Road & Bridge Design Publications

Monthly Update – October 2013

Revisions for the month of **October** are listed and displayed below. The special detail index from the “July Special Update” will remain in effect. Contact Wayne Pikka (pikkaw@michigan.gov) for questions related to the road changes. Contact Vladimir Zokvic (zokvicv@michigan.gov) for questions related to the bridge changes.

Road Design Manual

3.03.01D: Sight Distances: A typo was corrected in the stopping sight distance table.

7.01.01: References, 7.01.10: Clear Zone History, 7.01.21: Guardrail Strength Transitions, 7.01.23: Function of Guardrail Components, 7.01.25D: Guardrail Full Strength Point, 7.01.29A: Flare Rate, 7.01.31: Shielding Bodies of Water, 7.01.54: Warrants for Median Barriers on Freeways, 7.01.55C: Cable Barrier, 7.08: Mailbox Posts: Revised references to the 2011 Roadside Design Guide.

7.01.04: Identification of Guardrail Runs: This section was deleted since the information was obsolete.

7.01.11A: Obstacles Outside the Calculated Clear Zone: An additional opportunity to improve roadside safety (#4) and accompanying sketch was added.

7.01.11C: Clear Zone Chart: For design speeds of 40 mph or less and cut slopes 1:4 or flatter, the clear zone distances for ADTs of 750 or greater were revised to meet the 2011 Roadside Design Guide.

7.01.11D: Curve Correction Factors Table: The table was revised to meet the 2011 Roadside Design Guide. (Most Radii values were revised with minor changes to the values in the 65 mph and 70 mph Design Speeds.)

7.01.17: Strength Requirements for Steel Beam Guardrail: Several paragraphs were rewritten to meet the 2011 Roadside Design Guide and a MASH Test Levels table was added.

7.01.18: Suggested Shy Line Offset Values: A definition for shy line offset was added and the Shy Line Offset table was revised to match the 2011 Roadside Design Guide.

7.01.19: Suggested Runout Lengths for Barrier Design: A definition for runout length was added and the Runout Lengths Table was revised to match the 2011 Roadside Design Guide.

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7.01.20: Guardrail Deflection: Revised a reference to the 2011 Roadside Design Guide and added a paragraph on the "Zone of Intrusion".

7.01.25E: Clear Area Behind Guardrail Terminals: Added a sentence regarding the minimum recovery area behind a terminal.

7.01.30H: Guardrail Placed near Intersecting Streets and Driveways: This is a new section dealing with barrier placement when an intersecting street or driveway is located near a roadside object or feature (typically a bridge).

7.01.33C: Placing Guardrail in Rock: Added sketches and revised the section to match the 2011 Roadside Design Guide.

7.01.33D: Guardrail Posts through Paved Surfaces: This is a new section with guidance from the 2011 Roadside Design Guide.

7.01.33E: Additional Blockouts on Guardrail Posts: This is a new section with guidance from the 2011 Roadside Design Guide.

7.01.34: Guardrail in Conjunction with Curb: This section was updated to conform to the 2011 Roadside Design Guide. Revised guidance is given based on the design speed, type of curb, and location of guardrail run.

7.01.45: Alternative Barrier End Treatments: This section was revised to provide updated alternate endings devices for use when site conditions are restrictive.

7.08.02: Mailboxes, General: Made a minor revision to the second paragraph in regards to the reaction of the mailbox and post under impact. Also, added MASH criteria as an alternative to NCHRP Report 350 criteria.

7.08.03: Mailbox Design Considerations: Added a statement that internet mapping websites can also be used to determine the number of existing mailboxes on a project so the number of replacement posts can be determined.

11.06.01: Special Provision Approval Procedure: Text was added for dealing with Form 2908 Special Provision - Exception Risk Analysis. (Form for projects submitted with unapproved unique special provisions.)

MDOT
Michigan Department of Transportation

Road & Bridge Design Publications

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14.07: Project Numbers: A table was added outlining the proper use of phases.

14.58: Approval of Special Provisions: Text was added for dealing with Form 2908 Special Provision - Exception Risk Analysis. (Form for projects submitted with unapproved unique special provisions.)

Updates to MDOT Cell Library, Bridge Auto Draw Program, etc., may be required in tandem with some of this month's updates. Until such updates to automated tools can be made, it is the designer's/detailer's responsibility to manually incorporate any necessary revisions to notes and plan details to reflect these revisions.

3.03 (continued)

ALIGNMENT-GENERAL

C. Combined

Horizontal and vertical alignments are permanent design elements. It is extremely difficult and costly to correct alignment deficiencies after the highway is constructed.

A proper combination of horizontal and vertical alignment is obtained by engineering study using the following general controls.

1. Vertical curvature superimposed on horizontal curvature, generally results in a more pleasing appearance. Successive changes in profile not in combination with horizontal curvature may result in a series of humps visible to the driver for some distance.

2. Sharp horizontal curvature should not be introduced at or near the top of a pronounced crest vertical curve. This condition may make it difficult for the driver to perceive the horizontal change in alignment. This can be avoided if the horizontal curvature leads the vertical curvature, i.e., the horizontal curve is made longer than the vertical curve.

3. Sharp horizontal curvature should not be introduced at or near the low point of a pronounced sag vertical curve. Because the road ahead would appear to be fore-shortened, a relatively "flat" horizontal curve should be used to avoid this undesirable phenomenon.

4. Horizontal curvature and profile should be made as flat as possible at intersections where sight distance along both roads or streets is important.

See Chapter 3 of ***A Policy on Geometric Design of Highways and Streets***, AASHTO, 2004 for elements of design.

3.03.01 (revised 10-21-2013)

Horizontal Alignment - Design Controls

A. Minimum Radius

The minimum radius is a limiting value of curvature for a given design speed and is determined from the maximum rate of superelevation and the maximum side friction factor. The minimum radius of curvature should be avoided wherever practical. Attempt to use flatter curves, saving the minimum radius for the most critical conditions. The minimum radius (R_{min}) is shown in the Standard Plan R-107-Series superelevation tabulation at the bottom of each column for each design speed. Values for R_{min} are also tabulated for the straight line superelevation table in Section 3.04.03.

B. Minimum Curve Lengths

Curves should be sufficiently long for small deflection angles to avoid the appearance of a kink.

Curves on rural free access trunklines should be at least 500 feet long for a central angle of 5° and the minimum length should be increased 100 feet for each 1° decrease in the central angle. The minimum should be approximately 15 times the design speed with a desirable length of at least 30 times the design speed. For example a design speed of 60 mph multiplied by 15 gives a minimum curve length of 900’.

3.03.01 (continued)

Horizontal Alignment - Design Controls

C. Compound Curves

Compound curves should be used with caution. Although compound curves give flexibility to fitting the highway to the terrain and other controls, designers should avoid them whenever possible. When curves with considerably different radii are located too close together, the alignment will not have a pleasing appearance. On one-way roads such as ramps, the difference in radii of compound curves is not so important if the second curve is flatter than the first. On compound curves for open highways, the ratio of the flatter radius to the sharper radius should not exceed 1.5 to 1. On ramps the ratio of the flatter radius to the sharper radius may be increased to a 2 to 1 ratio.

D. Sight Distances

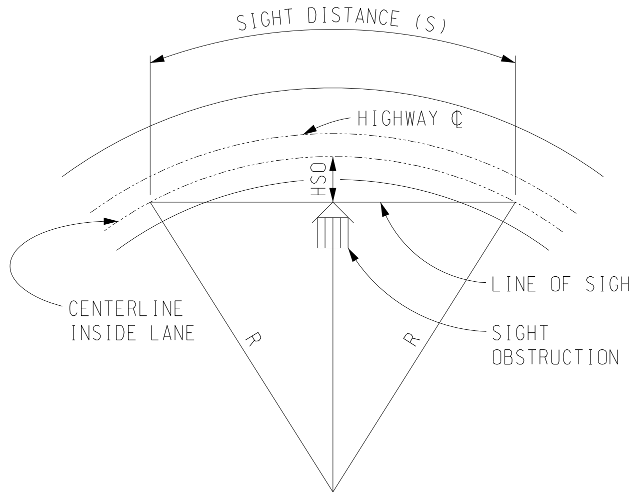
Both stopping sight distance and passing sight distance must be considered for two-way roadways. On one-way roadways only stopping sight distance is required. The designer must be aware that both horizontal and vertical alignments need to be considered when designing for sight distance.

From Exhibit 3-1 of ***A Policy on Geometric Design of Highways and Streets***, AASHTO, 2004 stopping sight distance can be determined from design speed.

Design Speed	Stopping Sight Distance (Design)
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570
65	645
70	730
75	820

3.03.01 (continued)

For general use in the design of a horizontal curve, the sight line is a chord of the curve and the stopping sight distance is measured along centerline of the inside lane around the curve



COMPONENTS FOR DETERMINING HORIZONTAL SIGHT DISTANCE

Knowing the stopping sight distance (SSD) and the radius of curve (R) the horizontal sightline offset (HSO) can be calculated from:

$$HSO = R\,(1 - \cos\frac{28.65SSD}{R})$$

or to verify that SSD is met for a given HSO:

$$SSD = \frac{R\cos^{-1}(1 - \frac{HSO}{R})}{28.65}$$

(R, SSD, HSO measured in feet)

These equations are exact only when the vehicle and sight obstruction are within the limits of a circular curve.

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ROAD DESIGN

CHAPTER 7

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CHAPTER 7

APPURTENANCES

7.01

ROADSIDE SAFETY BARRIERS

7.01.01 (revised 10-21-2013)

References

A. ***Guide for Selecting, Locating, and Designing Traffic Barriers***, AASHTO 1977

B. ***A Guide to Standardized Highway Barrier Rail Hardware***, AASHTO-AGC-ARTBA Joint Committee, 1995

C. ***A Supplement to A Guide for Selecting, Designing and Locating Traffic Barriers,*** Texas Transportation Institute and FHWA, March 1980

D. ***Roadside Design Guide,*** AASHTO, 2011, 4th edition

In addition, there are a number of National Cooperative Highway Research Program (NCHRP) research publications and reports of the major research and testing agencies that are available either within the Design Division or in the Transportation Library.

7.01.02 (revised 10-22-99)

Application of Section 7.01

In writing this portion of Chapter 7 it should be noted that the concepts presented will not necessarily be considered as absolutes to be rigidly adhered to, but will be considered as an aid to enhance the engineering judgement of the designer. Even when the word "should" is used, it is recognized that there may be circumstances unique to a situation that will suggest, or even dictate, alteration of a recommended treatment.

It is also intended that the barrier treatments recommended will be applicable to state trunkline projects and not necessarily to local government projects, except as local agencies wish to incorporate them.

7.01.03 (revised 10-22-99)

History of Guardrail and Barrier in Michigan

The practice of placing an artificial obstruction to prevent an errant vehicle from going down a steep embankment or into an area of water probably originated in the 1920's in the form of a line of posts placed at the edge of the shoulder. At some point in time the system was improved by the addition of connecting planks, which in turn were replaced by a more maintenance-free system of two steel cables. This design is illustrated on the old E-4-A-75 Series of standard plans. Following World War II some metal beam designs were introduced. One that found limited use in Michigan was the Tuthill Highway Guard, a convex smooth steel beam, 12" wide, fastened to spring steel supports, which were mounted on either wood or steel posts. In the early 1950's the concept of a metal beam was further refined with the introduction of the W-beam with the two corrugations that are essentially what we are familiar with today.

7.01.03 (continued)

History of Guardrail and Barrier in Michigan

Initially, the W-beam was not galvanized and had to be painted. The next step was to galvanize it for more economical maintenance.

The first installations of W-beam rail involved attaching the beam element directly to posts placed 12'-6" on centers, at a top of rail height of 24". This design later became known as our Beam Guardrail - Type A. Research and crash testing in the late 1950's and early 1960's, principally by the state of California and by General Motors at its Milford Proving Grounds, produced the recommendations of closer post spacing, (6'-3"), blocking out the beam from the post, and a higher top of rail mounting height. This resulted in Michigan's development of our Beam Guardrail - Type C in 1965, and Beam Guardrail - Type B in 1966. The most recent significant change in guardrail type in Michigan occurred in 1984 with the adoption of thrie beam, now called Guardrail, Type T.

Until 1995, Four basic end treatments had been used in conjunction with steel beam guardrail. Initially, a curved end shoe was placed on both ends of the run. The concept of turning down or burying the ending to form an anchorage was developed about 1966. The first standard plan to be approved by what was then the Federal Bureau of Public Roads was issued in 1968. A variation of the turned down ending, featuring the elimination of the first two posts (so the ending would collapse under impact) appeared in 1971 with the issuance of Standard Plan III-65A.

The Breakaway Cable Terminal (BCT) ending was adopted in 1973 with the issuance of Standard Plan III-58A. After 22 years as the standard guardrail terminal in most states, the FHWA disallowed further installation of the BCT on the National Highway System (NHS) after December 31, 1995. This, along with the adoption of new crash testing criteria (NCHRP 350) ended the use of the BCT as well as other traditional un-patented endings.

7.01.03 (continued)

This initiated the development and use of a number of proprietary terminals. The Department has divided these terminals into two basic categories of flared gating terminals and tangent terminals. Current standard designs are described in Section 7.01.25 along with other designs previously used.

Development of concrete barrier in this country, principally concrete median barrier having the concave safety shape, is generally attributed jointly to General Motors and to the state of New Jersey, both of whom conceived shapes that bear their names. Michigan's first concrete barrier was on the DeQuindre Yard bridge, on I-94 in Detroit, in 1965. Although the New Jersey shape was used in this initial installation, the GM shape was adopted as standard. In 1976 the New Jersey shape was adopted as standard.

7.01.04

Section deleted

7.01.10 (revised 10-21-2013)

Clear Zone – History

For a number of years road designers and safety authorities considered 30' a desirable requirement for a safe roadside free of obstacles. This was based upon a study by General Motors in the early 1960's which revealed that of 211 cases at the proving grounds involving vehicles leaving the road, 80% did not travel more than 29' from the edge of pavement. The 1967 “Yellow Book” (***Highway Design and Operational Practices Related to Highway Safety***, AASHTO), page 20, rounded this distance off to 30'. The 2nd edition of the “Yellow Book”, published in 1974, reiterated the 30' distance, but called for an application of engineering judgement by emphasizing that the "30' distance is not a “magic number" (page 38). The 1977 Barrier Guide defined clear zone, in the glossary on page iv, as "That roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. Establishment of a minimum width clear zone implies that rigid objects and certain other features with clearances less than the minimum width should be removed, relocated to an inaccessible position outside the minimum clear zone, or remodeled to make safely traversable, breakaway, or shielded."

The 1977 Barrier Guide introduced the concept that rate of sideslope, speed of traffic, horizontal curvature, and ADT would affect the width of clear zone. The 30' width was retained for 60 mph speed in combination with flat side slopes, tangent roadway alignment, and ADT exceeding 6,000. However, a graph on page 16 adjusts this basic 30' for traffic speed and rate of sideslope. These adjustments are both up or down (wider or narrower) for either descending or ascending slope. A formula on page 17 further adjusts the clear zone for horizontal curvature. Finally, a procedure shown on pages 60-65 adjusts the clear zone downward (narrower) for ADT's below 6,000. The Supplement to the 1977 Barrier Guide expanded on the clear

7.01.10 (continued)

zone criteria that begins on page 15 of the Barrier Guide by including a series of tables prepared by the state of Illinois that show clear zone requirements for various degrees of curve. These criteria have been criticized by a number of states because of the extreme clear zone widths, particularly for the combination of sharp curve, higher speed, high traffic volume and steep slope.

In anticipation of a proposed revision of the 1977 Barrier Guide, FHWA in April 1986 afforded the states a measure of relief with respect to clear zone requirements. It provided a formula for a curve correction factor that is based upon increasing the value for clear zone for a tangent section, obtained from the Barrier Guide. This new formula is more reasonable than the formula on page 17 of the Barrier Guide. It was adopted by the Department in July 1986. In 1989 the ***Roadside Design Guide*** was issued by AASHTO and adopted by MDOT as a guide. Updates to the ***Roadside Design Guide*** were published in 1996, 2002, 2006 and 2011.

7.01.11 (revised 10-21-2013)

Current Clear Zone Criteria

Virtually everyone agrees that a flat, smooth, unobstructed area adjacent to the driving lanes is highly desirable and significantly improves roadside safety. The only point of contention is how wide to make this area. The designer needs to understand that the clear zone distance is not an absolute number. Some designers have erroneously believed, that in all cases, the need for protecting motorists ends at the selected clear zone distance.

7.01.11 (continued)

Current Clear Zone Criteria

A. Treatment/Consideration of Obstacles Outside the Calculated Project Clear Zone

Occasionally, there may be opportunities to improve the roadside safety on a project for small cost by addressing a few obstacles outside the determined clear zone. Examples of these opportunities are as follows:

1. When installing landscape items: Since we have control over the location of new items, we can provide additional protection to the motorist by applying a more generous clear area to these items. For instance, our freeway guideline for a long time has been to plant trees at least 50 feet off the edge of traffic lanes.

2. When isolated trees, volunteer growth, utility poles, etc. are present: Depending on aesthetic concerns, it may be possible to offer the motorist a very generous clear area (beyond that required by the Clear Zone Distances tables) by simply removing or relocating a few isolated obstacles.

3. Obstacles near the bottom of a ditch are more likely to be hit by an errant vehicle since the ditch tends to funnel the vehicle. Relocating the obstacle further up the back slope, or even slightly up the front slope (closer to road but still outside the clear zone limit), would usually be preferable.

4. A clear runout area beyond the toe of a traversable (smooth and free of fixed objects) but non-recoverable (between 1:4 and 1:3) foreslope is desirable since vehicles traversing this steep slope are likely to continue to the bottom. The extent of this clear runout area can be determined by subtracting the distance between the edge of traveled way and the breakpoint of recoverable foreslope from the clear zone distance. This distance should be at least 10' if feasible.

7.01.11 (continued)

B. Treatment/Consideration of Obstacles Inside the Calculated Project Clear Zone

Where the following conditions exist, it may be necessary to retain trees that otherwise would be considered for removal.

1. At landscaped areas, parks, recreation or residential areas or where the functional and/or aesthetic values will be lost.

2. Exceptional or unique trees (because of their size, species, or historic value).

3. On designated heritage roads and low speed roads (including low speed urban areas).

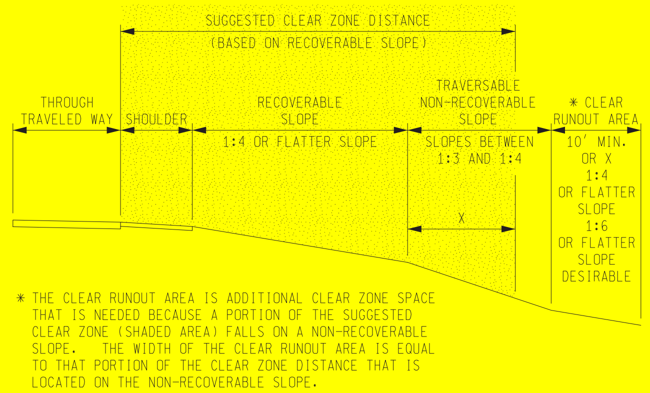
4. At locations where cumulative loss of trees would result in a significant change in character of the roadside landscape.

5. Behind nontraversable backslopes.

6. Behind barrier curbs, particularly in low speed areas.

7. Where shrubs and/or ornamental trees exist that would have a mature diameter of 4" or less at 4'-6" above ground line.

8. Where removal would adversely affect endangered/threatened species, wetland, water quality, or result in significant erosion/sedimentation problems.



7.01.11 (continued)

Current Clear Zone Criteria

C. Clear Zone Distance Chart

CLEAR ZONE DISTANCES
(IN FEET FROM EDGE OF DRIVING LANE)

DESIGN SPEED	DESIGN ADT	FILL SLOPES			CUT SLOPES		
		1:6 OR FLATTER	1:5 TO 1:4	1:3	1:3	1:4 TO 1:5	1:6 OR FLATTER
40 mph or Less	under 750	7 - 10	7 - 10	**	7 - 10	7 - 10	7 - 10
	750 - 1500	10 - 12	12 - 14	**	10 - 12	12 - 14	12 - 14
	1500 - 6000	12 - 14	14 - 16	**	12 - 14	14 - 16	14 - 16
	over 6000	14 - 16	16 - 18	**	14 - 16	16 - 18	16 - 18
45-50 mph	under 750	10 - 12	12 - 14	**	8 - 10	8 - 10	10 - 12
	750 - 1500	14 - 16	16 - 20	**	10 - 12	12 - 14	14 - 16
	1500 - 6000	16 - 18	20 - 26	**	12 - 14	14 - 16	16 - 18
	over 6000	20 - 22	24 - 28	**	14 - 16	18 - 20	20 - 22
55 mph	under 750	12 - 14	14 - 18	**	8 - 10	10 - 12	10 - 12
	750 - 1500	16 - 18	20 - 24	**	10 - 12	14 - 16	16 - 18
	1500 - 6000	20 - 22	24 - 30	**	14 - 16	16 - 18	20 - 22
	over 6000	22 - 24	26 - 32*	**	16 - 18	20 - 22	22 - 24
60 mph	under 750	16 - 18	20 - 24	**	10 - 12	12 - 14	14 - 16
	750 - 1500	20 - 24	26 - 32*	**	12 - 14	16 - 18	20 - 22
	1500 - 6000	26 - 30	32 - 40*	**	14 - 18	18 - 22	24 - 26
	over 6000	30 - 32*	36 - 44*	**	20 - 22	24 - 26	26 - 28
≥ 65 mph	under 750	18 - 20	20 - 26	**	10 - 12	14 - 16	14 - 16
	750 - 1500	24 - 26	28 - 36*	**	12 - 16	18 - 20	20 - 22
	1500 - 6000	28 - 32*	34 - 42*	**	16 - 20	22 - 24	26 - 28
	over 6000	30 - 34*	38 - 46*	**	22 - 24	26 - 30	28 - 30

* Where a site specific investigation indicates a high probability of continuing crashes, or such occurrences are indicated by crash history, the designer may provide clear zone distances greater than 30 feet as indicated. Clear zones may be limited to 30 feet for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

** Since recovery is less likely on the unshielded, traversable 1:3 slopes, fixed objects should not be present in the vicinity of the toe of these slopes.

7.01.11 (continued)

Current Clear Zone Criteria

D. Curve Correction Factors Table

The Curve Correction Factors Table shown below shall be applied to horizontal curves 2E or greater. The curve correction factor (Kcz) shall be applied to the outside of curve only. The inside portion of the curve will be treated as a tangent section.

CURVE CORRECTION FACTORS (Kcz)

Radius (ft)	DESIGN SPEED (mph)						
	40	45	50	55	60	65	70
2950	1.1	1.1	1.1	1.2	1.2	1.2	1.2
2300	1.1	1.1	1.2	1.2	1.2	1.2	1.3
1970	1.1	1.2	1.2	1.2	1.3	1.3	1.4
1640	1.1	1.2	1.2	1.3	1.3	1.3	1.4
1475	1.2	1.2	1.3	1.3	1.4	1.4	1.5
1315	1.2	1.2	1.3	1.3	1.4	1.4	
1150	1.2	1.2	1.3	1.4	1.5	1.5	
985	1.2	1.3	1.4	1.5	1.5	1.5	
820	1.3	1.3	1.4	1.5			
660	1.3	1.4	1.5				
495	1.4	1.5					
330	1.5						

7.01.11 (continued)

E. Other Controlling Factors

For free access highways, the clear zone should ideally be the same as for controlled access highways, but often this is impossible as it would require complete reconstruction of the highway, and destruction of the existing roadside features. Clear zone may often be restricted by drives, intersections, ditches, narrow R.O.W., and other features. While it may be argued that the dynamics of a vehicle running off the road are no different on a free access road than they are on a limited access facility, it remains as a fact of life that there will always be obstacles of some description on free access roads - mailboxes, driveway embankments, trees, buildings, etc. Enormous numbers of these obstacles occur on the trunkline system.

7.01.11 (continued)

Continued efforts should be made to reduce these obstacles as finances permit, even though some cannot be removed without great difficulty, because of socio-environmental considerations, e.g., mature shade trees in a west-facing front yard. However safety considerations should overrule, and if need be, even these mature shade trees may have to be removed.

The designer should note that the presence of an up-slope significantly reduces the clear zone width required. It is therefore seldom necessary to remove a tree or to shield an obstacle that is located at the top of a cut-slope if the elevation of the top of slope is approximately 5'-0" to 6'-0" higher than the edge of pavement. These situations should always be checked, however.

7.01.17 (revised 10-21-2013)

Strength Requirements of Steel Beam Guardrail

The Standard Specifications reference material requirements for steel beam guardrail and associated hardware to AASHTO Specification M 180, which requires 70,000 psi tensile strength in the base metal.

Crash testing of roadside safety devices, such as guardrail and other barriers, is standardized according to procedures outlined in *National Cooperative Highway Research Program Report 350* (NCHRP 350) and the *Manual for Assessing Safety Hardware* (MASH), respectively.

MASH contains the current guidelines for testing and evaluating roadside safety devices, thereby superseding NCHRP 350. As of January 1, 2011, newly tested or modified roadside safety devices must be evaluated using MASH criteria. However, all safety hardware accepted prior to adoption of MASH using NCHRP 350 criteria may remain in place and may continue to be manufactured and installed. As a result, it is acceptable to install new roadside safety devices that meet NCHRP 350 or MASH. MDOT-approved roadside safety hardware not accepted under NCHRP 350 or MASH with no suitable alternatives may remain in place and may continue to be installed.

7.01.17 (continued)

There are up to six test levels in NCHRP 350 and MASH, respectively, depending on the feature being evaluated. All six test levels apply to longitudinal barriers. Test levels 2 and 3 apply to breakaway features and test levels 1, 2, and 3 apply to crash cushions and end treatments.

Fundamentally, guardrail is intended to redirect the impacting vehicle, not stop it. Energy absorption and vehicle deceleration are the functions of an impact attenuator (or a Type 2 terminal, under certain conditions). For this reason, 25 degrees is the maximum angle used in testing for guardrail strength.

The designer will occasionally encounter situations where a broad area must be shielded. These may be areas wide enough to allow a vehicle to exceed 25 degrees in approach angle and too wide to make an impact attenuator feasible. These situations must be studied. The solution will usually involve guardrail placed in a curving configuration or the use of cable barrier if there is room for the deflection that is characteristic of a cable barrier.

NCHRP 350 Test Level	Vehicle	Impact Conditions	
		Nominal Speed (km/h)	Nominal Angle (deg)
1	2000P (2000 kg pick up truck)	50	25
2	2000P (2000 kg pick up truck)	70	25
3	2000P (2000 kg pick up truck)	100	25
4	8000S (8000 kg single unit truck)	80	15
5	3600V (3600 kg tractor van trailer)	80	15
6	3600T (3600 kg tractor tanker-type trailer)	80	15

7.01.17 (continued)

Strength Requirements of Steel Beam Guardrail

MASH Test Level	Test Vehicle Designation and Type	Impact Conditions		
		Vehicle Weight Kg (lbs)	Speed km/h (mph)	Angle Degrees
1	1,100C (Passenger Car) 2,270P (Pickup Truck)	1,100 (2,420) 2,270 (5,000)	50 (31) 50 (31)	25 25
2	1,100C (Passenger Car) 2,270P (Pickup Truck)	1,100 (2,420) 2,270 (5,000)	70 (44) 70 (44)	25 25
3	1,100C (Passenger Car) 2,270P (Pickup Truck)	1,100 (2,420) 2,270 (5,000)	100 (62) 100 (62)	25 25
4	1,100C (Passenger Car) 2,270P (Pickup Truck) 10,000S (Single Unit Truck)	1,100 (2,420) 2,270 (5,000) 10,000 (22,000)	100 (62) 100 (62) 80 (50)	25 25 15
5	1,100C (Passenger Car) 2,270P (Pickup Truck) 36,000V (Tractor-Van Trailer)	1,100 (2,420) 2,270 (5,000) 36,000 (79,300)	100 (62) 100 (62) 80 (50)	25 25 15
6	1,100C (Passenger Car) 2,270P (Pickup Truck) 36,000T (Tractor-Tank Trailer)	1,100 (2,420) 2,270 (5,000) 36,000 (79,300)	100 (62) 100 (62) 80 (50)	25 25 15

7.01.18 (revised 10-21-2013)

Suggested Shy Line Offset Values

Shy line offset is the distance from the edge of traveled way in which a roadside object will not be perceived as an obstacle or result in the driver reducing speed or changing the vehicle's path of travel.

Design Speed (mph)	Shy Line Offset (L_S) (ft)
80	12
75	10
70	9
60	8
55	7
50	6.5
45	6
40	5
30	4

7.01.19 (revised 10-21-2013)

Suggested Runout Lengths for Barrier Design

Runout length is the distance from the object being shielded to the point the vehicle is assumed to depart from the roadway.

	Traffic Volume (ADT) veh/day			
	Over 10,000	Over 5,000-10,000	1000-5000	Under 1000
Design Speed (mph)	Runout Length L_R (ft)	Runout Length L_R (ft)	Runout Length L_R (ft)	Runout Length L_R (ft)
70	360	330	290	250
60	300	250	210	200
50	230	190	160	150
40	160	130	110	100
30	110	90	80	70

7.01.20 (revised 10-21-2013)

Guardrail Deflection

Being flexible barriers, both steel beam guardrail and cable guardrail are expected to deflect under impact. This deflection is a result of deformation of the beam element or stretching of the steel cable, fracturing of the post (if wood) or bending of the post (if steel), and lateral displacement of the post in the soil. It is therefore necessary that room for deflection be provided between the back of the rail system (back of posts) and the object or area being shielded. For design purposes, use the chart at the end of this section for the expected deflections of the various barrier systems.

It should be noted that the above deflection distances are not well-defined values, and that deflections may vary for different soil types and moisture content, thawed or frozen ground, different types of anchorages, and differing lengths of installation. If specific site conditions are such that it is predictable that greater deflection values may occur, and space for deflection is restricted, then shorter post spacing or deeper embedment of posts should be considered. Shorter post spacing is only effective, however, if the full effect of proper post embedment is realized. See

7.01.20 (continued)

Section 7.01.41D, "8'-0" Posts". See also Section 5.5.2, 2011 AASHTO Roadside Design Guide.

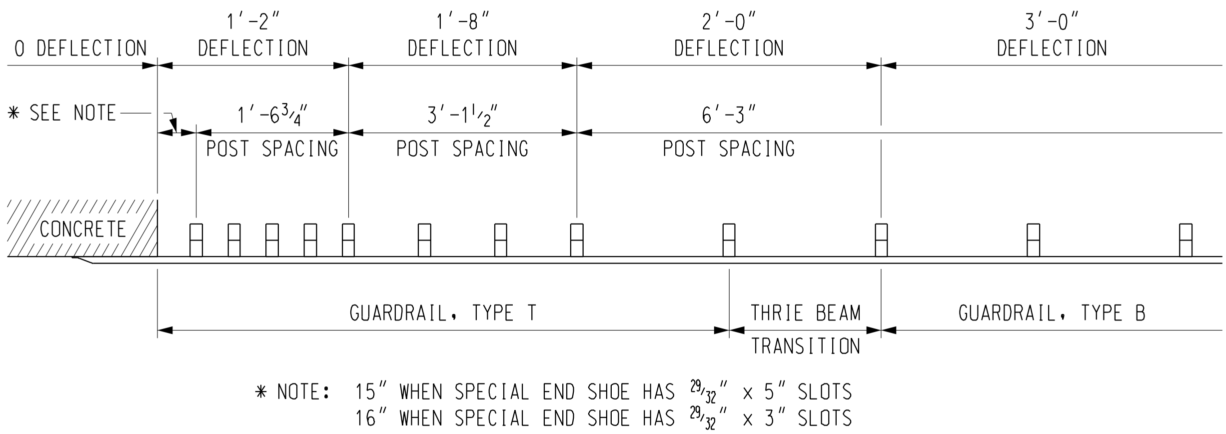
Guardrail	Post Spacing	Deflection
Type T	1'-6¾"	1'-2"
Type T	3'-1½"	1'-8"
Type T	6'-3"	2'-0"
Type C	6'-3"	2'-0"
Type B	3'-1½"	2'-0"
Type B	6'-3"	3'-0"
3-Cable	8'-0"	11'-6"

The Zone of Intrusion (ZOI) is the region measured above and behind the face of a barrier system where an impacting vehicle or any major part of the system may extend during an impact. For a typical TL-3 system, the ZOI extends between 18" and 30" behind the traffic side face of the barrier. Where practical, the designer should keep objects out of this area. See Section 5.5.2, 2011 AASHTO Roadside Design Guide, for additional ZOI guidance.

7.01.21 (revised 10-21-2013)

Guardrail Strength Transitions

Sudden and significant changes in lateral stiffness of a barrier system may cause an impacting vehicle to pocket, if it proceeds from a weaker system to a stronger system. A gradual modification of the deflection characteristics of the barrier is therefore needed. This may be achieved by closer post spacing, heavier barrier elements, larger posts or a combination of these. Illustrated below is a typical transition from Guardrail, Type B to a concrete barrier, filler wall, or barrier railing. The 2011 AASHTO, ***Roadside Design Guide*** (page 7-15) advocates that the transition length between joining barrier types should be approximately 10 to 12 times the difference in dynamic deflection. For a difference in deflection of 12", the transition stiffening length should occur in one effective beam element length or 12'-6". See Section 7.01.20 for dynamic deflections.



7.01.22 (10-22-99)

Minimum Guardrail Lengths and Gaps

A free-standing section of guardrail (one not attached to a bridge or other structure) should be at least 100' in length. Greater lengths are recommended; lesser lengths maybe acceptable under low speed conditions. A gap of less than approximately 200' between barrier installations should be avoided. Usually this will require filling in the gap with connecting barrier. An exception would be the unique situation where an approach and trailing ending, separated by a gap, can be buried in a cut slope, and the consequences of a vehicle encroaching on the cut slope would be less than hitting the guardrail filling the gap.

7.01.23 (revised 10-21-2013)

Function of Guardrail Components

It is essential that the designer understand the function of the various components of a guardrail system and some of the principles underlying barrier design details.

Beam height - The 28" top of rail height of single beam systems is a compromise between satisfying the conflicting demand of meeting the centers of gravity of heavier, higher cars and of smaller, lower cars. The use of a second beam element (Type C), or of a wider beam element (Type T), permits the 32" and 34" top of rail heights that cover a broader range of center of gravity heights.

7.01.23 (continued)

Function of Guardrail Components

Offset block - Serves two principal purposes, 1) locates beam farther from the post to minimize the possibility of wheel snagging on the post and pocketing in the guardrail, and 2) maintains top of rail height momentarily longer as the post rotates backward under impact, reducing the probability of the vehicle vaulting over the rail. (See page 5-16, 2011 AASHTO, ***Roadside Design Guide***)

Round washer - Provides an even bearing surface around holes that are often field-drilled and rough.

Post bolt washer - To prevent the head of the post bolt from pulling through the beam element. Recent recommendations, nationally, have been to delete the washer, on new construction, to allow the rail to strip off the posts and thus not go down under impact. Washers are now recommended only on the end post of the SRT, or on the end post in a Departing End Terminal.

Rail splice - Splices, of course, are unavoidable. They should be at least as strong as the rail itself; all eight connection bolts (twelve in thrie beam) are needed to distribute the load throughout the rail section. Lapped splices are usually such that the outer rail overlaps in the downstream direction, to prevent vehicle snagging.

7.01.24

Accommodation of Expansion

Provision must be made for the movement of guardrail beam elements caused by thermal expansion and contraction. The movement in rail elements is accomplished by means of oblong slots at the splices. Additional expansion at structures is obtained by means of longer slots in the Special End Shoes and Thrie Beam Expansion Section illustrated on Standard Plan R-67-Series (see Section 7.01.16I).

7.01.25 (revised 10-21-2013)

Guardrail Approach Terminals

Crashworthy end treatments are critical to guardrail installations. An approach terminal is designed to redirect an impacting vehicle and to reduce the occurrences of a vehicle being penetrated, rolled, or vaulted in an end on hit. The following section describes the characteristics and uses of approved standard treatments.

A. Type 1 Terminals

Type 1 Guardrail Approach Terminals are flared gating terminals. This is the preferred design when grading limits allow for the appropriate 4'-0" offset of the terminal end from the tangent extension of the standard line of guardrail run. When the Type 1 terminal is called for on plans by reference to Standard Plan R-61-Series, the contractor may use one of two terminal options. Descriptions of the current approved options are described in this section.

1. Slotted Rail Terminal (SRT)

The SRT was adopted by the Department in 1995 when FHWA mandated the discontinued use of the BCT. It subsequently became the first guardrail terminal to pass the NHCRP Report 350 crash test criteria.

The concept of a slotted rail terminal consists of longitudinal slots cut into the W-beam rail element to control the location of dynamic buckling thus reducing the potential for impact or penetration of the occupant compartment by the buckled rail element.

The SRT was originally intended as a retrofit or replacement for the BCT ending.

The SRT uses many of the same components used in the BCT. It also uses features common to other end treatments such as the yoke and strut and controlled release terminal (CRT) posts. The parabolic flare of the SRT is identical to that of the BCT, simplifying the retrofit of existing terminals.

7.01.25A (continued)

2. Flared Energy Absorbing Terminal (FLEAT)

FLEAT was adopted in 1998 after it passed NCHRP Report 350 crash testing. Among other reasons, it was chosen as an alternate for the SRT because of the similarities in the components and installation configuration of the two systems. In addition to these similarities to the SRT and other flared terminals, the FLEAT includes an energy absorbing impact head. Unlike the SRT, the 4'-0" offset of the FLEAT is a straight taper rather than a parabolic flare.

3. Minimum Offset

The Type 1 Terminal is designed to have a minimum offset of 4'-0", measured from the tangent line of the guardrail run. Whenever conditions allow, the line of guardrail designed in advance of the terminal should be flared to further increase the total offset of the terminal from the traveled lane. On curved roadways the offset is measured from the circular extension of the standard rail alignment along the curve.

Sometimes on certain minor trunklines and a great number of local roads, the end post may have to be placed on the slope beyond the shoulder hinge point, in which case care should be taken that the terminal end shoe and the steel sleeves are not left "high" nor placed too low.

B. Type 2 Terminals

Type 2 terminals are tangent, energy absorbing terminals. They are used when proper grading cannot be achieved to accommodate the 4'-0" offset called for with the Type 1 terminals. When the Type 2 terminal is called for on plans by reference to Standard Plan R-62-Series, the contractor may use one of two terminal options. Descriptions of the currently approved options are described in the following sections.

7.01.25B (continued)

Guardrail Approach Terminals

1. Extruder Terminal (ET)

The ET was installed experimentally by the Department in 1993 and was used occasionally when special situations called for a non flared terminal. In 1995 the ET became the first non-flared terminal to meet the NCHRP Report 350 crash test criteria. Frequent use of the ET led to its upgraded status as a standard plan in 1997. It features an impact head that, when hit head on, flattens the guardrail beam element as the head translates down the terminal rail. The flattened rail is then extruded away from the impacting vehicle.

2. Beam Eating Steel Terminal (BEST)

At the same time the ET was originally approved as a standard, the BEST was chosen as an approved alternate option. It's status as a standard was short lived when the SKT (see succeeding section) replaced it months after its adoption. The BEST featured an impact head that shredded and flattened the rail before extruding it. The developers and patent holders of the BEST discontinued marketing and production of this product shortly after they developed and patented the SKT.

3. Sequential Kinking Terminal (SKT)

The SKT was successfully crash tested in 1997 and adopted by the Department as a standard Type 2 terminal alternate in 1998, replacing the BEST. The materials and configuration of the SKT were more compatible with the ET. Like the FLEAT, its impact head includes a deflector plate that produces sequential kinks in the beam element before extruding it away from the impacting vehicle.

7.01.25B (continued)

4. Minimum Offset

The original intent of the Type 2 terminals was to provide endings that required no offset. This was the orientation used in the crash tested system. It was later determined by the FHWA that a 12" offset would be acceptable without further testing. This minimal offset was adopted in Standard Plan R-62-Series in order to minimize the number of nuisance accidents that may occur when the impact head was located close to or encroaching on the shoulder.

C. Function of the Various Guardrail Terminal Components

It is important that designers, as well as construction and maintenance personnel, understand the function of the components that make up Guardrail terminals:

Bearing plate - Distributes the forces in the cable to the wooden end post and steel sleeve. The slotted bearing plate design featured in the SRT, allows the bearing plate to separate from the cable upon breaking of the wooden end post.

Terminal End Shoe - This feature of the SRT absorbs some of the impact forces, spreading them over a wider area, to reduce the potential for the end of the beam element to penetrate the vehicle passenger compartment.

7.01.25 (continued)

Guardrail Approach Terminals

D. Guardrail Full Strength Point

When a standard guardrail terminal is used, the length of need is calculated to a point where the guardrail run develops the full strength of the system. This point on the approach end is considered to be the third post from the end (page 5-51, 2011 AASHTO, ***Roadside Design Guide***).

E. Clear Area Behind Guardrail Terminals

When determining the length of need of a guardrail run, the designer should verify that there will be no obstacle behind or to the behind side of a guardrail terminal that would prevent gating.

This is especially true with the Type 1 terminal since it is specifically designed to gate.

The area behind should be traversable for the vehicle after it passes through the terminal. The minimum recovery area behind and beyond a terminal should be an obstacle free area approximately 75' long and 20' wide. If it appears that the area behind will not be traversable, then the guardrail run will probably have to be extended to a point where the area behind the terminal is clear.

7.01.25 (continued)

F. Burying Ending in a Backslope

Occasionally high cut slopes adjacent to the traveled roadway do not provide sufficient clear area behind a Type 1 terminal to allow gating.

The designer should consider terminating the guardrail inside the backslope. The designer or project manager can obtain a special detail for this treatment from the Design Standards Unit.

G. Slope Under Guardrail Terminals

The area under the terminal should be graded to a 1:10 slope or flatter from the edge of the traveled lane to the shoulder hinge point (2'-0" behind the face of the post). See the appropriate guardrail approach terminal Standard Plans for grading details.

7.01.29 (revised 10-21-2013)

Guardrail Flare

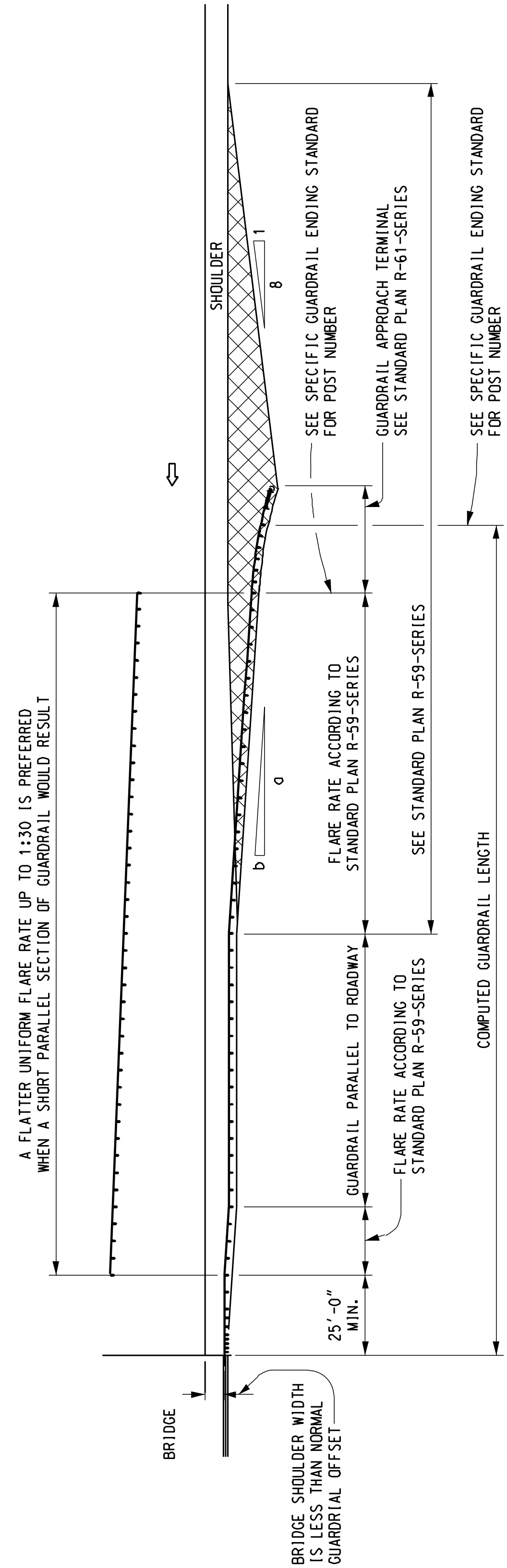
When designing guardrail, the designer should take advantage of opportunities to flare the installation. This reduces the required length of need. It also places the guardrail terminal farther from the traveled lane, thus reducing the potential for nuisance hits.

A. Flare Rate

Historically, 1:15 has been the preferred flare rate for guardrail in Michigan. Other maximum flare rates for semi-rigid barriers are listed on page 5-48 of the 2011 AASHTO, ***Roadside Design Guide*** and on Standard Plan R-59-Series according to design speed. Flatter flare rates listed by AASHTO for barrier inside the shy line should only be used where it will not increase the length of the guardrail run.

B. Uniform Flare from Structures

Guardrail may need to be flared inward to meet the bridge barrier railing of bridges with narrow shoulders. When the guardrail length at a structure is increased, such as for an embankment, a uniform guardrail flare rate (not flatter than 1:30) may be substituted for the combined short parallel section and the two flared sections. The Illustration at right shows this situation on a left approach rail. When the shielded area in advance of the bridge rail is a steep embankment, the length of need is determined as outlined in Standard Plan R-59-Series. A uniform flare can then be constructed from the end of the tangent length of barrier at the bridge rail (L1) to the first post of the guardrail terminal at offset distance “z”.



7.01.30 (revised 10-21-2013)

Guardrail at Embankments

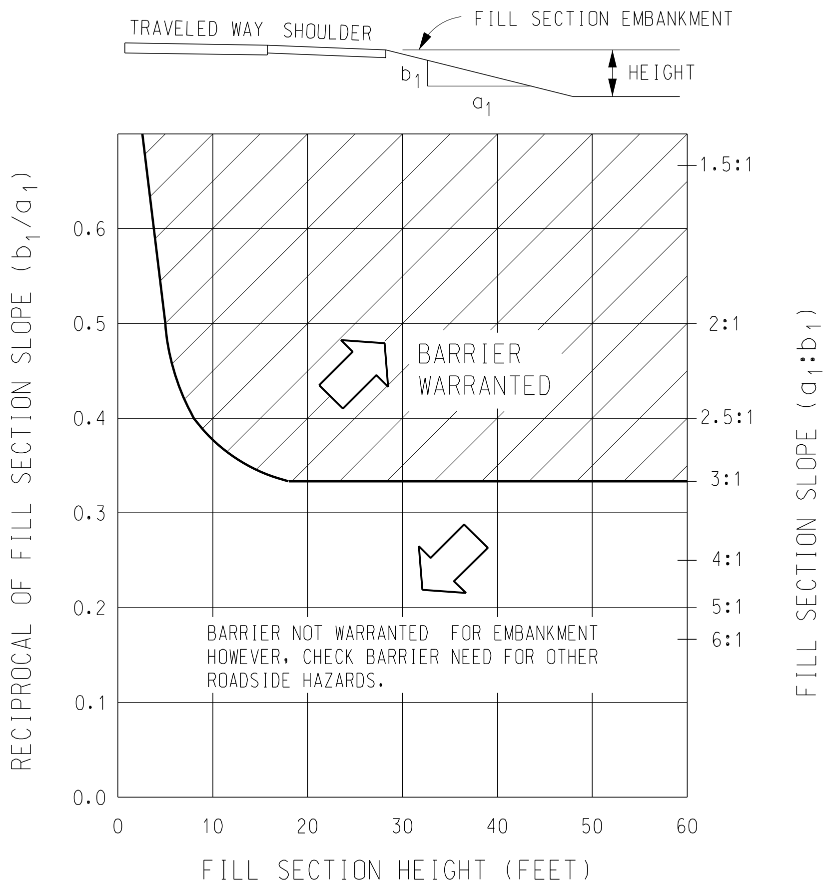
As a general rule, a barrier should be placed to protect a vehicle from going down an embankment only if the barrier itself is the least severe of the two features. Such a comparison must of necessity be very subjective because of the many variables involved. The Department generally follows the criterion that, if the fill slope is 1:3 or flatter, no barrier is required. For slopes of 1:3 or flatter, the height of fill does not increase severity.

7.01.30 (continued)

The economics of earthwork obviously dictate that all slopes cannot be 1:6, regardless of fill height. As the fill becomes higher, more consideration must be given to steepening the slopes, which in turn may call for a decision relative to placing a barrier.

Slopes intended to be traversable, i.e., one flat enough that a barrier can be omitted but still perhaps 1:3, should be relatively free of discontinuities that might "trip up" a vehicle. Plans should note that half-buried boulders and large rocks should be removed as part of the final trimming operation.

A. Height-Slope Guidelines



7.01.30 (continued)

Guardrail at Embankments

G. Placing Beam Guardrail on a Downslope

Usually the greater the distance from the roadway that a barrier can be placed, the less chance there is of it being struck and less barrier length will be needed to shield the object. However, placing a barrier on a downslope close to the shoulder hinge point (approximately 12'-0" or less) introduces the potential for the barrier to be less effective because of the tendency for a vehicle, leaving the shoulder, to vault over it. The following guidelines therefore apply:

1. Beam guardrail may be placed on a slope, beyond the shoulder point, if the slope is 1:10 or flatter.

2. Generally, a 1:10 or flatter slope should not be constructed specifically to locate the barrier farther out.

3. Usually, the placement of guardrail on a 1:6 slope is not recommended. There has been one crash test where guardrail was placed on a 1:6 slope, 18 feet off the shoulder point that satisfactorily redirected a vehicle. However, a flatter slope is more desirable. The placing of guardrail on 1:6 slopes should be confined to the applications specified in Section 7.01.32F.

7.01.30 (continued)

H. Guardrail Placed near Intersecting Streets and Driveways

An intersecting street or driveway located near a roadside object or feature may prevent installation of the full length of barrier required along the main road. An example of this would be a bridge on a main road with an intersecting driveway located near the bridge.

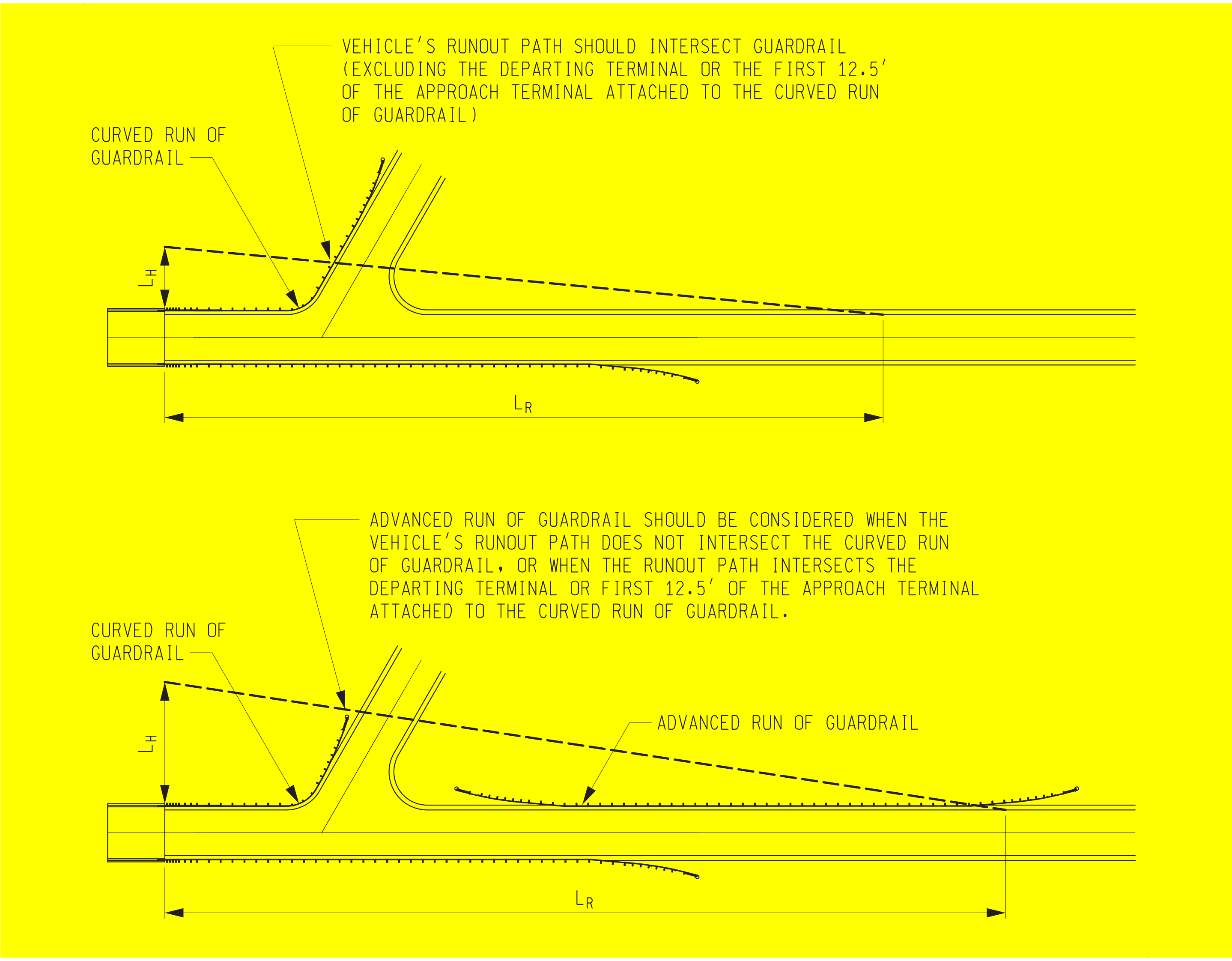
The preferred solution is to close or relocate the intersecting street or driveway in order to install the full length of barrier required along the main road. A crash cushion or other impact attenuating devices may be used to shield a fixed object such as a bridge railing end, however, this may not provide the length of need required to shield other roadside objects or features in the vicinity.

When closing or relocating the intersecting driveway or street is not feasible, two possible solutions are given in the accompanying sketches. A second guardrail run in advance of the intersecting street or driveway should be considered when the vehicle's runout path does not intersect guardrail, or when the runout path intersects the departing terminal or the first 12.5 feet of the approach terminal attached to the curved run of guardrail. See Special Detail 21 for installing a curved guardrail run near an intersecting street or driveway. Also, graphical design methods are suggested when utilizing the proposed solutions depicted in the accompanying sketches.

Site-specific constraints must be taken into consideration when designing guardrail near intersecting streets and driveways. Examples of these constraints include limited intersection sight distance, right-of-way limitations, and the presence of multiple intersecting driveways in close proximity to each other. In addition, the use of excessively short advanced guardrail runs should be avoided. Questions regarding guardrail installations near intersecting streets and driveways should be directed to the Geometric Design Unit of the Design Division.

7.01.30 (continued)

Guardrail at Embankments



7.01.31 (revised 10-21-2013)

Shielding Bodies of Water

Warrants for shielding streams or permanent bodies of water are judgement decisions based on location and depth of water and likelihood of encroachment (page 5-9, 2011 AASHTO, ***Roadside Design Guide***). Streams or permanent bodies of water more than 2'-0" in depth will usually require shielding by a barrier if within the clear zone (page 18, 1977 AASHTO, ***Guide for Selecting, Locating and Designing Traffic Barriers***). Barrier may also be required for bodies of water beyond the clear zone if, in the judgement of the designer, there is greater than usual potential for an errant vehicle to enter the water. An exception may be water close to the road for a considerable distance (a causeway is a case in point). In this case, speeds may have been correspondingly reduced because the roadside might be heavily used for recreational access to the water and for fishing. An intermittent barrier leaves many exposed endings to treat and space may not be available for proper flaring of the ends. After all factors are taken into consideration, it may be decided that the disadvantages of a barrier outweigh the advantages.

7.01.32 (revised 10-20-2008)

Barrier at Bridge Approaches (Over and Under)

Besides shielding embankments, the other most common use of a roadside barrier is shielding massive structural components. These fall into two general categories, the overpassing structure (approaches and railings) and the under passing structure (piers, drainage structures, and abutments).

A. Attachment to Barriers and Closer Post Spacings

Guardrail beam elements fastened to concrete structures should overlap the concrete sufficiently to place the end bolts onto the concrete a minimum of 3'-6". This distance is considered necessary to prevent the concrete from shattering and the bolts from pulling loose under impact.

All of the guardrail anchorage, bridge attachments specified on Standard Plans R-67-Series, B-22-Series and B-23-Series increase in lateral stiffness. This is done to keep an impacting vehicle from displacing the guardrail and pocketing against the rigid bridge structure. The transition for lateral stiffness of guardrail is described in Section 7.01.21. Additionally, Standard Plans B-22-Series and B-23-Series use heavier 10 gage (0.138") thrie beam elements to increase barrier strength.

7.01.32 (continued)

Barrier at Bridge Approaches (Over and Under)

F. Bridge Columns and Foundations in 70' Medians

Bridge columns and sign support foundations located in the center of 70' medians were once considered outside the clear zone. Shielding is now required and should be included in any programmed project upgrading.

The treatment for shielding columns and foundations for new construction and reconstruction projects should be according to the enclosed system designs shown on Standard Plan R-56-Series, Guardrail Median Object Protection.

In addition to the enclosed systems discussed in the previous section, an open system is detailed in Standard Plan R-56-Series for other than new construction and reconstruction projects with 70' medians and existing fill slope rates of 1:6 or flatter. This detail features twin parallel guardrail runs that shield the median objects independently for each direction of traffic. This option offers the advantage of better accessibility for maintenance equipment to service the median or sign foundations. It is intended only for the conditions stated above.

7.01.33 (revised 10-21-2013)

Maintaining Guardrail Strength When One or More Posts Must Be Omitted

A. Downspout Headers

Standard Plan R-32-Series, under "Notes", advises field personnel to determine the location of proposed guardrail posts prior to locating the spillway or downspout header(s). If this is done, there will be no conflict. There are occasions however, when miscalculation in construction layout or when upgrading guardrail, that an existing downspout header will prevent a post from being placed at the proper spacing. Downspout headers that were constructed prior to 1970 and according to Standard Plan E-4-A-144 series, are an example. These downspouts had deeper throats and were designed to fit 12'-6" post spacing. When a post cannot be properly placed, Standard Plan R-72-Series, "W-Beam Backed Guardrail Installations" should be used.

B. Wide Culverts

Maintaining the continuity of the barrier strength is also necessary when a run of guardrail spans a wide culvert and the proper embedment of a guardrail post(s) cannot be obtained. When the spanning of a wide culvert requires the omission of one or two posts, Standard Plan R-72-Series, "W-Beam backed Guardrail Installations" should be used. Where no barrier wall exists and the span is over 18'-9", Standard Plan R-73-Series, "Guardrail over Box or Slab Culverts" may be used.

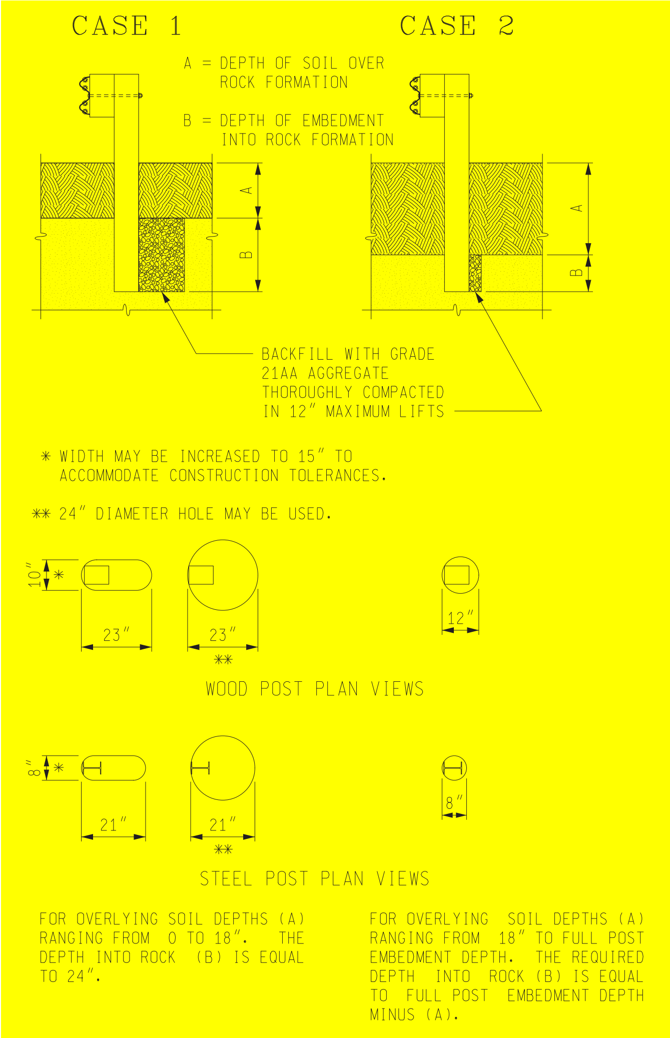
7.01.33 (continued)

Maintaining Guardrail Strength When One or More Posts Must Be Omitted

C. Placing Guardrail in Rock

Rock formations, which occur more frequently in the Upper Peninsula, may prevent the full embedment of guardrail posts. When only a partial embedment of posts can be obtained, backing the guardrail according to the method illustrated in Standard Plan R-72-Series is an option to individually drilling each hole. If the number of post locations in the influence of the rock formation would force the length of the backed guardrail section to exceed that allowed in the standard, the affected posts holes will have to be drilled. If the depth of soil overlying the rock formation is 18" or greater, the hole diameter required for steel posts is 8" (12" for wood) and full post embedment depth is required. If the depth of soil overlying the rock formation is less than 18", the hole diameter required for steel posts is 21" (23" for wood) and a 24" embedment depth into the rock is required. A strong-post W-beam guardrail exhibits better performance if the post is allowed to rotate in the soil. Thus, the post should not be placed in the center of the hole, but at the front, so the backfill is behind the back of the post. This work should be included by special provision.

7.01.33 (continued)



7.01.33 (continued)

Maintaining Guardrail Strength When One or More Posts Must Be Omitted

D. Guardrail Posts through Paved Surfaces

Guardrail posts embedded into paved surfaces present a problem similar to that of guardrail posts in rock formations. The paved surface will not allow the posts to rotate in their embedment (to distribute vehicle loads through the post into the embedment material) prior to breaking. Thus, an area of pavement around the post know as "leave out" must be omitted to allow the post to rotate. For both steel and wood posts, the size of the leave out should be an area of about 15" x 15" (square or round). The most critical measurement is the distance from the back of post to the back edge of the leave out, which should be a minimum of 7". After post installation, patching material is generally placed around the guardrail post in the "leave out" area. This work should be included by special provision.

7.01.33 (continued)

E. Additional Blockouts on Guardrail Posts

Double blockouts (16" deep) may be used to increase the post offset to avoid obstacles such as curbs. Except at terminals, there is no limit to the number of posts in a guardrail run that use double blockouts. Under special circumstances, one or two posts in a run of guardrail may employ as many as four blockouts (up to 36") to provide proper clearance. There should be no voids between blockouts when using double or multiple blockouts. Furthermore, for aesthetic reasons, double or multiple blockouts should be installed without creating sudden changes in guardrail alignment.

When using double or multiple blockouts, steps must be taken to prevent the placement of guardrail posts on steep fill slopes beyond the shoulder hinge point. Placing conventional length guardrail posts on steep fill slopes may result in posts having insufficient soil embedment depth, thereby reducing the post's strength to resist overturning. See Section 7.01.41.D, 8'-0" Posts, for guardrail post length requirements when placing guardrail at or near the shoulder hinge line.

7.01.34 (revised 10-21-2013)

Guardrail in Conjunction with Curb

When a vehicle strikes a curb, the trajectory of that vehicle depends upon several variables including the size and suspension characteristics of the vehicle, its speed and angle of impact, and the height and shape of the curb itself. Generally, the use of curb on high speed roadways (design speed greater than 50 mph) is discouraged.

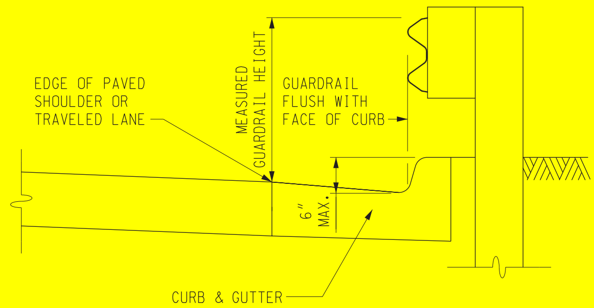
If guardrail/curb combinations are used when design speeds are less than 45 mph, the curb height should be 6" or less, with the face of guardrail being located either flush with the face of curb or at least 8' behind it.

For design speeds of 45 mph or 50 mph, a 6" curb (or less) may be used if the guardrail is located flush with the face of curb. If an offset from the curb is desired, the curb height should be 4" or less with the guardrail being located at least 13' behind the curb.

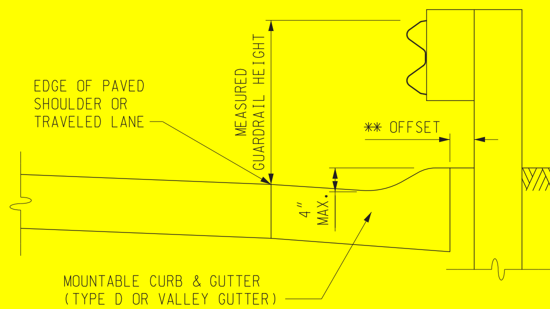
If guardrail/curb combinations are necessary when the design speed is greater than 50 mph, a mountable curb (Type D curb or valley gutter) should be used, and the curb height should be 4" or less, with the face of guardrail being located flush with the face of curb. .

When guardrail is located flush with the face of curb, the rail height should be measured from the front edge of the gutter pan, which is the point on the gutter pan that is closest to the edge of the traveled lane. At greater distances (typically 8'-0" to 13'-0") the rail height should be measured from the ground just in front of the guardrail.

7.01.34 (continued)

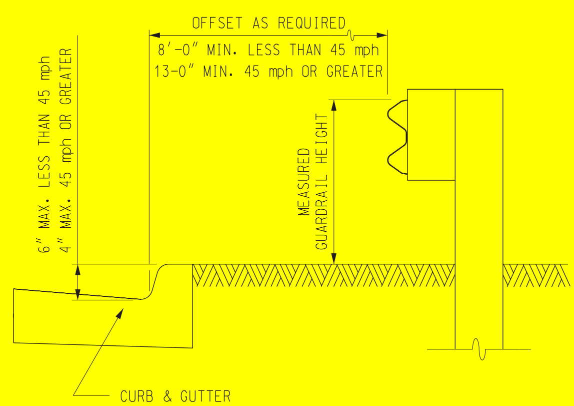


GUARDRAIL WHEN CURB IS ADJACENT TO
EDGE OF PAVED SHOULDER OR TRAVELED LANE
(DESIGN SPEED 50 mph OR LESS)



** 2" WHEN CURB IS PLACED NEXT TO SHOULDER
10" WHEN CURB IS PLACED NEXT TO TRAVELED LANE

GUARDRAIL WHEN CURB IS ADJACENT TO
EDGE OF PAVED SHOULDER OR TRAVELED LANE
(DESIGN SPEED GREATER THAN 50 mph)



GUARDRAIL - CURB OFFSET
WHEN GUARDRAIL IS PLACED AWAY FROM CURB

7.01.44 (continued)

Guardrail Upgrading on Local Roads

D. Cable on Chain Link Fence

Cable on chain link fence consists of attaching 2 steel cables to a chain link fence. This treatment may be useful in urban freeway areas where a local street ends at a service road and where a chain link fence is located parallel between the freeway and service road. Its possible use might be at locations where there is greater than usual potential for an errant vehicle to go down onto the freeway. Details are available from the Standards Unit.

7.01.45 (revised 10-21-13)

Alternative Barrier End Treatments

All the terminals discussed in this section have been crash tested as recommended by NCHRP Report 350 and approved by FHWA. As with all terminals where penetration behind and beyond the barrier can be expected, a traversable area, free of fixed objects, is recommended to aid post-crash vehicle stability. Alternative endings should be considered where restrictive site conditions exist, such as bi-directional traffic or two-sided directional traffic, and where the designer is unable to obtain the required offset, length, etc.

Note that this is not a comprehensive list of all alternative barrier end treatments, and future developments in the roadside safety industry will likely result in the availability of additional barrier end treatments. Consult with the Geometric Design Unit, Design Division, for additional information regarding alternative barrier end treatments.

7.01.45 (continued)

A. X-Tension / X-MAS

The X-Tension and X-MAS (X-Tension Median Attenuator System), respectively, are guardrail terminals manufactured by Barrier Systems (a Lindsay Corporation company), Vacaville, California. Both guardrail terminals are NCHRP 350, Test Level 3 compliant. The X-Tension may be installed as a flared or a tangent guardrail terminal for ending single-sided guardrail. The X-MAS is available for terminating double-sided guardrail.

The X-Tension and X-MAS terminals are non-gating terminals, so the beginning length of need point starts at the first guardrail post. As a result, the X-Tension and X-MAS may be desirable at locations where a redirective, non-gating guardrail terminal is considered advantageous due to site-specific conditions.

Detailed information on design, installation, and maintenance is available from the Geometric Design Unit, Design Division.

B. X-TENuator

The X-TENuator is an NCHRP 350, Test Level 3 compliant crash cushion manufactured by Barrier Systems (a Lindsay Corporation company), Vacaville, California. The X-TENuator may be used for both permanent and temporary applications, and may be used to terminate single-sided guardrail, double-sided guardrail, and concrete barriers. The X-TENuator is approximately 24'-9" long, and requires a concrete or asphalt base pad for installation. While the X-TENuator has a relatively low installation cost compared to other crash cushions, this device is considered to be a sacrificial unit that generally requires complete removal and replacement after a vehicular impact.

7.01.45 (continued)

Alternative Barrier End Treatments

The X-TENuator may be desirable for restrictive site conditions, such as shielding concrete barrier or bridge railing endings at locations that prevent the installation of a traditional guardrail bridge anchorage and guardrail approach terminal. Designers should note that the X-TENuator requires 12'-6" of longitudinal clear space behind the unit on both sides of the object being shielded in order for the side panels of the X-TENuator to slide back and telescope when the unit is impacted.

Detailed information on design and installation is available from the Geometric Design Unit, Design Division.

C. QuadTrend™

The QuadTrend system is a proprietary terminal manufactured by Energy Absorption Systems Inc. This device is for one-sided directional traffic and is intended for shielding concrete barrier endings, bridge railing endings, abutments, etc. This device can be attached directly to a rigid ending without a guardrail strength transition. Detailed design, construction and maintenance information is available from the Geometric Unit, Design Division.

7.01.45 (continued)

D. BEAT-SSCC

The BEAT-SSCC (Box Beam Bursting Energy Absorbing Terminal Single-Sided Crash Cushion) is an NCHRP 350, Test Level 3 compliant terminal manufactured by Road Systems Inc., Big Springs, Texas.

The BEAT-SSCC may be used for both permanent and temporary applications, and is intended for use as a single-sided terminal for shielding concrete barrier, bridge abutments/piers, and certain types of bridge railings. The BEAT-SSCC is available in the following lengths: 28', 32', 36', 40', and 44'. The BEAT-SSCC is available with driven (ground-mounted) posts or with surface-mounted posts for installation on a concrete surface. While the BEAT-SSCC has a relatively low installation cost compared to other crash cushions, this device is considered to be a sacrificial unit that generally requires complete removal and replacement after a vehicular impact.

The BEAT-SSCC may be desirable for restrictive site conditions, such as shielding concrete barrier or bridge railing endings at locations that prevent the installation of a traditional guardrail bridge anchorage and guardrail approach terminal.

Detailed information on design and installation is available from the Geometric Design Unit, Design Division.

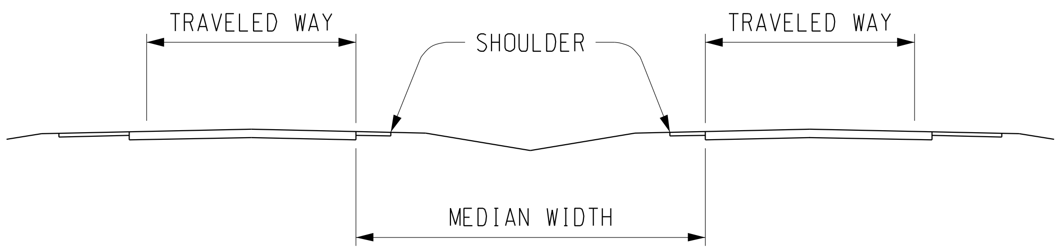
7.01.54 (revised 10-21-2013)

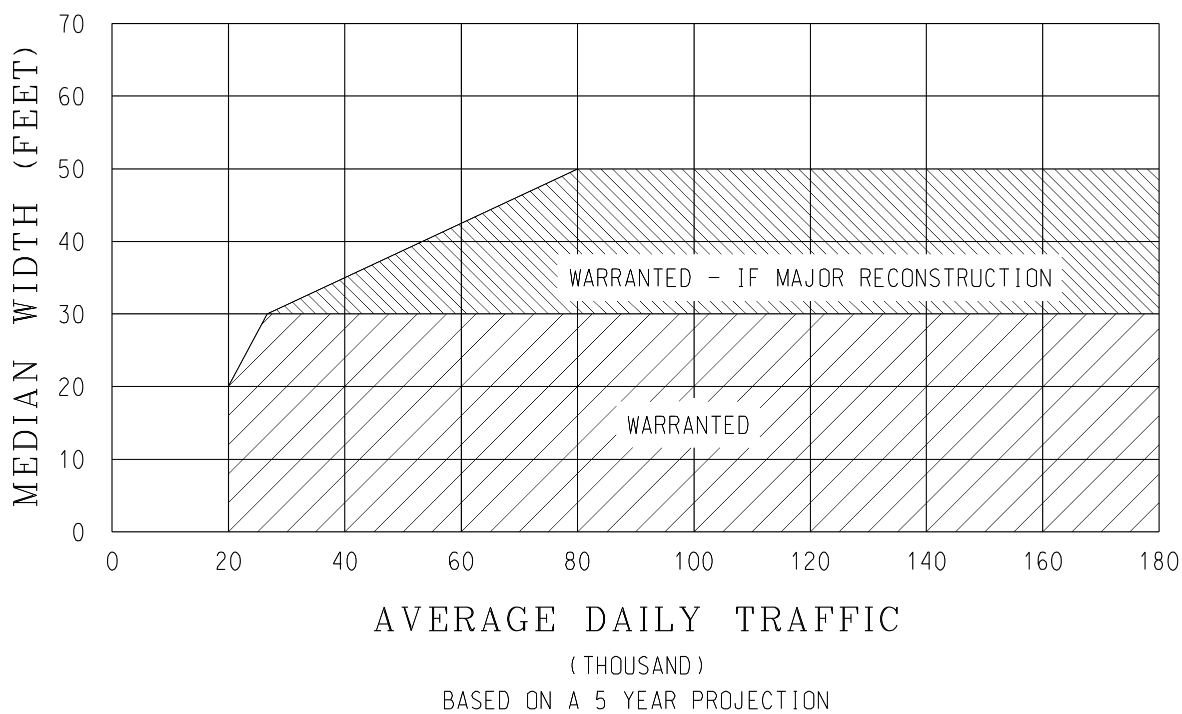
Warrants for Median Barriers on Freeways

Double thrie and double W-beam steel guardrail (semi-rigid), concrete median barrier (rigid) and Cable (Flexible) are considered equally suitable for reducing cross-median crashes. However, each has its application and each has its advantages and disadvantages. The designer should be knowledgeable of these when making decisions relative to which type of barrier to call for. The most desirable system is the one that satisfies the performance requirement

7.01.54 (continued)

and costs the least to install and maintain. Section 5.2 of the 2011 AASHTO ***Roadside Design Guide*** summarizes the major factors which should be considered before making a final selection. The current median barrier warrants formulated for placing barrier in freeway medians were developed by the former Traffic and Safety Division, accepted by the Barrier Advisory Committee and approved by the Engineering Operations Committee at their February 4, 1992 meeting. The warrant table is shown below:





7.01.55 (revised 10-21-2013)

Median Barrier Types

Median barriers, when used, are employed almost exclusively on controlled access highways. If the road is free access, openings would have to be provided at intersections and crossovers. This means that the barrier must be terminated at these points with a crash worthy end treatment. The lengths of the end treatments must be added to the length of the opening thus increasing the length of unprotected median, as the end treatments provide only marginal median crossover protection.

Generally, the initial installation cost of concrete median barrier is about 10-15% more than a double-sided metal guardrail. (However, this comparison does not include the possible additional cost of drainage alterations, etc., that might be required in conjunction with concrete barrier.) Advantages and disadvantages for the three barrier systems are as follows:

A. Concrete Median Barrier

Advantages

1. Very low maintenance.
2. Relatively good visibility.
3. Less vehicle damage at low angles of impact.
4. Easier on which to affix glare screen (glare screen can be integrally cast)

Disadvantages:

1. Greater “snow fence” effect (wind cannot pass through)
2. Traps blowing paper and trash
3. Usually requires some form of internal drainage

7.01.55 (continued)

B. Double Steel Beam Guardrail

Advantages

1. May be used in the wider medians (median width not a factor)
2. Less “snow fence” effect than concrete barrier
3. Lateral drainage can flow under
4. Performs better than concrete barrier for high angle impacts

Disadvantages:

1. Maintenance repair usually required after a hit
2. Harder to install in rock
3. No durable glare screen available for mounting on top

C. Cable Barrier

General Guidelines

- Cable median barrier is recommended on divided roadways where:
    1. Median crossover crashes have been reported, and
    2. Median barrier is not warranted based on Section 7.01.54 of the Michigan Road Design Manual.
- Median width should be a minimum of 30 feet.
- Median slopes shall be 1:4 or flatter.
- The cable barrier shall be placed at a location that permits the system to deflect unimpeded during a vehicular impact. The cable barrier shall not interfere with opposing traffic or other roadside objects during a vehicular impact. If a single run of cable barrier cannot satisfy the offset requirements, dual runs should be used.
- At locations where both NCHRP 350, TL-3 and TL-4 cable systems may be installed, NCHRP 350, TL-4 cable systems are preferred.

7.01.55C (continued)

Median Barrier Types

- The length of need (LON) for cable median barrier is based on engineering judgment. Consult with the Geometric Unit of the Design Division for additional information.
- Due to the advantages high-tension cable systems possess, high-tension cable systems are preferred over low-tension cable systems.

Approved Cable Median Barrier Systems

The following cable barrier systems are approved for use as median barrier. Questions regarding cable median barriers should be directed to the Geometric Unit of the Design Division.

A. Low-Tension Three-Cable Median Barrier (Type M Cable Barrier per Standard Plan R-70-Series)

This is a non-proprietary cable system that is described in the 2011 AASHTO ***Roadside Design Guide*** and MDOT Standard Plan R-70-Series. This design has been adopted by various agencies throughout the nation. The cable system and the end terminals have been successfully tested to NCHRP 350, TL-3.

Advantages:

1. Non-proprietary, usually less expensive than proprietary items
2. May be used on curved roadways with radii as low as 110 feet

Disadvantages:

1. Generally requires more maintenance than high-tension cable systems
2. System is usually inoperative after an impact (i.e., requires immediate inspection and maintenance after an impact)
3. Larger impact deflection compared to high-tension cable systems
4. Maximum length between terminals is considerably smaller than high-tension cable systems

7.01.55C (continued)

Table 1:

DESIGN CRITERIA FOR LOW-TENSION THREE-CABLE MEDIAN BARRIER		
Maximum Flare Rate	4:1	
Minimum Design Deflection Distance	16 feet	
Minimum Offset Between Median Ditch Line and Cable Barrier (Single Runs Only)	8 feet	
Maximum Length Between Terminals	2,000 feet	
Post Spacing and Roadway Curvature Requirements	**RADIUS**	**POST SPACING**
	Less than 110 feet	**CABLE BARRIER NOT RECOMMENDED**
	110 feet to 219 feet	6’-0”
	220 feet to 699 feet	12’-0”
	700 feet or more and Tangent Sections	16’-0”

7.01.66 (revised 10-21-2013)

Concrete Barrier, Single Face

Single face concrete barrier was developed to shield roadside objects or features from one side only. One such situation is found on depressed expressways, where the right side approaches to bridge piers need shielding from only one side. The Metro Region favors the use of a concrete barrier over the use of steel beam guardrail in these locations. The major justification for its use is the virtual absence of the need for maintenance. The results are less exposure to risk for maintenance personnel and the elimination of a damaged system being exposed to the motoring public between an impact and the completed repair.

If the normal width shoulder can be maintained and a concrete barrier safety shape is needed, it should be placed in front of the underpass bridge piers. Otherwise the concrete safety shape should be transitioned to the vertical face of the pier column as specified on Standard Plan R-54-Series. Because single face concrete barrier is most commonly used on urban depressed expressways, the approach ending is usually buried in the adjacent cut slope. See Standard Plan R-54-Series. If the approach end cannot be buried in a backslope, it should be shielded with a minimum of a Guardrail Anchorage, Bridge and a guardrail approach terminal.

The use of single face concrete barrier will usually be requested at the plan review meeting and will usually be restricted to the depressed urban freeway situation. Its use in rural areas is generally discouraged because of the cost factor, the "snow fence" effect, and drainage problems created by concentrating runoff at one or few locations on high fills. However, the single face concrete safety shape might be considered between two consecutive bridges having safety shape concrete railings that are approximately 200' apart or less.

7.01.67 (revised 10-21-2013)

Temporary Barrier

Temporary barrier was introduced in Michigan about 1972. Since that time, its use in construction work zones has steadily increased. Temporary barrier serves a dual purpose: it shields objects originating from construction practices and protects construction and maintenance personnel from the adjacent moving traffic.

Barrier sections were initially precast. Then, a cast-in-place or slip-formed barrier similar to permanent barrier was allowed. Current designs meeting NCHRP 350 / MASH criteria are now required.

When computing quantities of temporary barrier, the designer should review the staging plans and determine the maximum length of barrier required at any one time on the project. If the staging requires that barrier units be moved, additional pay items and quantities either for adjusting or relocating are necessary. Generally, the pay item "Conc Barrier, Temp, Adj" is used for moving the barrier laterally to a new alignment on the same roadbed and "Conc Barrier, Temp, Relocated" is used for relocating the barrier longitudinally on the same roadbed, or to another roadbed. See current specifications for exact methods of payment.

7.08

MAILBOX POSTS

7.08.01 (revised 10-21-2013)

References

A. Standard Plan R-74-Series, Bumper & Parking Rails, and Misc. Wood Posts

B. ***Roadside Design Guide,*** AASHTO, 2011, Chapter 11

7.08.02 (revised 10-21-2013)

General

Typically, the post supported rural mailbox is private property that occupies the R.O.W. by permission. During construction activities, the Department assumes the responsibility for maintaining serviceability of existing mailboxes. After construction activities are completed, the Department or its contractor will place a department approved support at the permanent location, remove the mailbox from the old support and attach it firmly to the new post, and dispose of the old support. The property owner shall be given the option of disposing of the old support. Existing newspaper boxes are removed and stored for the property owner's future installation and are not paid for separately.

Even though the authority to regulate mailbox installations is not well defined, the property owner should be discouraged from reconstructing unusual mailbox installations. Crash tests seem to show that the mailboxes that remain attached to the post go down under impact and away from the vehicle. Attaching several boxes to one large horizontal support is discouraged by Chapter 11 of the ***Roadside Design Guide,*** AASHTO, 2011. Department standard plans now show

7.08.02 (continued)

a mailbox post having a smaller cross-sectional area than previously. Alternate mailbox support designs meeting the performance criteria of NCHRP Report 350 or MASH may be used as approved by the Engineer.

7.08.03 (revised 10-21-2013)

Design Considerations

As a part of the design, the number of existing mailboxes should be determined and used as a basis for estimating the number of mailbox posts to be placed on the project. Sometimes this can be determined from the plans if buildings are included in the topography shown, but this method is usually not as accurate as actually counting those in the field. The photolog is a reliable source of this information. Internet mapping websites can also be used.

Placement of mailboxes in a curb and gutter section may pose questions, particularly if a curb is being constructed where it did not exist before. If it is a barrier curb, the posts must be within arm's reach of the face of curb; the question then is, are existing boxes concentrated on one side only, or on both sides of the road? If the curb is a roll curb, then the boxes can either be directly behind the curb or at the far edge of shoulder. Either location has advantages and disadvantages. If immediately behind the curb, the post may interfere with the movement of vehicles on the shoulder, pedestrians, and bicyclists, as well as snow removal on the shoulder. If placed at the far edge of the shoulder, the shoulder should be strong enough and wide enough for the delivery vehicle to get completely off the road. Snow removal may not always be complete to the point that the shoulder area is clear, back to the boxes. Generally, however, it has been our practice to place the boxes, in a roll curbed section, at the back of the shoulder, particularly if the purpose of the roll curb and paved shoulder is to provide a bicycle path. Traffic volume and speed are considerations that will influence the location of mailboxes in a roll curb and gutter section.

11.06

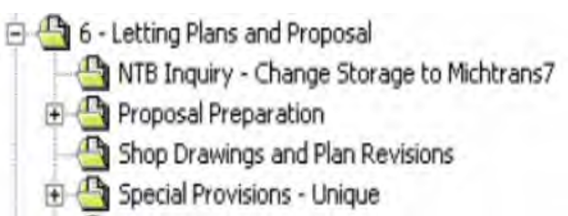
SPECIAL PROVISION APPROVAL PROCEDURE

11.06.01 (revised 10-21-2013)

Overview

All unique special provisions, except those listed as being exempt previously in Section 11.02.02A, that are part of the proposal must have approval of the Specifications Engineer. The Project Manager is required to submit all unique special provisions, even those written by consultants, to the Specifications Engineer at least 6 weeks prior to the plan completion date. Drafts of unique special provisions must be available for review and discussion at the Plan Review meeting.

The approval process is electronic and uses ProjectWise to route files, reviewers' comments and approvals. special provisions must be in Microsoft Word format and must be located in ProjectWise in the "Special Provisions - Unique" folder under the "6-Letting Plans and Proposal" folder for the project it applies to. For more details or assistance with using ProjectWise, contact appropriate support staff for your office.



An overview of the approval procedure is shown on the next page.

11.06.01 (continued)

The Specifications Engineer will return special provisions not meeting the defined voice, outline and format. Returned special provisions will be sent to the Project Manager for revisions. These documents will need to be resubmitted before the review and approval process can begin. See Section 11.02.05 for how to rename a special provision file name when it is resubmitted.

Project Managers are encouraged to use special provisions available on the Previously Approved Special Provisions web page whenever possible. If any changes are made to the approved document, it must be saved with a new filename. When submitting a revised (previously approved) special provision the track changes features of Microsoft Word must be used to delineate the changes made to the original document. This will substantially expedite the approval process.

If there are special circumstances such as tight project deadlines, or related special provisions that should be reviewed together, provide this information as a comment within the Word document when submitting the documents for review. Be sure to include the name of the individual that has provided preliminary reviews if it is appropriate to have this person assigned to review the final special provision.

Unique special provisions must be approved prior to advertisement. When a project is submitted to the Specifications and Estimates Unit for advertisement with unapproved unique special provisions, the Project Manager must complete Form 2908 Special Provision - Exception Risk Analysis, including approval by the appropriate region engineer. Although minimal use is encouraged, this form does allow for exceptions for multiple unique special provisions.

14.06

PROJECT ASSIGNMENT

MDOT projects that are ready to be designed are sent to the Engineer of Road Design, who determines whether the project is to be designed by Lansing Road Design, by a Region/TSC design unit or by a consultant. The project is then assigned and authority transmitted through MPINS to the appropriate Design Unit.

The Design Unit should check the Design Division correspondence files for any pertinent documents that may impact the design of the project. Also, the Design Unit should check to see that all information in both MPINS and MFOS is complete and correct on the electronic data screens for the project.

14.07 (revised 10-21-2013)

PROJECT NUMBERS

A project identification system is used to identify projects. A typical project identification would be: NH50022-05675C.

Funding Identity: "NH" Identifies the funding category to which the project is being charged. A list of funds can be found in Appendix C - Funding Codes - at the end of this chapter.

Control Section: "50022" The first two digits identify the county (50-Macomb) and, in conjunction with the last three digits, define a specific section of trunkline, as shown in the Control Section Atlas-Report No. 42.

Job Number: "05675" A number assigned sequentially by MFOS. The digits in the number have no significance.

Phase: A phase letter, or lack of one (blank), identifies the stage of the project development process.

Additional information

1. A job number cannot be charged against until MFOS indicates the "C" phase has been authorized with a chargeable account number.

2. Time spent developing ROW plans is charged against the "B" phase.

3. FHWA has agreed that the "C" phase can be charged against up to one month after the letting date.

4. Charges occurring after the Pre-Construction Meeting should be made against the "A" phase.

The proper use of phases is outlined in the following table.

14.07 (continued)

PROJECT NUMBERS

Phase Letter	Phase Name	Description	Examples / Notes
Blank	Early Preliminary Engineering	Work related to environmental clearance and classification of the project. Or Work related to study type projects. Or Work related to the design survey of the project. Or Work related to the scoping of the project. Or Work related to the operation of a transportation system component. Or Work that does not readily fit other phase definitions.	Note: design survey work can also be included in the C or D Phase. Traffic Operations Center (TOC) operations or maintenance.
A	Construction	Work related to the physical building of transportation system component.	
B	Real Estate	Work related to the appraisal and acquisition of right-of-way necessary to construct a project, including planning and condemnation activities, and the relocation of displaced persons and personal property. Or Work related to the demolition of or preparation of property to construct the project.	
C	Road Preliminary Design	Work related to the construction design of the road (non-structure) portion of the project.	
D	Structure Preliminary Design	Work related to the construction design of the structure portion of the project.	Note: MPINS requires a structure number.
Z	Utility – Reimbursable Relocations	Work related to the project's reimbursable utility relocations.	

14.58 (revised 10-21-2013)

APPROVAL OF SPECIAL PROVISIONS

In order to clarify terminology surrounding this subject, the following definitions are provided:

1. Standard Specifications.- The book of specifications approved for general application and repetitive use.

2. Supplemental Specifications.- Detailed specifications that add to or supersede the Standard Specifications.

3. Special Provisions.- Revisions or additions to the Standard and Supplemental Specifications applicable to an individual project.

4. Frequently Used Special Provisions.- An approved special provision with stable requirements applicable to a number of projects used on a regular basis.

5. Addendum - a change, addition and/or deletion to the contract documents occurring after a project is advertised but before the letting date.

Occasionally, information in the plan/proposal package may differ or conflict. To help in resolving such conflicts, the following order of preference has been established per the 2012 Standard Specifications for Construction:

1. All proposal material except those listed in subsections 104.06B through 104.06F
2. Special Provisions
3. Supplemental Specifications
4. Project Plans and Drawings
5. Standard Plans
6. Standard Specifications

14.58 (continued)

All unique special provisions that are part of the proposal must have the approval of the Design Division prior to contract printing and advertising. When a project is submitted to the Specifications and Estimates Unit for advertisement with unapproved unique special provisions, the Project Manager must complete Form 2908 Special Provision - Exception Risk Analysis, including approval by the appropriate region engineer. Although minimal use is encouraged, this form does allow for exceptions for multiple unique special provisions. These do not include the Frequently Used Special Provisions, which are reviewed and approved before they are placed on the list. The Project Manager should submit any unique special provisions to the Specifications Engineer in the Design Division as soon as possible for their review and approval (at least 30 days prior to the plan completion date). Submittals ***must*** be submitted electronically in MSWord format. Consultant Special Provisions will follow the same format and submittal procedure and will be the responsibility of the Consultant Project Manager. Drafts of these should be available for review and discussion at THE Plan Review meeting.

Project Managers are encouraged to use previously approved Special Provisions whenever possible. To review an index of available approved Special Provisions, see the Previously Approved Special Provisions page on the MDOT Web site. If any changes are made to the approved document, it must be saved with another filename. When submitting a revised (previously approved) Special Provision, the redline and strikeout features under MSWord should be used to delineate the changes made to the original document. This will substantially expedite the approval process.

For additional information regarding Special Provisions including a sample format see Chapter 11 (Specifications and Estimates) of the Road Design Manual.