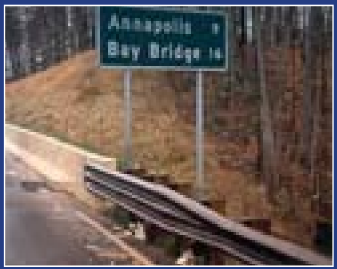
Maryland
Department of
Transportation

Guidelines for Traffic Barrier Placement and End Treatment Design

March 2006



Maryland Department of Transportation
State Highway Administration

GUIDELINES FOR TRAFFIC BARRIER PLACEMENT AND END TREATMENT DESIGN

March 2006

Chief, Design Technical Services Division

Director, Office of Highway Development

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STANDARDS AND LIST OF APPROVED SUBSTITUTES

REFER TO WEB SITE:

http://www.marylandroads.com/BusinessWithSHA/bizStdsSpecs/desManualStdPub/publicationsonline/ohd/bookstd/index.asp

I. HOW AND WHERE TO APPLY THIS GUIDE

This guide has been prepared as a supplement to the AASHTO Roadside Design Guide (RDG) for the determination of clear zone widths and guidance for the use of placing traffic barriers and their end treatments. These guidelines do not apply to structures; refer to SHA-OBD for appropriate standards.

To be consistent with AASHTO's A Policy on Geometric Design of Highways and Streets, design speed has been selected as the basic speed parameter to be used in this guide. However, the designer should always consider the speed at which encroachments are most likely to occur. Therefore, wherever the term "Design Speed" is used in this manual, the designer may substitute the Operating Speed of the roadway, but only if there is significant warranting reason. The Operating Speed is generally defined as the 85^{th} percentile of the distribution of observed speeds. This 85^{th} Percentile Operating Speed can be obtained from the District ADE – Traffic.

Because these are guidelines and not standards, engineering judgment and common sense should be exercised in applying them. For most situations, there are a multitude of solutions; unfortunately, the better solutions are generally the more costly. Hard decisions are required to make the most cost-effective choice, and there is seldom unanimity as to the absolute best. Limitations on resources will dictate prioritization of our needs based upon well-founded data and evaluation by trained and knowledgeable engineers. The safety of the traveling public, however, should always be a primary consideration when deviating from these guidelines.

II. OVERVIEW

When an errant vehicle leaves the roadway, the probability of an accident occurring depends on the vehicle's speed, the angle at which it leaves the travel lane, its trajectory, and what lies in its path. If a crash does occur, its severity is dependent upon several factors, including the use of restraint systems, vehicle type, and the nature of the roadside environment. Of these factors, the highway designer has a significant measure of control only over the roadside environment. The measure of control can be applied using the "Clear Zone" concept.

III. CLEAR ZONE CONCEPT

A clear zone is the total roadside border area, starting at the edge of the travel lane, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, and/or a traversable but non-recoverable slope and a clear run-out area. (A "recoverable" fill slope is defined as no steeper than 4:1; a "traversable but non-recoverable" slope is steeper than 4:1 but no steeper than 3:1 (a "critical" slope is steeper than 3:1 and considered an obstacle); cut slopes as steep as 3:1 are considered recoverable). The desirable clear zone width, from a roadside safety standpoint, is as wide as cost-effectively possible. However, some practical value needs to be established for design purposes. Design clear zone values have been determined and are dependent upon traffic speeds and the roadside geometry; they are given in TABLE 1.

TABLE 1: DESIGN CLEAR ZONE WIDTHS

DESIGN CLEAR ZONE WIDTHS			
Design Speed	**Slope 4:1 or Flatter (Recoverable)**	**Slope Steeper Than 4:1 to 3:1**	**Slope Steeper Than 3:1**
≤ 40 MPH*	16-Ft.	Traversable / Non- Recoverable**	Critical
45 - 50 MPH	24-Ft.	Traversable / Non- Recoverable**	Critical
≥ 55 MPH	30-Ft.	Traversable / Non- Recoverable**	Critical

* Off National Highway System (NHS): Clear zones do not normally apply to roadways off the NHS unless warranted by Accident History.
** The slope is considered acceptable if the remainder of the design clear zone (subtracting the width available at the top of the slope, but a minimum of 10-ft) is available at a 6:1 or flatter slope beyond the toe of the 3:1 slope.

The values given in TABLE 1 are generally applicable for new construction and most existing freeways; however, they may be impractical to achieve on 3R-type projects (even for some freeways). Application of the general principle of obtaining as much clear zone width as cost-effectively possible should yield the best solution.

IV. ROADSIDE OBSTACLES AND THEIR TREATMENT

Roadside obstacles include both non-traversable terrain and fixed objects, and may be either man-made (such as critical embankments, ditches, bridge piers, signs, or headwalls) or natural (such as trees or boulders). Although preferable, a flat clear recovery area may not be feasible due to economical or environmental constraints such as right of way, parklands, historic sites, certain classes of streams, or tidal and/or non-tidal wetlands. The highway designer has the following options to select from for the treatment of roadside obstacles within the design clear zone that should be considered in the following priority order:

1. Remove the obstacle or redesign it so it can be safely traversed; for example, possibly using beveled end sections in place of headwalls or flared end sections on cross culverts up to 36" diameter. See Section 3.4.3.2 Traversable Designs in the RDG.
2. Relocate the obstacle to where it is less likely to be impacted.
3. Reduce impact severity by using an appropriate breakaway device.
4. Shield the obstacle with a longitudinal traffic barrier and / or a crash cushion end treatment.
5. Delineate the obstacle where traffic barrier is not reasonable or cost-effective.

When none of the first three priorities can be applied, the designer must make the decision to shield or not to shield. Since barrier itself is a hazard, it should only be used when the consequences of impacting the obstacle are considered to be significantly more serious than striking the barrier. Barrier warrants for shielding of obstacles located within the Design Clear Zone Widths as noted above are as follows:

TABLE 2: WARRANTS FOR SHIELDING OF OBSTACLE LOCATED WITHIN THE DESIGN CLEAR ZONE

OBSTACLE LOCATED WITHIN THE DESIGN CLEAR ZONE WIDTH AS NOTED IN TABLE 1	TRAFFIC BARRIER WARRANTED
Embankments (critical and traversable, non-recoverable embankments without runout area)	YES *
Bridge Piers, Parapets, Etc.	YES
Signs/lighting standards which cannot be made Breakaway	YES
Signal Supports (high speed open sections)	Coordinate with OOTS
Streams or permanent bodies of water more that 2-ft. in depth	YES
Large Boulders	YES
Utility Poles	Shielding may be warranted on a case by case basis
Drainage features – ditches, headwalls	Judgment based on severity of obstacle and site specific circumstances; redesign, if possible, to be traversable
Trees	Judgment based on site specific circumstances

* Critical slopes less than 7’ high without obstacles either on or at the bottom of the slope need not be shielded

V. APPROVED ROADSIDE BARRIER SYSTEMS AND THEIR CHARACTERISTICS

The function of a roadside barrier is to shield the motorist from impacting an obstacle along the roadside.

The majority of roadside barrier used in Maryland is the strong post W-beam system. The W-beam system shown in the current Standards (Traffic Barrier W-Beam {TBWB}) was successfully tested (no penetration and smoothly redirected) with a 4,400 pound pick-up impacting the barrier at a 25º angle at 62 mph (NCHRP Report 350, TL-3). It achieves this performance primarily by developing tensile forces in the rail element, with additional contribution from the stiffness/resistance of the strong posts. The tension is developed as the barrier deflects backwards, a total of about 3 feet in the above test. The tension in the system must be maintained or the system will probably fail.

The other approved roadside barrier in Maryland is the F-shape concrete barrier. The typical configuration uses a 34" height (median application is 42" height). This configuration also passed the NCHRP Report 350 TL-4. (The standard was changed from the New Jersey shape to the F-shape because of improved performance with small vehicles and single unit trucks.) The concrete barrier develops its containment and redirection capability primarily by its structural strength. With the concrete barrier, which doesn't deflect, almost all of the energy of the impacting vehicle is absorbed by the vehicle, thus being a "harder" impact on the occupants than the softer, deflecting W-beam. The shape is designed to facilitate future overlays of up to 3"; however, any depth overlay can be placed against it as long as there is a minimum of 29" of exposed face remaining.

For special situations, a higher performing barrier system may be warranted. A moderately higher F-shape concrete barrier (42") can contain an 80,000 pound standard tractor-trailer truck impacting at a 15º angle and 50 mph (NCHRP 350, TL-5) and is an approved Standard; and in severe situations like on I-68 in Cumberland, MD, a 90" high concrete barrier which can contain the special 80,000 pound tanker-truck (NCHRP 350, TL-6) could be utilized.

For designs other than those described above, contact SHA-OHD for prior approval.

VI. ROADSIDE BARRIER SYSTEM SELECTION

Once it has been determined that a longitudinal barrier will be installed, the decision to use W-Beam or F- shaped concrete barrier must be made. Both systems have passed the required testing, but each has different characteristics that may enhance or subtract from their desirable performance under specific circumstances. Criteria that should be considered in barrier selection include: performance capability, deflection, site conditions (section cross-slope), compatibility with available end treatments and adjacent barrier systems, cost, and maintenance. The general principles of proper barrier placement must be addressed (see Section VII). The following table lists some of the advantages and disadvantages of the basic barrier systems:

TABLE 3: CONCRETE VS W-BEAM ADVANTAGES/DISADVANTAGES

TYPE	ADVANTAGES	DISADVANTAGES
W-BEAM BARR IER	• Lower installation costs • Relatively flexible placement criteria (see next section) • Softer impact to occupants	• Generally damaged on impact, incurring maintenance costs and exposing maintenance personnel to traffic • Must accommodate deflection • Vehicle damage with any impact
CONCRETE BARRIER	• Minimal damage on impact, lowering life cycle cost and minimizing exposure of maintenance personnel. • No deflection • Less (or none) vehicle damage on shallow angle impacts	• Higher installation costs • Harder impacts to occupants • Strict placement criteria • May require installation of storm drain system

VII. ROADSIDE BARRIER PLACEMENT CRITERIA

The first priority is to place barrier as far from the traveled way as possible to minimize the probability of contact. There are, however, several criteria that must be considered in selecting the location as identified below. Where these criteria or other factors preclude placing the barrier farther away from the roadway, the normal placement of the barrier is 2' from the edge of the shoulder. ***When the back of a single sided barrier placed in the median is within 50' of the opposing traffic and the median is traversable, the back of the barrier should have redirective capability*** (unless the required length is less than 50'); ***for W-beam barrier, this is achieved by using Traffic Barrier W-Beam – Median Barrier (TBWB-MB).***

One of the most critical characteristics of W-beam barrier, to ensure proper performance, is its height. To improve the likelihood that an impacting vehicle approaching over an unpaved surface will not strike the rail too high, ***all W-beam barrier that is placed beyond 2' from the shoulder on an unpaved surface is to be set to a 28 ½" height*** (measured from the ground directly beneath the face of rail). (For the height of the back rail of TBWB-MB, refer to Section XI. D.).

A. Deflection

No rigid vertical object shall be placed within the dynamic deflection distance from the back of the barrier system (see FIGURE 1). The F-shape concrete barrier, with proper foundation, has zero dynamic deflection, so that it may be placed directly against the obstacle. There is a concern of tall vehicle lean over, but though there is a possibility of this occurring it is infrequently considered in design. The rest of this sub-section deals with the W-beam system.

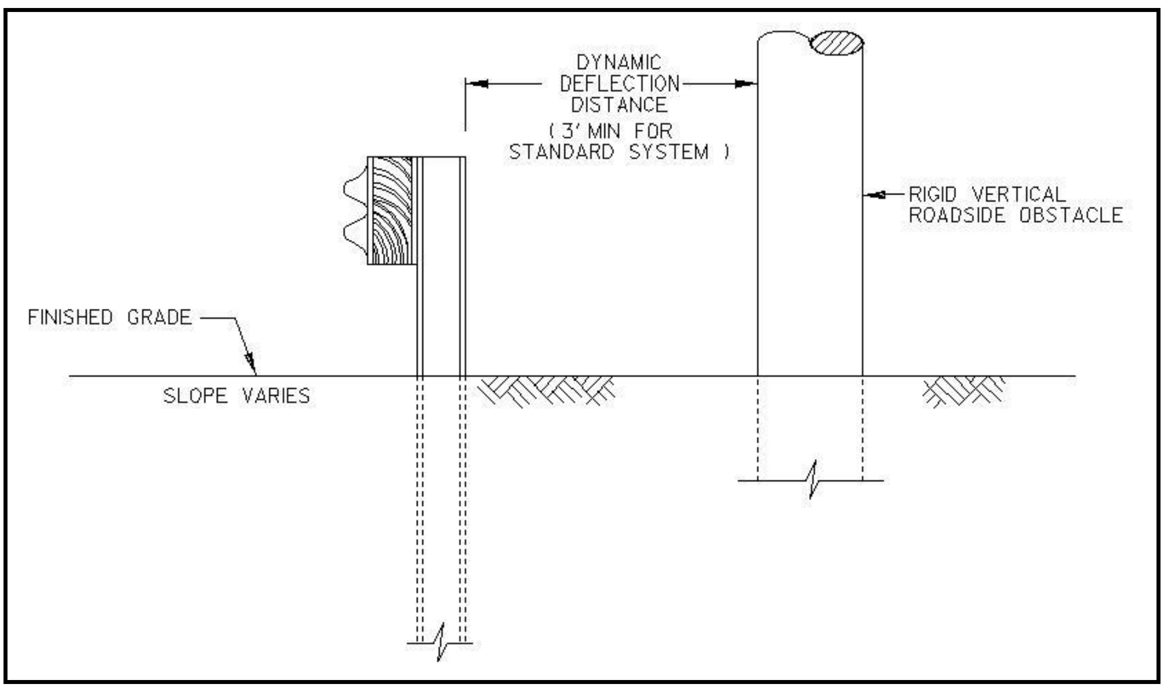


FIGURE 1: MINIMUM OFFSET TO RIGID OBSTACLE

If the 3 feet clearance for dynamic deflection from the back of the standard system cannot be achieved, the system must be stiffened in front of **and** upstream from the obstacle. Stiffening methods available include decreasing post spacing by half and nesting of rail elements. One stiffening system should conservatively decrease the dynamic deflection to 2'; two stiffening systems should decrease the dynamic deflection to 1' 6"; and three stiffening systems should decrease the dynamic deflection to about 1'. If one stiffening method is used, it should begin 25' in advance of the obstacle; for two or three stiffening methods, they should begin 50' in advance and be evenly distributed throughout the length. The stiffening should continue to the end of the obstacle (where the obstacle is solid and would not permit pocketing within its length, the stiffening may be eliminated beyond the beginning of the obstacle).

If the roadway is two directional and the W-beam is within the design clear zone of the opposing traffic, the same stiffening should be provided for that direction as well.

When only the minimum dynamic deflection distance is provided – including the 3' for the standard system – a minimum of 25' of the barrier in advance of the rigid object must be placed parallel to the roadway.

B. Soil Backing for W-Beam Barrier

Since there is a considerable contribution to the redirection capability of the system from the strength of the strong posts, it is necessary to develop adequate soil support for the post to prevent it from pushing backwards too easily. See FIGURE 2. Use 8' long posts in place of the normal 6' length posts when there is less than 2' of backing or slopes are steeper than 4:1.

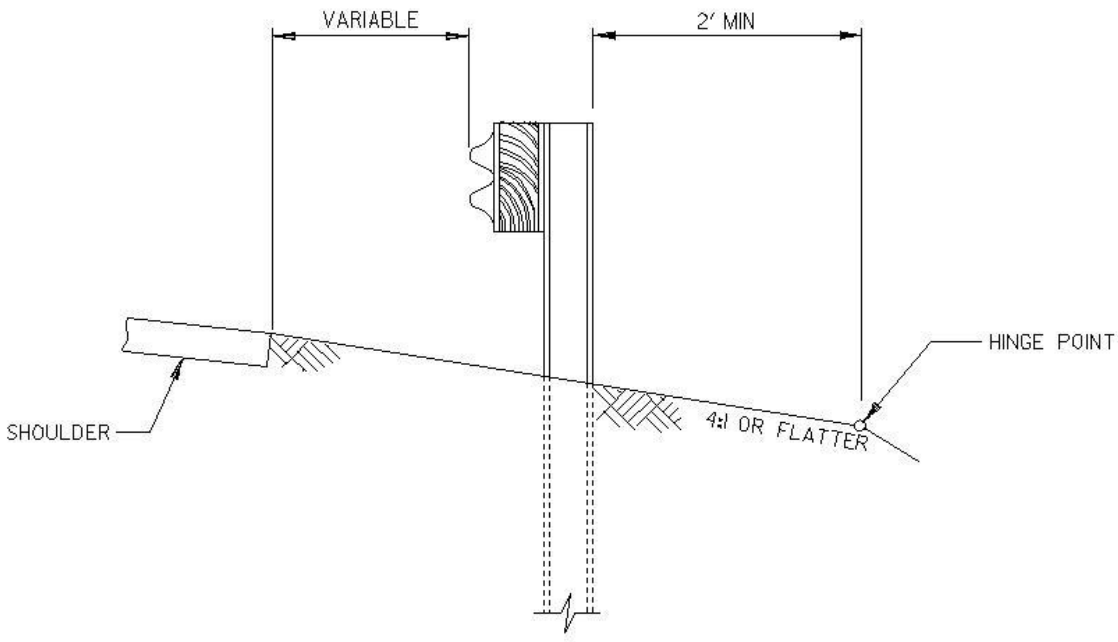


FIGURE 2: SOIL BACKING FOR W-BEAM BARRIER (6' POST)

C. Barriers on Slopes

1. Slopes 10:1 or flatter

   Either barrier system may be placed anywhere on slopes 10:1 or flatter (there is no maximum distance, even for concrete barrier - only reasonableness). The F-shape concrete barrier should only be placed on slopes 10:1 or flatter.

2. Slopes steeper than 10:1 but not steeper than 6:1

   The standard W-beam system may be placed on slopes steeper than 10:1, but not steeper than 6:1, under the following condition: the face of barrier needs to be either 2' or less, or 12' or more, from the slope hinge point (see FIGURE 3).

3. Slopes steeper than 6:1

   When the slope is steeper than 6:1, the face of the barrier must be aligned with the edge of shoulder.

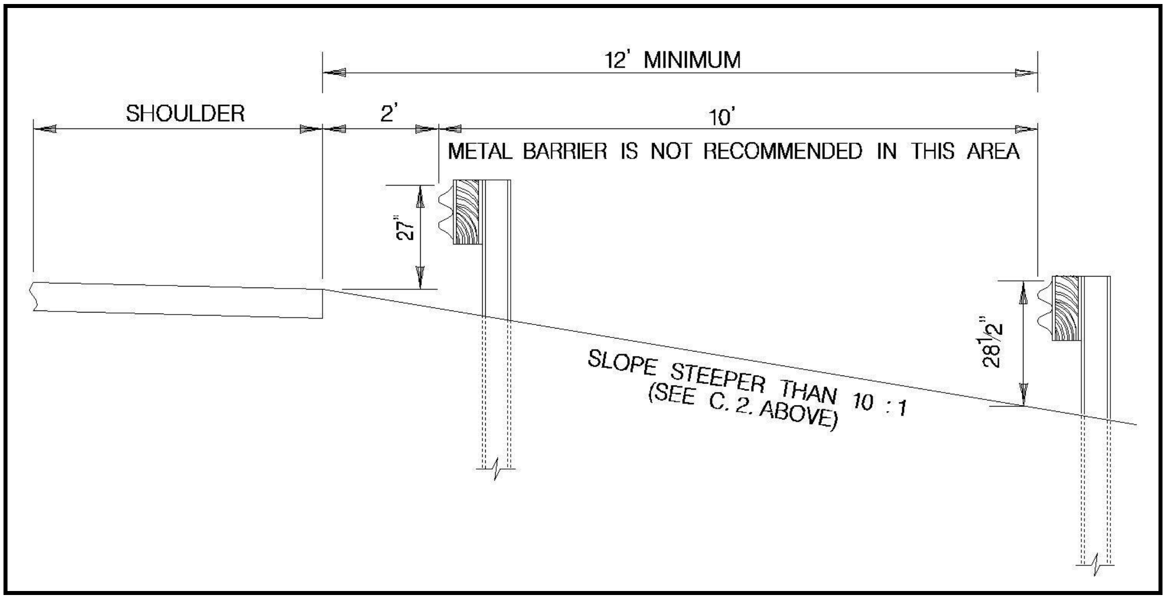


FIGURE 3: PLACEMENT OF METAL BEAM BARRIER ON SLOPES

D. Flare Rate

Flare rate is the rate at which a barrier moves from a larger offset to a closer offset from the edge of traveled way. Although it is desirable to flare the barrier system as quickly as possible, there are two criteria that must be satisfied for the barrier exposed to approaching traffic. ***First***, in order to keep the angle of impact with the barrier from being too severe, the flare rate is limited to the values shown in TABLE 4 which are based on speed and type of the barrier system. ***Second***, standard w-beam or concrete barrier should only be flared if it can be done on 10:1 or flatter slopes (unless standard W-beam is more than 12' beyond the hinge point on slopes as steep as 6:1). For one-directional roadways, the downstream flare rate, as the barrier moves away from the traveled way, should not be sharper than 2:1.

TABLE 4: FLARE RATES FOR BARRIER DESIGN

Design Speed (MPH)	FLARE RATE FOR BARRIER	
	Concrete	W-Beam
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
40	10 : 1	8 : 1
30	8 : 1	7 : 1

Source: Values from AASHTO Roadside Design Guide 2002.

VIII. SPECIAL W-BEAM BARRIER TREATMENTS

A. Long Span W-beam Installations

When it is not possible to drive a post to the standard depth due to some obstruction like a drop inlet, shallow culvert, or electrical pull box, it is permissible to leave out one or two posts and modify the rail element by adding a second rail section nested inside the normal rail (shortening the post is prohibited). The nested rails must extend at least to the second post on either side of the gap. The splice for the back rail must align with the front rail. (This treatment has only been tested under NCHRP 230 but its use is allowable by FHWA. A design in which 3 posts can be omitted has been tested to NCHRP Report 350 TL-3 criteria and can be used for special situations).

B. Extra Blockouts

When a post cannot be driven in its normal location, additional blockouts may be added to provide more offset, allowing the post to be placed farther back. For one post only, and only in unusual circumstances, a total of three blockouts may be used. Two blockouts may be used for any number of posts. (Rail systems using extra blockouts have not been tested but are considered acceptable.)

IX. CURB USE WITH W-BEAM BARRIER ON A TYPICALLY OPEN SECTION, HIGH SPEED

Curbs (which include combination curb and gutter) should not be used, with or without barrier, on high speed rural roads. If they are used with W-beam barrier, they shall only be used subject to the following conditions:

1. Curb height limited to a maximum of 4".
2. ***For curbs higher than 4", the W-beam barrier is stiffened by adding another rail on the back, or by adding a rubrail underneath the normal rail.***
3. The W-beam barrier must be aligned with or in front of the flow line.

The end treatment for W-beam barrier should be located beyond the need for the curb. If the curb must continue in advance of the barrier need, the curb should be dropped to a maximum 2” height for 50’ in advance of and through some length of the end treatment. If dropping the curb is not practical, the W-beam should be flared back from the face of curb on a 25:1 flare for 50’ at the same time as its height is raised to standard height measured from the top of the curb; then the appropriate end treatment is added with any offsets measured from the flare line extended. In no case should a turndown end treatment be used on a high speed, rural facility.

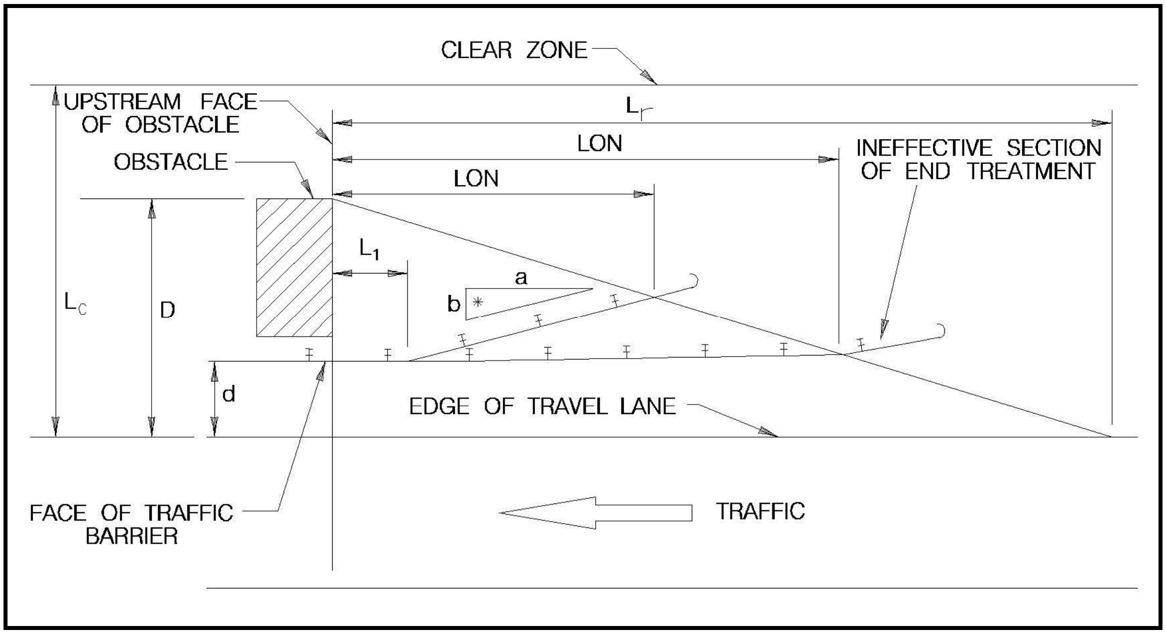
For urban street, closed sections, see Section XX. URBAN STREET SECTIONS.

X. LENGTH OF NEED (LON) DETERMINATION

Length of Need (LON) is defined as the length of effective barrier needed upstream, beginning at the obstacle, to adequately shield it. When the LON is provided, vehicles leaving the travel way in advance of an obstacle should either be: 1. safely brought to a stop before impacting the obstacle if the departure is in advance of the barrier and it gets behind the barrier; or 2. redirected by the barrier along its face (or impact its crashworthy end treatment). ***The LON generally includes some portion of the end treatment: for***

Type B and C end treatments, all except the last 12 ½' of the end treatment is effective barrier (contributing to the LON requirement).

To determine the LON, the following procedure is used. In some cases, the most difficult task is determining the physical limits of the obstacle, especially where it begins – the upstream face (a prime example of this is a critical embankment - refer to Section XIV A). Once the upstream face is determined, it is simply a matter of plugging the identified values from FIGURE 4 into the appropriate formula.



* If applicable for Flared Barrier.

FIGURE 4: FACTORS FOR DETERMINING LENGTH OF NEED (LON) FOR TRAFFIC BARRIER

FORMULAS FOR CALCULATING LENGTH OF NEED (LON)
FOR TRAFFIC BARRIER INSTALLATION

PARALLEL INSTALLATION	* FLARED APPROACH
$LON = \dfrac{L_r \times (D-d)}{D}$	$LON = \dfrac{D + (b/a) \times L_1 - d}{(b/a) + (D/L_r)}$

* Flared installations of standard barrier are not very common, so this formula is seldom used

Where: D = Distance (ft.) from edge of travel lane to back of obstacle or design clear zone width, whichever is less.

d = Distance (ft.) from edge of travel lane to face of traffic barrier measured at obstacle.

b/a = Flare rate for the selected design speed (TABLE 4).

L_r = Runout length, measured along the edge of the travel lane as shown based on design speed and ADT (TABLE 5).

L_1 = Tangent section in advance of obstacle (transitions should be tangent).

LON = Length of Need for traffic barrier from upstream face of obstacle to the effective point of the end treatment

L_c = Design Clear Zone Width (ft.) as shown in TABLE 1.

TABLE 5: RUNOUT LENGTHS FOR BARRIER DESIGN

	TRAFFIC VOLUME (A D T)			
	OVER 6000	**2000-6000**	**800-2000**	**UNDER 800**
Design Speed MPH	Runout Length L_r (ft.)	Runout Length L_r (ft.)	Runout Length L_r (ft.)	Runout Length L_r (ft.)
70	475	445	395	360
60	425	400	345	330
55	360	345	315	280
50	330	300	260	245
45	260	245	215	200
40	230	200	180	165
30	165	165	150	130

Source: Values from AASHTO Roadside Design Guide 2002.

Using this procedure produces very long runs of barrier in advance of the obstacle. This must be realized for proper application of the procedure.

For example: Assume Parallel Installation

Design Speed: 60 MPH, ADT: 5000

D = 20 ft., d = 8 ft.

Determine L_r = 400 ft. (from TABLE 5)

$$LON = \frac{L_r \times (D - d)}{D} = \frac{400 \times (20 - 8)}{20} = 240\,ft$$

As the barrier placement gets closer to the edge of the travel lane, the LON gets progressively longer; this is another reason to locate the barrier as far away as possible.

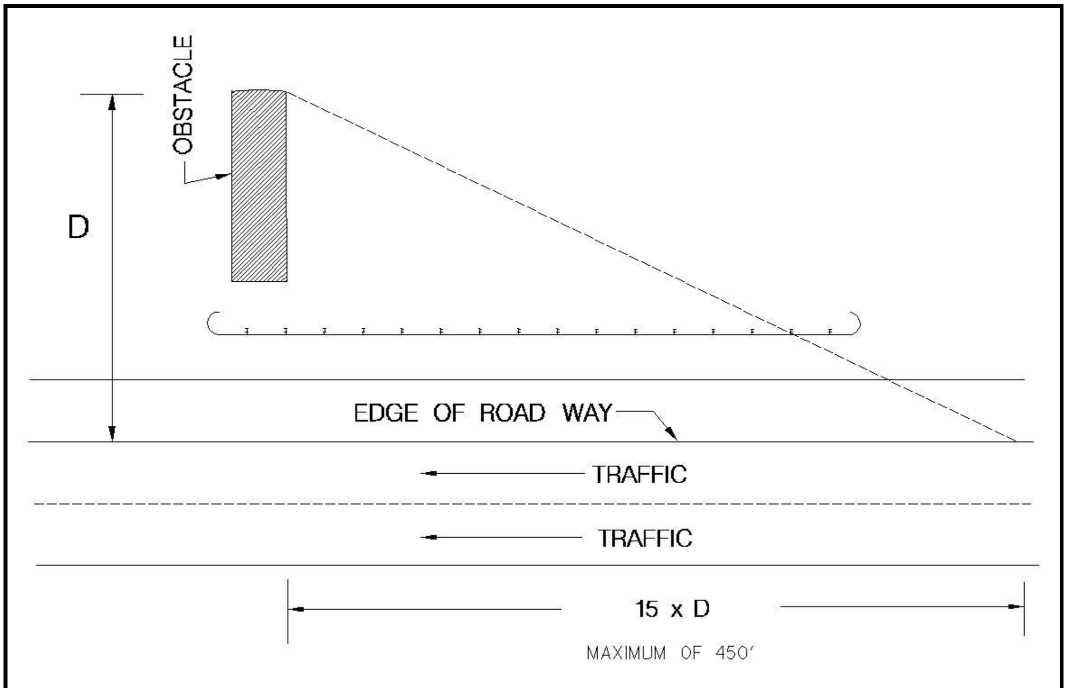
Caution: the cross-section geometry of the roadway can have an effect on the amount of barrier needed: for example, if it is a cut section, the backslope may redirect a vehicle back toward an obstacle on the frontslope. In this case, even though application of the formula would result in a LON supposedly sufficient to shield the obstacle, application of good engineering judgment would result in a significant additional length of barrier to adequately shield it.

The minimum run of barrier upstream of an obstacle, including LON and the total end treatment, is 75-ft. unless otherwise documented.

Determine LON for opposing traffic in the same manner as above; **HOWEVER**, lateral dimensions are measured from the left edge of travel way of the opposing traffic. If there is a two-way divided roadway, the edge of the travel way for the opposing traffic would be the edge of the driving lane on the median side.

When successive runs of traffic barrier have an open space between the ends which is 300-ft. or less in length, the traffic barrier should be made continuous to eliminate the space unless other conditions, especially maintenance, preclude it. This is safer and more cost effective than leaving a gap and placing end treatments.

A “field expedient” procedure for approximately determining the LON on high speed roadways is provided for use on field reviews. This procedure will be fairly close to the formula application for obstacles that extend beyond the design clear zone, but will yield somewhat lesser values as the back of the obstacle is less distance from the edge of the pavement; but it is still good for rough application.



Procedure:

- Identify upstream face of obstacle
- Identify back of obstacle – estimate or measure distance D in feet – limit to 30'
- Beginning at the upstream face of obstacle, walk upstream along the edge of traveled way a distance of 15 x D
- From this position, sight to the upstream, back edge of obstacle (limit to 30' offset)
- End treatment of barrier should lie on the line of sight

FIGURE 5: FIELD EXPEDIENT APPROXIMATE LENGTH OF NEED (LON)

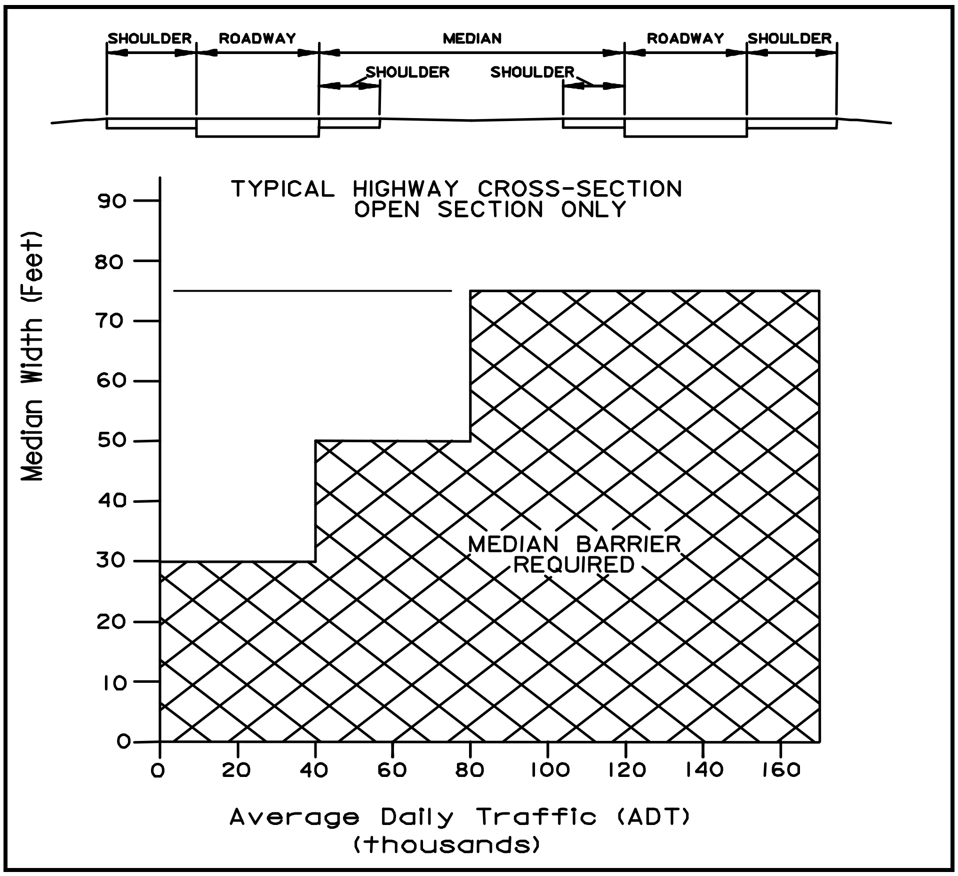
If there is a significant difference between the location determined using the above procedure and either the existing or proposed installation location, the site should be reviewed to assure appropriate application of LON.

XI. MEDIAN BARRIERS

A. Median Barrier Warrants

The function of a median barrier is to prevent a vehicle from encroaching into the opposing traffic roadway.

Median barriers along expressways and fully controlled access highways are warranted when the combination of average daily traffic (ADT) and median width fall within the applicable range as shown in FIGURE 6 below.



NOTE: WITHIN THE HATCHED AREA, MEDIAN BARRIER IS REQUIRED. ABOVE THE HATCHED AREA, BARRIER MAY BE WARRANTED DUE TO ACCIDENT HISTORY OR BY RECOMMENDATION OF SHA.

FIGURE 6: MEDIAN BARRIER WARRANTS CHART FOR EXPRESSWAYS AND DIVIDED CONTROLLED-ACCESS HIGHWAY

NOTE: Median barrier may also be required on divided highways not meeting these criteria where justified by accident experience or other special circumstance. Where a section of highway is less than one-mile in length that does not meet the requirement for median barrier is bordered on each end by a section where median barrier is required, the barrier should be extended through the subject section if the ADT for the subject section meets three-quarters of the ADT criteria (i.e., the width of the median in the subject section is less than 50’ and the ADT is 30,000 or greater; the width of the median in the subject section is less than 75’ and the ADT is 60,000 or greater). Opening in the median barriers may be provided when necessary for authorized-vehicle crossovers and routine maintenance operations, in which case proper end treatment is required.

B. Median Barrier Systems and Their Characteristics

The barrier systems available for median applications are essentially the same as are available for roadside application plus the cable systems described below. However, they are designed to redirect vehicles striking either side of the barrier system.

The W-beam median barrier configuration, with the second rail on the back side, performs similarly to the single face system, with the dynamic deflection reduced to approximately 2’, resulting in a somewhat harder impact. Tension is still the primary mechanism enabling the barrier to redirect vehicles, and must be maintained.

The F-shape concrete median barrier is slightly different than the roadside configuration – its height is 42” (34” high concrete median barrier is prohibited). The 42” high barrier is able to contain 80,000 pound tractor-trailer trucks. This is most important on high volume divided freeways/expressways with narrow medians (generally 30’ or less) where penetration would normally be catastrophic. The system’s primary capability is still its structural capacity, though its continuous longitudinal reinforcing contributes both to its distribution of impact loading and minimization of structure debris.

A new system receiving much attention nationally is the cable barrier system. It relies totally on the tension developed in its cable strands to redirect vehicles. Currently it has only been tested with the pick-up truck (as well as the small car). Because it uses light posts to hold the cables up, the barrier exhibits larger deflections with resultant softer impacts. There are two different types of cable systems available: a generic system using three standard cable wires anchored at the ends of limited length runs with minimal tension, resulting in dynamic deflection of approximately 11 feet; and several proprietary systems, some of which use pre-stressed cables and all apply a post tensioning to the cables, either three or four, which results in lesser deflections than the generic system, approximately 7 feet, but still quite soft, and long runs between anchorages.

C. Median Barrier Selection

All of the above systems have passed the basic acceptance testing (with the pick-up) but there is significant difference in performance capabilities and behavior. With the normal w-beam and concrete systems, it is a fairly straight-forward selection procedure – high volume urban freeways would get concrete and more rural, wider median sections would get W-beam.

TBWB-MB System - The advantages and disadvantages are similar to those enumerated for single face barrier in Section VI. It is generally preferred to use it when the median is wider than 30 feet. This lessens the likelihood it will be impacted – with the resultant repair effects, but it most likely will not stop a heavy vehicle impacting at high speed/high angle from penetrating. Its somewhat low initial cost is a strong factor in its favor, including minimal drainage requirements.

Double-sided F-shape Concrete System – Again, the advantages and disadvantages are similar to those enumerated for single face barrier in Section VI with the major addition that the 42” height should contain tractor-trailer combinations that could otherwise have catastrophic consequences. Thus, for high volume urban freeways/expressways, it is generally the system of choice, despite its high initial cost.

Unfortunately there are no developed guidelines for making the selection among the systems; there is a national study underway but no results have been published yet.

Generic Cable System – This system is not currently approved for use in Maryland. The system provides a very soft impact and a very smooth and shallow redirection performance. It is the least expensive initial installation system. Although its large deflection would be a problem in narrow medians or those having many obstacles, its use on wide, fairly clear medians are generally appropriate. However, its major disadvantage occurs under impacts – it is a fragile system and when impacted, generally is rendered useless. Therefore, in areas that have a history of frequent median encroachments, it would not be the appropriate system selection.

Proprietary Cable Systems – These systems are being considered for use in Maryland. They were developed to overcome the major disadvantages of the generic cable system. The post-tensioning reduces the deflection somewhat; but the major advantage is that upon impact, the cables generally do not fall down and the system is still effective. Thus, they can be used in many of the same situations as W-beam barrier. And there is an additional major advantage in the placement criteria – on slopes (see sub-section D).

TABLE 6 provides a recap of the information above and previously presented in TABLE 3, with the addition of the two cable systems.

TABLE 6: MEDIAN BARRIER SYSTEMS: ADVANTAGES/DISADVANTAGES

TYPE	ADVANTAGES	DISADVANTAGES
W-BEAM BARRIER	• Moderate installation costs • Relatively flexible placement criteria (see next section) • Relatively soft impact to occupants	• Generally damaged on impact, incurring maintenance costs and exposing maintenance personnel to traffic, but typically still functional • Must accommodate moderate deflection • Vehicle damage with any impact
CONCRETE BARRIER	• Minimal damage on impact, lowering life cycle cost and minimizing exposure of maintenance personnel. • Tractor-trailer containment • No deflection • Less (or none) vehicle damage on shallow angle impacts	• Higher installation costs • Harder impacts to occupants • Strict placement criteria • Generally requires installation of storm drain system
GENERIC CABLE	• Lowest initial installation cost • Flexible placement criteria on slopes • Very soft impact • Excellent redirection • Fairly simple repair	• Impacts render system ineffective • Large deflection making it difficult to accommodate median obstacles • Placement near ditch can allow under-ride of vehicles crossing ditch • Vehicle damage with any impact • Fairly frequent anchorage (2000’)
PROPRIETARY CABLE	• Initial installation cost similar to W-beam • Flexible placement criteria on slopes • Relatively soft impact • System still effective after impacts • Fairly simple repair • Long distance (10,000’) between anchorage	• Vehicle damage with any impact • If anchorage system impacted, a significant length (1000’) of system ineffective

D. Median Barrier Placement

All the criteria applicable to roadside placement pertain to median placements as well; this includes deflection, soil backing, placement on slopes, and flare rates. A major change in barrier placed on slopes is that the cable systems can be placed **anywhere** on 6:1 or flatter slopes, giving a lot of flexibility for barrier placement.

As with roadside barrier, median barrier is a hazard and placement as far away as possible is desirable. Different median cross-sections present different conditions controlling barrier placement.

The most typical placement for a symmetrical cross-section is in the center of the median, meeting the placement criteria especially with respect to cross-slope. For properly designed W-beam barrier placed near the median ditch, the post placement should be offset 3' from the ditch bottom. For cable systems placed in the center where slopes are steeper than 10:1, the posts should be offset either less than 1' or greater than 10' from the ditch bottom (to minimize under-ride possibility as the vehicle crosses the ditch).

Unless approved by OHD, median barrier shall not be placed closer than 12-feet (median shoulder width plus offset to barrier) from the edge of travel lane.

For bifurcated cross-sections where the barrier cannot be placed far away from the shoulder edge, the general placement is adjacent (2' offset) to the higher roadway, especially on the outside of curves. If the median is non-traversable, a run of TBWB along each roadway may be required to shield the median obstacle (this applies to symmetrical cross-section as well).

The current median barrier warrants can require barrier to be placed in medians as wide as 75'. Even though this could result in the back of the barrier being as far as 67' from the opposing traffic***, all barrier that is placed in compliance with the median barrier***

warrant shall be redirectional on both sides (unless it is virtually impossible to be impacted from the back).

For depressed medians, whether symmetrical or bifurcated, one side of the barrier will generally be exposed to vehicles approaching on an **upslope**. Currently, none of the barriers have been tested (or even studied) when placed on an upslope. Until definitive guidance is provided, the following should be used:

1. Concrete – the back face should not be exposed to any upslope steeper than 10:1; if the barrier is located at the top of a steeper slope, the ground immediately adjacent to the back face can be flattened to 10:1 desirably for at least 10'. A vertical back face for the barrier desirably should be used if any steeper slope must be maintained, and even used with a 10:1 upslope; this would limit the uplift on an impacting vehicle.

2. ***W-beam –for TBWB-MB, the back rail is set at the same elevation as the front rail; this configuration is used on upslopes 6:1 or flatter. For upslopes steeper than 6:1, a "Traffic Barrier Median Barrier With Bottom Rail" (MD 605.28-01) is used; this consists of standard TBWB-MB with a W-beam panel (without blockouts) added 3" below the back rail to prevent snagging***. Neither a back rail nor a lower panel is required if the barrier is more than 10' up a 2:1 or steeper slope.

3. Cable – the upslope (no steeper than 4:1) on the back side of the barrier should present no performance problem.

In some situations, it is desirable to change the median barrier location such as moving from adjacent to one roadway to adjacent to the other roadway. As long as the median is flat (10:1 or flatter), any barrier can be moved using the appropriate flare rate. If the barrier is being flared toward approaching traffic, the flare rates given in TABLE 4 should be used. If the barrier is being flared away from approaching traffic, flare rates as steep as 2:1 can be used (to get it away fast). If the side slopes are steeper than 10:1 but no steeper than 6:1, moving barrier across the slope may violate the barrier placement on slope criteria. (No barrier is placed on slopes steeper than 6:1.) For cable barrier systems, there is no problem; but W-beam barrier has a problem. A design treatment that resolves the problem is to modify the standard W-beam by using a double rail transition system (a second rail spaced 3" below the top rail) similar to the double rail Type A end treatment for slopes steeper than 10:1. The double rail section must extend through the area where standard W-beam barrier is not recommended (2' to 12' from the hinge point) and then transition back to normal W-beam barrier beyond the 12' mark (generally in 25'). The approach end of the bottom panel must be hidden to prevent snagging, either by tucking it into the web of the post or by flaring it behind the post. Only one rail element is needed on the back of the double rail section (at 30" height). Flare rates shall be from TABLE 4. (This same treatment can also be applied to roadside W-beam barrier.). Refer to APPENDIX B for Double Rail Transition.

For narrow, flat medians, less than 18' wide, it is desirable to offset the barrier to one side of the center. It is undesirable to present an offset between the edge of the travel lane and the face of the median barrier that is less than 8' (but more than 4'), as it misleads motorists as to a refuge area that is not really safe. For example, placing a 2' wide median barrier in the center of a 14' median would leave only 6' refuge on both sides. By offsetting that same barrier to have only 4' on one side, a minimum 8' refuge would be available on the other; this is also helpful on the inside of curves for sight distance.

XII. W-BEAM BARRIER ANCHORAGES TO RIGID OBJECTS

Rigid objects are defined basically as any unyielding obstacle such as piers, bridge parapet ends, concrete barrier, and retaining walls. When attaching W-beam barrier directly to a rigid object, a transition from the semi-flexible W-beam barrier to the non-deflecting rigid object must be provided. MSHA standards contain several anchorages to achieve this, depending on the geometry of the rigid object. All of the anchorages contain the same basic elements: a nested rail providing extra stiffness strongly connected to the rigid object (to maintain tension); closer post spacing approaching the rigid object; and some design to prevent wheel snagging on the rigid object – either a rubrail or flared back concrete. The designer should assure that all anchorages on the project contain these elements. If the narrow blunt end of the rigid object is the only obstacle that is being shielded, an approved end treatment may be connected directly to the upstream end of the anchorage.

XIII. END TREATMENTS

It is the policy of the Administration to install traffic barrier end treatments that meet current Federal Highway Administration (FHWA) requirements on the ends of existing and proposed W-beam or concrete traffic barriers for all highway projects (see TABLE 7 for exceptions).

The function of an end treatment is twofold. First, if hit on the end, it must minimize the injury to the vehicle's occupants; second, it must develop the necessary tension at the end of a tension-requiring system in order to redirect a vehicle on a downstream impact. The end treatments discussed below have all successfully passed the required testing using a small car and a pick-up. The terms "gating" and '"non-gating" are used to describe characteristics of these systems. A gating system will allow a vehicle impacting, either at an angle and/or head-on, at or near the end of the end treatment to pass on through – it gates; at some distance downstream from its end, it will be effective barrier and able to redirect an impacting vehicle. A non-gating system is capable of: 1. redirecting a side impacting vehicle through essentially its entire length; and 2. capturing the vehicle when impacted on the end at an angle of 15º or less.

Regardless of which type of end treatment is used, it should be installed as close as possible to the tested conditions. This is most important with respect to the grading. Testing was done with the vehicle in a stable condition upon impact, having traversed a smooth, level approach. Grading requirements for each end treatment are typically shown on the standards, and need to be complied with to ensure the best chance of good performance of the unit.

A. Roadside W-beam End Treatments and Characteristics

1. Type A (aka Buried-in-Backslope {BIB}): This is the **most desirable method** to terminate barrier: to bury the end in an existing back slope (no building of mounds is allowed) where it cannot be hit end on. The burying must provide the necessary anchorage to develop the tension forces and must be deep enough so that the end of the rail will not become exposed; both are provided by the current two standards. The single rail design can **ONLY** be used when the slope between the edge of the shoulder and the toe of the back slope is 10:1 or flatter. If the slope is steeper than 10:1, the rail is held level relative to the roadway, so as not to violate barrier placement on slope criteria, and a bottom rail must be added to prevent snagging. The type of Type A – single or double rail – should be specified on the plans to ensure the contractor installs the correct type. The anchorage, which is 12 ½' long for either system, is paid for per each. The traffic barrier is measured and paid for as shown on the applicable standard.

   The point of effectiveness (where redirection is expected) of the BIB is the point where the face of the rail crosses the ditch bottom/toe of backslope. The rail that extends upstream from this point – a maximum of 50' – is not necessarily effective barrier (especially that portion that is buried in the ground). The determination of how far the point of effectiveness is in advance of the obstacle – the Length of Need (LON) – depends on the backslope where the anchorage is being established as follows:

   a. For backslopes steeper than 1:1 – the barrier is anchored in the backslope as quickly as possible but not exceeding an 8:1 flare rate; the intention is solely to establish tension continuity as the steep backslope is considered a barrier itself. (A rock anchor may be used with the approval of the engineer. No ground cover is necessary for rock anchors.)

b. For backslopes 1:1 or flatter but steeper than 2.5:1, a minimum of 125' for Single Rail and 75' for Double Rail Installations (50' for lower speed facilities) from the upstream face of the obstacle to the point of effectiveness is required. The flare rate may be flatter than the flare rate shown on the standard to achieve the minimum length; (the prime example of this would be where there is no ditch – fully effective barrier would be required for either 125' or 75' upstream of the obstacle **before** the 50' anchorage begins).

c. If the BIB were to be used with backslopes 2.5:1 or flatter a calculation of LON is required, using the procedure in Section X.

This terminal should not be used for these flatter backslopes if the toe of the backslope is less than 20' from the edgeline.

The application of the double rail standard may be the best compromise end treatment at locations where the ditch front slope is steeper than 4:1 (the maximum steepness tested under NCHRP 350) and it is impractical to extend the barrier farther upstream to a more appropriate end treatment application. As long as the ditch is not deeper than 2', this application should provide acceptable performance.

The Type A should also be used even when the barrier system LON would normally end downstream of a cut slope if the cut slope is within 200' and there is not a large available runout area (400' x 50') beyond the cut slope.

The Type A may not be the best end treatment selection when the backslope is not very high. The following guidance is offered: for a single rail system, the height of the backslope should be at least 2'; for the double rail system, the height of the backslope should be at least 3'. Offset of the toe of slope should also affect the decision to use the Type A; good engineering judgment must be exercised.

2. Type B: flared (4'), gating end treatment. The system is designed to allow a vehicle impacting on/near the end to pass through the end of the terminal with minimal reduction of speed or energy. (One of the approved substitutes in the Book of Standards for the Type B, the FLEAT system, will absorb significant energy on head on impacts, but since it is bid as an option, the criteria must cover all options.) Therefore, ***Type B shall only be used when both the LON and full grading is provided. In all cases, a minimum of 75' should be provided from the beginning of the end treatment to any obstacle.*** The point of effective barrier for this system is at the third post.

3. Type C: parallel, gating end treatment. The system is designed to allow a vehicle impacting head on to be brought to a controlled stop by absorbing its energy. For higher angle end impacts, the vehicle will pass through with little absorption of energy and reduction in speed. The point of effective barrier for this system is at the third post. As indicated on the standard, the first post should generally be offset 1' from the normal run of barrier to prevent nuisance hits, especially snowplows. This system should not be placed beyond the Point of Curvature (PC) of sharper curves, but should begin while the roadway is still tangent; in any case, the system must be placed on a **straight line**.

4. Type G: single-sided turndown end treatment. It is for use on closed or open sections on low speed facilities; it is prohibited for use on the National Highway System (NHS).

When Type B or, more likely, Type C end treatments are to be installed on 3-R projects, the bid item for grading adjustment must be provided.

If the Type B or Type C end treatments are used to terminate TBWB-MB, eliminate the, back rail on the first 12 1/2' of the standard barrier beyond the end treatment.

B. Two-side End Treatments and Characteristics – typically used to end median barriers

1. Type D: two-sided, gating end treatment. Because this system is somewhat fragile (its rail elements must remain straight), it should not be used within 12' of the edge of travelway. Type D is **NOT** an alternative for the Type F, but the Type F may be used as an alternative for the Type D. The Type D CAT has also been used as a roadside barrier end treatment; when used to terminate single-side W-beam barrier, an additional cable anchorage is required at its downstream end; the point of effective barrier is at the fourth post.

2. Type E: two-sided, non-gating end treatment. Because this system is expensive, it normally should only be used where it's non-gating characteristic and/or its durability is needed. The most obvious application would be at a maintenance opening on a high volume urban freeway with a paved median and continuous concrete median barrier. The unit must meet or exceed the Design Speed of the facility. It comes in various widths so it can be used to shield wider obstacles.

3. Type F: two-sided, semi-gating end treatment called the BRAKEMASTER. Because this system does not utilize a breakaway cable to develop tension capability for downstream hits, it successfully captured the pick-up in the 15º end-on impact test (but it does not have total redirecting capability – its point of effective barrier is designated at the midpoint of the system). Also, due to its tension cable design, it is a fairly hardy system. Therefore it can be used in relatively narrow situations where fully non-gating systems are not deemed cost-effective. The BRAKEMASTER has also been used as a roadside barrier end treatment. The Type F system may be used as an alternate to the Type D system. Grading for this system must provide a flat (12:1 or flatter) base for the diaphragms to slide on.

4. Type H: two-sided, turndown end treatment. It is for use on closed median sections on low speed facilities and on open median sections on low speed facilities; it is prohibited for use on the National Highway System (NHS).

5. Type J: two-sided, non-gating end treatment. The same applications as a Type E with the additional benefit of being self-restoring; therefore, it is used where high frequency of impacts is expected. Care must also be exercised if the height of a specific system could impact site distance.

C. Type K - Downstream End Anchor

A non-crashworthy end treatment, it is designed only to develop tension and to be used on the downstream end. Although it has not been subjected to formal crashtesting, it is generally accepted that its redirecting capability is fully developed by the third post (the point of effective barrier) from the end. Therefore, the third post must be at or beyond the end of effective barrier need. For simplicity, the end of need is generally taken as the end of the obstacle. However, if the obstacle is offset well behind the barrier, a significant length (20±') of unnecessary barrier may be eliminated. This is done by establishing a 25º line (approximated by a longitudinal distance equal to twice the offset between the face of the barrier and the front face of the obstacle) from the end of the obstacle back to the third post from the end of the barrier.

D. Type L – Traffic Barrier Anchorage

The Type L is an enhanced treatment to the common radius treatment used at turnouts on lower speed roadways. It adds a cable anchorage similar to the Type K with the anchor located at the post before the radius begins; it develops tension for impacts immediately downstream of the cable attachment. (When used with only a 12 ½' panel beyond the anchorage post, bent at a 16' radius, it is a crashworthy terminal for TL-2 (43 mph).)

E. Reference for Standards and Approved Substitutes

Please refer to the following web site for End Treatment Standards and a List of Approved Substitutes that have been approved by the Administration and may be substituted for those shown on the standards:

http://www.sha.state.md.us/BusinessWithSHA/bizStdsSpecs/desManualStdPub/publicationsonline/ohd/bookstd/index.asp.

F. Bullnose End Treatment

There is a NCHRP 350 TL-3 (62 mph) approved Bullnose, which is essentially a crash-worthy 180º± radius barrier. It should only be used when none of the standard end treatments are applicable. A distance of 62' from the front of the radius to the front of a rigid obstacle is required since end on impacts will intrude into the system. It should not be used in a median unless there is more than 20' offset from the opposing traffic edgeline to the face of the longitudinal barrier to which the bullnose is connected. If this treatment is used, prior approval by SHA-OHD is required.

XIV. TYPICAL BARRIER INSTALLATIONS

The following special case conditions and treatments are examples of actual field situations that have been addressed and are provided to assist in determining the most appropriate traffic barrier placement and end treatment. It is impossible to include or document in this guide all field conditions that require treatment, or all possible treatments for a given situation. Good engineering judgment in applying proper barrier principles is to be used for all situations; the examples given below may not be the best for all situations and other alternatives, complying with the principles, may be better. (In the following figures and discussion, EOTL stands for Edge of Travel Lane, EOS stands for Edge of Shoulder, and TBWB-MB stands for Traffic Barrier W-Beam-Median Barrier.)

A. Roadside Barrier to Shield a Critical Embankment

Many existing barrier installations intended to shield critical embankments are significantly short of the required LON. Identifying the upstream face of the obstacle can be difficult. When there is a serious obstacle at the toe of the slope, the upstream face of the embankment obstacle will be the location where the slope goes steeper than 4:1 (POINT 1). See FIGURE 7. If the area at the toe of slope is free of obstacles (and is expected to remain so), the upstream face of the embankment obstacle will be the location where the slope goes steeper than 3:1 (POINT 2). If there are obstacles on the slope, regardless of the steepness, a determination of LON for these obstacles will also have to be made. Refer to Section X for LON determination and definition of factors.

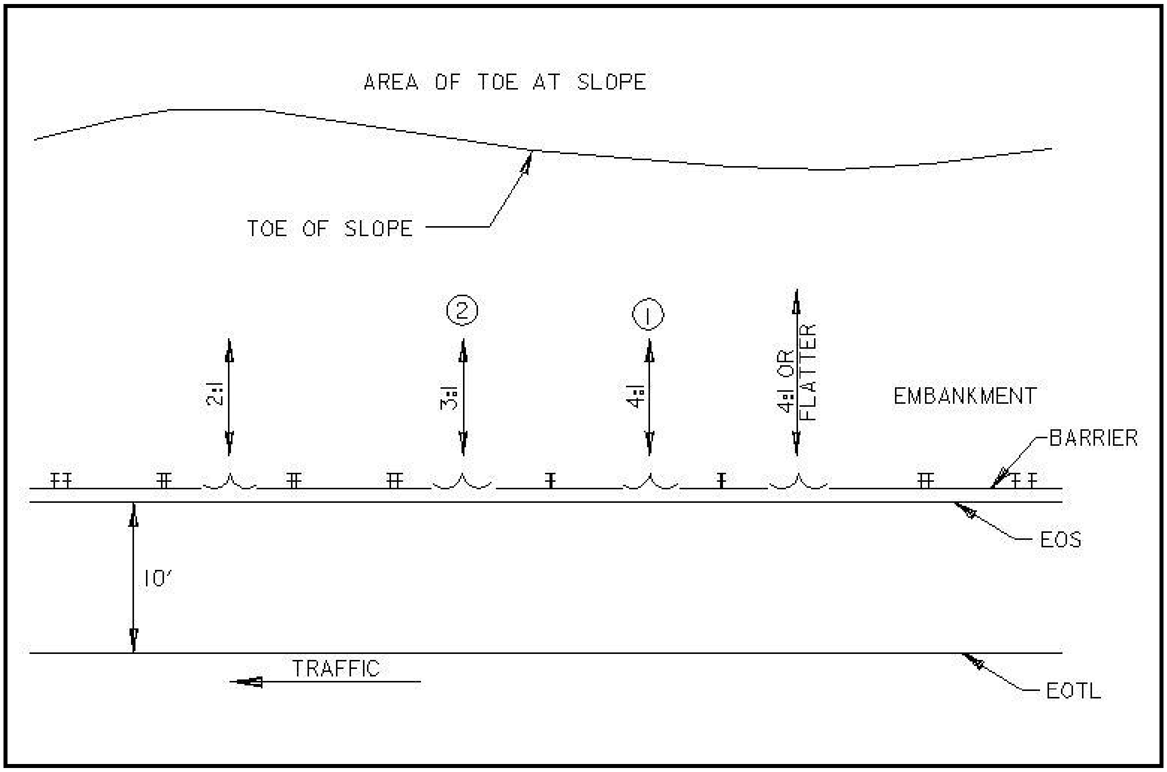


FIGURE 7: CRITICAL EMBANKMENT

Example: High speed/ high volume roadway with Design Clear Zone = 30'(equal to D in example), L_r = 475', d = 12' (2' w-beam offset + 10' shoulder);

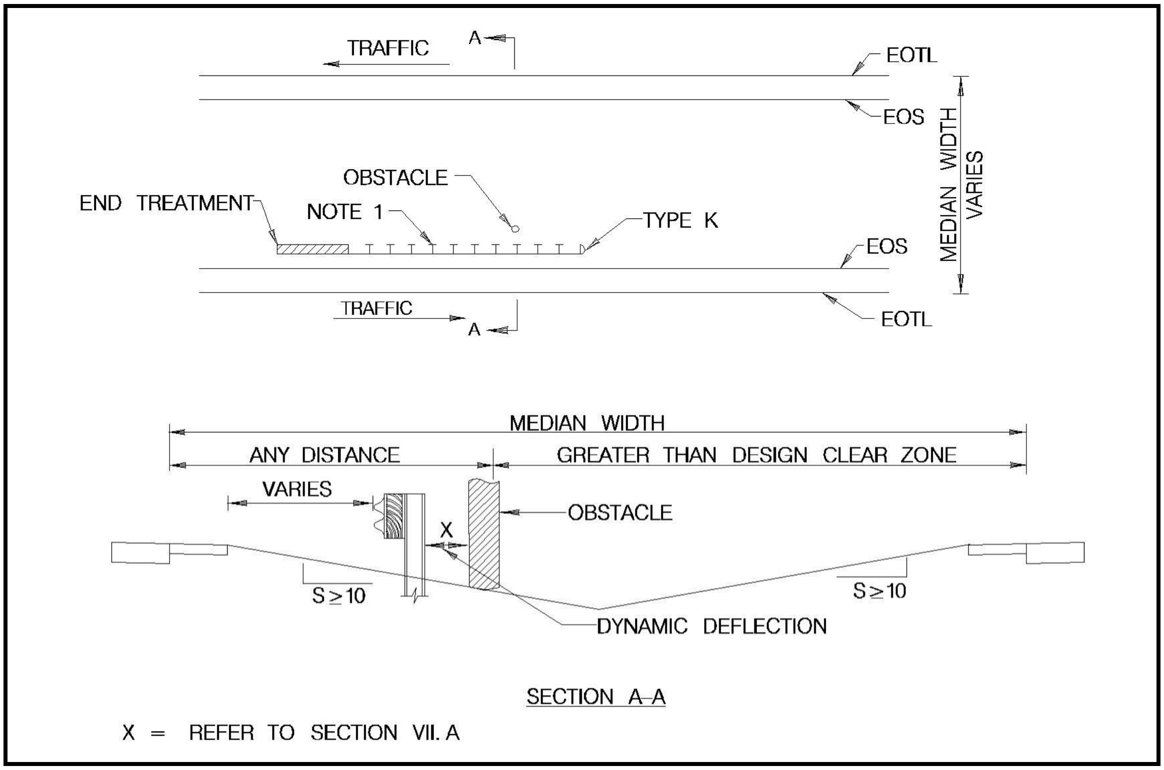
$$LON = \frac{L \times (D-d)}{D} = \frac{475-(30-12)}{30} = 285'$$

in **ADVANCE OF** Point 1 or Point 2, whichever is applicable.

Isolated Obstacle in Open Median (no continuous median barrier)

1. The obstacle is within the Design Clear Zone of only one roadway. (See FIGURE 8.)

   Design the LON for a typical roadside obstacle. However, if the barrier is within 50’ of the opposing traffic, TBWB-MB is needed as shown in NOTE 1 on the figure. Since the obstacle is more than the design clear zone from the opposing edge of travel lane and is of short length, barrier is not necessarily required along that side (but the TBWB-MB rail could be split to shield the back if the obstacle is close behind the barrier).



NOTE 1: IF THE BACK OF THE BARRIER IS LESS THAN 50’ FROM THE OPPOSING TRAFFIC, A TBWB-MB IS REQUIRED (UNLESS THE REQUIRED LENGTH IS LESS THAN 50’).
NOTE 2: IF THE END TREATMENT IS 35’ OR LESS FROM THE OPPOSING TRAFFIC, USE A TW0-SIDED END TREATMENT IF BARRIER IS TBWB-MB. TYPE B OR TYPE C CAN BE USED BEYOND 35’ EVEN IF THE BARRIER IS TBWB-MB. DO NOT USE A TWO-SIDED END TREATMENT TO END SINGLE FACE W-BEAM IN THE MEDIAN

FIGURE 8: EXAMPLE – MEDIAN: FLAT SIDESLOPE, ISOLATED OBSTACLE INSIDE DESIGN CLEAR ZONE OF ONE ROADWAY

2. The obstacle is within the Design Clear Zone for both roadways.

If the median slopes are flat (10:1 or flatter), barrier would be placed on either side of the obstacle (just beyond the deflection distance), and would be terminated by bringing both runs together, with the appropriate approach flare rates, to a Type D or Type F (Type F for narrower medians) end treatment. Typically the upstream end treatment would be placed farther away than the downstream end treatment. See FIGURE 9.

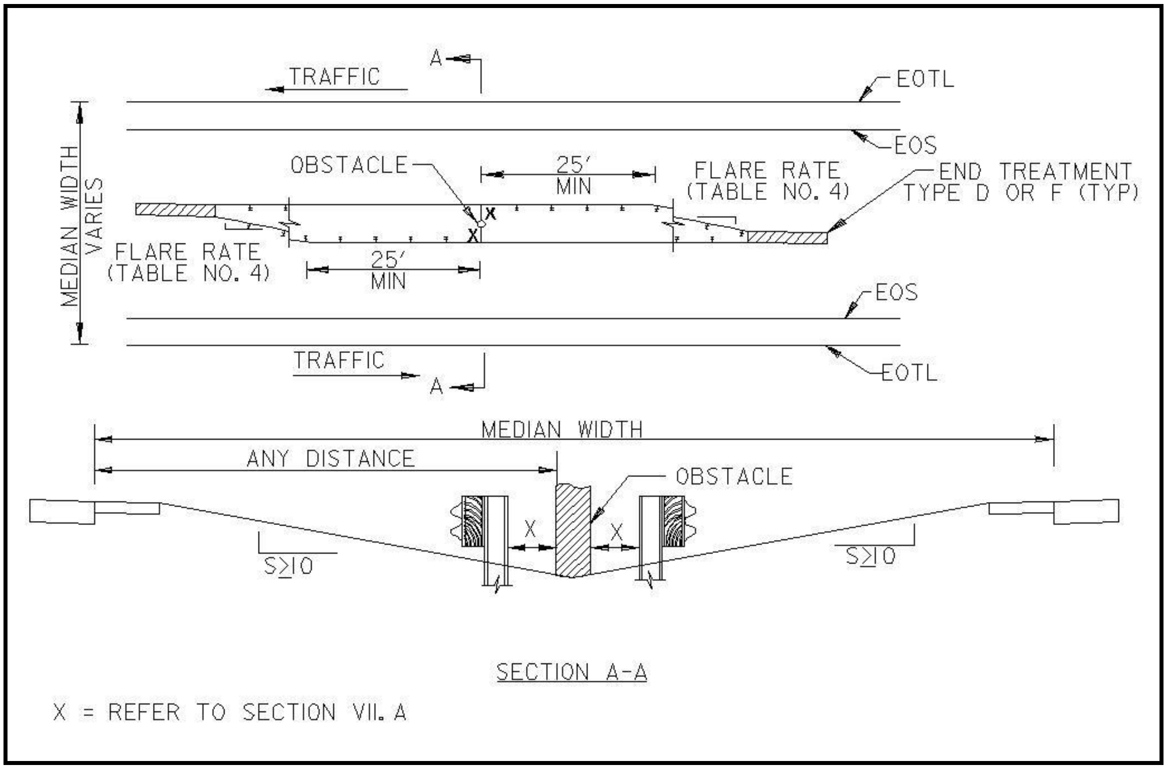
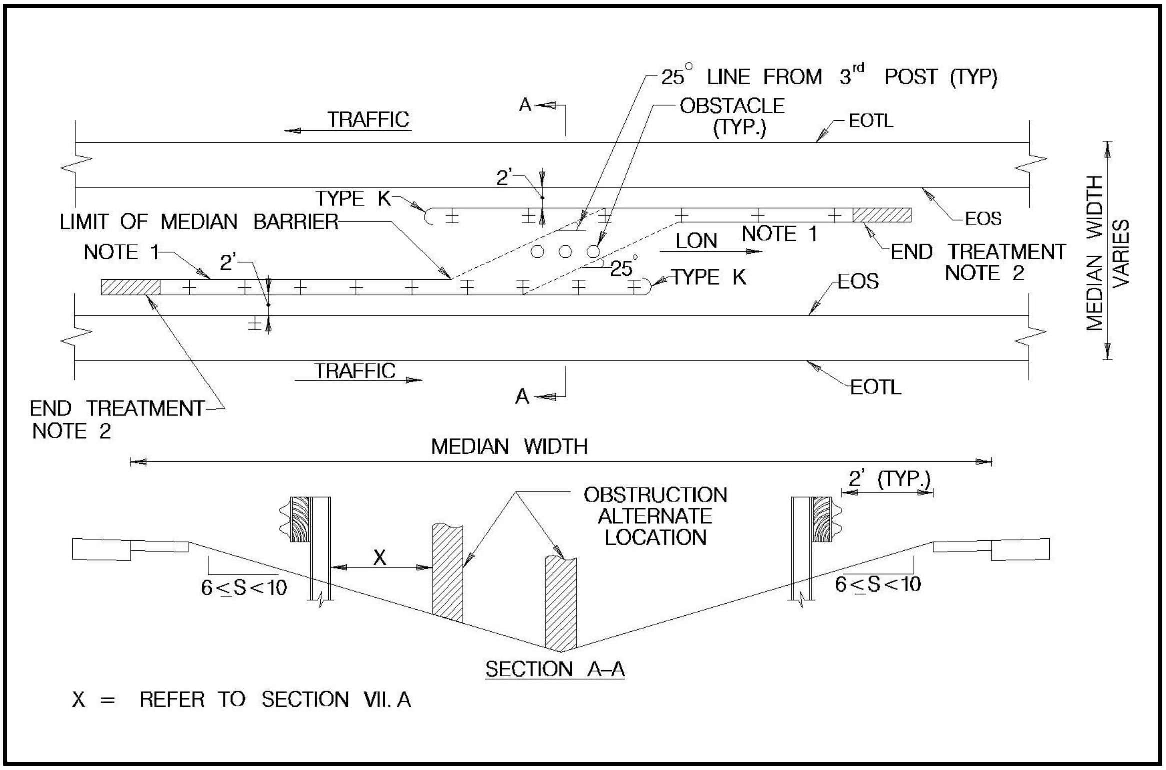


FIGURE 9: EXAMPLE - MEDIAN: FLAT SIDESLOPE, ISOLATED OBSTACLE INSIDE DESIGN CLEAR ZONE OF BOTH ROADWAYS

If the median slopes are steeper than 10:1 but no steeper than 6:1, the location of the barrier must comply with the placement criteria for barrier on slope. If the barrier can not be placed down the slope, then the barrier should be placed along both roadways; each side would be located desirably at the 2' offset from the shoulder edge and would extend upstream by the LON and have the appropriate end treatment. See FIGURE 10. The downstream ends would have End Anchors located as described in Section XIII C. If the back of the single-sided W-beam were within 50’ of the opposing traffic lane, TBWB-MB would be used to make the back of the W-beam safe for the length where it could be impacted from the back side (unless the total required length were less than 50’). If TBWB-MB were required, the appropriate end treatment would depend on the distance from the opposing traffic. If more than 35’ a Type B or C could be used; if 35’ or less a Type D or F, as appropriate, would be used.



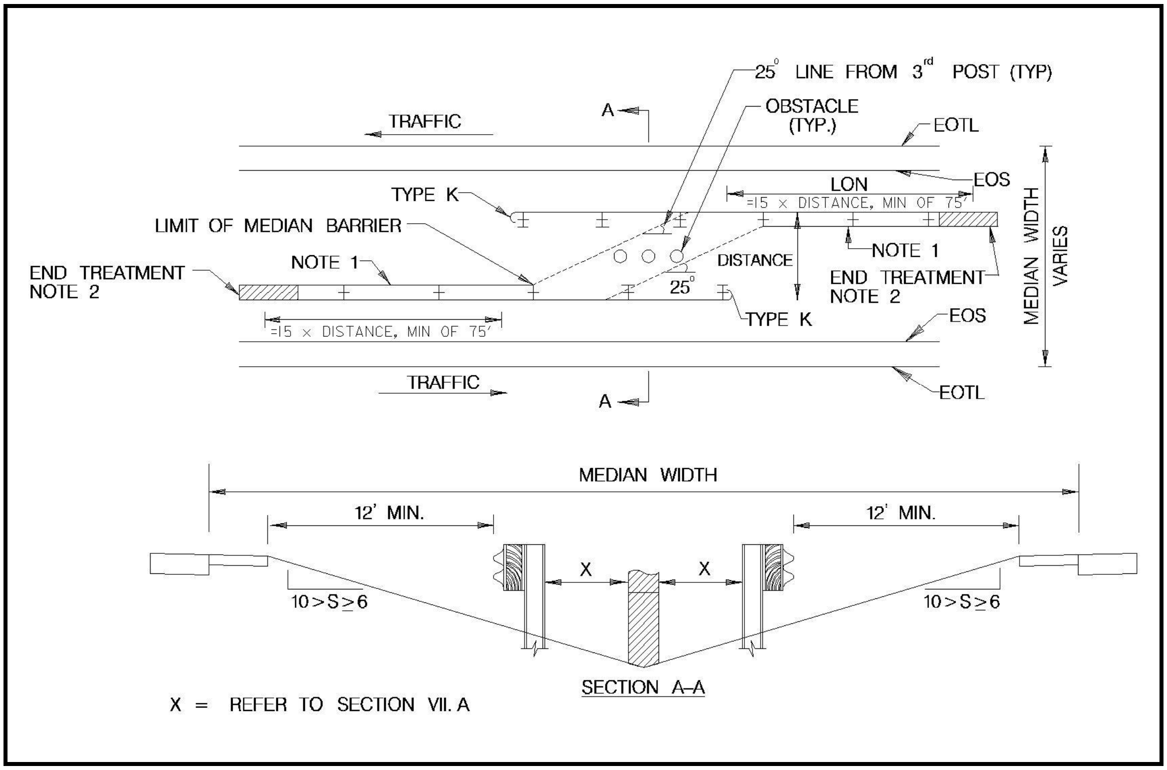
NOTE 1: IF THE BACK OF THE BARRIER IS LESS THAN 50’ FROM THE OPPOSING TRAFFIC, A TBWB-MB IS REQUIRED (UNLESS THE REQUIRED LENGTH IS LESS THAN 50’).
NOTE 2: IF THE END TREATMENT IS 35’ OR LESS FROM THE OPPOSING TRAFFIC, USE A TW0-SIDED END TREATMENT IF BARRIER IS TBWB-MB. TYPE B OR TYPE C CAN BE USED BEYOND 35’ EVEN IF THE BARRIER IS TBWB-MB. DO NOT USE A TWO-SIDED END TREATMENT TO END SINGLE FACE W-BEAM IN THE MEDIAN

FIGURE 10: EXAMPLE - MEDIAN: STEEPER SIDESLOPE, ISOLATED OBSTACLE, BARRIER NEAR SHOULDER EDGE, OVERLAP INSTALLATION

However, if the barrier can be placed down the slope, barrier should be placed on each side of the obstacle. There are two options to terminate it:

1. If drainage can be accommodated, the two parallel barriers would be brought together and a Type D end treatment could be used (same as FIGURE 9);

2. Upstream end treatments would be in accordance with FIGURE 11 with Type K end treatments on the downstream ends. The "controlling" obstacle for the LON (the amount of rail in advance) would be the Type K end treatments and the LON would be 15 times the distance between the barriers, but not less than 75'.

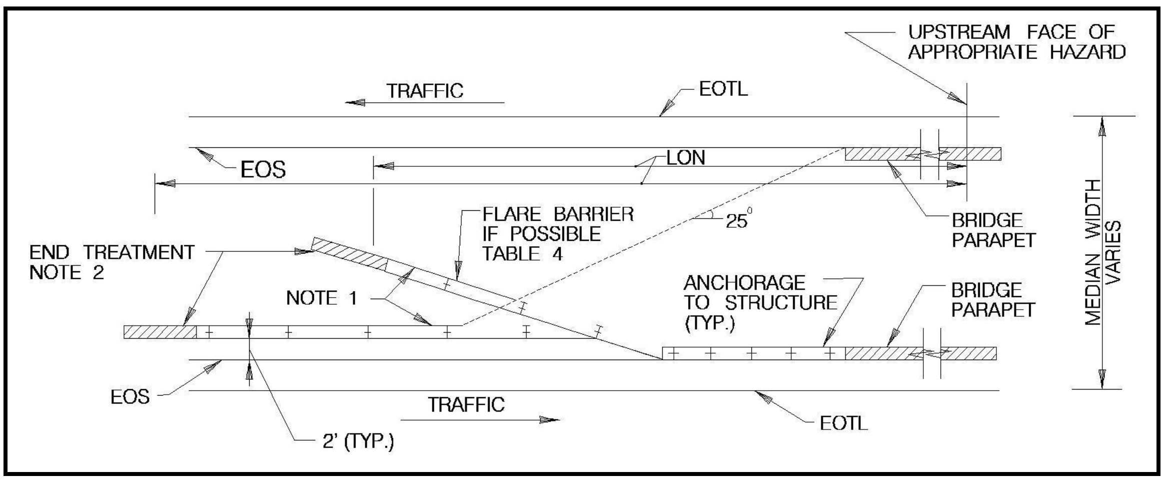


NOTE 1: IF THE BACK OF THE BARRIER IS LESS THAN 50' FROM THE OPPOSING TRAFFIC, A TBWB-MB IS REQUIRED (UNLESS THE REQUIRED LENGTH IS LESS THAN 50').
NOTE 2: IF THE END TREATMENT IS 35' OR LESS FROM THE OPPOSING TRAFFIC, USE A TW0-SIDED END TREATMENT IF BARRIER IS TBWB-MB. TYPE B OR TYPE C CAN BE USED BEYOND 35' EVEN IF THE BARRIER IS TBWB-MB. DO NOT USE A TWO-SIDED END TREATMENT TO END SINGLE FACE W-BEAM IN THE MEDIAN

FIGURE 11: EXAMPLE – MEDIAN: STEEPER SIDESLOPE, ISOLATED OBSTACLE, BARRIER GREATER THAN OR EQUAL TO 12' FROM SHOULDER EDGE

B. "Elephant Trap" in an Open Median (no median barrier)

An "elephant trap" is defined as the opening between dual bridges on a divided roadway. Barrier is designed for the upstream end of the near side parapet only as a roadside barrier, using the procedure in Section X with the back of obstacle being either the opposing traffic bridge parapet or the Design Clear Zone, whichever is less. No barrier is used on the downstream end of the parapet unless the median has an obstacle not shielded by the end of the parapet determined by the 25º line. If there is an obstacle beyond this line, the W-beam barrier would be extended to the appropriate length to place a Type K end treatment. See FIGURE 12.



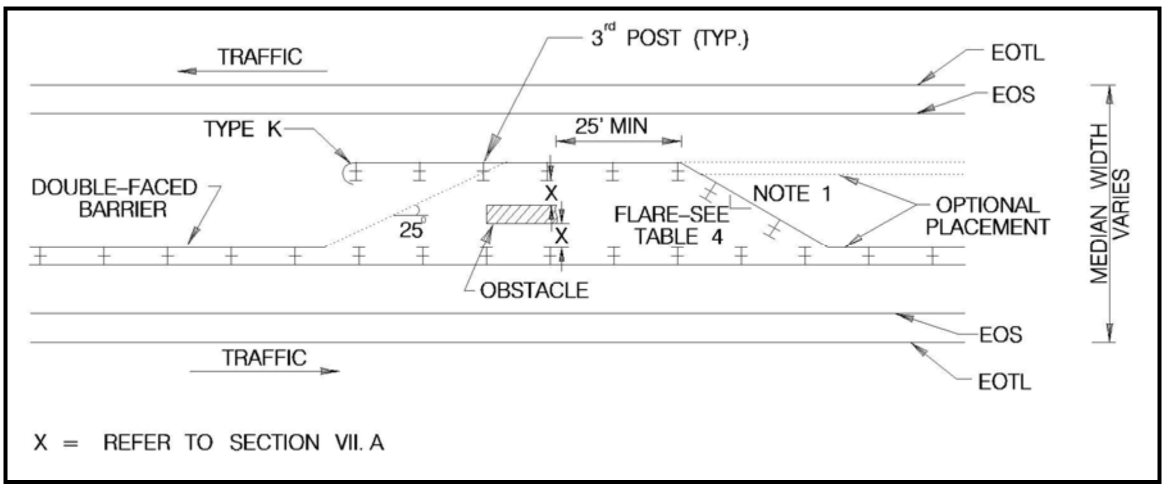
NOTE 1: IF THE BACK OF THE BARRIER IS LESS THAN 50' FROM THE OPPOSING TRAFFIC, A TBWB-MB IS REQUIRED (UNLESS THE REQUIRED LENGTH IS LESS THAN 50').
NOTE 2: IF THE END TREATMENT IS 35' OR LESS FROM THE OPPOSING TRAFFIC, USE A TW0-SIDED END TREATMENT IF BARRIER IS TBWB-MB. TYPE B OR TYPE C CAN BE USED BEYOND 35' EVEN IF THE BARRIER IS TBWB-MB. DO NOT USE A TWO-SIDED END TREATMENT TO END SINGLE FACE W-BEAM IN THE MEDIAN

FIGURE 12: EXAMPLE – ELEPHANT TRAP, OPEN MEDIAN

C. Isolated Obstacle in Median with Continuous Median Barrier

The upstream near side face of the median barrier would be extended in front of the obstacle for both approaches. For W-beam barrier, a Type K Traffic Barrier End Anchor would terminate one end of the separated barrier and the TBWB-MB would begin again where the 25º line from the third post would intersect the continuing barrier. See FIGURE 13.

Note: If median barrier is carried continuously on one side of the roadway and a separate run of single sided barrier is placed along the other roadway, the median barrier is required to have a back rail only where it is within a longitudinal distance, determined as 10 times the transverse separation between the barriers or 300' maximum, from the beginning of the end treatment for the single sided barrier.

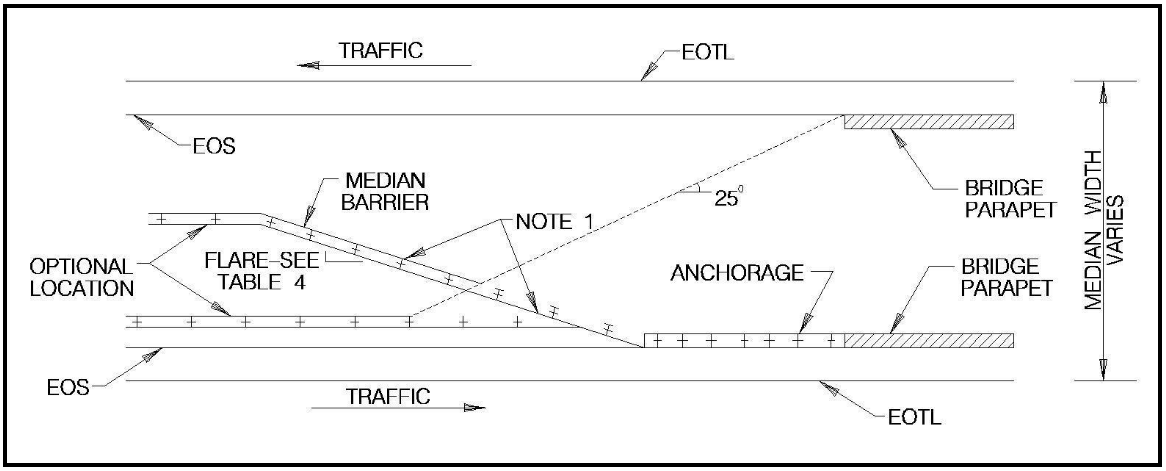


NOTE 1: FOR W-BEAM BARRIER, NO BARRIER SHOULD BE PLACED IN THE AREA NOT RECOMMENDED IN SECTION VII C UNLESS MODIFIED AS DESCRIBED IN SECTION XI D. next to last paragraph

FIGURE 13: EXAMPLE – ISOLATED OBSTACLE, CONTINUOUS MEDIAN BARRIER

D. "Elephant Trap" in Median with Continuous Median Barrier

The median barrier will be connected into the upstream side of the bridge parapet. No barrier is required at the downstream end of the bridge parapet (unless there is an obstacle in the median). For TBWB-MB, the barrier will continue until it becomes shielded by the downstream end of the parapet for the opposing traffic bridge determined by the 25º line – then single-sided barrier can continue to the upstream side parapet (with anchorage). See FIGURE 14.

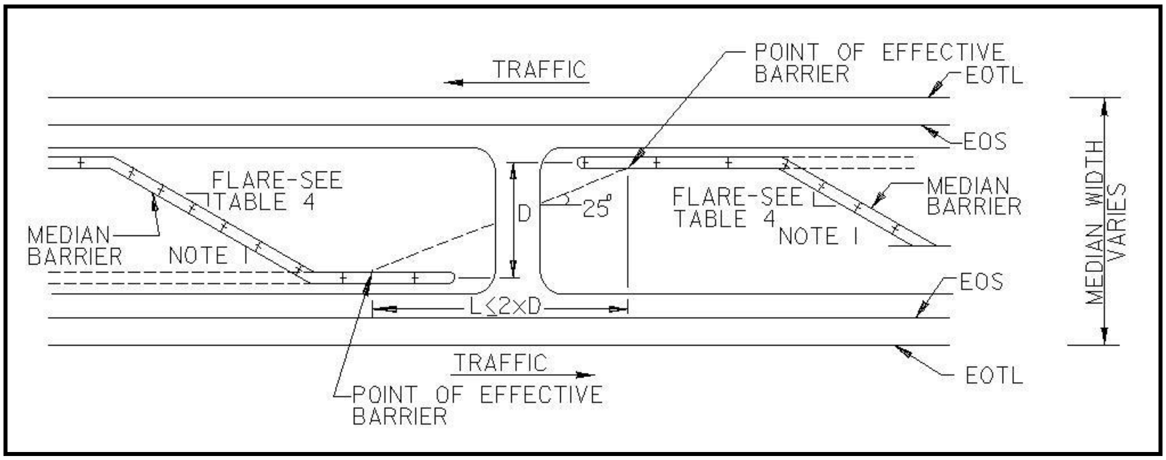


NOTE 1: FOR W-BEAM BARRIER, NO BARRIER SHOULD BE PLACED IN THE AREA NOT RECOMMENDED IN SECTION VII C UNLESS MODIFIED AS DESCRIBED IN SECTION XI D. next to last paragraph

FIGURE 14: EXAMPLE – ELEPHANT TRAP, CONTINUOUS MEDIAN BARRIER

E. Median Opening in Continuous Median Barrier

When median barriers have to be broken to provide emergency or maintenance access – or cross streets on uncontrolled or partial controlled facilities, there are several ways to treat the ends of the barrier. Most commonly, crashworthy end treatments are applied to the barrier; non-gating systems would be used in narrower medians with high traffic to minimize the length of unprotected median opening; gating systems would be used where it is determined that the additional length of ineffective end treatment is cost-effective. Regardless, the most effective and preferred treatment is to offset the downstream end treatments to the nearside roadways as shown in FIGURE 15. A cost-effective treatment is not to use crashworthy end treatments, but to offset the blunt ends of the barrier such that they are hidden by each other. See FIGURE 15. The maximum width of the opening between the ends of effective barrier (L) is determined by the 25º line between the points of effectiveness of the barrier (approximated by twice the offset (D) between the points of effectiveness). For concrete barrier, the point of effectiveness is the actual end of the barrier. For W-beam barrier using a Type K end treatment to establish tension, the point of effectiveness is the third post; designs establishing redirection through the entire length of the barrier (in essence, a non-gating, non-crashworthy end treatment) allow for elimination of any ineffective barrier and maximize the actual available opening width. This offset configuration should be used even when the barrier ends cannot be protected by the overlap such that crashworthy end treatments are used.



NOTE 1: FOR W-BEAM BARRIER, NO BARRIER SHOULD BE PLACED IN THE AREA NOT RECOMMENDED IN SECTION VII C UNLESS MODIFIED AS DESCRIBED IN SECTION XI D. next to last paragraph

FIGURE 15: EXAMPLE – MEDIAN OPENING IN CONTINUOUS MEDIAN BARRIER

F. Non-controlled Access Roadways – Access Breaks in Roadside Barrier

When an entrance causes a break in what would otherwise be a continuous run of barrier, and provision of a Type B or C end treatment would not provide any substantial benefit, take the barrier around the radius of the entrance using shop-manufactured curved rail elements.

XV. GORE TREATMENTS

Many times, the area between a continuing roadway and an exiting ramp, or between two diverging roadways, contains obstacles requiring barrier to be placed along both traveled ways. The design of the end treatments for these barriers has several options, as follows.

A. Access Between Barriers Does Not Present Significant Hazard

If a vehicle passing between the end treatments for both runs of barrier will not result in more serious harm than impacting a two-side end treatment, standard roadside barrier end treatments (Type B or Type C) may be used. However, care must be taken to ensure that their installation will allow each end treatment to work as designed. Desirably, there should be at least 7' lateral separation between the end posts so that no more than one end treatment would be impacted. If a Type C end treatment is used, it must have sufficient clear area behind it to allow the distorted rail element(s) to extrude out the back without interference; NO Type C end treatment should be used without this clear area. (An approximation of the area needed would be the area inside a 45º line extending back behind the system from post #1 – see FIGURE 16.) Where there is concern about this clear area in back, a Type B FLEAT end treatment may be used in lieu of the Type C end treatment, since the FLEAT extrudes its distorted rail to the traffic side of the barrier; also, in special circumstances the FLEAT can have a reduced offset of 2 ½' (rather than the standard 4'). If this alternative is used, a special provision must be included, specifying only the FLEAT system and, if used, the reduced offset at the specific end treatment location.

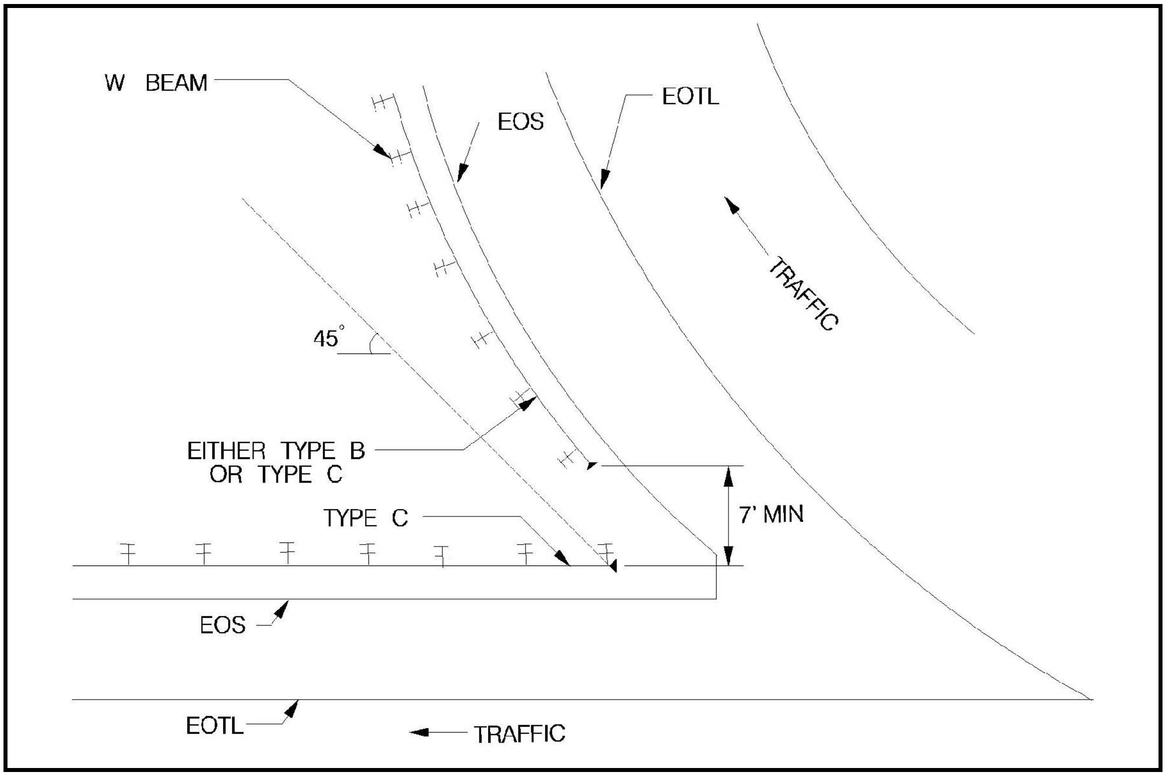


FIGURE 16: GORE END TREATMENT – TYPE C

B. Access Between Barriers Must Be Prevented

The two barrier runs are brought parallel to each other and a two-sided end treatment is provided. There must be sufficient distance in advance of the standard barrier to install the Type D or Type F end treatment. The Type D CAT end treatment must not have the attached barrier runs diverge more than a 15:1 flare rate for the first 12 ½' beyond its end since its rail elements must freely slide along the outside of the standard barrier. Also, if there is likelihood of minor nuisance hits on the end treatment, the Type D should not be used as it is fairly fragile as described in Section XIII B 1. If nuisance hits could be a big problem, a more durable device such as a Type E may be more cost-effective; and finally, if there is a likelihood of frequent severe impacts, a Type J (self-restoring) end treatment may be the most cost-effective. Regardless of the type of end treatment selected, closure of access to the gore infield needs to be discussed with District Maintenance prior to final design/installation.

If the barrier runs cannot be brought parallel (or there is insufficient room), a higher type end treatment that can cover a wider width may be necessary — a wide Type E. If there is very little likelihood of an impact, or if the width required to be shielded is greater than what is available with the Type E, the use of sand barrels as an end treatment is acceptable. If sand barrels are used, the standard barrier must be anchored (to develop tension, typically Type K End Treatments) and, because sand barrels are non-redirective crash cushions, the barrier ends must be shielded behind the last sand barrels. If the sand barrels are unacceptable (clear with District maintenance before using them) and the standard barrier runs diverge at a wide angle, use of the special NCHRP 350 approved "bullnose" may be the best solution: this is, in effect, a radius treatment that has been designed to be crashworthy. A distance of 62' from its nose to a rigid obstacle is needed for proper performance. Contact SHA-OHD for details of this design.

XVI. FLOW CHARTS FOR EXPOSED END TREATMENT SELECTION GUIDANCE

It should be noted that the flowcharts are guides and the user may find that all conditions are not covered.

A. Roadside End Treatments

Is location a downstream end outside the opposing traffic's design clear zone?

YES → Use TYPE K End Treatment (Std. MD 605.10 & MD 605.10-01)

NO ↓

Is it a low speed facility off the NHS?

YES → Use TYPE G End Treatment (Std. MD 605.08 & MD 605.08-01)

NO ↓

Is there a cut slope in which to anchor the traffic barrier?

YES → Use TYPE A End Treatment (Std. MD 605.01 or MD 605.01-01) **- Use appropriate LON – - Refer to Section XIII. A -**

NO ↓

Is LON provided <u>AND</u> is width of flat grading behind normal face of rail ≥ 8 feet?

YES → Use TYPE B End Treatment (Std. MD 605.02)

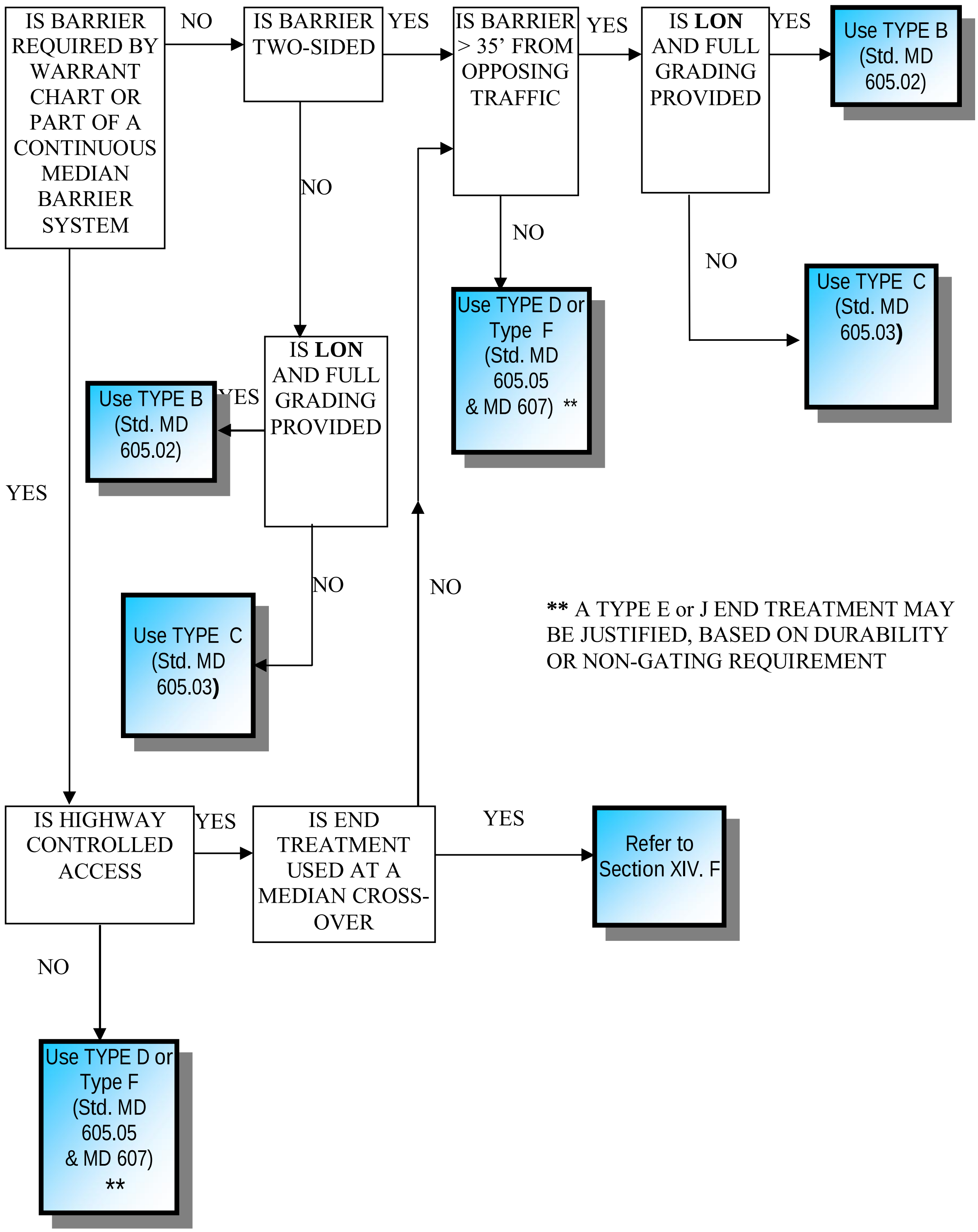
NO ↓

Use TYPE C End Treatment (Std. MD 605.03 & MD 605.04)

Provide necessary grading adjustments for end treatments, including the bid item for grading adjustment on 3-R projects, to allow system to operate at maximum potential.

FLOW CHART 1: ROADSIDE END TREATMENTS

B. Median End Treatments



FLOW CHART 2: MEDIAN END TREATMENTS

XVII. DAMAGED W-BEAM BARRIER AND END TREATMENTS

Damaged W-beam barrier must be replaced with barrier that meets the current standards. This most importantly pertains to the proper height and use of approved blockouts. The amount of W-beam barrier to be repaired depends on the length of damaged barrier related to the total length of barrier. If the total run of barrier is less than 200’, the full system will be replaced to current standards. For longer runs, if the amount of damaged rail needing repair is more than 50% of the total length, the full system will be replaced to current standards. If only a portion of the existing barrier is being repaired, only that portion that is being repaired needs to be to current standards — that portion that is not touched does not need to be upgraded. Mixing of steel and new blockouts within the full length of the run is allowed, but all repaired barrier shall have current approved blockouts.

Likewise, W-beam transitions to rigid objects that do not meet NCHRP 230 (the old) requirements should not be replaced in kind. The characteristics of any acceptable transition are: a strong connection to the rigid object (minimum of 4 each 7/8” bolts); a nested rail immediately in advance of the rigid object; 1’-3 ½” post spacing for at least three posts in advance of the rigid object or oversized posts at a larger post spacing with thrie-beam; and some feature to prevent wheel snagging — either an 8” curb or a rub rail.

Damaged end treatments (even cosmetic) must be replaced with a treatment that meets the current requirements. Consideration shall be given to each application to ensure the necessary right of way or grading easement is available for the proper installation and function of the end treatment. Length of Need (LON) must be reviewed for adequacy. In most cases, damaged Type B – SRT’s should not be replaced in kind (unless they meet new installation criteria) as very few current installation have sufficient LON (refer to Section X for determination of LON)– they should be replaced with Type C with the maximum amount of LON achievable. If the standard W-beam beyond the end treatment is not damaged, it does not need to be upgraded to current standards.

XVIII. UPGRADING OF TRAFFIC BARRIER AND END TREATMENTS

Deficient barriers are generally upgraded through spot improvement, system wide safety improvement projects, or in conjunction with other roadway work such as resurfacing, rehabilitation, or restoration (3R) projects. In each case, the highway designer must determine the scope and extent of the barrier upgrading to be accomplished.

When a roadway is being considered for a significant improvement, the highway designer needs to evaluate the existing safety situation by reviewing the accident history of the facility and visiting the site to observe the existing barrier and end treatments as well as potentially hazardous situations. The first priority is to remove any obstacles within the design clear zone including obstacles presently shielded by barrier so as to get rid of an unnecessary hazard – the barrier. Any unshielded obstacles that warrant shielding should have new barrier installed. The need to reset the existing barrier as a result of the project should be determined, with particular attention paid to tension development and proper height. All non-crashworthy end treatments in locations likely to be impacted need to be upgraded using the current criteria after determining the proper length of barrier. See TABLE 7.

NOTE: The Design Engineer should obtain the necessary approvals for a design exception for conditions that warrant special retrofit applications.

TABLE 7: GUIDELINES FOR TRAFFIC BARRIER AND TRAFFIC BARRIER END TREATMENT UPGRADES

TYPE OF WORK	FUNDING	GUIDELINES
New Construction Reconstruction	70-72	All barrier and end treatments must meet current Standards.
Resurfacing/Safety	77	All barrier and end treatments must meet current Standards.
Noise Abatement	26	All barrier and end treatments must meet current Standards.
Geometric Improvements Traffic Barrier Intersection Improvements Streetscapes Reconstruct R/R Crossing	76 32 83 84	All barrier and end treatments must meet current Standards.
Bridge	80	If the existing traffic barrier is within 500-ft. of bridge work, the barrier, end treatments and attachments must meet current Standards.
Maintenance	14	If the existing traffic barrier is disturbed, the barrier, end treatments and attachments must meet current Standards.
Landscape C.H.A.R.T. Wetland Replacement Rideshare Rest Area/Information Bridge Painting Miscellaneous (Slide repair, Drainage, Safety, and Lighting) Preventive Maintenance		New traffic barrier and end treatments must meet current Standards. If the existing traffic barrier is disturbed, the barrier, end treatments and attachments must meet current Standards.
NOTE: The existing steel blockouts may remain in place if the existing run of traffic barrier is not disturbed.		

XIX. ROADSIDE BARRIER INSPECTION CHECKLIST

Older barrier installations usually fall into one of three categories: first, those that meet current guidelines; second, those that do not meet current structural guidelines; and third, those that do not meet current design and location guidelines. Existing systems should be checked for their adequacy using the following guidelines:

1. Structural adequacy is inherent in the barrier itself, rather than resulting from design, placement or maintenance. An inadequate barrier can be defined as having characteristics which would result in unsatisfactory performance if the barrier were struck by passenger cars at design speeds and likely impact angles. The most obvious include: lack of tension capability in W-beam system, substandard or obsolete barrier, inadequate post spacing, no block-out for a strong post system, inadequate, non-conforming, or non-existent end treatment, or inadequate transition section.

2. Functional adequacy results from barrier design (e.g. LON) or placement and is essential for barrier effectiveness.

Below is a checklist that should be reproduced and used for field inspection of traffic barriers and end treatments. Please note height requirements.

TABLE 8: BARRIER AND END TREATMENT INSPECTION CHECKLIST

Rte No.	Route Name	Date
Inspector	From	To
District No. and County	Milepost/Milepoint	Milepost/Milepoint
Phone #	Direction ☐NB ☐SB ☐EB ☐WB	☐Outside ☐Median ☐ Other_______________________
Email		

LONGITUDINAL SECTION	Is barrier warranted? ☐ Can obstacle be removed ☐ Relocated ☐ Made Breakaway		Remarks
	Is Length of Need (LON) Adequate? ☐ Yes ☐ No	Existing Length Proposed Length	Remarks (Identify total length of barrier)
	Proper Barrier Height after Completion (29"min concrete, 25"-30" W-beam)? ☐ Yes ☐ No	Average Existing Height, measurements taken every 100': __________________ ☐ W-beam ☐ Concrete	Remarks
	Proper Flare Rate? ☐ Yes ☐ No	Existing Proposed	Remarks
	Placement? ☐ At Edge ☐ 2-Ft. ☐≥12-Ft. on 6:1 or flatter for W-beam	Does barrier need to be reset? ☐ Yes See Appendix A ☐ No	Remarks
	3' Minimum between back of W-Beam and Obstacle? ☐ Yes ☐ No	Is Stiffening Required? ☐ Yes ☐ No	Remarks
	Adequate Soil Backing ☐ Yes ☐ No	Are 8' Posts Required? ☐ Yes ☐ No	Remarks
END TREATMENT	Appropriate Grading? ☐ Yes ☐ No	Regrading Recommended? ☐ Yes ☐ No	Remarks
	Appropriate End Treatment? ☐ Yes ☐ No	End Treatment Required? ☐ A ☐ B ☐ C ☐ D ☐ E ☐ F ☐ G ☐ H ☐ J ☐ K ☐ L	Remarks
ANCHORAGE TO RIGID OBJECT	Standard Anchorage Design? ☐ Yes ☐ No – identify deficiency(s) below		Remarks (Identify anchorage type)
	Tension Connection ☐ Yes ☐ No	Remarks	
	Post Spacing: 1'-6" for STD Steel Posts or longer with Wood Posts ☐ Yes ☐ No	Remarks	
	Nested Rail ☐ Yes ☐ No	Remarks	
	Adequate Blockout and/or Bottom panel? ☐Yes ☐No	Remarks	

It is suggested that a separate checklist be completed for each traffic barrier location.

XX. URBAN STREET SECTIONS

Urban streets provide direct access to adjacent properties in developed areas. There are sidewalks, driveways, storefronts, porches, utility poles, fire hydrants, and other objects adjacent to the roadway. Traffic barriers following curb radii at intersections have a higher potential for being impacted at adverse angles. These installations also have the potential to impede pedestrian traffic. There are also certain areas where the use of traffic barrier end treatments can create sight distance problems. For these reasons, it is SHA Policy to refrain from installing traffic barrier on curbed urban street sections. Type A curbs/combination curb and gutter are generally used on these types of roadways and although they do not provide any significant redirection capability, they are a visual deterrent to the motorist.

There are site specific applications where traffic barrier is appropriate in urban street sections. Traffic barriers are usually placed at bridges where errant vehicles could fall on roadways below, in high fill areas, in sensitive areas such as school playgrounds, or where errant vehicles could impact hazardous storage structures. When W-Beam must be installed, it should be installed in accordance with FIGURE 17 or FIGURE 18.

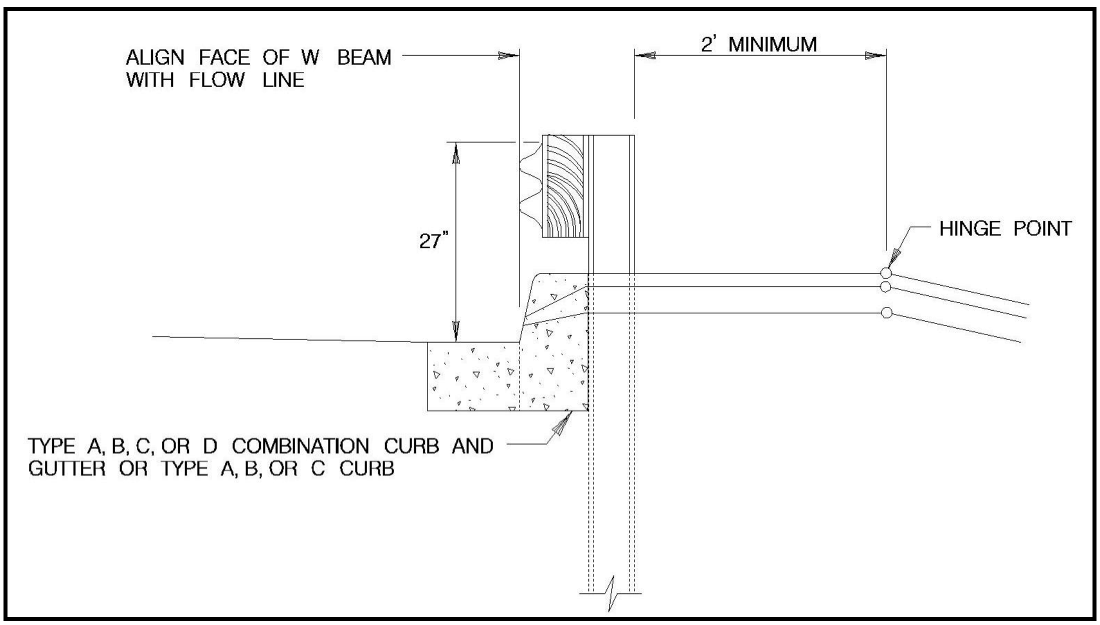
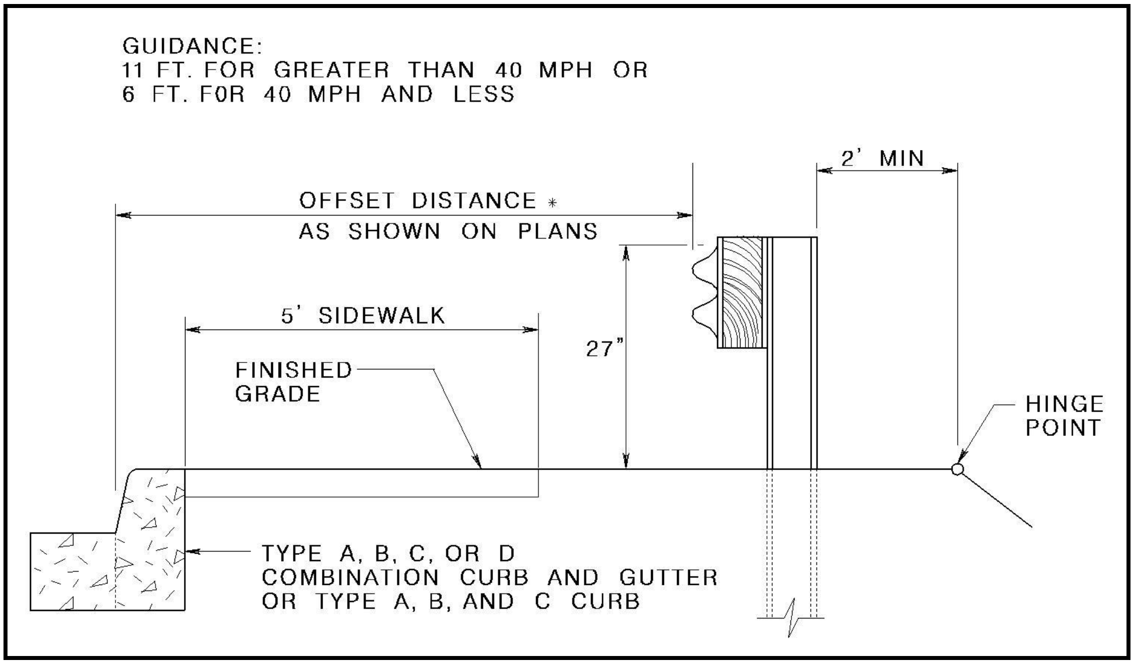


FIGURE 17: PLACEMENT AT CURBS (URBAN AREA - WITHOUT SIDEWALKS)



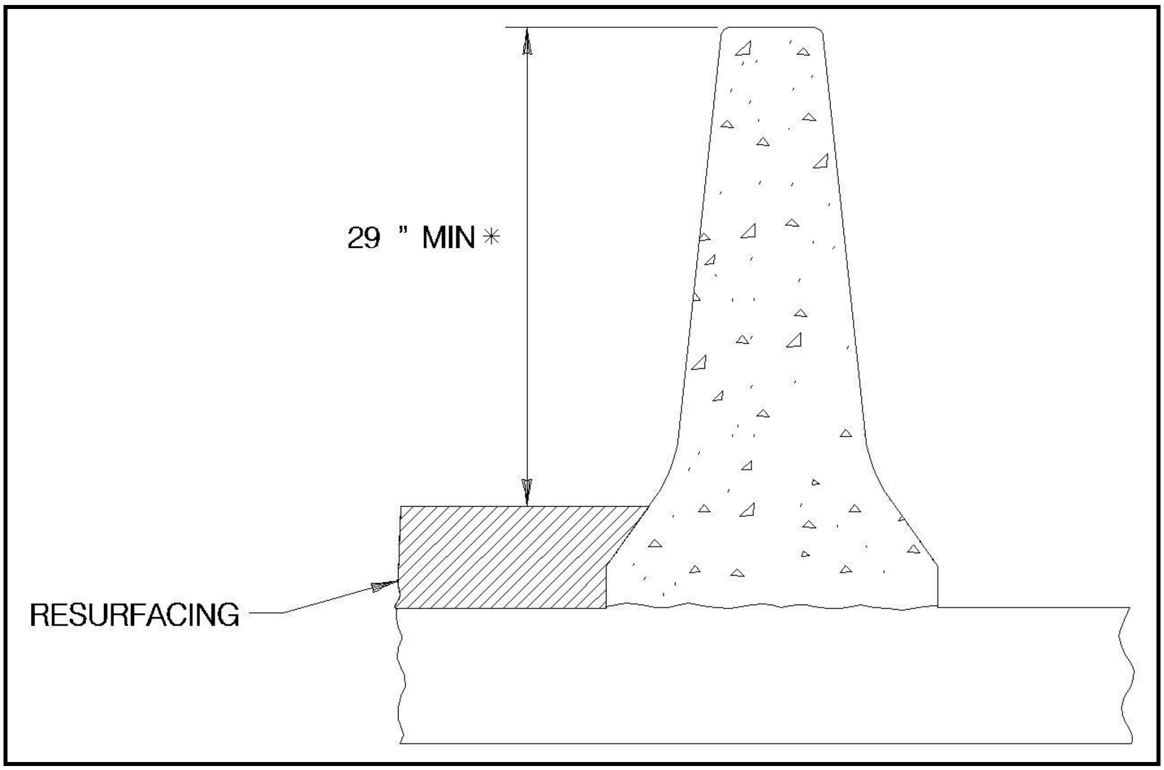
* BARRIER MAY BE PLACED ON THE TRAFFIC SIDE OF THE SIDEWALK WITH APPROPRIATE DESIGN

FIGURE 18: PLACEMENT BEHIND SIDEWALK AREA

Appropriate end treatments for installations according to FIGURE 17 are the Type G (or Type H for median applications) turned down treatment for a low-speed facility. For a high-speed facility, if possible, eliminate the curb in the area immediately prior to and through a crashworthy end treatment. Appropriate end treatments for installations according to FIGURE 18 would be designs as provided in the standards

XXI. PAVEMENT OVERLAY CONSIDERATIONS

Resurfacing may affect the height at which a vehicle impacts the barrier. Any concrete barrier that is less than 29" high (for 42" original height concrete barrier, the minimum height is 39") after the resurfacing needs to be modified to the new construction height. Any W-beam whose height after resurfacing is less than 25" must be reset to the new construction height. If the existing W-Beam barrier is to be reset and has metal blockouts, the blockouts must be replaced with approved ones. Refer to FIGURES 19 and 20.



* FOR 42" F-SHAPED BARRIER, THE MINIMUM HEIGHT AFTER RESURFACING IS 39"

FIGURE 19: PAVEMENT RESURFACING CONSIDERATIONS FOR CONCRETE BARRIER

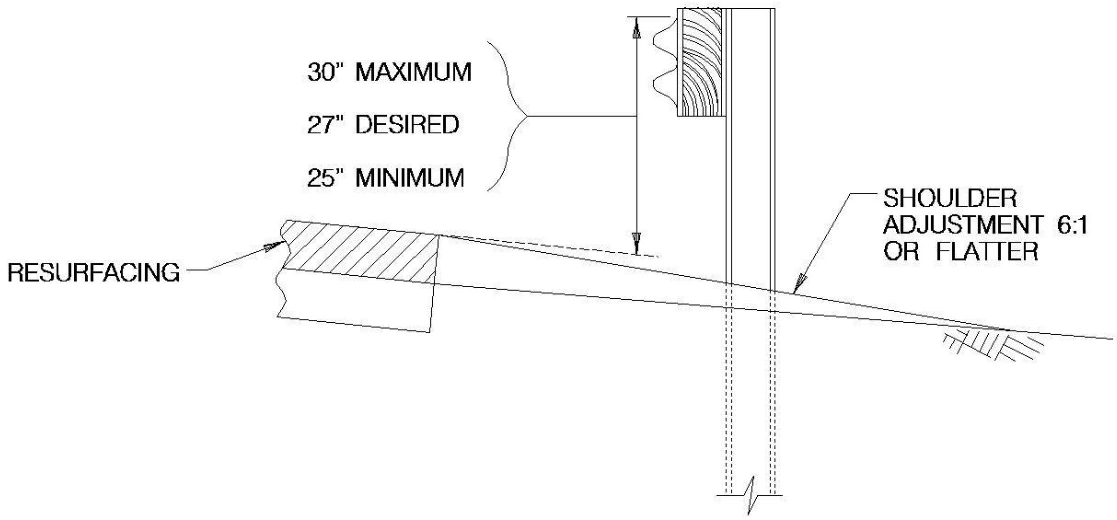


FIGURE 20: PAVEMENT RESURFACING CONSIDERATIONS FOR W-BEAM

XXII. TEMPORARY CONCRETE BARRIER

Double-faced concrete barrier used on roadways for control of traffic must be crash-worthy. Only the F-shape barrier (except for grand-fathered Jersey Shape when approved by the District) is acceptable; however, any connection that is NCHRP 350 approved is acceptable. All of these systems will have some method to develop tension continuity from one segment to the next. The design to utilize any of the systems must recognize that they are not rigid systems but will deflect a significant amount upon impact. Double-faced temporary concrete barrier used on roadways is not designed for use on bridges; for bridge temporary concrete barrier, refer to the bridge plans or standards.

Also, the ends must be appropriately treated. Unless the barrier segments themselves are firmly anchored, they will incur even more significant deflection if impacted near a free end – full redirection capability generally does not begin till around the fifth segment. Likewise, the blunt end of the barrier must be shielded. If the system is free-standing, a work zone end treatment, of which there are several types, is applied to the upstream end. If there is little likelihood of an impact, a sand barrel array, designed for the appropriate speed, can be used; however, this is a non-redirecting system. For free-standing locations with a higher likelihood of impacts, use of the work zone systems of the Type E and Type J end treatments can be called for.

For locations where temporary concrete barrier will butt up to existing barrier (and no access is needed), standards 605.48 or .49 should be used. Existing W-beam barrier should never be left unattached to concrete barrier (unless the concrete barrier is extended at least 50' behind the W-beam barrier and offset at the end 4').

Use of a "Movable Barrier System" may be appropriate for some projects. This system allows the special concrete barrier segments to be moved from one location to a parallel location up to 16' away in a very short time (hours). This permits use of a travel lane during certain periods while providing a protected work area during other periods for the same area. Contact SHA-OHD prior to using this system.

XXIII. SUMMARY

When designing the traffic barrier and end treatments for any project, the highway designer should always consider all options available to assure that the most appropriate solution is selected for the case. For existing facilities, it is important for the highway designer to visit the project site to review the existing conditions and inspect any high accident locations. These field observations can provide additional data in assessing barrier needs and warrants.

When the project site has been reviewed and it is determined that traffic barrier is warranted, then the type, location, and length has to be determined. The selection of an appropriate end treatment can be made depending on the site conditions. Specific items, such as gating, non-gating, wide or narrow width obstacles, and the width of the median or gore area will play an important part in the design process. Clear zones and other features must also be considered.

The best approach is to always remember the three steps in the designing traffic barrier needs:

1. Try to eliminate the obstacle with all options available.
2. If traffic barrier is to be incorporated into the project, keep it as far from the travel way as possible.
3. Select an end treatment that in your engineering judgment is the most appropriate and cost-effective for the site.

Maryland Department of Transportation
State Highway Administration

GUIDELINES FOR TRAFFIC BARRIER PLACEMENT AND END TREATMENT DESIGN

Glossary

GLOSSARY OF TERMS

Clear Zone - The total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, and/or a traversable but non-recoverable slope and a clear run-out area. The minimum desired width is dependent upon the traffic volumes and speeds, and on the roadside geometry.

Crash Cushion End Treatment– An end treatment that can prevent an errant vehicle from impacting an obstacle by gradually decelerating the vehicle to a safe stop or by redirecting the vehicle away from the obstacle. Another term to describe Types D, E, F, and J end treatments.

1. **Non-redirective Crash Cushion** – An end treatment that does not provide redirection capability for a side impact; a sand barrel array is an example. The vehicle does not normally reach the obstacle.

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

Design Speed – A selected speed used to determine the various geometric design features of the roadway, as well as the performance capability requirements for barrier systems.

Gating - Characteristic of an end treatment that allow a vehicle impacting the nose of the unit at an angle to pass through the device.

Length of Need (LON) - The length of effective barrier needed upstream of the obstacle to adequately shield the obstacle. It includes the effective portion of the end treatment.

Non-Gating - Characteristic of an end treatment that has the capability of redirecting a side impacting vehicle essentially through its entire length and capturing the vehicle when impacted on the end at an angle of 15º or less.

Obstacle - obstacles include both non-traversable terrain and fixed objects, and may be either man-made (such as critical embankments, ditches, bridge piers, signs, or headwalls) or natural (such as trees or boulders)

Operating Speed - The speed at which drivers are observed operating their vehicles during free flow conditions, generally taken as the 85^{th} percentile speed.

Penetration - When a vehicle passes through an appurtenance either by overcoming its redirective resistance or by vaulting over or submarining under the appurtenance.

Self-restoring - Characteristic of an end treatment that almost returns to its original condition after impact.

Shy Distance - The distance from the edge of the traveled way, on the right hand side, within which a roadside object will be perceived as an immediate hazard by the typical driver to the extent that the driver will change the vehicle's placement or speed.

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

1. **Rigid Barrier** - A longitudinal barrier which does not deflect upon impact and dissipates a negligible amount of the vehicle's impact energy. An example is the F-Shape concrete barrier.

2. **Semi-Rigid Barrier** - A longitudinal barrier, ranging from practically rigid to quite flexible, which will dissipate some of the impact energy through yielding of the rail and post elements and in some cases the soil. An example is the W-beam barrier.

3. **Flexible Barrier** - A longitudinal barrier that offers relatively large lateral deflection, with supports which serve primarily to hold the barrier in place. Examples are cable and weak post traffic barrier.

Transition - A section of barrier between two different barriers of different stiffness; most commonly, where a W-beam barrier is connected to a bridge end post or other rigid object. It is only needed when the "softer" barrier is upstream of the "harder" barrier and should produce gradual stiffening so vehicular pocketing, snagging, or penetration is avoided.

Travel Lane - That portion of the pavement contained within the outer pavement marking lines (does not include shoulder).

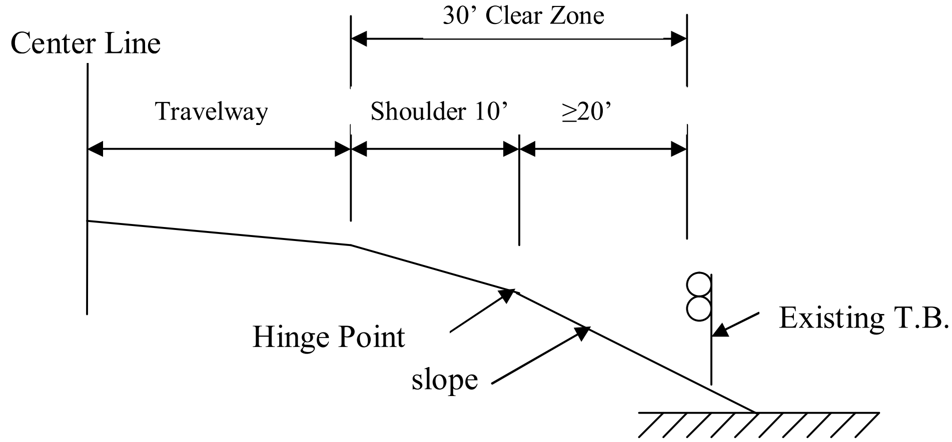
Maryland Department of Transportation
State Highway Administration

GUIDELINES FOR TRAFFIC BARRIER PLACEMENT AND END TREATMENT DESIGN

Appendices

Appendix A: I-70 Placement Criteria - Example for 3R Projects

Case (1) – Traffic Barrier @ or beyond edge of clear zone



Existing Conditions:
- 6:1 or flatter
- T.B. located ≥ 20'
- TB height ≥ 24"

Recommendation:
- No action, maintain Ex. T.B. & E.T.
- If TB < 24" Reset to Height of 28.5" in existing location

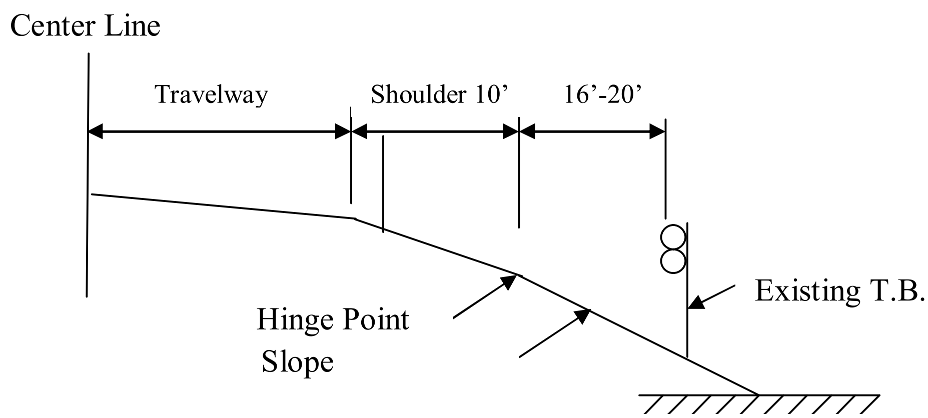
Existing Conditions:
- Steeper than 6:1, but no steeper than 4:1
- T.B. located ≥ 20'
- T.B. height ≥ 24"

Recommendation:
- No action, maintain Ex. G.R. & E.T.
- If TB < 24" Reset to Height of 28.5" in existing location

Existing Conditions:
- Steeper than 4:1
- T.B. located ≥ 20'
- T.B. height ≥ 24"

Recommendation:
- Determine if TB warranted, remove or relocate flush with the hinge point or 2ft offset from hinge point and re-grade slope to 6:1 in front of TB (recommended)

Case (2) - Slope 6:1 or Flatter, Traffic Barrier within 4 ft. of the edge of clear zone



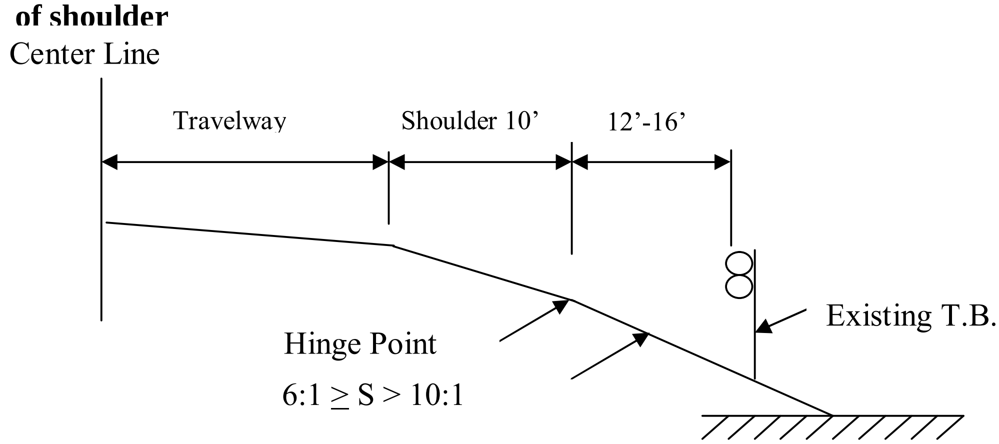
Existing Conditions:
- 6:1 or flatter
- T.B. located 16’ to 20’
- T.B. meets height requirements

Recommendation:
- No action, maintain Ex. T.B. & E.T.

Existing Conditions:
- 6:1 or flatter
- T.B. located 16’ to 20’
- T.B. does not meet height requirements

Recommendation:
- Remove& Reset at the same location at 28.5” height.
- Install new E.T. Type A, B or C , or other specified detail, depending on existing grading conditions.

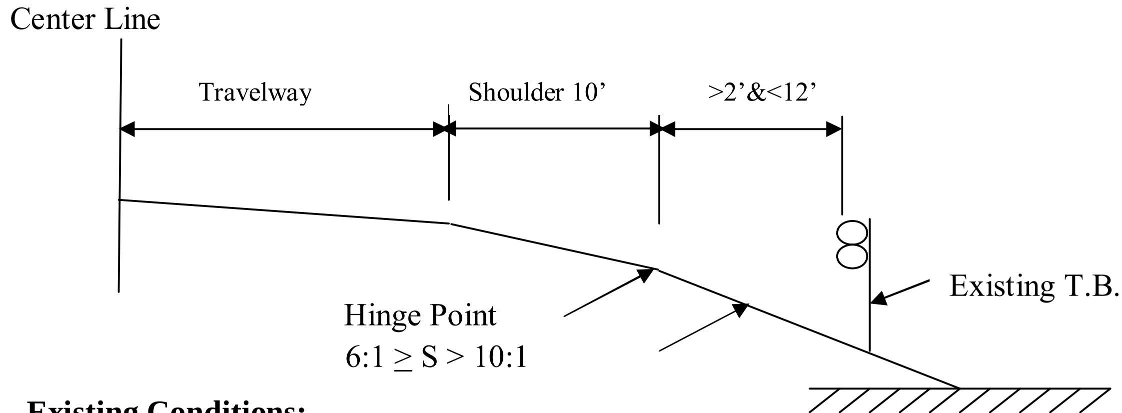
Case (3) - Slope 6:1 or Flatter, Traffic Barrier between 12 ft. and 16 ft from the edge of shoulder



Existing Conditions:
- 6:1 or flatter
- T.B. located @ 12’ – 16’
- T.B. meets height requirements
- **Recommendation:**
- Install new E.T. Type A, B or C , or other specified detail, depending on existing grading

- **Existing Conditions:**
- 6:1 or flatter
- T.B. located @ 12’ – 16’
- T.B. does not meet height requirements
- **Recommendation:**
- Remove& Reset at the same location to obtain 28.5” height.
- Install new E.T. Type A, B or C , or other specified detail, depending on existing grading

Case (4) - Slope 6:1 or Flatter, Traffic Barrier between 2 ft. and 12 ft from the hinge point



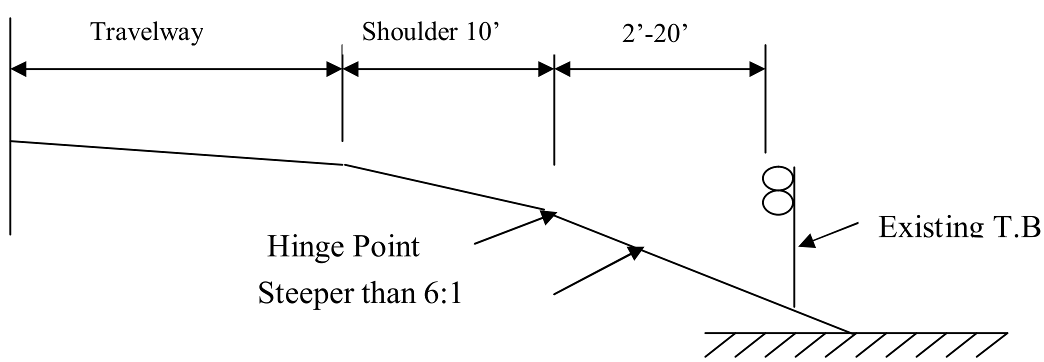
Existing Conditions:

— Slope 6:1 or flatter but steeper than 10:1
— T.B. located >2’ and <12’
— Regardless of T.B. height

Recommendation:

— Remove& Relocate either to 2’ from hinge point or to at least 12’ from hinge point at proper height
— Install new E.T. Type A, B or C depending on existing grading conditions.

Case (5 **Traffic Barrier located 2 – 20 ft from hinge point**



Existing Conditions:

— Steeper than 6:1
— T.B. located 2’ to 20’
— Regardless of TB Height

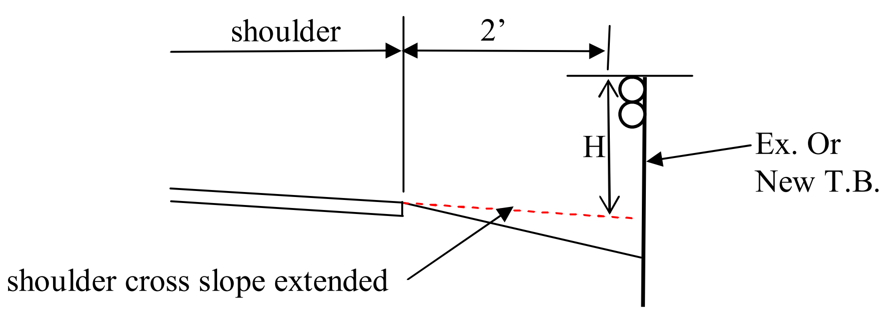
Recommendation:

— Regrade to 6:1 in front of Barrier and relocate 2 ft. from hinge point (recommended) or relocate flush with edge of shoulder.
— Determine need for long posts for soil backing per manual guidance
— Install new E.T. Type A, B or C depending on existing grading conditions.

Notes:

Traffic Barrier Height

- Height of existing traffic barrier meets requirements when ±3" of standard barrier installation height of 27". FHWA is pursuing a change in this tolerance value to allow a maximum of -2" from the standard barrier installation height of 27". Therefore, you should consider resetting any barrier under 25" in height, even though it is not yet mandatory. **(25" minimum is now mandatory by MSHA.)**
- The ±3" tolerance does not apply to placement of new barrier or resetting of existing barrier.
- Traffic Barrier placed more than 12 ft from the hinge point should be placed at a 28.5" height to account for the vehicle's vertical fluctuations when traveling down the slope.
- When traffic barrier is installed 2 ft. from the hinge point, the height is measured by extending the shoulder cross slope to the face of Barrier with a 6 ft min. straight edge and measuring the distance to the top of barrier from this point.



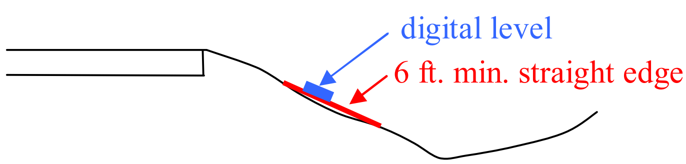
- When traffic barrier is installed more than 2 ft. from the hinge point, the height is measured from the top of the barrier to the ground line. The ground line should be determined by placing a 6 ft minimum straight edge along the slope to the barrier face to disregard any erosion that has occurred around the barrier.

Alternate End Treatment Detail

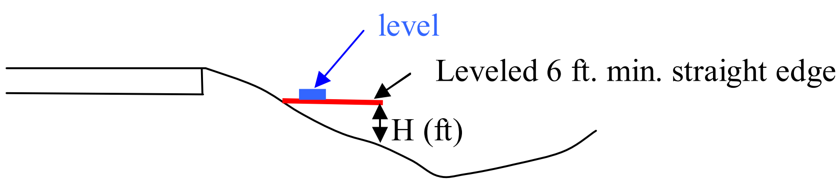
- We are currently looking into an alternate end treatment that can be placed away from the edge of shoulder on slopes steeper than 10:1. With FHWA approval, we will provide details for this end treatment to be used in lieu of Type B or C end treatments in certain situations.

Measurement of Slope

- Slopes should be measured by placing a digital level on a six foot minimum straight edge, or measuring the distance from a leveled 6 foot straight edge to the ground surface. An average of several measurements should be taken to compute the existing ground slope.

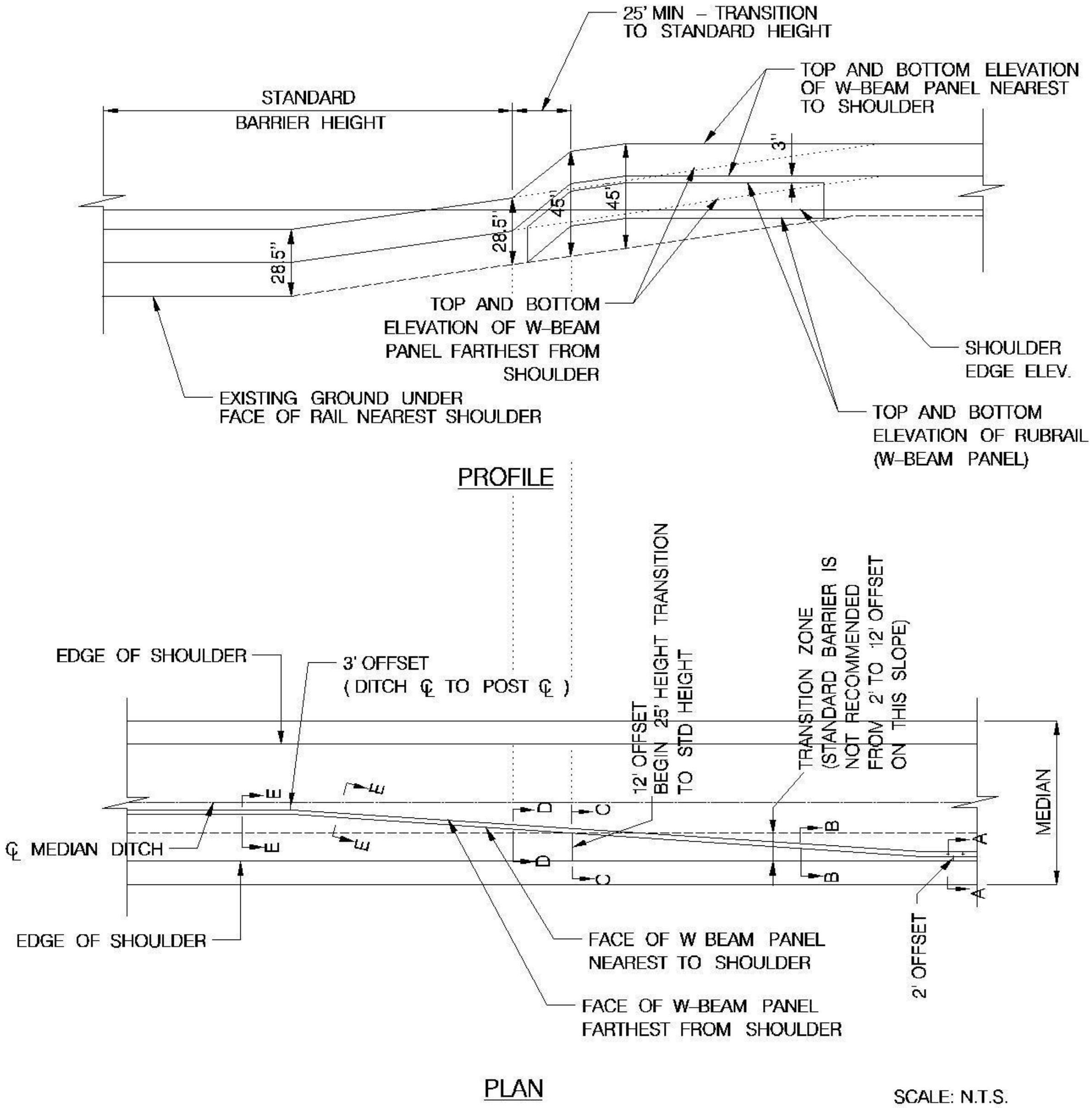


or

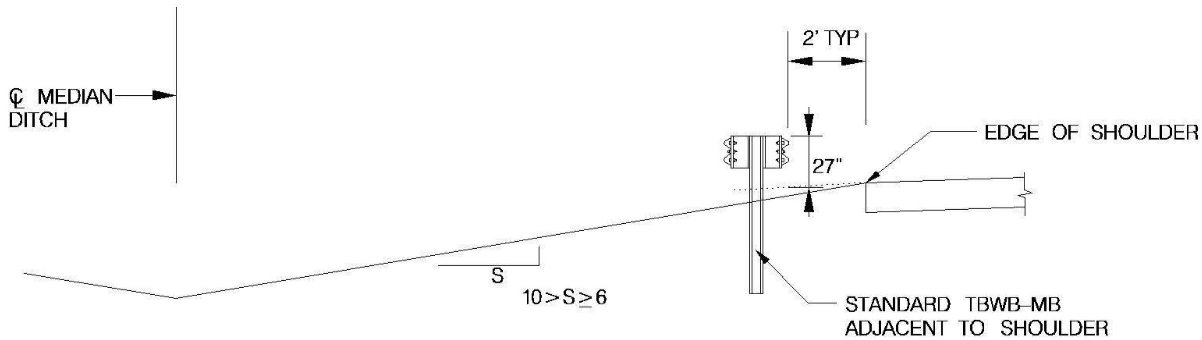


Slope = 6:H

Appendix B: Double Rail Transition (Across Slopes 10:1 to 6:1)

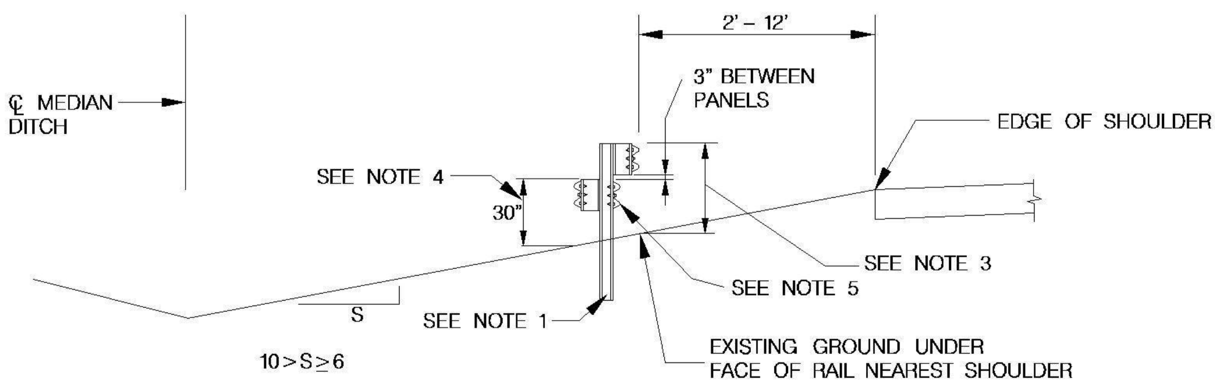


DOUBLE RAIL TRANSITION
(ACROSS SLOPES 10:1 TO 6:1)



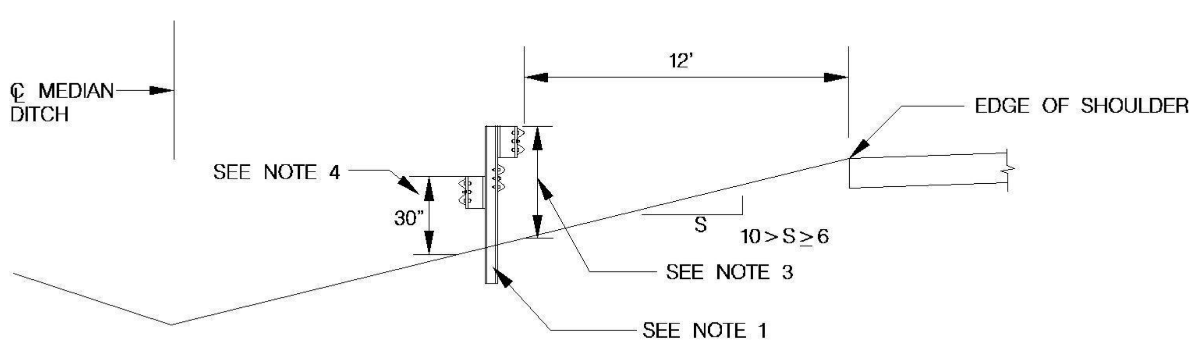
SECTION A-A

STANDARD TBWB-MB AT 2' OFFSET



SECTION B-B

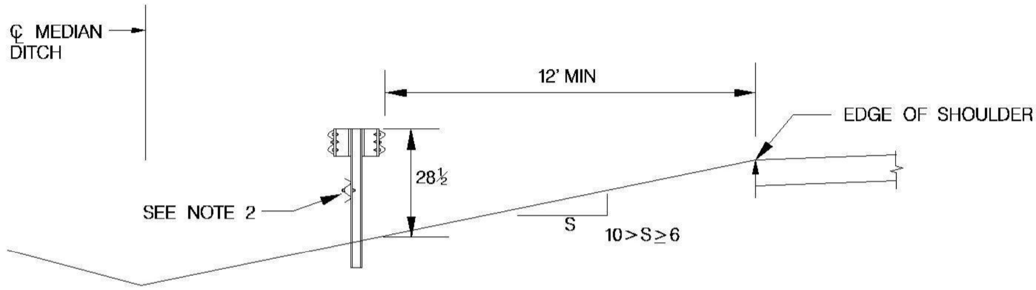
TRANSITION ZONE - 2' TO 12' OFFSET



SCALE: N.T.S.

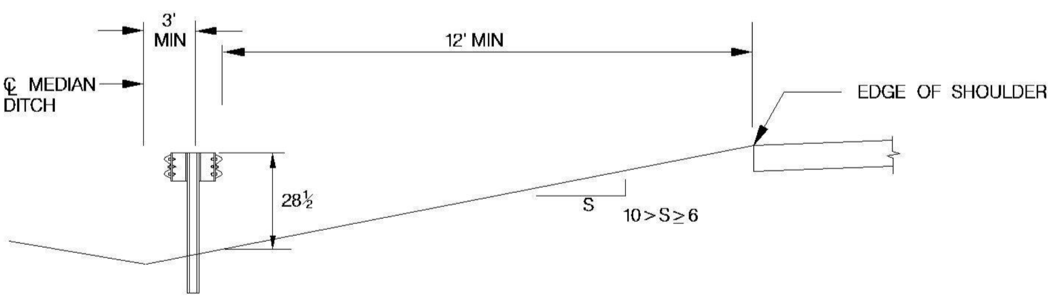
SECTION C-C

END OF TRANSITION AT 12' OFFSET



SECTION D–D

TBWB–MB AT THE END OF HEIGHT TRANSITION



SCALE: N.T.S.

SECTION E–E

NORMAL TBWB–MB AT 12' OR GREATER OFFSET

DOUBLE RAIL TRANSITION

(ACROSS SLOPES 10:1 TO 6:1)

NOTE:

1. USE 8' POSTS FOR THE DOUBLE RAIL TRANSITION WHEN THERE IS A BOTTOM RAIL; OFFSET BLOCKS ARE NOT REQUIRED FOR THE BOTTOM RAIL.
2. THE BOTTOM RAIL SHALL BE TUCKED BEHIND AND BOLTED TO POST AT D–D USING A 5⁄8" DIA. HEX. HEAD BOLT.
3. THE TOP OF RAIL SHALL MAINTAIN IT'S HEIGHT RELATIVE TO THE EDGE OF SHOULDER UNTIL A MAXIMUM HEIGHT OF 45" ABOVE THE GROUND IS ATTAINED AT FACE OF RAIL.
4. WHEN MEDIAN BARRIER IS TRANSITIONING ACROSS SLOPES THE HEIGHT OF THE RAIL FARTHEST FROM TRAFFIC WILL BE 30" ABOVE THE GROUND WHEN THERE ARE TWO RAILS ON THE FRONT; IT WILL BE THE SAME HEIGHT AS THE FRONT RAIL WHEN ONLY A SINGLE RAIL.
5. USE RUBRAIL (W–BEAM) WHEN BOTTOM OF TOP RAIL IS MORE THAN 18" ABOVE THE GROUND AT THE FACE OF RAIL. ATTACH THE RUBRAIL TO POST 3" BELOW BOTTOM OF TOP RAIL.
6. TRANSTION HEIGHT FROM HEIGHT ABOVE GROUND AT SECTION C–C TO HEIGHT OF 28 1⁄2" OVER A LENGTH OF 25' MIN.
7. USE FLARE RATE BASED ON DESIGN SPEED

Maryland Department of Transportation
State Highway Administration

Appendix C: Record of Changes To The Guidelines

RECORD OF CHANGES TO THE GUIDELINES – Change #1 June 2006

1. Table of Contents

Add APPENDIX C: RECORD OF CHANGES TO THE GUIDELINES … C-1

2. Section XIII. End Treatments

Make the Pen and Ink Changes on Page 27 shown below in red:

b. For backslopes 1:1 or flatter but steeper than 2.5:1, a minimum of 125' for Single Rail and 75' for Double Rail Installations (50' for lower speed facilities) from the upstream face of the obstacle to the point of effectiveness is required. The flare rate may be flatter than the flare rate shown on the standard to achieve the minimum ___ length; (the prime example of this would be where there is no ditch – fully effective barrier would be required for either 125' or 75' upstream of the obstacle before the 50' anchorage begins).

c. If the BIB were to be used with backslopes 2.5:1 or flatter, _____ a calculation of LON is required, using the __ procedure __ in Section X. This terminal should not be used for these flatter backslopes if the toe of the backslope is less than 20' from the edgeline.

The application of the double rail standard may be the best compromise end treatment at locations where the ditch front slope is steeper than 4:1 (the maximum steepness tested under NCHRP 350) and it is impractical to extend the barrier farther upstream to a more appropriate end treatment application. As long as the ditch is not deeper than 2', this application should provide acceptable performance.

The Type A should also be used even when the barrier system LON would normally end downstream of a cut slope if the cut slope is within 200' and there is not a large available runout area (400' x 50') beyond the cut slope. ______

Change the date in the lower left corner to June 2006.

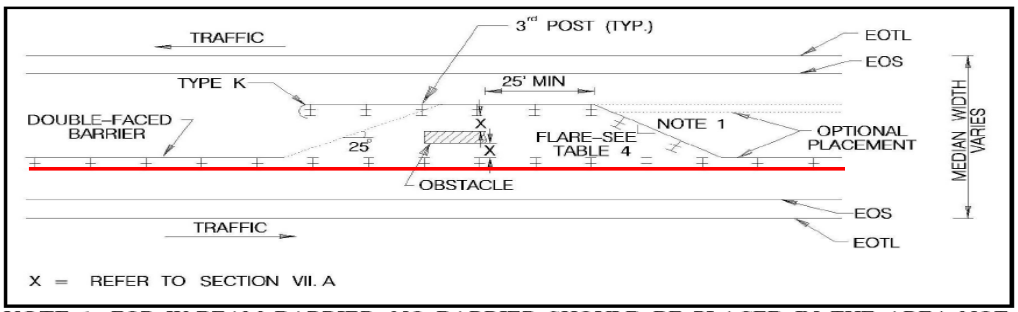
Make the Pen and Ink Changes to the last sentence on Page 30 shown below in red:

(When used with only a 12 ½’ panel beyond the anchorage post, bent at a 16’ radius, it is a crashworthy terminal for TL-2 (43 mph).)

Change the date in the lower left corner to June 2006.

3. Section XIV Typical Barrier Installations

Make the Pen and Ink Changes to the Figure on Page 38 shown below in red:



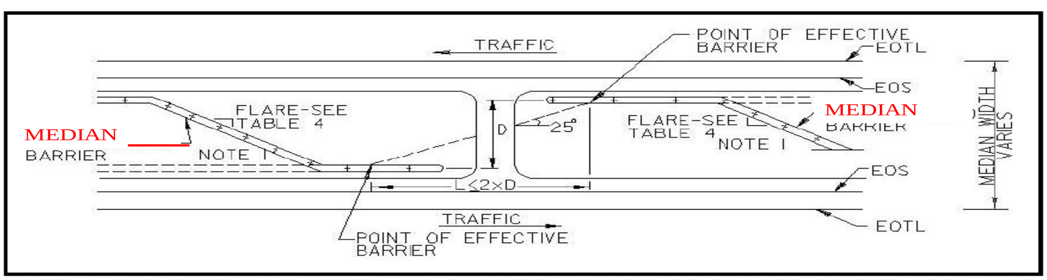
NOTE 1: FOR W-BEAM BARRIER, NO BARRIER SHOULD BE PLACED IN THE AREA NOT RECOMMENDED IN SECTION VII C UNLESS MODIFIED AS DESCRIBED IN SECTION XI D. next to last paragraph

FIGURE 13: EXAMPLE – ISOLATED OBSTACLE, CONTINUOUS MEDIAN BARRIER

PAGE 38

Change the date in the lower left corner to June 2006.

Make the Pen and Ink Changes to the Figure on Page 40 shown below in red:



NOTE 1: FOR W-BEAM BARRIER, NO BARRIER SHOULD BE PLACED IN THE AREA NOT RECOMMENDED IN SECTION VII C UNLESS MODIFIED AS DESCRIBED IN SECTION XI D. next to last paragraph

FIGURE 15: EXAMPLE – MEDIAN OPENING IN CONTINUOUS MEDIAN BARRIER

PAGE 40

Change the date in the lower left cornor to June 2006