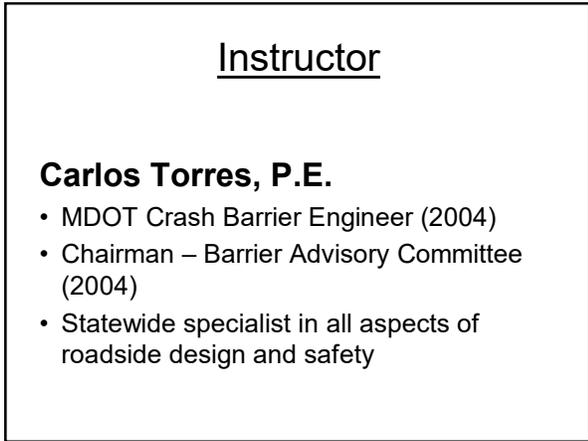
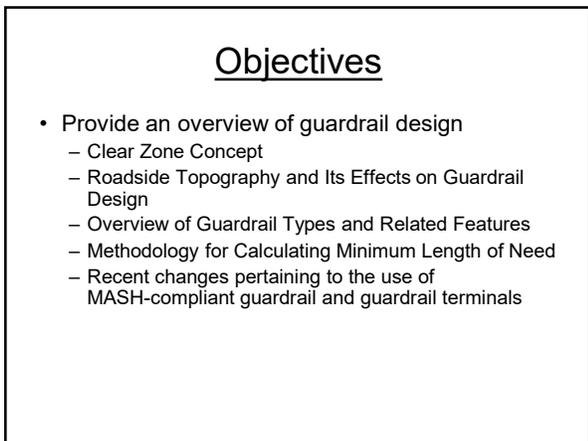


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2



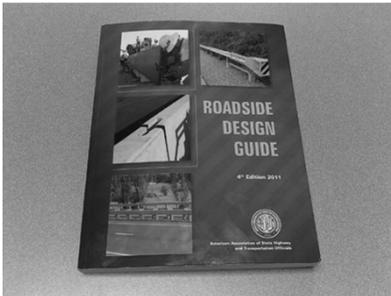
3

Objectives

- Provide an overview of guardrail design
 - Guidelines and Standards Related to Guardrail Design
 - Michigan Road Design Manual – Chapter 7
<http://mdotcf.state.mi.us/public/design/englishroadmanual/>
 - MDOT Standard Plans and Special Details
<http://mdotcf.state.mi.us/public/design/englishstandardsplans/>
 - 2011 AASHTO Roadside Design Guide
 - Available for purchase through AASHTO website

4

4th Edition, 2011 AASHTO Roadside Design Guide



5

Objectives

- Solve example problems
 - Type 2M Guardrail Approach Terminals
 - Type MGS-8 Guardrail
 - M Series Guardrail Bridge Anchorages
 - MDOT Guardrail Worksheet

6

What is MASH?

- MASH stands for Manual for Assessing Safety Hardware
 - AASHTO Publication
- *MASH is the current standard for establishing the crash worthiness of roadside safety features*

7

History of Crash Testing Standards

- 1962: HRB 482
- 1971: NCHRP 115
- 1972: NCHRP 118
- 1974: NCHRP 153
- 1978: TRC 191
- 1981: NCHRP 230
- 1993: NCHRP 350
- 2009: MASH 2009 (MASH-09)
- 2016: MASH 2016 (MASH-16)

8

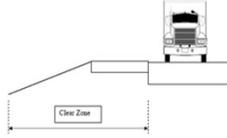
Roadside Topography



9

Clear Zone Concept

- An area available for use by an errant vehicle
- This area should be free of hazards
- If hazards exist within this area, appropriate action should be taken



10

Clear Zone Concept

- In the early 1970s, most state agencies used 30 feet as the clear zone distance
 - However, a 30-foot clear zone is not adequate for certain applications
- In the late 1970s, AASHTO developed a clear zone table, taking into consideration:
 - Design Speed
 - Traffic Volume (ADT)
 - Roadside Geometry

11

MDOT Clear Zone Table Section 7.01.11.C – Michigan Road Design Manual

DESIGN SPEED	DESIGN ADT	FALL SLOPES			CUT SLOPES		
		1:6 TO 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	16-20	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	16-20	20-22
	1500-6000	28-32*	34-42*	**	16-20	22-24	26-28
	over 6000	30-34*	36-46*	**	22-24	26-30	28-30

* Where 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 projects 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 unsheltered, traversable 1:3 slopes, fixed objects should not be present in the vicinity of the toe of these slopes.

12

Horizontal Curve Adjustments

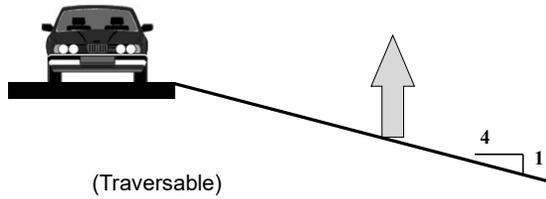
CURVE CORRECTION FACTORS (K_{cZ})

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						

$$CZ_{\text{corr}} = CZ + \Delta CZ = K_{cZ} \times CZ$$

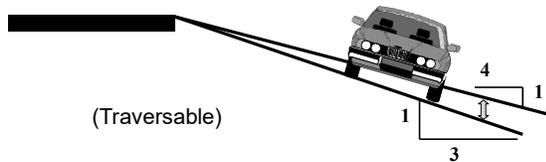
16

Recoverable

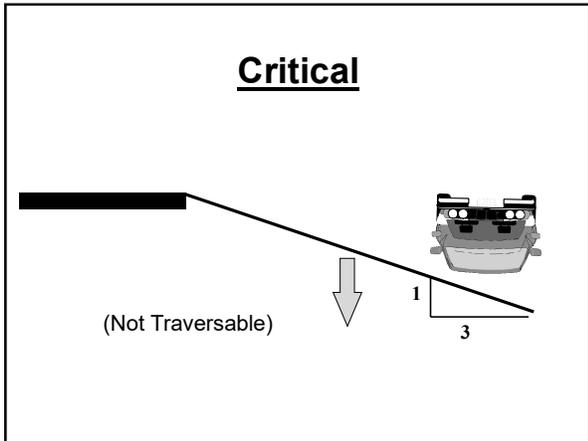


17

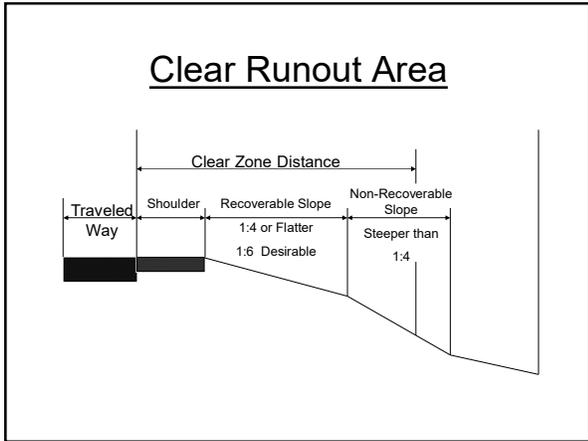
Non-Recoverable



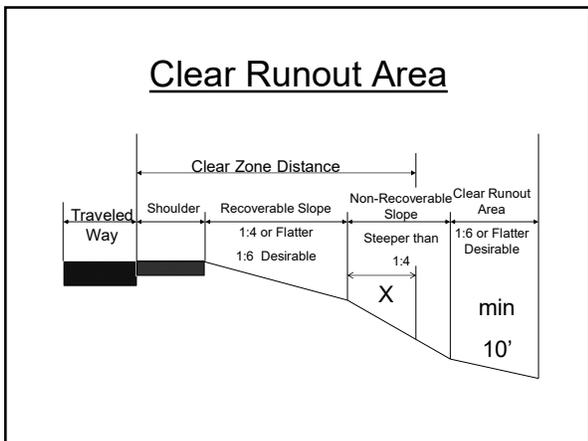
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19

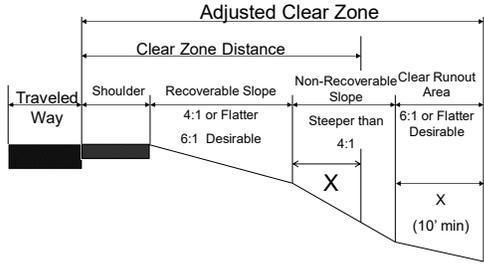


20



21

Adjusted Clear Zone



22

Clear Zone for Auxiliary Lanes

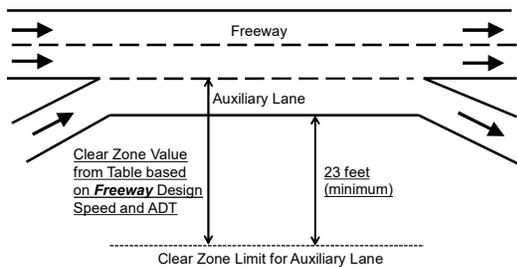
MDOT Method

Section 7.01.11 of the Michigan Road Design Manual

- Obtain clear zone value from the clear zone table based on design speed and traffic volume (ADT) of adjacent through lanes
- Resulting clear zone distance:
 - 1) Should be measured from the outer edge of the *through lane*, and;
 - 2) Should not be less than 23 feet from the outer edge of the auxiliary lane.

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Clear Zone for Auxiliary Lane MDOT Method



24

Clear Zone for Freeway Ramps

MDOT Method

Preferred:

Clear Zone Based on Speed, Volume, and Horizontal Curvature of Ramp at Selected Point

- Engineering Judgment must be used

Acceptable Alternative:

May also use Clear Zone of 30 feet if:

- Traffic Volume and/or Speed at Selected Point are unknown or not well established, or
- Previous satisfactory experience with similar designs

25

Transverse Slopes

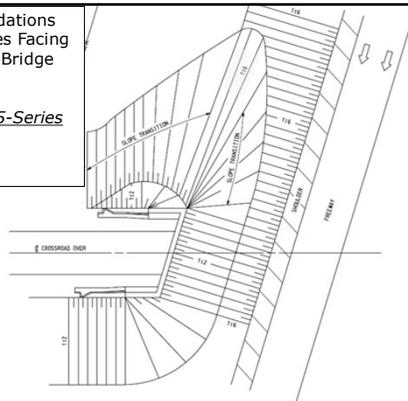
- 1:10 or flatter desirable
- 1:6 or flatter for high-speed roadways, especially within clear zone
- May be considered a hazard under certain conditions
 - steep transverse slopes



26

Grading Recommendations for Transverse Slopes Facing Oncoming Traffic at Bridge Approach Berms

Standard Plan R-105-Series

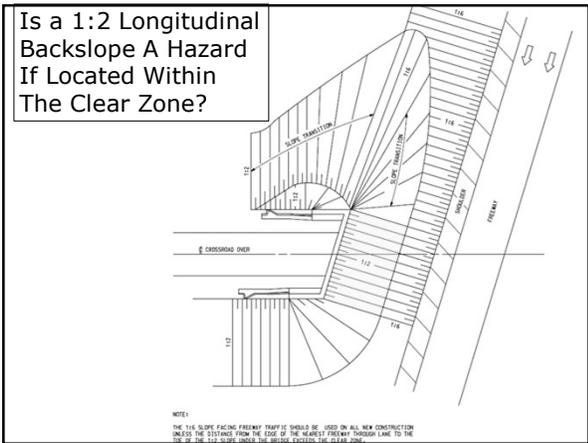


NOTE:
THE 1:16 SLOPE FACING TRAFFIC SHOULD BE USED ON ALL NEW CONSTRUCTION UNLESS THE DISTANCE FROM THE EDGE OF THE ROADWAY TO THE THROUGH LANE TO THE

27



28



29

A 1:2 backslope generally is not a hazard if:

- Relatively Smooth, and;
- Obstacle Free, and;
- Foreslope between roadway and toe of backslope is traversable (1:3 or flatter)

30



31

**Shielding Bodies of Water
RDM - 7.01.31**

- Permanent water > 2' in depth usually require shielding if within the CZ
- May be necessary to shield for bodies of water outside the CZ if there is potential for entry

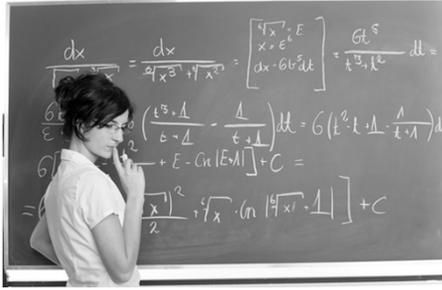
32

**Bridge Columns and Foundations
in 70' Medians**

- At one time these were considered outside the CZ
- Shielding columns and foundation new construction/ reconstruction should be according to Standard Plan R-56 Series
- Standard Plan R-56 also covers medians 36' – 70'

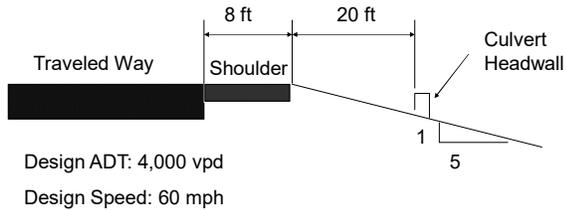
33

Clear Zone Examples



34

Clear Zone Example #1



35

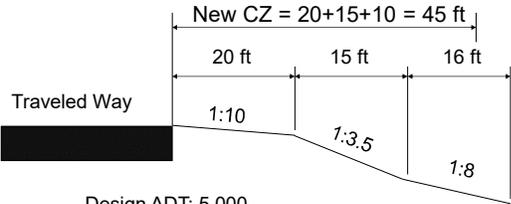
CLEAR ZONE DISTANCES (IN FEET FROM EDGE OF DRIVING LANE)						
DESIGN SPEED	DESIGN ADT	FILL SLOPES			CUT SLOPES	
		1:8 OR FLATTER	1:5 TO 1:4	1:3	1:4 TO 1:5	1:6 OR FLATTER
40 mph or Less	under 750	7-10	7-10	**	7-10	7-10
	750-1500	10-12	12-14	**	10-12	12-14
	1500-6000	12-14	14-16	**	12-14	14-16
	over 6000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

* 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.

36

Clear Zone Example #2

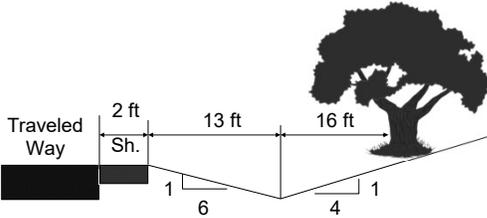


Design ADT: 5,000

Design Speed: 60 mph

43

Clear Zone Example #3



Design ADT: 1,400 vpd

Design Speed: 60 mph

44

DESIGN SPEED	DESIGN ADT	CLEAR ZONE DISTANCES (IN FEET FROM EDGE OF DRIVING LANE)					
		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*	38-48*	**	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.

45

Clear Zone Example #3

CZ = 20 - 24 ft

Traveled Way: 2 ft
 Sh.: 13 ft
 Tree: 16 ft

1:6 1:4

• 2011 AASHTO RDG Method (e.g., Example 3-F)

➤ Use larger of the two clear zones

46

Clear Zone Example #4

Where should the clear zone for EB traffic be measured from?

Fixed Object

CZ₁? CZ₂?

EOP

47

Clear Zone Example #4

Where should the clear zone for EB traffic be measured from?

Normal Practice

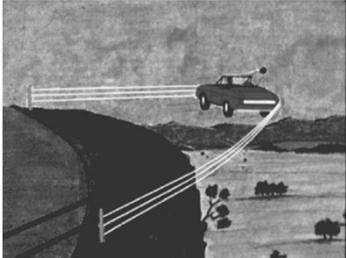
Fixed Object

CZ₁ CZ₂

EOP

48

Roadside Barriers



49

Design Options in Order of Preference

- Remove Obstacle
- Relocate Obstacle
- Reduce Impact Severity
- Shield Obstacle
- Delineate Obstacle



50

Barrier Types

- Roadside Barriers
- Median Barriers
- Bridge Railings



51

Barrier Classifications

<i>TYPE</i>		<i>DEFLECTION</i>
Flexible		Over 5 Feet
Semi-Rigid		2 - 5 Feet
Rigid		0 - 1 Foot

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MDOT

Semi-Rigid Systems (Guardrail)

NCHRP 350 or Older Guardrail Systems

- Type A (Standard Plan R-60 Series)
- Type B (Standard Plan R-60 Series)
- Type BD (Standard Plan R-60 Series)
- Type C (old Standard Plan III-60 E)
- Type CD (old Standard Plan III-60 E)
- Type T (Standard Plan R-60 Series)
- Type TD (Standard Plan R-60 Series)

MASH-Compliant Guardrail Systems

- Type MGS-8 (Standard Plan R-60 Series)
- Type MGS-8D (Standard Plan R-60 Series)

53

Type A Guardrail

Key Features

- No offset blocks
- 12'-6" post spacing (typical)
- Typical top rail height is 28 inches
- Current use:
 - Cul-de-sacs
 - Parking lots
 - Locations not exposed to through traffic



54

Type B Guardrail

Key Features

- W-beam guardrail with 8" offset blocks
 - Offset blocks are made of wood or plastic
- 6'-3" post spacing (typical)
- Typical top rail height is 28 inches
- NOT PERMITTED FOR CONSTRUCTING NEW GUARDRAIL RUNS
- Current use:
 - Repairing existing runs of Type B guardrail



55

Type BD Guardrail

Key Features

- Double-sided Type B guardrail
- W-beam guardrail and offset blocks on both sides
- Same post spacing and guardrail height as Type B
- NOT PERMITTED FOR CONSTRUCTING NEW GUARDRAIL RUNS
- Current use:
 - Repairing existing runs of Type BD guardrail



56

Type C Guardrail

Key Features

- Consists of two w-beams
- Upper beam has offset blocks
- Lower beam (rub rail) has no offset blocks
- 6'-3" post spacing (typical)
- Typical top rail height is 32 inches
- Current use:
 - Repairing existing runs of Type C guardrail



NOT PERMITTED FOR CONSTRUCTING NEW GUARDRAIL RUNS

57

Type CD Guardrail

Key Features

- Double-sided Type C guardrail
- Same post spacing and guardrail height as Type C
- Current use:
 - Repairing existing runs of Type CD guardrail



NOT PERMITTED FOR
CONSTRUCTING NEW
GUARDRAIL RUNS

58

Type T Guardrail

Key Features

- Three-beam guardrail with 8" offset blocks
- 6'-3" post spacing (typical)
- Typical top rail height is 34 inches
- NOT PERMITTED FOR CONSTRUCTING NEW GUARDRAIL RUNS
- Current use:
 - Repairing existing runs of Type T guardrail



59

Type TD Guardrail

Key Features

- Double-sided Type T guardrail
- Same post spacing and guardrail height as Type T
- NOT PERMITTED FOR CONSTRUCTING NEW GUARDRAIL RUNS
- Current use:
 - Repairing existing runs of Type TD guardrail



60

Type MGS-8 Guardrail

Key Features

- W-beam guardrail with 8" offset blocks
 - Offset blocks are made of wood or plastic
- 6'-3" post spacing (typical)
- Typical top rail height is 31 inches
- Beam element splice located at midspan
- MASH, TL-3 Compliant
- Current use:
 - Basic type for all roadways; free access roads, limited access roads, and freeways



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Type MGS-8

31" Tall W-Beam Guardrail with 8" Offset Blocks (MGS-8)



Source: TTI

62



Source: TTI

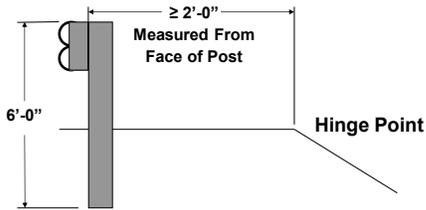
63

**Type MGS-8 Guardrail
US-23 Flex Route Project, University Region**



64

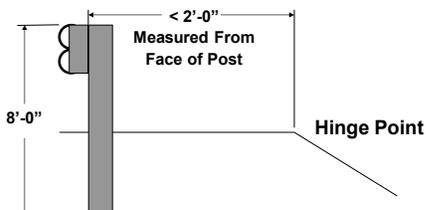
**Type B
Post Length Requirements**



Specified in Standard Plan R-60-Series

65

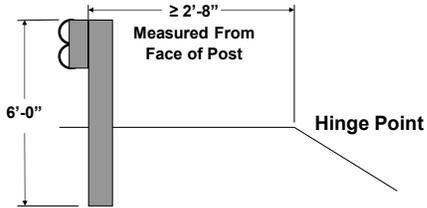
**Type B
Post Length Requirements**



Specified in Standard Plan R-60-Series

66

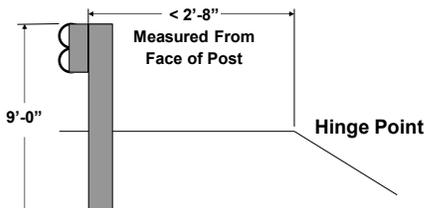
Type MGS-8 Post Length Requirements



Specified in Standard Plan R-60-Series

67

Type MGS-8 Post Length Requirements



Specified in Standard Plan R-60-Series

68

General Plan Note Commonly Used by Designers

GUARDRAIL POST LENGTH

When the plans specify guardrail to be placed at the shoulder hinge point, rather than as specified on Standard Plan R-60 series, 8' (type B or T) or 9' (type MGS-8) posts shall be provided, with the additional length embedded for added stability. The additional post length will not be paid for separately but shall be included in the appropriate guardrail pay item.

69

Type MGS-8D Guardrail

Key Features

- Double-sided Type MGS-8 guardrail
- Same post spacing and guardrail height as Type MGS-8
- Beam element splice located at midspan
- MASH, TL-3 Compliant
- Current use:
 - Basic median guardrail type for all roadways; free access roads, limited access roads, and freeways



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Type MGS-8 Guardrail Details & Revisions

- MDOT Standard Plan (Special Detail) R-60-J
 - Type MGS-8 & MGS-8D Details
 - Transition Details from Type MGS-8 to Other Guardrail Types
 - Type MGS-8/8D to Type B/BBD
 - Type MGS-8/8D to Type T/TD
 - Transition Details from Type MGS-8 to Guardrail Anchorages
 - Transition Details from Type MGS-8 to Type 1B and Type 2B Guardrail Approach Terminals
- Chapter 7 – Road Design Manual
 - Revisions Pertaining to Type MGS-8 Guardrail
 - Revised Guardrail Worksheet

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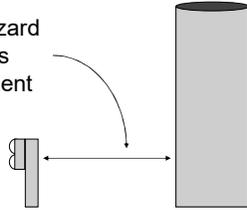
Barrier Location

Place Barrier
As Far From
Traveled Way
As Possible

72

Barrier Location

Barrier to Hazard
Distance Is
Critical Element



73

MDOT Guardrail Deflection Table

- Guardrail deflections are typical values
- Deflection may vary:
 - Soil Type
 - Thawed/Frozen Ground
 - Length of installation
 - Impact Characteristics
- Treat deflections from table as minimums
 - If possible, consider adding factor of safety (e.g., 1') to guardrail deflections listed in table

Guardrail	Post Spacing	Minimum Design Offset*
Type T	1'-6 1/2"	1'-2"
Type T	3'-1 1/2"	1'-8"
Type T	6'-3"	2'-0"
Type B	1'-6 1/2"	1'-0"
Type B	3'-1 1/2"	2'-0"
Type B	6'-3"	3'-0"
Type MGS-B	1'-6 1/2"	2'-0"
Type MGS-B	3'-1 1/2"	2'-11"
Type MGS-B	6'-3"	3'-8"
Type MGS-B Adjacent to Curb	6'-3"	4'-1"
Type MGS-B Near Shoulder Edge Point**	6'-3"	4'-1"

* An additional 12" or more is desirable where feasible
 ** Less than 2'-0" from the shoulder edge point to the face of guardrail post

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Terrain Effects



- Curbs
- Slopes

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Curbs and Guardrail

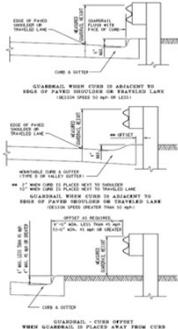


MUST Take Certain Precautions!!

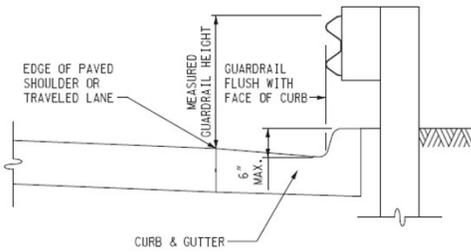
76

MDOT Guidelines Curb & Guardrail

- Section 7.01.34 of the RDM discusses curb & guardrail
- Use only Type D or valley gutter when design speed >50 mph
- Follow offset and max curb height recommendations when guardrail is placed away from curb

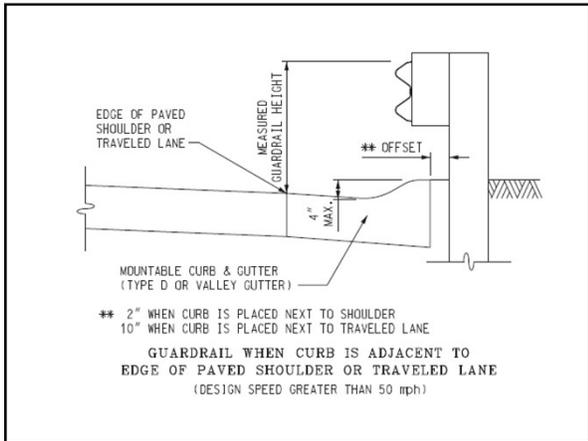


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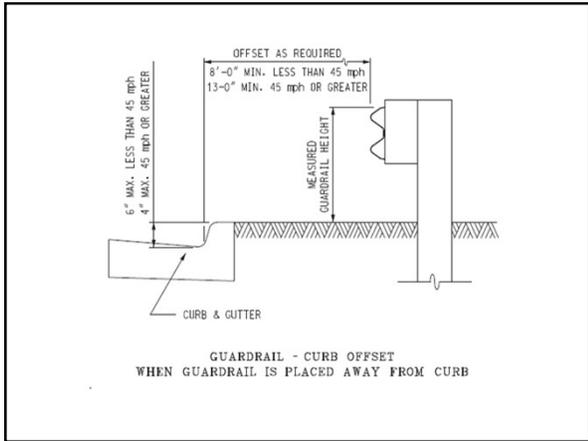


**GUARDRAIL WHEN CURB IS ADJACENT TO
EDGE OF PAVED SHOULDER OR TRAVELED LANE
(DESIGN SPEED 50 mph OR LESS)**

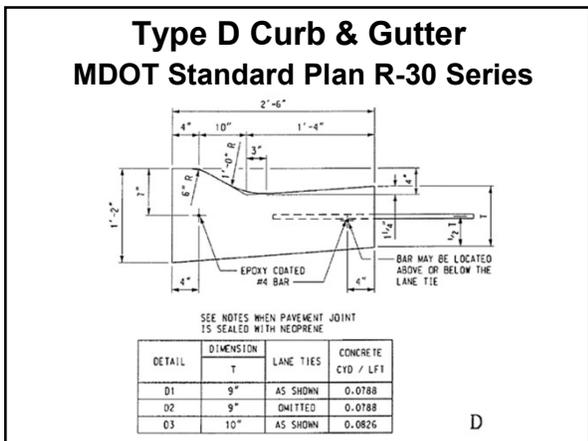
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79

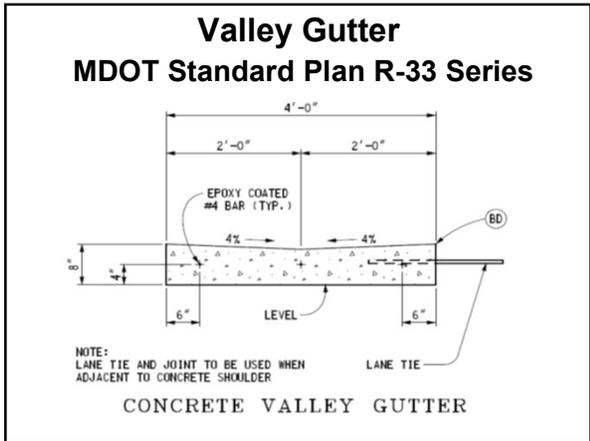


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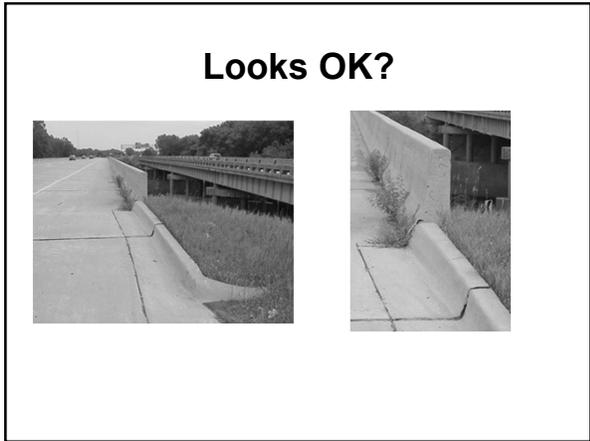


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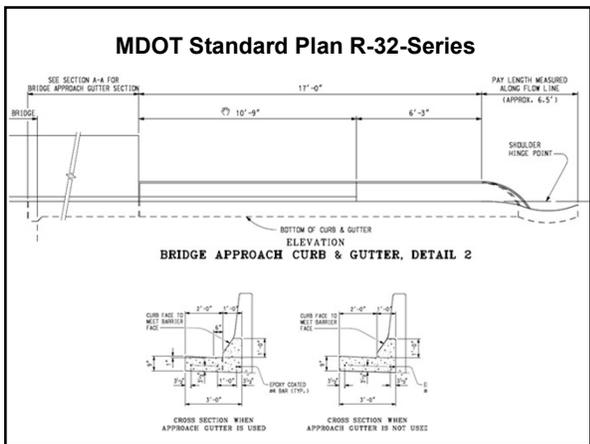




82



83



84

Looks OK?

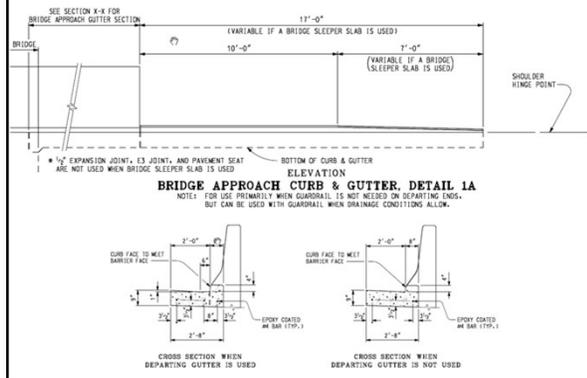


No !!

Use Detail 1A Bridge Approach Curb & Gutter (Std. Plan R-32 Series) when there is no guardrail

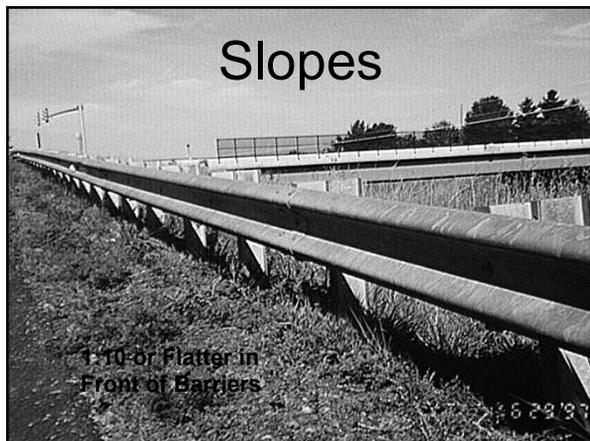
85

MDOT Standard Plan R-32-Series



86

Slopes



87

Guardrail on Slopes

- Optimum performance on 1:10 slopes or flatter
- May be installed on slopes as steep as 1:6 under certain (site-specific) conditions:
 - Consult with the Geometric Design Unit (MDOT - Design Division)

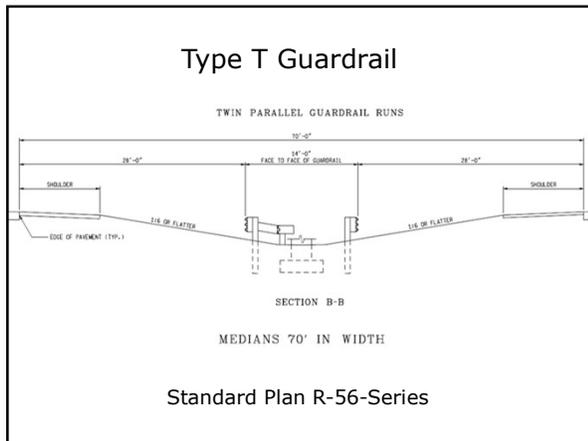
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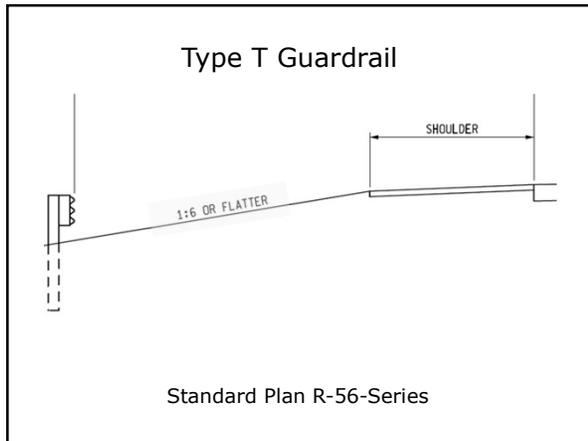
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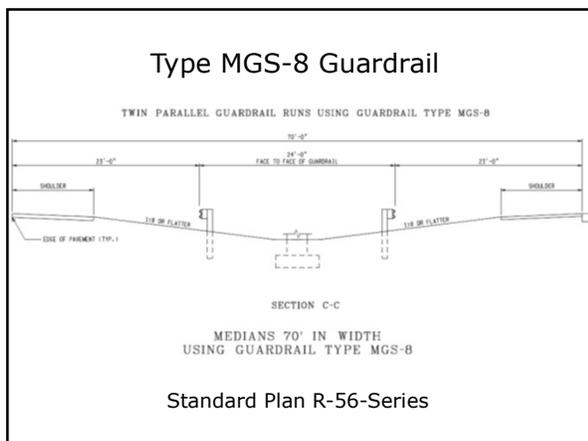
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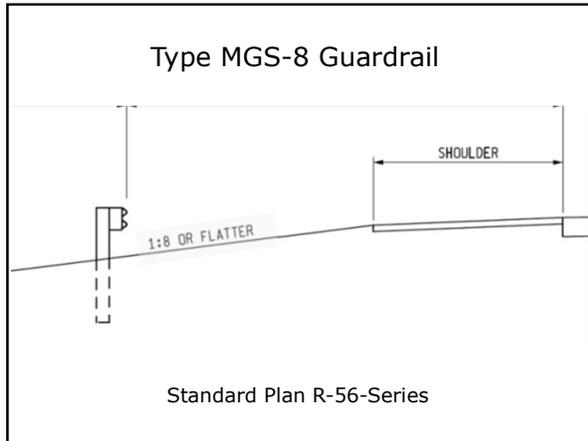
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92



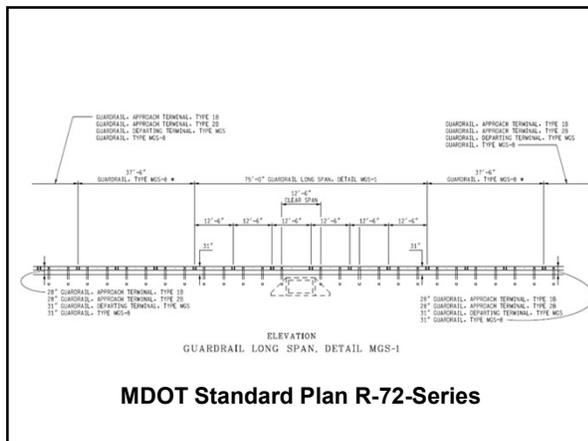
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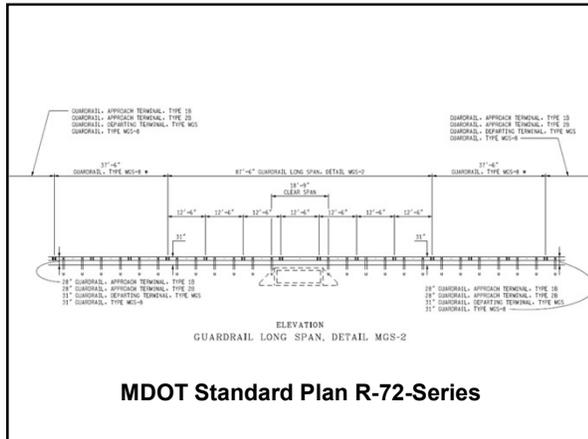
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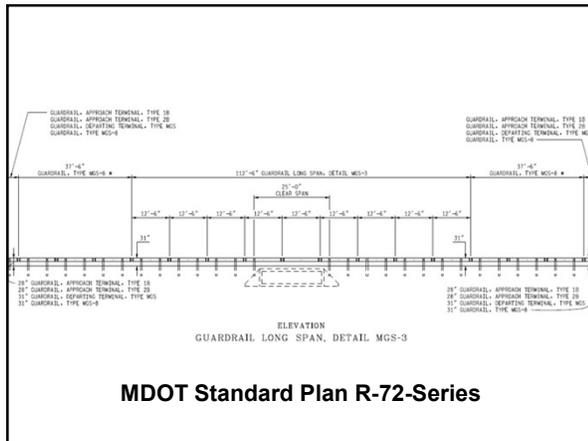
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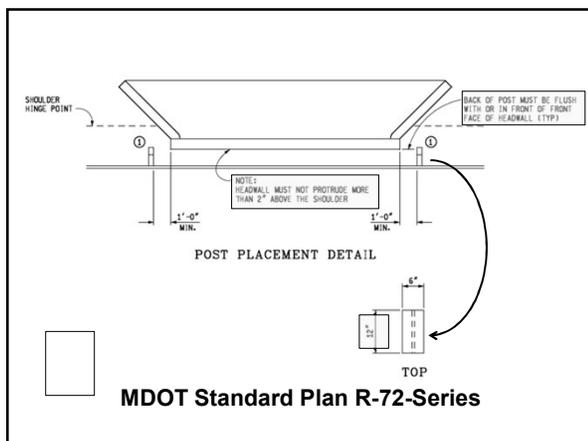
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97



98

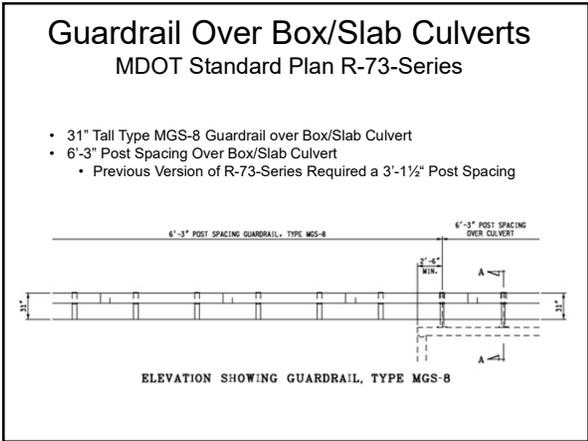


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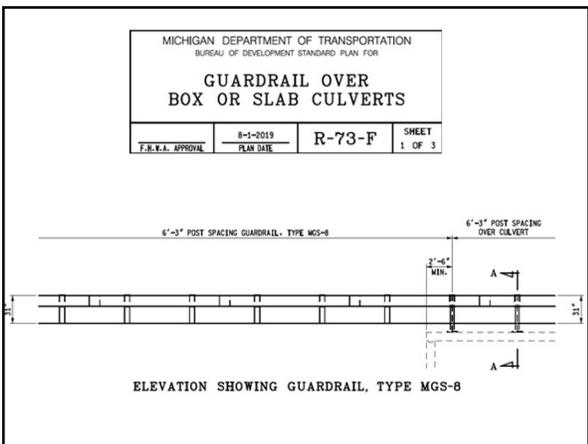




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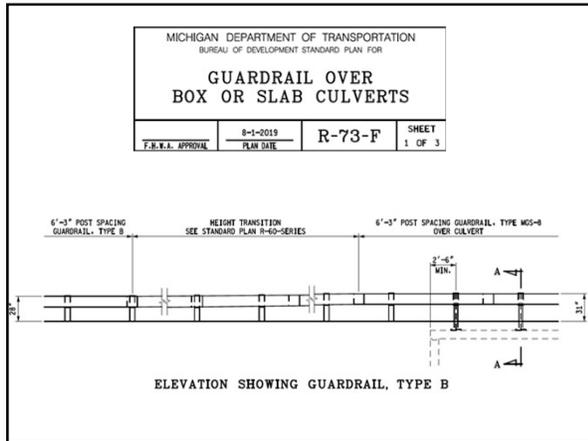


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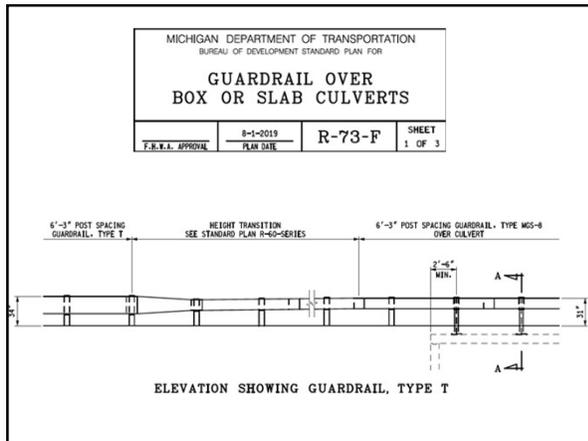


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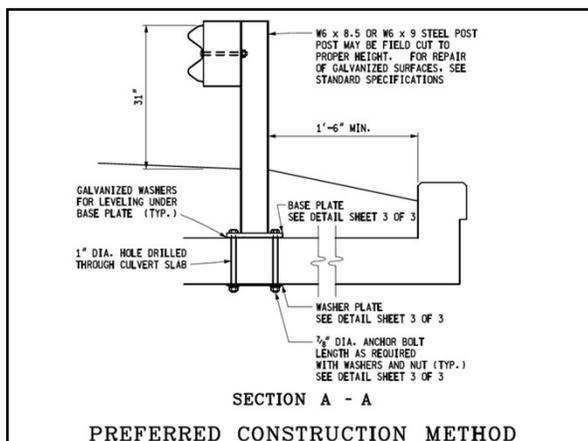




106



107



108



Barrier End Treatments



112

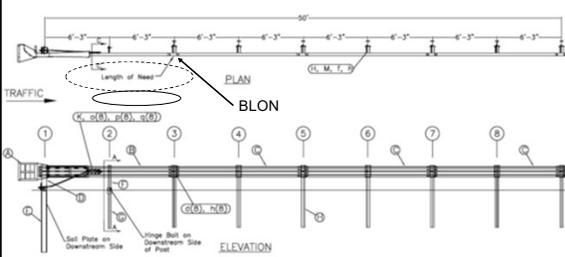
Guardrail Terminals

- Gating
- Non-Gating



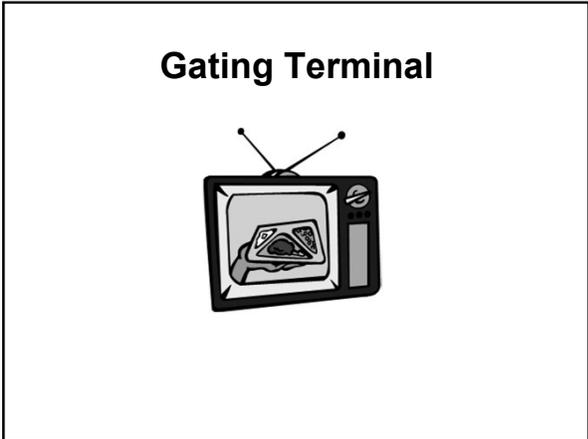
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Example of Gating Guardrail Terminals

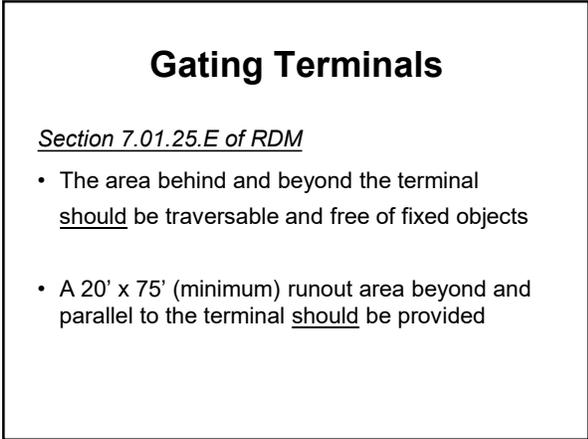


Beginning Length of Need Point (BLON)
Point where terminal is capable of redirecting a vehicle

114



115



116



117

MDOT MASH Compliant Guardrail Approach Terminals

Type 2M (Tangent) Approach Terminals

- Soft-Stop
- MSKT
- MAX-Tension

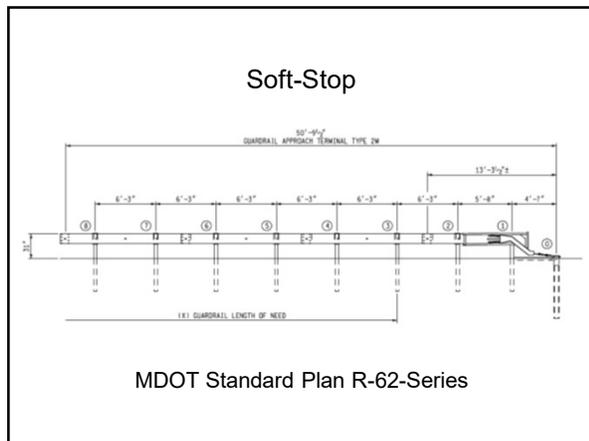
- Beginning Length of Need (BLON) varies

USED FOR MAJORITY OF NEW SINGLE-SIDED GUARDRAIL
APPROACH TERMINAL INSTALLATIONS

118



119



120

MASH Compliant Guardrail Terminals



Source: Road Systems

MSKT (Road Systems, Inc.)

121

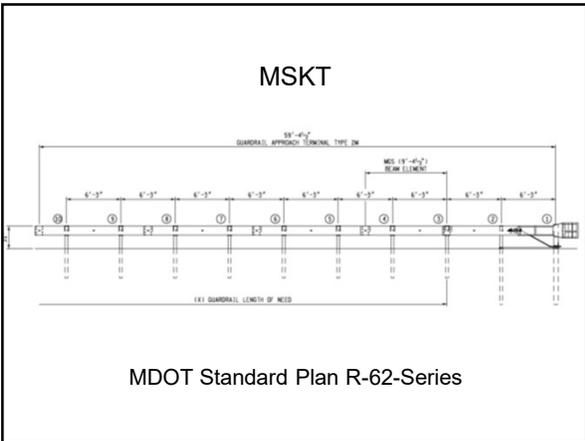


SKT
NCHRP 350 Compliant

MSKT
MASH Compliant

Source: Road Systems

122

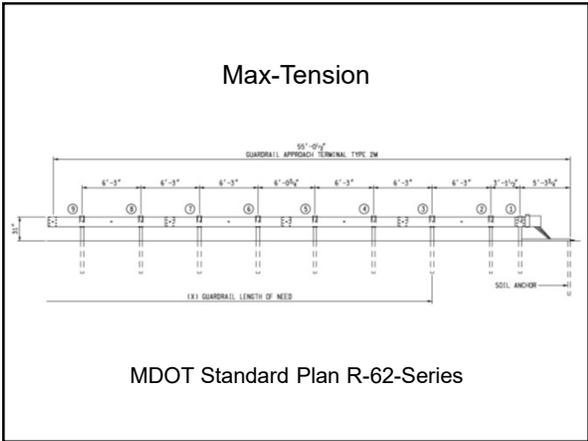


MDOT Standard Plan R-62-Series

123



124



125



126

Max-Tension Crash Test Pickup Truck (MASH, TL-3)



127

MDOT NCHRP 350 Compliant Guardrail Approach Terminals

Type 1B or 1T (Flared) Approach Terminals

- SRT
- FLEAT

- Beginning Length of Need (BLON) starts 12'-6" from nose

USED VERY RARELY IN NEW GUARDRAIL INSTALLATIONS !
CONSULT WITH GEOMETRIC DESIGN UNIT BEFORE USING.

128

SRT (Slotted Rail Terminal)



129

FLEAT (Flared Energy Absorbing Terminal)



130

**MDOT
NCHRP 350 Compliant
Guardrail Approach Terminals**

Type 2B or 2T (Parallel) Approach Terminals

- ET
- SKT
- X-Lite-Tangent-50

• Beginning Length of Need (BLON) starts 12'-6" from nose

NOT USED FOR NEW GUARDRAIL INSTALLATIONS !

131

ET (Extruder Terminal)



132



133



134



135

**MDOT
NCHRP 350 Compliant
Guardrail Approach Terminals**

Type 3 (Double-Sided) Approach Terminals

- CAT (Standard Plan R-63 Series)
- FLEAT-MT (Standard Plan R-63 Series)
- All Type 3 Terminals are gating
 - BLON varies – see MDOT Standard Plan R-63 Series

STILL USED FOR NEW GUARDRAIL INSTALLATIONS

136

**CAT (Crash Cushion
Attenuation Terminal)**



137

**FLEAT-MT (Median
Terminal)**



138

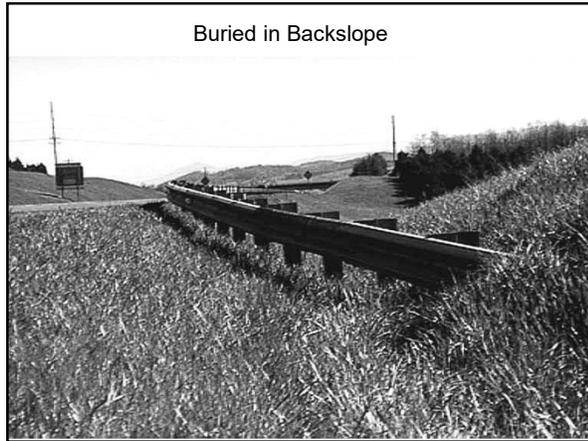
MDOT Guardrail Approach Terminals

Type 4 (Buried in Backslope)

- Non-proprietary
- Special Detail 24
- Non-gating Terminal

USED FOR NEW GUARDRAIL INSTALLATIONS

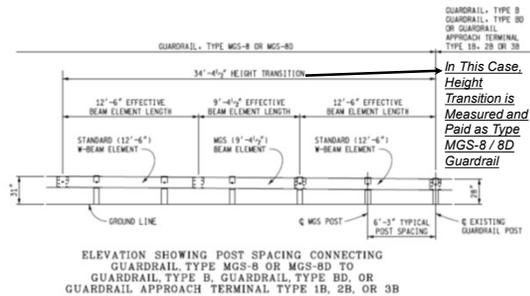
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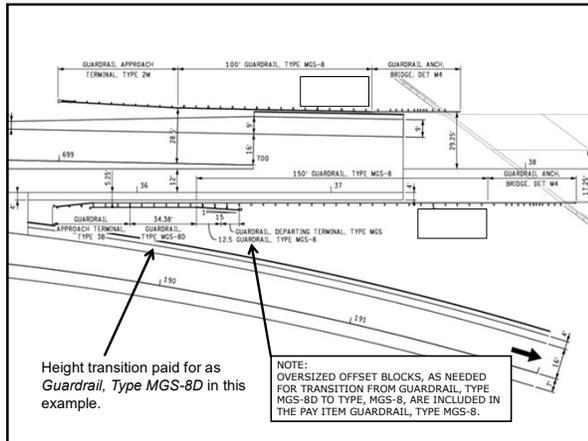
140

Transition: MGS-8/8D to Type B or Guardrail Approach Terminals 1B/3B

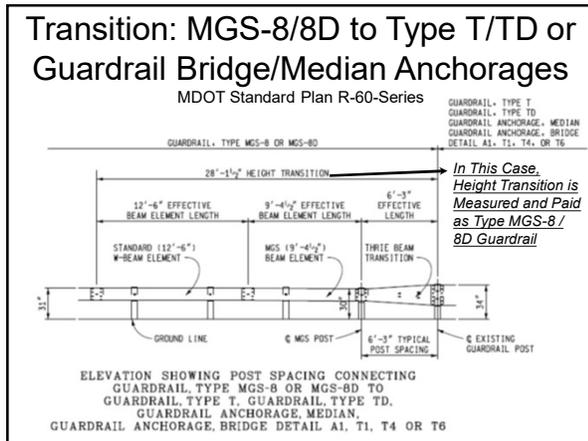
MDOT Standard Plan R-60-Series



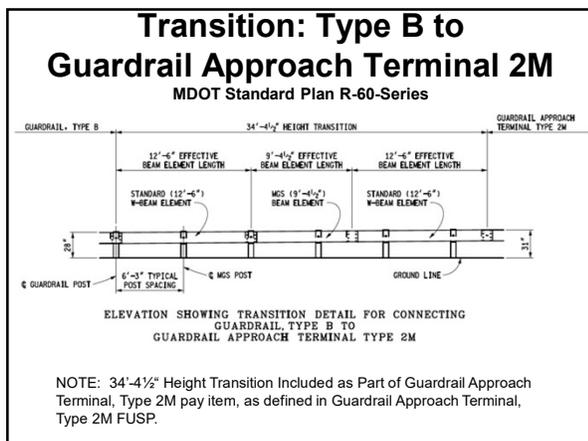
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142



143



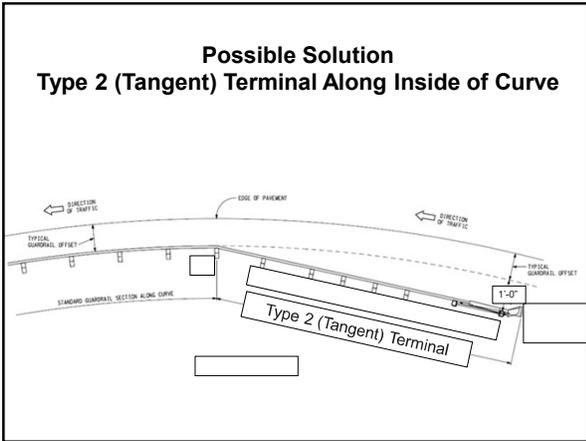
144



May be difficult to install Type 2 (tangent) approach terminal in this case

- Consult with MDOT Geometric Design Unit, Design Division

148



149

Guardrail Terminal Action Plan

- It will be necessary to obtain project-specific special details, and possibly develop a special provision, in order to use Type 1B or 1T guardrail approach terminals on a project.

150

Guardrail Terminal Action Plan

- Use the Type 2M guardrail terminal *frequently used special provision (FUSP)* and *Standard Plan R-62-Series* when specifying Type 2M guardrail approach terminals
 - Per the FUSP, manufacturers will be required to provide an electronic copy of detailed drawings, installation manuals, and maintenance manuals for each type of terminal being provided.

151

Guardrail Terminal Action Plan

- Continue using NCHRP 350 compliant, currently-approved, double sided Type 3 terminals (Standard Plan R-63-Series) until suitable MASH-compliant alternatives become available, and are approved for use by MDOT.

152

Guardrail Terminal Action Plan

- Continue using Buried-in Backslope or Type 4 terminals (Special Detail 24-Series).

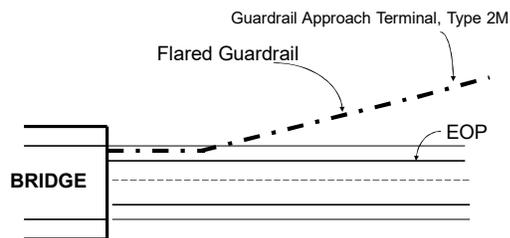
153

Guardrail Terminal Additions & Revisions

- Chapter 7 – Road Design Manual
 - Type 2M Guardrail Approach Terminals
 - Guardrail Worksheet
 - Deduction Value Revisions
- Guardrail Approach Terminal Design Advisory

154

Can a Type 2 Terminal be Attached to Flared Guardrail?



Answer: YES

155

Departing Terminals

- Detailed in MDOT Standard Plan R-66 Series

Important Note:

- Departing terminals may not be placed within approaching traffic's clear zone
 - Not designed to withstand a head-on impact
 - Comparable to blunt end

156

Departing Terminals

- Type B Departing Terminals are used for terminating Type B guardrail (i.e., W-Beam Guardrail)
- Type T Departing Terminals are used for terminating Type T guardrail (i.e., Thrie-Beam Guardrail)
- Terminal is not flared
- It has a semi-circular end shoe
- Last post does not have an offset block
- No ground strut



157

Departing Terminals

- Type MGS Departing Terminals are used for terminating Type MGS-8 guardrail
- Terminal is not flared
- It has a semi-circular end shoe
- Last post does not have an offset block
- No ground strut



158

Curved Guardrail



159

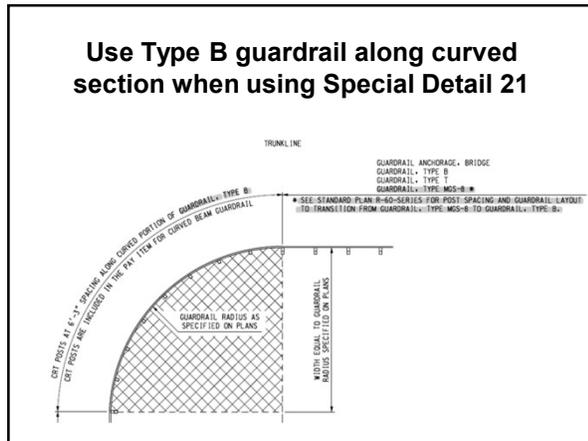
Curved Guardrail

Key Features:

- Used primarily when there is guardrail at intersections (e.g., driveways, freeway ramps, side streets, etc.).
- Guardrail can be terminated at the end of the curve with either an approach terminal or departing terminal.
- Guardrail may continue to run parallel to intersecting roadway beyond curved portion.
 - **MDOT Special Detail 21**

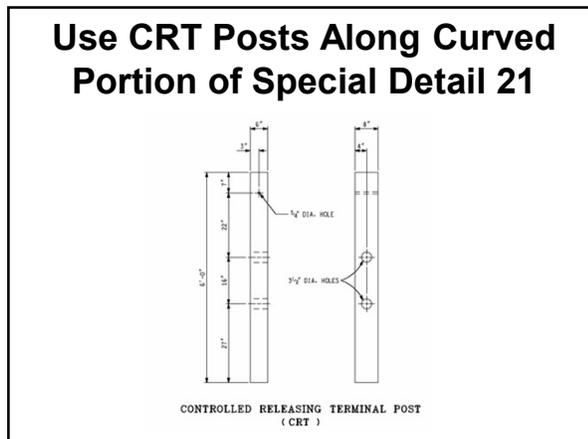
160

Use Type B guardrail along curved section when using Special Detail 21



161

Use CRT Posts Along Curved Portion of Special Detail 21



162

Curved Guardrail

NOTE:
 FOR DRIVEWAYS, IF R.O.W. ALLOWS, USE DEPARTING END TERMINAL.
 (SEE STANDARD PLAN R-66-SERIES) IF R.O.W. IS LIMITED SUCH
 THAT A TYPICAL DEPARTING END TERMINAL CANNOT BE FIT IN, DRILL
 8 HOLES IN THE CURVED BEAM GUARDRAIL TO ACCOMMODATE AN ANCHOR
 PLATE AND INSTALL A CABLE ANCHOR SIMILAR TO THAT OF THE
 DEPARTING END TERMINAL ON STANDARD PLAN R-66-SERIES. THIS
 WILL BE PAID FOR AS GUARDRAIL, DEPARTING TERMINAL.

- Always use an approach terminal or departing terminal, as appropriate, to terminate curved guardrail
- Never use a terminal end shoe by itself
 - Common mistake

163

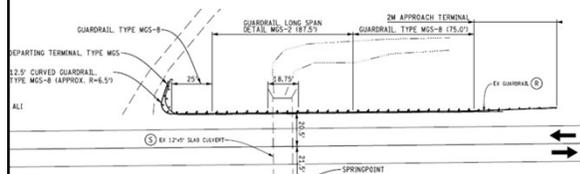
Purpose of Cable Assembly



164

Curved Guardrail

- NOTE:**
- Not all curved guardrail installations are constructed per Special Detail 21.



- In the example above, curved Type MGS-8 guardrail was correctly specified.
 •Not constructed according to Special Detail 21.

165

Grading

1:10 slope or flatter at least 2'-0" feet behind guardrail posts and tapering toward road in advance of terminal

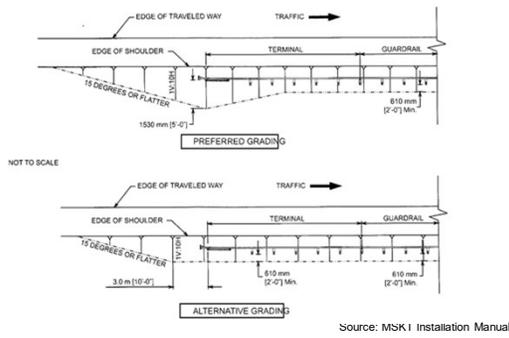


Note, this applies to ALL guardrail approach terminals

Designers must ensure grading quantities are included!

166

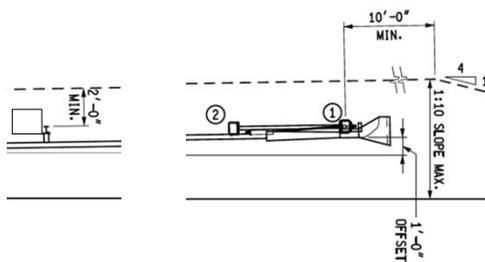
AASHTO Roadside Design Guide Terminal Grading Recommendations



167

Guardrail Approach Terminal, Type 2M Grading Requirements

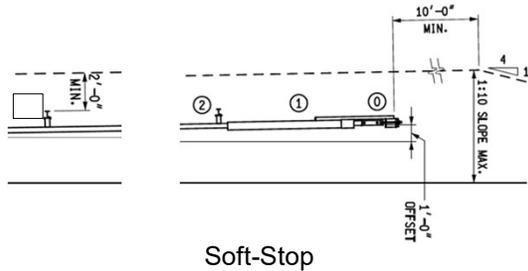
MDOT Standard Plan R-62 Series



168

Guardrail Approach Terminal, Type 2M Grading Requirements

MDOT Standard Plan R-62 Series

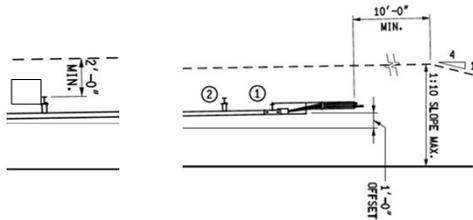


Soft-Stop

169

Guardrail Approach Terminal, Type 2M Grading Requirements

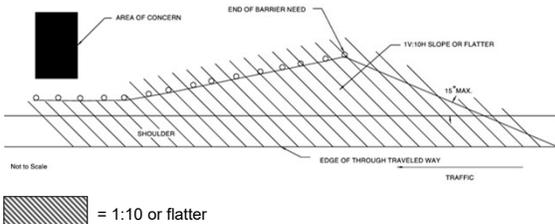
MDOT Standard Plan R-62 Series



Max-Tension

170

Preferred Grading In Vicinity of Flared Guardrail and Terminal



171

High-Profile Curb in Advance of Guardrail Approach Terminal

- Transition from high profile curb to Type D or valley gutter in advance of approach terminal
- Transition should occur prior to 1:4 grading transition



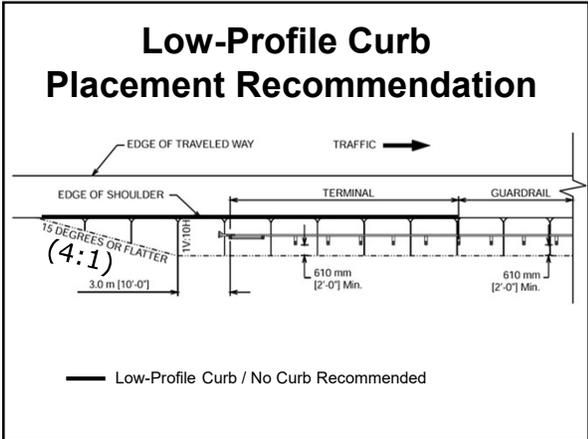
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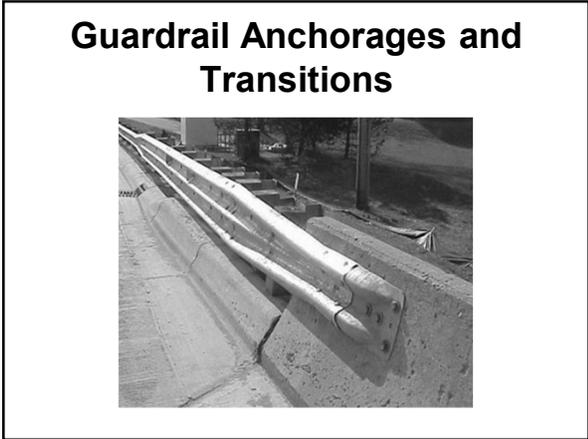
173



174



175



176

Anchorages & Transitions

- Adequate Connection
- Block Outs as Specified
- Adequate Length
- Gradually Increase Stiffness

177

MDOT Approved Guardrail Transitions

- Guardrail Anchorage
Bridge Detail M-1
- Guardrail Anchorage
Bridge Detail M-2
- Guardrail Anchorage
Bridge Detail M-3



MASH-Compliant Anchorages
Detailed in MDOT Standard Plan R-67 Series

181

MDOT Approved Guardrail Transitions

- Guardrail Anchorage
Bridge Detail M-4
- Guardrail Anchorage
Bridge Detail M-5
- Guardrail Anchorage
Bridge Detail M-6



MASH-Compliant Anchorages
Detailed in MDOT Standard Plan R-67 Series

182

MDOT Approved Guardrail Transitions

- Guardrail Anchorage
Bridge Detail M-7
- Guardrail Anchorage
Bridge Detail M-8
- Guardrail Anchorage
Bridge Detail M-9



MASH-Compliant Anchorages
Detailed in MDOT Standard Plan R-67 Series

183

MDOT Approved Guardrail Transitions

- Guardrail Anchorage Bridge Detail T-1
- Guardrail Anchorage Bridge Detail T-2
- Guardrail Anchorage Bridge Detail T-3



Detailed in MDOT Standard Plan R-67-SD

NOTES: Only Used for Connecting to Existing Safety-Shape Barriers

NCHRP 350 Compliant

184

MDOT Approved Guardrail Transitions

- Guardrail Anchorage Bridge Detail T-4
- Guardrail Anchorage Bridge Detail T-5
- Guardrail Anchorage Bridge Detail T-6



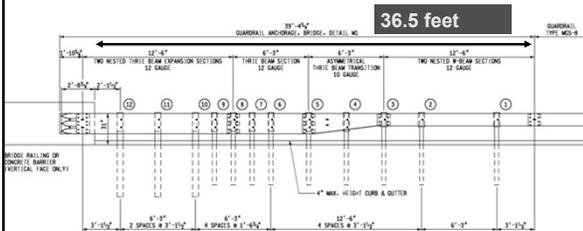
Detailed in MDOT Standard Plan R-67-SD

NOTES: Only Used for Connecting to Existing Safety-Shape Barriers

NCHRP 350 Compliant

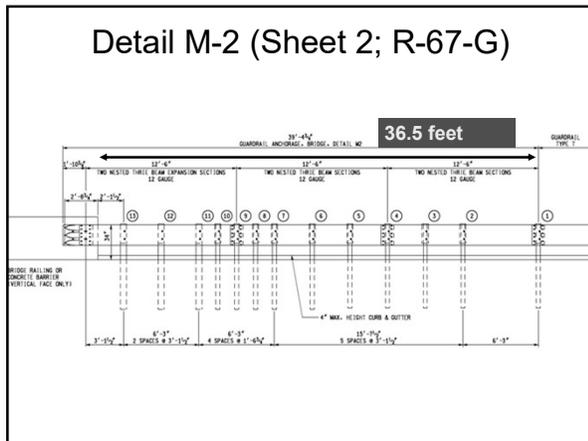
185

Detail M-1 (Sheet 1; R-67-G)



186

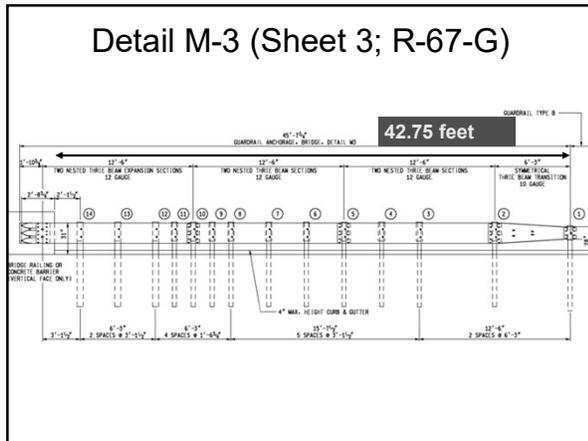
Detail M-2 (Sheet 2; R-67-G)



187



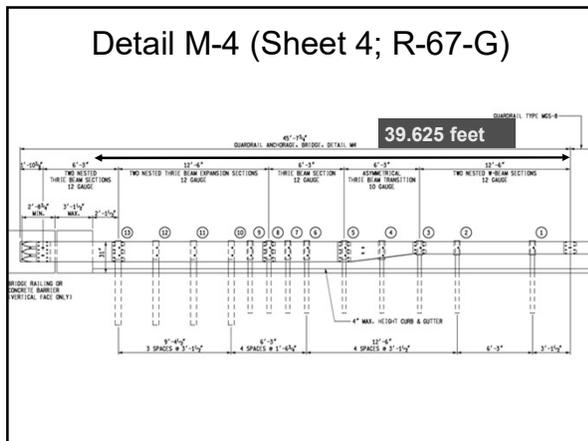
Detail M-3 (Sheet 3; R-67-G)



188



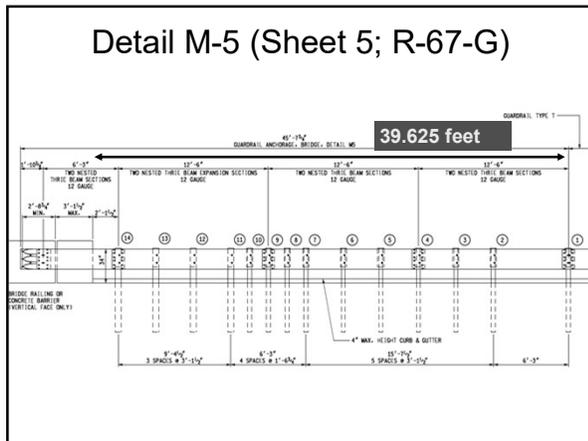
Detail M-4 (Sheet 4; R-67-G)



189



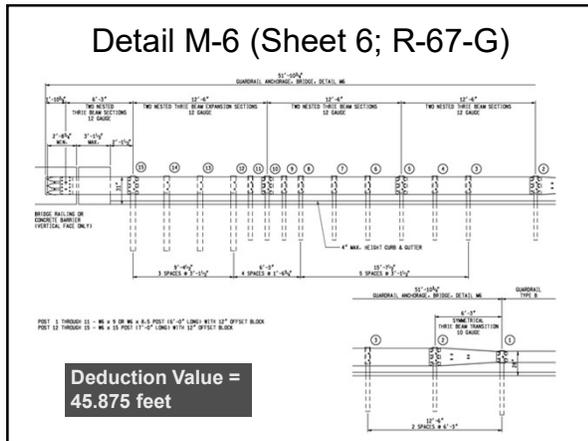
Detail M-5 (Sheet 5; R-67-G)



190



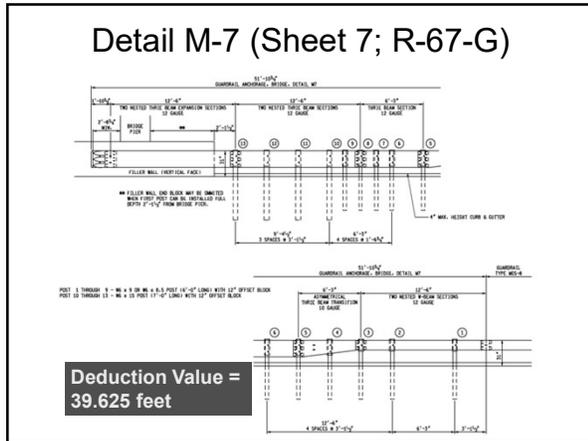
Detail M-6 (Sheet 6; R-67-G)



191



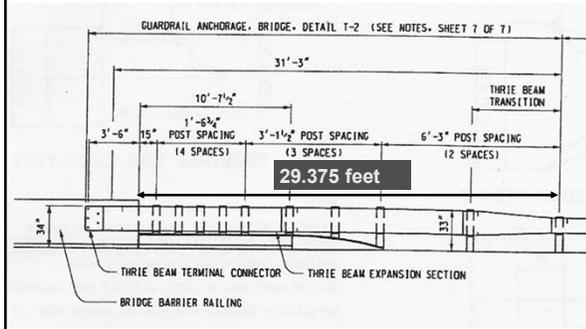
Detail M-7 (Sheet 7; R-67-G)



192

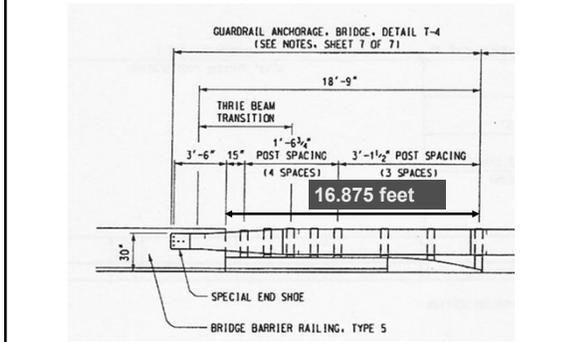


Detail T-2 (Sheet 1; R-67-SD)



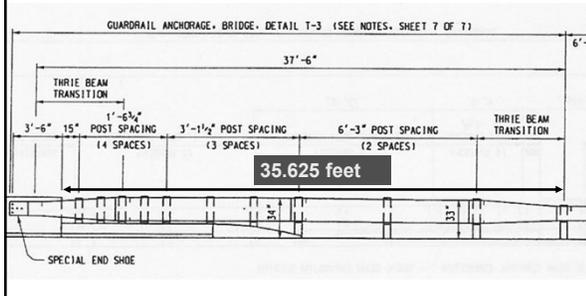
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Detail T-4 (Sheet 2; R-67-SD)

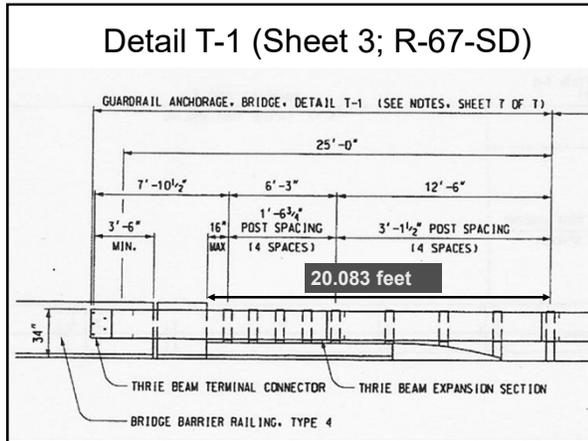


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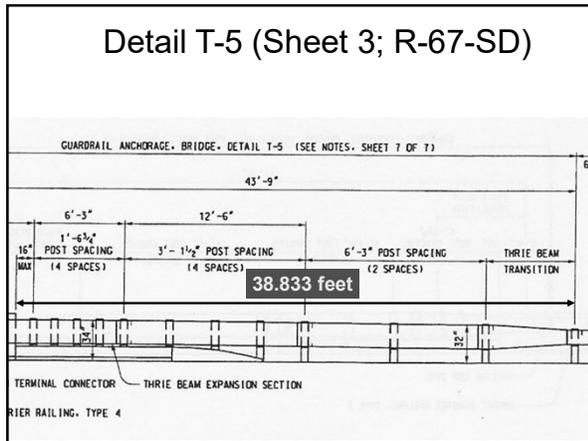
Detail T-3 (Sheet 2; R-67-SD)



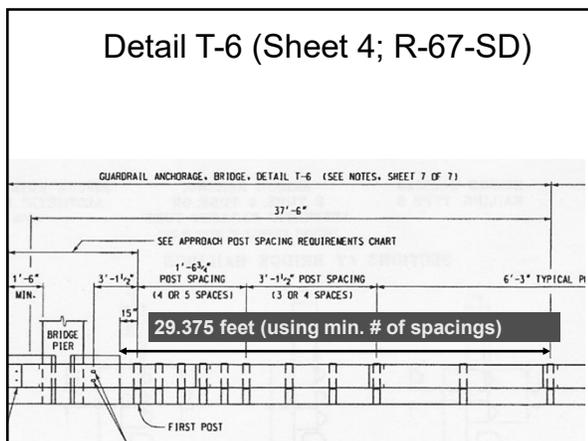
198



199



200



201

MDOT Approved Guardrail Transitions

Standard Plan B-22 and B-23 Series

- Guardrail Anchorage, Bridge, Detail A-3
- Guardrail Anchorage, Bridge, Detail A-4
- Guardrail Anchorage, Bridge, Detail A-5



205

MDOT Approved Guardrail Transitions

Standard Plan B-22 and B-23 Series



- May be constructed with or without curb
- 4" max curb height !!

206

MDOT Approved Guardrail Transitions

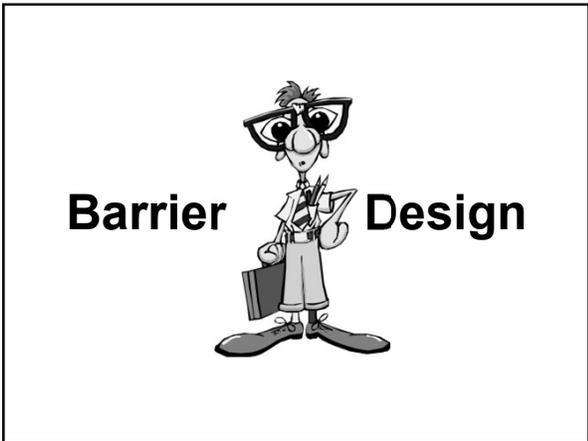
- Guardrail Anchorage, Median
- Used to connect double-sided guardrail to concrete barrier



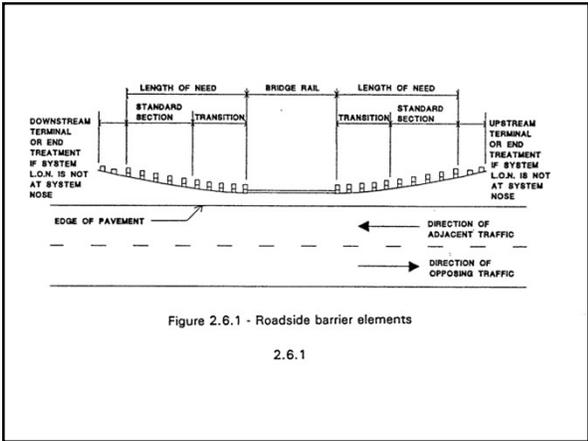
Detailed in MDOT Standard Plan R-71 Series

NCHRP 350 Compliant

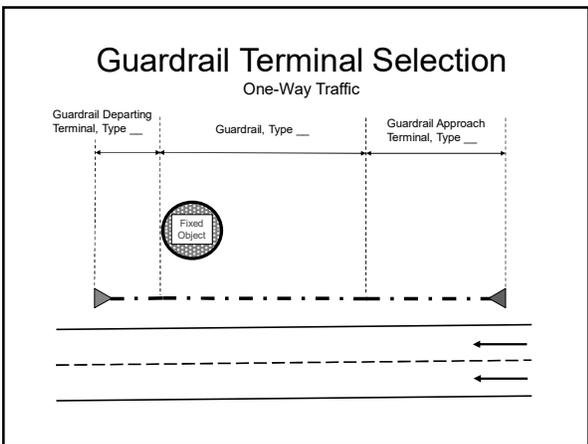
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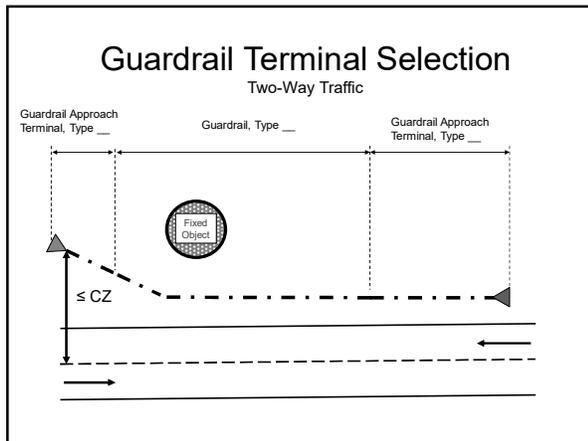
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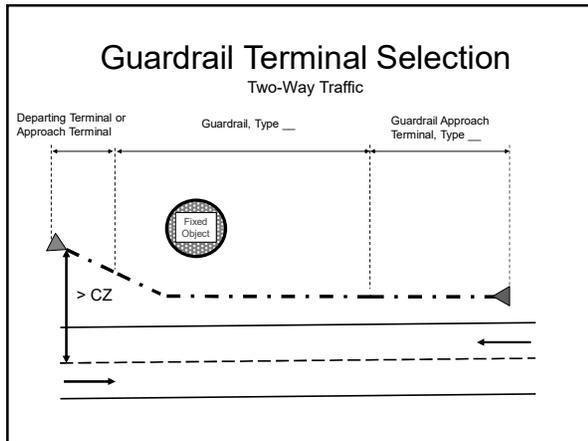
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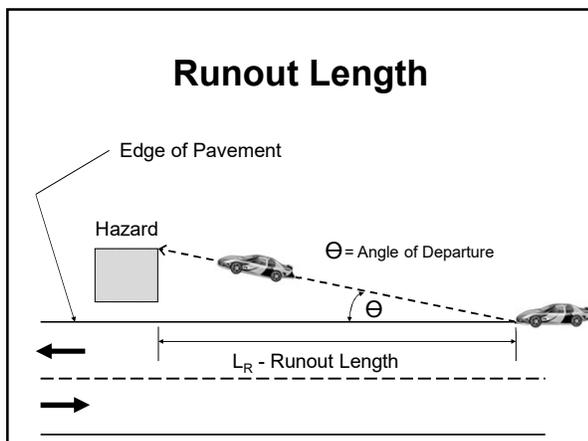
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211



212



213

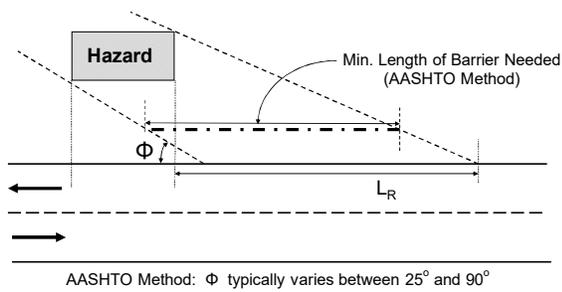
Runout Length

Design Speed (mph)	Traffic Volume (ADT) veh/day			
	Over 10,000	Over 5,000-10,000	1000-5000	Under 1000
80	470	430	380	330
70	360	330	290	250
60	300	250	210	200
50	230	190	160	150
40	160	130	110	100
30	110	90	80	70

- RDM – Section 7.01.19
- Runout length is a function of *design speed* and *traffic volume*
- Interpolation is recommended for intermediate design speeds
 - Example: DS = 75 mph & ADT = 12,000: $L_r = 415'$

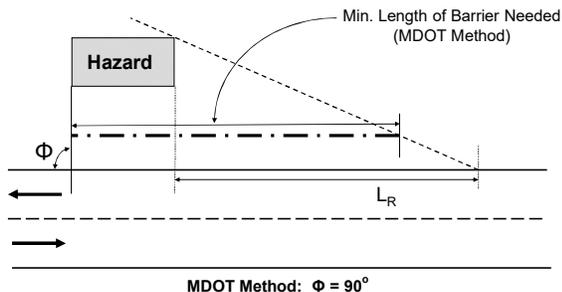
214

Minimum Length of Barrier Needed

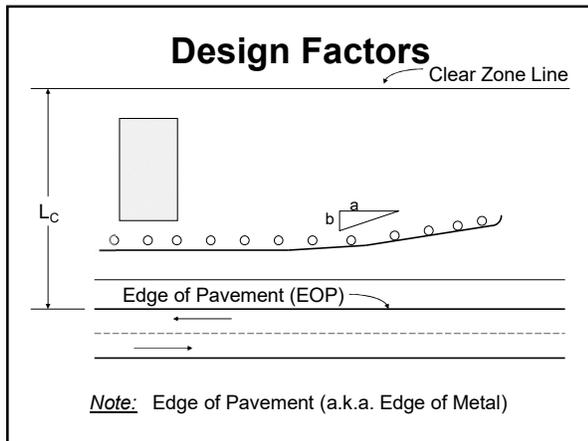


215

Minimum Length of Barrier Needed



216



217

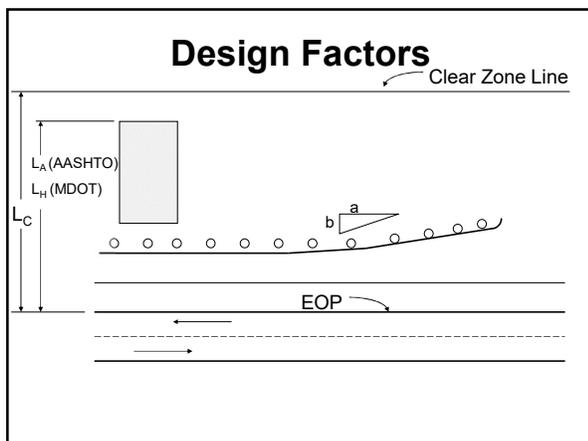
**CLEAR ZONE DISTANCES
(IN FEET FROM EDGE OF DRIVING LANE)**

DESIGN SPEED	DESIGN ADT	FILL SLOPES			CUT SLOPES		
		1:6 OR FLATTER	1:5 TO 1:4	1:3	1:3	1:4 TO 1:6	1:8 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	24-28
	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

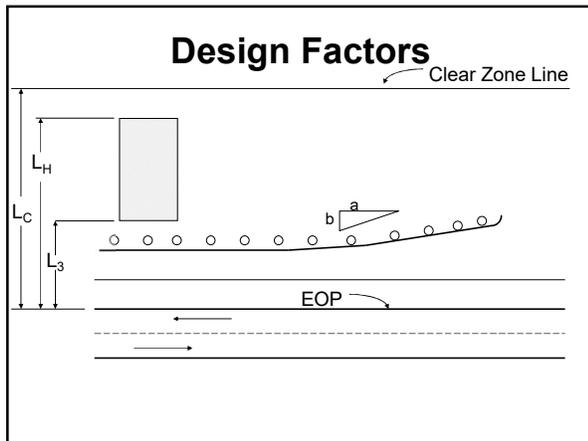
* Where a site specific investigation indicates a high probability of continuing crashes, or such occurrences are indicated by crash history, the designer may provide clear zone distances greater than 30 feet as indicated. Clear zones may be limited to 30 feet for practicality and to provide a consistent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

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

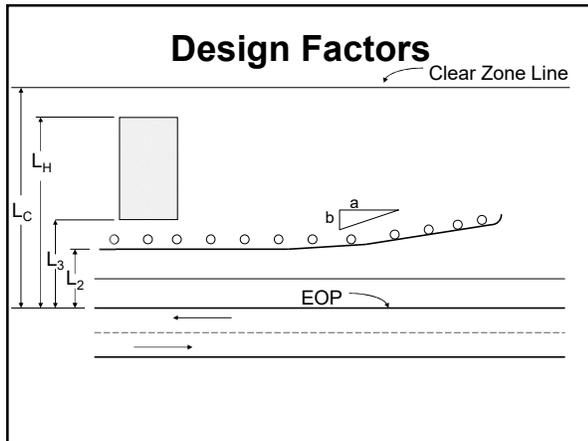
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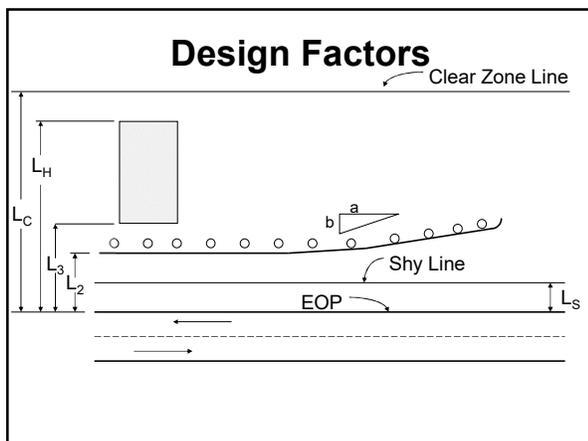
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220



221



222

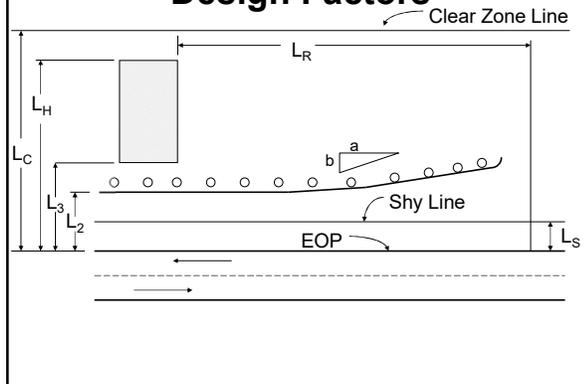
MDOT Shy Distance Table

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

RDM - Section 7.01.18

223

Design Factors



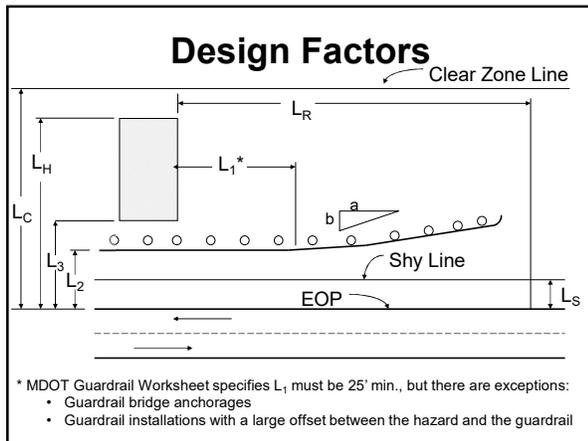
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MDOT Runout Length Table

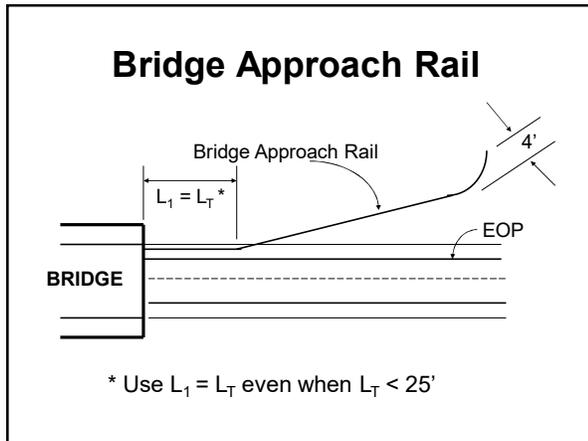
Design Speed (mph)	Traffic Volume (ADT) veh/day			
	Over 10,000	Over 5,000-10,000	1000-5000	Under 1000
80	470	430	380	330
70	360	330	290	250
60	300	250	210	200
50	230	190	160	150
40	160	130	110	100
30	110	90	80	70

RDM - Section 7.01.19

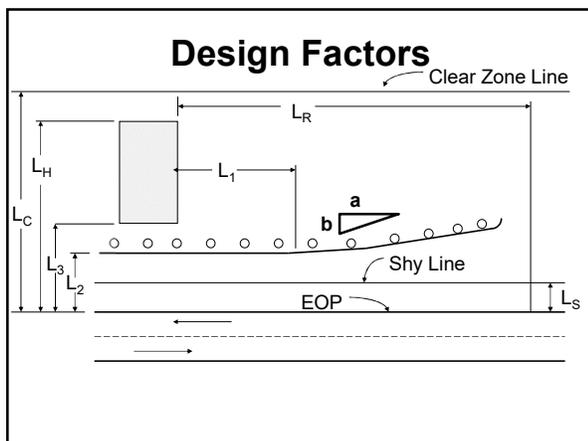
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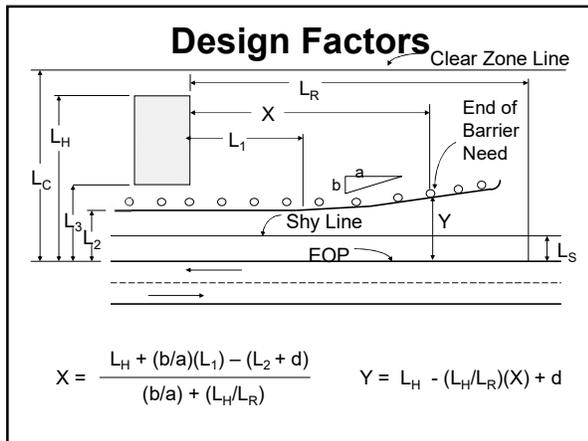
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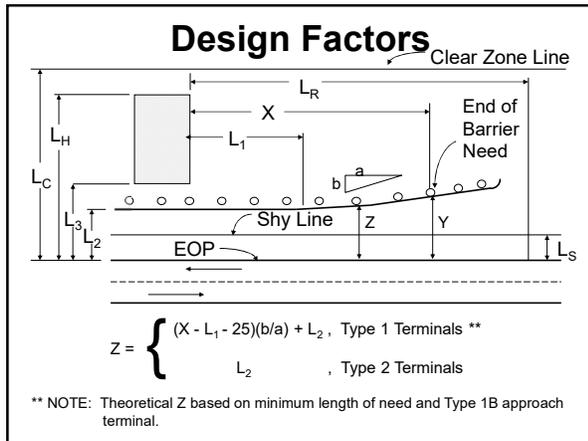
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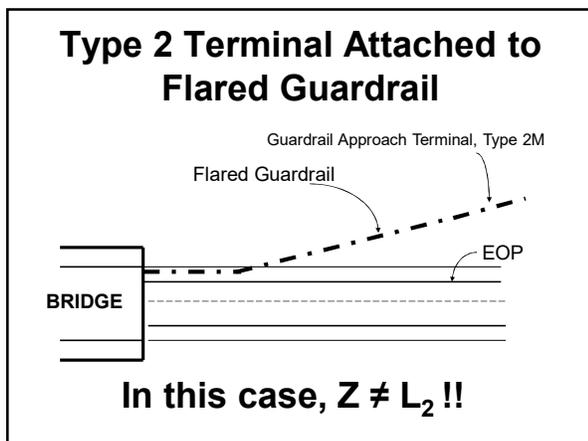
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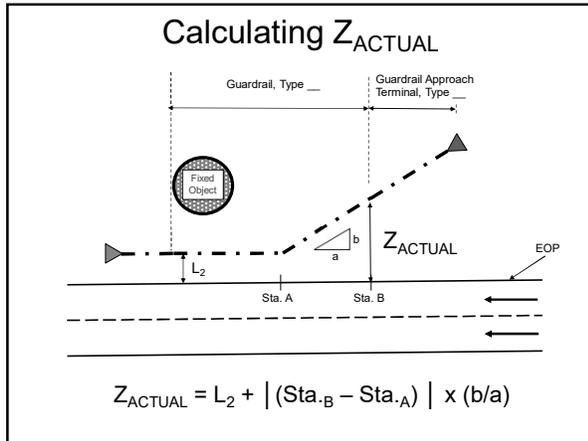
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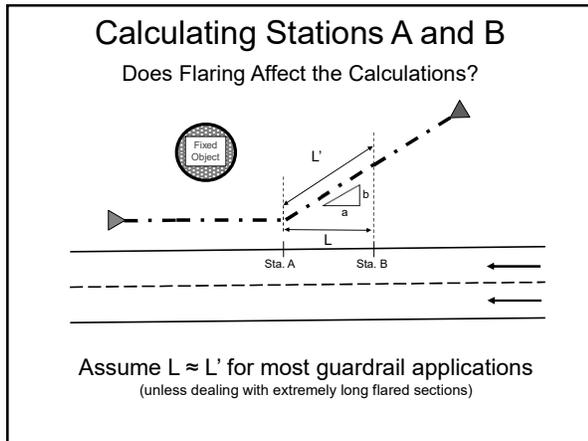
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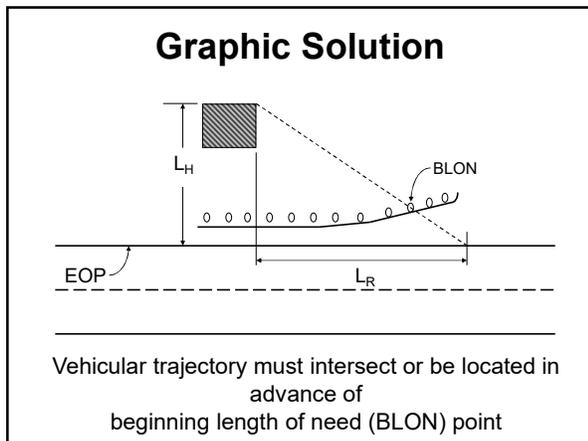
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235

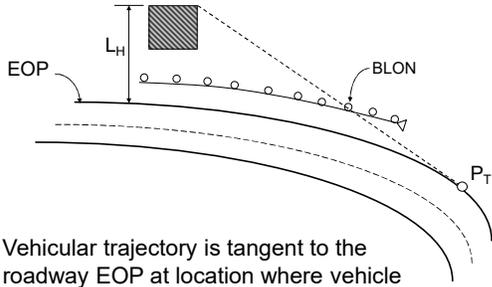


236



237

Horizontal Curve Solution



- Vehicular trajectory is tangent to the roadway EOP at location where vehicle leaves the roadway (at location P_T)

238

Length of Need – Approach End Flared vs. Parallel

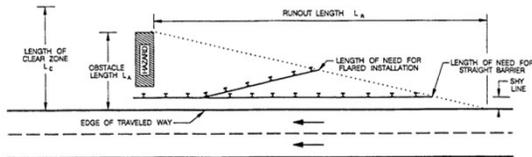
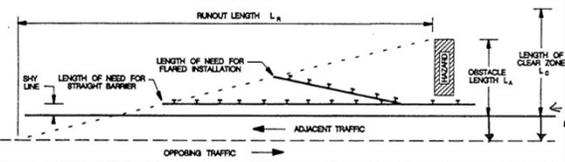


Figure 2.6.5 - Simplified representation of length of need

Flaring the guardrail reduces the length of need (X)

239

Length of Need – Departing End Flared vs. Parallel



Flaring the guardrail reduces the length of need (X)

240

Grading Requirements

SHOULDER

b 0 8 1

= 1:10 or flatter

- Grading requirements for flared installations may be impractical or cost-prohibitive
- Decision to install flared or parallel guardrail run is site-specific

241

Calculating Length of Guardrail

Freestanding Guardrail Shielding Fixed Object & One-Way Traffic

Guardrail Departing Terminal, Type ___ Guardrail, Type ___ Guardrail Approach Terminal, Type ___

H X G M BLON

$G^* = X - M + H$

242

M (Deduction Value)

MDOT Guardrail Worksheet

	DEDUCTION TABLE	
	GUARDRAIL APPROACH TERMINAL	
	TYPE 1	TYPE 2
GUARDRAIL TYPE B	25'	37.5'
GUARDRAIL TYPE T	31.25'	43.75'
GUARDRAIL TYPE MGS-8**	N/A	34.3'

For Type 2M terminals, use 34.3' for the deduction value

243

Soft-Stop (Type 2M Terminal)

Of the three MDOT-approved Type 2M terminals, Soft-Stop has the smallest deduction value

- Use deduction value of 34.3' whenever specifying a Type 2M terminal

244

Calculating Length of Guardrail

Freestanding Guardrail Shielding Fixed Object & One-Way Traffic

- H = fixed object width
- M = portion of approach terminal located within length of need
 - Deduction values from guardrail worksheet
- G = guardrail quantity

$$G^* = X - M + H$$

*** Important Notes**

- Always round up guardrail quantity based on whole number of guardrail panels
- With a freestanding run consisting of Type 2M approach terminals, Type MGS-8 guardrail, and/or Type MGS departing terminals, guardrail quantity will be divisible by 12.5'
- When interconnecting NCHRP 350 and MASH-compliant guardrail features, guardrail quantity might **not** be divisible by 12.5'
 - ❖ Examples: Type MGS-8 guardrail to Type B or Type T guardrail, or Type MGS-8 guardrail to NCHRP 350-compliant anchorages
 - ❖ Must take MGS (9'-4.5") beam elements and three-beam transition panels into consideration when determining guardrail quantities

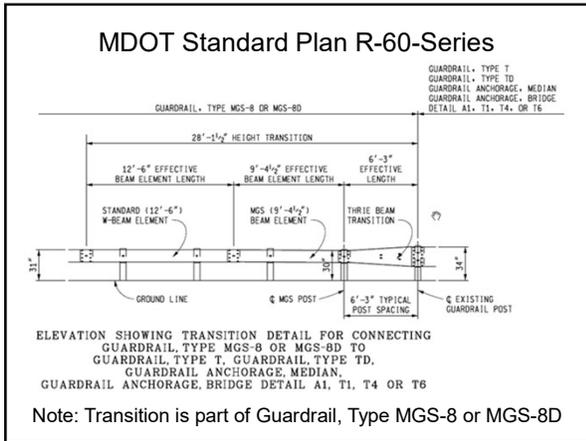
245

MDOT Standard Plan R-60-Series

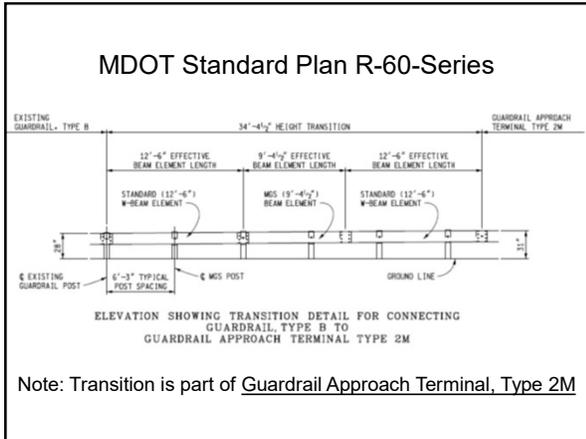
ELEVATION SHOWING TRANSITION DETAIL FOR CONNECTING GUARDRAIL, TYPE MGS-8 OR MGS-8D TO GUARDRAIL, TYPE B, GUARDRAIL, TYPE BD, OR GUARDRAIL APPROACH TERMINAL TYPE 1B, 2B, OR 3B

Note: Transition is part of Guardrail, Type MGS-8 or MGS-8D

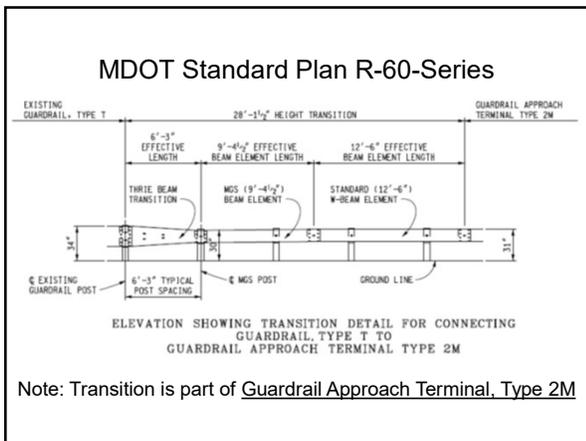
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247

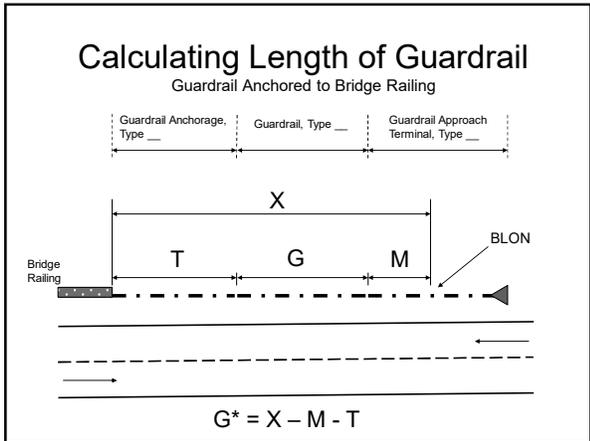


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249





250

Calculating Length of Guardrail

Guardrail Anchored to Bridge Railing

- T = transition length measured from edge of bridge railing/barrier (if applicable)
 - Do not deduct overall transition length
 - Deduction lengths for M-series and T-series anchorages provided in earlier slides
- M = portion of approach terminal located within length of need
 - Deduction values from guardrail worksheet
- G = guardrail quantity

$G^* = X - M - T$

*** Important Notes**

- Always round up guardrail quantity to the nearest whole number of guardrail panels
- Must take MGS (9'-4.5") beam elements and three-beam transition panels into consideration when determining guardrail quantities
 - ❖ Guardrail quantity may not be divisible by 12.5' in certain cases

251

Reflectors

- MDOT Standard Plan R-60 Series describes recommended reflector spacing
- *Do not install reflectors on approach terminals*

$$N_R = \left(\frac{\text{Guardrail Length}^*}{\text{Reflector Spacing}} \right) + 1$$

N_R is always rounded up to nearest integer

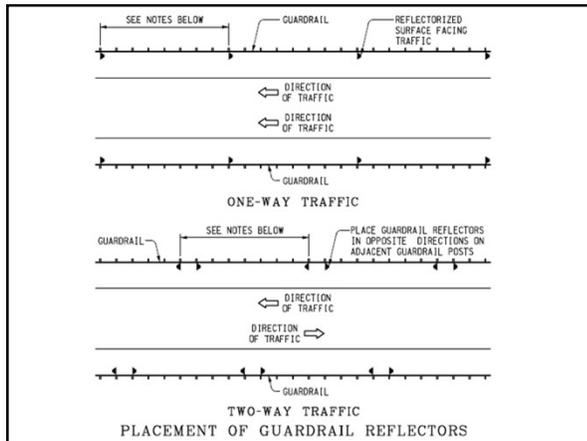
* Total Guardrail Length, including anchorages, but excluding approach terminals

252

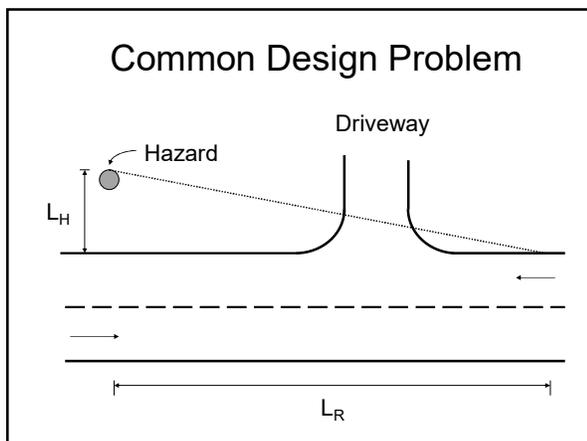
Reflectors

- One-Way Roads:
 - Reflector quantity = N_R
- Two-Way Roads:
 - Reflector quantity = $2N_R$

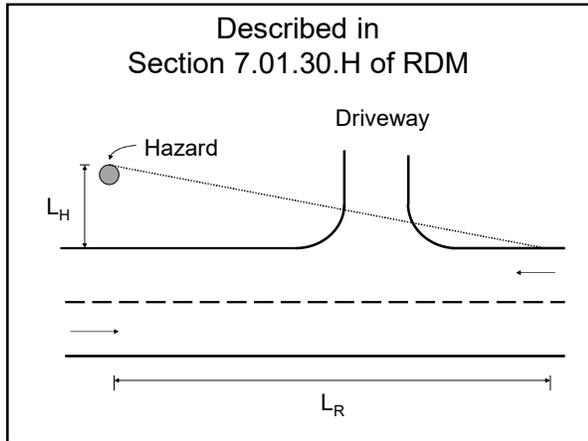
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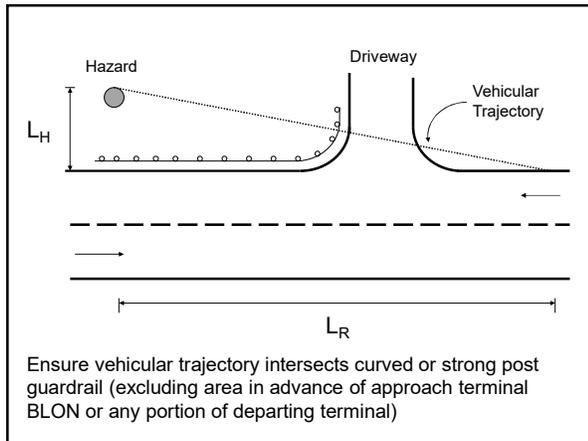
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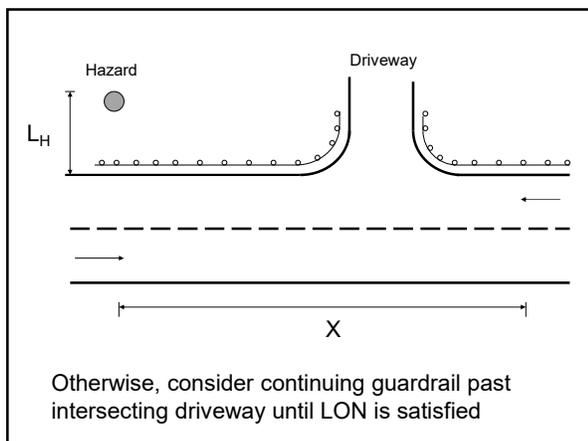
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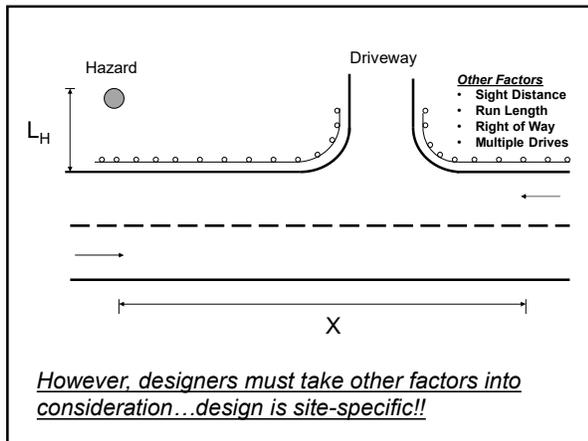
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257



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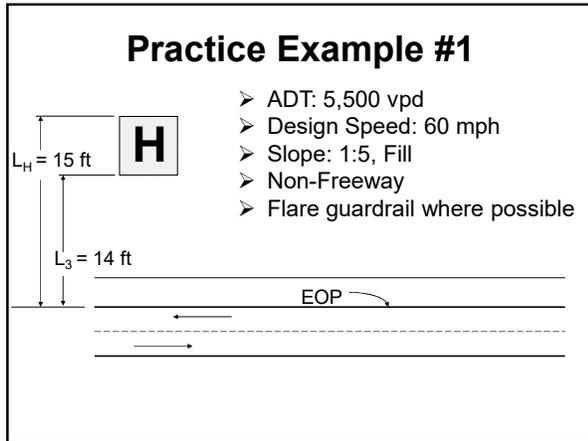
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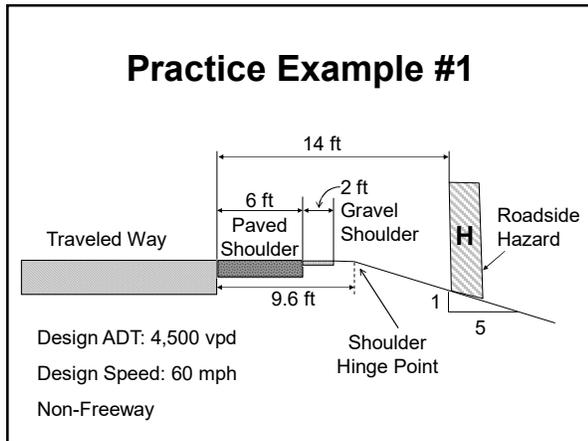
260



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263

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.

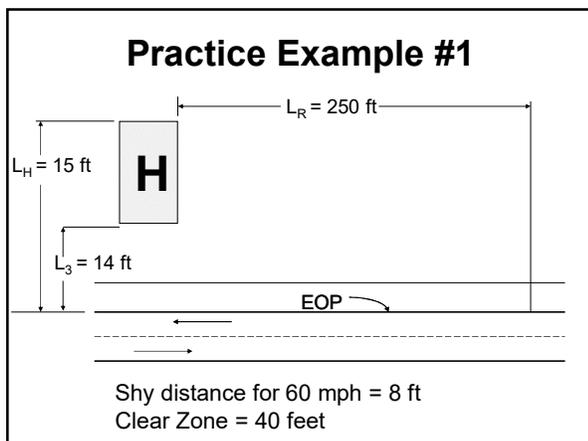
264

Design Speed (mph)	Traffic Volume (ADT) veh/day			
	Over 10,000	Over 5,000-10,000	1000-5000	Under 1000
80	470	430	380	330
70	360	330	290	250
→ 60	300	250	210	200
50	230	190	160	150
40	180	130	110	100
30	110	90	80	70

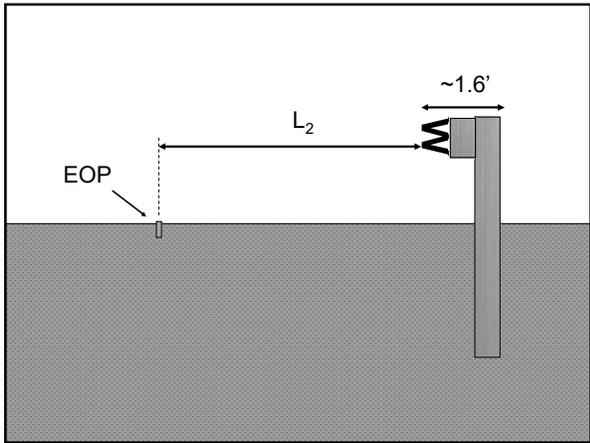
268

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

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270



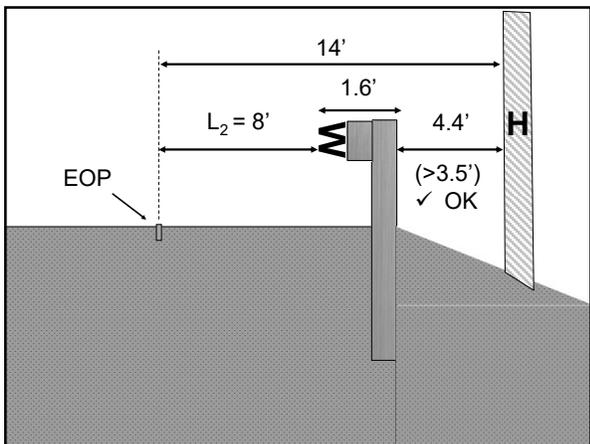
271

**MDOT
Guardrail Deflection Table**

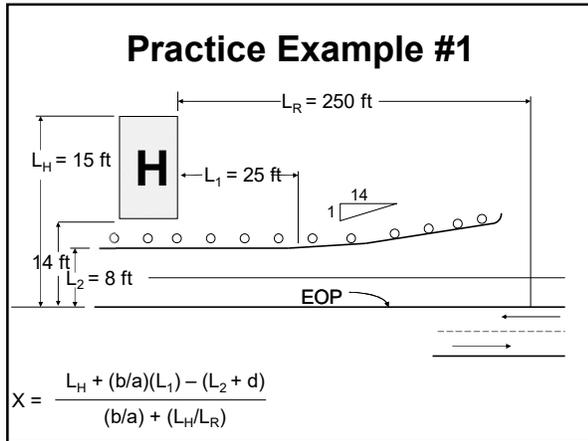
Guardrail	Post Spacing	Minimum Design Offset *
Type T	1'-6 1/2"	1'-2"
Type T	3'-1 1/2"	1'-8"
Type T	6'-3"	2'-0"
Type B	1'-6 1/2"	1'-6"
Type B	3'-1 1/2"	2'-0"
Type B	6'-3"	3'-0"
Type MGS-8	1'-6 1/2"	2'-5"
Type MGS-8	3'-1 1/2"	2'-11"
Type MGS-8	6'-3"	3'-6"
Type MGS-8 Adjacent to Curb	6'-3"	4'-1"
Type MGS-8 Near Shoulder Hinge Point **	6'-3"	4'-1"

RDM - Section 7.01.20

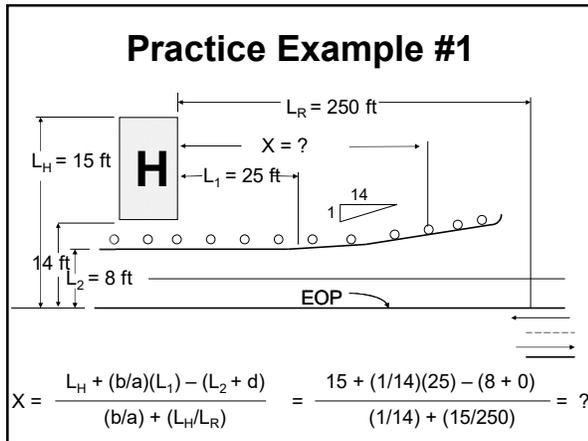
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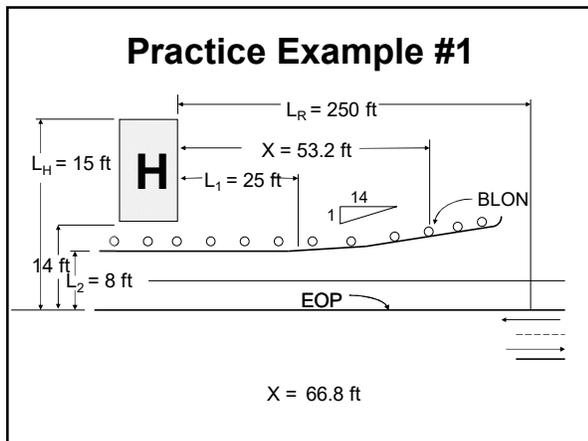
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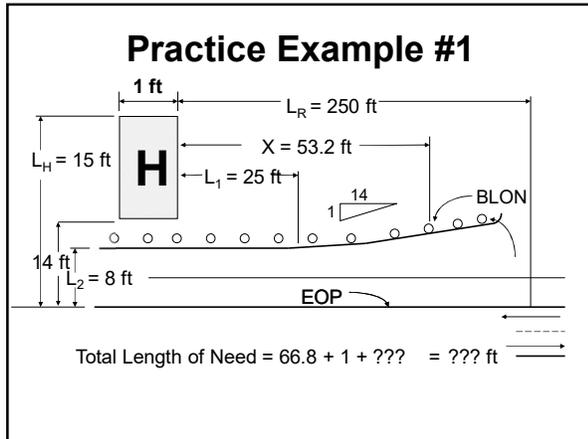
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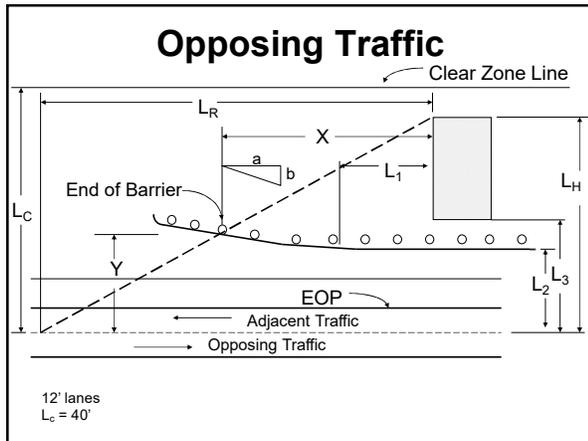
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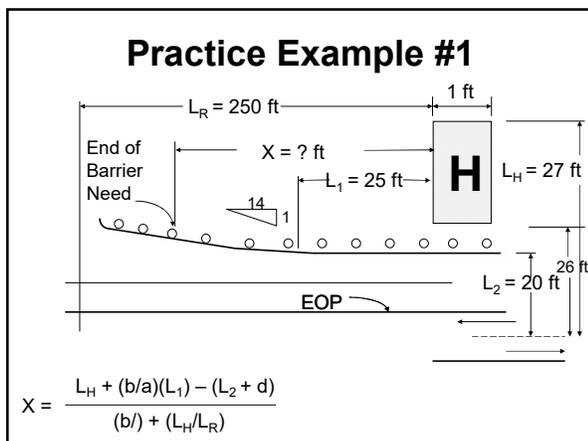
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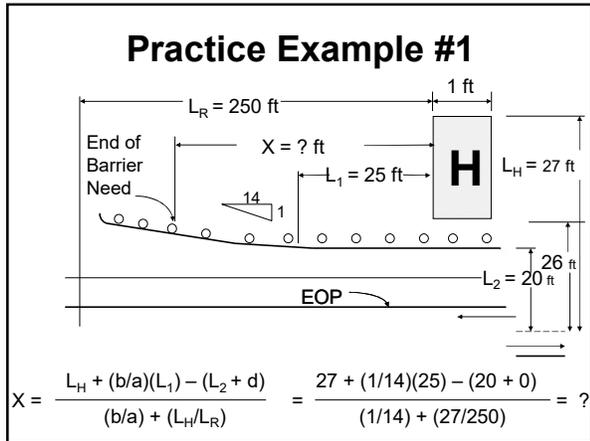
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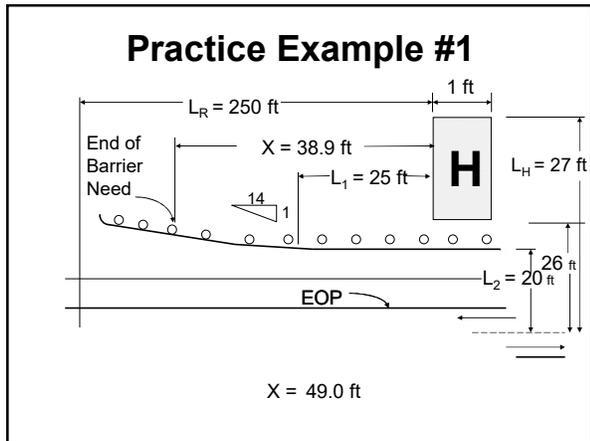
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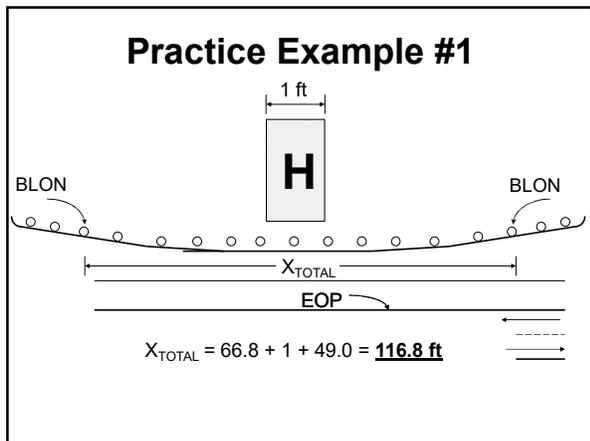
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285

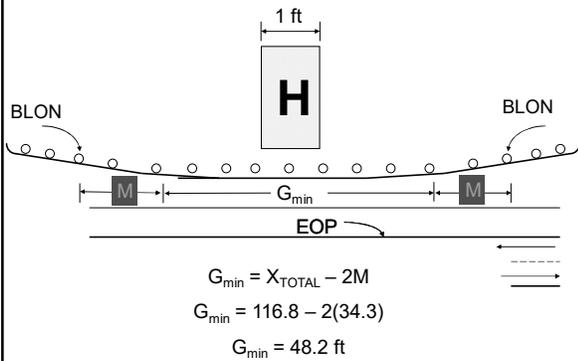
Deduction Value Type 2M Approach Terminal

MDOT Guardrail Worksheet

DEDUCTION TABLE		
	GUARDRAIL APPROACH TERMINAL	
	TYPE 1	TYPE 2
GUARDRAIL TYPE B	25'	37.5'
GUARDRAIL TYPE T	31.25'	43.75'
GUARDRAIL TYPE MGS-8**	N/A	(34.3')

286

Practice Example #1



287

Calculating Guardrail Quantity

Number of Guardrail Panels

- Type MGS-8 guardrail connected to Type 2M approach terminals
- Guardrail quantity is divisible by 12.5 (i.e., whole number of 12.5' panels)

$$\frac{G_{min}}{12.5} = \frac{48.2}{12.5} = 3.86 \longrightarrow 4 \text{ panels}$$

$$\text{Type MGS-8 Guardrail Length} = (12.5)(4) = 50 \text{ ft}$$

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Reflectors

- Do not install reflectors on approach terminals

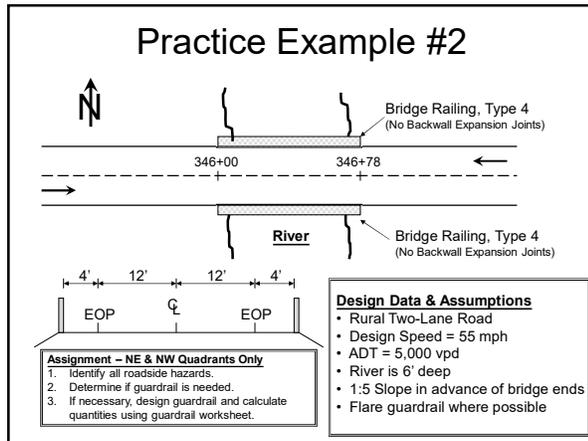
$$N_R = \left(\frac{50}{50} \right) + 1 = 2 \rightarrow 2$$

Since this is a two-way road, number of reflectors is $2N_R$:

$$\text{Number of Reflectors} = 2(2) = 4$$

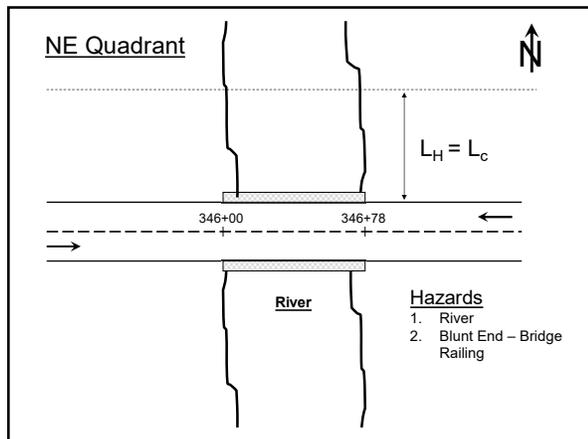
289

Practice Example #2

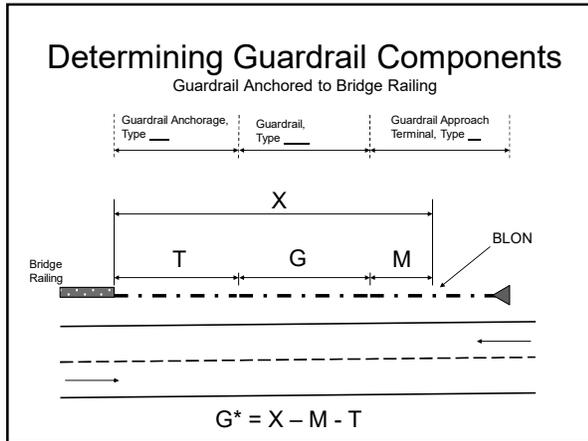


290

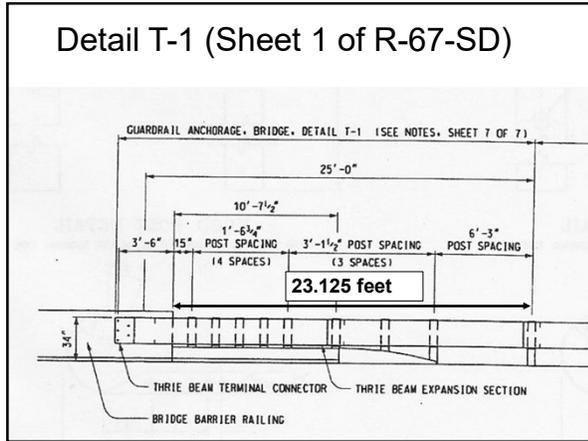
NE Quadrant



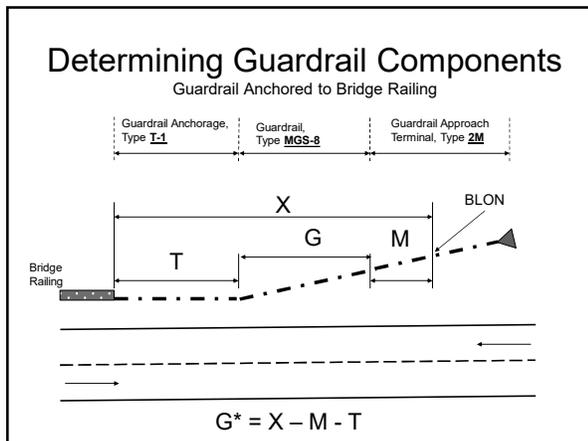
291



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GUARDRAIL RUNOUTSHEET
FOR HYBRID TERMINALS IN R-40-SERIES AND R-40-SERIES

ROUTE Practice Example #2 CONTROL SECTION 000000 JOB # EXAMPLE
DESIGNED BY JMC DATE 00/01/10 CHECKED BY XYZ DATE 00/01/10
APPROX. STATION OR W/340+70 DESCRIPTION Practice Example #2

IF STATIONING IS NOT AVAILABLE, LOCATE TO NEAREST FIXED OBJECT

NOTE: TYPE 1 TERMINAL ILLUSTRATED

$X = \frac{L_M + \left(\frac{b}{a}\right)(L_1) - (L_B + d)}$
 $X = \frac{L_M + \left(\frac{b}{a}\right)(L_1) - (L_B + d)}$
 $Z = (X - L_1 - 25) \left(\frac{b}{a}\right) \cdot L_B$
 $Z = L_B \text{ (For Type 0 Terminals)}$

LENGTH OF NEED $X = 113.76'$ DESIGN ADT 5,000 vpd
 RUNOUT LENGTH (7.01.19) $L_B = 185'$ DESIGN SPEED 55 mph
 GUARDRAIL TAPER RATE (R-50-SERIES) $\frac{b}{a} = 1/12$ APPROACH SLOPE 1:5
 E.O.P. TO FACE OF BARRIER (DESIGNED) $L_B = 4'$
 CLEAR ZONE (7.01.11) $L_C = 30'$ $L_1 = .23.125'$ ' MIN.)
 E.O.P. TO ROADSIDE FEATURE (MEASURED) $L_B = 4'$ $L_B = 7'$ SHY LINE (7.01.18)
 EFFECTIVE TURNED OUT DISTANCE OF ANCHORAGE ... $d = 0$ STATION AT A -347+01.1
 LATERAL EXTENT OF ROADSIDE FEATURE (MEASURED) $L_B = 30'$ STATION AT B -347+66.8
 LATERAL OFFSET AT END OF FLARE $Z = 9.47'$ **

NOTE: DISTANCE OF OBJECT FROM BACK OF BARRIER MUST BE GREATER THAN THE MINIMUM REFLECTION (7.01.19) ** Refer to Calculations and Notes
 $L_B = L_2$
 REFER TO STANDARD PLAN R-40-SERIES AND DESIGN MANUAL SECTION 6.01.09 FOR DIMENSIONS OF ELEMENTS

SHEET 1 OF 2

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$d = 1.8'$ FOR TYPE 1 TERMINALS
 $d = 0$ FOR TYPE 2 TERMINALS

$X = \frac{L_M + \left(\frac{b}{a}\right)(L_1) - (L_B + d)}$
 $X = \frac{L_M + \left(\frac{b}{a}\right)(L_1) - (L_B + d)}$
 $Z = (X - L_1 - 25) \left(\frac{b}{a}\right) \cdot L_B$
 $Z = L_B \text{ (For Type 0 Terminals)}$

LENGTH OF NEED $X = 113.76'$ DESIGN ADT 5,000 vpd
 RUNOUT LENGTH (7.01.19) $L_B = 185'$ DESIGN SPEED 55 mph
 GUARDRAIL TAPER RATE (R-50-SERIES) $\frac{b}{a} = 1/12$ APPROACH SLOPE 1:5
 E.O.P. TO FACE OF BARRIER (DESIGNED) $L_B = 4'$
 CLEAR ZONE (7.01.11) $L_C = 30'$ $L_1 = .23.125'$ ' MIN.)
 E.O.P. TO ROADSIDE FEATURE (MEASURED) $L_B = 4'$ $L_B = 7'$ SHY LINE (7.01.18)
 EFFECTIVE TURNED OUT DISTANCE OF ANCHORAGE ... $d = 0$ STATION AT A -347+01.1
 LATERAL EXTENT OF ROADSIDE FEATURE (MEASURED) $L_B = 30'$ STATION AT B -347+66.8
 LATERAL OFFSET AT END OF FLARE $Z = 9.47'$ **

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MDOT Runout Length Table

Design Speed (mph)	Traffic Volume (ADT) veh/day			
	Over 10,000	Over 5,000-10,000	1000-5000	Under 1000
	Runout Length L _R (ft)	Runout Length L _R (ft)	Runout Length L _R (ft)	Runout Length L _R (ft)
80	470	430	380	330
70	360	330	290	250
60	300	250	210	200
50	230	190	160	150
40	160	130	110	100
30	110	90	80	70

RDM - Section 7.01.19
 ** Must interpolate in this case to obtain L_R

297

$d = 1.8'$ FOR TYPE 1 TERMINALS
 $d = 0$ FOR TYPE 2 TERMINALS

$$X = \frac{L_B \cdot \left(\frac{b}{a}\right) (L_1) - (L_2 \cdot d)}{\frac{b}{a} + \frac{L_B}{L_R}}$$

$$X = \frac{L_B \cdot \left(\frac{b}{a}\right) (L_1) - (L_2 \cdot d)}{\frac{b}{a} + \frac{L_B}{L_R}}$$

$$Z = (X - L_1 - 25) \left(\frac{b}{a}\right) \cdot L_B$$

$$Z = L_B \text{ (For Type 2 Terminals)}$$

LENGTH OF NEED $X = 113.76'$ DESIGN ADT 5,000 vpd
 RUNDOUT LENGTH (7.01.19) $L_B = 185'$ DESIGN SPEED 55 mph
 GUARDRAIL TAPER RATE (R-59-SERIES) $\frac{b}{a} = 1/12$ APPROACH SLOPE 1:5
 E.O.P. TO FACE OF BARRIER (DESIGNED) $L_2 = 4'$
 CLEAR ZONE (7.01.11) $L_C = 30'$ $L_1 = .23.125'$ (MIN.)
 E.O.P. TO ROADSIDE FEATURE (MEASURED) $L_3 = 4'$ $L_B = 7'$ SHY LINE (7.01.18)
 EFFECTIVE TURNED OUT DISTANCE OF ANCHORAGE ... $d = 0$ STATION AT A -347+01.1
 LATERAL EXTENT OF ROADSIDE FEATURE (MEASURED) $L_B = 30'$ STATION AT B -347+66.8
 LATERAL OFFSET AT END OF FLARE $Z = 9.47'$ **

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

DESIGN SPEED	DESIGN ADT	FILL SLOPES			CUT SLOPES		
		1:6 FLATTER	1:5 TO 1:4	1:3	1:4 TO 1:6	1:8 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
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
55	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	18-20	20-22
60	under 750	22-24	26-32*	**	16-18	20-22	22-24
	750 - 1500	16-18	20-24	**	10-12	12-14	14-16
	1500 - 6000	20-24	26-32*	**	12-14	16-18	20-22
≥ 65	under 750	26-30	32-40*	**	14-18	18-22	24-26
	750 - 1500	18-20	20-26	**	10-12	14-16	14-16
	1500 - 6000	24-26	28-36*	**	12-16	18-20	20-22
≥ 65	under 750	28-32*	34-42*	**	16-20	22-24	26-28
	750 - 1500	30-34*	38-46*	**	22-24	26-30	28-30
	1500 - 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 unshaded, traversable 1:3 slopes, fixed objects should not be present in the vicinity of the toe of these slopes.

302

$d = 1.8'$ FOR TYPE 1 TERMINALS
 $d = 0$ FOR TYPE 2 TERMINALS

$$X = \frac{L_B \cdot \left(\frac{b}{a}\right) (L_1) - (L_2 \cdot d)}{\frac{b}{a} + \frac{L_B}{L_R}}$$

$$X = \frac{L_B \cdot \left(\frac{b}{a}\right) (L_1) - (L_2 \cdot d)}{\frac{b}{a} + \frac{L_B}{L_R}}$$

$$Z = (X - L_1 - 25) \left(\frac{b}{a}\right) \cdot L_B$$

$$Z = L_B \text{ (For Type 2 Terminals)}$$

LENGTH OF NEED $X = 113.76'$ DESIGN ADT 5,000 vpd
 RUNDOUT LENGTH (7.01.19) $L_B = 185'$ DESIGN SPEED 55 mph
 GUARDRAIL TAPER RATE (R-59-SERIES) $\frac{b}{a} = 1/12$ APPROACH SLOPE 1:5
 E.O.P. TO FACE OF BARRIER (DESIGNED) $L_2 = 4'$
 CLEAR ZONE (7.01.11) $L_C = 30'$ $L_1 = .23.125'$ (MIN.)
 E.O.P. TO ROADSIDE FEATURE (MEASURED) $L_3 = 4'$ $L_B = 7'$ SHY LINE (7.01.18)
 EFFECTIVE TURNED OUT DISTANCE OF ANCHORAGE ... $d = 0$ STATION AT A -347+01.1
 LATERAL EXTENT OF ROADSIDE FEATURE (MEASURED) $L_B = 30'$ STATION AT B -347+66.8
 LATERAL OFFSET AT END OF FLARE $Z = 9.47'$ **

Used distance to face of bridge railing

303

$d = 1.8'$ FOR TYPE 1 TERMINALS
 $d = 0$ FOR TYPE 2 TERMINALS

$$X = \frac{L_H \cdot \left(\frac{b}{a}\right) (L_1) - (L_2 \cdot d)}{\frac{b}{a} + \frac{L_H}{L_2}}$$

$$X = \frac{L_H - (L_2 \cdot d)}{\left(\frac{\text{No Flare or Type 2 Terminal}}{L_2}\right) + \frac{L_H}{L_2}}$$

$$Z = (X - L_1 - 25) \left(\frac{b}{a}\right) + L_2$$

$$Z = L_2 \text{ (For Type 2 Terminals)}$$

<p>LENGTH OF NEED $X = 113.76'$</p> <p>RUNOUT LENGTH (7.01.19) $L_H = 185'$</p> <p>GUARDRAIL TAPER RATE (R-59-SERIES) $\frac{b}{a} = \frac{1}{12}$</p> <p>E.O.P. TO FACE OF BARRIER (DESIGNED) $L_2 = 4'$</p> <p>CLEAR ZONE (7.01.11) $L_1 = 30'$</p> <p>E.O.P. TO ROADSIDE FEATURE (MEASURED) $L_2 = 4'$</p> <p>EFFECTIVE TURNED OUT DISTANCE OF ANCHORAGE ... $d = 0$</p> <p>LATERAL EXTENT OF ROADSIDE FEATURE (MEASURED) $L_H = 30'$</p> <p>LATERAL OFFSET AT END OF FLARE $Z = 9.47'$ **</p>	<p>DESIGN ADT 5,000 vpd</p> <p>DESIGN SPEED 55 mph</p> <p>APPROACH SLOPE 1:5</p> <p>$L_1 = 23.125'$ (MIN.)</p> <p>$L_2 = 7'$ SHOULDER (7.01.18)</p> <p>STATION AT A -347+01.1</p> <p>STATION AT B -347+66.8</p>
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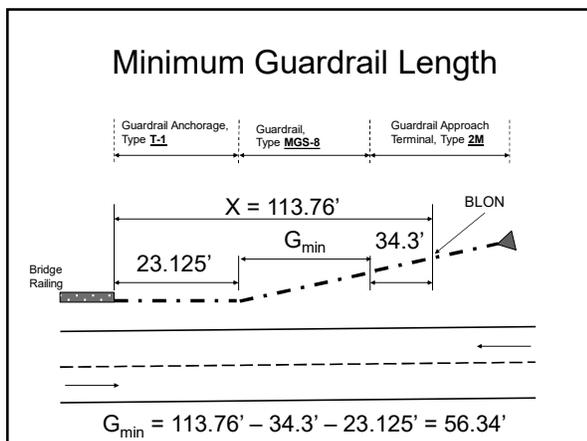
$L_1 < 25'$ in this case because $L_1 = L_T$
 (exception to $L_1 = 25'$ min. rule)

310

Length of Need (X)

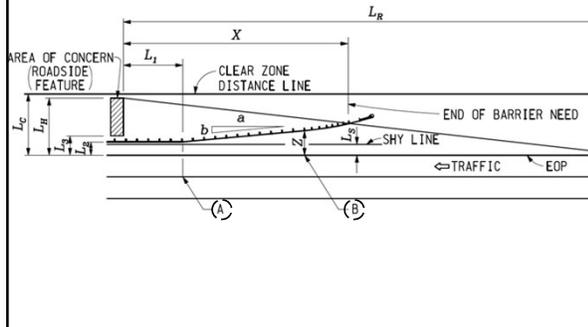
$$X = \frac{30 + \left(\frac{1}{12}\right) \times (23.125) - 4}{\left(\frac{1}{12}\right) + \left(\frac{30}{185}\right)} = 113.76'$$

311



312

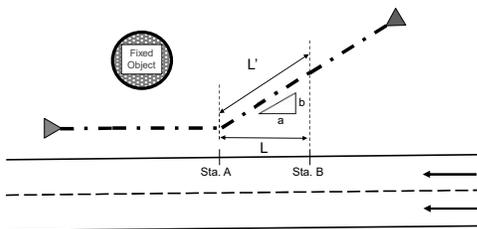
Stations A and B



316

Calculating Stations A and B

Does Flaring Affect the Calculations?



Assume $L \approx L'$ for most guardrail applications
(unless dealing with extremely long installations)

317

Stations

$$\text{Station A} = (346+78) + 23.125' \approx \underline{347+01.1}$$

$$\text{Station B} = (346+78) + 23.125 + 65.625' \approx \underline{347+66.8}$$

318

Calculating Z

$$Z_{\text{formula}} = (113.76 - 23.125 - 34.3) \times \left(\frac{1}{12}\right) + 4 = 8.69'$$

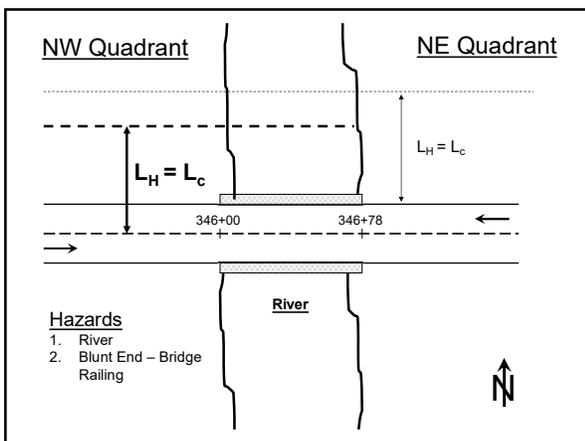
$$Z_{\text{actual}} = L_2 + (\text{Distance}_{B-A}) \times \left(\frac{b}{a}\right)$$

$$= 4 + (65.625) \times \left(\frac{1}{12}\right) = \underline{9.47'}$$

319

PAY ITEMS	
65.625 Ft	* Guardrail, Type MGS-8
_ 1 _ Ea	Guardrail Anchorage, Bridge, Det T-1
_____ Ft	Bridge Railing, Thrie Beam Retrofit
_ 1 _ Ea	Guardrail Approach Terminal, Type 2M
_____ Ea	Guardrail Departing Terminal, Type _____
_ 6 _ Ea	Guardrail Reflector
_____ Cyd	Embankment, LM

320



321

Stations

$$\text{Station A} = (346+00) - 23.125' \approx \underline{345+76.9}$$

$$\text{Station B} = (346+00) - 23.125 - 28.125' \approx \underline{345+48.8}$$

328

Calculating Z

$$Z_{\text{formula}} = (64.88 - 23.125 - 34.3) \times \left(\frac{1}{12}\right) + 16 = 16.62' \text{ (measured from CL)}$$

$$Z_{\text{actual}} = L_2 + (\text{Distance}_{B-A}) \times \left(\frac{b}{a}\right)$$

$$= 16 + (28.125) \times \left(\frac{1}{12}\right) = \underline{18.34'} \text{ (measured from CL)}$$

or

$$= 4 + (28.125) \times \left(\frac{1}{12}\right) = \underline{6.34'} \text{ (measured from EOP)}$$

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**Guardrail Design
Shielding Embankments**



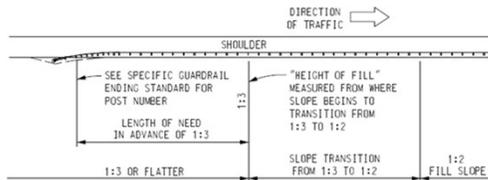
330

Guardrail at Embankments

MDOT Method

Parallel Guardrail Installations

- Section 7.01.30F of RDM



331

Guardrail at Embankments

MDOT Method

Parallel Guardrail Installations

- Section 7.01.30F of RDM

GUARDRAIL AT EMBANKMENTS (PARALLEL INSTALLATIONS)				
HEIGHT OF FILL AT 1:3 (ft)		LENGTH OF NEED IN ADVANCE OF 1:3 (ft)		
OVER	TO	70 mph	60 mph	50 mph
5	10	147	121	100
10	12	197	171	122
12	14	235	205	153
14	16	269	238	179
16	18	296	262	198
18	20	316	280	212
20	22	331	294	223
22	24	343	305	231
24	25	349	309	235

332

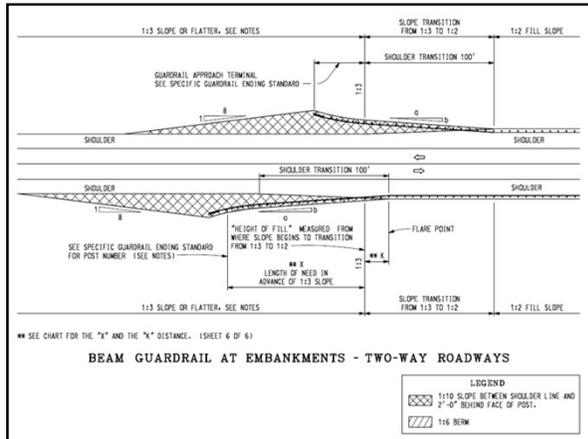
Guardrail at Embankments

MDOT Method

Flared Guardrail Installations

- Section 7.01.30E of RDM
- MDOT Standard Plan R-59 Series

333



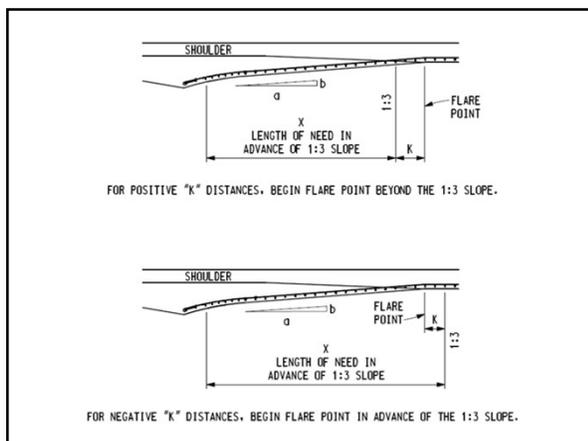
334

Standard Plan R-59-E X & K Values

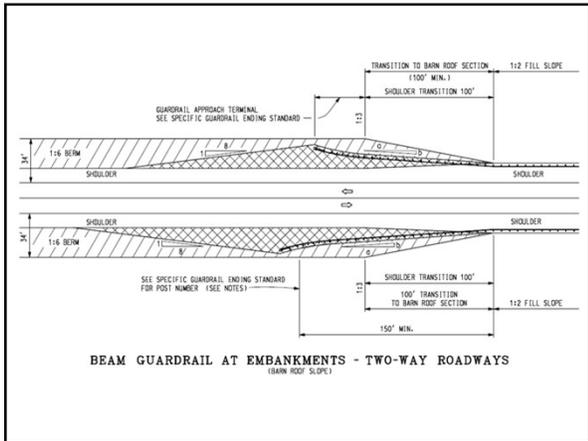
GUARDRAIL AT EMBANKMENTS (FLARED INSTALLATIONS, b/a)

HEIGHT OF FILL AT 1:3 SLOPE (FEET)		70 MPH FLARE 1 : 15		60 MPH FLARE 1 : 14		50 MPH FLARE 1 : 11	
OVER	TO	X	K	X	K	X	K
5	10	100	37.5	100	12.5	100	0
10	12	100	37.5	100	12.5	100	0
12	14	100	37.5	100	12.5	100	0
14	16	113	24.5	110	2.5	100	0
16	18	155	-17.5	149	-36.5	101	-1
18	20	193	-55.5	182	-69.5	127	-27
20	22	223	-85.5	207	-94.5	148	-48
22	24	246	-108.5	227	-113.5	164	-64
24	25	256	-118.5	235	-122.5	171	-71

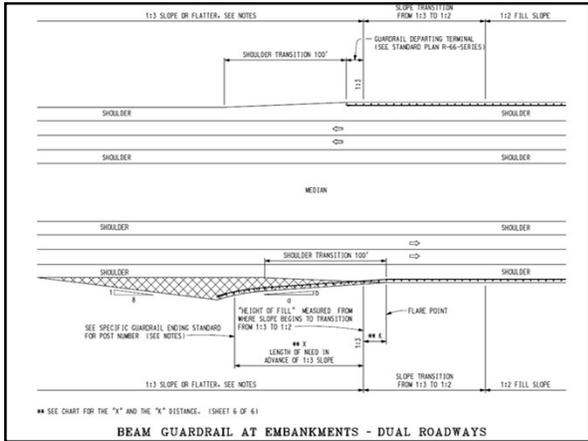
335



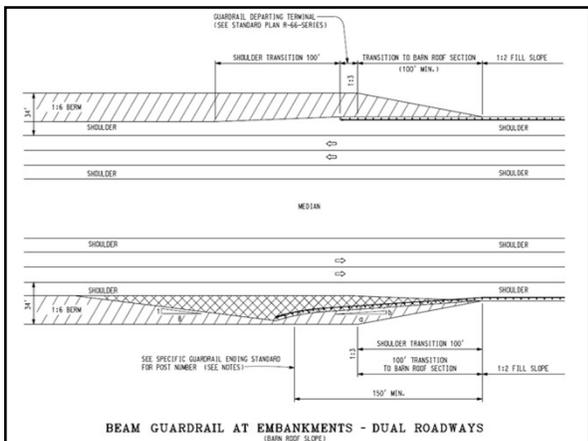
336



337

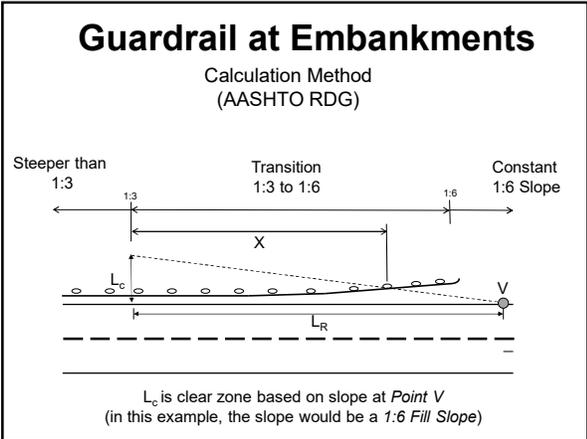


338

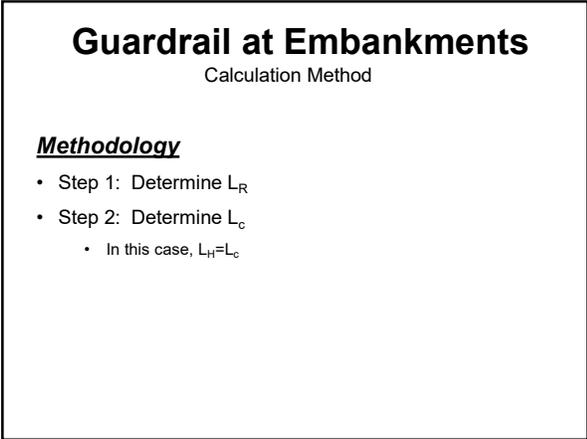


339

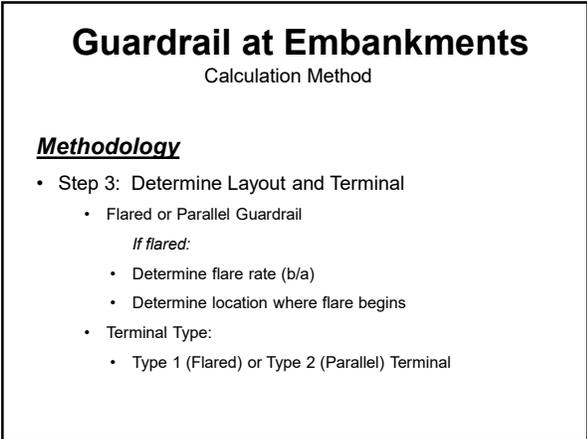




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Guardrail at Embankments

Calculation Method

Methodology

- Step 4: Determine Guardrail Location (L_2)

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Guardrail at Embankments

Calculation Method

Methodology

- Step 5: Use appropriate formula to calculate length of need (X) in advance of 1:3 point

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Guardrail at Embankments

Calculation Method

Methodology

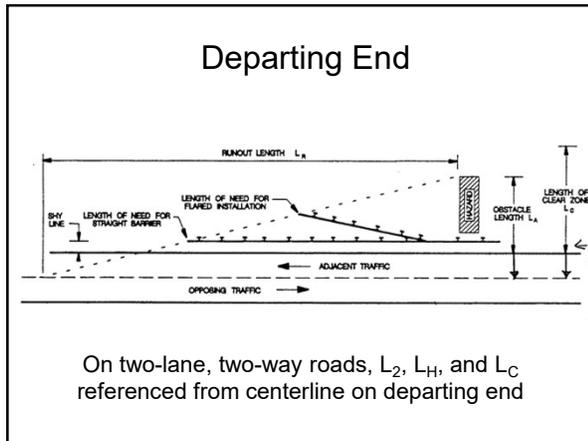
- Step 5: Use appropriate formula to calculate length of need (X) in advance of 1:3 point

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

345

LENGTH OF NEED	$X = 90.63'$	DESIGN ADT	8,700 vpd
RUNOUT LENGTH (7.01.19)	$L_R = 250'$	DESIGN SPEED	60 mph
GUARDRAIL TAPER RATE (R-59-SERIES)	$\frac{b}{m} = 0$	APPROACH SLOPE	1:6
E.O.P. TO FACE OF BARRIER (DESIGNED)	$L_B = 20.4'$	$L_2 =$ N/A	
CLEAR ZONE (7.01.11)	$L_C = 32'$	$L_2 = 8'$ SHY LINE (7.01.18)	
E.O.P. TO ROADSIDE FEATURE (MEASURED)	$L_B = 16'$	STATION AT A	N/A
EFFECTIVE TURNED OUT DISTANCE OF ANCHORAGE ...	$d = 0$	STATION AT B	170+72.7
LATERAL EXTENT OF ROADSIDE FEATURE (MEASURED)	$L_H = -32'$		
LATERAL OFFSET AT END OF FLARE	$Z = 8.4'$		

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353

Length of Need (X) – South End (Using Guardrail Worksheet)

$$X = \frac{32 - 20.4}{\left(\frac{32}{250}\right)} = 90.63' \text{ (measured from 1:3 point; Sta. 171+29)}$$

354

Total Guardrail Length

$$\text{Min. Length} = (178+84) - (171+29) + 205 + 90.63 - 2(34.3) = 982.03'$$

$$\text{\# of panels} = \frac{982.03}{12.5} = 78.56 \rightarrow \text{round up to 79 panels}$$

$$\therefore \text{Type MGS-8 Guardrail Length} = (12.5)(79) = \underline{987.5 \text{ feet}}$$

355

Reflectors

$$\text{\# of reflectors} = \left(\frac{987.5}{50}\right) + 1 = 20.75 \rightarrow \text{round up to 21}$$

*** But two-way roads require reflectors facing both sides ***

$$\therefore \text{\# of reflectors} = 21 \times 2 = \underline{42 \text{ reflectors}}$$

356

Stations

- The difference between the minimum guardrail length and the actual guardrail length = $987.5 - 982.03 \approx 5.47'$
- The additional 5.47' of guardrail will be placed on the north (approach) end.

357

North (Approach) End

Station where approach terminal meets Type MGS-8 guardrail on the north (approach) end is:

$$\text{Station } B_n = (178+84) + 205 + 5.47 - 34.3 = \underline{180+60.2}$$

Station $A_n \rightarrow$ N/A in this case

358

South (Departing) End

Station where approach terminal meets Type MGS-8 guardrail on the south (departing) end is:

$$\text{Station } B_s = (171+29) - 90.63 + 34.3 \approx \underline{170+72.7}$$

Station $A_s \rightarrow$ N/A in this case

359

Check: Type MGS-8 Guardrail Length = Sta. B_n - Sta. B_s

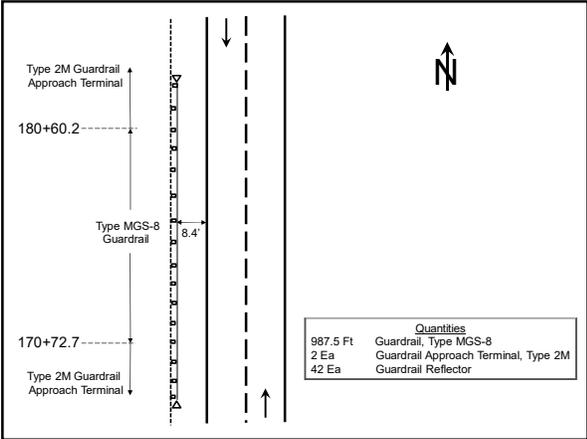
$$987.5 \text{ feet} = (180+60.2) - (170+72.7)$$

$$987.5 \text{ feet} = 987.5 \text{ feet } \checkmark$$

360

Calculating Z
Z = 8.4' (measured from EOP)

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Questions?

Contact Information
Carlos Torres
Phone: (517) 335-2852
E-mail: torresc@michigan.gov

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