

CALIFORNIA LOCAL COUNTY ROADS

ROADSIDE SAFETY POCKET GUIDE



**GUIDELINES FOR THE INSPECTION AND
MAINTENANCE OF ROADSIDE SAFETY HARDWARE
NOVEMBER 2016**



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Introduction

The purpose of this pocket guide is to present basic guidelines for guardrail inspectors and maintenance personnel. This pocket guide presents important information contained in the AASHTO Roadside Design Guide, California Department of Transportation Design Guidelines, Standards, Drawings, Policies, and Approved Product List to ensure that all barrier installations are built and maintained to current standards.

Guardrail systems are designed and installed for one primary reason – to reduce the severity of a crash by preventing a motorist from reaching a more hazardous fixed object or terrain feature.

Frequently Asked Questions

When reviewing proposed and existing barrier installations in the field, the following questions must be addressed:

1. Is the guardrail system more hazardous than the condition being shielded? (page 7 – Design Option)
2. Is an existing guardrail installation long enough to shield the hazard? (page 13 – Length of Need)
3. If new guardrail is installed as shown on the plans, is there a possibility of a motorist still reaching the primary hazard? (page 18 – Length of Need Field Check)
4. Should the guardrail be extended to shield a secondary hazard or obstruction? (page 18 – Length of Need Field Check)
5. Are there any vertical obstructions within the guardrail system's design deflection? (page 11e- Zone of Intrusion, or AASHTO Roadside Design Guide, Section 5.5.2 – Barrier Deflection Characteristics)
6. Does the guardrail end within 200 feet of the start of another guardrail run that could be connected? (Caltrans Traffic Manual, Chapter 7-03.6)
7. Does the guardrail terminate within 200 feet of a cut slope appropriate for a buried in backslope terminal? (page 41e- Buried in Backslope)
8. Do the slopes around the terminal (approach, adjacent, and runout) need regrading? (page 54 – Terminal Grading)
9. Has the guardrail height been reset after an overlay? (page 24 – Guardrail Height)

10. Is an appropriate end treatment being used? (page 39 – Terminal Decision Tree)
11. Is guardrail considered in sensitive areas such as school playgrounds and reservoirs? (AASHTO Roadside Design Guide, Section 5.2.3 – Bystanders, Pedestrians, and Bicyclists)
12. Is there adequate soil support behind strong post guardrail shielding a slope or are longer posts required? (page 26 – Barrier Placement on Slope, page 26)
13. Are there dike (curbs) in front of the barrier or terminal that could adversely affect crash performance? (page 27 – Guardrail and Dikes)
14. Can the guardrail be curved around the radius of a minor low speed roadway or driveway in order to better protect the motorist from hitting the hazard being shielded? (page 37 – Guardrail at Intersections and Driveways)
15. If damaged guardrail is along a curve, are there adequate advance warning signs and/or curve delineation in place? (page 74 – Repair/Upgrade/Remove)

This document, used in conjunction with field reviews, and appropriate Caltrans Traffic Manual, standards, policies and procedures provides the information needed to answer these and other questions pertaining to optimal design, inspection, and maintenance of guardrail systems.

Guardrail Basics

Barrier Guidelines

The use of a traffic barrier is based on the premise that a barrier should be installed only if it reduces the severity of potential crashes.

There are instances where it is not immediately obvious whether the barrier or the unshielded condition presents the greater danger to a motorist.

In such instances, guidelines may be established by using a benefit/cost analysis whereby factors such as design speed, roadway alignment, crash history and traffic volumes can be evaluated in relation to the barrier need.

The primary benefit obtained from selecting one design over another based on safety is the expected reduction in the future costs of crashes. These costs typically include property damage costs and personal injury costs. The costs used in a benefit/cost analysis are generally the direct construction, right-of-way, and maintenance costs incurred by the highway agency.¹

This procedure is typically used to evaluate three options:

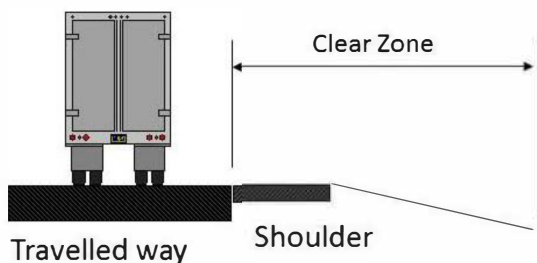
1. Remove or reduce the condition so that it no longer requires shielding.
2. Install an appropriate barrier.
3. Leave the condition unshielded with adequate delineation.

¹ AASHTO Roadside Design Guide, 4th Edition, 2011, 2.1 Benefit/Cost Analysis

Clear Zone

The clear zone is defined as the unobstructed, traversable area provided beyond the edge of the through traveled way for the recovery of errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function like through lanes.²

It can be used as a designate area bordering the roadway, starting at the edge of the traveled way, which is available for safe use by errant vehicles. Safe use generally means the slope is flat enough and free of fixed object hazards so a motorist leaving the road is able to stop and return to the roadway safely.



The clear zone distances shown below represent minimum recommended distances for new construction or reconstruction and are based on limited data. The best answer to the question “How wide should the clear zone be?” is “As wide as practical in each situation – but at least as wide as the distances shown in Table 1.

² AASHTO Roadside Design Guide, 4th Edition, 2011, 3.1 The Clear-Zone Concept

Table 1: Design Clear Zone

Design Speed (mph)	Design ADT	Foreslopes			Backslopes		
		1V:6H or flatter	1V:5H to 1V:4H	1V:3H	1V:3H	1V:5H to 1V:4H	1V:6H or flatter
≤40	UNDER 750 ^c	7-10	7-10	b	7-10	7-10	7-10
	750-1500	10-12	12-14	b	10-12	10-12	10-12
	1500-6000	12-14	14-16	b	12-14	12-14	12-14
	OVER 6000	14-16	16-18	b	14-16	14-16	14-16
45-50	UNDER 750 ^c	10-12	12-14	b	8-10	8-10	10-12
	750-1500	14-16	16-20	b	10-12	12-14	14-16
	1500-6000	16-18	20-26	b	12-14	14-16	16-18
	OVER 6000	20-22	24-28	b	14-16	18-20	20-22
55	UNDER 750 ^c	12-14	14-18	b	8-10	10-12	10-12
	750-1500	16-18	20-24	b	10-12	14-16	16-18
	1500-6000	20-22	24-30	b	14-16	16-18	20-22
	OVER 6000	22-24	26-32 ^a	b	16-18	20-22	22-24
60	UNDER 750 ^c	16-18	20-24	b	10-12	12-14	14-16
	750-1500	20-24	26-32 ^a	b	12-14	16-18	20-22
	1500-6000	26-30	32-40 ^a	b	14-18	18-22	24-26
	OVER 6000	30-32 ^a	36-44 ^a	b	20-22	24-26	26-28
65-70 ^d	UNDER 750 ^c	18-20	20-26	b	10-12	14-16	14-16
	750-1500	24-26	28-36 ^a	b	12-16	18-20	20-22
	1500-6000	28-32 ^a	34-42 ^a	b	16-20	22-24	26-28
	OVER 6000	30-34 ^a	38-46 ^a	b	22-24	26-30	28-30

Ref: AASHTO Roadside Design Guide, 4th Edition 2011, Chapter 3, Table 3-1, Pg 3-3

NOTES:

- a) Where a site-specific investigation indicates a high probability of continuing crashes, or such occurrences are indicated by crash history, the designer may provide clear-zone distances greater than the clear zones shown in this table. Clear zones may be limited to 30 ft. for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.
- b) Because recovery is less likely on unshielded, traversable 1V:3H fill slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of slope. Determination of the recovery area at the toe of the slope should consider right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the

through travelled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of the slope. See the Roadside Design Guide, AASHTO 2011 for more information.

- c) For roadways with low volumes, it may not be practical to apply even the minimum values found in Table. See the Roadside Design Guide, AASHTO 2011 for more information.
- d) When design speeds are greater than the values provided, the designer may provide clear-zone distances greater than those shown in Table.

Design Options (In order of preference)

Design options for reducing roadside obstacles, in order of preference, are as follows³:

1. Remove the obstacle
2. Redesign the obstacle so it can be safely traversed
3. Relocate the obstacle to a point where it is less likely to be struck
4. Reduce impact severity by using an appropriate breakaway device
5. Shield the obstacle with a longitudinal traffic barrier designed for redirection or use a crash cushion
6. Delineate the obstacle if the previous alternatives are not appropriate

REMEMBER: A barrier should only be considered if the consequences of a vehicle striking a fixed object or running off the road are considered more serious than hitting a traffic barrier.

³ AASHTO Roadside Design Guide, 4th Edition, 2011, Section 1.2 – Strategic Plan for Improving Roadside Safety

Roadside Obstacles

Roadside features that are normally considered for shielding are shown in Table 2. Note that many man-made hazards can be redesigned or relocated to make shielding unnecessary. Crash history, traffic volumes and speeds, roadway geometrics, and the offset distances to the hazard are factors that should be considered when deciding on barrier installation.

Table 2: Barrier Guidelines for Non-Traversable Terrain and Roadside Obstacles

Obstacle	Guidelines
Bridge piers, abutments, and railing ends	Shielding generally needed.
Boulders	Judgment decision based on nature of fixed object and likelihood of impact.
Culverts, pipes, headwalls	Judgment decision based on size, shape and location of obstacle.
Foreslopes and backslopes (smooth)	Shielding not generally required.
Foreslopes and backslopes (rough)	Judgment decision based on likelihood of impact.
Ditches (parallel)	Refer to Figures 3-6 and 3-7 in RDG.
Ditches (transverse)	Shielding generally required if likelihood of head-on impact is high.
Embankment	Judgment decision based on fill height and slope (see Figure 5-1 in RDG).
Retaining Walls	Judgment decision based on relative smoothness of wall and anticipated maximum angle of impact.
Sign/Luminaire supports	Shielding generally required for non-breakaway supports.
Traffic signal supports	Isolated traffic signals within clear zone on high-speed rural facilities may need shielding.
Trees	Judgment decision based on site-specific circumstances
Utility poles	Shielding may be needed on a case by case basis.
Permanent bodies of water	Judgment decision based on location and depth of water and likelihood of encroachment.

Ref: AASHTO Roadside Design Guide , 4th Edition 2011 Chapter 5, Table 5-2, Pg. 5-9

Roadside Slopes (Embankments)

Although the CALTRANS graph for barrier requirements at embankments, as shown in Figure 1 below, suggests that slopes steeper than 1V:3H are candidates for shielding, it does not take traffic speeds, volumes or roadway geometry into consideration. If the slope does not warrant barrier but there are significant hazards on the slope or at its base, barrier may still be appropriate.

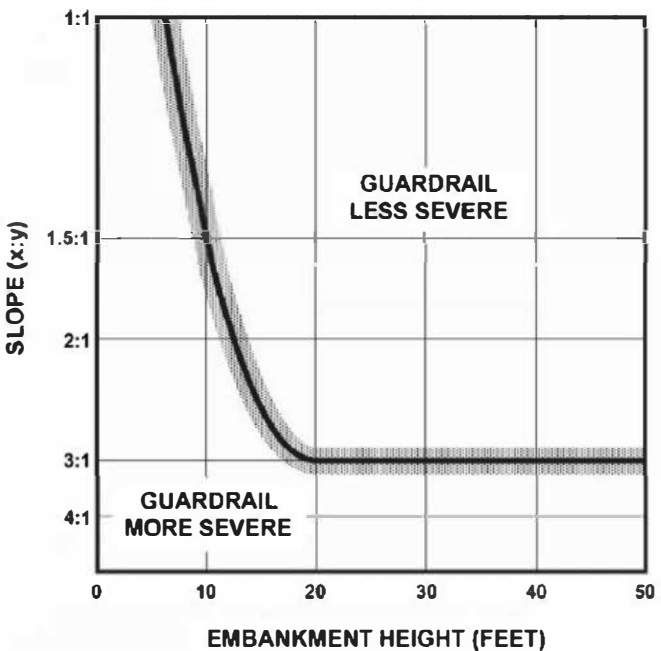


Figure 1: Barrier Requirements for Embankment Heights

REF: CALTRANS Traffic Manual – Figure 7-1: Equal Severity Curve

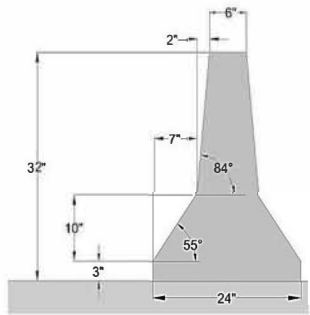
Barriers

A roadside barrier is a longitudinal barrier used to shield motorists from natural or man-made obstacles located along either side of a traveled way⁴. Barriers are usually categorized as rigid, semi-rigid or flexible depending on their deflection characteristics when impacted.

For more information, go to FHWA Resource Charts at http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/resource_charts/

Rigid Systems

The **New Jersey Safety-Shape Barrier** was the most widely used safety shape concrete barrier prior to the introduction of the F-shape. As shown, the "break-point" between the 55 deg and 84 deg slope is 13 inches above the pavement, including the 3 inch vertical reveal.



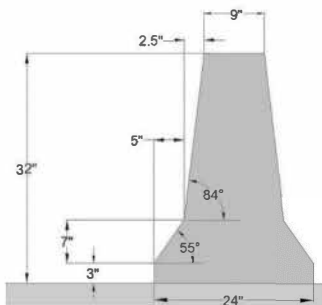
The flatter lower slope is intended to redirect vehicles impacting at shallow angles with little sheet metal damage, but can cause significant instability to vehicles impacting at high speeds and angles.

NCHRP 350 TL-4: 32" Tall and TL-5: 42" Tall.

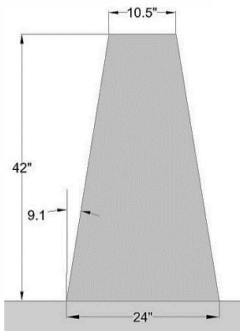
The **F-shape Barrier** has the same basic geometry as the New Jersey barrier, but the "break-point" between the lower and upper slopes is 10 inches above the pavement. This modification results in less vehicle climb in severe impacts and improved post-crash trajectories.

⁴ AASHTO Roadside Design Guide, 4th Edition, 2011, Chapter 5 – Roadside Barriers

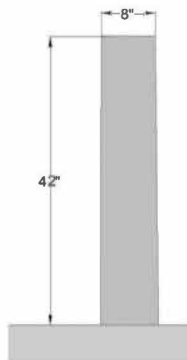
The 7.5 inch horizontal distance from the toe of the F-shape to its top corner also reduces the roll angle of impacting trucks and other vehicles with high centers-of-gravity.



Caltrans developed and successfully tested a **single slope concrete barrier** having a 9.1 degree angle from vertical. In crash tests, it performed very much like the F-shape with good post-impact vehicle trajectories.



A **vertical concrete barrier** may be a good choice where vehicle roll must be minimized, such as when shielding a bridge pier. This shape offers the best post-crash trajectories with only slight roll, pitch, and yaw angles. Occupant risk and lateral deceleration forces maybe somewhat higher than with a safety shape design.



For TL-4 and higher applications the 'Zone of Intrusion (ZOI)' should be considered as part of the barrier layout for new and reconstruction projects. The Zone of Intrusion (ZOI) is the region measured above and behind the face of a barrier system where an impacting vehicle or any major part of the system may extend during an impact.⁵

⁵ AASHTO Roadside Design Guide, Section 5.5.2 Barrier Deflection Characteristics.

Semi-Rigid Systems

Strong-Steel Post W-Beam Guardrail

Test Level: NCHRP 350/MASH TL-3

Post: W6 x 9 or W6 x 8.5 x 6 ft.
Steel.

Post Spacing: 6'-3"

W-beam splices: Located at posts

Block-outs: 6" wide x 8" x 14" synthetic block-outs.

Height: 29"

Tolerance: +1" or -1¼"

Ref: Caltrans Traffic Manual, Chapter 7



Midwest Guardrail System (MGS)

Test Level: NCHRP 350/MASH TL-3

Post: W6 x 9 or W6 x 8.5 x 6 ft.
Steel or 6" x 8" or 8" diameter
wood posts.

Post Spacing: 6'-3"

W-beam splices: Located between posts

Block-outs: 8" or 12" timber or plastic block-outs.

Height: 31"

Tolerance: +1" or -3¼"

Ref: Caltrans Traffic Manual, Chapter 7



Rail Lapping – Guardrail must be lapped in the direction of travel of the adjacent traffic. This is done to minimize potential vehicle snagging on the end of a section should the guardrail pocket under impact.



Length of Need

Length of Need (L) is defined as the length of barrier needed in advance (upstream) of a fixed object hazard or a non-traversable terrain feature to prevent a vehicle that has left the roadway from reaching the shielded feature. It is determined by selecting the appropriate variables and using the formula to calculate the LON (the "L" value) shown in Figure 2.

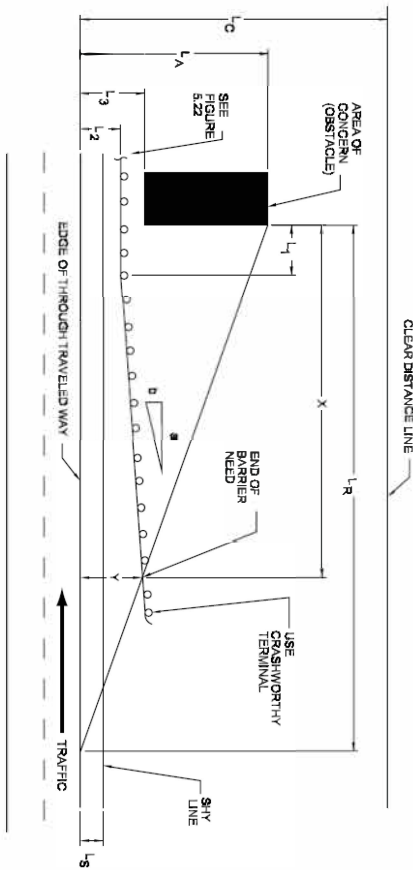


Figure 2: Approach Barrier Layout

X = Distance from the obstruction to end of barrier need.

Y = Distance from edge of through traveled way to the beginning of the Length-of-need.

L_A = Distance from edge of through traveled way to lateral extent of obstruction.

L₁ = Tangent length of barrier upstream from obstruction.

L₂ = Distance from edge of through traveled way to barrier.

L₃ = Distance from edge of through traveled way to obstruction.

L_C = Distance from edge of through traveled way to outside edge of the clear zone.

L_R = The theoretical Runout Length needed for a vehicle leaving the roadway to stop, see Table 3, page 15.

a : b = Flare Rate.

2011 AASHTO Roadside Design Guide, 4th Edition 2011, Figure 5-39, pg. 5-49.

Table 3: Runout Lengths

Design Speed (mph)	Runout Length (L_R) Given Traffic Volume (ADT) (ft.)			
	Over 10,000 veh/day	5,000 to 10,000 veh/day	1,000 to 5,000 veh/day	Under 1,000 veh/day
80	470	430	380	330
70	360	330	290	250
60	300	250	210	200
50	230	190	160	150
40	160	130	110	100
30	110	90	80	70

Ref: AASHTO Roadside Design Guide, 4th Edition 2011, Chapter 5, Table 5-10(b), Pg. 5-50.

Length of Need Procedure:

1. Choose an appropriate L_A as it is a critical part of the design process. This distance should include all features or hazards that need to be shielded, up to the design clear zone at each site.
2. Select a Runout Length (L_R) from Table 3.
3. The designer selects the tangent length, (L_1), if the barrier is flared. If the installation is parallel to the roadway, $L_1 = 0$. If a semi rigid barrier is connected to a rigid barrier, the tangent length should be at least as long as the transition section.
4. If the barrier is flared away from the roadway, the maximum recommended flare rate shown on Table 4, page 22 should not be exceeded.

5. Calculate the Length of Need (X) from the following equation and round the calculated value up to the nearest 12.5-foot or 25-foot rail segment:

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

6. For parallel installations i.e. no flare rate, the previous equation becomes:

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

Length of Need for Opposing Traffic

- X is determined using the same equation.
- All lateral dimensions are measured from the centerline for a two-lane roadway. See Figure 3 for layout on page 17.
- There are three ranges of clear zone width, L_C , which deserve special attention:
 1. If the barrier is beyond the appropriate clear zone for opposite direction traffic, no additional barrier and no crashworthy end treatment is required. (NOTE: an appropriate barrier anchor remains necessary to ensure proper containment and redirection for near-side impacts).
 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.

Length of Need (LON) Field Check

A straightforward method to verify correct LON in the field is to stand on the roadway edge directly opposite the shielded feature (Figure 4)

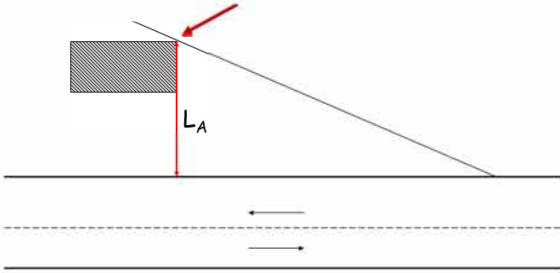


Figure 4: Identify the hazard

Then pace off the appropriate runout length from the Table 3 on page 15. (Figure 5)

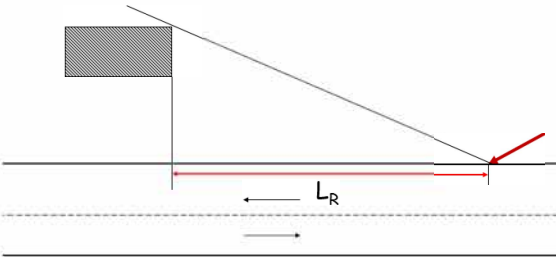


Figure 5: Define the point of departure

At that point, turn and look at the shielded area. (Figure 6).

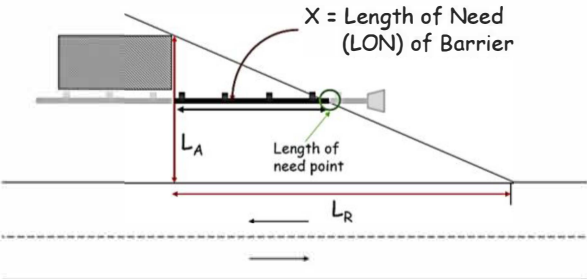


Figure 6: Intersect the hypotenuse (Length of need point)

If the proposed (or actual) guardrail installation crosses that line of sight, then the area is adequately covered.

(NOTE: if the terrain makes it impossible for a vehicle to reach the hazard from that point, the installation may be longer than needed. On the other hand, if the intervening terrain is also hazardous or if there are other significant obstacles in the immediate vicinity, it may be desirable to extend the barrier to shield these secondary concerns.

Additional Design Considerations

Although it is critical that the correct length of need be installed, there are several other placement considerations essential to good barrier performance. These include adequate deflection distances behind each type of barrier, barrier height, guardrail flare rates, and the location of barrier on slopes and behind curbs. These factors are discussed further on pages 20 to 37.

Design Deflection Distance

This is based on the results of 62-mph impacts into the barrier at a 25-degree impact angle by the NCHRP Report 350 or MASH pickup truck. In the field, actual deflections can be much greater (or less) depending on actual impact conditions. CALTRANS specifies a minimum of lateral deflection of 3 ft. for standard w-beam (see in Figure 7), less than 3 ft. but greater than 1 ft. for stiffened section (see Figure 8), and less than 1 ft. for concrete (see Figure 9) section per Caltrans Traffic Manual Section 7-03.5.

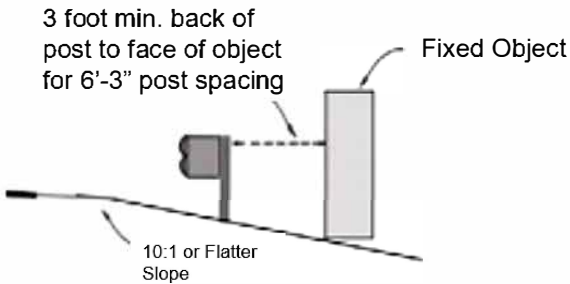


Figure 7: Design Deflection for Standard Section

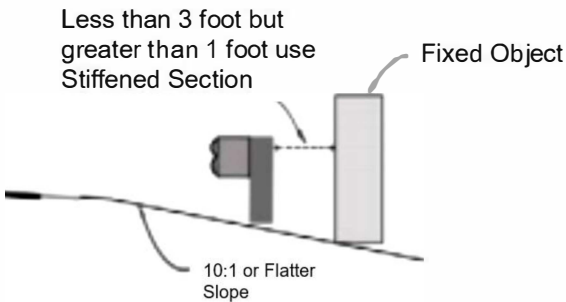


Figure 8: Design Deflection Distance for Stiffened Section

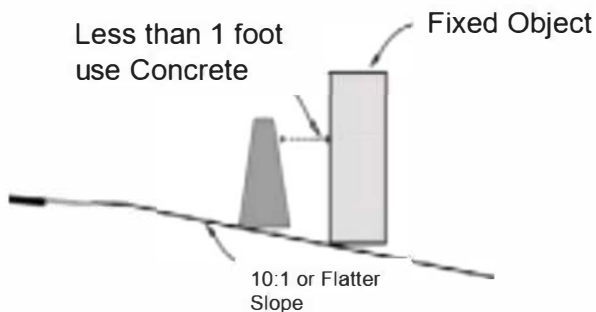


Figure 9: Design Deflection for Concrete Section

Guardrail Flare Rates

- A roadside barrier is considered flared when it is not parallel to the edge of the traveled way.
- The flare is normally used to locate the barrier terminal farther from the roadway and/or to reduce the total length of barrier needed.
- Disadvantages are it increases the angle of impact when struck and may require extensive site grading to ensure a flat approach.
- If a terminal used in conjunction with a flared barrier also has a flare, all offsets should be measured from an extension of the barrier flare.
- Refer to Table 4 for suggested flare rates.

Table 4: Suggested Flare Rates for Barrier Design

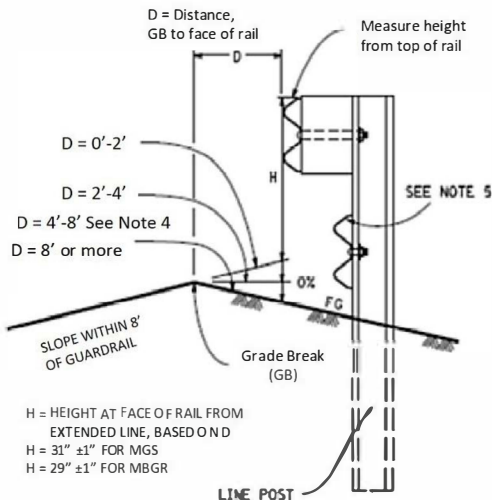
Design Speed (mph)	Flare Rate for Barrier inside Shy Line	Flare Rate for Barrier at or Beyond Shy Line	
		Rigid Barrier	Semi-Rigid Barrier
70	30:1	20:1	15:1
60	26:1	18:1	14:1
55	24:1	16:1	12:1
50	21:1	14:1	11:1
45	18:1	12:1	10:1
40	16:1	10:1	8:1
30	13:1	8:1	7:1

Ref: AASHTO Roadside Design Guide, 4th Edition, 2011 Table 5-9, pg. 5-48.

Height Measurement

The standard height of Strong-Steel Post W-Beam Guardrail is 29" and 31" for MGS. The height of guardrail can be measured from the following per Caltrans Standard (see Figure 10):

- Guardrail located above the pavement ($D = 0'-2'$): Measure the height from the pavement to the top of the w-beam rail.
- Guardrail located off the edge of pavement ($D = 2'-4'$): Measure the height in accordance to Figure 10.
- Guardrail located off the edge of pavement ($D = 4'-8'$): See Note 4: When there is a grade break within 4'-8' in front of the w-beam, the height will be determined by the engineer.
- Guardrail located 8 ft. or more from the edge of pavement: Measure the height from the ground at the rail location to the top of the rail.



Note 5: Place rub rail (guardrail element) and attach to post with no block when the height of guardrail is more than 2 ft. above the standard placement height.

Figure 10: Height Measurement

Pavement overlays that impact the effective height of rail elements shall include the required action from Caltrans Traffic Manual Table 7-4 for metal beam guardrail.

Table 5: Barrier Height Standards (Caltrans)

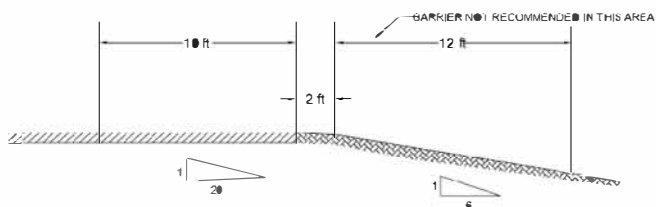
Existing Railing or Barrier	Std Height (in)	Tolerance (in)	Required Action
Metal Beam Guardrail (MBGR)	29	+1 -1½	Raise block and rail using additional hole(s) in post. If out of tolerance: <ul style="list-style-type: none"> • Add rub rail if top of rail is above 30" • Reconstruct if top of rail is below 27-¾"
Metal Beam Barrier	30	N/A	Should be upgraded per policy to current standards. If not, contact the Headquarters Traffic Operations Liaison.
Thrie Beam	32	-3	Reconstruct if top of rail is below 29"
Type 50	32	-3	Remove and install Type 60 Barrier if height, not including glare extension or cap, is below 29"
Type 60	36	-7	Remove and install new Type 60 Barrier
All other barriers	N/A	N/A	Consult Bridge Barrier and Railing Specialists – Division of Engineering Services.
Crash Cushions	N/A	N/A	Remove, raise pad to grade and replace cushion all per manufacturer.

Caltrans Policy Directive 03-01: "All new and replacement guardrail shall be specified with steel posts if the surrounding environment contains potential fuel for wildfire".

Barrier Placement on Slopes

Barrier, regardless of type, performs best when an impacting vehicle is stable when contact is first made. Since vehicles running off the road at high speeds tend to become airborne and are likely to override barrier placed on a slope, the following guidelines apply:

- Rigid or semi-rigid barriers (including concrete median barrier and guardrail) should not be placed where the adjacent slope or roadside slope leading up to the barrier exceeds 1V:10H.
- Strong post systems with 6 ft posts need a minimum of 3 ft from the face of the rail to the hinge point.
- Strong post systems with less than 3 ft from the face of the rail to the hinge point, 7 ft posts should be used.
- MGS barrier can be placed at the hinge point of a 1V:2H when 9 ft steel posts are used.
- When the slopes are between 1V:10H and 1V:6H, the face of the barrier must not be between 2 to 12 feet beyond the grade hinge point, as shown in Figure 11.



See AASHTO Roadside Design Guide, 4th Edition 2011, Figure 5-38, pg. 5-47.

Figure 11: Recommended Barrier Placement on 1V:6H

Guardrail and Dike

Dikes do not have a significant redirection capability and can have the same type effect on vehicle trajectory as slopes, i.e., wheel impact with a dike can cause a vehicle to vault over a barrier placed above or beyond it. The following guidelines apply (See Caltrans Standard plans A77N4)

For Metal Beam Guardrail (See Figure 12)

- Type F dike is placed directly under the face of metal beam guardrail installations. Type F dike is 4 inches high and is necessary for drainage underneath a guardrail installation.
- Type C dike (2-inch high) is the only dike that may be used in front of the guardrail or end terminal. In such cases, it is not necessary to place compacted embankment material behind Type C dike.

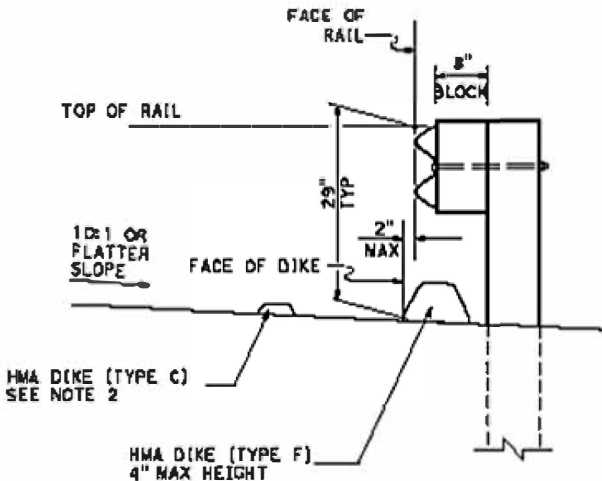


Figure 12: MBGR Dike Positioning

For MGS (see Figure 13)

- Dikes up to 6-inch high may be used under the rail or out up to 7-inches from the face of the rail to face of dike (for 12" blocks only).
- Type F (4-inch) dike may also be used underneath rail elements.
- Only Type C (2-inch) dike shall be placed in front of all terminals.
- Mountable dike should not be used.

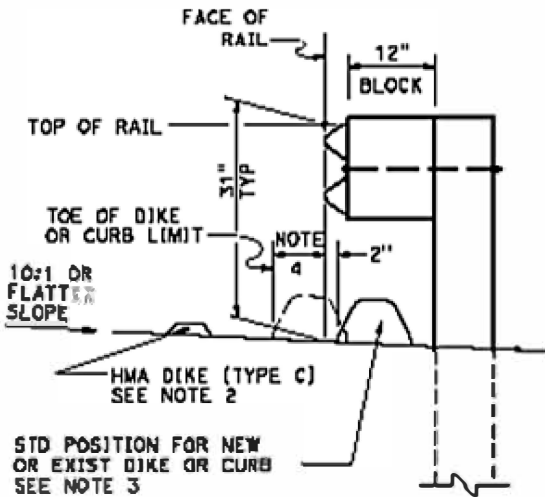


Figure 13: MGS Dike Positioning

For dike and curb details, see Standard Plans A87A and A87B.

Guardrail and Trees

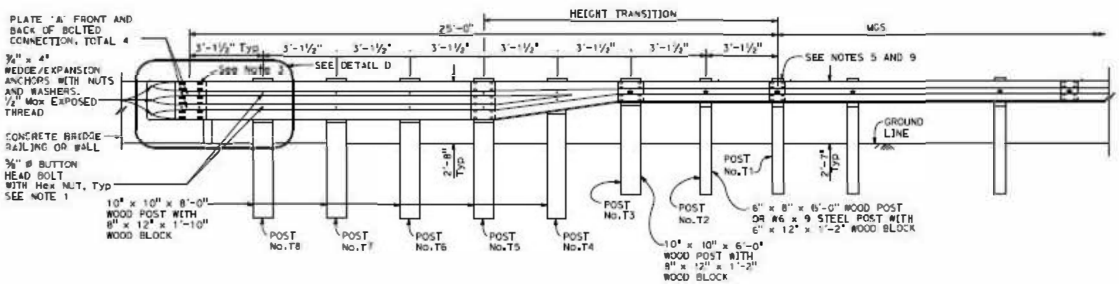
- Generally guardrail is not used to shield utility poles or trees. However, individual trees and poles that are in vulnerable locations and cannot be removed or relocated are sometimes shielded.
- Where trees or poles are present behind barrier warranted by other features (e.g. bridge ends or steep embankments), adequate deflection distance must be available or the barrier must be stiffened in advance of these secondary hazards.
- Consider removing trees where they are an obstruction or in locations where they are likely to be hit.
- Use crash history at similar sites, scars indicating previous crashes or field reviews to determine removable trees.
- Tree removal is usually a preferred option but an assessment regarding its expense and effectiveness should be considered.
- 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.

Connections to Bridge Barriers

Since there are numerous bridge barrier designs currently in place on California highways, standard transition designs are not always directly applicable to existing bridges. However, crashworthy designs can be developed if three concerns are met: an adequate transition between the bridge end and the approach guardrail, an adequate attachment to the bridge barrier itself, and the elimination of any potential snag points at the bridge end.

- A transition is simply a gradual stiffening of the approach guardrail at the bridge end so the rail cannot deflect enough to result in a vehicle “pocketing” when it reaches the rigid bridge barrier.
- A structurally adequate attachment of the guardrail to the bridge barrier is shown on the transition details as well. This detail is needed to prevent the approach railing from pulling free from the bridge barrier. Figure 14 shows the Caltrans Transition Design for MGS barrier on new construction.
- If the existing bridge railing is structurally deficient, two options should be considered. A successfully crash tested as per AASHTO MASH independent anchor block may be installed into which the approach rail may be transitioned, or successfully crash tested as per AASHTO MASH w-beam structure mounted railing can be continued over the structure. The second treatment eliminates the need for a new anchor block and increases the capacity of a substandard bridge railing. It also eliminates the probability of a motorist striking the anchor block at the departure end of a bridge.
- Finally, if the bridge barrier is significantly higher than the approach railing, a truck or SUV impacting the approach railing could lean over the railing far

enough to snag on the end of the bridge barrier, or if no rubrail or concrete curb is used, a vehicle's tire could fold under the guardrail and snag on the bottom edge of the bridge parapet.



Ref. CALTRANS 2015 Standard Drawing, A77U4

Figure 14: CALTRANS Transition Design

Guardrail Post Obstructions

Guardrail post spacing (6'-3") provides resistance for rail deflection on impact and lessens the tendency of the rail to pocket during impact. Sometimes situations in the field occur where a guardrail post cannot be driven that interfere with the standard post spacing. These locations can be at a pipe culvert, drainage inlet, buried utility or a low-cover pipe or culvert. The following are available alternatives:

Longitudinal Adjustment

A single post may be shifted up to 12 inches along the length of the rail. The locations of adjacent line posts should not be adjusted to compensate for the displacement (as illustrated in Figure 15).

Bolt block to post but do not drill new hole to bolt rail to block/post.

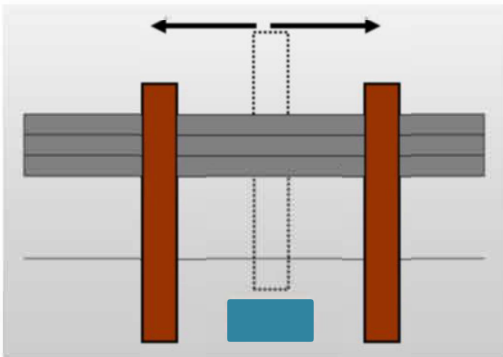


Figure 15: Longitudinal Adjustment

Ref: Caltrans Standards for Shift Post details for MGS.

Lateral Adjustment

A post may be shifted a maximum of 8" or 12" back (perpendicular to the rail). This allows for the addition of a second block.

No more than one additional block is allowed (or two blocks max.). See Caltrans Standard for Multiple Block-out details for MGS.

Omitting Post

Standard w-beam: either one or two posts may be omitted, resulting in a clear span 18 feet. Additionally rail stiffness is obtained by "nesting" w-beam rail elements over the clear span and extending this double rail 12.5 feet at both ends of the clear span. Since all connections are made at a splice, there will be four thickness of rail at the same location, as shown in Figure 16. See Caltrans Traffic Manual, Chapter 7



Figure 16: Typical Nested Panel

NOTE: Two sections of W-Beam rail element, one set inside the other.

MGS: Up to 3 posts can be omitted and the rail is not nested. Three breakaway wood posts (CRT posts) must be used at both ends of the clear span for standard w-beam and the MGS design.

Guidelines:

1. When posts are removed for either metal beam guardrail or MGS, the guardrail needs extra length (about 100 ft) before another post is skipped so that the guardrail can function as expected
2. Posts may not be skipped within the transitions, and end terminals or within 25 ft. of them.
3. Posts may not be skipped within strengthened rail sections where there are fixed objects as there is an increase in deflection when the post is skipped.

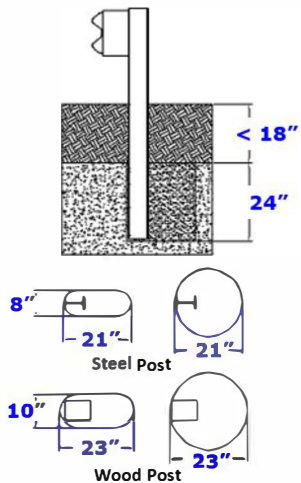
If the above standards are not met in field, please contact Caltran's Traffic Division for further guidance.

Guardrail Placement in Rock and Mowing Strips

Strong-post (both wood and steel posts) w-beam guardrail is designed to absorb some crash energy through post rotation in the soil prior to post failure. Restraining these posts by setting them in narrow holes drilled into solid rock, by setting them in concrete, or by placing a “mowing strip” around the posts can lead to early post failure, placing more load on the rail element itself and possibly leading to rail rupture and subsequent penetration by an impacting vehicle.⁶

If solid rock is encountered within **0” to 18”** of the finished grade.

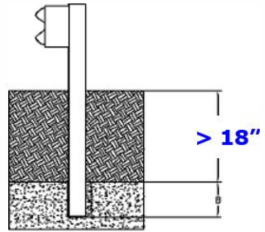
Drill a **21”** dia. hole for steel post or **23”** dia. hole for wood post, **24”** into the rock.



⁶ FHWA Memorandum, March 10, 2014, HAS-10/B64-B

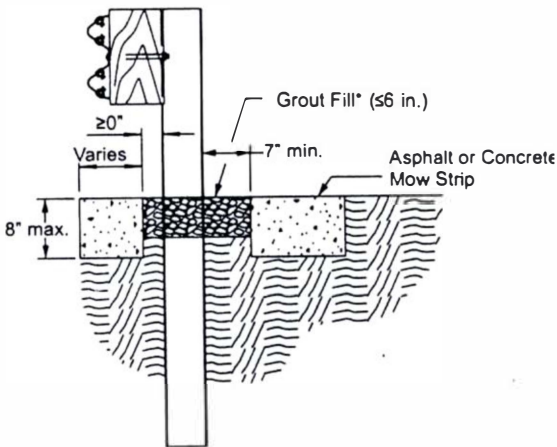
If solid rock is encountered below **18"**.

Drill a 8" dia. hole for steel post or 12" dia. hole for wood post, for 12" into the rock or to the desired standard embedment depth minus the depth of soil whichever is less.



8"  Steel Post

12"  Wood Post



- Any excess post length, after meeting these depths, may be field cut to ensure proper guardrail mounting height.
- Backfill with a cohesionless material.



Guardrail at Intersections and Driveways

When secondary roads or driveways intersect a main road so close to a bridge or other hazard that a full run of barrier cannot be installed, the following are design alternatives:

- Relocate or close the intersecting roadway/entrances.
- Terminate the guardrail in advance of the intersecting roadway.
- Short Radius Guardrail

While the site conditions can vary greatly, there are two major concerns that should be addressed.

1. If the hazard is a bridge end or pier, a crashworthy transition design is required. A crash cushion can be used if the space is too limited to use a standard transition. The section of barrier along the primary road must be long enough to react in tension to redirect impacting vehicles away from the shielded rigid object.
2. Oftentimes the feature traversed by a structure or another hazardous feature between the intersecting road and the structure can be shielded using a curved rail design. By using a curved rail design, high angle impacts into the curved section are likely. To reduce the risk of a vehicle going through or over the W-beam, modifications can be made to the posts, the W-beam-to-post connections, and the end treatment along the

intersecting road or driveway. A non-breakaway anchor should be used to add intermediate anchorage parallel to the main road when the guardrail is continued down an intersecting road or if there is an area of concern on the side slope that would cause a more severe collision than impacting the guardrail.

Terminals and Crash Cushions

Terminals

Crashworthy terminals anchor a barrier installation and are designed to eliminate spearing or vaulting when hit head-on, and redirect a vehicle away from the shielded object or terrain feature when the barrier is struck on the traffic face near the terminal. See Figure 17 as a guide in selecting the type of terminal.

For additional terminals go to the FHWA website at

http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/index.cfm

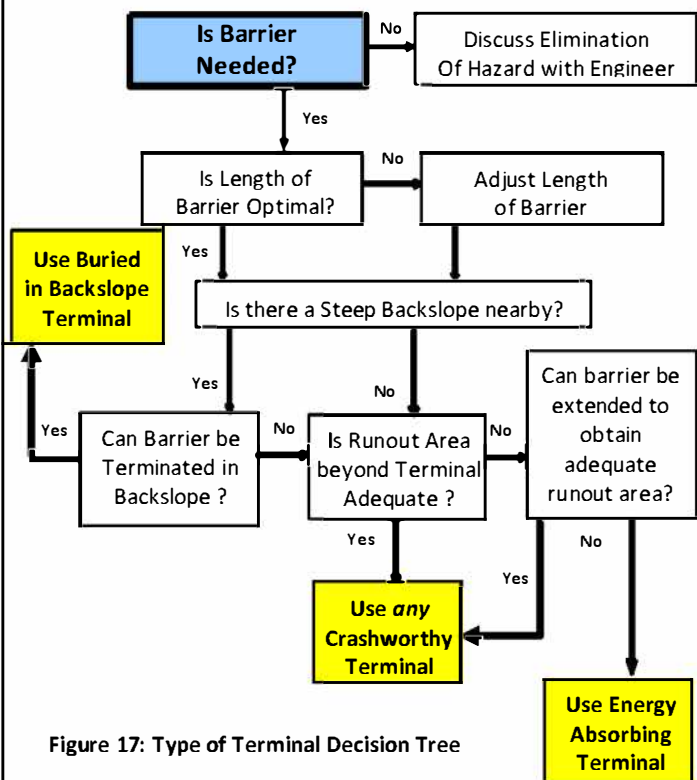


Figure 17: Type of Terminal Decision Tree

Terminal Types

Energy Absorbing Terminals – Terminals that can stop vehicles in relatively short distances in direct end-on impacts (usually 50 feet or less depending on type of terminal). Common terminals of this type include the ET-Plus, SKT, FLEAT, as well as several newer MASH designs.

Non-Energy Absorbing Systems – Systems that have a very limited ability to slow or capture an impacting vehicle. The SRT and the TL-2 MELT are two terminals in this category.

Flared Terminals – Terminals that have up to 4-foot offset at the approach end, but require a larger platform for installation. Both the SRT and the FLEAT are flared terminals.

Tangent Terminals – Terminals that are installed parallel to the roadway but may have a 2-foot offset over the first 50 feet of length. ET Plus and SKT are in this category.

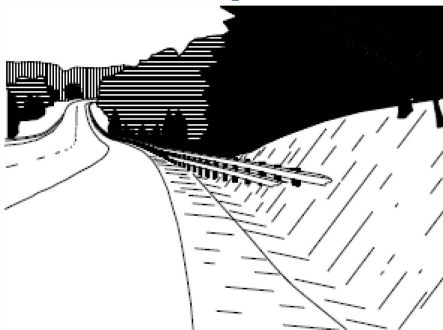
For more information see AASHTO Roadside Design Guide, 4th Edition 2011, Section 8.3.2.

NOTE:

- On two lane highways with two way traffic, provide crashworthy end treatments on both the approach and departure ends of the guardrail.
- On four-lane divided highways, use crashworthy end treatments on the approach ends. If the departure rail is within the clear zone for opposing traffic, provide crashworthy terminals on both the approach and departure ends. Note that oftentimes rail is not needed on the departure ends of bridges on divided roadways unless site specific circumstances require additional barrier.
- The ~~new~~ beam terminals shown below (except for the Buried in backslope design) are proprietary products. For each terminal, its major components are listed. Refer to the manufacturers' installation manual and

inspection checklists for detailed information on these designs and on any terminals that are subsequently approved for use in the state.

Buried in Backslope Guardrail Terminal



Test Level: NCHRP 350: TL-3

Characteristics:

- Used when the natural backslope perpendicular to the roadway is non-traversable.
- Keep the height of the w-beam rail constant relative to the roadway grade until the barrier crosses the ditch flow line.
- Use a flare rate appropriate for the design speed.
- Add a w-beam rubrail where needed, and
- Use an anchor (concrete block or steel post) capable of developing the full tensile strength of the w-beam rail or bolt to solid rock.

Note: Any existing terminals that are not anchored in a steep backslope and are similar to a turned-down terminal should be identified and scheduled for replacement if they are within the clear zone.

Energy Absorbing Terminals (Extruder Type)

An energy absorbing extruder type end terminal is designed to:

- a. Shield the blunt end of a w-beam guardrail,
- b. Bring an impacting vehicle to a safe stop by deforming the w-beam guardrail as the impact head is forced along the rail and
- c. To provide an anchor for downstream impacts. The following proprietary terminals are in this category.

Extruder Terminal ET-Plus (NCHRP 350)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:

<http://www.highwayguardrail.com/products/etplus.html>

Test Level: NCHRP 350: TL-2 and TL-3

Characteristics:

- Tangential end terminal.
- Rectangular impact front face (Extruder head).
- Rectangular holes in 1st rail support the tabs of the cable anchor bracket.
- Steel HBA and SYTP and wood post options are available.
- SYTP Retrofit in tube sleeve option available.
- End of W-beam rail with offset of 0' to 2'-0".

Sequential Kinking Terminal (SKT- NCHRP 350)



MASH Sequential Kinking Terminal (MSKT-MASH)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:

<http://roadsystems.com/skt.html>

Testing Criteria and Test Level:

- NCHRP 350: SKT TL-2 and TL-3
- AASHTO MASH: MSKT TL-3

Characteristics:

- Tangential end terminal.
- Square impact front face.
- Has a feeder chute (channel section that surrounds the rail) which gets wider at the downstream end.
- Rail has 3 (1/2" x 4" long) slots in the valley of the rail.
- There may be 5 additional slots (1/2" x 4" long) on both the top and bottom corrugations of the w-beam section, which makes it interchangeable with the FLEAT system.

- SP Standard Steel Posts, all hinge steel post, plug weld steel posts, or wood posts available.
- End of W-beam rail with offset of 0' to 2'-0".

NOTE: MSKT-MASH head may be used on 350 SKT device per Eligibility letter CC-130 – “350 SKT Terminal with MASH SKT Impact Head”

Softstop (MASH)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:

<http://www.highwayguardrail.com/products/SoftStop.html>

Testing Criteria and Test Level: AASHTO MASH: TL-3

Characteristics:

- Tangential end terminal.
- Breakaway steel posts at #1 and #2, standard posts 3 and beyond.
- Impact head crushes w-beam vertically when impacted head-on.

Energy Absorbing Terminals (Friction Type)

These terminals slow a vehicle impacting head-on through a combination of friction (using a slider mechanism or cables) and telescoping w-beam panels.

X-Lite (NCHRP 350)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:

<http://www.barriersystemsinc.com/xlite-end-terminal>

Test Level: NCHRP 350: TL-3

Characteristics:

- Tangential or Flared end terminal.
- Rectangular Impact Face.
- All steel driven posts.
- Uses a slider mechanism between post 1 and 2 that gathers and retains the rail when hit.
- Requires use of special shear bolts (yellow) at Posts 3 and 5 to allow rail to telescope in end-on impacts
- The anchor consists of posts #1 and #2 connected by tension struts and a soil plate below grade on post #2.

X-Tension (NCHRP 350)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:

<http://www.barriersystemsinc.com/#/x-tension>

Test Level: NCHRP 350: TL-3

How it works: Uses cable friction and collapsing rail elements to bring an impacting vehicle to a controlled stop in end-on impacts.

Characteristics:

- Tangential, Flared and Median end terminal.
- Impact head with locking bar to lock cables into place.
- Strut between the first post and a front anchor post.
- Steel and wood post options available.
- Two cables attached to soil anchor extend the entire length of the terminal.

Non-Energy Absorbing Terminals

While terminals in this category are considered crashworthy, they are not designed to slow an impacting vehicle significantly and should be used primarily at locations where there is a usable recovery area behind and beyond the terminal itself.

Slotted Rail Terminal (SRT-350) (NCHRP 350)



Slotted Rail Terminal (SRT-M10) (MASH)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:
<http://www.highwayguardrail.com/products/et-srt350.html>

Test Level Criteria and Test Level:

- NCHRP 350: SRT TL-2 and TL-3
- AASHTO MASH: SRT M10 TL-3

Characteristics:

- Flared end terminal.
- No impact head.
- Longitudinal slots on w-beam rail element.
- Strut and cable anchor bracket between posts #1 and #2 act together to resist the cable loads.
- Slot Guards on downstream end of slots.
- Steel and wood post options available.
- Parabolic flare on wood post option.
- Straight line flare on all SYTP steel post and HBA steel/wood post option.
- Should be installed at locations where sufficient runout area exists behind and downstream of the terminal.
- End of w-beam rail with offset of 4'-0"
- Wood post option has 3'-0" to 4'-0" offsets.

NOTE: Per Caltrans Letter to Trinity Highway Products, LLC, date September 28, 2016:

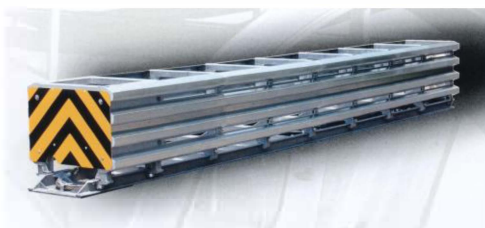
The SRT 350 (6-post, 8-post, & 9-post systems), SRT-27SP, and SRT-31 guardrail end treatments shall include directional labels on second slotted rails and slot guards. Manufacturer's instructions also available for proper installation.

Crash Cushions/Impact Attenuators

These devices are generally used to shield hazards in freeway gore areas or the ends of permanent or temporary traffic barriers.

For additional commonly used crash cushion throughout the U.S., go to the FHWA website at http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/index.cfm

Smart Cushion Innovation (SCI-100GM) (NCHRP 350/MASH)



For current details of this system, see Manufacturers Installation Assembly Manual at this website: <http://www.workareaprotection.com/attenuator.htm>

Test Level Criteria and Test Level:

- NCHRP 350: TL-2 and TL-3
- AASHTO MASH: TL-3

How it works: Hydraulic cylinders and cables in the attenuator provide resistance to stop a vehicle before it reaches the end of the cushion's usable length.

Requires a paved pad.

Locations: Median or shoulder protection. Gore two-side protection.

TAU-IIR (NCHRP 350)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:

<http://www.barriersystemsinc.com/tau-ii-r-crash-cushion>

Test Level: NCHRP 350 TL-3

How it works: Hyperelastic modules crush upon impact.

Three beam panels slide back when struck head-on.

Anchored at the front and rear of system. Requires a paved pad.

Locations: Median or shoulder protection. Gore Two-side protection.

TAU-II (NCHRP 350)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:

<http://www.barriersystemsinc.com/tau-ii-crash-cushion>

Test Level: NCHRP 350 TL-2 and TL-3

How it works: Energy absorbing cartridges crush upon impact. Three beam panels slide back when struck head-on.

Anchored at the front and rear of system.

Energy absorbing cartridges in each bay need to be replaced after each crash. Requires a paved pad.

Locations: Median or shoulder protection. Gore two-side protection.

QuadGuard Family (NCHRP 350/MASH)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:

http://www.energyabsorption.com/products/products_quadguard2_crash.asp

Test Level Criteria and Test Level:

- NCHRP 350: TL-2 and TL-3
- AASHTO MASH: TL-3

How it works: Hex-foam cartridges crush upon impact. Specially fabricated side panels having four corrugations slide back on a single track when struck head-on. Energy absorbing cartridges in each bay need to be replaced after each crash. Requires a paved pad.

Locations: Median or shoulder protection. Gore two-side protection.

Trinity Attenuating Crash Cushion (TRACC)(NCHRP 350)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:

<http://www.highwayguardrail.com/products/tracc.html>

Test Level: NCHRP 350 TL-2 and TL-3

How it works: Consists of a series of w-beam fender panels and an impact face which absorbs energy by cutting through slotted metal plates on the top sides of the guidance tracks when forced backward in an end on impact. Requires Paved Pad.

Locations: Median or shoulder protection. Gore two-side protection.

Crash Cushion Attenuating Terminal (CAT-350)(NCHRP 350)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:

<http://www.highwayguardrail.com/products/cat350.html>

Test Level: NCHRP 350 TL-3

How it works: During head-on impacts, the system telescopes rearward, shearing out tabs between the slots to decelerate the vehicle.

Locations: Median end protection.

Sand Barriers

Test Level: NCHRP 350 TL-2 and TL-3

How it works: Sand-filled plastic barrels dissipate the kinetic energy of an impacting vehicle by transferring the vehicle's momentum to the variable masses of sand in the barrels that are hit.

Locations: Temporary Construction Worksites i.e. Ends of Concrete Barriers; Gore Two-sided Protection; Wide Medians; Bridge Piers.

Energite III Module (sand)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:

http://www.energyabsorption.com/products/products_energite_iii.asp

Fitch Universal Module (sand)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:

http://www.energyabsorption.com/products/products_universal_barrels.asp

Big Sandy (sand)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:

<http://www.traffixdevices.com/cgi-local/SoftCart.exe/bigandy.htm?E+scstore>

CrashGard (TL-3)



For current details of this system, see Manufacturers Installation Assembly Manual at this website:

<http://plasticsafety.com/Products/Crash-Cushion/CrashGard-Sand-Barrel-System.aspx>

Terminal Grading Details

A barrier terminal is most likely to perform best when a vehicle is stable at the moment of impact and there is a traversable runout area immediately behind the terminal. Whenever practical, a barrier should be extended until these conditions can be met. Figure 18 shows the three grading areas of concern. Figure 19 shows CALTRANS Standard A77Q1 for grading at the terminal.

When a grading platform must be built it is critical that it be designed and constructed to blend with the original embankment and not cause instability in a vehicle before, during, or after a crash into the terminal. Note that the areas approaching and immediately adjacent to the terminal should be no steeper than 1V:10H. Steeper adjoining slopes should be gently transitioned to a flatter slope to minimize rollover potential.

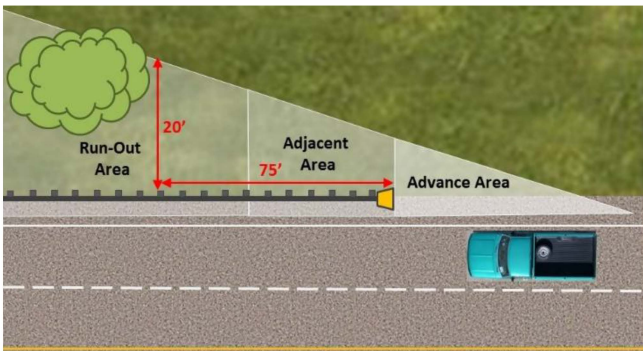
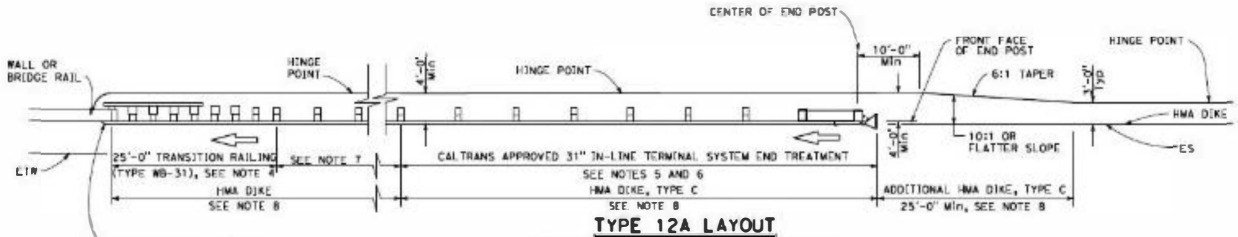
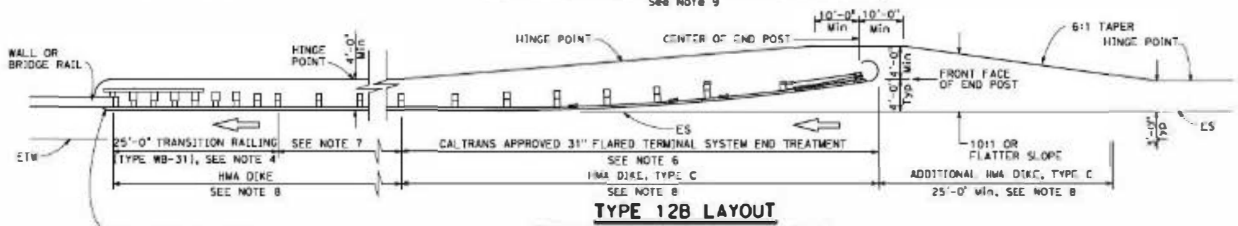


Figure 18: Grading Areas



TYPE 12A LAYOUT

(MCS installation at structure approach with 31' in-line end treatment at traffic approach end of railing)
See Note 9



TYPE 12B LAYOUT

(MCS installation at structure approach with 31' flared end treatment at traffic approach end of railing)
See Note 9

Figure 19: CALTRANS 2015 Standard Drawings A77Q1

Guardrail End Terminal Inspection

The following information was extracted from Caltrans 2016 Traffic Safety Systems for the Selection, Design, and Installation of Terminal Systems and Crash Cushions and from Construction Policy Directive (CPD) 16-6, May 11, 2016 provides direction on how to ensure these end terminals are properly installed and reviewed.

<http://www.dot.ca.gov/hq/construc/CPDirectives/cpd16-6.pdf>

Guardrail end terminals are safety elements used to protect those using the transportation system. It is important that end terminals are installed in accordance to manufacturer's recommendations and proper quality assurance reviews are performed prior to construction contract acceptance.

To ensure adequate quality assurance reviews for the installation of end terminals, implement the following steps for each end terminal location before, during, and after the end terminal is completely installed:

- Prior to the beginning of work, the contractor must inform the resident engineer of the type of end terminal to be installed at each location. The resident engineer will request from the contractor the manufacturer's documentation and checklist for the type of end terminal to be installed.
- Before installation begins, the ground where the end terminal will be installed must be graded and soil must be compacted in accordance with project specifications and contract plans.
- At any time prior to and during end terminal installation, the resident engineer will consult with the

project's design engineer about any necessary changes based on the site condition.

- During installation, the inspector will use the manufacturer's checklist to check end terminal components and details as recommended by the manufacturer. The inspector will notify the installer of any issues that do not conform to the manufacturer's recommendations.
- At completion of installation, the inspector will do a thorough quality assurance review using the manufacturer's checklist and make sure all components are set as required by the manufacturer's recommendations. The inspector must file a copy of the completed checklist in Category 46, "Assistant Resident Engineer's Daily Reports," of the project records. Grading and compaction of soil underneath the end terminal must be rechecked for proper grading and compaction.
- Pictures of the completed end terminal must be taken and placed in the project records.
- Information about the type of end terminal installed must be recorded on the project as built plans.

Common Installation Issues with Terminals

1. Grading not completed prior to installation.
2. Slope behind system does not meet standard drawing requirements.
3. Anchor cable and bearing plate not installed properly. Anchor cable loose and/or bearing plate buried.
4. Foundation tubes higher than 4 inches above ground line.
5. Systems with impact heads, head is not parallel to rail element.

6. CRT post breakaway hole or soil foundation tube more than 4" above grade.
7. Wrong type of dike under guardrail or terminal.
8. Shoulder backing not placed under guardrail.
9. Wood blocks not nailed to post.
10. Old existing concrete anchors not removed.

Contractor Responsibilities

These are some typical contractor responsibilities:

- Contractor must submit a manufacturer supplied Installer Certificate for each type of end treatment installed on a project demonstrating that the installer is certified by the manufacturer.
- After installation the contractor must submit a manufacturer's checklist (signed) that the system is installed according to the Departments and manufacturer's specifications.
- Contractor will supply at minimum one copy of the installation manual for each type of system being installed, preferably two copies.

Inspector and Maintenance Responsibilities

- Inspect installer certifications that have been submitted.
- The inspector must verify that the device is approved and is listed in The Approved Products List:
http://www.dot.ca.gov/hq/esc/approved_products_list/pdf/highway_safety_features.pdf
- The inspector must verify that all grading and slopes, in the approach area, adjacent run out area and recover area meet the requirements of the applicable standard drawings.

Inspection Guidelines

- Verify that all end treatment components are installed to manufacturer's and the Departments specifications which are to include but not limited to:

- Dimensions, bolting and fastening, rail overlaps, transition elements and markings as required depending on the type of crash cushion installed.
- Inspector must have the manufacturer's installation manual provided by contractor prior to installation.
- Inspector should verify all requirements for approaches and slopes meet project specifications or an approved FACT SHEET/DESIGN EXCEPTION has been obtained if not.
- Each approved system has an Inspection Checklist. Maintenance should retain a copy and provide a copy to the District Traffic Safety Devices Coordinator. Construction should file the checklist with the RE Project File/Book.

Maintenance

Guardrail systems must be kept in good working condition (“as-built condition”) if they are to contain and redirect impacting vehicles. Some deterioration occurs as a result of crash damage and environmental degradation. Much of this wear can be considered “cosmetic” and may not measurably affect barrier performance. However, some kinds of damage may seriously degrade performance such as those listed below in the Longitudinal Barrier Damage and Terminal Damage sections. Repairs to these types of damage should be given priority.

While it is not practical to quantitatively define “in a timely manner”, each identified damaged barrier site must be assessed, prioritized and scheduled for repairs based upon risk exposure (highway type, extent of barrier/terminal damage, potential for being struck again within the repair time window).

Longitudinal Barrier Damage

The types of guardrail damage listed below may result in inadequate structural and substandard redirective performance.

- Vertical tears in the W-beam rail that begin at the top or bottom edge. These are likely to result in rail separation in a subsequent crash.
- Similarly, holes in the rail resulting from damage or deterioration that reaches the top or bottom of a rail or one hole with a section greater than 1 inch or several holes with a dimension less than 1 inch within a 12.5-foot length of rail.
- More than 2 missing or ineffective splice bolts.
- More than 9 inches of lateral deflection over a 25-foot length of rail.

- Top rail height more than 2 inches lower than the original rail height.
- Rail flattening that increases the W-beam section width from its original 12 inches.

Terminal Damage

These types of guardrail terminal damage can result in poor barrier performance and increased occupant injury severities in a crash:

- Broken or damaged end posts.
- Missing or very slack rail-to-end post cables.
- Missing or misaligned cable bearing plate at end posts.
- Impact head not properly aligned with W-beam rail elements.
- W-beam rail element not properly seated in the impact head or incorrect rail element for terminal type.

The following pages consist of excerpts from NCHRP Report 656, Criteria for the Restoration of Longitudinal Barrier.

<http://www.trb.org/Publications/Blurbs/163512.aspx>

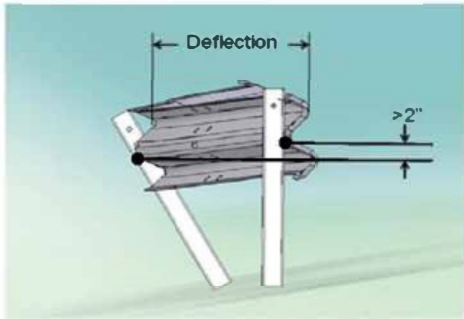
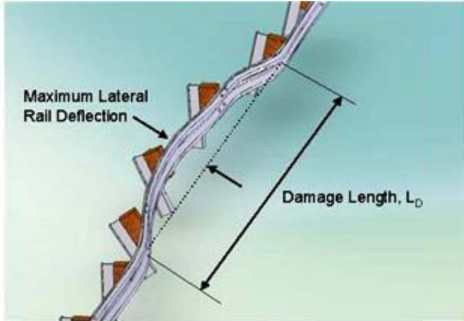
Note that the types and degree of damage to the barrier itself and to barrier terminals is prioritized as High, Medium, or Low. These rankings, along with the perceived likelihood of a second impact in the same location can be used to set repair priorities.

Repair priority scheme

Priority Level	Description
High	A second impact results in unacceptable safety performance including barrier penetration and/or vehicle rollover.
Medium	A second impact results in degraded but not unacceptable safety performance.
Low	A second impact results in no discernible difference in performance from an undamaged barrier.

W-beam Barrier Repair Threshold

Damage Mode: Post and Rail Deflection

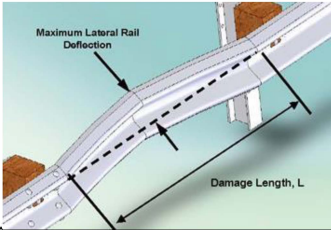


(Weak Post W-Beam Shown Only for Clarity. Each measurement taken at rail middle fold)

Relative Priority	Repair Threshold
High	One or more of the following thresholds: <ul style="list-style-type: none"> • More than 9 inches of lateral deflection anywhere over a 25 ft. length of rail. • Top of rail height 2 or more inches lower than original top of rail height.
Medium	6-9 inches lateral deflection anywhere over a 25 ft. length of rail.
Low	Less than 6 inches of lateral deflection over 25 ft. length of rail.

W-beam Barrier Repair Threshold

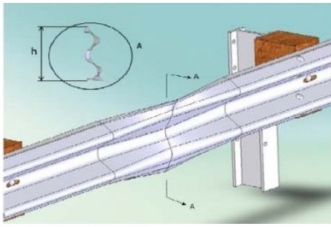
Damage Mode: Rail Deflection Only



Relative Priority	Repair Threshold
Medium	6-9 inches of lateral deflection between any two adjacent posts. Note: For deflection over 9 inches, use post/rail deflection guidelines.
Low	Less than 6 inches of lateral deflection between any two adjacent posts.

W-beam Barrier Repair Threshold

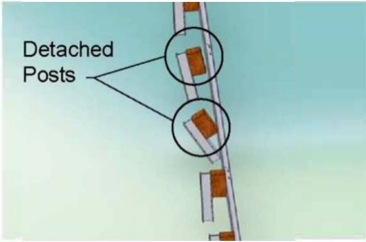
Damage Mode: Rail Flattening



Relative Priority	Repair Threshold
Medium	One of more of the following thresholds: <ul style="list-style-type: none"> • Rail cross-section height, h, more than 17" (such as may occur if rail is flattened). • Rail cross-section height, h, less than 9" (such as a dent to top edge).
Low	Rail cross-section height, h , between 9 and 17 inches.

W-beam Barrier Repair Threshold

Damage Mode: Posts Separated from Rail



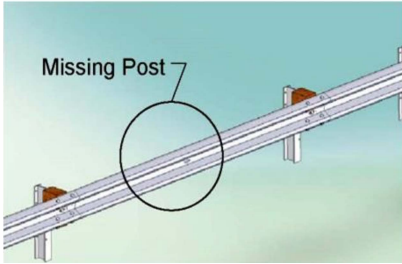
Note:

1. If the blockout is not firmly attached to the post, use the missing blockout guidelines.
2. Damage should also be evaluated against post/rail deflection guidelines.

Relative Priority	Repair Threshold
Medium	One or more of the following thresholds: <ul style="list-style-type: none">• 2 or more posts with blockout attached with post-rail separation less than 3 inches.• 1 or more post with post-rail separation which exceeds 3 inches.
Low	1 post with blockout attached with post-rail separation less than 3 inches.

W-beam Barrier Repair Threshold

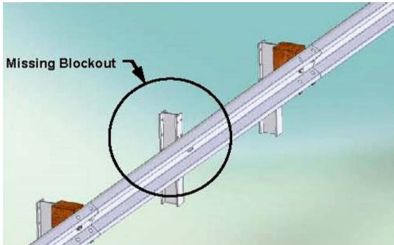
Damage Mode: Missing/Broken Posts



Relative Priority	Repair Threshold
High	One or more posts: <ul style="list-style-type: none"> • Missing • Cracked across the grain • Broken • Rotten • With metal tears

W-beam Barrier Repair Threshold

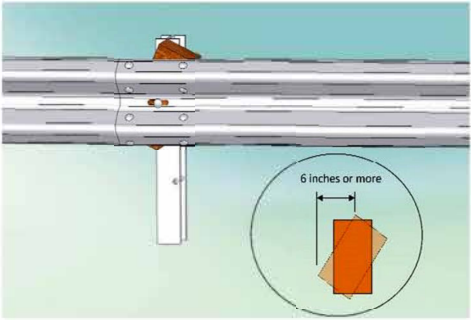
Damage Mode: Missing Blockout



Relative Priority	Repair Threshold
Medium	Any blockouts <ul style="list-style-type: none"> • Missing • Cracked across the grain • Cracked from top or bottom blockout through post bolt hole • Rotted

W-beam Barrier Repair Threshold

Damage Mode: Twisted Blockout

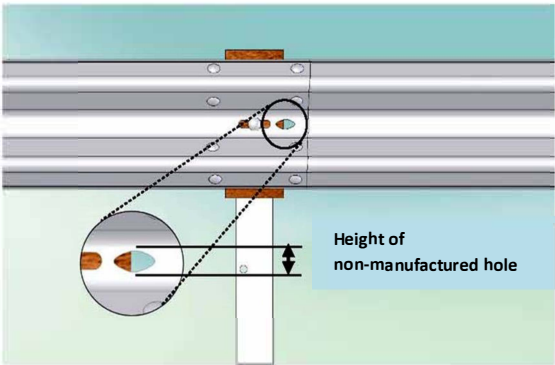


Relative Priority	Repair Threshold
<p>Low</p>	<p>Any misaligned blockouts, top edge of block 6 inches or more from bottom edge.</p> <p>Note: Repairs of twisted blockout are relatively quick and inexpensive</p>

W-beam Barrier Repair Threshold

Damage Mode: Non-Manufactured holes

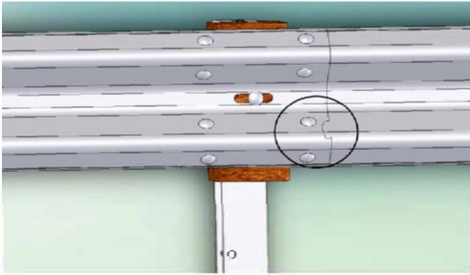
(such as crash induced holes, lug-nut damage, or holes rusted-through the rail)



Relative Priority	Repair Threshold
High	One or more of the following thresholds: <ul style="list-style-type: none"> • More than 2 holes less than 1" in height in a 12.5' length of rail. • Any holes greater than 1" height. • Any hole which intersects either the top or bottom edge of the rail.
Medium	1-2 holes less than 1" in height in a 12.5' length of rail.

W-beam Barrier Repair Threshold

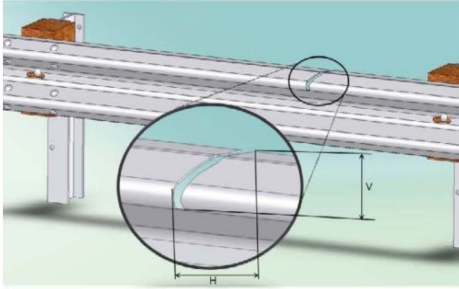
Damage Mode: Damage at Rail Splice



Relative Priority	Repair Threshold
High	More than 1 splice bolt: <ul style="list-style-type: none"> • Missing • Damaged • Visibly missing any underlying rail • Torn through rail
Medium	1 splice bolt: <ul style="list-style-type: none"> • Missing • Damaged • Visibly missing any underlying rail • Torn through rail

W-beam Barrier Repair Threshold

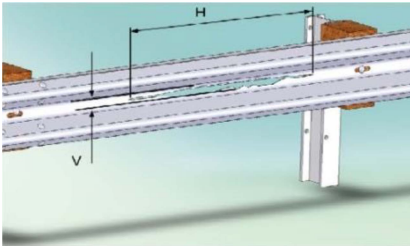
Damage Mode: Vertical Tear



Relative Priority	Repair Threshold
High	Any length vertical (transverse) tear

W-beam Barrier Repair Threshold

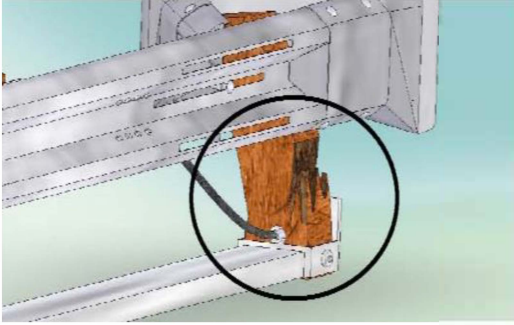
Damage Mode: Horizontal Tear



Relative Priority	Repair Threshold
Medium	Horizontal (longitudinal) tears greater than 12 inches long or greater than 0.5 inches wide. Note: for horizontal tears less than 12 inches in length or less than 0.5 inches in height, use the non-manufactured holes guidelines.

End Terminal Repair Threshold

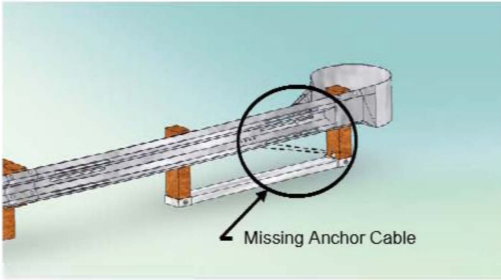
Damage Mode: Damage End Post



Relative Priority	Repair Threshold
High	Not functional (sheared, rotted, cracked across the grain)

End Terminal Repair Threshold

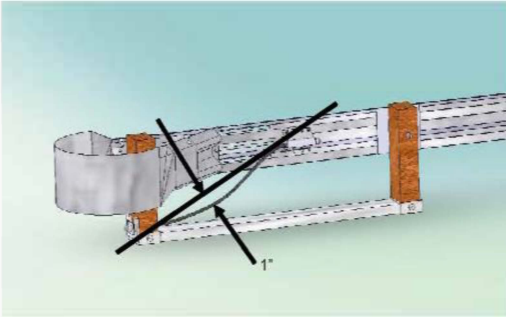
Damage Mode: Anchor Cable



Relative Priority	Repair Threshold
High	Missing

End Terminal Repair Threshold

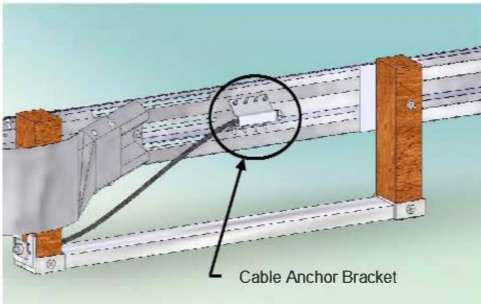
Damage Mode: Anchor Cable



Relative Priority	Repair Threshold
Medium	More than 1" of movement when pushed down by hand

End Terminal Repair Threshold

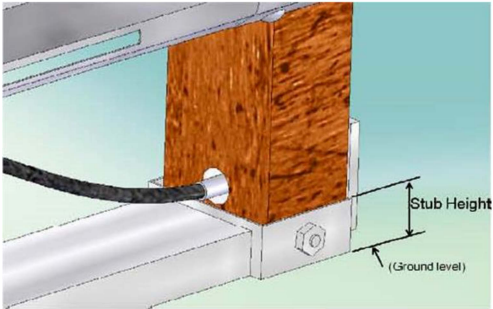
Damage Mode: Cable Anchor Bracket



Relative Priority	Repair Threshold
Medium	Loose or not firmly seated in rail

End Terminal Repair Threshold

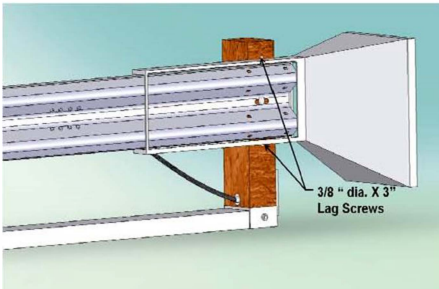
Damage Mode: Stub Height



Relative Priority	Repair Threshold
Medium	Height which exceeds 4"

End Terminal Repair Threshold

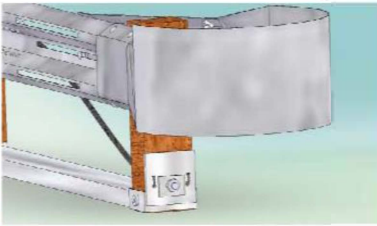
Damage Mode: Lag Screws (Energy Absorbing Terminals Only)



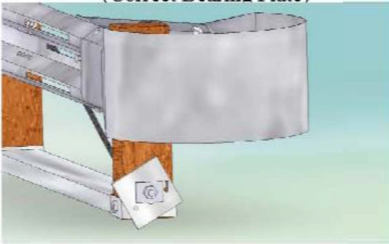
Relative Priority	Repair Threshold
High	Missing or failed lag Screws

End Terminal Repair Threshold

Damage Mode: Bearing Plate



(Correct Bearing Plate)

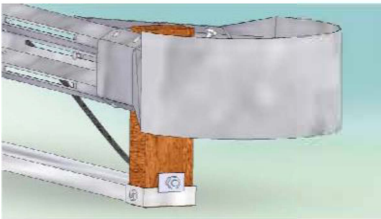


(Misaligned Bearing Plate)

Relative Priority	Repair Threshold
Medium	Loose or Misaligned

End Terminal Repair Threshold

Damage Mode: Bearing Plate



Relative Priority	Repair Threshold
High	Missing Bearing Plate

Note: Although not included in NCHRP 656 improper seating of the rail in an extruder head terminal (as shown in Figure 20) creates a serious problem in an end on impact by allowing the rail a chance to penetrate an impacting vehicle.



Figure 20: Improper Installation

Repair/Upgrade/Remove

When a guardrail or terminal is damaged to the point where repairs are needed, several questions should be asked before the damaged hardware is simply replaced in-kind:

- Is the barrier warranted or could it be removed?
- Does the barrier meet current design standards or should it be upgraded?
- Is the terminal an acceptable crash-tested design? (NOTE: the Breakaway Cable Terminal (BCT) must be replaced; the Modified Eccentric Loader Terminal (MELT) is considered crashworthy only at speeds up to 45 mph).
- If crashworthy, is the terminal the most appropriate type for the location? (NOTE: Non-energy absorbing terminals require a significant traversable runout area behind and parallel to the rail; energy absorbing terminals require less runout distance for low-angle impacts).
- Turned-down terminals are not crashworthy.
- Non-compliant connections of guardrail to bridge ends must be replaced with a successfully crash tested as per AASHTO MASH design.
- Is the damaged guardrail on or near a horizontal curve (and especially if it has been hit frequently)? Verify that the appropriate advance warning signs (W1-1 Turn or W1-2 Curve Signs), supplemental warning signs (W1-1a combination Turn/Advisory Speed or W1-2a Curve/Advisory Speed Signs) or W1-8 Chevron Alignment Signs are installed where warranted. Detailed information on the use and placement of these and other warning signs can be found in CHAPTER 2C. WARNING SIGNS AND OBJECT MARKERS in the California MUTCD 2014 Edition.

Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ACZ	Adjusted Clear Zone (After all adjustments)
ADT	Average Daily Traffic
CALTRANS	California Department of Transportation
CRZ	Clear Recovery Zone
CZ	Clear Zone (Table Value)
EMS	Emergency Medical Services
FHWA	Federal Highway Administration
LON	Length of Need
MUTCD	Manual on Uniform Traffic Control Devices
MASH	Manual for Assessing Safety Hardware
NCHRP	National Cooperative Highway Research Program
RDG	Roadside Design Guide
ROR	Run off Road
SS	Single Slope (Rigid Barrier)
TCP	Traffic Control Plan
TL	Test Level
TTC	Temporary Traffic Control
TTCZ	Temporary Traffic Control Zone
VF	Vertical Face (Rigid Barrier or Retaining Wall)
WZ	Work Zone
ZOI	Zone of Intrusion

Glossary⁷

Adjacent Grading—Adjacent grading refers to the area on which the terminal is installed and the area immediately behind it.

Advance Grading—Advance grading refers to the area over which a vehicle may travel before any contact with a barrier terminal is made.

Anchorage— A device which anchors a flexible or semi-rigid barrier to the ground so as to develop the barrier's tensile strength during an impact. Anchorages differ from terminals in that they are not considered crashworthy.

Area of Concern—An object or roadside condition that may warrant safety treatment.

Barricade—A device which provides a visual indicator of a hazardous location or the desired path a motorist should take. It is not intended to contain or redirect an errant vehicle.

Barrier—A device which provides a physical limitation through which a vehicle would not normally pass. It is intended to contain or redirect an errant vehicle.

Bi-directional—For the purposes of classifying crash cushions, bi-directional describes the capability of a crash cushion to safely operate in the median of a divided highway or on an undivided roadway, where it will be exposed to impacts from two different directions of traffic. A bi-directional crash cushion is also a uni-directional crash cushion. A crash cushion is considered to be bi-directional when it has been qualified through a reverse-direction crash test.

⁷ AASHTO Roadside Design Guide, 4th Edition, 2011

Breakaway—A design feature which allows a device such as a sign, luminaire, or traffic signal support to yield or separate upon impact. The release mechanism may be a slip plane, plastic hinges, fracture elements, or a combination of these.

Bridge Railing—A longitudinal barrier whose primary function is to prevent an errant vehicle from going over the side of the bridge structure.

Clearance—Lateral distance from edge of traveled way to a roadside object or feature.

Clear Runout Area—The area at the toe of a non-recoverable slope available for safe use by an errant vehicle.

Clear Zone—The unobstructed, traversable area provided beyond the edge of the through traveled way for the recovery of errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function like through lanes.

Conservation of Momentum Principle—A concept of crash cushion design which involves the dissipation of the kinetic energy of an impacting vehicle by transferring the vehicle's momentum to the variable masses of materials in the crash cushion, such as sand contained in sand barrels.

Cost-effective—An item or action taken that is economical in terms of tangible benefits produced for the money spent.

Crash Cushion—Crash cushions, also known as impact attenuators, are typically attached to or placed in front of concrete barriers (median barriers, roadside barriers, or bridge railings) or other rigid fixed objects, such as bridge piers, to prevent an errant vehicle from impacting fixed objects by gradually decelerating the vehicle to a safe stop or by redirecting the vehicle away from the obstacle.

Crash Tests—Vehicular impact tests by which the structural and safety performance of roadside barriers and other highway appurtenances may be determined. Three evaluation criteria are considered, namely (1) structural adequacy, (2) impact severity, and (3) vehicular post-impact trajectory.

Crashworthy—A feature that has been proven acceptable for use under specified conditions either through crash testing or in-service performance.

Design Speed—A selected speed used to determine the various geometric design features of the roadway. The assumed design speed should be a logical one with respect to the topography, anticipated operating speed, the adjacent land use, and the functional classification of highway.

Drainage Feature—Roadside items whose primary purpose is to provide adequate roadway drainage such as curbs, culverts, ditches, and drop inlets.

End Treatment—The designed modification of the end of roadside or median barriers, including anchorages, terminals, and crash cushions.

Flare—The variable offset distance of a barrier to move it farther from the traveled way; generally in reference to the upstream end of the barrier.

Frangible—A structure quality or feature that makes the structure readily or easily broken upon impact.

Fuse Plate—The plate which provides structural reinforcement to the sign post hinge to resist wind loads but which will release or fracture upon impact of a vehicle with the post.

Glare Screen—A device used to shield a driver's eye from the headlights of an oncoming vehicle.

Hinge—The weakened section of a sign post designed to allow the post to rotate upward when impacted by a vehicle.

Impact Angle—For a longitudinal barrier, it is the angle between a tangent to the face of the barrier and a tangent to the vehicle's path at impact. For a crash cushion, it is the angle between the axis of symmetry of the crash cushion and a tangent to the vehicle's path at impact.

Impact Attenuator—See *Crash Cushion*.

Length of Need (LON)—Total length of a longitudinal barrier needed to shield an area of concern. The LON point for a given system is usually confirmed by successfully passing a redirection crash test with impact at the LON point.

Length-of-Need (LON) Point—That point on the terminal or longitudinal barrier at which it will contain and redirect an impacting vehicle along the face of the terminal or barrier.

Longitudinal Barrier—A barrier whose primary function is to prevent penetration and to safely redirect an errant vehicle away from a roadside or median obstacle.

Low-Maintenance/Self-Restoring Crash Cushions—Crash cushions that 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, or otherwise disabled.

Median—The portion of a divided highway separating the traveled ways for traffic in opposite directions.

Median Barrier—A longitudinal barrier used to prevent an errant vehicle from crossing the highway median.

Multidirectional—The capability of the fracture mechanism of a breakaway support or the plates of a slip-base support to

work when struck from any direction. These are also referred to as omni-directional.

Non-Recoverable Slope—A slope which is considered traversable but on which the errant vehicle will continue on to the bottom. Embankment slopes between 1V:3H and 1V:4H may be considered traversable but non-recoverable if they are smooth and free of fixed objects.

Offset—Lateral distance from edge of traveled way to a roadside object or feature.

Omni-directional—See *Multidirectional*.

Operating Speed—The highest speed at which reasonably prudent drivers can be expected to operate vehicles on a section of highway under low traffic densities and good weather. This speed may be higher or lower than posted or legislated speed limits or nominal design speeds where alignment, surface, roadside development, or other features affect vehicle operations.

Recoverable Slope—A slope on which a motorist may, to a greater or lesser extent, retain or regain control of a vehicle. Slopes flatter than 1V:4H are generally considered recoverable.

Recovery Area—Generally synonymous with clear zone.

Reusable Crash Cushions—Reusable crash cushions have some major components that may be able to survive most impacts intact and can be salvaged when the unit is being repaired.

Roadside—That area between the outside shoulder edge and the right-of-way limits. The area between roadways of a divided highway may also be considered roadside.

Roadside Barrier—A longitudinal barrier used to shield roadside obstacles or non-traversable terrain features. It may occasionally be used to protect pedestrians or “bystanders” from vehicle traffic.

Roadside Signs—Roadside signs can be divided into three main categories: overhead signs, large roadside signs, and small roadside signs. Large roadside signs may be defined as those greater than or equal to 5 m² [50 ft²] in area. Small roadside signs may be defined as those less than 5 m² [50 ft²] in area.

Roadway—The portion of a highway, including shoulders, for vehicular use.

Rounding—The introduction of a vertical curve between two transverse slopes to minimize the abrupt slope change and to maximize vehicle stability and maneuverability.

Runout Distance Grading—Refers to the area into which a vehicle may travel after impacting a terminal ahead of its LON point.

Sacrificial Crash Cushions—Sacrificial crash cushions are crashworthy roadside safety devices designed for a single impact. These systems’ major components are destroyed in impacts and must be replaced, but many of the other parts of the system can be reused.

Severity Index—A severity index (SI) is a number from zero to ten used to categorize accidents by the probability of their resulting in property damage, personal injury, or a fatality, or any combination of these possible outcomes. The resultant number can then be translated into an accident cost and the relative effectiveness of alternate safety treatments can be estimated.

Shielding—The introduction of a barrier or crash cushion between the vehicle and an obstacle or area of concern to reduce the severity of impacts of errant vehicles.

Shy Distance—The distance from the edge of the traveled way beyond which a roadside object will not be perceived as an obstacle by the typical driver to the extent that the driver will change the vehicle's placement or speed.

Slip Base—A structural element at or near the bottom of a post or pole which will allow release of the post from its base upon impact while resisting wind loads.

Slope—The relative steepness of the terrain expressed as a ratio or percentage. Slopes may be categorized as positive (backslopes) or negative (foreslopes) and as parallel or cross slopes in relation to the direction of traffic.

Staged Attenuation Device—A crash cushion that is designed to be progressively stiffer as an impacting vehicle deforms or penetrates it.

Temporary Barrier—Temporary barriers are used to prevent vehicular access into construction or maintenance work zones and to redirect an impacting vehicle so as to minimize damage to the vehicle and injury to the occupants while providing worker protection.

Terminal—A terminal is essentially a crashworthy anchorage, a device used to anchor a flexible or semi-rigid barrier to the ground. Being crashworthy, terminals are normally used at the end of a barrier that is located within the clear zone or that is likely to be impacted by errant vehicles.

Traffic Barrier—A device used to prevent a vehicle from striking a more severe obstacle or feature located on the roadside or in the median or to prevent crossover median accidents. As defined herein, there are four classes of traffic

barriers, namely, roadside barriers, median barriers, bridge railings, and crash cushions.

Transition—A section of barrier between two different barriers or, more commonly, where a roadside barrier is connected to a bridge railing or to a rigid object such as a bridge pier. The transition should produce a gradual stiffening of the approach rail so vehicular pocketing, snagging, or penetration at the connection can be avoided.

Traveled Way—The portion of the roadway for the movement of vehicles, exclusive of shoulders.

Through Traveled Way—The portion of roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

Traversable Slope—A slope from which a motorist will be unlikely to steer back to the roadway but may be able to slow and stop safely. Slopes between 1V:3H and 1V:4H generally fall into this category.

Uni-directional—For the purposes of classifying crash cushions, uni-directional describes the capability of a crash cushion to operate in a location where it will be exposed to traffic impacts from only one direction. Such locations may include gore areas, or roadside locations on a divided highway. A crash cushion is considered to be uni-directional unless it has been qualified as bi-directional through a reverse-direction crash test.

Vehicle—A motorized unit for use in transporting passengers or freight, ranging from an 820-kg [1,800-lb] automobile to a 36000-kg [80,000-lb] van-type tractor-trailer.

Warrants—The criteria by which the need for a safety treatment or improvement can be determined.

Work-Energy Principle—“A concept of crash cushion design which involves the reduction of an impacting vehicle’s kinetic energy to zero, the condition of a stopped vehicle, through the conversion of kinetic energy into other forms of energy.”

Working Width—The distance between the traffic face of the test article before the impact and the maximum lateral position of any major part of the system or vehicle after the impact.

Zone of Intrusion (ZOI)—The region measured above and behind the face of a barrier system where an impacting vehicle or any major part of the system may extend during an impact

Resources

AASHTO, Roadside Design Guide, 2011

Manual on Uniform Traffic Control Devices for Streets and Highways, 2009

AASHTO, Manual for Assessing Safety Hardware, 2009

FHWA Hardware Policy and Guidance

http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/

FHWA Longitudinal Barriers

http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/

AASHTO Task Force 13 website <http://www.aashtotf13.org/>

AASHTO Guide to Standardized Highway Barrier Hardware;

<http://www.aashtotf13.org/Barrier-Hardware.php>

NHTSA FARS web site: [http://www-](http://www-fars.nhtsa.dot.gov/Main/index.aspx)

[fars.nhtsa.dot.gov/Main/index.aspx](http://www-fars.nhtsa.dot.gov/Main/index.aspx)

Roadside Safety Pooled Fund sites:

MwRSF: <http://mwrsf-ga.unl.edu/>

TTI: <http://www.roadsidepooledfund.org/>

NCHRP Research Projects

<http://www.trb.org/NCHRP/Public/NCHRPProjects.aspx>

Task Force 13 Bridge Rail Guide: <http://guides.roadsafellc.com/>

NCHRP Report 350:

http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_350-a.pdf

Caltrans Design Information Bulletin number 79-03

Caltrans Memorandum 07/31/2015 Maintenance of Safety Devices

Caltrans Maintenance Manual Vol. II, M60010

Caltrans Manual on Uniform Traffic Control

<http://www.dot.ca.gov/trafficops/camutcd/>

Caltrans Traffic Manual, Chapter 7

<http://www.dot.ca.gov/trafficops/camutcd/traffic-manual.html>

Caltrans approved products list:

http://www.dot.ca.gov/hq/esc/approved_products_list/pdf/highway_safety_features.pdf

Caltrans Standard Plans and Standard Specifications:

<http://www.dot.ca.gov/des/oe/construction-contract-standards.html>

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