
	40	**45**	**50**	**55**	**60**	**65**	**70**
2860	1.1	1.1	1.1	1.2	1.2	1.2	1.3
2290	1.1	1.1	1.2	1.2	1.2	1.3	1.3
1910	1.1	1.2	1.2	1.2	1.3	1.3	1.4
1640	1.1	1.2	1.2	1.3	1.3	1.4	1.5
1430	1.2	1.2	1.3	1.3	1.4	1.4	—
1270	1.2	1.2	1.3	1.3	1.4	1.5	—
1150	1.2	1.2	1.3	1.4	1.5	—	—
950	1.2	1.3	1.4	1.5	1.5	—	—
820	1.3	1.3	1.4	1.5	—	—	—
720	1.3	1.4	1.5	—	—	—	—
640	1.3	1.4	1.5	—	—	—	—
570	1.4	1.5	—	—	—	—	—
380	1.5	—	—	—	—	—	—

$CZ_c = (L_c)(K_{cz})$

Where: CZ_c = CLEAR ZONE WIDTH ON OUTSIDE OF CURVATURE (ft)
L_c = CLEAR ZONE WIDTH (ft), TABLE 12.1
K_{cz} = CURVE CORRECTION FACTOR

Note: THE CLEAR ZONE CORRECTION FACTOR IS APPLIED TO THE OUTSIDE OF CURVES ONLY. CURVES WITH RADII GREATER THAN 2860 ft DO NOT REQUIRE AN ADJUSTED CLEAR ZONE WIDTH.

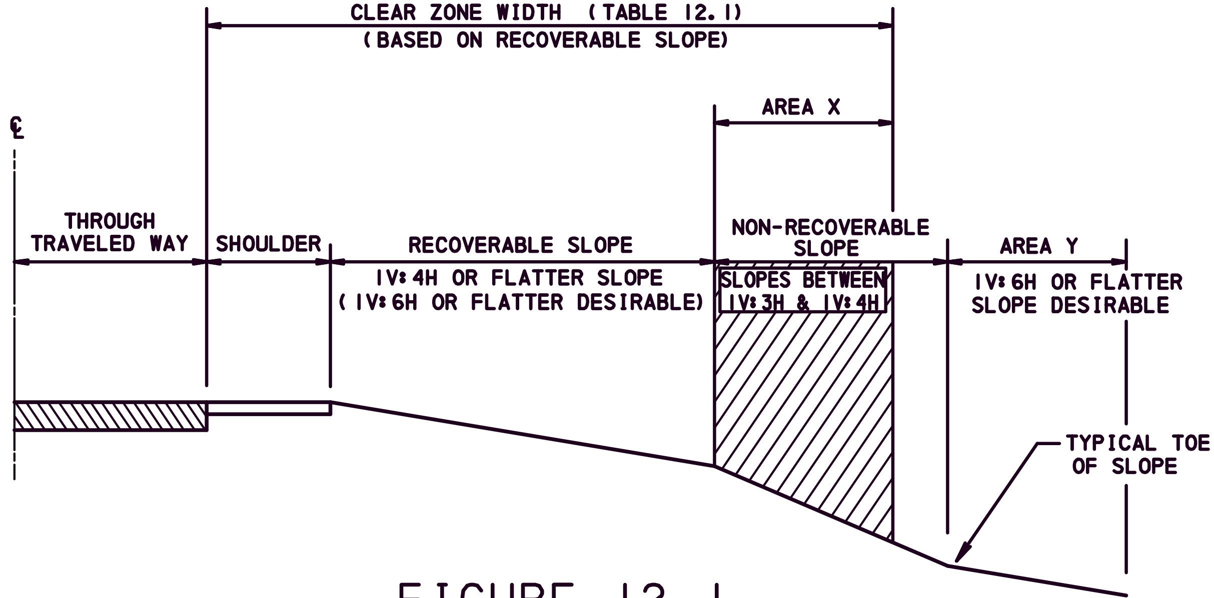

FIGURE 12.1
EXAMPLE OF A PARALLEL EMBANKMENT SLOPE DESIGN

THIS FIGURE ILLUSTRATES A RECOVERABLE SLOPE FOLLOWED BY A NON-RECOVERABLE SLOPE. SINCE THE CLEAR ZONE WIDTH EXTENDS ONTO A NON-RECOVERABLE SLOPE, THE PORTION OF THE CLEAR ZONE WIDTH ON SUCH A SLOPE MAY BE PROVIDED BEYOND THE NON-RECOVERABLE SLOPE IF PRACTICAL.

NOTE:

A. WHEN THE ENTIRE SLOPE IS RECOVERABLE, THE RECOVERY AREA EQUALS THE CLEAR ZONE WIDTH.

B. AREA X IS EQUAL TO AREA Y. IF AREA Y IS LESS THAN 3 m (10 ft), USE 3 m (10 ft).

C. Backslopes. When a highway is located in a cut section, the backslope may be traversable depending upon its relative smoothness and the presence of fixed obstacles. If the foreslope between the roadway and the base of the backslope is traversable (1V:3H or flatter) and the backslope is obstacle-free, it may not be a potential concern, regardless of its distance from the roadway. On the other hand, a steep, rough-sided rock cut should normally begin outside the clear zone or be shielded. A rock cut is normally considered to be rough-sided when the face can cause excessive vehicle snagging rather than provide relatively smooth redirection.

12.2 BREAKAWAY SUPPORTS

The term "breakaway support" refers to all types of signs, luminaire and traffic signal supports that are designed to yield when impacted by a vehicle. The release mechanism may be a slip plane, plastic hinge, fracture element or a combination thereof. The criteria used to determine if a support is considered breakaway are presented in the AASHTO publication, *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals* and National Cooperative Highway Research Program (NCHRP) Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*. These criteria require that a breakaway support fail in a predictable manner when struck head-on by an 820 kg (1800 lb) vehicle, or its equivalent, at speeds of 35 km/h and 100 km/h (20 mph and 60 mph). It is desirable to limit the longitudinal component of the occupant impact velocity to 3.0 m/s (10 ft/s), but values as high as 5.0 m/s (15 ft/s) are considered acceptable. These specifications also establish a maximum stub height of 100 mm (4 in) to lessen the possibility of snagging the undercarriage of a vehicle after a support has broken away from its base (see Figure 12.2).

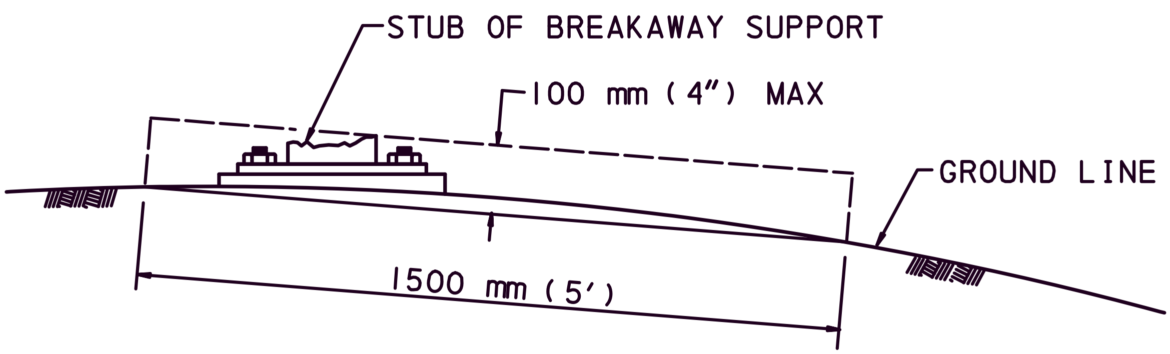

FIGURE 12.2
BREAKAWAY SUPPORT STUB HEIGHT MEASUREMENTS

As a general rule, breakaway supports should be used unless an engineering study indicates otherwise. However, concern for pedestrian involvement has led to the use of fixed supports in some urban areas. Examples of sites where breakaway supports may be imprudent are adjacent to bus shelters or in areas of extensive pedestrian concentrations.

12.3 ROADSIDE BARRIERS

A roadside barrier is a longitudinal barrier used to shield motorists from natural or man-made obstructions located along either side of a traveled way for unidirectional traffic. It may occasionally be used to protect bystanders, pedestrians and cyclists from vehicular traffic under special conditions.

The primary purpose of all roadside barriers is to prevent a vehicle from leaving the traveled way and striking a fixed object or terrain feature that is less forgiving than the barrier itself.

A. Standard Roadside Barriers. Roadside barriers are usually categorized as flexible, semi-rigid or rigid, depending on their deflection characteristics on impact. Flexible systems are generally more forgiving than the other categories since much of the impact energy is dissipated by the deflection of the barrier and lower impact forces are imposed upon the vehicle.

Barrier systems that have been accepted for use in Pennsylvania are:

1.	FLEXIBLE SYSTEMS:	W-Beam (Weak Post) Guide Rail
2.	SEMI-RIGID SYSTEMS:	W-Beam (Strong-Steel Post) Guide Rail with Wood or Plastic Block
3.	RIGID SYSTEMS:	Concrete F-Shape Barrier

B. Barrier Guidelines. The barrier guidelines in this document are to be considered an indicator that **consideration** should be given to utilizing the barrier. Satisfaction of these guidelines is not a guarantee that a barrier is needed. As such, these guidelines should be considered in the determination of the need for a barrier rather than absolute criteria. Since these guidelines are based on average or normal conditions, they are not conclusive justification for the installation of a barrier at any particular location, and they are not a substitute for engineering judgment. The unique circumstances of each location and the amount of funds available will dictate if and when a barrier should be installed. These barrier guidelines are based on the premise that a traffic barrier should be installed only if it reduces the severity of potential crashes.

Typically, barrier guidelines have been based on an analysis of certain roadside elements or conditions. There are instances where it is not immediately obvious whether the barrier or the unshielded condition presents the greater undesirable situation. In such instances, barrier guidelines may be established by using a benefit/cost analysis whereby factors such as design speed and traffic volumes can be evaluated in relation to barrier need. Costs associated with the barrier (installation costs, maintenance costs and crash costs) are compared to similar costs associated with the unshielded condition. This procedure is typically used to evaluate three options: (1) remove or reduce the condition so that it no longer requires shielding, (2) install an appropriate barrier or (3) leave the condition unshielded. The one-time cost to flatten foreslopes and eliminate guide rail may be cost effective when compared against the life-cycle cost of installation and maintenance of guide rail.

Consideration should be given to eliminating short lengths of guide rail since these sections are often more undesirable than no section at all. Where guide rail cannot be eliminated, it shall be a minimum of 15 m (50 ft) plus proper end treatment.

If guide rail is not required due to the height of the slope, consideration should be given to keep the slope clear of fixed objects.

Avoid short gaps between guide rail installations. If the points of need are determined to be about 60 m (200 ft) apart or less, the guide rail protection should be made continuous between them.

Extending guide rail to be buried with an anchored backslope terminal (see Section 12.9.D.1) is cost effective and provides superior performance over the cost and maintenance of an impact attenuating device.

Guide rail should be considered in sensitive areas such as school playgrounds or reservoirs even when they are outside the clear zone.

C. Design and Selection Procedures. GUIDE RAIL SHOULD ONLY BE USED WHERE THE RESULT OF STRIKING THE OBJECT OR LEAVING THE ROADWAY WOULD BE MORE SEVERE THAN THE CONSEQUENCE OF STRIKING THE GUIDE RAIL. Where guide rail is required, the roadway should be examined to determine the feasibility of adjusting site features so that the guide rail can be eliminated (e.g., flattening an embankment slope, removing a fixed object or eliminating a drainage head wall). The initial cost to eliminate the guide rail may appear excessive; however, a guide rail installation including impact attenuating devices requires maintenance for many years and this fact should not be overlooked.

Consult Publication 72M, *Roadway Construction Standards*, for the details of all barrier systems (RC-50M Series). Table 12.3 shows the "minimum unobstructed distance" that shall be provided behind the various types of guide rail and median barrier systems. The values of the "minimum unobstructed distance" (measured from the rear face of the guide rail post to the front face of the obstruction), as specified in the Table, are based on the anticipated barrier deflection under maximum impact on a 25° hit at 100 km/h (60 mph) by a 2000 kg (4500 lb) vehicle.

Table 12.4 gives the maximum post spacing for weak post guide rail on curves such as ramps. Do not use weak post guide rail around radii at intersections where it can be hit at severe impact angles.

To determine the need for guide rail, refer to Section 12.4, Barrier Placement, and the preceding sections of this Chapter. Additional selection guidelines and criteria for standard and nonstandard conditions are presented below in Sections 12.3.D and 12.3.E.

TABLE 12.3 (METRIC)
GUIDE RAIL AND MEDIAN BARRIER SYSTEMS

TYPE DESIGNATION	DESCRIPTION	MOUNTING HEIGHT	MINIMUM UNOBSTRUCTED DISTANCE	POST SPACING
2 - W	WEAK POST W-BEAM GUIDE RAIL (NORMAL POST SPACING)	815 mm TO TOP OF BEAM	2.1 m	3810 mm
2 - WC	WEAK POST W-BEAM GUIDE RAIL (CLOSE POST SPACING)	815 mm TO TOP OF BEAM	1.5 m	1905 mm
2 - WCC	WEAK POST W-BEAM GUIDE RAIL (VERY CLOSE POST SPACING)	815 mm TO TOP OF BEAM	1.2 m	952.5 mm
2 - S	STRONG POST W-BEAM GUIDE RAIL (NORMAL POST SPACING)	706 mm TO TOP OF BEAM	0.9 m	1905 mm
2 - SC	STRONG POST W-BEAM GUIDE RAIL (CLOSE POST SPACING)	706 mm TO TOP OF BEAM	0.6 m	952.5 mm
2 - SCC	STRONG POST W-BEAM GUIDE RAIL (VERY CLOSE POST SPACING)	706 mm TO TOP OF BEAM	0.3 m	476.25 mm
—	CONCRETE MEDIAN BARRIER SINGLE & DOUBLE FACE	810 mm TO TOP OF BARRIER	0.0 m	—
—	CONCRETE GLARE SCREEN	1270 mm TO TOP OF BARRIER (TYP)	0.0 m	—

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TABLE 12.3 (ENGLISH)
GUIDE RAIL AND MEDIAN BARRIER SYSTEMS

TYPE DESIGNATION	DESCRIPTION	MOUNTING HEIGHT	MINIMUM UNOBSTRUCTED DISTANCE	POST SPACING
2 - W	WEAK POST W-BEAM GUIDE RAIL (NORMAL POST SPACING)	32" TO TOP OF BEAM	7' - 0"	12' - 6"
2 - WC	WEAK POST W-BEAM GUIDE RAIL (CLOSE POST SPACING)	32" TO TOP OF BEAM	5' - 0"	6' - 3"
2 - WCC	WEAK POST W-BEAM GUIDE RAIL (VERY CLOSE POST SPACING)	32" TO TOP OF BEAM	4' - 0"	3' - 1 1/2"
2 - S	STRONG POST W-BEAM GUIDE RAIL (NORMAL POST SPACING)	27 3/4" TO TOP OF BEAM	3' - 0"	6' - 3"
2 - SC	STRONG POST W-BEAM GUIDE RAIL (CLOSE POST SPACING)	27 3/4" TO TOP OF BEAM	2' - 0"	3' - 1 1/2"
2 - SCC	STRONG POST W-BEAM GUIDE RAIL (VERY CLOSE POST SPACING)	27 3/4" TO TOP OF BEAM	1' - 0"	1' - 6 3/4"
—	CONCRETE MEDIAN BARRIER SINGLE & DOUBLE FACE	32" TO TOP OF BARRIER	0' - 0"	—
—	CONCRETE GLARE SCREEN	50" TO TOP OF BARRIER (TYP)	0' - 0"	—

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TABLE 12.4
WEAK POST W-BEAM GUIDE RAIL SYSTEMS ON CURVES

TYPE DESIGNATION	CURVE DESCRIPTION	POST SPACING
2-W	R > 70 m (R > 220' - 0")	3810 mm (12' - 6")
2-WC	R = 35 m TO 70 m (R = 110' - 0" TO 220' - 0")	1905 mm (6' - 3")
2-WCC	R < 35 m (R < 110' - 0")	952.5 mm (3' - 1 1/2")

D. Standard Conditions.

1. Generally, the guide rail system which provides the largest dynamic deflection should be used.

2. Weak post guide rail (2-W or 2-WC) should be used where guide rail is required, if the minimum unobstructed distance behind the guide rail is available. Weak post systems shall not be used where the fill slope is steeper than 1V:1.5H.

3. Strong post guide rail (2-S and 2-SC) should be used when the minimum unobstructed distance behind the guide rail is not adequate to permit the use of a weak post system.

4. Types 2-S and 2-SC guide rail should be used at approaches to structures (see Standard Drawings). Where this requires a transition from a weak post system, the transition shown on the Standard Drawings shall be used.

5. Mixing of strong post and weak post systems in the same run of guide rail shall be used only when the proper transition treatment between systems can be provided, as shown on the Standard Drawings. Frequent transitions between strong post and weak post systems should be avoided.

E. Nonstandard Conditions. The following criteria may be used where special conditions exist:

1. Type 2-WCC guide rail should be used for the following conditions:

a. Weak post to strong post transitions (see Publication 72M, *Roadway Construction Standards*),

b. Where isolated obstructions are located more than 1.2 m (4 ft) but less than 1.5 m (5 ft) behind the back of the guide rail in areas where a continuous run of weak post guide rail is used and

c. Weak post guide rail systems on curves as presented in Table 12.4.

2. Side road intersections close to the ends of structures should be avoided. However, if this condition exists and cannot be avoided, the recommended guide rail treatment should be installed as shown in Publication 72M, *Roadway Construction Standards*, Drawing RC-54M.

3. The use of guide rail/curb combinations should be avoided where high speed, high-angle impacts are likely. Where it is necessary to use guide rail behind concrete curbed areas, the guide rail shall be positioned so that the front face of the rail element is in front or flush with the front face of the curb. The height of the curb should be 100 mm (4 in) maximum and the guide rail should be Type 2-SC or 2-S. In areas where curb 100 mm (4 in) or lower is not possible, use Type 2-SC guide rail or nested panels.

4. When the minimum unobstructed distance is not available, consideration should be given to using single-face barrier as indicated in Section 12.7.

5. When a strong post guide rail system is installed and the 0.6 m (2 ft) minimum clearance from the rear face of the guide rail post to the fill slope break point cannot be maintained, use strong posts that are a minimum of 0.3 m (1 ft) longer. The locations and the number of extra-length posts should be shown in the project proposal.

6. A weak post guide rail system, without extra-length posts, may be installed out to the fill slope if the fill slope is not steeper than 1V:2H. A weak post guide rail system may be installed out to the fill slope if the slope is steeper than 1V:2H but is not steeper than 1V:1.5H, provided weak posts that are a minimum of 0.3 m (1 ft) longer are used. The locations and the number of extra-length posts should be shown in the PS&E package. Weak post systems shall not be used where the fill slope is steeper than 1V:1.5H.

Chapter 2 of the AASHTO Roadside Design Guide presents an analysis procedure called the Roadside Safety Analysis Program (RSAP), a cost-effectiveness selection procedure that can be used to compare several alternative safety treatments and to provide guidance to the designer for selecting an appropriate design.

F. Embankment Protection. Embankment height and side slope are the basic factors to consider in determining barrier requirements as shown in Table 12.5. These criteria are based on studies of the relative severity of encroachments on embankments versus impacts with roadside barriers. Embankments with slopes of 1V:3H or flatter do not require shielding unless they contain obstructions within the clear zone. Table 12.5 takes into account the decreased probability of encroachments on lower volume roads and the relative cost of installing a traffic barrier versus leaving the slope unshielded. This is based on site-specific conditions in Pennsylvania and associated crash costs with a safety factor applied to account for increased traffic volumes approaching the design year.

Rounding at the shoulder and at the toe of an embankment can reduce the severity of run-off-the-road crashes. A rounded slope should reduce the chances of an errant vehicle becoming airborne, and should afford the driver more control over the vehicle. In view of the safety benefits, rounding should be considered in the design process. Refer to the Typical Roadway Cross Sections in Chapter 1 for shoulder rounding details and to the AASHTO Roadside Design Guide for rounding at the toe of an embankment slope.

G. Protection from Roadside Obstructions. Although a traversable and unobstructed roadside is highly desirable from a safety standpoint, some appurtenances simply must be placed near the pavement. Man-made fixed objects which frequently occupy highway right-of-way include highway signs, roadway lighting, traffic signals, railroad warning devices, motorist-aid call boxes, mailboxes and utility poles.

The AASHTO Roadside Design Guide, Chapter 11 contains information on mailbox supports and their location on the roadside. These guidelines are compatible with the requirements of the US Postal Service and are presented in the interest of providing the highest degree of safety practicable for the motoring public, mail carriers and postal patrons. Mailboxes are predominant in rural and suburban roads and streets and need to be considered as part of roadside safety management. These guidelines may be useful when necessary to explain installation and control procedures to the general public.

The designer should provide the safest facility practical, within given constraints. Generally, there are six options from which to choose a safe design. In order of preference, these are:

1. Remove the obstruction.

2. Redesign the obstruction so it can be traversed safely.

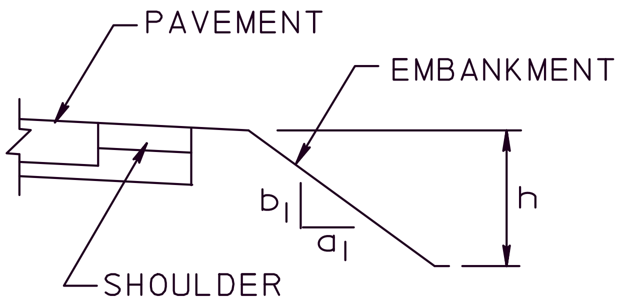
3. Relocate the obstruction to a point where it is less likely to be struck.

4. Reduce impact severity by using an appropriate breakaway device or impact attenuator.

5. Shield the obstruction with a longitudinal traffic barrier if it cannot be eliminated, relocated or redesigned.

6. Delineate the obstruction if the above alternatives are not appropriate.

TABLE 12.5
BARRIER REQUIREMENTS FOR EMBANKMENT HEIGHTS



METRIC:

EMBANKMENT SLOPE ($S = b_1 : a_1$)	EMBANKMENT HEIGHT (h)			
	AVERAGE DAILY TRAFFIC (ADT)			
	> 5000	751 - 5000	401 - 750	≤ 400
1V:1.5H	1.2 m	1.8 m	2.7 m	5.2 m
1V:2H	2.4 m	3.0 m	4.9 m	9.4 m
1V:2.5H	3.7 m	4.9 m	7.6 m	14.9 m
1V:3H OR FLATTER	GUIDE RAIL NOT REQUIRED			

ENGLISH:

EMBANKMENT SLOPE ($S = b_1 : a_1$)	EMBANKMENT HEIGHT (h)			
	AVERAGE DAILY TRAFFIC (ADT)			
	> 5000	751 - 5000	401 - 750	≤ 400
1V:1.5H	4.0 ft	6.0 ft	9.0 ft	17.0 ft
1V:2H	8.0 ft	10.0 ft	16.0 ft	31.0 ft
1V:2.5H	12.0 ft	16.0 ft	25.0 ft	49.0 ft
1V:3H OR FLATTER	GUIDE RAIL NOT REQUIRED			

While options 1 and 2 are the preferred choices, these solutions are not always practical, especially for highway signing and lighting which must remain near the roadway to serve their intended functions.

Every effort should be made to lessen the number of roadside obstructions along the highway. Special effort should be given to keeping gore areas and other high-exposure areas free from obstructions that would require guide rail.

Usually, posts of breakaway design should be used for sign supports regardless of their distance from the pavement except when the post is located behind guide rail installed for other reasons or located a sufficient distance up a backslope where it is unlikely to be hit by an errant vehicle. Table 12.6 provides the requirements for barrier placement for fixed objects within the clear zone.

If the required clear zone adjacent to the pavement cannot be cleared of roadside obstructions due to practical or economic reasons, adequate guide rail should be provided, as determined from Table 12.6 except as justified elsewhere in this Chapter. The amount that the guide rail deflects upon impact is the critical factor to consider when installing guide rail in front of obstructions. The minimum unobstructed distance should be sufficient to avoid vehicle contact with the fixed object during impact and should not be less than the values presented in Table 12.3.

TABLE 12.6
GUIDE RAIL REQUIREMENTS
FOR FIXED OBJECTS
WITHIN THE CLEAR ZONE

FIXED OBJECTS WITHIN THE CLEAR ZONE	**BARRIER REQUIRED**	
	YES	**NO**
1. SIGN SUPPORT (GROUND MOUNTED):		
(A) POST OF BREAKAWAY DESIGN		**X**
(B) SIGN BRIDGE SUPPORTS	**X**	
(C) CONCRETE BASE EXTENDING 100 mm (4 in) OR MORE ABOVE GROUND	**X**	
2. LIGHTING POLES AND SUPPORTS OF BREAKAWAY DESIGN		**X**
3. BRIDGE PIERS AND ABUTMENTS AT UNDERPASSES	**X**	
4. CULVERT HEADWALLS 100 mm (4 in) OR MORE ABOVE GROUND	**X**	
5. TREES *		**X**
6. UTILITY POLES *		**X**
7. LIGHTING POLES WITH HIGH MAST LIGHTING	**X**	
8. RETAINING WALLS **		**X**

* The designer shall exercise sound engineering judgment and consider protection in some special cases where such obstructions are likely to be hit due to geometric roadway conditions (outside of a curve, steep grade at beginning of a curve, etc.). Protection should also be considered in sensitive areas, such as school playgrounds or reservoirs.

** A judgment decision based on relative smoothness of wall and anticipated maximum angle of impact (refer to AASHTO Roadside Design Guide, Table 5-2).

At the trailing end of guide rail, a distance of 15.0 m (50 ft) beyond the end treatment is to be kept clear of all roadside obstructions. This "downstream clear zone" is intended to minimize the likelihood that a vehicle may be directed into an obstruction by the barrier.

H. Non-Traversable Roadside Obstructions. Non-traversable roadside obstructions require special consideration to provide safety and to afford protection if encountered by motorists and pedestrians within the clear zone or adjacent to the highway right-of-way. These obstructions include: (1) permanent bodies of water; (2) mined areas including coal strip mining, stone quarries and other open pit mining operations and (3) storage locations of hazardous substances.

Because of the size of some of these features along the roadway, the probability of an errant vehicle encountering such a condition is greater than that of a vehicle encountering a fixed object. Therefore, any non-traversable obstruction that requires shielding should be removed, if practical. Otherwise, a longitudinal barrier system, such as guide rail, should be considered. A barrier system shall be provided for permanent bodies of water, with depths greater than 0.6 m (2 ft), that are located within the clear zone or adjacent to the right-of-way. For mined areas, earthen barrier and safety barricades for protection of both motorists and pedestrians should be provided.

I. Utility Poles and Trees. For new construction or reconstruction projects, every effort should be made to install or relocate utility poles as far from the traveled way as practical.

For existing utility pole installations, a concentration of crashes at a site or a certain type of crash that seems to occur frequently in a given jurisdiction may indicate that the highway/utility system is contributing to the crash potential. Utility pole crashes are subject to the same patterns as other types of roadway crashes; thus, they are subject to traditional highway crash study procedures.

Generally, guide rail should not be used to shield a line of utility poles or trees. However, where guide rail is used in front of utility poles and trees due to other roadside obstacles, the minimum unobstructed distance behind the guide rail post shall be as presented in Table 12.3.

The removal of individual trees should be considered when they are determined both to be an obstruction and to be in a location where they are likely to be hit. Such trees can often be identified by past crash history at similar sites, by scars indicating previous crashes or by field reviews. Because tree removal can be expensive and often has adverse environmental impacts, this countermeasure should be used only when it is an effective solution.

Roadways through wooded areas with heavy nighttime traffic volumes, frequent fog and narrow lanes should be well delineated. Pavement markings and post mounted delineators are among the most effective and least costly improvements that can be made to a roadway.

J. Guide Rail End Treatments. The terminal end of the guide rail should be designed and located so that there are no exposed rail element ends on which a vehicle could be impaled. The preferred treatment is to bury the end of the guide rail into a backslope, retaining its full height even if the guide rail must be extended a short distance to accomplish this. Evaluate opportunities for nearby locations to bury the end of the guide rail into a backslope.

Provide appropriate end treatments, on both the approach and trailing ends of the guide rail on two-lane highways with two-way traffic. On four-lane divided highways, end treatments are required on the approach ends only for strong post guide rail. End treatments are required on both ends of weak post guide rail for anchoring purposes.

A crashworthy end treatment is considered essential if the barrier terminates within the clear zone and/or is in an area where it is likely to be hit by an errant vehicle.

The designer must exercise sound engineering judgment and ensure that the most appropriate available guide rail terminals are specified and provisions incorporated so they can be properly installed based on the type of facility. Higher type treatments should be considered in sensitive locations, in areas with tight geometrics, areas with an unusually high crash history, etc.

Type 2 Strong Post End Treatments and Type 2 Weak Post End Treatments cannot be used to terminate the approach end of: (a) any guide rail on the National Highway System (NHS) or (b) any guide rail on non-NHS high-speed, high-volume routes. Use crashworthy end treatments on all NHS routes and on non-NHS roadways with a posted speed limit of 70 km/h (45 mph) and above and with current traffic volumes of 4000 vehicles per day and above. On two-lane roadways where crashworthy end treatments are required, use on both the approach and trailing ends. For high-speed, NHS divided roadways, Type 2 Strong Post End Treatments or Type 2-S Post Anchorages may be used on the trailing end of guide rail. For Weak Post Guide Rail, if crashworthy end treatments are required, the Weak Post Guide Rail must be transitioned with a 15.2 m (50 ft) Type 2-S Guide Rail section to anchor the Type 2-W Guide Rail prior to the attachment of a crashworthy end treatment.

As an alternative to Type 2 Strong Post End Treatments and Type 2 Weak Post End Treatments, the non-proprietary Modified Eccentric Loader Terminal (MELT), as described in FHWA Acceptance Letter CC-84, may be used on the NHS as a Test Level 2 (TL-2) W-beam guide rail anchor when anticipated impact speeds are not expected to exceed 70 km/h (44 mph).

The approach terrain to any end treatment should be graded to a 1V:10H slope or flatter. For gating terminals, the flat slope should extend behind the terminal as shown on the Standard Drawings and this Chapter.

Use Publication 72M, *Roadway Construction Standards*, RC-50M Series when specifying end treatments for either Type 2 Weak Post or Type 2 Strong Post Guide Rail and Section 12.9.

K. Bridge Barrier End Transitions. When updating guide rail systems, barrier systems, end treatments, and crash cushions for Pavement Preservation projects, refer to the pavement guidelines in Publication 242, *Pavement Policy Manual*. Chapter 12, Appendix A includes details of bridge barrier end transitions for the retro-fit of certain bridge barrier ends. These retro-fits provide an opportunity to attach to upgraded guide rail systems. A decision tree is included for selection of the applicable retro-fit details.

L. Weathering Steel Guide Rail. The use of weathering steel (sometimes called Cor-Ten, A-588, or Rusting Steel) in guide rail should be limited. Where aesthetic concerns are primary, weathering steel guide rail may be used if the owner agency adopts a frequent periodic inspection and replacement schedule.

Roadside barriers and bridge rails are usually close enough to the traveled way that they can be sprayed with water from passing traffic. In most parts of the country this water contains deicing chemicals during winter months. In seaside locations in warmer climates the salt laden air deposits corrosive chemicals on barriers. In northern climates plows can throw snow onto the rail and the abrasive action of the snow can erode the protective layer. When exposed to these environments, weathering steel never develops the 'patina' that slows corrosion as in other less aggressive environments. Within a few years significant section loss may result. The interior lap splice of W-beams can corrode rapidly to the point where the barrier may become more hazardous than the feature it was meant to shield.

Weathering steel may continue to be used on the backside of steel backed timber rail as the steel thickness is significantly greater than the typical 12 gage W-beam section.

Use of thicker sections (exclusive of the terminal) may also prolong the life, but maintenance should still include inspection of the sections and joints. Powder or zinc coating of galvanized guide rail may be an acceptable aesthetic option.

Barrier terminals are also subject to section loss at rail splices. Questions on aesthetic treatments of barrier terminals should be addressed to the manufacturer.

12.4 ROADSIDE BARRIER PLACEMENT

Upon deciding that a roadside barrier is to be considered at a given location, and selecting the type of barrier to be used, the designer should specify the exact layout required. The major factors that must be considered include the following:

- Lateral Offset (from the edge of traveled way)
- Terrain Effects
- Flare Rate
- Length of Need

Most of these factors are interrelated to the extent that the final design may be a compromise selected by the designer. More detailed guidelines on each of these factors are included in the next subsections.

A. Lateral Offset. A roadside barrier should be placed as far from the traveled way as possible, while maintaining the proper operation and performance of the system. Such placement reduces the likelihood of errant vehicles impacting the barrier. It also provides better sight distance, particularly at nearby intersections.

The minimum unobstructed distance behind a barrier is a critical factor in its selection as well as in its placement, especially if the obstruction being shielded is a rigid object. In some cases, the available space between the barrier and the object may not be adequate. In such cases, the barrier should be stiffened in advance of and alongside the fixed object. Commonly used methods to reduce deflection in a semi-rigid or flexible barrier system include reduced post spacing, increased post size, use of soil plates, intermediate anchorages, and stiffened rail elements. The effects on deflection of reduced post spacing are shown in Table 12.3 with the individual barrier descriptions. In some cases, a more rigid barrier type may be needed.

A barrier-to-embankment distance of 0.6 m (2 ft), as shown in the AASHTO Roadside Design Guide, Figure 5-33, is desirable for adequate post support but may vary depending on the slope of the embankment, soil type, expected impact conditions, and post cross section and embedment. Increasing the embedment length of guide rail posts by 0.3 m (1 ft) or more can compensate for the reduced soil foundation support near the slope break point.

B. Terrain Effects. Regardless of the type of roadside barrier being used or the size and type of vehicle that strikes it, the best results will usually occur if, at the moment of impact, all of the vehicle's wheels are on the ground and its suspension system is neither compressed nor extended. Thus, terrain conditions between the traveled way and the barrier can have significant effects on the barrier's impact performance.

Curbs and roadside slopes are two particular features that deserve special attention. A vehicle which traverses one of these features prior to impact may override the barrier if the vehicle is partially airborne at the moment of impact or may "underride" the rail elements and snag on the support posts if it strikes the barrier too low. Use of guide rail/curb combinations should be discouraged where high-speed, high-angle impacts are likely.

Roadside barriers perform most effectively when they are installed on slopes of 1V:10H or flatter. Caution should be taken when considering installations on slopes as steep as 1V:6H and any such installation should be offset so that an errant vehicle is in its normal attitude at the moment of impact. Depending on actual encroachment conditions, the distance from the traveled way at which a barrier can be installed and expected to perform adequately will vary, but in general, the placement recommendations shown in the AASHTO Roadside Design Guide, Figure 5-38 should be followed.

C. Flare Rate. A roadside barrier is considered flared when it is not parallel to the edge of traveled way. The flare is normally used to locate the barrier terminal farther from the roadway in order to minimize a driver's reaction to an obstruction near the road. The flare gradually introduces a parallel barrier installation, transitions a roadside barrier to an obstruction nearer the roadway such as a bridge parapet or railing, or reduces the total length of barrier needed.

One disadvantage to flaring a section of roadside barrier is that the greater the flare rate, the higher the angle at which the barrier can be hit. As the angle of impact increases, the severity of the crash increases, particularly for rigid and semi-rigid barrier systems.

As shown in Table 12.7, the maximum recommended flare rates are a function of design speed and barrier type. Flatter flare rates may be used and often are, particularly where extensive grading would be required to ensure a flat approach to the barrier from the traveled way.

TABLE 12.7 (METRIC)
FLARE RATES FOR BARRIER DESIGN

DESIGN SPEED (km/h)	MAXIMUM FLARE RATES	
	CONCRETE BARRIER	GUIDE RAIL
110	20:1	15:1
100	18:1	14:1
90	16:1	12:1
80	14:1	11:1
70	12:1	10:1
60	10:1	8:1
50	8:1	7:1

TABLE 12.7 (ENGLISH)
FLARE RATES FOR BARRIER DESIGN

DESIGN SPEED (mph)	MAXIMUM FLARE RATES	
	CONCRETE BARRIER	GUIDE RAIL
70	20:1	15:1
60	18:1	14:1
55	16:1	12:1
50	14:1	11:1
45	12:1	10:1
35	10:1	8:1
30	8:1	7:1

Note: The required length of barrier and flare rate for each location will be determined by the designer and will be shown on the tabulation sheets and remarks column.

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D. Length of Need. Figure 12.3 illustrates the variables that should be considered in designing a roadside barrier to shield a condition effectively. The primary variables are the Runout Length, L_R, and the Lateral Extent of The Obstruction, L_A.

The Runout Length, L_R, as presented in Table 12.8, is the theoretical distance needed for a vehicle that has left the roadway to come to a stop. It is measured from the upstream extent of the obstruction, along the roadway, to the point at which a vehicle is assumed to leave the roadway. These distances have been further modified to reduce the length of barrier on low volume facilities.

The Lateral Extent, L_A, is the distance from the edge of through traveled way to the far side of the obstruction if it is a fixed object or to the outside edge of the clear zone, L_C, if it is an embankment or a fixed object that extends beyond the clear zone. Selection of an appropriate L_A distance is a critical part of the design process.

Once L_R and L_A have been selected, the length of barrier required at a specific location depends upon the tangent length of barrier upstream from the obstruction (L_1), its lateral distance from the edge of through traveled way (L_2) and the flare rate (a:b) specified for the installation.

The tangent length of the barrier immediately upstream from the obstruction (L_1) is a variable length selected by the designer. If a semi-rigid barrier is connected to a rigid barrier, the tangent length should be at least as long as the transition section to reduce the possibility of pocketing at the transition and to increase the likelihood of smooth redirection if the guide rail is impacted immediately adjacent to the rigid barrier.

The final variable to be selected by the designer to calculate the required length of guide rail at a specific location is the flare rate (see Table 12.7).

Once the appropriate variables have been selected, the required length of need, X, in advance of the obstruction can be calculated with the following equation:

$$X = \frac{L_A + (b/a)(L_1) - L_2}{b/a + (L_A / L_R)}$$

Note that for a parallel installation, i.e., no flare rate, the above equation reduces to:

$$X = \frac{L_A - L_2}{(L_A / L_R)}$$

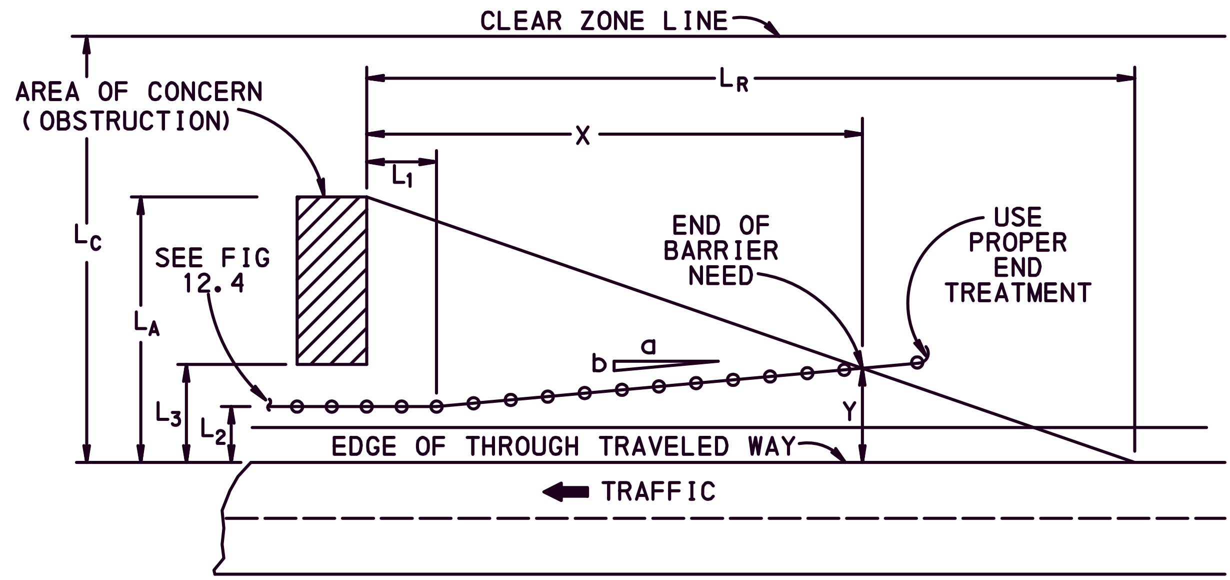
The lateral offset, Y, from the edge of traveled way to the beginning of the length of need can be calculated using the following equation:

$$Y = L_A - \frac{L_A}{L_R}(X)$$

Figure 12.4 illustrates the layout variables of an approach barrier for opposing traffic. The length of need, X, is determined in the same manner as previously described, but all lateral dimensions are measured from the left edge of traveled way of the opposing traffic, i.e., from the centerline for a two-lane roadway. If there is a two-way divided roadway, the edge of traveled way for the opposing traffic would be the edge of the driving lane on the median side. There are three ranges of clear zone width, L_C, that deserve special attention for an approach barrier for opposing traffic:

1. If the barrier is beyond the appropriate clear zone, no additional barrier and no crashworthy end treatment is required.

2. If the barrier is within the appropriate clear zone but the area of concern is beyond it, no additional barrier is required; however, a crashworthy end treatment should be used.



Where:

X	=	DISTANCE FROM OBSTRUCTION TO END OF BARRIER NEED.
Y	=	DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO END OF BARRIER NEED.
L_A	=	DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO LATERAL EXTENT OF OBSTRUCTION.
L_1	=	TANGENT LENGTH OF BARRIER UPSTREAM FROM OBSTRUCTION.
L_2	=	DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO BARRIER.
L_3	=	DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO OBSTRUCTION.
L_C	=	DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO THE OUTSIDE EDGE OF THE CLEAR ZONE.
L_R	=	THE THEORETICAL RUNOUT LENGTH NEEDED FOR A VEHICLE LEAVING THE ROADWAY TO STOP.
a : b	=	FLARE RATE.

FIGURE 12.3
APPROACH BARRIER LAYOUT

TABLE 12.8 (METRIC)
DESIGN PARAMETERS FOR
ROADSIDE BARRIER LAYOUT

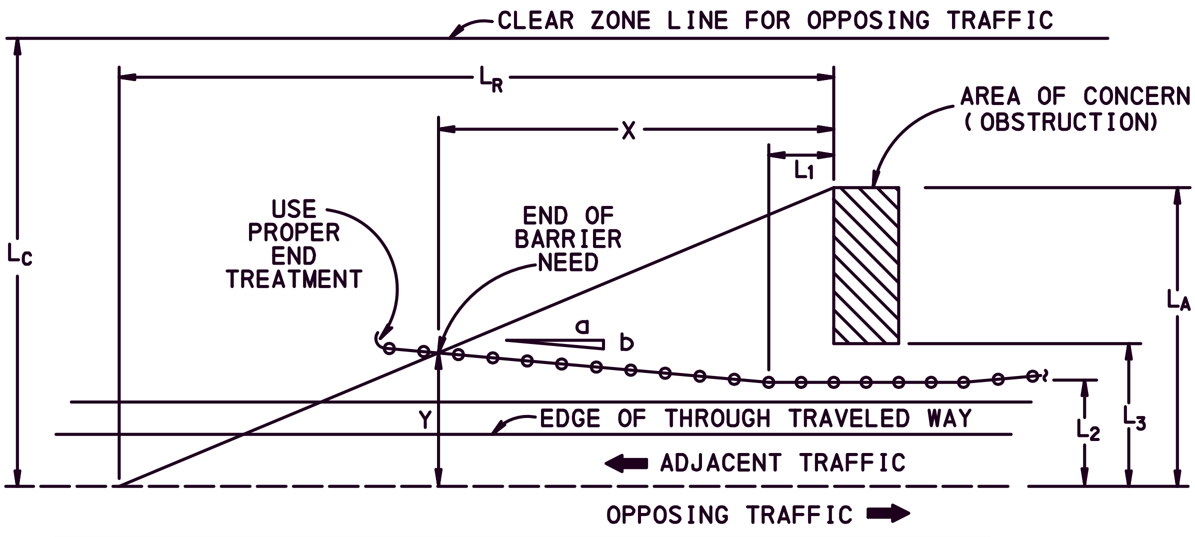
DESIGN SPEED (km/h)	DESIGN TRAFFIC VOLUME (ADT)			
	800 & UNDER	801 - 2000	2001 - 6000	OVER 6000
	L_R*	L_R*	L_R*	L_R*
110	110	120	135	145
100	100	105	120	130
90	85	95	105	110
80	75	80	90	100
70	60	65	75	80
60	50	55	60	70
50	40	45	50	50

*L_R = RUNOUT LENGTH (IN METERS)

TABLE 12.8 (ENGLISH)
DESIGN PARAMETERS FOR
ROADSIDE BARRIER LAYOUT

DESIGN SPEED (mph)	DESIGN TRAFFIC VOLUME (ADT)			
	800 & UNDER	801 - 2000	2001 - 6000	OVER 6000
	L_R*	L_R*	L_R*	L_R*
70	360	395	445	475
60	330	345	400	425
55	280	315	345	360
50	245	260	300	330
45	200	215	245	260
40	165	180	200	230
30	130	150	165	165

*L_R = RUNOUT LENGTH (IN FEET)



Where: X = DISTANCE FROM OBSTRUCTION TO END OF BARRIER NEED.
Y = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO END OF BARRIER NEED.
L_A = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO LATERAL EXTENT OF OBSTRUCTION.
L_1 = TANGENT LENGTH OF BARRIER UPSTREAM FROM OBSTRUCTION.
L_2 = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO BARRIER.
L_3 = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO OBSTRUCTION.
L_C = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO THE OUTSIDE EDGE OF THE CLEAR ZONE.
L_R = THE THEORETICAL RUNOUT LENGTH NEEDED FOR A VEHICLE LEAVING THE ROADWAY TO STOP.
a : b = FLARE RATE.

FIGURE 12.4
APPROACH BARRIER LAYOUT FOR OPPOSING TRAFFIC

3. If the area of concern extends well beyond the appropriate clear zone (e.g., a river), the designer may choose to shield only that portion which lies within the clear zone, by setting L_A equal to L_C in Figure 12.4.

A traffic barrier should be set as far as possible from the edge of traveled way. The slopes between a barrier installation and the roadway should be 1V:10H or flatter (see Figure 12.5). The barrier may also be located on a 1V:6H slope or flatter 3.6 m (12 ft) from the hinge point such that an errant vehicle is in normal mode at the moment of contact.

Perhaps the most straightforward method to determine length of need is to scale the barrier layout directly on the plan sheets. By selecting an appropriate runout length and the lateral distance to be shielded, the designer can specify a guide rail installation (i.e., lateral offset and flare) that satisfies all placement criteria. This method is most appropriate for determining the length of barrier required to shield embankments or fixed objects on non-tangent sections of roadway. Examples of this technique are provided below in Section 12.4.E (see Figures 12.6 through 12.9).

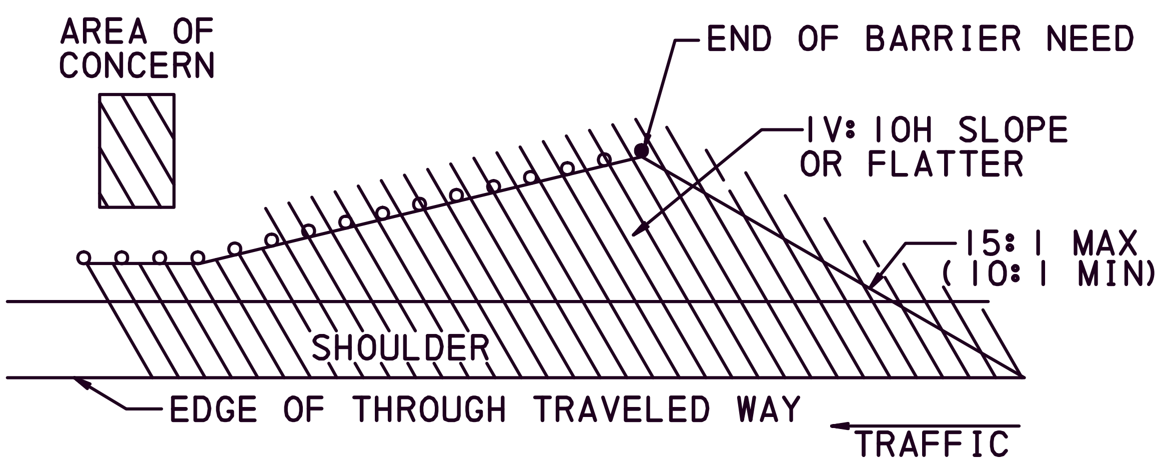


FIGURE 12.5
ROADSIDE SLOPES FOR APPROACH BARRIERS

E. Example Problems.

METRIC EXAMPLE:

GIVEN: ADT = 6200
Design Speed = 110 km/h
Embankment Slope = 1V:6H (right);
1V:10H (median)

SELECT: Clear Zone, L_C = 9.0 m (for 1V:6H slope from Table 12.1)
Clear Zone = 9.0 m (for 1V:10H median slope from Table 12.1)
Lateral Extent of Area of Concern, L_A = 9.0 m
Runout Length, L_R = 145 m (from Table 12.8)
Transition, L_1 = 7.6 m
Barrier Offset, L_2 = 3.6 m (right)
= 2.4 m (median)
Flare Rate = 15:1 (from Table 12.7)

DISCUSSION:

For the right shoulder installation, the designer can scale 145 m back from the bridge rail end and 9.0 m laterally from the same point. The hypotenuse of this triangle approximates a vehicle's runout path. To shield the bridge end and the river to the edge of the clear zone, the barrier installation must intersect this line. Based on the variables selected, a barrier length of 45.9 m is required. If this were an existing bridge and the approach embankment slopes were 1V:2H, the barrier would have to be installed parallel to the shoulder to minimize earthwork and approximately 100 m would be needed to shield the same area. Calculations for the flared installation are as follows:

$$\text{Length of Need} = \frac{9.0 + (1/15)(7.6) - 3.6}{(1/15) + (9.0/145)} = 45.9 \text{ m}$$

Note that on the median side, the designer may shield the entire opening even though this distance exceeds the recommended clear zone for the 1V:10H slope. This emphasizes that the clear zone distance is not a precise number and that engineering judgment must be used in its application.

ENGLISH EXAMPLE:

GIVEN: ADT = 6200
Design Speed = 70 mph
Embankment Slope = 1V:6H (right);
1V:10H (median)

SELECT: Clear Zone, L_C = 30 ft (for 1V:6H slope from Table 12.1)
Clear Zone = 30 ft (for 1V:10H median slope from Table 12.1)
Lateral Extent of Area of Concern, L_A = 30 ft
Runout Length, L_R = 475 ft (from Table 12.8)
Transition, L_1 = 25 ft
Barrier Offset, L_2 = 12 ft (right)
= 8 ft (median)
Flare Rate = 15:1 (from Table 12.7)

DISCUSSION:

For the right shoulder installation, the designer can scale 475 ft back from the bridge rail end and 30 ft laterally from the same point. The hypotenuse of this triangle approximates a vehicle's runout path. To shield the bridge end and the river to the edge of the clear zone, the barrier installation must intersect this line. Based on the variables selected, a barrier length of 151.5 ft is required. If this were an existing bridge and the approach embankment slopes were 1V:2H, the barrier would have to be installed parallel to the shoulder to minimize earthwork and approximately 328 ft would be needed to shield the same area. Calculations for the flared installation are as follows:

$$\text{Length of Need} = \frac{30 + (1/15)(25) - 12}{(1/15) + (30/475)} = 151.5 \text{ ft}$$

Note that on the median side, the designer may shield the entire opening even though this distance exceeds the recommended clear zone for the 1V:10H slope. This emphasizes that the clear zone distance is not a precise number and that engineering judgment must be used in its application.

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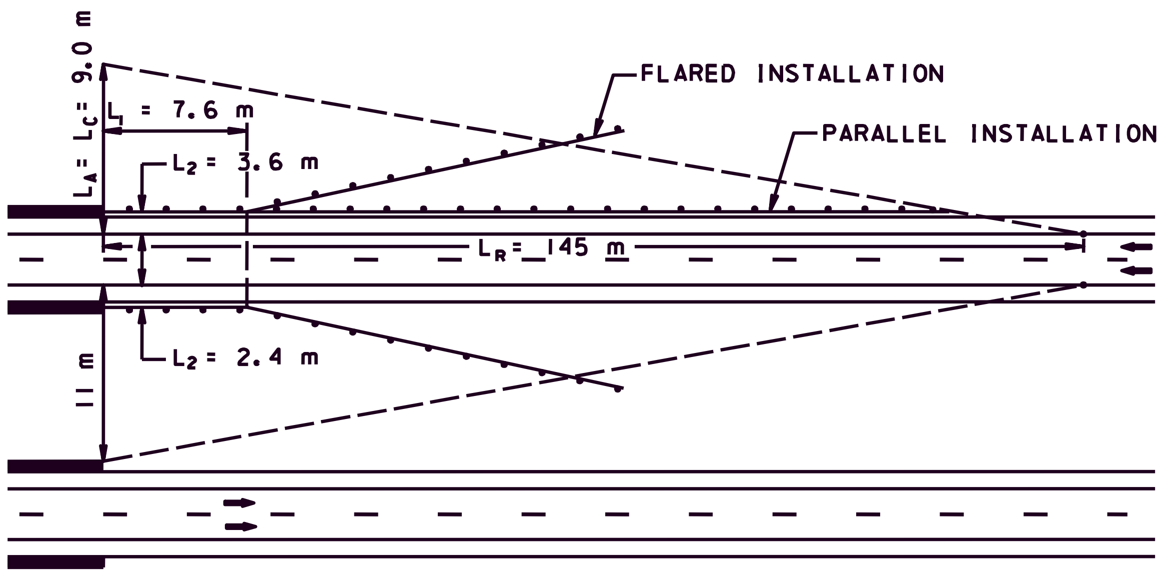

FIGURE 12.6 (METRIC)
EXAMPLE OF BARRIER DESIGN
FOR BRIDGE APPROACH

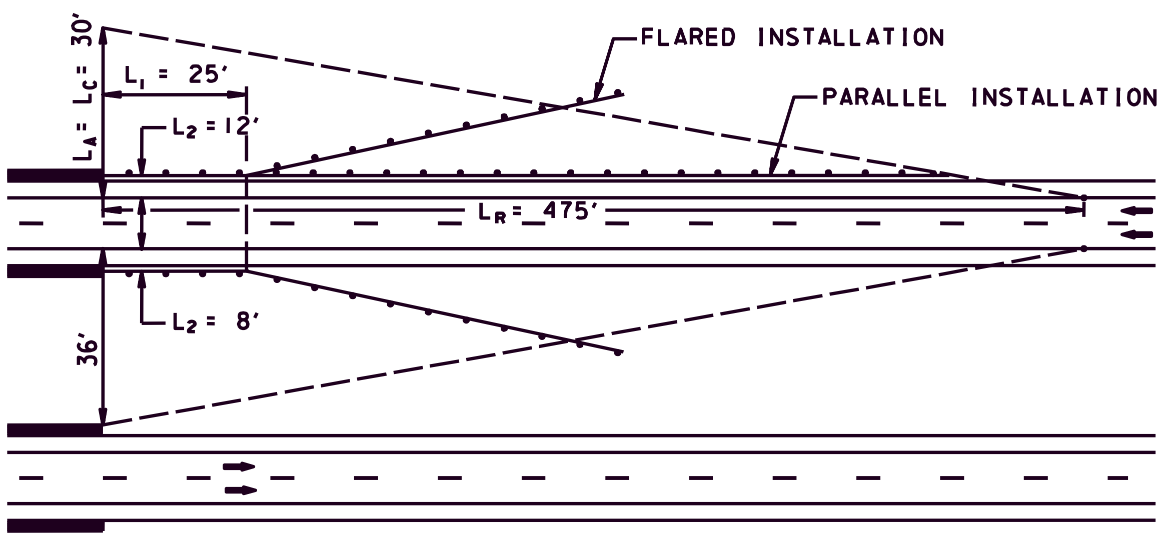

FIGURE 12.6 (ENGLISH)
EXAMPLE OF BARRIER DESIGN
FOR BRIDGE APPROACH

GIVEN: ADT = 850
Design Speed = 80 km/h (50 mph)
Embankment Slope = 1V:10H

SELECT: Clear Zone, L_C = 4.5 m (15 ft) (from Table 12.1)
Runout Length, L_R = 80 m (260 ft) (from Table 12.8)
Lateral Extent of Area of Concern, L_A = 3.6 m (12 ft)
Transition, L_1 = 7.6 m (25 ft)
Barrier Offset, L_2 = 2.5 m (8.2 ft)
Flare Rate = 11:1 (from Table 12.7)

DISCUSSION:

If the bridge piers are the only fixed object within the clear zone, the barrier needed is a function of L_A, L_1, L_R and the selected flare rate. However, if the bridge abutment also lies within the clear zone, the designer may elect to shield it as well, in which case an L_A greater than 3.6 m (12 ft) would be used to determine the length of barrier needed in advance of the piers. The calculations for shielding only the piers are as follows:

$$\text{METRIC:} \quad \text{Length of Need} = \frac{3.6 + (1/11)(7.6) - 2.5}{(1/11) + (3.6/80)} = 13.2 \text{ m}$$

$$\text{ENGLISH:} \quad \text{Length of Need} = \frac{12 + (1/11)(25) - 8.2}{(1/11) + (12/260)} = 44.3 \text{ ft}$$

A semi-rigid rail system must be located far enough in front of the piers to permit deflection of the rail without the vehicle snagging on the piers; otherwise, a stiffened transition section must be used as in this example. Even if a fixed object is beyond the design deflection distance of a semi-rigid barrier, a vehicle with a high center of gravity may roll far enough to snag on the shielded object. If this is a major concern, a stiffer and/or higher barrier should be considered.

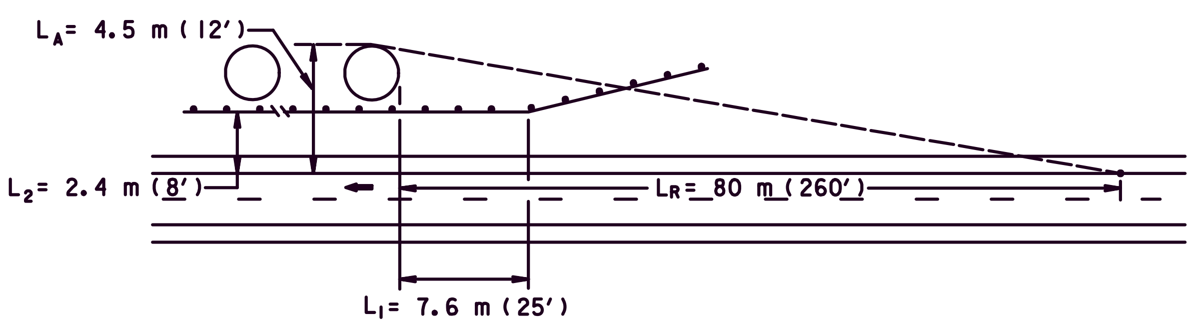

FIGURE 12.7
EXAMPLE OF BARRIER DESIGN FOR BRIDGE PIERS

GIVEN: ADT = 3000
Design Speed = 110 km/h (70 mph)
Embankment Slope at Beginning of L_R = 1V:6H
Slope at L_C is Critical, i.e., steeper than 1V:3H

SELECT: Clear Zone, L_C = 9.0 m (30 ft) (from Table 12.1)
$L_A = L_C$
Runout Length, L_R = 135 m (445 ft) (from Table 12.8)
Barrier Offset, L_2 = 2 m (6.6 ft)

DISCUSSION:

The area of concern begins at the top of the critical slope. Since the purpose of a barrier installation is to prevent a vehicle from reaching a non-traversable terrain feature or fixed object, the designer may elect to shield more of the slope by selecting a larger clear zone distance. It is often advantageous to review planned barrier lengths on-site just before installation to ensure adequate shielding.

The barrier may be introduced by anchoring it in a backslope, thus placing an end treatment that is not vulnerable to impact. This treatment effectively blocks off the entire embankment area. However, if no backslope exists or if it would require a significantly longer barrier installation to reach it without exceeding the recommended flare rate, a free-standing end treatment remains appropriate.

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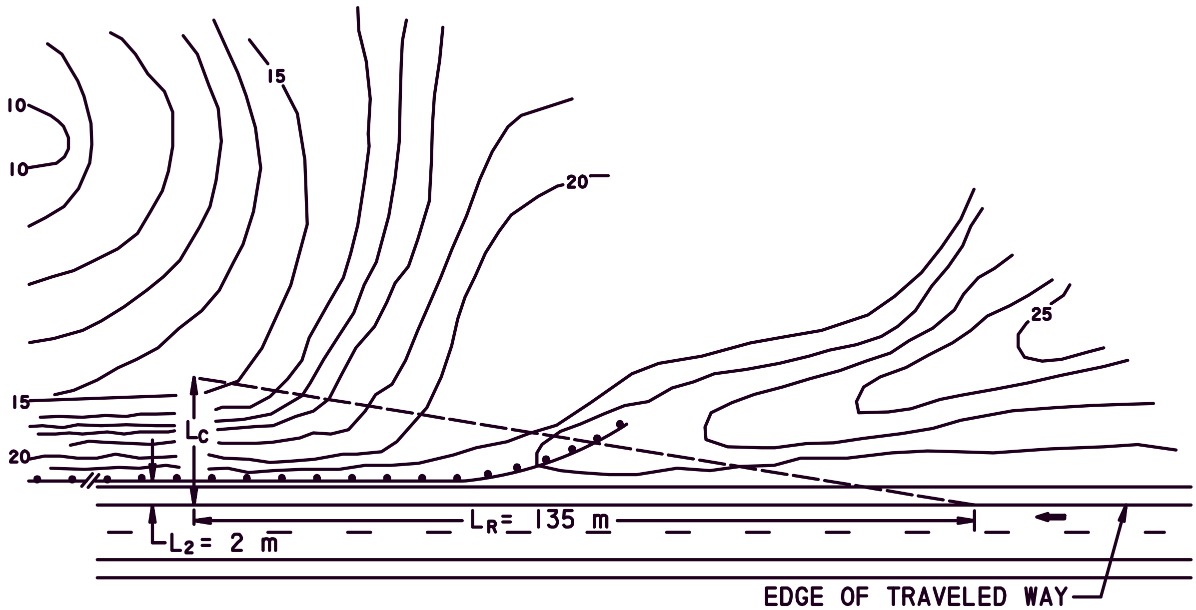


FIGURE 12.8 (METRIC)
EXAMPLE OF BARRIER DESIGN FOR
NONTRAVERSABLE EMBANKMENT

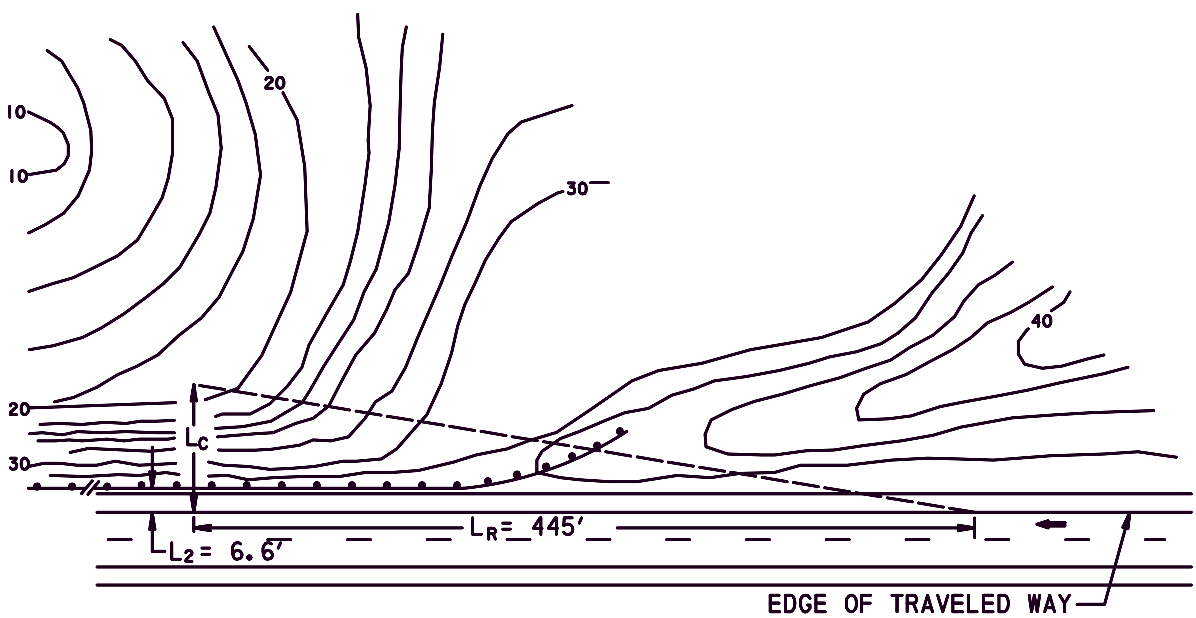


FIGURE 12.8 (ENGLISH)
EXAMPLE OF BARRIER DESIGN FOR
NONTRAVERSABLE EMBANKMENT

GIVEN: ADT = 650
Design Speed = 100 km/h (60 mph)
Embankment Slope = 1V:6H
Horizontal Curvature = 450 m radius (4°)

SELECT: Clear Zone, L_C = 6.0 m (20 ft) (from Table 12.1)
Adjustment Factor for Curvature = 1.4 (1.4) (from Table 12.2)
Adjusted Clear Zone = (6.0)(1.4) = 8.4 m
(Adjusted Clear Zone = (20)(1.4) = 28 ft)
Runout Length, L_R = Not Applicable (see DISCUSSION below)
Barrier Offset, L_2 = 1.2 m (4 ft)
Flare Rate = Not Applicable

DISCUSSION:

The length of need formula for a traffic barrier is directly applicable to straight highway alignment only. A vehicle leaving the roadway on the outside of a curve generally follows a tangential runout path if the area outside the roadway is flat and traversable. Thus, rather than using the theoretical L_R distance to determine a barrier length of need, a line from the curve to the outside edge of the area of concern (or to the clear zone if the condition is continuous, such as the streambed shown in Figure 12.9) should be used to determine the appropriate length of barrier needed. The barrier length then becomes a function of the distance from the edge of the driving lane and can most readily be obtained graphically by scaling. A flare rate is not generally used along a horizontal curve.

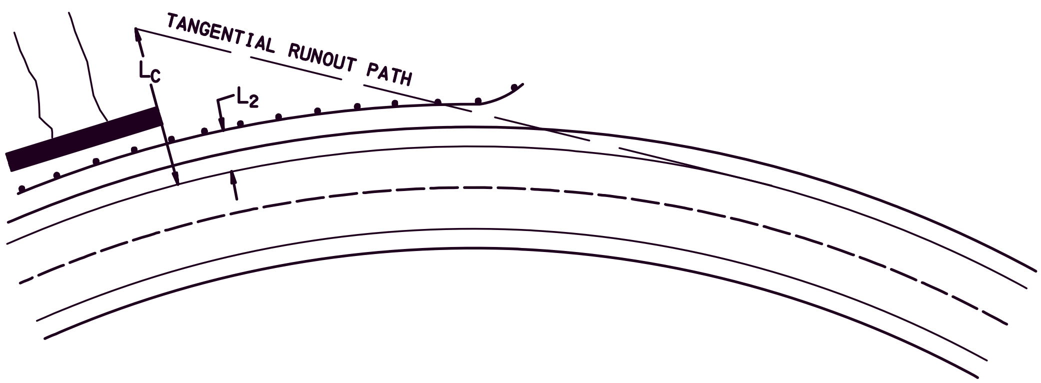


FIGURE 12.9
EXAMPLE OF BARRIER DESIGN FOR
FIXED OBJECT ON HORIZONTAL CURVE

12.5 MEDIAN BARRIER

A. Median Barrier Guidelines. Median barrier represents a longitudinal system used to prevent an errant vehicle from crossing the median of a divided highway. A median separates the traffic moving in opposite directions. However, median barriers, as discussed in this Chapter, are those designed to redirect vehicles striking either side of the barrier.

It is recognized that the increased use of median barriers has some disadvantages. The initial costs of installing a barrier can be significant. In addition, the installation of a barrier will generally increase the number of reported crashes as it reduces the recovery area available. As a result, there could be increased maintenance costs to repair the barrier as well as increased exposure to the maintenance crews completing the repairs. Another concern associated with the installation of a median barrier is that it will limit the options of maintenance and emergency service vehicles to cross the median. In snowy climates, a median barrier may also affect the ability to store snow in the median. There may be other environmental impacts depending on the grading required to install the barrier. For these reasons, a one-size-fits-all recommendation for the use of median barrier is not appropriate.

The need for median barriers is based on several factors including, but not limited to, median width, traffic volume and crash history. Figure 12.10 presents guidelines for median barriers based on two of these factors, median width and traffic volume. The guidelines presented in Figure 12.10 are for use on high speed, full access controlled roadways which have flat, traversable medians. A high-speed roadway is defined as having a posted speed limit of 70 km/h (45 mph) or greater.

Crash data indicating a high number of head-on and/or sideswipe crashes or substandard horizontal and/or vertical alignment may also be considered in evaluating the need for a median barrier.

These median barrier guidelines are to be considered an indicator that consideration should be given to utilizing the barrier. Satisfaction of these guidelines is not a guarantee that a barrier is needed. As such, these guidelines should be considered in the determination of the need for a barrier rather than absolute criteria.

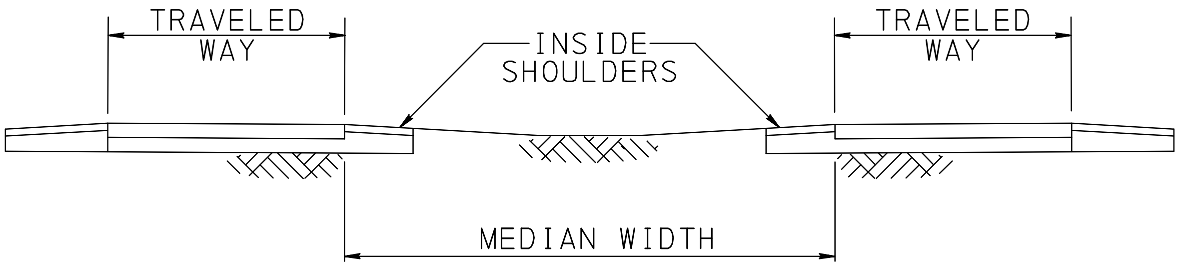
Specific median barrier guidelines for high-speed, divided highways are as follows:

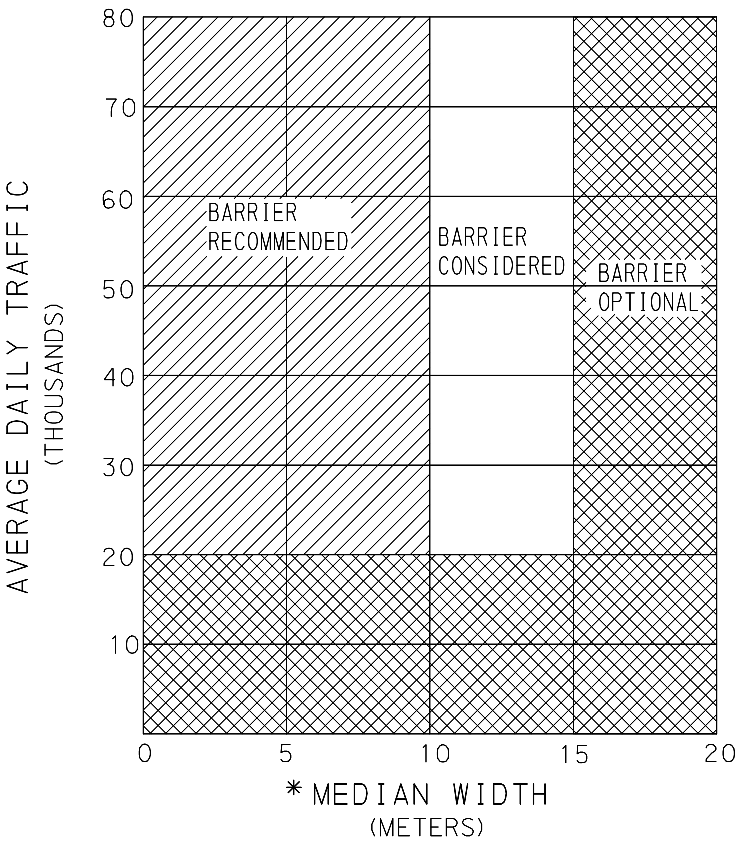
1. New Roadways on New Alignment.

a. Median Widths Less Than or Equal to 10 m (30 ft). All new high-speed divided highways with a proposed median width of 10 m (30 ft) or less shall be designed and constructed with an approved median barrier system.

b. Median Widths Greater Than 10 m (30 ft) and Less Than 15 m (50 ft). All new high-speed divided highways with a proposed median greater than 10 m (30 ft) and less than 15 m (50 ft) shall be designed to allow for the future installation of a median barrier system by providing a 1.8 m (6 ft) level area in the median. The District Safety Review Committee shall review the proposed roadway horizontal and vertical alignment to determine if the median is traversable. If the design ADT is greater than 20,000 and if the median is traversable, then the designer shall consider placement of barrier, and the District Safety Review Committee would concur with the designer's decision.

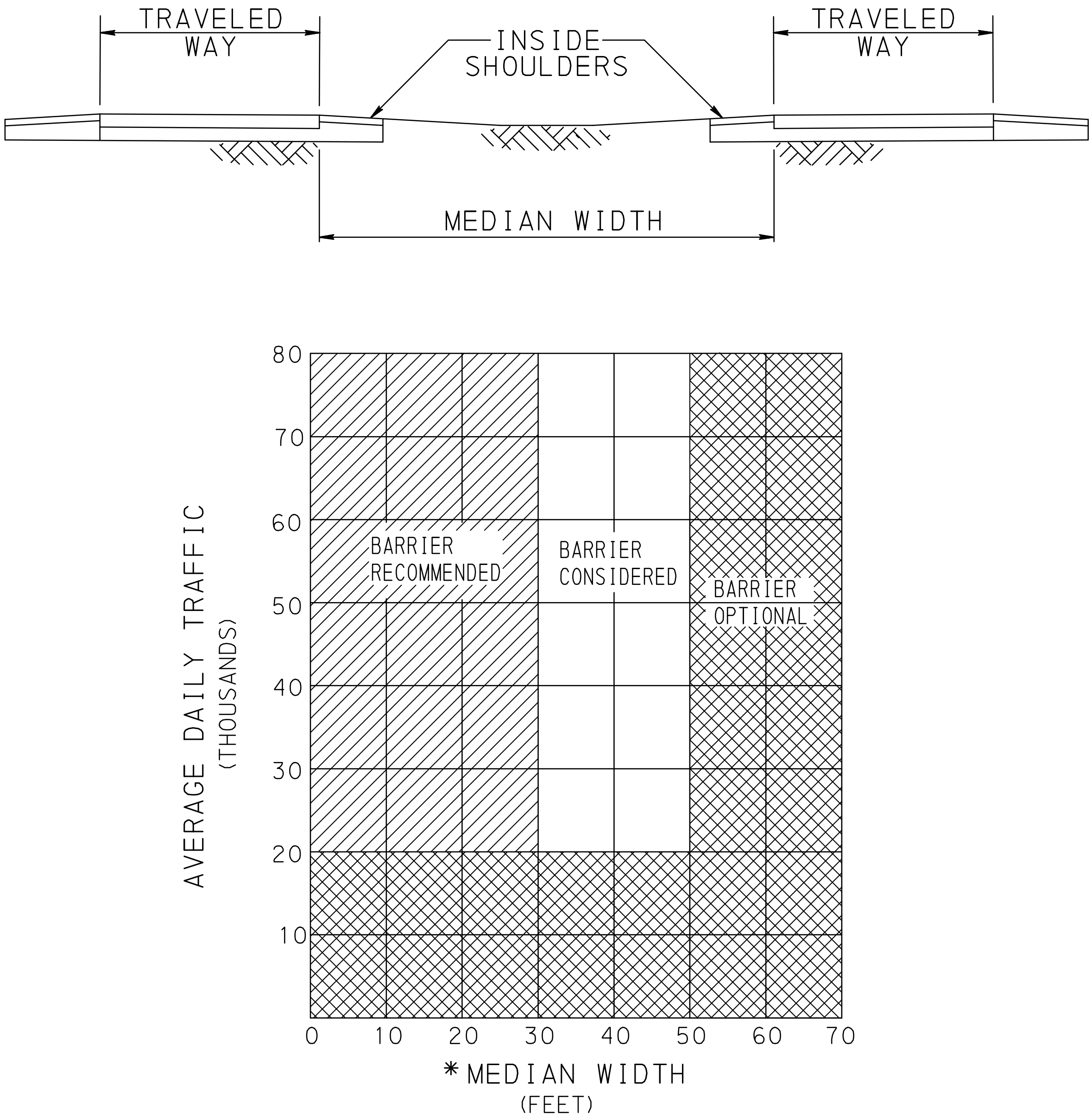
c. Median Widths Greater Than or Equal to 15 m (50 ft). All new high-speed divided highways with a proposed median of 15 m (50 ft) or greater shall be designed to allow for the future installation of a median barrier system by providing a 1.8 m (6 ft) level area in the median.





* MEASURED FROM EDGE OF TRAVELED WAY TO EDGE OF TRAVELED WAY AND INCLUDES BOTH INSIDE SHOULDERS.

FIGURE 12.10 (METRIC)
MEDIAN BARRIER GUIDELINES ON HIGH-SPEED, FULLY CONTROLLED-ACCESS ROADWAYS



* MEASURED FROM EDGE OF TRAVELED WAY TO EDGE OF TRAVELED WAY AND INCLUDES BOTH INSIDE SHOULDERS.

FIGURE 12.10 (ENGLISH)
MEDIAN BARRIER GUIDELINES ON HIGH-SPEED, FULLY CONTROLLED-ACCESS ROADWAYS

2. Existing Roadways on Existing Alignment.

a. Median Widths Less Than 15 m (50 ft). All existing high-speed divided highways with an existing median of 15 m (50 ft) or less will be evaluated for the need for median barrier during the design of every highway improvement project. The District Safety Review Committee will review the existing horizontal and vertical alignment and existing median slopes to determine if the existing median is traversable. If the existing median is determined to be traversable, the District Safety Review Committee will review the roadway's existing horizontal and vertical alignment, crash history, traffic volumes, and vehicle classifications. From that review, the District Safety Review Committee will determine if a median barrier system is needed for the entire project or just certain curve or tangent sections of the roadway. The District Safety Review Committee should make its recommendations before Design Field View.

For projects not on the National Highway System (NHS), the District Executive will review the District Safety Review Committee recommendations and approve or disapprove the recommendations. For projects on the NHS with Federal Oversight (FO), the Federal Highway Administration (FHWA) will review the District Safety Review Committee recommendations and approve or disapprove the recommendations. For projects on the NHS with PENNDOT Oversight (PO), the District Executive will review the District Safety Review Committee recommendations and approve or disapprove the recommendations.

b. Median Widths Greater Than or Equal to 15 m (50 ft). All existing high-speed divided highways with an existing median of 15 m (50 ft) or greater will be evaluated for the need for median barrier during the design of every highway improvement project. The District Safety Review Committee will review the existing horizontal and vertical alignment and existing median slopes to determine if the existing median is traversable. If the existing median is determined to be traversable, the District Safety Review Committee will review the roadway's existing horizontal and vertical alignment, crash history, traffic volumes, and vehicle classifications. From that review, the District Safety Review Committee will determine if a median barrier system is needed for the entire project or just certain curve or tangent sections of the roadway. The District Safety Review Committee should make its recommendations before Design Field View.

For projects not on the NHS, the District Executive will review the District Safety Review Committee recommendations and approve or disapprove the recommendations. For projects on the NHS with Federal Oversight (FO), the Federal Highway Administration (FHWA) will review the District Safety Review Committee recommendations and approve or disapprove the recommendations. For projects on the NHS with PENNDOT Oversight (PO), the District Executive will review the District Safety Review Committee recommendations and approve or disapprove the recommendations.

For locations with median widths equal to or greater than 15 m (50 ft), a barrier is not normally considered except in special circumstances such as a location with a significant history of cross-median crashes.

Since these median barrier guidelines are based on average or normal conditions, they are not conclusive justification for the installation of a barrier at any particular location, nor are they a substitute for engineering judgment. The unique circumstances of each location and the amount of funds available will dictate if and when a barrier should be installed.

Median barriers are sometimes used on high-volume facilities, which do not have fully controlled access. As indicated in Figure 12.10, these median barrier guidelines were developed for use on high-speed, fully controlled-access roadways. Utilizing these median barrier guidelines on roadways that do not have full access control requires the need for engineering analysis and judgment, taking into consideration such items as, right-of-way constraints, property access needs, number of intersections and driveway openings, adjacent commercial development, sight distance at intersections, barrier end termination, etc.

The following median barriers are currently acceptable for use in Pennsylvania:

1. F-shape concrete median barrier (810 mm (32 in))
2. F-shape concrete tall barrier (1270 mm (50 in))
3. Steel-post W-beam with wood or plastic block
4. Other appropriate systems (e.g., high-tension cable median barrier---see Section 12.5.D)

The F-shape concrete median barrier has an overall height of 810 mm (32 in); this includes provision for a 75 mm (3 in) future pavement overlay, reducing the height to 735 mm (29 in) minimum. When total overlay depths are expected to exceed 75 mm (3 in) or when an 810 mm (32 in) height is considered inadequate, the total height of the concrete must be adjusted. This adjustment must be made above the slope breakpoint. The height extension may follow the slope of the upper face if the barrier is thick enough or adequately reinforced at the top, or the extension may be vertical. A height extension may also be considered for use as a screen to block headlight glare from opposing traffic lanes.

B. Selection Guidelines. The first decision to be made, when selecting an appropriate median barrier, concerns the level of performance needed.

In critical locations, where heavy vehicle containment is considered necessary, median barriers having significantly greater capabilities than commonly-used barriers (i.e., higher than 810 mm (32 in)) may be installed. Factors to consider in reaching a decision on special designs include:

1. High percentage or large average daily number of heavy vehicles.
2. Adverse geometrics (horizontal curvature).
3. Severe consequences of vehicular (or cargo) penetration into opposing traffic lanes.
4. Severe headlight glare from opposing traffic.

The following criteria shall be used for installation of median barrier:

a. Access Controlled Freeways. When median barrier is specified, the standard (F-shape) concrete median barrier should be used. Double-face strong post or weak post W-beam may be used. However, metal systems are not cost effective in the median.

b. Ramps. For opposing ramps where barrier protection is specified, use the same criteria as in the mainline.

c. Free Access Facilities. Careful consideration should be given to the installation of median barrier on four or more lane free access facilities. The intent of the median barrier is to prevent crossover type crashes and not to control turning movements. Problems are created at each intersection or median crossover since the median barrier is terminated at these points. An evaluation of the number of crossovers, crash history, alignment, sight distance, design speed, traffic volume and median width should be made prior to installations on these facilities.

d. Two or Three-Lane Facilities. For two-lane or three-lane, two-way highway facilities, the installation of median barrier is not required.

Special attention should be given to properly adjust the edge of traveled way grades on the median sides of superelevated sections to assure a barrier system can be utilized.

Generally, the type of median barrier used on the approaching roadway, adjacent to a structure, should also be carried across the structure.

Where median barrier is proposed on a facility which has existing barriers adjacent to the project, the existing type of barrier should be continued if the added length is about 300 m (1000 ft) or less and the median widths are similar.

Where left-hand turning lanes are provided, the barriers shall be terminated with impact attenuating devices or other safety measures in advance of the turning lanes based on the posted speed limit.

Other significant factors to consider in the lateral placement of a median barrier are the effect of the terrain between the edge of traveled way and the barrier, the flare rate at transition sections and the treatment of rigid objects in the median.

When it becomes necessary to flare a median barrier in order to shield a rigid object in a median, the flare rate should be gradual and within acceptable limits. For minimum flare rates, refer to Table 12.7.

C. Median Barrier End Treatments. Median barrier termination is ideally accomplished where the median is wide and exposure to the end is limited. Proper end treatments such as end transitions or impact attenuating devices, based on type of facility should be provided to reduce vehicle deceleration upon impact and provide protection against spearing. End treatments may be tapered, flared or both.

1. Tapered End Treatments. This type of end treatment is primarily intended to eliminate the spearing or high deceleration characteristics of blunt-ended terminals. However, since a tapered end treatment can cause an impacting vehicle to become airborne and/or overturn, its use should be limited to low-speed situations and/or locations where end-on impacts are unlikely. See Publication 72M, *Roadway Construction Standards,* Drawing RC-57M.

A typical end transition may be used for permanent barrier installations only when the last barrier section is located outside the required clear zone. A 20:1 sloped end transition is acceptable for permanent installations where the legal speed limit is 60 km/h (35 mph) or less; otherwise, use an impact attenuating device. When concrete barrier is terminated at the end of parallel ramps or T intersections, a 2.1 m (7 ft) end transition may be used where the legal speed is 60 km/h (35 mph) or less. For barrier installations, an impact attenuating device is not required if any of the following conditions are satisfied:

a. The barrier is extended at the proper flare rate until the end of the barrier system is located outside the required clear zone.

b. The barrier is extended at the proper flare rate until the end of the barrier system can be buried in a cut section.

c. The barrier is extended at the proper flare rate until the end of the barrier system is properly connected or overlapped with existing guide rail.

Refer to Table 12.7 for flare rate requirements of permanent concrete barrier installations.

2. Flared End Treatment. In this case, the barrier can be introduced far enough from the approaching traffic that no additional safety treatment is needed. The flare rate should meet the minimum criteria shown in Table 12.7.

3. Flared and Tapered End Treatment. By combining Items 1 and 2 above, a median barrier terminal can be located where it is unlikely to be hit and designed so any impacts that do occur do not result in severe crashes.

The most desirable median is one that is relatively flat and free of rigid objects where the barrier is normally placed at the center of the median. When the cross slope becomes steeper than 1V:10H in depressed or mounded medians, placement of the barrier depends on the rate and height of the slope and other geometric relationships between opposing traffic. Illustrations and suggestions on median barrier placement are found in the AASHTO Roadside Design Guide, Chapter 6.

For additional guidelines refer to Publication 72M, *Roadway Construction Standards*, Drawing RC-50M Series, for end transitions and to Section 12.9 for design guidelines and selection procedures for impact attenuating devices.

D. High-Tension Cable Median Barrier. There are several proprietary, high-tension cable barrier systems that have been developed and are increasing in use. These systems are installed with a significantly greater tension in the cables than generic three-cable systems installed previously throughout the Commonwealth. The deflection of these systems depends on the type of system and the post spacing. The high-tension systems also result in less damage to the barrier and in many cases, the cables remain at the proper height after an impact that damages several posts. The posts can be installed in concrete sleeves in the ground to facilitate removal and replacement.

The Department recommends four-cable barrier systems over three-cable barrier systems because the four-cable barrier systems have performed better in recent testing by FHWA. Four-cable barrier systems provide a wider safety net to accommodate most vehicle types and with respect to having at least two cables engage the vehicles. FHWA has noted that at least two cables engaging vehicles are desired for systems to perform well.

The Department recommends four-cable barrier systems to meet Test Level 4 (TL-4) criteria instead of Test Level 3 (TL-3) criteria, primarily to withstanding impacts by larger vehicles. For TL-3 criteria, the largest vehicle mass (2000 kg (4400 lb)) impacts the barrier at a speed of 100 km/h (62 mph) and at an angle of 25°. For TL-4 criteria, the largest vehicle mass (17,650 lb (8000 kg)) impacts the barrier at a speed of 80 km/h (50 mph) and at an angle of 15°. Test criteria are as set forth in NCHRP Report 350 and subsequent FHWA criteria adopted in the AASHTO publication *Manual for Assessing Safety Hardware (MASH).*

When designs for a high-tension cable barrier system are being considered, consult and coordinate with the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section. The Highway Design and Technology Section will provide assistance in evaluating design considerations for these systems and in addressing concerns raised by using these systems.

Table 12.9 presents design/location guidelines for high-tension cable barrier systems to be installed in medians.

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TABLE 12.9
DESIGN/LOCATION GUIDELINES
FOR HIGH-TENSION CABLE BARRIER SYSTEMS
INSTALLED IN MEDIANS

FEATURE	GUIDELINE
Crash Requirements (NCHRP Report 350)	• Cable Barriers: Test Level 4 (TL-4), minimum • End Anchor Terminals: Test Level 3 (TL-3), minimum
Number of Cables	• 4 cables, minimum
Post Spacing (maximum)	• 3.0 m (10 ft)
Median Width (minimum)	• Slopes 6:1 to 10:1 - 10.8 m (36 ft) • Slopes 10:1 or Flatter - 7.2 m (24 ft)
Median Slope	6:1 or flatter For median slopes 4:1 to 6:1, consult with Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section
Deflection	• Barrier placement location needs to account for the deflection limits of the system used. • Deflections from a hit in any direction should not encroach into a travel lane. • Do not specify deflection distances greater than 2.4 m (8 ft).
Barrier Placement (Swale Line)	• Slopes 6:1 to 10:1 - Not within 2.4 m (8 ft) of swale line • Slopes 10:1 or Flatter - Not within 0.6 m (2 ft) of swale line • Do not locate posts or end anchors in saturated soils.
Barrier Placement (Shoulder versus Center)	• For slopes greater than 6:1, install two systems in median. • For 6:1 slopes or flatter, install one system in median. • Place high-tension cable barrier systems a minimum of 3.0 m (10 ft) and preferably 3.6 m (12 ft) or more from the edge of traveled way. • For additional guidance, see the AASHTO Roadside Design Guide, Section 6.6 (Placement Recommendations).
Maximum Distance Between Anchors	Varies by manufacturer and system
Transitions to Existing Barrier Systems	If encountered, needs to be addressed. Examples include bridge piers, sign structures, concrete median barrier, W-beam guide rail, dual structures with barrier dikes, etc. Consult with the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section for guidance.
Soil Properties	Contractor to provide for a design to account for the anticipated soil type and to be sealed by a Professional Engineer (P.E.) licensed in Pennsylvania. Soil properties for the design of the end anchors must be part of the contract documents. Existing geotechnical reports from the original construction project are to be made available for the installation contractor to review. In locations where complete geotechnical reports are not available, the supplied soil properties should include AASHTO Soil Classifications, moisture content; for cohesionless soils, the friction angle, density, and strength; for cohesive soils, the consistency and undrained shear strength. Cone penetrometer testing is one acceptable method to determine soil strength properties. Depth of soils information to 1500 mm (60 in) is recommended.

E. Gate Barrier Systems. An emergency opening may be required, for example, to route traffic around a crash that requires the roadway to be temporarily closed. Proprietary devices have been developed and tested that can be used to provide a temporary opening in conjunction with a concrete safety-shaped median barrier. These gate barrier systems include:

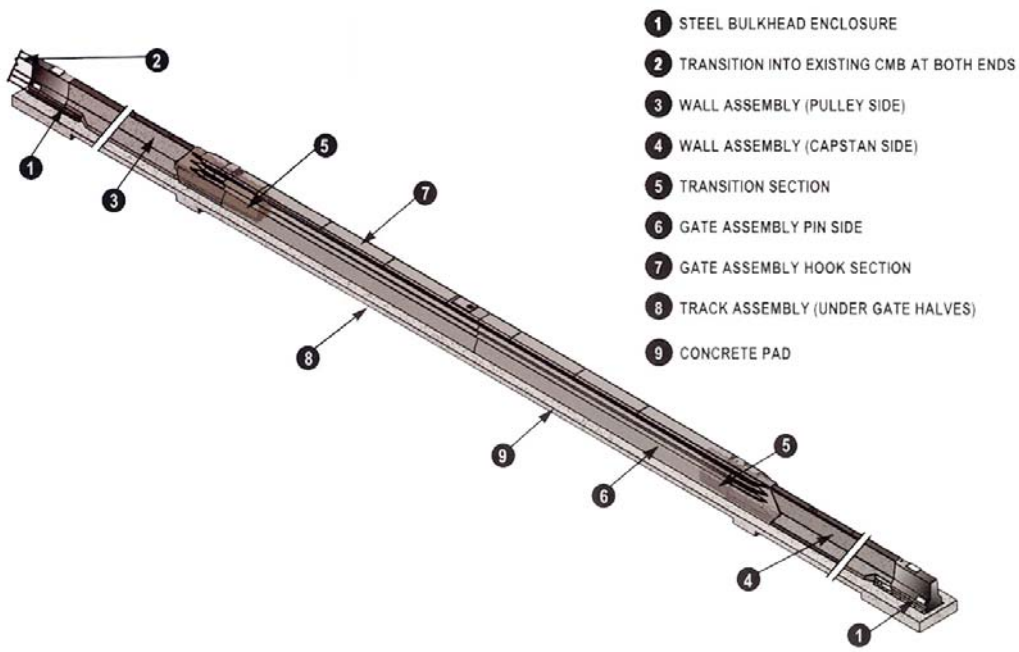
- The BarrierGate
- The ArmorGuard Gate
- The Vulcan Gate

1. The BarrierGate. The BarrierGate (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-25) is a proprietary longitudinal nongating barrier which opens to provide a 12.2 m or 7.9 m (40 ft or 26 ft) wide opening for controlled access through barrier openings.

The outermost ends of the gate assembly are equipped with transition assemblies that attach to custom concrete median barrier (CMB) sections.

The movement of the gate assemblies is directed by track assemblies anchored to a concrete foundation and guide rail assemblies anchored to the tops of the concrete transition assemblies.

The BarrierGate is a proprietary system, and as such, must be purchased or obtained through competitive bidding with an equally suitable alternate steel barrier system such as the ArmorGuard Gate and the Vulcan Gate.



2. The ArmorGuard Gate. The ArmorGuard Gate (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-87) is a proprietary longitudinal nongating barrier specifically designed to span a permanent opening in a concrete median barrier ranging from 8 m (26 ft) to 16 m (52 ft) long. The ArmorGuard Gate is a heavily reinforced steel barrier that is designed for emergency openings. The typical length of each gate section is 4 m (13 ft) and the effective overall height is 830 mm (33 in). The ArmorGuard Gate is 710 mm (28 in) wide at its base.

The ArmorGuard Gate is a proprietary system, and as such, must be purchased or obtained through competitive bidding with an equally suitable alternate steel barrier system such as the BarrierGate and the Vulcan Gate.

3. The Vulcan Gate. The Vulcan Gate (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-134C) is a proprietary longitudinal nongating barrier specifically designed to provide an emergency opening in a concrete median barrier. The median openings range from 8.28 m (27.17 ft) for a two-section Vulcan Gate (V2000) to 24.70 m (81.04 ft) for a six-section Vulcan Gate (V6000).

A typical Vulcan Gate system is comprised of existing Vulcan segments, two tested and accepted transitions to concrete median barrier, and two hinge segments. The hinges may also be used in a run of Vulcan barrier to create a gate opening.

The Vulcan Gate is a proprietary system, and as such, must be purchased or obtained through competitive bidding with an equally suitable alternate steel barrier system such as the BarrierGate and the ArmorGuard Gate.

12.6 TALL BARRIER

The primary use of tall barrier (glare screen) is to improve night visibility by reducing or eliminating glare from opposing headlights. At the same time it provides a greater level of performance for heavy vehicle containment. It may also be used in construction zones and in non-median locations such as between two-way frontage roads and freeways, and between highways and railroad tracks.

At the present time, there are no specific nationally recognized requirements established for the installation of glare screen. In the absence of such requirements, the following factors should be considered when assessing the need for a glare screen system:

1. Median width and crash experience.
2. Roadway curvature (horizontal and vertical).
3. Traffic volumes and vehicle characteristics.
4. Topographic characteristics.
5. Grades.
6. Number of lanes.
7. Horizontal sight distance.
8. Aesthetics.

In addition to the above factors, consideration should be given to determine whether the glare screen system should be a "closed" system that establishes a solid barrier between opposing traffic or an "open" system that provides unobstructed lateral vision.

Acceptable types of glare screen systems in Pennsylvania are concrete and plastic paddles or modular systems as shown in Figure 12.11. The concrete glare screen system details are shown in Publication 72M, *Roadway Construction Standards*. The plastic paddle or modular glare screen systems are acceptable for use as a retrofit on top of existing concrete median barrier or new 810 mm (32 in) barrier via special provisions based on the manufacturers' specifications and construction methods. Either system shall be provided by an approved manufacturer as listed in Publication 35, *Approved Construction Materials* (Bulletin 15).

A description for each system is as follows:

1. Concrete Glare Screen System. A concrete glare screen system represents a "closed" system using an F-shape concrete median barrier whose height is extended vertically to create an effective glare screen. Methods of construction include monolithic cast-in-place or slip-form or precast as shown on the Standard Drawings.

2. Plastic Paddle Glare Screen System. A plastic paddle glare screen system represents an "open" system using plastic paddles or modular systems anchored in an upright position on top of F-shape barrier or other conventional types of median devices and deployed parallel to the roadway in louver fashion resembling a picket fence.

A glare screen system for narrow medians may obstruct sight distance on curves to the left. Therefore, spacing or width of glare screen elements must be adjusted in proportion to the radius and calculations should be made to ensure that the glare screen does not reduce the sight distance needed for safe stopping. Glare screen should not be used where its installation would reduce the sight distance to less than safe stopping sight distance. The accepted design cutoff angle for glare screen should be 20° for tangent sections and 20° plus the quantity 1750 divided by the radius in meters for non-tangent sections (20° plus the degree of curvature for non-tangent sections).

Other types of glare screen systems of fabric and metal designs are undergoing research and development and may be considered on an experimental basis.

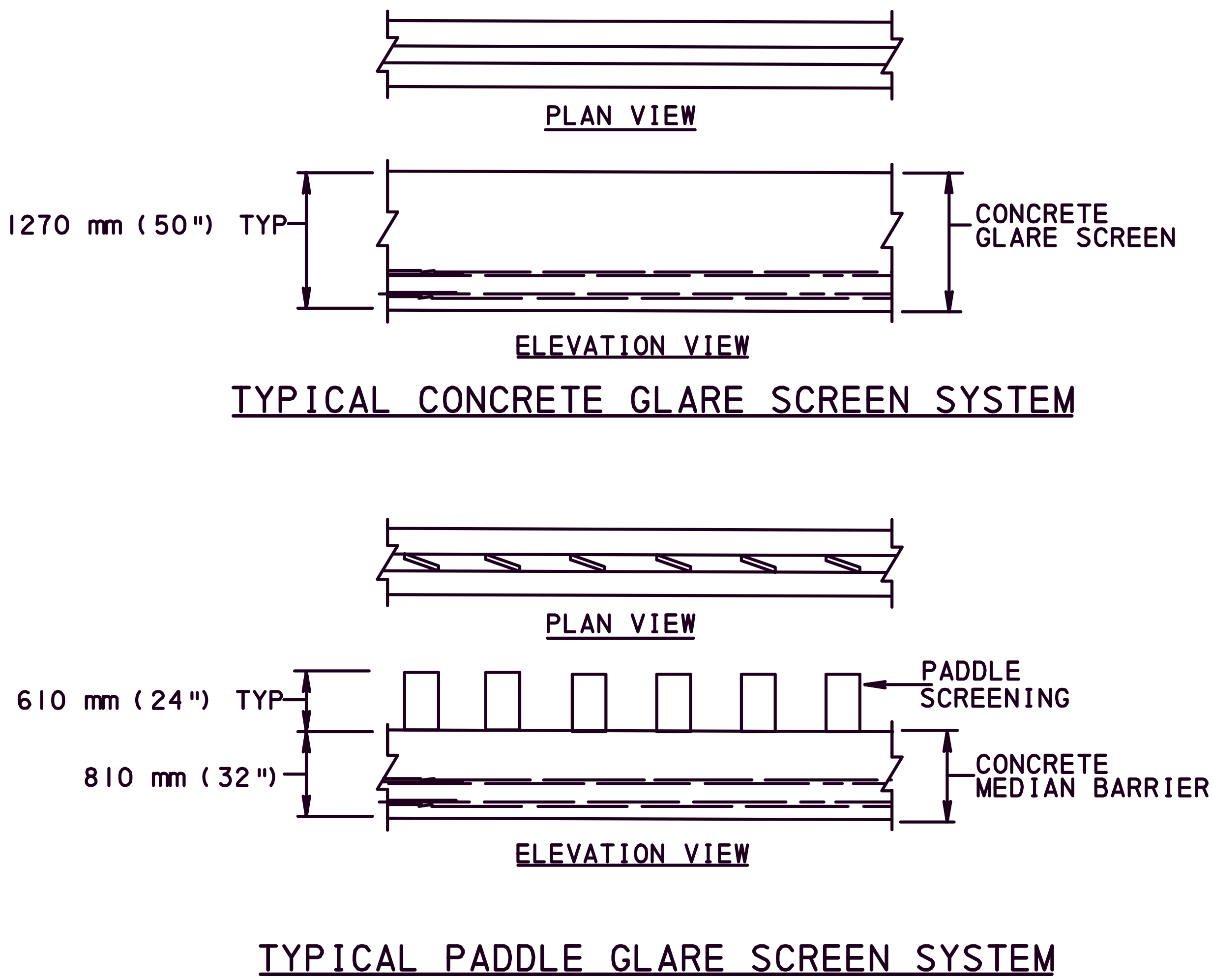


FIGURE 12.11
GLARE SCREEN SYSTEMS

12.7 SINGLE FACE CONCRETE BARRIER

Single face concrete barrier represents a rigid longitudinal barrier system used for the protection of piers and other roadside obstructions. The need for single face barrier shall be determined from Table 12.5, Figures 12.3 and 12.4 or Table 12.8 and the details shall conform to the Standard Drawings.

In special cases, single face barrier may be considered as a roadside (shoulder) barrier on projects where the minimum unobstructed distance (see Table 12.3) behind the guide rail is not available or on projects with a maintenance or design problem. Stability for single face barrier without back support is significantly affected by a reduction of the base width and additional base restraint is required to support the barrier in place. Emphasis should be placed on minimizing the number of such installations to only those that can be justified giving consideration to the social, environmental and economic factors as well as protective aspects.

Single face concrete barrier is **ONLY** appropriate for temporary barrier or roadside (shoulder) barrier when the barrier has full back support as shown in Publication 72M, *Roadway Construction Standards*.

Single face concrete barrier without full back support may be used if it is part of a moment slab. Design details for moment slabs are to be shown in the project plans following the guidance and details in BD-627M and Publication 15M, *Design Manual Part 4*.

Proper end treatments shall be provided as indicated on the Standard Drawings. Where single face barriers adjoin existing barrier systems, they shall be properly connected or overlapped in accordance with the Standard Drawings. All connection details not addressed by the Standard Drawings should be approved by the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section, prior to inclusion in the project plans. For federally-funded projects, approval by the Federal Highway Administration (FHWA) is also required.

12.8 SHOULDER TREATMENTS

A. Rumble Strips. Rumble strips are depressed corrugations which provide an audible alert to motorists who drift off the travel lane. This audible warning provides an opportunity for errant drivers to react and make steering corrections that are needed to return to the travel way.

Rumble strips provide low-cost safety benefits and are to be included for both bituminous and concrete shoulders on new construction, reconstruction or resurfacing projects as indicated in Publication 72M, *Roadway Construction Standards*.

1. Limited Access Highways (Interstates and Expressways/Freeways). Provide shoulder rumble strips on each right and left shoulder which meet the following conditions:

- **a.** Right shoulders with a minimum paved width of 2.4 m (8 ft).
- **b.** Left (median) shoulders with a minimum paved width of 1.2 m (4 ft).

Installing rumble strips on bituminous paved shoulders requires an ID-2, ID-3, or Superpave HMA surface with BCBC base or better. Type 1-SP, Type 6-SP, and Type 7 shoulders should be specified in the design phase.

Shoulder rumble strips do not have to be part of a construction or restoration project. They can be installed via projects initiated exclusively for this purpose.

Shoulders should be in sufficiently good condition, as determined by the District, to effectively retrofit shoulder rumble strips without raveling or deteriorating. Otherwise, upgrade the shoulders prior to constructing shoulder rumble strips.

Do not install shoulder rumble strips on bridge decks, across transverse joints on concrete shoulders or across longitudinal joints.

Coordinate the construction of shoulder rumble strips with all necessary project phases. Do not construct the rumble strips until all construction phases, which utilize the shoulder to maintain traffic or construction vehicles/equipment, are complete.

2. Free Access Highways. Rumble strips for free access highways should be considered on a project by project basis and indicated on the construction plans. Rural and urban restoration (3R and reconstruction) projects should be evaluated.

Installing rumble strips on bituminous pavement requires an ID-2, ID-3, or Superpave HMA surface with BCBC base or better.

The following types of longitudinal rumble strips should be considered only on non-Interstate and non-expressway undivided two-lane or four-lane rural and urban roadways:

a. Shoulder Rumble Strips. Installed to reduce the number of single vehicle, run-off-the-road crashes.

b. Bicycle Tolerable Shoulder Rumble Strips. Installed in place of shoulder rumble strips that can pose problems for bicyclists who utilize paved shoulders for travel.

c. Centerline Rumble Strips. Installed to reduce the number of head-on and opposing crashes.

d. Edgeline Rumble Strips. Installed in lieu of shoulder rumble strips when the travel lane and shoulders are both of sufficient width.

For additional guidance on selecting longitudinal rumble strips, refer to Publication 46, *Traffic Engineering Manual*.

B. Safety Edge$_{\mathbf{SM}}$. The Safety Edge is a simple but extremely effective solution that can help save lives by allowing drivers who drift off highways to return to the road safely. Instead of a vertical drop-off, the Safety Edge consolidates the edge of the pavement to a 30° taper (with a 26° to 40° construction tolerance). Research has shown this is the optimum angle to reduce or eliminate tire scrubbing and allow drivers to re-enter the roadway safely. The Safety Edge provides a strong, durable transition for all vehicles. Even at higher speeds, vehicles can return to the paved road smoothly and easily. By including the Safety Edge detail while paving, this countermeasure can be implemented system-wide at a very low cost. The Safety Edge also provides a more durable pavement edge that prevents edge raveling. FHWA's goal is to accelerate the use of the Safety Edge technology, working with States to develop specifications and adopt this pavement edge treatment as a standard practice on all new and resurfacing bituminous pavement projects.

The Safety Edge is a proven technology with the following primary benefits:

- Reduces crashes and saves lives by mitigating pavement edge drop-off
- Is a low-cost, systematic improvement applied during paving
- Improves durability by reducing edge raveling
- Reduces tort liability

The Safety Edge is formed during a bituminous paving operation using a special removable wedge shaped shoe or end gate attached to the paver. See Publication 72M, *Roadway Construction Standards*, RC-25M for Safety Edge details.

The Safety Edge is to be used as a standard pavement edge treatment on the outside edge of bituminous pavements and shoulders for both wearing and binder courses having a depth of 1.5 in and greater. The total depth of the Safety Edge should not be more than 5 in.

The Safety Edge should not be included in urban typology projects where curb and sidewalk are encountered and it should not be used for base, leveling, or scratch courses at this time.

The Safety Edge is considered incidental to the paving course being placed and will result in an approximate 1% increase in the HMA/WMA material quantity. For tonnage items the 1% increase must be added to the project quantities.

The Safety Edge must be added to projects that meet the above guidelines via special provision N-a13401-A. The special provision specifies an **adjustable** Safety Edge device to prevent roll up of the edge. Fixed devices extrude the edge at a 30° angle, but after rolling, the angle of the edge may not meet the 40° maximum angle requirement. All pilot projects that used adjustable devices met the edge angle criteria.

No special preparation of the shoulder is required when placing the edge only on the final wearing course. However, preparation of the granular shoulder prior to placement is incidental to the paving items for wearing and binder courses. The incidental preparation work should be minor. Keep in mind that the asphalt material is incidental to the paving item. Thus, if more extensive prep work is required to prepare the shoulder area to address washouts or large drop-offs, the designer should include a separate item in the contract or work with County Maintenance Organizations to prepare the shoulders in advance of the project.

Shoulder backup is still to be placed with the Safety Edge as in the past with the traditional vertical edge.

The Safety Edge is not to be used as a longitudinal joint (i.e. lane to lane). A vertical or notched wedge joint for longitudinal joints is used as per Publication 408, Section 409.

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12.9 IMPACT ATTENUATING DEVICES

A. Introduction. Barrier end treatments and crash cushions are protective systems that prevent errant vehicles from impacting fixed objects by either gradually decelerating the vehicle to a stop when hit head-on, or by redirecting it away from the object for glancing impacts. These devices are used to shield barrier ends and other rigid objects that cannot be removed, relocated or made breakaway. Crash cushions and barrier end treatments are not intended to reduce crashes but rather to lessen their severity.

The intended function of all types of impact attenuating devices is to dissipate the energy of the vehicle either partially during a side-on impact or fully in the case of a head-on impact. This is accomplished through the principle of mechanics: "the change in kinetic energy is equal to the work done on the system." Some devices dissipate energy by crushing the elements of the system; others by putting the components of the attenuating system into motion. A third type operates on a combination of these two principles.

National Cooperative Highway Research Program (NCHRP) Report No. 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, has previously contained the recommendations for testing and evaluating the performance of safety devices. The Federal Highway Administration adopted NCHRP Report 350 in the July 16, 1993 Federal Register. This document superseded the previous NCHRP Report 230 which was published in 1980.

NCHRP 350 provides a wider range of test procedures to permit safety performance evaluations for a wider range of barriers, terminals, crash cushions, breakaway support structures and utility poles, truck-mounted attenuators, and work zone traffic control devices. Six Test Levels (1-6) are described in this report with full-scale vehicle crash testing. The nominal speed for Test Level 1 is 50 km/h (31 mph), 70 km/h (44 mph) for Test Level 2 and 100 km/h (62 mph) for Test Levels 3 through 6. Test Level 3 is the basic level required by the Federal Highway Administration for use on high-speed roadways on the National Highway System. In special conditions where containment of single-unit trucks, tractor trailers and tank trailers is necessary, the criteria for Test Levels 4, 5 and 6 are used respectively.

In 2009, AASHTO published the *Manual for Assessing Safety Hardware* (MASH). MASH is an update to and supersedes NCHRP Report 350 for the purposes of evaluating new safety hardware devices. MASH does not supersede any guidelines for the design of roadside safety hardware contained within the AASHTO Roadside Design Guide. MASH was developed through NCHRP Project 22-14(02), *Improvement of Procedures for the Safety-Performance Evaluation of Roadside Features*.

The purpose of MASH is to present uniform guidelines for the crash testing of both permanent and temporary highway safety features and evaluation criteria to assess test results. MASH also includes guidelines for the in-service evaluation of safety features. These guidelines and criteria incorporate current technology and the collective judgment and expertise of professionals in the field of roadside safety design. They provide: (1) a basis on which researchers and user agencies can compare the impact performance merits of candidate safety features, (2) guidance for developers of new safety features, and (3) a basis on which user agencies can formulate performance specifications for safety features. The need for updated crash test criteria was based primarily on changes in the vehicle fleet.

An implementation plan for MASH was adopted jointly by AASHTO and FHWA. The plan states that all highway safety hardware accepted prior to the adoption of MASH - using criteria contained in NCHRP Report 350 - may remain in place and may continue to be manufactured and installed. In addition, highway safety hardware accepted using NCHRP Report 350 criteria is not required to be retested using MASH criteria. However, new highway safety hardware not previously evaluated must utilize MASH for testing and evaluation.

Implementation of MASH on the NHS, as described in a FHWA memorandum November 20, 2009, will be as follows:

- The AASHTO Technical Committee on Roadside Safety is responsible for developing and maintaining the evaluation criteria as adopted by AASHTO. FHWA shall continue its role in the review and acceptance of highway safety hardware.

- All highway safety hardware accepted prior to adoption of MASH using criteria contained in NCHRP Report 350 may remain in place and may continue to be manufactured and installed.

- Highway safety hardware accepted using NCHRP Report 350 criteria is not required to be retested using MASH criteria.

- If highway safety hardware that has been accepted by FHWA using criteria contained in NCHRP Report 350 fails testing using MASH criteria, AASHTO and FHWA will jointly review the test results and determine a course of action.

- Upon adoption of MASH by AASHTO, any new highway safety hardware not previously evaluated shall utilize MASH for evaluation and testing.

- Any new or revised highway safety hardware under development at the time the MASH is adopted may continue to be tested using the criteria in NCHRP Report 350. However, FHWA will not issue acceptance letters for new or revised highway safety hardware tested using NCHRP Report 350 criteria after January 1, 2011.

- Highway safety hardware installed on new construction and reconstruction projects shall be those accepted under NCHRP Report 350 or MASH.

- Agencies are encouraged to upgrade existing highway safety hardware that has not been accepted under NCHRP Report 350 or MASH:

    - During reconstruction projects,
    - During 3R projects, or
    - When the system is damaged beyond repair.

- Highway safety hardware not accepted under NCHRP Report 350 or MASH with no suitable alternatives available may remain in place and may continue to be installed.

Updates to existing highway safety hardware are to be addressed as part of the Department's Interstate and Expressway Pavement Preservation Guidelines and Non-Expressway Pavement Preservation (NEPP) Guidelines for Federal Aid and State Projects. These guidelines are described in Publication 242, *Pavement Policy Manual*, Appendix G.

The best choice a designer can make is to eliminate the need for barrier. Roadside barrier and terminals must be selected, installed, and maintained in such a manner that a motorist striking it at any speed or angle has the best chance for survival. Terminal selection must be a deliberate design decision based on site conditions and on the known performance characteristics of the various terminals.

B. Terminal Characteristics. Crashworthy terminals are classified as non-gating or gating by design. A non-gating system will gradually stop or redirect a vehicle away from a fixed object, while a gating terminal allows a vehicle to pass through after impact when the tension in the system is released.

Non-gating terminals are the high type crash cushions used to terminate median barriers for bidirectional traffic, gore areas and other narrow or wide obstructions. Crash cushion systems such as sand barrels or water filled are gating terminals that can be used to shield a narrow or wide obstruction. However, they are not designed to redirect vehicles for side impacts.

All of the W-beam guide rail terminals discussed in Section 12.9, except for the anchored backslope terminal, are gating terminals. That means simply that all of them, when struck at or near the nose at an angle of 15° or greater, will yield readily, allowing a vehicle to continue into the area immediately behind and beyond the terminal. Thus, for angle hits of 15° or higher at or near the first post, all W-beam terminals perform about the same and most impacting vehicles will travel behind and beyond the terminal.

W-beam guide rail terminals have also been classified as either tangent designs (installed parallel to the roadway edge) or flared designs (flared away from the roadway). Experience has shown, however, that even "tangent" terminals are best installed with a 0.3 m or 0.6 m (1 ft or 2 ft) offset from the line of barrier proper (over the entire terminal length) to minimize nuisance hits. Typical flared terminals generally require a 1.2 m (4 ft) offset from the barrier itself, although some designs have been successfully tested with lesser offsets. The actual offset distance of a terminal may have a significant effect on site grading requirements as discussed later in more detail. However, the most significant difference in terminal performance is whether or not a terminal is likely to slow an impacting vehicle appreciably in near end-on crashes.

Most gating terminals for W-beam guide rail have been designed and developed to dissipate significant amounts of the kinetic energy in a head-on crash and are considered to be **energy-absorbing designs**. In high-speed, head on impacts on the terminal nose, energy-absorbing terminals have demonstrated their ability to stop impacting vehicles safely in relatively short distances (usually 15 m (50 ft) or less depending on type of terminal). Some gating terminals for W-beam guide rail are classified as **non-energy absorbing designs** and will allow an unbraked vehicle to travel over 45 m (150 ft) behind and parallel to the guardrail installation or along the top of the barrier when struck head-on at high speeds.

The decision to use an energy-absorbing terminal versus a non-energy absorbing terminal should be based on the likelihood of a near end-on impact and the nature of the recovery area immediately behind and beyond the terminal. **If the barrier length of need was properly determined, it is unlikely that a vehicle will reach the primary shielded object after an end-on impact regardless of the terminal type selected. However, if the terrain beyond the terminal end and immediately behind the barrier is not safely traversable, an energy-absorbing terminal is recommended.**

C. Site Grading Requirements. Grading in the area of the terminal is an important consideration regardless of the specific terminal type used. The grading must be considered from three perspectives: ***advance grading***, ***adjacent grading*** and ***runout distance grading***. Proper grading in **advance** of the terminal is needed to be sure the vehicle is stable at the point of initial contact. Proper grading **adjacent** to the terminal is needed to be sure the vehicle remains stable while in physical contact with the terminal. Finally, proper ***runout distance grading*** immediately downstream and behind the terminal is needed to be sure the vehicle remains stable after it clears the terminal and comes to a stop. This runout distance, not to be confused with the runout length needed to calculate barrier length of need, is especially important for near end-on hits into non-energy absorbing terminals.

1. Advance Grading. ***Advance grading*** must be applied to the terrain over which a vehicle may travel before contact with a barrier terminal. For W-beam terminals, this area should be no steeper than 1V:10H to ensure that a vehicle is stable at the moment of impact and that its suspension is neither extended nor compressed. When grading platforms are built, they must be smoothly transitioned to existing sideslopes so that the entire roadside approach to the barrier remains traversable as well as the area immediately behind it. In many instances, it will be more cost-effective to extend the barrier itself so its terminal can be installed without the need for additional earthwork or to use a terminal that requires less flare.

2. Adjacent Grading. ***Adjacent grading*** refers to the area on which the terminal is installed and the area immediately behind it. Ideally, this area should be essentially flat so the terrain itself does not exacerbate vehicle roll, pitch or yaw upon impact with the terminal. For impacts into the side of a terminal where redirection is expected (from the third post back for current W-beam terminals), the terminal posts should have at least 0.6 m (2 ft) of soil support behind them. For near head-on impacts, a relatively flat area should extend 1.5 m (5 ft) behind the terminal nose in a direction away from the roadway so a motorist striking the terminal with the left front of a vehicle will not have reached a high roll angle prior to impact. These recommended dimensions are shown in Figures 8-2 and 8-3 in the AASHTO Roadside Design Guide. If a grading platform was constructed, the departure end of this platform must be gradually blended into the (usually) steeper sideslopes behind the barrier. From a practical standpoint, a recoverable slope of 1V:4H behind the terminal may be a practical compromise, and in some cases a traversable slope as steep as 1V:3H may be acceptable. While such grading should be possible on freeways and many other high-speed arterial highways, it may not be cost-effective on roadways with limited rights-of-way and reduced clear zones. In these locations, the area immediately behind the terminal should be at least similar in nature to the roadside immediately upstream from the terminal.

3. Runout Distance Grading. ***Runout distance grading*** refers to the area into which an impacting vehicle may travel after breaking through a gating terminal. The physical extent of the area needed will vary depending on vehicle size and impact speed, impact angle, driver reaction, terrain character, and terminal type.

While it is desirable to have a long recovery area available immediately behind the barrier, practical considerations will often dictate a much smaller area. As recommended in Section 8.3.3.3 of the AASHTO Roadside Design Guide, the minimum recovery area behind and beyond all W-beam terminals should be an area approximately 23 m (75 ft) long and 6 m (20 ft) wide. Note that if the roadside in advance of the terminal does not have a 6 m (20 ft) wide recovery area, it is not intended that additional clear zone be provided behind the terminal, but the recovery area should at least be consistent with that available elsewhere along the road. In many cases, it may not be practical to provide even a minimum runout area due to physical constraints such as restricted rights-of-way or environmental concerns.

D. Crashworthy End Treatments / Crash Cushions. Crashworthy end treatments/crash cushions acceptable for use in Pennsylvania are listed below by type for a particular application. They are categorized by type as follows:

- Type I - Anchored Backslope Terminal
- Type II - Energy Absorbing Terminals
- Type III - Non-Energy Absorbing Terminals
- Type IV - Gating Systems Used Where Two-Way Traffic Is Present
- Type V - Non-Gating Terminals Used Where Two-Way Traffic Is Present
- Type VI - Gating, Non-Redirective Crash Cushion Systems
- Miscellaneous Systems

Publication 408, *Specifications*, and special provisions, as well as Publication 35, *Approved Construction Materials* (Bulletin 15), indicate a list of approved devices as follows:

- Publication 408, *Specifications*, Section 619 - Permanent Impact Attenuating Devices

- Publication 408, *Specifications*, Section 696 - Temporary Impact Attenuating Devices (This work is the furnishing, placing and removing of temporary impact attenuating devices for maintenance and protection of traffic during construction.)

- Publication 408, *Specifications*, Section 697 - Reset Temporary Impact Attenuating Devices (This work is the resetting of a temporary impact attenuating device from one construction area to another within the project limits.)

Table 12.10 shows the approved impact attenuating devices, Type I through Type VI. As listed in Publication 35, *Approved Construction Materials* (Bulletin 15), some devices may be used as either permanent or temporary devices and they are as follows: Type IV, Type V - Standard, and Type VI.

Conversely, the Type V Low Maintenance/Self Restoring systems **are only to be used in permanent locations** where there are high traffic volumes and there is high potential for being impacted. Although the Type V-Low Maintenance/Self Restoring systems are designed to accept a second hit without repair (in most cases), the Department does not have enough experience with a second hit or with the service life capabilities of these systems. Type V-Low Maintenance/Self Restoring systems could be used in a long-term work zone with unique setting conditions, but they cost twice as much as a Type V-Standard device and are not considered the best choice.

A proprietary system may be justified based on unique and special highway conditions. Prior approval must be acquired to use proprietary items. Refer to Publication 51, *Bid Package Preparation and Policies Manual*, for guidance.

1. Type I - Anchored Backslope Terminal.

a. Description. This terminal is constructed by attaching the W-beam guide rail to a concrete anchor or a post anchor buried into the backslope while retaining its full height relative to the edge of traveled way.

A W-beam guide rail that can be terminated in a backslope is a preferred end treatment because it eliminates any possibility of a true end-on hit. However, an effective installation must satisfy several design criteria.

First and foremost of these must be the steepness of the slope into which the W-beam is anchored. The ideal slope is one that is nearly vertical, in which case the slope in effect becomes an extension of the barrier and a motorist cannot physically get behind the terminal. In such a case, the barrier can be brought into the backslope as soon as practical using the maximum flare rate appropriate for the design speed of the highway.

If the backslope is significantly flatter than 1V:1H, a buried-in-backslope design behaves essentially like a turned-down terminal and can be overridden. In these instances, the full design length of need of the barrier must be provided and there should be a minimum distance behind the rail that is 23 m (75 ft) long and 6 m (20 ft) wide that is both free of fixed objects and reasonably traversable, just as with all other W-beam terminals. Note that if the roadside in advance of the terminal does not have a 6 m (20 ft) wide recovery area, it is not intended that additional clear zone be provided behind the terminal, but the recovery area should at least be consistent with that available elsewhere along the road. **For the anchored backslope terminal, the length of need begins at the point where the W-beam remains at full height in relation to the roadway shoulder, usually at the point where the barrier crosses the ditch line. If the backslope continues under and in front of the flared W-beam, the rail height is effectively reduced and the slope forms a ramp that could allow a vehicle to override the rail instead of being redirected.**

The anchored backslope terminal has been successfully tested over 1V:10H, 1V:6H, and 1V:4H foreslopes. In each case, the height of the W-beam rail was held constant in relation to the roadway shoulder elevation until the rail crossed the ditch bottom. When the distance from the ground to the bottom of the W-beam exceeds approximately 450 mm (18 in), a W-beam rubbing rail must be added to minimize wheel snagging on the support posts. On high-speed routes with a design speed above 70 km/h (45 mph), the W-beam height, even across a 1V:10H slope, should match the roadway grade.

b. Application. The most desirable method to terminate guide rail is to bury the end in a backslope where it cannot be hit end on. This system should also be used even when the barrier system's Length of Need (LON) would normally end downstream of a backslope if the backslope is within 60 m (200 ft) and there is not a large available runout area (60 m × 15 m (200 ft × 50 ft)) beyond the terminal. Standard details for the backslope end treatment are shown in Publication 72M, *Roadway Construction Standards*, Drawing RC-54M.

2. Type II - Energy Absorbing Terminals.

a. Description. Energy absorbing terminals may be categorized as flared or tangent. Flared terminals are preferred because they are installed 1.2 m (4 ft) away from the edge of shoulder at the approach end. Both types require level (1V:10H) terrain in front of the system and 1.0 m (3 ft) behind since they are gating systems. Tangent terminals are used when the area required for flared terminals is not available and they are installed parallel to the shoulder with 0.3 m (1 ft) to 0.6 m (2 ft) offset at the nose. They will redirect vehicles for side angle impacts beyond the third post.

Energy absorbing terminals have been designed and developed to dissipate significant amounts of the kinetic energy in a head-on crash. In high-speed, head on impacts on the terminal nose, energy-absorbing terminals have demonstrated their ability to stop impacting vehicles safely in relatively short distances (usually 15 m (50 ft) or less depending on type of terminal). In contrast, non-energy absorbing terminals will allow an unbraked vehicle to travel over 45 m (150 ft) behind and parallel to the guide rail installation or along the top of the barrier when struck head-on at high speeds.

If the barrier length of need was properly determined, it is unlikely that a vehicle will reach the primary shielded object after an end-on impact regardless of the terminal type selected. However, if the terrain beyond the terminal end and immediately behind the barrier is not safely traversable, an energy-absorbing terminal is recommended.

b. Application. These end terminals are used on the approach end of single runs of Strong Post (Type 2-S) W-beam guide rail on either side of the roadway. They may also be used to terminate Weak Post (Type 2-W) guide rail with a 15.2 m (50 ft) transition of Strong Post guide rail between the Weak Post system and the terminal. See Section 12.4.D for appropriate length of need determination and Publication 72M, *Roadway Construction Standards*, Drawing RC-54M for site grading details.

c. Approved Systems. Type II approved energy absorbing terminals include:

Energy Absorbing Terminals (Flared):

- Flared Energy Absorbing Terminal (FLEAT-350)
- Flared Energy Absorbing Terminal (FLEAT-SP)
- X-Tension End Terminal (X-Tension)

Energy Absorbing Terminals (Tangent):

- Extruded Terminal (ET-2000)
- Sequentially Kinking Terminal (SKT-350)
- Box Beam Bursting Energy Absorbing Terminal - Single-Sided Crash Cushion (BEAT-SSCC)
- Sequentially Kinking Terminal (SKT-SP)
- X-Tension End Terminal (X-Tension)

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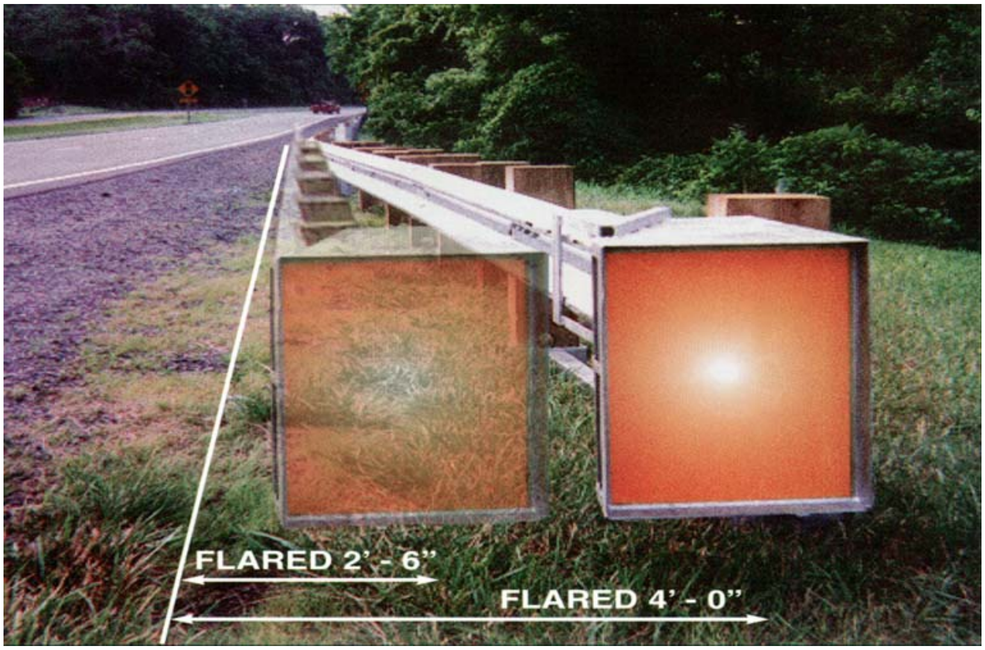
(1) FLEAT-350. The FLEAT-350 (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-46) is a flared energy absorbing terminal system designed to terminate W-beam guide rail for unidirectional traffic. When impacted, the extruder head is driven along the rail, separating several weak posts from the rail. As the extruder head slides along the rail, it forces the rail through an opening that flattens and kinks the corrugations. The kinetic energy of an impacting vehicle is primarily absorbed in the flattening and bending of the rail.

The FLEAT-350 is 11.43 m (37.5 ft) long and is to be installed with a 1.2 m (4 ft) straight flare. The FLEAT was also tested with a 0.75 m (2.5 ft) flare and may be installed between 0.7 m (2.25 ft) and 1.2 m (4 ft) flare. However, the standard is 1.2 m (4 ft) with exceptions. The FLEAT-350 is a proprietary system and should be acquired on the basis of competitive bidding with the FLEAT-SP and X-Tension.



(2) FLEAT-SP. The FLEAT-SP (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-88B) is also a flared energy absorbing terminal system designed to terminate W-beam guide rail for unidirectional traffic. The FLEAT-SP is a two-post system and differs from the FLEAT-350 in the following ways:

- Post #1 has an enhanced upper and lower hinge.
- Post #2 has a hinged post with no ground strut.
- Post #3 and beyond may use generic standard W150 × 13.5 (W6 × 9) guide rail posts and standard W-beam rail sections.

When impacted, the vehicle extruder head is driven along the rail, separating several weak posts from the rail. As the extruder head slides along the rail, it forces the rail through an opening that flattens and kinks the corrugations. The kinetic energy of an impacting vehicle is primarily absorbed in the flattening and bending of the rail.

The FLEAT-SP is 11.43 m (37.5 ft) long and is to be installed with a 1.2 m (4 ft) straight flare. The FLEAT was also tested with a 0.75 m (2.5 ft) flare and may be installed between 0.7 m (2.25 ft) and 1.2 m (4 ft) flare. However, the standard is 1.2 m (4 ft) with exceptions. The FLEAT-SP is a proprietary system and should be acquired on the basis of competitive bidding with the FLEAT-350 and X-Tension.

(3) X-Tension. The X-Tension (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-102) is a flared energy absorbing terminal system and a tangent energy absorbing terminal system designed to terminate W-beam guide rail for unidirectional traffic. The X-Tension is capable of redirecting vehicles impacting from the length of need, which starts at the first post.

In all end on impacts, varying amounts of energy are dissipated depending on the length of time the vehicle remains in contact with the impact head. During end on impacts the head, rail one and the slider, telescope over rail two until rail two comes to rest in the back of the impact head. At this point, the V notch bolts joining rail one and two are sheared allowing the entire rail one, head, slider and rail two assembly to slide over rail three. As the head is pushed down the two cables, the cables are pulled through the brake bar in a torturous path, which dissipates energy.

The X-Tension complies with NCHRP 350 in the following ways:

- The tangent and flared configurations using either wood (CRT) or steel line posts (first two posts crimped near the ground line).

- The tangent and flared configurations use a small "kit" of key components that are used in conjunction with standard W-beam guide rail, wood or composite block-outs, steel line posts or CRT wood posts and standard guide rail component hardware to make up any of the noted configurations.

- The amount of offset for flared applications can be between the tangent position (no offset) and the fully flared (1.2 m (4 ft) offset) as tested.

- Recognition of the redirective capability of the system from the first post. Therefore, the system qualifies as a "Redirective, Non-Gating" Terminal under the definitions in NCHRP Report 350.

When impacted, the vehicle extruder head is driven along the rail, separating several weak posts from the rail. As the extruder head slides along the rail, it forces the rail through an opening that flattens and kinks the corrugations. The kinetic energy of an impacting vehicle is primarily absorbed in the flattening and bending of the rail.

The X-Tension is 13.02 m (42.71 ft) long. The X-Tension is a proprietary system and should be acquired on the basis of competitive bidding with flared systems (FLEAT-SP, FLEAT-350) or with tangent systems (ET-2000, SKT-350, BEAT-SSCC, SKT-SP).

Flared Application:

Tangent Application:

(4) ET-2000. The ET-2000 (NCHRP approved, TL-3, FHWA Acceptance Letter CC-12D) is a tangent energy absorbing terminal system. The ET-2000 is a proprietary system designed to be used on the approach of a run of strong post W-beam guide rail. When impacted, the shoe is driven along the rail, separating several weak posts from the rail. As the shoe passes along the rail, it forces the rail through an opening that flattens the corrugations. The kinetic energy of an impacting vehicle is primarily absorbed in the flattening and bending of the rail. The ET-2000 can also be attached to Weak Post guide rail with a 15.2 m (50 ft) transition of strong post guide rail between the terminal and the weak post system. This system is considered gating up to post number 3 where redirection begins. The ET-2000 is 15.2 m (50 ft) long and can be installed parallel to the roadway or with a straight taper of 25:1 or 50:1 to move the nose 0.3 m or 0.6 m (1 ft or 2 ft) away from the edge of the shoulder.

Since its original approval based on NCHRP 350 Guidelines, the manufacturer has made three modifications:

- Designed a new extruder head, "ET-PLUS", that is almost 45 kg (100 lb) lighter than the original ET-2000 head and differs from the original head in the size and shape of its faceplate.

- Introduced an optional hinged breakaway (HBA) steel post design. Two different HBA posts are used in the new design, both of which consist of two sections of W150 × 13 (W6 × 9) steel beams bolted together at splice plates welded to the flanges of each post section near the ground line. The first two posts consist of 740 mm (29 in) long top posts and 1780 mm (70 in) long bottom posts. These posts are connected to each other with a 76 mm × 76 mm × 6 mm (3 in × 3 in × 1/4 in) steel ground strut and, with the addition of a steel cable, from the anchorage for the barrier system. The remaining HBA posts are similar to the first two, but the top posts are 665 mm long (26 1/4 in) long and the bottom posts are 1070 mm (42 1/8 in) long.

- Is accepted for use having a modified post design with either the ET or ET-Plus W-beam guide rail terminals. Previous acceptances have allowed the use of timber CRT posts, Steel Hinged Breakaway Posts (HBA) or W200 × 15 (W8 × 10) Steel Yielding Terminal Posts (SYTP) in post positions 2 and beyond.

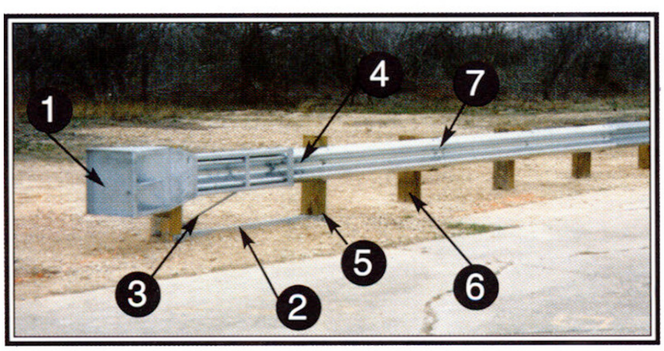
  The modified post design substituted a standard 1830 mm (6 ft) long steel line post (W150 × 13 (W6 × 8.5/9)) with one 13 mm (0.5 in) diameter hole in each flange (4 total) at the ground line for the previously approved W200 × 15 (W8 × 10) Steel Yielding Terminal Post (SYTP) with 21 mm (0.8125 in) diameter holes in each flange. The holes are centered 725 mm (28.5 in) from the top of the post and approximately 20 mm (0.75 in) in from the outside edge of the flanges.

Based on the above, the ET-Plus can be used in lieu of the original ET-2000 extruder head on any ET-2000 systems previously accepted and the steel HBA posts may be substituted for any or all of the eight breakaway wood posts.

Since the ET-2000 is a proprietary system, it should be acquired on the basis of competitive bidding with other equally suitable tangent energy absorbing terminal systems such as the SKT-350, the BEAT-SSCC, the SKT-SP, and the X-Tension.

(5) SKT-350. The SKT-350 (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-40) is a tangent energy absorbing terminal system. The SKT-350 is designed to be used on the approach of a run of strong post W-beam guide rail. On impact, the impact head is driven along the rail, separating several weak posts from the rail. As the impact head slides along the rail, it feeds the rail through an opening that sequentially kinks the corrugations. The kinetic energy of the impacting vehicle is primarily absorbed through the kinking of the rail. The SKT-350 is 15.2 m (50 ft) long and can be installed parallel to the roadway or with a straight taper of 25:1 or 50:1 to move the nose 0.3 m or 0.6 m (1 ft or 2 ft) away from the edge of the shoulder. The SKT-350 is capable of redirecting 820 kg to 2000 kg (1800 lb to 4400 lb) vehicles when impacting the system at an angle beyond the third post.

The SKT-350 is a proprietary system and should be acquired on the basis of competitive bidding with other equally suitable tangent energy absorbing terminal systems such as the ET-2000, the BEAT-SSCC, the SKT-SP, and the X-Tension.



1. Impact Head
2. Ground Strut
3. Cable Anchor
4. Cable Anchor Bracket
5. Foundation Tub Sleeve
6. Timber Post & Block
7. W-Beam Rail

(6) BEAT-SSCC. The BEAT-SSCC (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-69B) is a tangent energy absorbing terminal system. The BEAT-SSCC attaches directly to rigid barrier, bridge abutments, and bridge rails and serves as both a transition and an end treatment. The BEAT-SSCC comes available with surface mounted posts or ground mounted posts; the ground mounted design does not need a concrete pad to be built.

The BEAT-SSCC is comprised of the following main components: (1) an impact head assembly; (2) a Stage 1 energy absorber (152 mm × 152 mm × 3.2 mm (6 in × 6 in × 1/8 in) box beam rail); (3) a Stage 2 energy absorber (152 mm × 152 mm × 4.8 mm (6 in × 6 in × 3/8 in) box beam rail); (4) eight breakaway steel posts; and (5) a fabricated end section for transitioning the BEAT-SSCC to a F-shaped concrete barrier.

The shortest length of the BEAT-SSCC is 8.5 m (28 ft). For sites needing additional length of need, the BEAT-SSCC is available in lengths of 9.8 m (32 ft), 11.0 m (36 ft), 12.2 m (40 ft) and 13.4 m (44 ft).

The BEAT-SSCC is a proprietary system and should be acquired on the basis of competitive bidding with other equally suitable tangent energy absorbing terminal systems such as the ET-2000, the SKT-350, the SKT-SP, and the X-Tension.

(7) SKT-SP. The SKT-SP (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-61A) is a tangent energy absorbing terminal system. The SKT-SP is designed to be used on the approach of a run of strong post W-beam guide rail. The SKT-SP is a two-post system and differs from the SKT-350 in the following ways:

- Post #1 has an enhanced upper and lower hinge.
- Post #2 has a hinged post with no ground strut.
- Post #3 and beyond may use generic standard W150 × 13.5 (W6 × 9) guide rail posts and standard W-beam rail sections.

On impact, the impact head is driven along the rail, separating several weak posts from the rail. As the impact head slides along the rail, it feeds the rail through an opening that sequentially kinks the corrugations. The kinetic energy of the impacting vehicle is primarily absorbed through the kinking of the rail. The SKT-SP is 11.43 m (37.5 ft) long and can be installed parallel to the roadway or with a straight taper of 25:1 or 50:1 to move the nose 0.3 m or 0.6 m (1 ft or 2 ft) away from the edge of the shoulder. The SKT-SP is capable of redirecting 820 kg to 2000 kg (1800 lb to 4400 lb) vehicles when impacting the system at an angle beyond the third post.

The SKT-SP is a proprietary system and should be acquired on the basis of competitive bidding with other equally suitable tangent energy absorbing terminal systems such as the ET-2000, the BEAT-SSCC, and the X-Tension.

3. Type III - Non-Energy Absorbing Terminals.

a. Description. Non-energy absorbing terminals will allow an unbraked vehicle to travel over 45 m (150 ft) behind and parallel to the guide rail installation or along the top of the barrier when struck head-on at high speeds.

b. Application. These end terminals are used on the approach end of single runs of Strong Post (Type 2-S) W-beam guide rail on either side of the roadway. They can also be used to terminate Weak Post (Type 2-W) guide rail with a 15.2 m (50 ft) transition of Strong Post guide rail between the terminals and the Weak Post system. See Section 12.4.D for appropriate length of need determination and RC-54M for site grading details.

c. Approved Systems. The Type III approved flared non-energy absorbing terminal is:

- Slotted Rail Terminal (SRT-350)

(1) SRT-350. The SRT-350 (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-51) is a flared non-energy absorbing terminal system. The SRT-350 is a proprietary gating system intended to be used as a guide rail end treatment. The design of the SRT-350 consists of an 11.4 m (37.5 ft) straight flare with the first post offset 1.2 m (4 ft) from the downstream guide rail. The two anchor posts are steel Hinged Breakaway (HBA) posts while the remaining posts are standard 1830 mm (6 ft) long CRT posts. The HBA posts include the use of 102 mm × 152 mm × 5 mm (4 in × 6 in × 3/16 in) soil tubes in lieu of W150 × 13 (W6 × 8.5) steel stub posts, and two parallel ground struts between post No. 1 and post No. 2. The rail to the post attachment hole at post No. 1 is slotted to the end of the beam element. A total of five CRT posts and two HBA posts are used.

The SRT may be used to terminate Weak Post guide rail with a 15.2 m (50 ft) section of Strong Post guide rail between the Weak Post System and the end treatment.

The SRT-350 is a unidirectional end treatment. Since the SRT-350 is proprietary, it should be acquired on the basis of competitive bidding if other equally suitable flared non-energy absorbing terminal systems become available.

4. Type IV - Gating Systems Used Where Two-Way Traffic Is Present

a. Description. These systems use a variety of methods to dissipate the kinetic energy of an impacting vehicle in head-on crashes, arresting the vehicle in a controlled manner such that the risk of serious injuries to the occupants is minimized.

b. Application. These systems can be used to terminate W-beam guide rail, concrete median barrier, and double-faced W-beam median barrier. They are typically used in roadway medians that are 3.0 m (10 ft) wide or more, but also have application in shoulder and gore areas and on point hazards such as bridge piers. Redirection of the impacted vehicle begins at different points along each of the devices, but impacting vehicles will pass through the device on side angle impacts at the approach end. Approved terminal to barrier connections as required are incidental to each system. These systems can be installed in permanent locations or temporary in work zones.

c. Approved Systems. Type IV approved terminals include:

- Crash-Cushion Attenuating Terminal (CAT-350)
- Brakemaster 350
- Advanced Dynamic Impact Extension Module (ADIEM)
- Flared Energy Absorbing Terminal - Median Terminal (FLEAT-MT)

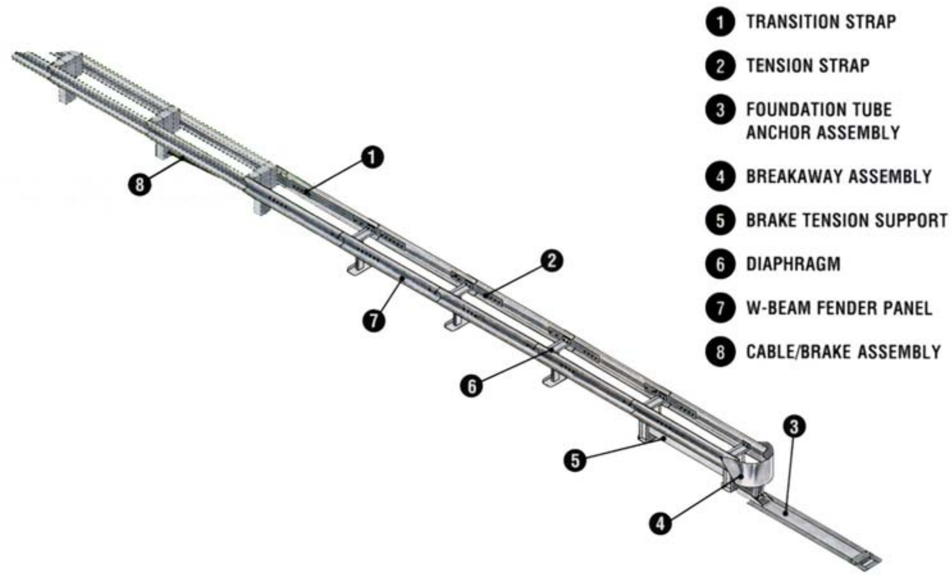
(1) Crash Cushion/Attenuating Terminal (CAT-350). The CAT-350 is a proprietary system (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-33) and is both a bidirectional and a unidirectional energy absorbing crash cushion and end treatment. The system can be used to protect motorists from barriers in the median or on the shoulder, or to shield fixed objects. The CAT-350 is considered gating, however, redirection begins at post number 4 from the approach end. The CAT-350 should not be used in narrow medians less than 3.0 m (10 ft).

The CAT-350 is a cable-anchored, three-stage system utilizing a soft nose piece, slotted 2.75 mm (12 gage) and 3.51 mm (10 gage) W-beam rails and breakaway wooden posts. The CAT-350 functions by first folding up the soft nose which creates a buffer. The rails are then activated and begin to translate by shearing out tabs of steel between adjacent slots in the guide rail until the vehicle has been decelerated. Since the CAT-350 is a proprietary system, it should be acquired on the basis of competitive bidding with other equally suitable systems such as the Brakemaster 350.

A tail-end section is required to attach the CAT-350 to the existing barrier or fixed object and it is incidental to the CAT-350 system.

(2) Brakemaster 350. The Brakemaster 350 (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-41) is a proprietary gating system that offers an alternative for low frequency impact applications. The unit is designed to protect a variety of narrow fixed objects in low frequency impact areas in wide medians such as double-sided guide rail ends, bridge pillars, and lighting or sign supports. It may also be used to terminate W-beam guide rail on the shoulders. The Brakemaster 350 should not be used in narrow medians less than 3.0 m (10 ft).

The Brakemaster 350 consists of a framework of W-beam steel guide rail panels which move rearward when hit head-on. A special braking mechanism provides frictional resistance, which brings an impacting vehicle to a complete stop. A tail end section is required to attach the Brakemaster 350 to the barrier or fixed objects and it is incidental to the Brakemaster 350. Since the Brakemaster 350 is a proprietary system, it should be acquired on the basis of competitive bidding with other equally suitable systems such as the CAT-350.



(3) Advanced Dynamic Impact Extension Module (ADIEM). The ADIEM (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-38) is a proprietary end treatment and crash cushion for portable and permanent concrete barriers, bridge parapet rail, etc. The ADIEM attaches directly to concrete barrier and it is installed with pins on a smooth surface in the same plane as the barrier on soil, asphalt or concrete. For this system, redirection begins 4.2 m (14 ft) from the approach end. For temporary or construction zone applications, the system may be relocated as the work zone changes, and from project to project.

The energy absorption elements of the ADIEM are lightly reinforced, ultra low strength perlite concrete modules. The ADIEM dissipates the energy of an impact as the light weight modules are crushed. Clean up and restoration of the system to full service requires replacement of the damaged modules and minor sweep up of debris.

(4) Flared Energy Absorbing Terminal - Median Terminal (FLEAT-MT). The FLEAT-MT (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-46D) is a proprietary end treatment for use in wide medians. The components of the original roadside FLEAT are combined with a couple of small additional components to create the FLEAT-MT. The FLEAT-MT attaches directly to median double-sided W-beam guide rail and can be used with wood or steel breakaway posts.

Two impact heads are required. One of the impact heads is at the fourth post in from the end of the barrier and fits over the backside W-beam rail element. The other impact head fits over the end of the traffic-side rail element ahead of the first and is offset from the face of the median barrier proper in a straight flare.

The front single-sided section of the FLEAT-MT is similar to the FLEAT-350 and functions the same. Depending on the severity of the impact, the vehicle may be stopped before reaching the second impact head at the fourth post. If the end-on impact is severe enough, the vehicle will activate the second impact head. This impact head will then begin to slide down the rail sequentially kinking the backside rail.

5. Type V - Non-Gating Terminals Used Where Two-Way Traffic Is Present.

a. Description. These systems use a variety of methods to dissipate the kinetic energy of an impacting vehicle in head-on crashes, arresting the vehicle in a controlled manner such that the risk of serious injuries to the occupants is minimized. The redirection point of these devices begins at the approach end of the device, i.e., they are non-gating.

b. Application. These systems can be used to terminate concrete median barrier, double-faced W-beam median barrier, and other obstructions. They are typically used in narrow or wide roadway medians, but also have application in shoulder and gore areas and on point hazards such as bridge piers and other wide obstructions. Approved terminal to barrier connections as required for reverse direction impacts, are incidental to each system. These systems can be installed in permanent locations or temporary in work zones. In the PS&E package, include a special provision to indicate what width "W" is to be protected by the Type V impact attenuating device. For maximum values for "W," refer to Table 12.10 in the column for "ADDITIONAL INFO".

c. Approved Systems. Type V approved terminals include:

- Standard
  - QuadGuard
  - TRACC
  - TAU-II
  - QUEST

- Low Maintenance/Self Restoring
  - QuadGuard Elite
  - REACT 350
  - REACT 350 (60")
  - SCI100GM and SCI70GM
  - QuadGuard LMC

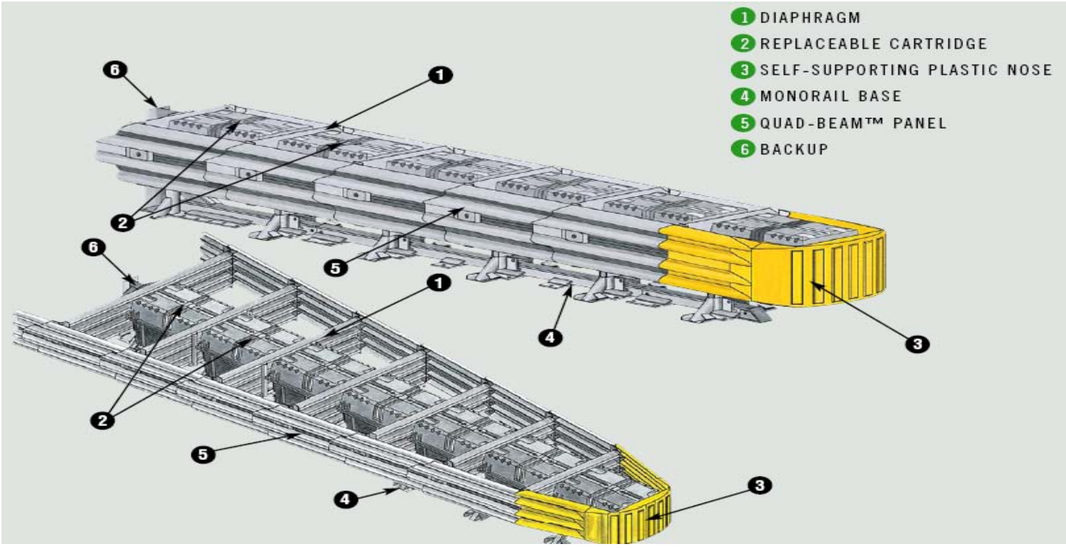
Type V Low Maintenance/Self Restoring crash cushions either suffer very little, if any damage, upon impact and are easily pulled back into their full operating condition, or they partially rebound after an impact and may only need an inspection to ensure that no parts have been damaged, misaligned, etc. Although some attenuators can still function and save lives after being struck once, no device is completely maintenance free.

(1) QuadGuard. The QuadGuard (NCHRP 350 approved, TL-2 and TL-3) is a proprietary system and can be used for unidirectional or bidirectional traffic. The QuadGuard is a nongating system and is intended for use to terminate roadside barrier of various types and other obstructions up to 2.3 m (90 in) wide. When used for bidirectional traffic, FHWA approved transitions are required in the event of a reverse direction impact at the rear of the system.

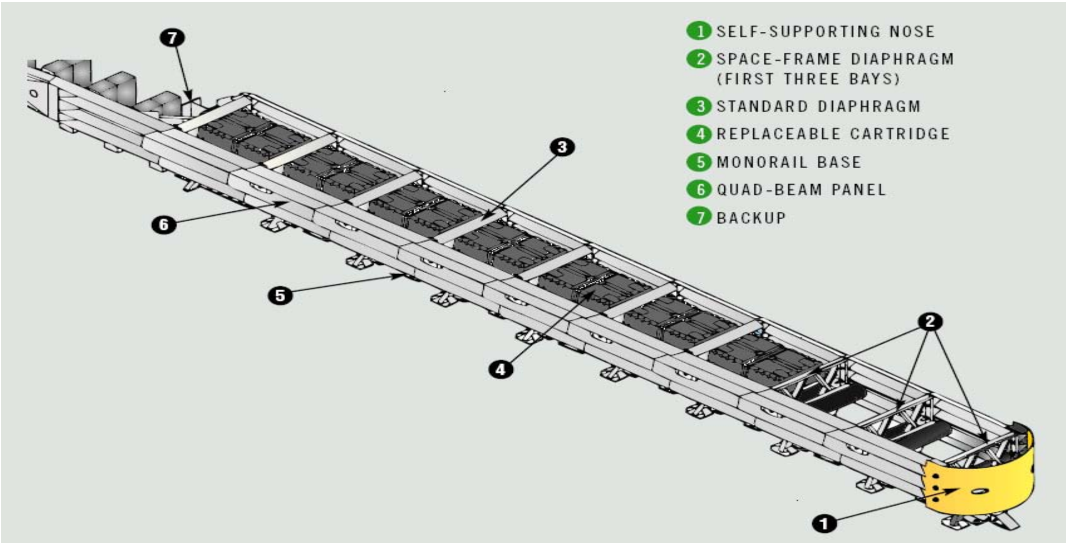
The Standard Quadguard system (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-35) uses crushable energy absorbing cartridges surrounded by diaphragms. The Quadguard HS (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-35E) is also a proprietary system for design speeds up to 113 km/h (70 mph). The Quadguard HS features space-frame diaphragms that are used in the first three bays of the system, which do not contain a cartridge. A 3-bay QuadGuard system (NCHRP 350 approved, TL-2, FHWA Acceptance Letter CC-35C) is also available. If any of these QuadGuard systems is impacted and the cartridges are damaged, they have to be replaced.

Since the QuadGuard is proprietary, it should be acquired on the basis of competitive bidding with other equally suitable systems such as the TRACC, the TAU-II and the QUEST.

QuadGuard:



QuadGuard HS:



(2) TRACC. The TRACC system (NCHRP 350 approved, TL-2 and TL-3, FHWA Acceptance Letter CC-54) can be used for unidirectional or bidirectional traffic. The TRACC is a redirective, nongating system and is intended for use to terminate median barrier. When used for bidirectional traffic, an FHWA approved transition is required in the event of a reverse direction impact at the rear of the system and is incidental to the TRACC system.

The TRACC can be installed on a 150 mm (6 in) thick reinforced concrete base and anchored with twenty-seven 190 mm (7.5 in) long steel anchor studs 16 mm (0.63 in) in diameter. The TRACC can also be used as a temporary crash cushion resting on 200 mm (8 in) of asphalt (or 150 mm (6 in) of asphalt over 150 mm (6 in) of compacted subbase) if anchored with twenty-seven 460 mm (18 in) long Grade 5 threaded studs set in drilled holes using a polyester resin meeting ACI 349 requirements.

Since its original approval based on the NCHRP 350 guidelines, the manufacturer has modified its design into three other products. The first product, SHORTRACC (NCHRP 350 approved, TL-2, FHWA Acceptance Letter CC-54A), is similar to the TL-3 TRACC, with the second and third stages of the TL-3 TRACC shortened for the TL-2 design. The second product, WIDETRACC (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-54D), is available in varying lengths, widths, and test levels. The WIDETRACC can be custom designed for any appropriate wide application. The third product, FASTRACC (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-54H), is longer than the TL-3 TRACC because of the addition of a set of standard two-bay side panels on each side of the system supported by two additional sliding frames which ride along a lengthened base assembly.

The TRACC is a proprietary system and, as such, must be purchased or obtained through competitive bidding with equally suitable alternate systems such as the standard QuadGuard, the TAU-II and the QUEST.

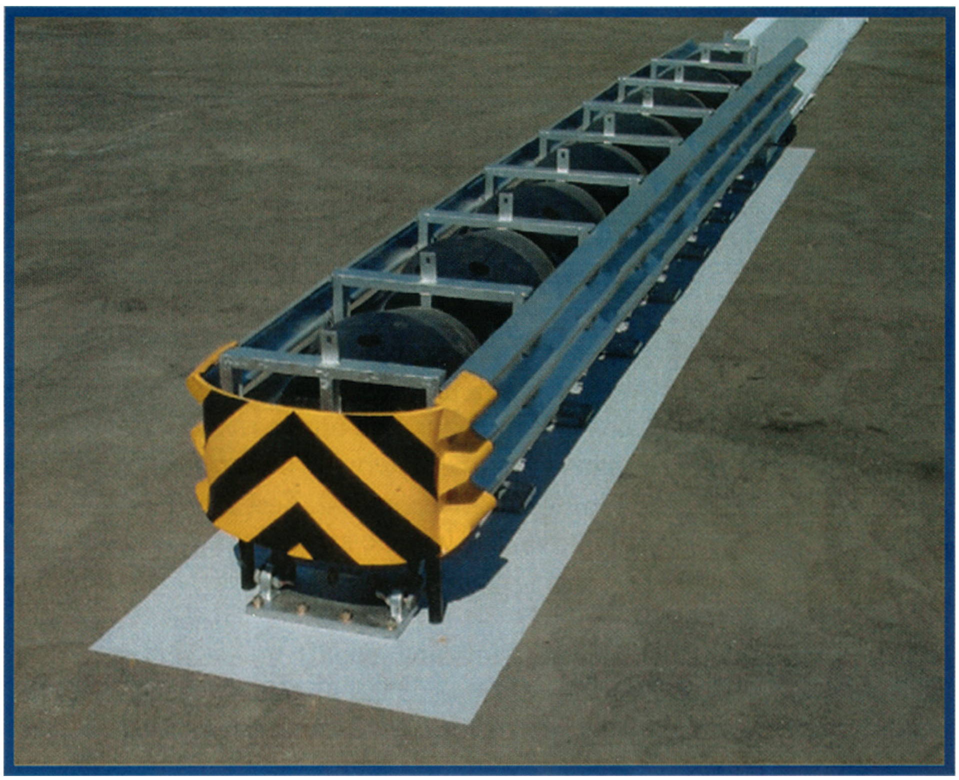

WIDETRACC™

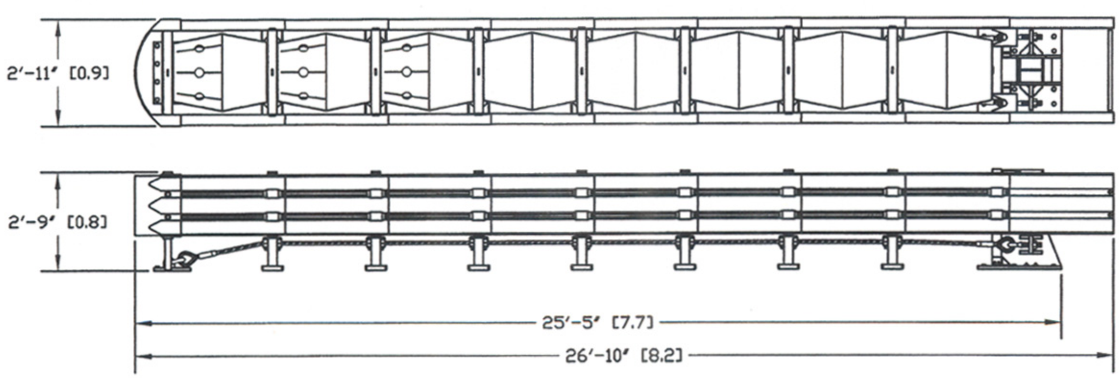

FASTRACC™

(3) TAU-II. The TAU-II (NCHRP 350 Approved, TL-2 and TL-3, FHWA Acceptance Letter CC-75) is a redirective, non-gating crash cushion system for edge of road and narrow median applications. The TAU-II is designed for attachment to permanent or portable concrete barrier.

An eight-bay system (approximately 8 m (26 ft) in length) met NCHRP 350's requirements for Test Level 3 (TL-3). A four-bay system (approximately 4.3 m (14 ft) in length) met NCHRP 350's requirements for Test Level 2 (TL-2). Both systems of TAU-II consist of galvanized steel elements in accordance with ASTM standards and plastic components made of high molecular weight polyethylene.

The TAU-II is a proprietary system and, as such, must be purchased or obtained through competitive bidding with equally suitable alternate systems such as the standard QuadGuard, the TRACC and the QUEST.





TAU-II™ Redirective, Non-Gating Crash Cushion
(Plan and Elevation Views—8 Bay (100 km/h) System

(4) QUEST. The QUEST (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-87) is a proprietary system and can be used for unidirectional or bidirectional traffic. The QUEST is a nongating system and is intended for use to terminate concrete median barrier or W-beam guide rail. When used for bidirectional traffic, FHWA approved transitions are required in the event of a reverse direction impact at the rear of the system.

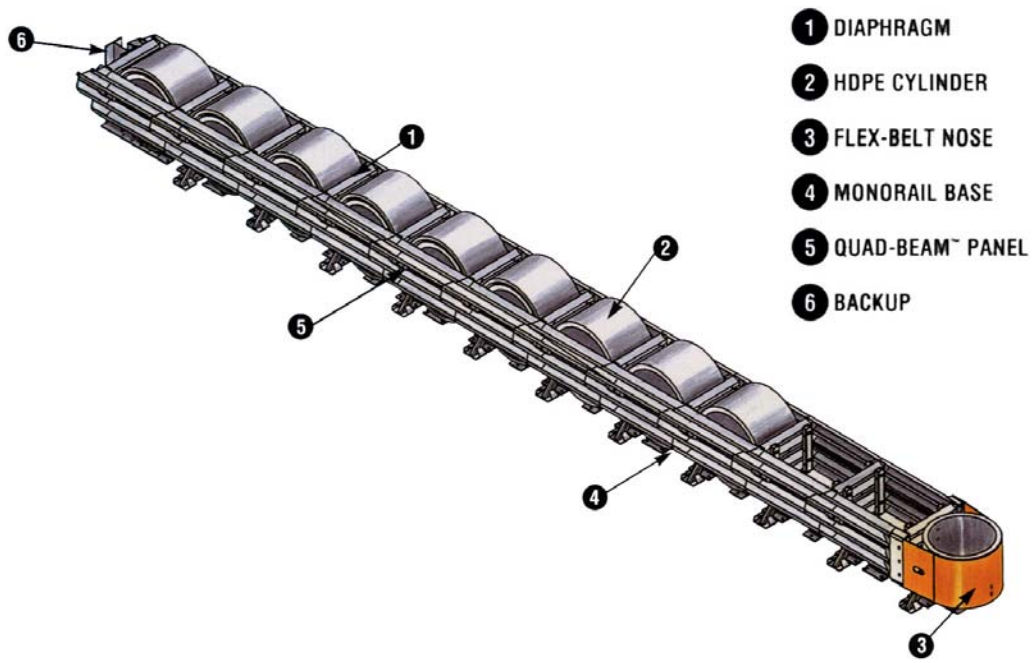
The main components of the QUEST include a ground-anchored backup assembly, two ground-anchored front anchors, two front rails, two rear rails, nose, trigger assembly, sled, diaphragm, bridge and panel assemblies. All components are galvanized to resist corrosion in accordance with ASTM standards. The series of W-beam panels are supported by the diaphragms with a trigger mechanism at the nose which, when hit, releases a "front assembly" to absorb the energy of impact. The system can be preassembled and moved to the installation site or can be assembled on-site.

The QUEST is a proprietary system and, as such, must be purchased or obtained through competitive bidding with equally suitable alternate systems such as the standard QuadGuard and the TRACC.

(5) QuadGuard Elite. The QuadGuard Elite (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-57) is a proprietary system and can be used for unidirectional or bidirectional traffic. The QuadGuard Elite is a nongating system and is intended for use to terminate roadside barrier of various types and other obstructions up to 2.3 m (90 in) wide. When used for bidirectional traffic, a FHWA approved transition is required in the event of a reverse direction impact at the rear of the system and is incidental to the QuadGuard Elite.

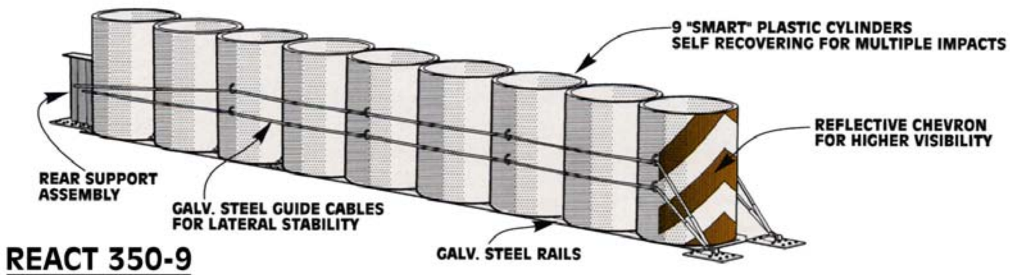
The QuadGuard Elite is a low maintenance/self restoring crash cushion that uses self-restoring high density plastic cylinders in place of crushable cartridges used in the standard QuadGuard. However, many of the components are identical to those used in the standard or LMC systems.

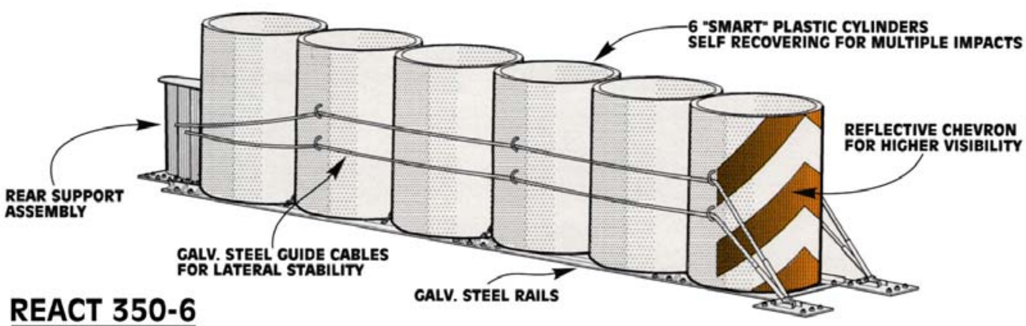
The QuadGuard Elite is a proprietary system and, as such, must be purchased or obtained through competitive bidding with equally suitable alternate systems such as the REACT 350 and the SCI100GM.

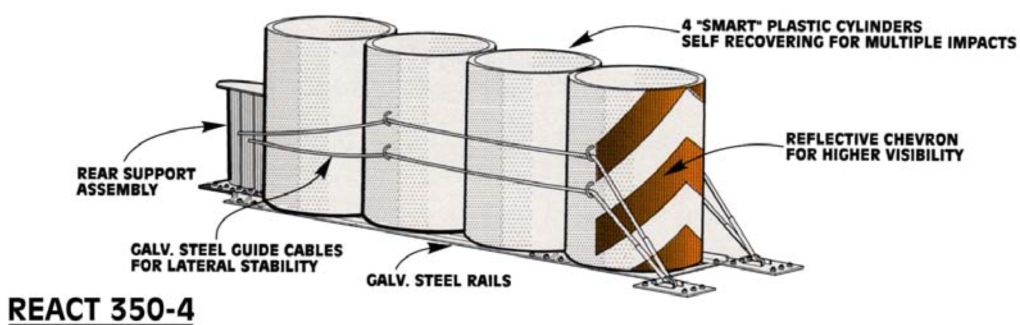


(6) REACT 350. The REACT 350 (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-26B) is a proprietary, non-gating crash cushion designed to terminate concrete median barrier and other narrow fixed objects from 0.9 m (3 ft) to 1.5 m (5 ft) wide. This system is designed in three different performance levels: REACT 350-9, REACT 350-6 and REACT 350-4. Each level corresponds to a different test speed. The REACT 350 is self restoring, at least to 90% according to the manufacturer.

The REACT 350 is composed of high molecular weight and high density polyethylene cylinders of varying wall thickness. Each cylinder is 910 mm (36 in) in diameter and 1220 mm (48 in) high. Two 25.4 mm (1 in) cables are located on each side of the attenuator to provide redirection in side impacts. These cables are connected to anchor plates at the front of the REACT 350 and to a backup assembly at the rear of the unit. The REACT 350 unit rests on a steel support structure and is stiffened laterally at the back of three chain assemblies attached to rods in the support structure on each side and to steel plates located between cylinders. When used for bidirectional traffic, FHWA approved transitions are required in the event of a reverse direction impact at the rear of the system.





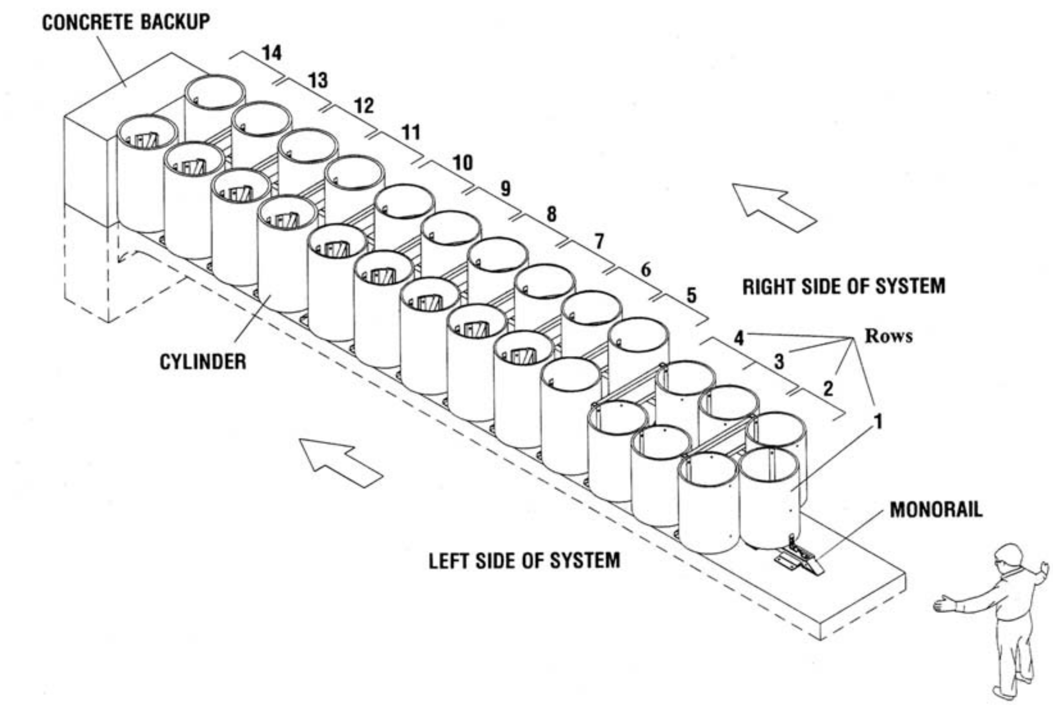


(7) REACT 350 (60"). The REACT 350 (60") (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-73) is a redirective, non-gating, low maintenance/self restoring crash cushion. This system is capable of shielding hazards up to 1.5 m (5 ft) wide.

The REACT 350 (60") consists of 27 cylinders in 14 rows attached to a monorail via diaphragms. After a design impact as described in NCHRP 350, the system has the ability to recover a major portion of its shape, position and energy absorbing capability.

The REACT 350 (60") utilizes various cylinder wall thicknesses to accommodate both light cars and heavier, high center-of-gravity vehicles. The system can be mounted to a new or existing concrete backup.

Since the REACT 350 and REACT 350 (60") are proprietary, it should be acquired on the basis of competitive bidding with other equally suitable systems such as the QuadGuard Elite and the SCI100GM.



(8) SCI100GM and SCI70GM. The SCI100GM system (NCHRP 350 Approved, TL-3, FHWA Acceptance Letter CC-85) and SCI70GM (NCHRP 350 Approved, TL-2, FHWA Acceptance Letter CC-85A) can be used for unidirectional or bidirectional traffic. The SCI100GM and SCI70GM are redirective, nongating systems and are intended for use to terminate median barrier. When used for bidirectional traffic, an FHWA approved transition is required in the event of a reverse direction impact at the rear of the system and is incidental to the SCI100GM and SCI70GM systems.

These redirective, non-gating crash cushions are 850 mm (34 in) high, with a length of 6550 mm (21.5 ft) for the SCI100GM and a length of 4118 mm (13.5 ft) long for the SCI70GM. Their main components include base and side frame assemblies fabricated of mild steel tubing, a front sled assembly, and a series of 10-gauge galvanized Grade 60 steel side panels mounted to collapsing steel frames and a shock arresting cylinder. A 28.6 mm (1.125 in) diameter steel cable is attached to the front sled assembly and is then routed around a front sheave to dual sheave assemblies located at the back of the attenuator (one at either end of the shock arresting cylinder). The SCI70GM is three bays shorter than the SCI100GM and the cylinder stroke was reduced accordingly. The units telescope backward upon frontal impact and generate stopping force from a combination of friction between the cable and the non-rotating sheaves, acceleration of the attenuator's masses, crush factors in the body and frame of the vehicle, and the variable resistance created by the shock arresting cylinder as it compresses between the rear sheave assemblies by the tensioned cable. The base unit is anchored to the mounting substrate with 48 bolts for the SCI100GM and 34 bolts for the SCI70GM. Testing was performed on a unit mounted on a concrete pad with galvanize Grad B7 all-thread rods 19 mm (0.75 in) in diameter and 178 mm (7 in) long. These rods were inserted into 22.2 mm (0.875 in) diameter holes and set with epoxy.

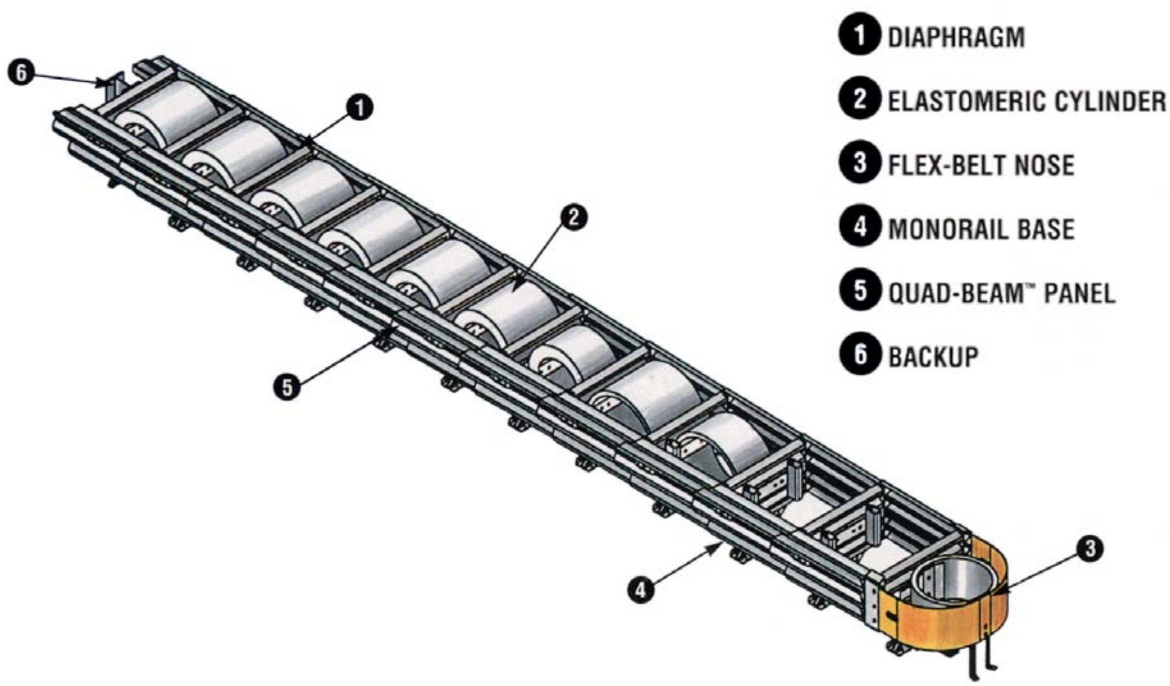
The transition designs are acceptable when the SCI100GM or SCI70GM is connected to a solid concrete barrier or backup. When attached to W-beam or Thrie-beam median barrier, that barrier must include an acceptable transition design, such as RC-50M, to redirect vehicles impacting from the backside and to prevent their snagging on the back corner of the attenuator.

The SCI100GM and SCI70GM are proprietary systems and, as such, must be purchased or obtained through competitive bidding with equally suitable alternate systems such as the QuadGuard Elite and the REACT 350.

(9) QuadGuard LMC. The QuadGuard LMC (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-43) is a proprietary system and can be used for unidirectional or bidirectional traffic. The QuadGuard LMC is a nongating system and is intended for use to terminate roadside barrier of various types and other obstructions up to 2.3 m (90 in) wide. When used for bidirectional traffic, an FHWA approved transition is required in the event of a reverse direction impact at the rear of the system and is incidental to the QuadGuard LMC system.

The QuadGuard LMC is a low maintenance crash cushion that uses self-restoring elastomeric cylinders in place of crushable cartridges used in the standard QuadGuard. However, several parts are identical to those used in the standard or wide systems. It is recommended for use in potentially high frequency impact areas.

The QuadGuard LMC is a proprietary system and, as such, must be purchased or obtained through competitive bidding with equally suitable alternate systems such as the REACT 350 and the SCI100GM.



6. Type VI – Gating, Non-Redirective Crash Cushion Systems.

a. Description. These systems include a group of unrestrained barrels partially filled with sand and a crash cushion system filled with water. The energy of an impacting vehicle is dissipated by a transfer of the vehicle's momentum to the mass of the sand barrels or water-filled crash cushions. These systems can be used to shield a narrow or wide obstruction. However, they are not designed to redirect vehicles for side impacts.

b. Application. Appropriate arrangements of sand filled barrels may be used to shield barrier walls up to 4.0 m (13 ft) wide, gore areas and other fixed objects in low frequency impact areas. Sand barrels are not designed to redirect vehicles for side impacts; consequently, modules near the rear of the array should be carefully placed to minimize the likelihood of a motorist striking the corner of the object being shielded.

Recommended locations of the water filled crash cushion system (ABSORB 350) are gore areas, ramps and other locations where penetration of an errant vehicle is not likely to cause a crash in opposing traffic lanes, or impacts with workers behind the barrier. This device should only be used in locations where non-redirection is appropriate and is not to be used in medians with opposing traffic unless the device is located outside the clear zone for both directions. Vehicle penetration is likely to occur for angle hits from the nose to near the mid-point of the array, and penetration/override of the system is possible for high-speed, high angle impacts near the rear of the device. Also note that proper anti-freezing agents must be used when the ABSORB 350 is used in areas where low temperature can be anticipated.

c. Approved Systems. Proprietary Type VI (NCHRP 350 approved, TL-3) crash cushion systems include:

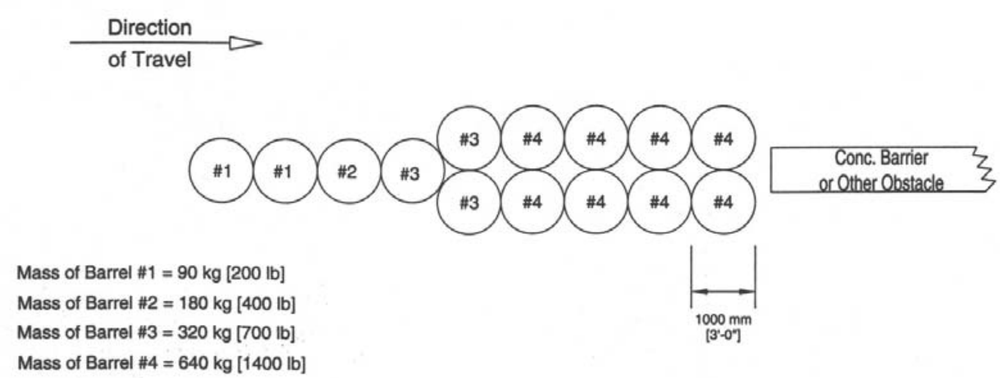
- Sand Filled
  - Energite III Module (FHWA Acceptance Letter CC-29)
  - Fitch Universal Module (FHWA Acceptance Letter CC-28)
  - Traffix (FHWA Acceptance Letter CC-52)

- Water Filled
  - ABSORB 350

(1) Energite III Module.
(2) Fitch Universal Module.
(3) Traffix.

Although there are differences in the parts that comprise the individual modules of each system, the overall size and weight of the modules are very similar. Module size has been standardized at 914 mm (36 in) diameter. Standard module weights are 100 kg (220 lb), 200 kg (440 lb), 300 kg (660 lb), 650 kg (1435 lb) and 950 kg (2100 lb). No back-up structure or wall is required for these devices since the force that a vehicle exerts on the individual modules is not transmitted through the cushion. These systems are intended to protect wide fixed objects in low frequency impact areas.

Since these sand filled crash cushion systems are proprietary, they should be acquired on the basis of competitive bidding with other equally suitable alternate, non-redirective (Type VI) systems such as water filled crash cushions (ABSORB 350).



(4) ABSORB 350. The ABSORB 350 (NCHRP approved, TL-2 and TL-3, FHWA Acceptance Letter CC-66A and CC-66) is a non-redirective, gating water filled crash cushion primarily intended to shield the approach ends of temporary concrete barrier in general and Quick Change Median Barrier (QMB) segments in particular. The water filled crash cushion may also be used to shield permanent concrete barrier at appropriate locations.

The ABSORB 350 system consists of a nosepiece assembly followed by five, eight or nine element assemblies, and a transition/attachment assembly. Two types of element assemblies must be alternated when installed. Both types are made from low-density polyethylene and have internal structural components and connection hardware fashioned from ASTM A-36 mild steel. These elements are 800 mm (32 in) tall and 610 mm (24 in) wide. When empty, the elements assemblies weigh 48 kg (106 lb) each. When filled with approximately 300 L (79 gal) of water, they weigh 315 kg (694 lb). The first element in an array must be kept empty to ensure proper performance. All other elements must be filled with water. The eight-element and nine-element TL-3 designs are 8.2 m (27 ft) long and 9.2 m (30 ft) long, respectively; the five-element TL-2 design is 5.2 m (17 ft) long.

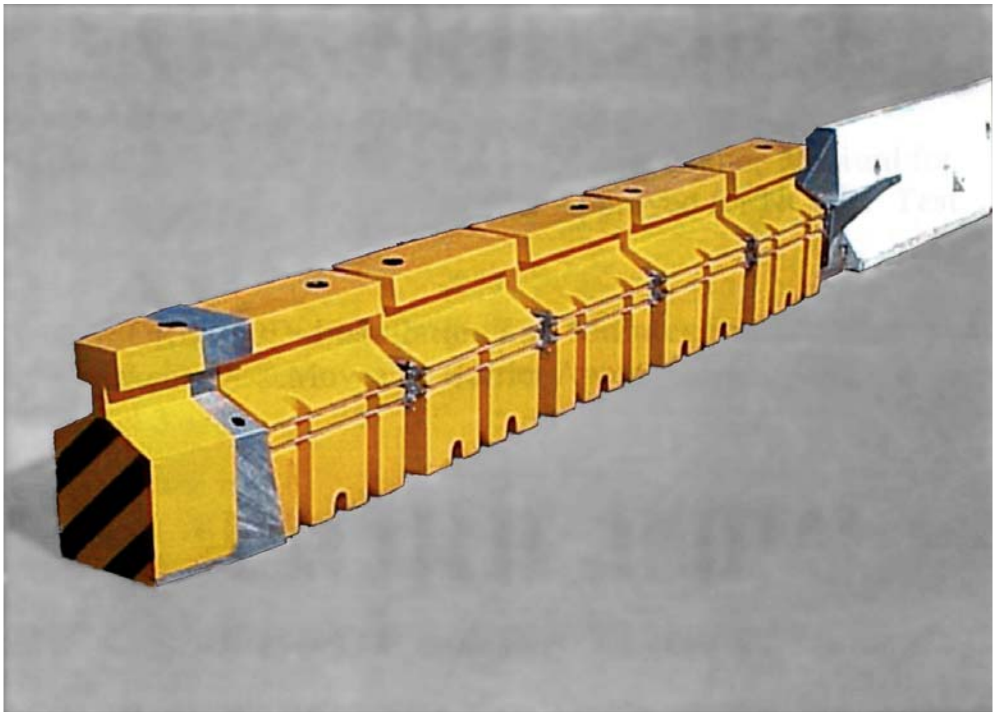
The ABSORB 350 TL-3 designs may be considered for use on the NHS as follows:

- Quick-Change Moveable Median Barrier (QMB). The TL-3 design consists of the nosepiece assembly, eight ABSORB 350 elements and the leading top edge of the first QMB unit tapered as shown on the installation manual.

- F-Shape Median Barrier (Permanent and Temporary). The TL-3 design consists of the nosepiece assembly, nine ABSORB 350 elements and the special attachments/transition assembly (for attachment to standard concrete barrier). The F-shape barrier sections must have a minimum length of 3.6 m (12 ft) to use the ABSORB 350.

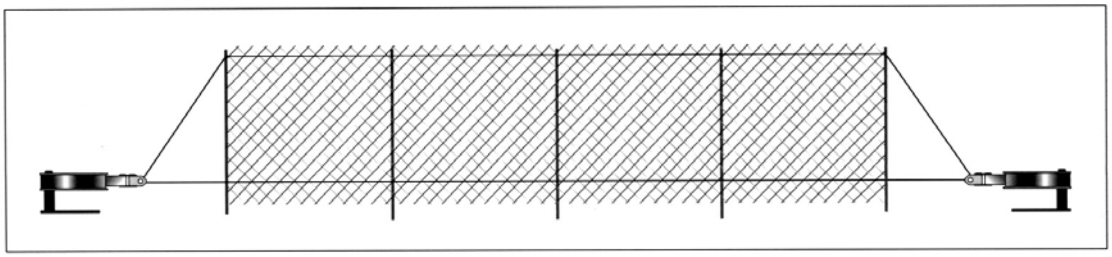
The ABSORB 350 TL-2 design consists of the nosepiece assembly, five ABSORB 350 elements and a special attachment/transition assembly (for attachment to standard concrete barrier). The TL-2 design is acceptable for use on the NHS for speeds less than 70 km/h (45 mph). When attached to QMB barrier, the first QMB unit must be tapered as noted above.

The ABSORB 350 is a proprietary system, and as such, must be purchased or obtained through competitive bidding with an equally suitable alternate, non-redirective (Type VI) system such as sand barrels.

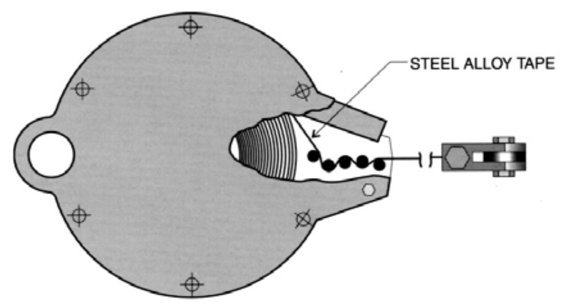


7. Miscellaneous Systems. The DRAGNET (NCHRP 350 approved, FHWA Acceptance Letter B-15) is not normally used except in special conditions. The DRAGNET system is an arresting type of attenuator that provides a safe, controlled stop with a minimum of damage to the impacting vehicle, regardless of speed or vehicle size. The DRAGNET system, with its ability to span any road width, is ideal for utilization in work zones.

The DRAGNET should be used under unique circumstances on a case by case basis, since it is proprietary and a sole source item.



The **DRAGNET VEHICLE ARRESTING BARRIER**, (or "VAB") consists of a net with a continuous cable running through the top and bottom, both ends of which are attached to customized "enegry absorbers". These energy absorbers contain a spool of coiled steel alloy tape. The tape is lead through a series of offset steel pins contained in the energy absorbers. As the net is hit, the metal tape is pulled through the pins, constantly bending and straightening the tape.



ENERGY ABSORBER

This metal deformation causes the smooth, safe deceleration of the vehicle. By changing the gauge of the metal tape and configuration of the pins, a barrier can be designed to handle any situation from an 1,800 pound car to an 80,000 pound tractor trailer.

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E. Design Considerations and Criteria. Common applications of end treatments and crash cushions include roadside and median installations to terminate barriers for protection of potential impacts with fixed "point" objects. Obstacles such as bridge abutments, bridge piers, fixed-base overhead sign bridge supports and other obstacles of similar geometry (short in the longitudinal direction) represent examples where crash cushions can be effectively used to reduce a potential serious impact.

Impact attenuating devices are designed to restrain vehicle impacts under what may be termed "normally expected impact modes". That is, the vehicle is expected to be in stable on-the-surface mode at impact although obviously out of the normal travel lane. They are designed to mechanically restrain an impacting vehicle through a force line at expected bumper height when the vehicle is in a wheels-on-the-ground mode.

The approach to impact attenuating devices needs to be level (1V:10H or flatter). Also the area behind the terminal should be free of significant fixed objects for those systems that are designed to move laterally. If a clear runout path is not attainable, this area should be at least similar in character to upstream, unshielded roadside areas.

Refer to Table 12.10 for design guidelines for impact attenuating devices. Further discussion of this criteria can be found in the AASHTO Roadside Design Guide, Chapter 8.

F. Approval Policy. There are several levels of consideration for the approval of impact attenuating devices on Department projects. Currently, all of the systems listed above have been accepted based on crash testing as per NCHRP Report 350 or MASH. As outlined in Section 12.9.A, all new installations of impact attenuating devices must meet the criteria of NCHRP Report 350 or MASH. The following steps in sequence shall ensure uniform application of these safety devices, how to handle requests to the Department and provide a means for quality control statewide.

1. New Products:

a. The Department has a formal Product Evaluation (PE) system to coordinate the review of new products. Any new system or major change to an already accepted system should be processed through the PE system (Master Policy Statement #418).

b. The Product Evaluation Review Board has the authority to make judgment on the acceptability of a particular system or material. This shall be accomplished through coordination with respective personnel from the Bureaus of Project Delivery and Maintenance and Operations, as well as by the review of appropriate crash data and FHWA status reports.

c. Once a product or system is found acceptable, a generic specification or special provision shall be developed to control its use on Department projects. The provisions will have enough latitude to allow for site considerations, such as width and length or the number of bays or barrels. Approved systems shall be listed in Publication 35, *Approved Construction Materials* (Bulletin 15).

2. Project Application. Inclusion in a particular project shall be based on the use of the specification including specific site conditions. The manufacturer shall be required to provide shop drawings and, if necessary, design calculations for approval for each site on a project-by-project basis. Concept approval shall be given at the Final Design Office Meeting. For permanent impact attenuating devices, final review shall be made by the District office based on the manufacturer's pre-approved shop drawings by the Bureau of Project Delivery.

TABLE 12.10
DESIGN GUIDELINES FOR IMPACT ATTENUATING DEVICES

	SYSTEM	TERMINAL	CRUSH CUSHION	ENERGY ABSORBING	NON-ENERGY ABSORBING	NONGATING	GATING	UNIDIRECTIONAL	BIDIRECTIONAL	IF BIDIRECTIONAL MINIMUM MEDIAN WIDTH	TRANSITIONS TO: SEE TRANSITION CODES BELOW				ADDITIONAL INFO
											STRONG POST W BEAM	WEAK POST W BEAM	CMB (F-SHAPE)	DOUBLE FACED W BEAM	
Type I	ANCHORED BACKSLOPE	X		X		X		X			1A	N/A	N/A	N/A	SEE RC-54M FOR DETAILS
Type II	FLEAT-350	X		X			X	X			1A	3C	N/A	N/A	REDIRECTION BEGINS BEYOND POST #3 L = 11.43 m (37.5 ft)
Type II	FLEAT-SP	X		X			X	X			1A	3C	N/A	N/A	REDIRECTION BEGINS BEYOND POST #3 L = 11.43 m (37.5 ft)
Type II	X-Tension	X		X		X		X	X	0.67 m (2.2 ft)	1A	3C	N/A	N/A	REDIRECTION BEGINS BEYOND POST #1 L = 13.17 m (43.21 ft)
Type II	ET-2000	X		X			X	X			1A	3C	N/A	N/A	REDIRECTION BEGINS AT POST #3 FROM THE APPROACH END L = 15.24 m (50 ft)
Type II	ET-PLUS with SYTP	X		X			X	X			1A	3C	N/A	N/A	REDIRECTION BEGINS AT POST #3 FROM THE APPROACH END L = 15.24 m (50 ft)
Type II	SKT-350	X		X			X	X			1A	3C	N/A	N/A	REDIRECTION BEGINS BEYOND POST #3 L = 15.24 m (50 ft)
Type II	BEAT-SSCC	X		X			X	X			N/A	N/A	1A	N/A	REDIRECTION BEGINS AT POST #3 FROM THE APPROACH END L = 8.5 m (28 ft) to 13.4 m (44 ft)
Type II	SKT-SP	X		X			X	X			1A	3C	N/A	N/A	REDIRECTION BEGINS BEYOND POST #3 L = 11.43 m (37.5 ft)
Type III	SRT-350	X			X		X	X			1A	3C	N/A	N/A	REDIRECTION BEGINS BEYOND POST #3 L = 11.43 m (37.5 ft)
Type IV	CAT-350	X	X	X			X	X	X	3.0 m (10 ft)	N/A	N/A	3B	2D	REDIRECTION BEGINS AT POST #4 FROM THE APPROACH END L = 9.6 m (31.5 ft) + Transition
Type IV	Brakemaster 350	X	X	X			X	X	X	3.0 m (10 ft)	N/A	N/A	2D	2D	REDIRECTION BEGINS BEYOND POST #3 L = 9.6 m (31.5 ft)
Type IV	ADIEM	X	X	X			X	X	X	3.0 m (10 ft)	N/A	N/A	1A	2D	REDIRECTION BEGINS 4.2 m (14 ft) FROM THE APPROACH END L = 9.14 m (30 ft) + Connection
Type IV	FLEAT-MT	X		X			X	X	X	3.6 m (12 ft)	N/A	N/A	2D	2D	REDIRECTION BEGINS BEYOND POST #3 L = 11.43 m (37.5 ft)

TABLE 12.10 (CONTINUED)
DESIGN GUIDELINES FOR IMPACT ATTENUATING DEVICES

	SYSTEM	TERMINAL	CRUSH CUSHION	ENERGY ABSORBING	NON-ENERGY ABSORBING	NONGATING	GATING	UNIDIRECTIONAL	BIDIRECTIONAL	IF BIDIRECTIONAL MINIMUM MEDIAN WIDTH	TRANSITIONS TO: SEE TRANSITION CODES BELOW				ADDITIONAL INFO
											STRONG POST W BEAM	WEAK POST W BEAM	CMB (F-SHAPE)	DOUBLEFACED W BEAM	
Type V- Standard	QuadGuard		X	X		X		X	X	0.6 m (2 ft)	N/A	N/A	2D	2D	ALSO AVAILABLE FOR TL-1 AND TL-2 L = 6.3 m (20.75 ft) + Transition W = 0.6 m (2 ft)
Type V- Standard	TRACC		X	X		X		X	X	0.6 m (2 ft)	N/A	N/A	2D	2D	ALSO AVAILABLE FOR TL-2 L = 6.5 m (21.25 ft) + Transition W = 0.6 m (2 ft)
Type V- Standard	SHORTRACC		X	X		X		X	X	0.6 m (2 ft)	N/A	N/A	2D	2D	L = 4.33 m (14.21 ft) + Transition W = 0.6 m (2 ft)
Type V- Standard	WIDETRACC		X	X		X		X	X	1.47 m (4.83 ft)	N/A	N/A	2D	2D	L = 6.5 m (21.25 ft) + Transition W = 1.47 m (4.83 ft) Can be customized to protect any width
Type V- Standard	FASTRACC		X	X		X		X	X	0.6 m (2 ft)	N/A	N/A	2D	2D	L = 7.924 m (26 ft) + Transition W = 0.6 m (2 ft)
Type V- Standard	TAU-II		X	X		X		X	X	0.6 m (2 ft)	N/A	N/A	2D	2D	ALSO AVAILABLE FOR TL-2 L = 7.7 m (25.42 ft) + Transition W = 0.6 m (2 ft)
Type V- Standard	QUEST		X	X		X		X	X	0.6 m (2 ft)	N/A	N/A	2D	2D	ALSO AVAILABLE FOR TL-2 L = 5.74 m (18.75 ft) + Transition Can be customized to protect widths up to 0.9 m (3 ft)
Type V - Low Maintenance / Self Restoring	QuadGuard Elite		X	X		X		X	X	0.6 m (2 ft)	N/A	N/A	2D	2D	ALSO AVAILABLE FOR TL-2 L = 10.8 m (36 ft) + Transition W = 0.6 m (2 ft) Can be customized to protect widths up to 2.3 m (90 in)
Type V - Low Maintenance / Self Restoring	REACT 350		X	X		X		X	X	0.9 m (3 ft)	N/A	N/A	2D	2D	ALSO AVAILABLE FOR TL-1 AND TL-2 W = 0.9 m (3 ft) L = 9.4 m (31 ft) + Transition
Type V - Low Maintenance / Self Restoring	REACT 350 (60")		X	X		X		X	X	1.5m (5 ft)	N/A	N/A	N/A	N/A	L = 8.9 m (29 ft) + Transition Attached to a 1.5 m (5 ft) wide reinforced and anchored concrete backup.
Type V - Low Maintenance / Self Restoring	SCI100GM SCI70GM		X	X		X		X	X	0.6 m (2.0 ft)	N/A	N/A	2D	2D	SCI100GM: L = 6.6 m (21.5 ft) + Transition SCI70GM: L = 4.1 m (13.5 ft) + Transition W = 0.6 m (2 ft)
Type V - Low Maintenance / Self Restoring	QuadGuard LMC		X	X		X		X	X	0.9 m (3 ft)	N/A	N/A	2D	2D	L = 9.8 m (32 ft) + Transition W = 0.9 m to 2.3 m (3 ft to 7.5 ft)

TABLE 12.10 (CONTINUED)
DESIGN GUIDELINES FOR IMPACT ATTENUATING DEVICES

	SYSTEM	TERMINAL	CRUSH CUSHION	ENERGY ABSORBING	NON-ENERGY ABSORBING	NONGATING	GATING	UNIDIRECTIONAL	BIDIRECTIONAL	IF BIDIRECTIONAL MINIMUM MEDIAN WIDTH	TRANSITIONS TO: SEE TRANSITION CODES BELOW				ADDITIONAL INFO
											STRONG POST W BEAM	WEAK POST W BEAM	CMB (F-SHAPE)	DOUBLEFACED W BEAM	
Type VI	Energite III		X	X			X	X	X	2.0 m (6.5 ft)	N/A	N/A	1B	1B	CUSTOM DESIGNS USED ESPECIALLY FOR WIDE HAZARDS (i.e., GREATER THAN 2.4 m (8 ft) WIDE)
	Fitch Universal		X	X			X	X	X	2.0 m (6.5 ft)	N/A	N/A	1B	1B	CUSTOM DESIGNS USED ESPECIALLY FOR WIDE HAZARDS (i.e., GREATER THAN 2.4 m (8 ft) WIDE)
	Traffix		X	X			X	X	X	2.0 m (6.5 ft)	N/A	N/A	1B	1B	CUSTOM DESIGNS USED ESPECIALLY FOR WIDE HAZARDS (i.e., GREATER THAN 2.4 m (8 ft) WIDE)
	ABSORB 350		X	X			X	X	X	0.6 m (2.0 ft)	N/A	N/A	2D	2D	CUSTOM DESIGNS USED ESPECIALLY FOR WIDE HAZARDS (i.e., GREATER THAN 2.4 m (8 ft) WIDE)

<u>TRANSITION CODES</u>

1. NO ADDITIONAL PARTS NEEDED
   - A. Attaches Directly to system.
   - B. System is placed in front of hazard offset for bidirectional traffic.

L = System Length
W = System Width

2. TRANSITION PIECE REQUIRED OR DESIRABLE
   - A. THREE-to-W Transition
   - B. End shoe
   - C. NJ offset panel
   - D. FHWA approved transitions

3. TRANSITION SECTION
   - A. 3810 mm (12 ft, 6 in) section of strong post W-beam guide rail
   - B. Any federally approved transition section from W-beam guide rail to CMB or concrete wall
   - C. 15.2 m (50 ft) sections of 2-S guide rail
   - D. 3810 mm (12 ft, 6 in) section of double-faced guide rail

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12.10 TEMPORARY BARRIERS

A. Introduction. Temporary barriers are devices designed to help prevent penetration by vehicles while minimizing injuries to vehicle occupants, and to protect workers, bicyclists, and pedestrians.

The four primary functions of temporary barriers are to:

- Keep vehicular traffic from entering work areas, such as excavations or material storage sites;
- Separate workers, bicyclists, and pedestrians from motor vehicle traffic;
- Separate opposing directions of vehicular traffic; and
- Separate vehicular traffic, bicyclists, and pedestrians from the work area such as false work for bridges and other exposed objects.

If temporary barriers are used to channelize vehicular traffic, standard delineations, pavement markings, or channelizing devices should supplement temporary barrier for improved daytime and nighttime visibility. The delineation color is to match the applicable pavement marking color.

Temporary barriers, including their end treatments, are to be crashworthy. To mitigate the effect of striking the upstream end of a temporary traffic barrier, install the end by flaring until the end is outside the acceptable clear zone or by providing crashworthy end treatments.

Use of longitudinal temporary barriers should be based on an engineering analysis. A number of factors such as traffic volume, traffic operating speed, offset, and duration affect barrier need within work zones. However, improper use of temporary barriers can provide a false sense of security for both the motorist and the worker. Therefore, care must be taken in their design, installation, and maintenance.

Several designs for temporary barriers are available that may be appropriate for work-zone applications. Although no consensus on specific warrants exists, barriers are usually justified for bridge widening; shielding of roadside structures; roadway widening (especially with edge dropoffs); and for separating two-lane, two-way traffic on one roadway of a normally widened facility.

The material and construction requirements for temporary barriers are described in:

- Publication 408, *Specifications*, Section 627 - Temporary Barrier
- Publication 408, *Specifications*, Section 628 - Reset Temporary Barrier

Publication 35, *Approved Construction Materials* (Bulletin 15), lists the approved temporary barriers, including:

- Precast Concrete Barriers and Glare Screens
- Steel Barriers
- Water-Filled Barriers

The approved temporary barriers listed in Bulletin 15 are further categorized for use by Test Level. As discussed previously in Section 12.9.A, the nominal speed for Test Level 2 (TL-2) is 70 km/h (44 mph) and 100 km/h (62 mph) for Test Levels 3 through 6 (TL-3 through TL-6).

Each of the approved temporary barriers listed in Bulletin 15 is described by name, type, material, tested height, tested deflection, and reference number (FHWA Acceptance Letter). The deflection distances shown resulted from controlled crash tests at a 25 degree impact angle. The severe impact angle crash test may not be representative of actual field conditions during construction.

Additional information is found below about temporary barriers approved for use on PennDOT projects.

B. Temporary Barrier - Concrete.

1. PennDOT F-Shape Temporary Concrete Barrier. The PennDOT F-Shape Temporary Concrete Barrier (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-79) is an 860 mm (34 in) high modified F-shape portable barrier in segment lengths of 3.6 m (12 ft). The use of a 127 mm (5 in) vertical reveal in lieu of the standard 76 mm (3 in) dimension increases the total barrier height to the 860 mm (34 in) noted above and raises the slope break-point to 300 mm (12 in). The base width is 610 mm (24 in) and the barrier tapers to a 230 mm (9 in) top width.

The connection between segments is a 300 mm (12 in) long × 690 mm (27 in) high × 13 mm (0.5 in) thick steel plate that fits loosely into a vertical slot formed into the end of each segment. The segments are tightly butted together during installation.

The design deflection distance of PennDOT's F-Shape Temporary Concrete Barrier was reported to be 2.555 m (8.4 ft).

When this barrier is used as a permanent barrier, the lower 50 mm (2 in) of the base will be set into the roadway surface, thereby resulting in a barrier having the standard F-shape profile that can be expected to have little or no deflection under normal impacts.

2. Other Temporary Concrete Barriers. Bulletin 15 lists other approved temporary concrete barrier systems (NCHRP 350 approved, TL-3) that may be used on PennDOT projects. The listing in Bulletin 15 includes the systems' names, tested heights, tested deflections, and reference numbers (FHWA Acceptance Letters).

3. Single Face Concrete Barrier. Single face concrete barrier is never appropriate for temporary barrier or roadside (shoulder) barrier unless the barrier has full back support as shown in Publication 72M, *Roadway Construction Standards*.

Single face concrete barrier may be used if it is part of a moment slab. Design details should be approved by the Department prior to inclusion in the project plans.

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C. Temporary Barrier - Steel.

1. Vulcan Barrier System. The Vulcan Barrier System (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-134) is a proprietary, longitudinal, nongating barrier for use as a temporary barrier (portable longitudinal barrier) in work zones. Each segment has a nominal length (pin to pin) of 4115 mm (13.5 ft), a height of 813 mm (32 in) and a width of 546 mm (21.5 in). The mass (weight) of each segment is approximately 395 kg (871 lb). The upper portion incorporates standard thrie-beam guide rail panels, and the bottom incorporates sheet metal rub rails.

Five steel bulkheads tie the sides of the Vulcan together. The end bulkheads incorporate vertically aligned holes to facilitate pinning Vulcan segments together. The center bulkhead incorporates a lifting table for assembly and transport. A stiffener plate also runs the length of each segment. Vulcan sections are pinned together using 51 mm (2 in) diameter steel connecting pins. When installed in straight configurations, an optional steel space can be installed in the connecting joint to reduce lateral deflection. The Vulcan's end bulkheads can also be used to connect an appropriate crash cushion to a Vulcan installation.

In its unanchored configuration, at least 23 segments of Vulcan (92 m (302 ft) must be attached to each end of unanchored Vulcan barriers to establish a "beginning of length of need" (BLON) point and to limit the barrier's dynamic deflection within the length of need to that noted in the crash test. For an installation of the Vulcan in an unanchored configuration, the minimum length is 64 sections. The freestanding, unshielded end of this design is not crashworthy and requires either shielding with a suitable anchored impact attenuator for uni-directional applications or introduction outside the appropriate clear zone. Anticipated lateral deflection of the Vulcan for anchored and unanchored configurations must be communicated to end users so effective field installations can be designed.

The moveable Vulcan Barrier System, as described above, had a design deflection distance of 1.8 m (6 ft).

Two other Vulcan Barrier Systems approved for use as temporary barrier are: (1) moveable Vulcan System Minimum Deflection System (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-134C) with a deflection distance of 300 mm (12 in); and (2) Vulcan System (NCHRP 350 approved, TL-4, FHWA Acceptance Letter B-134D) with a deflection distance of 1.143 m (3.75 ft).

2. Zoneguard. The Zoneguard (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-176A) is a proprietary longitudinal nongating barrier for use as a temporary barrier (portable longitudinal barrier) in work zones. The Zoneguard portable longitudinal barrier system is comprised of 4.2 mm thick (8 gage, 0.165 in thick), ASTM A36 pressed, galvanized steel panels assembled in 15.24 m (50 ft) long sections. Each section is 820 mm (2.69 ft) high with a base width of 700 mm (2.3 ft) and a top beam width of 157 mm (0.52 ft). The Zoneguard has a step 150 mm (0.5 ft) wide on each side just above surface level, which slopes upward to meet the upper beam section. Each section has a mass (weight) of approximately 1406 kg (3097 lb). The base of each 15.24 m (50 ft) long section has twelve rubber feet, 700 mm × 165 mm × 13 mm (2.30 ft × 0.54 ft × 0.043 ft), which are fixed using an adhesive compound.

The complete barrier test installations were each nominally 820 mm (2.69 ft) high, 700 mm (2.3 ft) wide, and 76.2 m (250 ft) long. Tests were conducted for two different anchoring patterns: (1) the standard arrangement which includes anchoring at each end of the barrier and (2) the minimum deflection arrangement which includes anchoring every 10.2 m (33.3 ft) along the barrier. The standard arrangement is anchored at points 500 mm (1.64 ft) and 5.1 m (16.67 ft) from each end on both sides for a total of four anchors per end. These anchors were 38 mm (1.5 in) diameter ASTM 1018 smooth rod, 305 mm (12 in) long and installed 200 mm (8 in) deep into concrete. The minimum deflection Zoneguard arrangement is identical to the standard arrangement described above apart from the addition of the intermediate threaded resin anchors placed in both sides of the "foot" section on 10.2 m (33.3 ft) centers. Alternate anchor designs certified by the manufacturer may be used to provide equal or greater anchorage strength to that provided for the test installations.

When used across a bridge joint, it should be noted that the Zoneguard can accommodate 250 mm (10 in) of movement.

Standard 15.24 m (50 ft) Zoneguard units can be installed on curves down to 244 m (800 ft) radius. Special units can be provided for tighter curves, as well as flared sections. A 13 mm (0.5 in) thick rubber pad on the foot section allows for water drainage off the road surface.

The Zoneguard had a design deflection distance of 1.93 m (6.33 ft) for the standard arrangement and 0.41 m (1.33 ft) for the minimum deflection arrangement. The recorded deflections were the maximum dynamic deflections of the top of the barrier.

3. BarrierGuard 800. The BarrierGuard 800 (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-131) is a proprietary, longitudinal, nongating barrier for use as a temporary barrier (portable longitudinal barrier) in work zones. The BarrierGuard 800 is constructed from 5 mm (0.2 in) thick A36 galvanized steel panels assembled in 12 m (40 ft) segments. Each segment is 800 mm (31.5 in) high with a base width of 540 mm (21.5 in) and a top width of 230 mm (9 in). The BarrierGuard 800 has a sloped face with a "step" 255 mm (10 in) above the ground. Each segment weighs approximately 1080 kg (2380 lb). The system is anchored at each end and at a point approximately 6 m (1.8 ft) in from each end with a total of sixteen 24 mm (0.95 in) diameter by 460 mm (18 in) long threaded steel rods (4 rods at each anchor location) in a minimum of 75 mm (3 in) of asphaltic concrete over at least 200 mm (8 in) of compacted dense graded aggregate. Alternative designs certified by the manufacturer to provide anchorage equal to or better than the tested design may also be used.

The BarrierGuard 800 described above should account for a design deflection distance of 1.5 m (4.9 ft).

A second system, the BarrierGuard 800 - Minimum Deflection System (NCHRP 350 approved, TL-4, FHWA Acceptance Letter B-158), is a modification of the previously approved BarrierGuard 800 system and is designed to minimize the dynamic deflection of the system. Minimum Deflection systems are valuable in application where there is only limited space available, such as bridge deck repairs/replacement projects. To achieve this reduction in deflection, the BarrierGuard 800 - Minimum Deflection System incorporates the following modifications to the standard BarrierGuard 800:

- The barrier is anchored every 6 m (20 ft) with either joint anchors or intermediate anchors.
- The system consists of either 6 m (20 ft) or 12 m (40ft) BarrierGuard 800 sections.
- The barrier sections are fitted with a T-top attachment to aid in the redirection and stability of the vehicle after impact. The T-top measures 473 mm (15 5/8 in) wide and 121 mm (4 3/4 in) tall. The effective width of the top section with the T-top installed is 474 mm (18 5/8 in). With the T-top installed the barrier height is 921 mm (36 in) and the mass of each 6 m (20 ft) BarrierGuard 800 section is approximately 135 kg/m (90 lb/ft) or 800 kg (1800 lb). The mass of a similar 12 m (40 ft) section is approximately 135 kg/m (90 lb/ft) or 1600 kg (3600 lb).

The BarrierGuard 800 - Minimum Deflection System should account for a design deflection distance of 305 mm (12 in).

4. Mobile Barrier Trailer. The Mobile Barrier Trailer (MBT-1) (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-178) is an integrated, rigid wall, semi-trailer that is used in conjunction with standard semi-tractors to provide mobile, improved, safety, and work environments for personnel at applicable maintenance, construction, and security sites. It is an extended, mobile, longitudinal barrier that provides a physical and visual wall between passing traffic and the maintenance and construction personnel. With an integrated crash attenuator at the rear, a semi-tractor at the front, and a rigid wall on the side toward passing traffic, the MBT will provide approximately 30.5 m (100 ft) of barrier and protected work area.

The basic trailer is comprised of two platforms and up to three wall sections. The platforms are each 6.4 m (21 ft) in overall length, 2.54 m (100 in) wide and 1.22 m (4 ft) high (riding approximately 1.52 m (5 ft) high with 305 mm (12 in) of ground clearance). The wall sections are each 6.10 m (20 ft) long, 610 mm (24 in) wide, and 1.22 m (4 ft) high (riding approximately 1.52 m (5 ft) high with 305 mm (12 in) of ground clearance). A homogenous 6.4 mm (0.25 in) steel plate is welded to cover the outer side of each wall section. Each wall section abuts up against another of the platforms and is built the same to take an impact from either direction. There are no snag points at the seams. The outer 6.4 mm (0.25 in) plate and associated welds are ground beveled to transition from one to the other.

The MBT, as described above, had a design deflection distance of 0.61 m (2 ft).

D. Temporary Barrier - Water-Filled.

1. Guardian Safety Barrier. The Guardian Safety Barrier (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-34E) is a proprietary, longitudinal, nongating barrier for use as a temporary barrier (portable longitudinal barrier) in work zones. The barrier is made of plastic and is fitted with steel tubing.

The Guardian Safety Barrier should account for a design deflection distance of 1.98 m (6.5 ft).

The TL-3 version of the Guardian Safety Barrier requires a specially-made highway kit to be installed according to the manufacturer's drawings and specifications.

2. Triton Barrier System. The Triton Barrier System (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-179 and TL-2, FHWA Acceptance Letter B-21) are proprietary, longitudinal, nongating, water-filled barriers for use as temporary barrier (portable longitudinal barrier) in work zones.

The Triton barrier consists of 1981 mm (78 in) long by 813 mm (32.25 in) high by 533 mm (21.5 in) wide segments of lightweight polyethylene plastic shells designed to accept water ballast. The plastic barrier shell is supplemented by an internal steel framework to provide additional rigidity during handling and impacts. There is also a cable along the top connecting the joints between barrier segments. This cable provides the barrier's tensile capacity during impacts. The barrier is molded in a shape that interacts with an impacting vehicle to reduce its roll, pitch, and yaw.

The exterior dimensions of the Trition Barrier System are the same for TL-2 and TL-3. However, the interior U-bolts at the ends of each module are double-nutted to the interior steel framework in the TL-3 units. Each module is set on two 178 mm (7 in) high plastic pedestals to raise its center of gravity in order to meet TL-3 evaluation criteria. These pedestals are strapped to each individual unit and are also tethered together (in groups of ten) with a braided polyester cord to reduce debris scatter following an impact.

The Triton Barrier System should account for a design deflection distance of 2.7 m (8.9 ft) at TL-2 and over 3.0 m (10 ft) at TL-3.

3. Yodock Model 2001 Barrier System. The Yodock Model 2001 Barrier System (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-97) and Model 2001M Barrier System (NCHRP 350 approved, TL-2, FHWA Acceptance Letter B-97) are proprietary, longitudinal, nongating, water-filled barriers for use as temporary barrier (portable longitudinal barrier) in work zones.

The Yodock Model 2001 Barrier System is 1170 mm (46 in) tall, 610 mm (24 in) wide at the base, and 280 mm (11 in) wide at the top. The individual units are connected at the ends with polyethylene couplers and along the sides by 89 mm × 89 mm × 6.4 mm (3.5 in × 3.5 in × 0.25 in) structural steel tubes supported by steel brackets which extend through two forklift holes in each unit. The steel side tubes are 1830 mm (6 ft) long and spliced with 280 mm (11 in) 64 mm × 64 mm × 6.4 mm (2.5 in × 2.5 in × 0.25 in) steel tubes using two 19 mm (0.75 in) × 114 mm (2.25 in) long Grade 8 hex head bolts. The centerline height of the rails is 706 mm (27 in). Dynamic deflection was reported to be 4.28 m (14.0 ft) for TL-3.

The Yodock Model 2001M Barrier is similar to the Yodock Model 2001 Barrier System, except that it is 813 mm (32 in) tall, 457 mm (18 in) wide at the base, and 203 mm (8 in) wide at the top. Also, the centerline height of the steel rails is 596 mm (23.5 in). Dynamic deflection was reported to be 3.68 m (12.1 ft) for TL-2.

4. Sentry Water-Cable Barrier System. The Sentry Water-Cable Barrier System (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-196) is a proprietary, longitudinal, nongating, water-filled barrier for use as a temporary barrier (portable longitudinal barrier) in work zones. The Sentry Water-Cable Barrier was designed without the need for an external attached structure to meet TL-2 and TL-3 barrier performance. A second design objective was to produce a product with minimal lateral deflection of the barrier. Each section is a freestanding longitudinal wall unit with an approximate width, height, and length of 635 mm × 1092 mm × 2032 mm (25 in × 46 in × 84 in), respectively.

Each section has eleven connecting lugs, five on one end, and six on the opposite end. The four upper lugs on each barrier section contain one each independent corrosion resistant steel wire rope molded into the Sentry Water-Cable Barrier. The four wire rope pieces in each section act similarly to a cable barrier when impacted. A 31.8 mm (1.25 in) diameter steel T-pin drops through the 38.1 mm (1.5 in) diameter holes in the lugs, linking the sections together. The shell of each section is made up of high density polyethylene (HDPE).

Wall sections for the Sentry Water-Cable Barrier are set in position, connected by the T-pin and T-pin clip, and filled with water. The empty mass (weight) of each Sentry Water-Cable Barrier section is approximately 75 kg (165 lb). The mass (weight) of each Water-Cable Barrier section when filled with water is approximately 975 kg (2,150 lb). The Sentry Water-Cable Barrier does not use an external structure to achieve TL-2 or TL3 barrier performance, reducing the chance of improper assembly of the barrier.

The design deflection distance was reported as 2.74 m (9 ft) for TL-3 and 1.8 m (5 ft, 9 in) for TL-2.

E. Lateral Placement of Temporary Barrier in a Dropoff Condition.

1. Design Considerations. Work zones may have locations where dropoffs greater that 50 mm (2 in) in height are adjacent to an active travel lane. During the design and construction phases, work zone set-ups must be reviewed thoroughly for locations where temporary barrier may be placed between the active travel lane and the dropoffs.

For locations where temporary barrier is to be located beside dropoffs, three linear measurements are to be identified:

- Dropoff Height. The dropoff height is typically greater than 50 mm (2 in).
- Lateral Space (LS). The LS is the distance available behind the temporary barrier to accommodate barrier deflection.
- Barrier Deflection Distance (BDD). The BDD is equal to the tested deflection for the temporary barrier at the specified Test Level (e.g., TL-2, TL-3, TL-4). For the BDD of various PennDOT-approved temporary barriers, refer to Publication 35, *Approved Construction Materials* (Bulletin 15).

Figure 12.12 describes three dropoff conditions with lateral placement of temporary barrier:

- Condition 1 - BDD ≤ LS: This is a desirable condition for dropoff heights greater than 50 mm (2 in). The LS behind the temporary barrier is equal to or greater than the BDD for the selected temporary barrier.
- Condition 2 - BDD > LS, Dropoff Height < 150 mm (6 in): This condition is only permissible when the dropoff is less than 150 mm (6 in) and the work zone set-up has been reviewed to maximize the LS.
- Condition 3 - BDD > LS, Dropoff Height ≥ 150 mm (6 in): Under this condition, the temporary barrier is to be stiffened with restraints. Methods to limit the BDD for temporary barriers must be approved by the Bureau of Project Delivery.

2. Plans and Proposal. In the instances where temporary barrier for dropoff conditions is to be included in the plans and proposal:

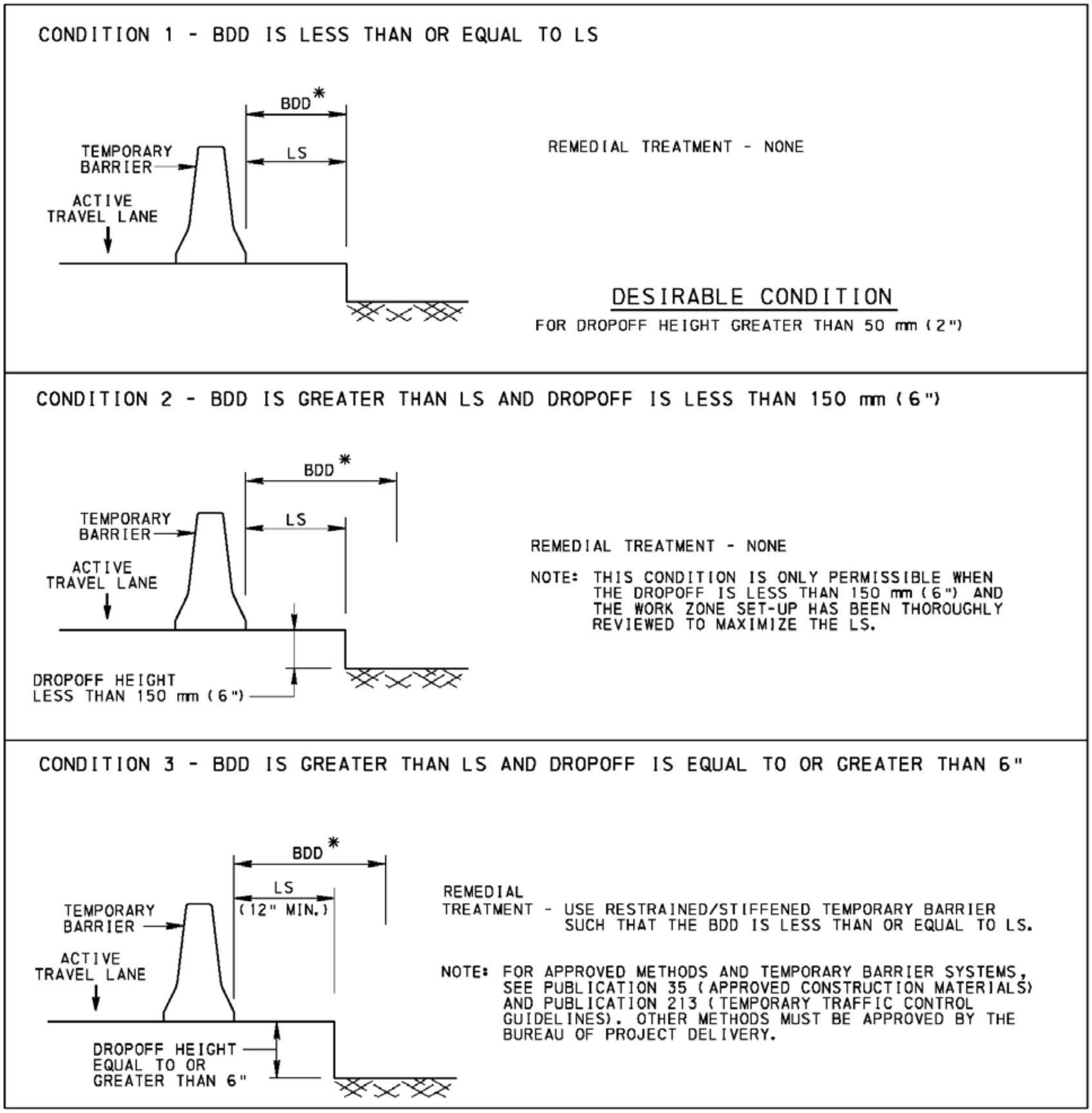
a. Identify the LS and the anticipated maximum dropoff height behind each run of temporary barrier.

b. Select a PennDOT-approved temporary barrier from one of the following categories:

- Test Level 3, BDD ≤ 0.6 m (2 ft)
- Test Level 3, BDD ≤ 1.5 m (5 ft)
- Test Level 3, BDD ≤ 2.7 m (9 ft)
- Test Level 3, BDD ≤ 4.6 m (15 ft)
- Test Level 2, BDD ≤ 2.7 m (9 ft)
- Test Level 2, BDD ≤ 4.6 m (15 ft)

Following are examples to clarify what PennDOT-approved temporary barriers may be selected.

FIGURE 12.12
LATERAL PLACEMENT OF TEMPORARY BARRIER
IN A DROPOFF CONDITION



Where: BDD= BARRIER DEFLECTION DISTANCE
LS = LATERAL SPACE - DISTANCE AVAILABLE BEHIND TEMPORARY BARRIER TO ACCOMMODATE BARRIER DEFLECTION
* = For the deflection distance of various approved barriers, see Publication 35, *Approved Construction Materials* (Bulletin 15).

EXAMPLE 1: A temporary barrier is to be placed between an active travel lane and a dropoff condition. The following conditions through the work zone are anticipated:

GIVEN: Work Zone Posted Speed Limit = 80 km/h (50 mph)
Maximum Dropoff Height = 250 mm (10 in)
LS = 1.8 m (6 ft)

DISCUSSION:

The above example corresponds with Condition 1 in Figure 12.12, where the BDD is less than or equal to the LS and no remedial treatment is needed. Also, the work zone posted speed limit is greater than the nominal speed for Test Level 2 (70 km/h (44 mph)) but is less than the nominal speed for Test Level 3 (100 km/h (62 mph)).

Therefore, for this example, a PennDOT-approved temporary barrier may be selected from a category that satisfies Test Level 3 and has a BDD less than the LS of 1.8 m (6 ft). The applicable categories are:

- Test Level 3, BDD ≤ 0.6 m (2 ft)
- Test Level 3, BDD ≤ 1.5 m (5 ft)

EXAMPLE 2: A temporary barrier is to be placed between an active travel lane and a dropoff condition. The following conditions through the work zone are anticipated:

GIVEN: Work Zone Posted Speed Limit = 56 km/h (35 mph)
Maximum Dropoff Height = 125 mm (5 in)
LS = 3.0 m (10 ft)

DISCUSSION:

The above example corresponds with Condition 1 and Condition 2 in Figure 12.12. The BDD for some temporary barriers is less than or equal to the LS (Condition 1). The BDD for other temporary barriers is greater than the LS and has a dropoff less than 150 mm (6 in) (Condition 2). Also, the work zone posted speed limit is less than the nominal speed for Test Level 2 (70 km/h (44 mph)) and Test Level 3 (100 km/h (62 mph)).

Therefore, for this example, a PennDOT-approved temporary barrier may be selected from a category that satisfies Test Level 2 or Test Level 3 and has a BDD less than the LS of 3.0 m (10 ft) (Condition 1). The applicable categories are:

- Test Level 3, BDD ≤ 0.6 m (2 ft)
- Test Level 3, BDD ≤ 1.5 m (5 ft)
- Test Level 3, BDD ≤ 2.7 m (9 ft)
- Test Level 2, BDD ≤ 2.7 m (9 ft)

Because the dropoff is less than 150 mm (6 in) in this example, a PennDOT-approved temporary barrier may also be selected from a category that satisfies Test Level 2 or Test Level 3, and has a BDD greater than LS. The applicable categories are:

- Test Level 3, BDD ≤ 4.6 m (15 ft)
- Test Level 2, BDD ≤ 4.6 m (15 ft)

Temporary barrier selected from Condition 1 is the desirable condition, since the BDD is less than the LS. However, Condition 2 is permissible if the dropoff is less than 150 mm (6 in) and if the work zone set-up has been thoroughly reviewed to maximize the LS.

EXAMPLE 3: A temporary barrier is to be placed between an active travel lane and a dropoff condition. The following conditions through the work zone are anticipated:

GIVEN: Work Zone Posted Speed Limit = 80 km/h (50 mph)
Maximum Dropoff Height = 600 mm (24 in)
LS = 0.6 m (2 ft)

DISCUSSION:

The above example corresponds with Condition 3 in Figure 12.12, where the BDD is greater than the LS and the dropoff is greater than 150 mm (6 in). Also, the work zone posted speed limit is greater than the nominal speed for Test Level 2 (70 km/h (44 mph)) but is less than the nominal speed for Test Level 3 (100 km/h (62 mph)).

Therefore, for this example, a PennDOT-approved temporary barrier may be selected from a category that satisfies Test Level 3 and has a BDD less than the LS of 0.6 m (2 ft). If the BDD is greater than 0.6 m (2 ft), the temporary barrier must be stiffened. The applicable categories are:

- Test Level 3, BDD ≤ 0.6 m (2 ft)

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12.11 RAILING SYSTEM TEST LEVEL SELECTION FOR BRIDGES

The selection criteria presented herein is applicable to railings mounted on bridges.

Provide bridge railings that meet the requirements of Test Level 5 (TL-5) of NCHRP Report 350, unless another test level is authorized by the District Executive. The Typical Concrete Barrier (shown in Publication 218M, *Standards for Bridge Design,* Drawing BD-601M) provides a high level of safety and low maintenance cost. This barrier is considered the default bridge railing system unless the District Executive authorizes a different railing system due to environmental, public request, or other requirements.

Test Levels 4 and 6 (TL-4 and TL-6) may be authorized by the District Executive on a case-by-case basis. A copy of the Alternate Bridge Railing Test Level Authorization will be kept in the permanent bridge inspection file. TL-6 may be considered for locations where a history of, or the potential for, tanker-truck rollover exists.

TL-4 may be considered in the following cases:

- Case I - Where favorable conditions of alignment, grade and speed exist and, hence, the probability of severe crashes is minimal.

- Case II - Where the height required for railings satisfying TL-5 may hinder sight distance requirements.

- Case III - Along the sides of bridges with sidewalks not separated from traffic with a crashworthy traffic railing.

Other than situations where the smaller height of TL-4 barriers is required to alleviate sight distance problems, select the Test Level for railing systems using Table 12.11. The adjusted ADT to be used in this table is calculated as follows:

$$\text{Adjusted ADT} = K_c \times K_g \times K_s \times \text{(The estimated construction-year total ADT for the highway)}$$

Where: K_g = Correction factor for grade, see Figure 12.13.

K_c = Correction factor for curvature, see Figure 12.13. The sharpest curvature on the bridge or the bridge approaches shall be used in determining K_c.

K_s = Correction factor for drop-off distance and under-structure conditions, see Figure 12.14.

The estimated construction-year ADT may be limited to 10,000 vehicles per day per lane for design speeds of 80 km/h (50 mph) or greater.

<u>EXAMPLE</u>:
Select the railing test level for a bridge with the following characteristics:

GIVEN:
- Bridge is on a four-lane divided highway.
- Bridge is on a section of the highway that has a 3% grade.
- Bridge is on a curve that has a 4 degree curvature.
- Bridge crosses a river that has water 4500 mm (15 ft) deep. The bridge deck is 13 500 mm (45 ft) above water.
- Estimated construction year ADT = 9,250.
- Railing offset from the driving lanes is 1800 mm (6 ft).
- Percent trucks = 10%.
- Highway design speed = 80 km/h (50 mph).

SOLUTION:

From Figure 12.13:

K_c = 2.0 for a 4 degree curvature
K_g = 1.25 for a 3% grade

From Figure 12.14:
K_s = 1.6 for a bridge deck 13 500 mm (45 ft) above water and using the curve for water > 10 ft deep

Adjusted ADT = 9,250 × 2 × 1.25 × 1.6 = 37,000 vpd < No. of lanes × 10,000 = 40,000 vpd – OK

Use Adjusted ADT = 37,000 vpd

From Table 12.11 for 80 km/h (50 mph) design speed:

- Go to the block of lines corresponding to 10% trucks.
- Chose the line for rail offset 900 mm to 2100 mm (3 ft to 7 ft). This range encompasses the 1800 mm (6 ft) given.
- Move horizontally to the area that corresponds to Divided highway.

→ TL-4 is allowed for Adjusted ADT up to 60,000.
→ TL-5 is required for Adjusted ADT > 60,000.

Therefore, for an Adjusted ADT = 37,000 vpd, TL-4 may be used if authorized by the District Executive.

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TABLE 12.11
RAILING SYSTEMS TEST LEVEL SELECTION CRITERIA

Site Characteristics					Adjusted ADT Ranges for Railing Test Levels (10^3 vpd)	
					Highway Type	
Design Speed		Truck percent	Rail Offset		Divided or undivided with 5 or more lanes *	Undivided with 4 lanes or less
					TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required	TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required
(km/h)	(mph)		(mm)	(ft)		
50	30	0	0-900	0-3	∞	∞
50	30	0	900-2100	3-7	∞	∞
50	30	0	2100-3600	7-12	∞	∞
50	30	0	>3600	>12	∞	∞
50	30	5	0-900	0-3	∞	∞
50	30	5	900-2100	3-7	∞	∞
50	30	5	2100-3600	7-12	∞	∞
50	30	5	>3600	>12	∞	∞
50	30	10	0-900	0-3	179	148
50	30	10	900-2100	3-7	258	228
50	30	10	2100-3600	7-12	404	365
50	30	10	>3600	>12	∞	∞
50	30	15	0-900	0-3	103	85
50	30	15	900-2100	3-7	147	129
50	30	15	2100-3600	7-12	229	205
50	30	15	>3600	>12	472	467
50	30	20	0-900	0-3	72	59
50	30	20	900-2100	3-7	102	90
50	30	20	2100-3600	7-12	159	143
50	30	20	>3600	>12	329	325
50	30	25	0-900	0-3	55	45
50	30	25	900-2100	3-7	79	69
50	30	25	2100-3600	7-12	122	110
50	30	25	>3600	>12	253	250

* For one way highways, use half the ADT shown for divided or undivided with 5 or more lanes.

TABLE 12.11 (CONTINUED)
RAILING SYSTEMS TEST LEVEL SELECTION CRITERIA

Site Characteristics					Adjusted ADT Ranges for Railing Test Levels (10^3 vpd)	
					Highway Type	
Design Speed		Truck percent	Rail Offset		Divided or undivided with 5 or more lanes *	Undivided with 4 lanes or less
					TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required	TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required
(km/h)	(mph)		(mm)	(ft)		
65	40	0	0-900	0-3	∞	∞
65	40	0	900-2100	3-7	∞	∞
65	40	0	2100-3600	7-12	∞	∞
65	40	0	>3600	>12	∞	∞
65	40	5	0-900	0-3	280	202
65	40	5	900-2100	3-7	335	254
65	40	5	2100-3600	7-12	452	367
65	40	5	>3600	>12	∞	∞
65	40	10	0-900	0-3	80	56
65	40	10	900-2100	3-7	90	69
65	40	10	2100-3600	7-12	132	102
65	40	10	>3600	>12	184	157
65	40	15	0-900	0-3	46	32
65	40	15	900-2100	3-7	52	40
65	40	15	2100-3600	7-12	78	59
65	40	15	>3600	>12	105	60
65	40	20	0-900	0-3	33	23
65	40	20	900-2100	3-7	37	28
65	40	20	2100-3600	7-12	55	42
65	40	20	>3600	>12	74	63
65	40	25	0-900	0-3	25	18
65	40	25	900-2100	3-7	28	22
65	40	25	2100-3600	7-12	42	32
65	40	25	>3600	>12	57	48

* For one way highways, use half the ADT shown for divided or undivided with 5 or more lanes.

TABLE 12.11 (CONTINUED)
RAILING SYSTEMS TEST LEVEL SELECTION CRITERIA

Site Characteristics					Adjusted ADT Ranges for Railing Test Levels (10^3 vpd)	
					Highway Type	
Design Speed		Truck percent	Rail Offset		Divided or undivided with 5 or more lanes *	Undivided with 4 lanes or less
(km/h)	(mph)		(mm)	(ft)	TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required	TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required
80	50	0	0-900	0-3	∞	∞
80	50	0	900-2100	3-7	∞	∞
80	50	0	2100-3600	7-12	∞	∞
80	50	0	>3600	>12	∞	∞
80	50	5	0-900	0-3	162	107
80	50	5	900-2100	3-7	189	134
80	50	5	2100-3600	7-12	247	172
80	50	5	>3600	>12	315	245
80	50	10	0-900	0-3	50	32
80	50	10	900-2100	3-7	60	42
80	50	10	2100-3600	7-12	71	49
80	50	10	>3600	>12	89	68
80	50	15	0-900	0-3	30	19
80	50	15	900-2100	3-7	37	25
80	50	15	2100-3600	7-12	41	29
80	50	15	>3600	>12	52	39
80	50	20	0-900	0-3	21	13
80	50	20	900-2100	3-7	26	18
80	50	20	2100-3600	7-12	29	20
80	50	20	>3600	>12	36	28
80	50	25	0-900	0-3	16	10
80	50	25	900-2100	3-7	20	14
80	50	25	2100-3600	7-12	23	16
80	50	25	>3600	>12	28	21

* For one way highways, use half the ADT shown for divided or undivided with 5 or more lanes.

TABLE 12.11 (CONTINUED)
RAILING SYSTEMS TEST LEVEL SELECTION CRITERIA

Site Characteristics					Adjusted ADT Ranges for Railing Test Levels (10^3 vpd)	
					Highway Type	
Design Speed		Truck percent	Rail Offset		Divided or undivided with 5 or more lanes *	Undivided with 4 lanes or less
(km/h)	(mph)		(mm)	(ft)	TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required	TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required
100	60	0	0-900	0-3	∞	∞
100	60	0	900-2100	3-7	∞	∞
100	60	0	2100-3600	7-12	∞	∞
100	60	0	>3600	>12	∞	∞
100	60	5	0-900	0-3	107	70
100	60	5	900-2100	3-7	126	83
100	60	5	2100-3600	7-12	158	106
100	60	5	>3600	>12	204	138
100	60	10	0-900	0-3	40	25
100	60	10	900-2100	3-7	48	29
100	60	10	2100-3600	7-12	53	34
100	60	10	>3600	>12	68	44
100	60	15	0-900	0-3	24	15
100	60	15	900-2100	3-7	29	18
100	60	15	2100-3600	7-12	32	20
100	60	15	>3600	>12	41	26
100	60	20	0-900	0-3	18	11
100	60	20	900-2100	3-7	21	13
100	60	20	2100-3600	7-12	23	14
100	60	20	>3600	>12	29	19
100	60	25	0-900	0-3	14	9
100	60	25	900-2100	3-7	17	10
100	60	25	2100-3600	7-12	18	11
100	60	25	>3600	>12	23	15

* For one way highways, use half the ADT shown for divided or undivided with 5 or more lanes.

TABLE 12.11 (CONTINUED)
RAILING SYSTEMS TEST LEVEL SELECTION CRITERIA

Site Characteristics					Adjusted ADT Ranges for Railing Test Levels (10^3 vpd)	
					Highway Type	
Design Speed		Truck percent	Rail Offset		Divided or undivided with 5 or more lanes *	Undivided with 4 lanes or less
					TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required	TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required
(km/h)	(mph)		(mm)	(ft)		
110	70	0	0-900	0-3	191	165
110	70	0	900-2100	3-7	380	301
110	70	0	2100-3600	7-12	∞	402
110	70	0	>3600	>12	∞	∞
110	70	5	0-900	0-3	63	42
110	70	5	900-2100	3-7	80	52
110	70	5	2100-3600	7-12	96	64
110	70	5	>3600	>12	128	84
110	70	10	0-900	0-3	32	20
110	70	10	900-2100	3-7	39	23
110	70	10	2100-3600	7-12	42	27
110	70	10	>3600	>12	53	33
110	70	15	0-900	0-3	22	13
110	70	15	900-2100	3-7	25	15
110	70	15	2100-3600	7-12	27	17
110	70	15	>3600	>12	34	21
110	70	20	0-900	0-3	16	10
110	70	20	900-2100	3-7	19	11
110	70	20	2100-3600	7-12	20	12
110	70	20	>3600	>12	24	15
110	70	25	0-900	0-3	13	8
110	70	25	900-2100	3-7	15	9
110	70	25	2100-3600	7-12	16	10
110	70	25	>3600	>12	19	12

* For one way highways, use half the ADT shown for divided or undivided with 5 or more lanes.

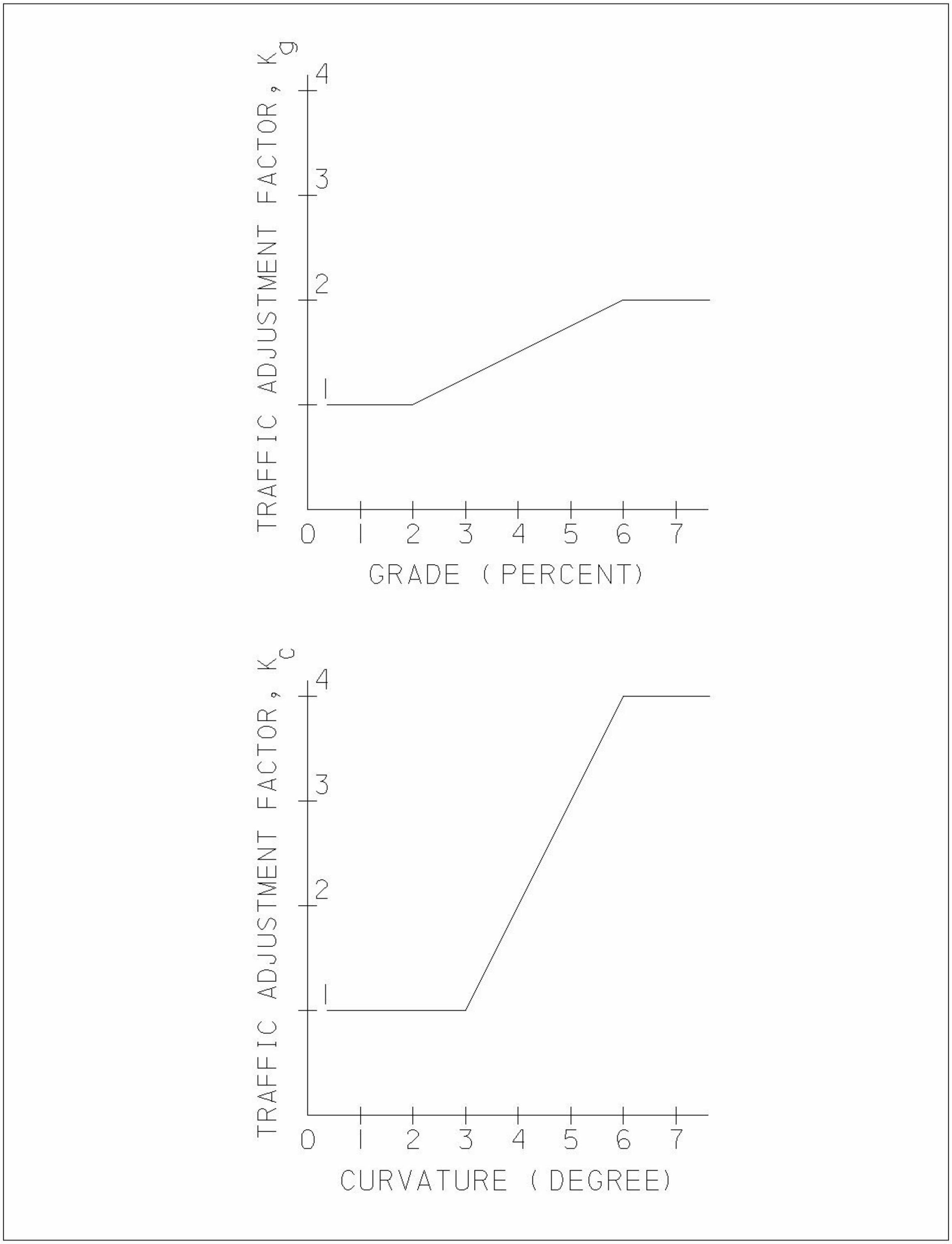

FIGURE 12.13
GRADE TRAFFIC ADJUSTMENT FACTOR (K_g) AND CURVATURE TRAFFIC ADJUSTMENT FACTOR (K_c)

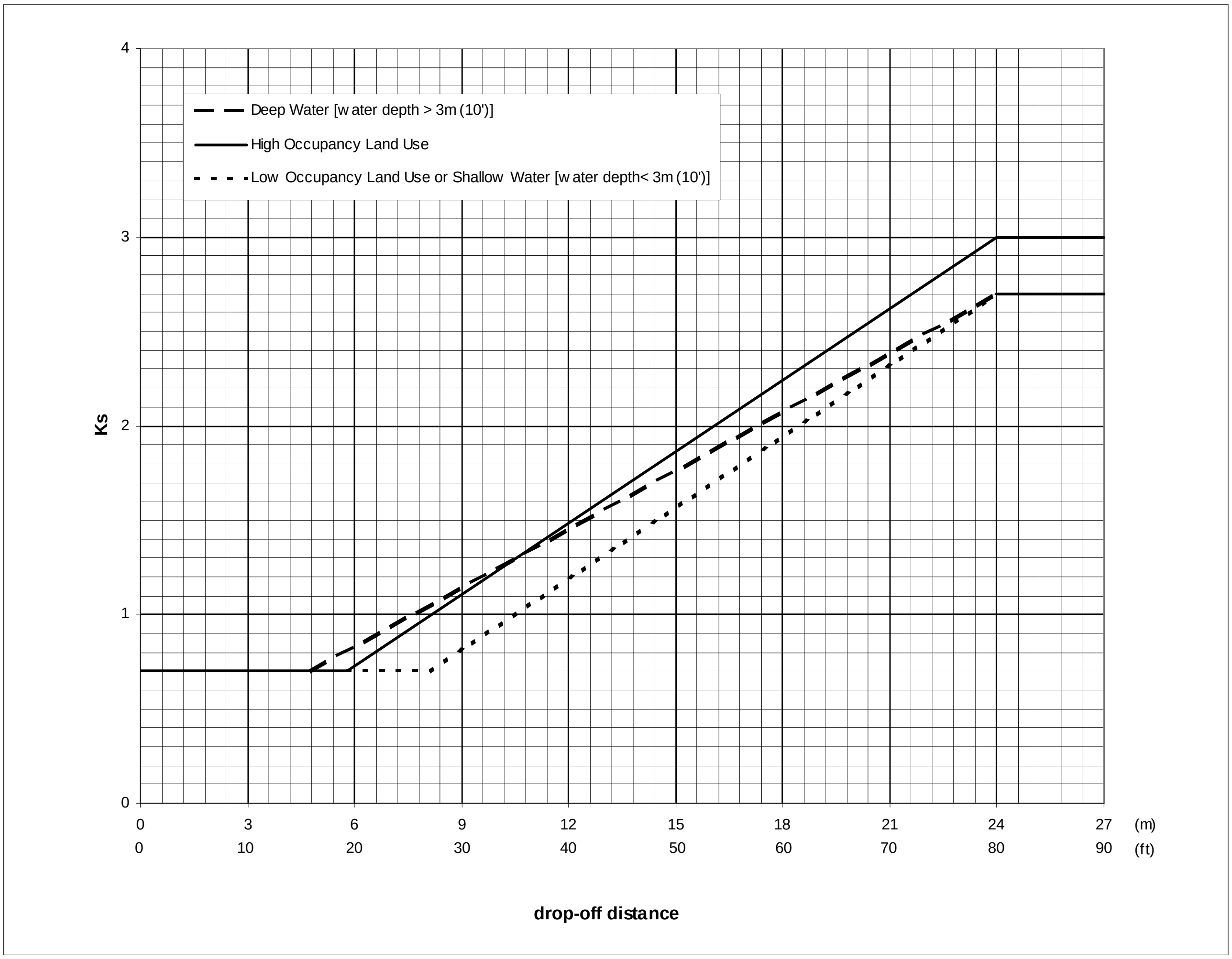

FIGURE 12.14
DROP-OFF TRAFFIC ADJUSTMENT FACTOR (K_S)

FIGURE 12.15
SAMPLE AUTHORIZATION

Date:

Subject: Alternate Bridge Railing Test Level Authorization
___________ County
SR____ Section____
Segment ____ Offset____

To: District Executive

From: Assistant District Executive - Design

Reference is made to your request dated (date) to specify Test Level ___ (TL-__) (Name of Standard Railing) detail (Railing Height) for the subject project in lieu of the Typical Bridge Railing.

The District Bridge Engineer and District Plans Engineer reviewed computations as per current Publication 13M (DM-2) Chapter 12, Section 12.11, Railing System Test Level Selection for Bridges and concurs with the use of Test Level 4 (TL-4) (Name of Standard Railing) detail (Railing Height) as per (Standard) on the proposed structure.

A copy of this Authorization will be kept in the permanent bridge inspection file.

Concurrence: ______________________ Date: _____
District Plans Engineer

Concurrence: ______________________ Date: _____
District Bridge Engineer

Concurrence: ______________________ Date: _____
District Executive

cc: Chief, Highway Design and Technology Section, Highway Delivery Division, Bureau of Project Delivery