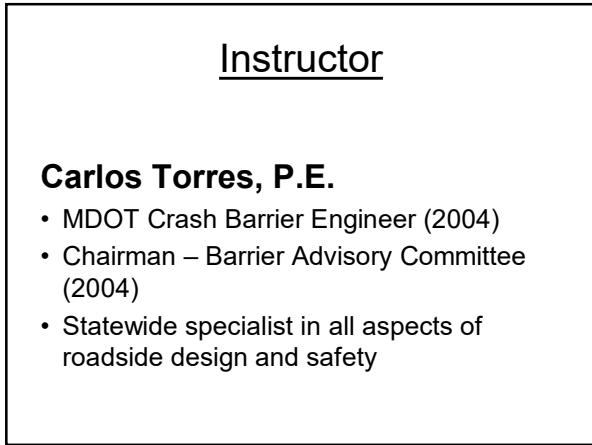
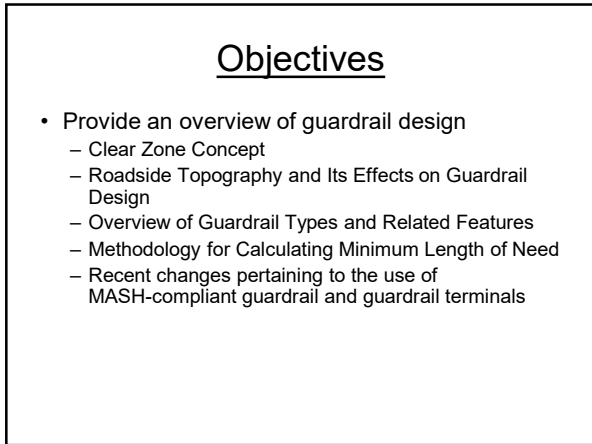


1



2



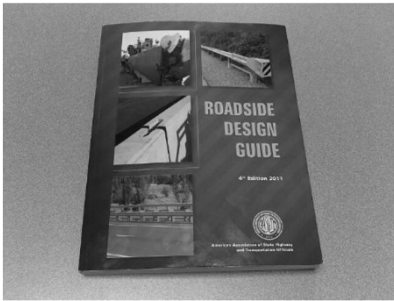
3

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
 - 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)
- 2016: *MASH 2016 (Update)*

8

Why did MASH become a hot topic in recent times?

End of the Road for NCHRP 350!!!

- **NCHRP 350 and MASH 2009* compliant devices will no longer be acceptable for new installations beyond the sunset date for each device category**

* Only devices that require retesting under MASH 2016

9

NCHRP 350/MASH 2009 Sunset Dates

- December 31, 2017:
 - Guardrail & Permanent Concrete Barriers
 - June 30, 2018:
 - Tangent, Single-Sided Guardrail Terminals⁽¹⁾
 - December 31, 2018:
 - Impact Attenuators
 - December 31, 2019:
 - Bridge rails, transitions, cable barriers & cable terminals⁽¹⁾, flared guardrail terminals⁽²⁾, double-sided guardrail terminals⁽²⁾, temporary work zone devices⁽³⁾, other longitudinal barriers, other terminals, sign supports, and all other breakaway hardware
- 1) Revised per 8/6/18 FHWA Memorandum with subject line *Change to the 12/31/18 Sunset Date*
- 2) Revised per 6/26/18 FHWA-AASHTO *Clarification of June 2018 Sunset Date* document
- 3) Temporary work zone devices manufactured before 12/31/19 that were successfully crash tested under NCHRP 350 or MASH 2009 may continue to be used throughout their "normal service lives"

10

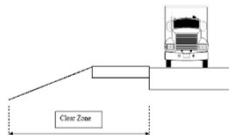
Roadside Topography



11

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



12

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

13

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

| DESIGN SPEED | DESIGN ADT OR FLATTER | FILL SLOPES | | | | | CUT SLOPES | | | | |
|----------------|-----------------------|-------------|------------|------------|------------|------------|------------|------------|------------|------------|-------|
| | | 1:6 TO 1:4 | 1:3 TO 1:4 | 1:3 TO 1:3 | 1:3 TO 1:3 | 1:3 TO 1:3 | 1:6 TO 1:4 | 1:6 TO 1:4 | 1:6 TO 1:4 | 1:6 TO 1:4 | |
| 40 mph or Less | under 750 | 7-10 | 7-10 | ** | 7-10 | 7-10 | 7-10 | 7-10 | 7-10 | 7-10 | 7-10 |
| | under 750 | 10-12 | 12-14 | ** | 10-12 | 12-14 | 12-14 | 12-14 | 12-14 | 12-14 | 12-14 |
| | over 1000 | 14-16 | 14-16 | ** | 12-14 | 14-16 | 14-16 | 14-16 | 14-16 | 14-16 | 14-16 |
| 45-50 mph | under 750 | 10-12 | 12-14 | ** | 10-12 | 12-14 | 12-14 | 12-14 | 12-14 | 12-14 | 12-14 |
| | under 750 | 14-16 | 16-20 | ** | 12-14 | 14-16 | 14-16 | 14-16 | 14-16 | 14-16 | 14-16 |
| | over 1000 | 20-22 | 24-26 | ** | 14-16 | 18-20 | 20-22 | 20-22 | 20-22 | 20-22 | 20-22 |
| 55 mph | under 750 | 12-14 | 14-16 | ** | 10-12 | 12-14 | 12-14 | 12-14 | 12-14 | 12-14 | 12-14 |
| | under 750 | 16-18 | 20-24 | ** | 14-16 | 16-18 | 16-18 | 16-18 | 16-18 | 16-18 | 16-18 |
| | over 1000 | 22-24 | 24-30 | ** | 16-18 | 18-20 | 20-22 | 20-22 | 20-22 | 20-22 | 20-22 |
| 60 mph | under 750 | 14-16 | 16-20 | ** | 12-14 | 14-16 | 14-16 | 14-16 | 14-16 | 14-16 | 14-16 |
| | under 750 | 18-20 | 24-30 | ** | 14-16 | 18-20 | 20-22 | 20-22 | 20-22 | 20-22 | 20-22 |
| | over 1000 | 24-26 | 30-40 | ** | 16-18 | 20-22 | 24-26 | 24-26 | 24-26 | 24-26 | 24-26 |
| 65 mph | under 750 | 16-18 | 20-24 | ** | 14-16 | 16-18 | 16-18 | 16-18 | 16-18 | 16-18 | 16-18 |
| | under 750 | 20-24 | 26-32 | ** | 16-18 | 18-22 | 20-22 | 20-22 | 20-22 | 20-22 | 20-22 |
| | over 1000 | 26-30 | 32-40 | ** | 18-20 | 22-24 | 26-28 | 26-28 | 26-28 | 26-28 | 26-28 |

Where a site specific investigation indicates a high probability of crossing crashes, or both 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 top of these slopes.

14

Only difference between MDOT and AASHTO CZ values

MDOT

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

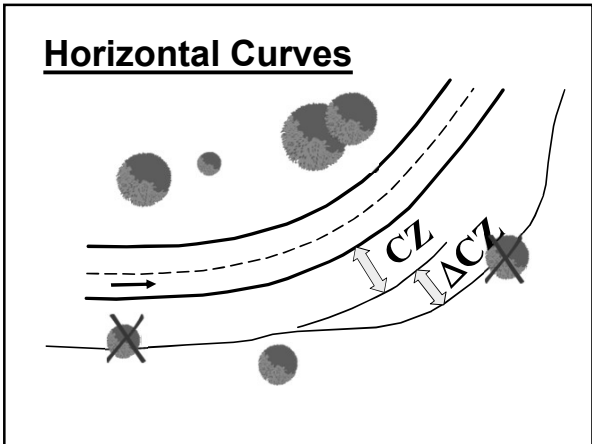
| DESIGN SPEED | DESIGN ADT OR FLATTER | FILL SLOPES | | | | | CUT SLOPES | | | | |
|----------------|-----------------------|-------------|------------|------------|------------|------------|------------|------------|------------|------------|-------|
| | | 1:6 TO 1:4 | 1:3 TO 1:4 | 1:3 TO 1:3 | 1:3 TO 1:3 | 1:3 TO 1:3 | 1:6 TO 1:4 | 1:6 TO 1:4 | 1:6 TO 1:4 | 1:6 TO 1:4 | |
| 40 mph or Less | under 750 | 7-10 | 7-10 | ** | 7-10 | 7-10 | 7-10 | 7-10 | 7-10 | 7-10 | 7-10 |
| | under 750 | 10-12 | 12-14 | ** | 10-12 | 12-14 | 12-14 | 12-14 | 12-14 | 12-14 | 12-14 |
| | over 1000 | 14-16 | 14-16 | ** | 12-14 | 14-16 | 14-16 | 14-16 | 14-16 | 14-16 | 14-16 |

AASHTO

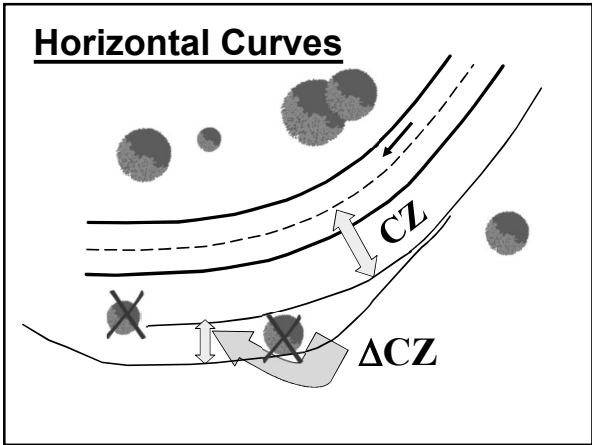
U.S. Customary Units

| Design Speed | Design ADT | FILL SLOPES | | | | | CUT SLOPES | | | | |
|----------------|------------|-------------|------------|------------|------------|------------|------------|------------|------------|------------|-------|
| | | 1:6 TO 1:4 | 1:3 TO 1:4 | 1:3 TO 1:3 | 1:3 TO 1:3 | 1:3 TO 1:3 | 1:6 TO 1:4 | 1:6 TO 1:4 | 1:6 TO 1:4 | 1:6 TO 1:4 | |
| 40 mph or Less | under 750 | 7-10 | 7-10 | ** | 7-10 | 7-10 | 7-10 | 7-10 | 7-10 | 7-10 | 7-10 |
| | under 750 | 10-12 | 12-14 | ** | 10-12 | 12-14 | 12-14 | 12-14 | 12-14 | 12-14 | 12-14 |
| | over 1000 | 14-16 | 14-16 | ** | 12-14 | 14-16 | 14-16 | 14-16 | 14-16 | 14-16 | 14-16 |

15



16



17

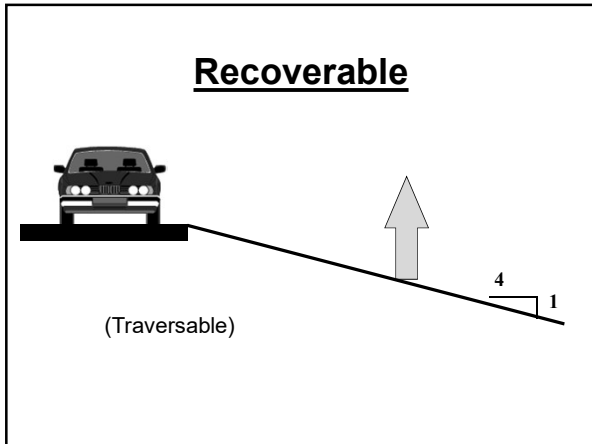
Horizontal Curve Adjustments

CURVE CORRECTION FACTORS (K_{cz})

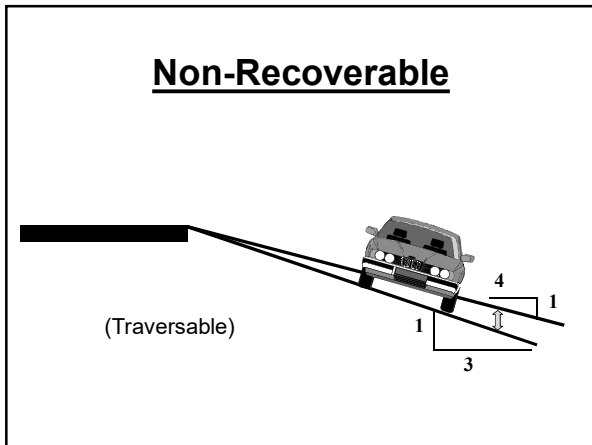
| Radius (ft) | DESIGN SPEED (mph) | | | | | | |
|-------------|--------------------|-----|-----|-----|-----|-----|-----|
| | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
| 2950 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 |
| 2300 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 | 1.3 |
| 1970 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 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 | | | | | | |

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

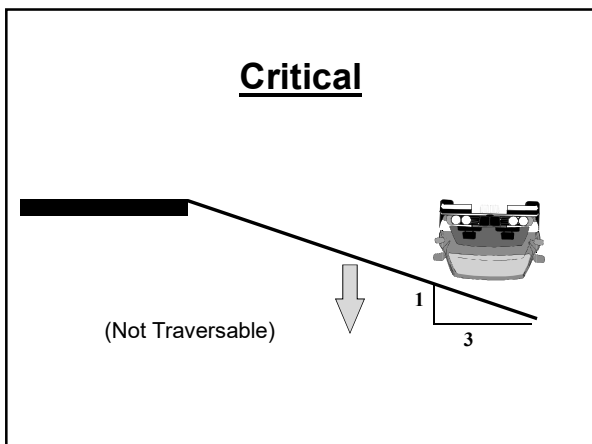
18



19

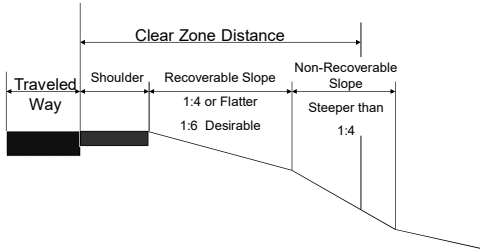


20



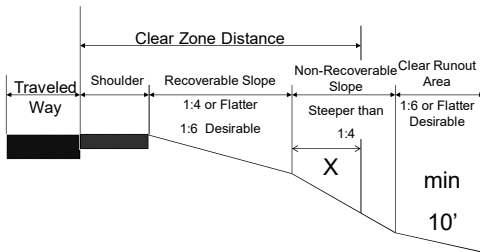
21

Clear Runout Area



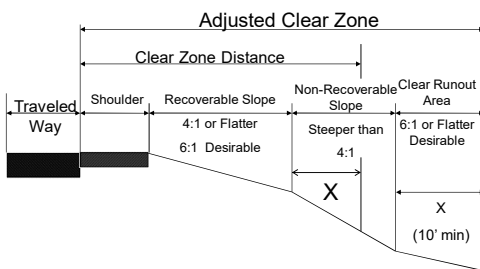
22

Clear Runout Area



23

Adjusted Clear Zone



24

Clear Zone for Auxiliary Lanes

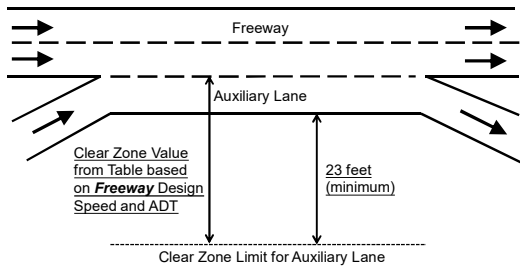
MDOT Method

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.

25

Clear Zone for Auxiliary Lane MDOT Method



26

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

27

Transverse Slopes

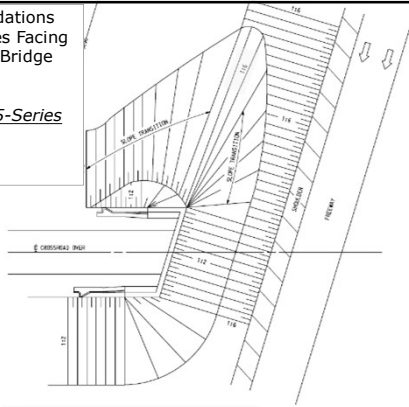
- 1:10 or flatter desirable
- 1:6 or flatter for high-speed roadways, especially within clear zone
- May be considered a hazard under certain conditions
 - steep transverse slopes



28

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

Standard Plan R-105-Series

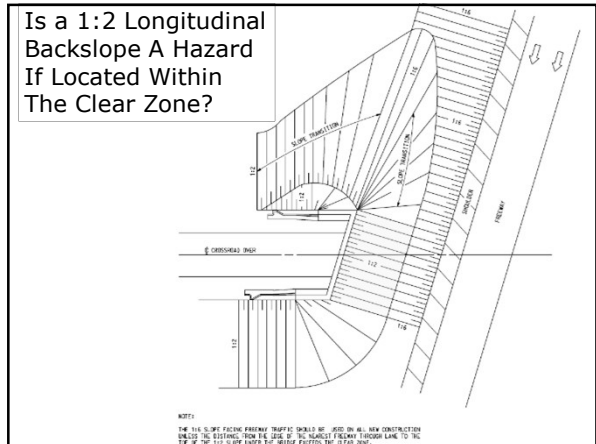


NOTE:
THE 1:10 SLOPE FACING FREEWAY TRAFFIC SHOULD BE USED ON ALL NEW CONSTRUCTION UNLESS THE EXISTING FROM THE JUNE 19, 2004, STANDARD PLAN R-105D IS USED TO THE LEFT OF THE ROADWAY AND THE RIGHT SIDE OF THE ROADWAY.

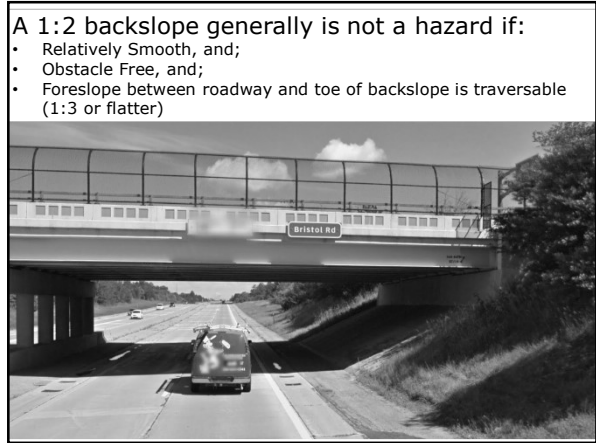
29



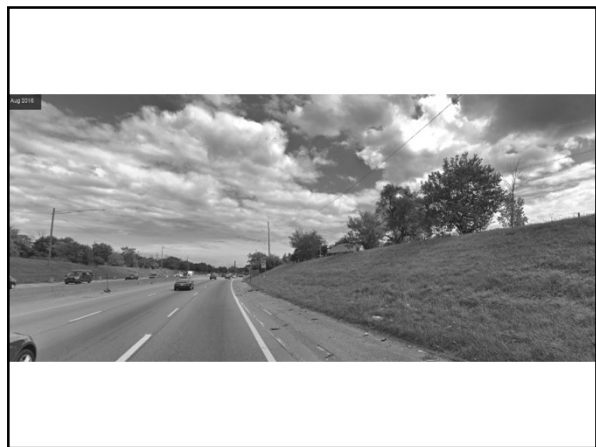
30



31



32



33

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

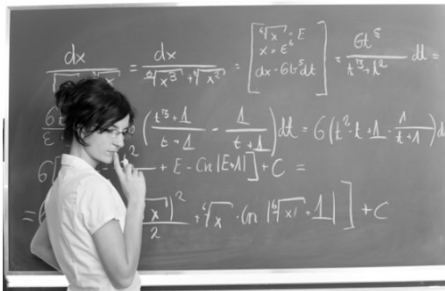
34

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'

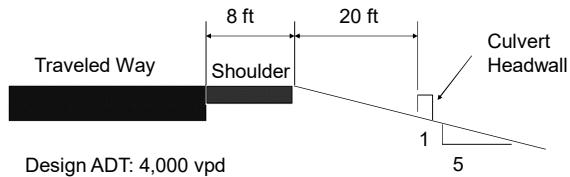
35

Clear Zone Examples



36

Clear Zone Example #1



Design ADT: 4,000 vpd
Design Speed: 60 mph

37

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

38

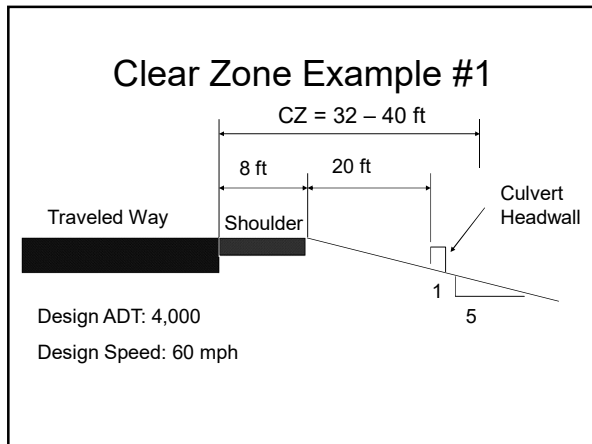
CLEAR ZONE DISTANCES
(IN FEET FROM EDGE OF DRIVING LANE)

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

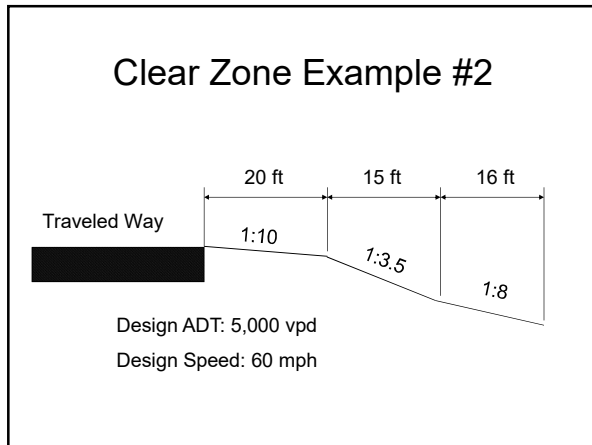
Where a site specific investigation indicates a high probability of continuing crashes, or such occurrences are indicated by crash history, the designer may provide clear zone distances greater than 30 feet as indicated. Clear zones may be limited to 30 feet for practicality and to provide a consistent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

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

39



40



41

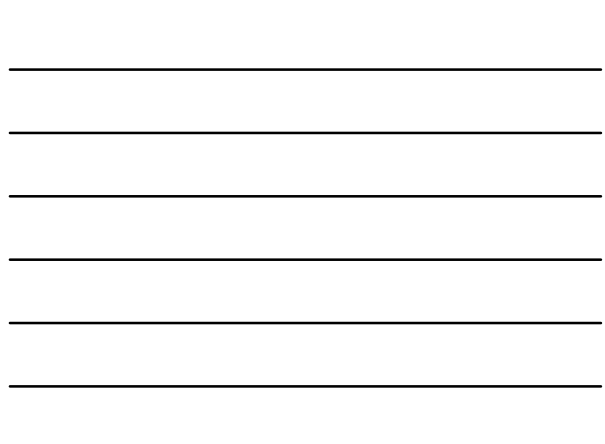


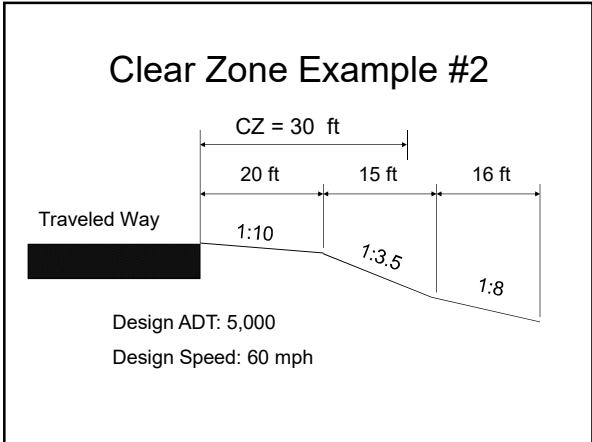
| DESIGN SPEED | DESIGN ADT | CLEAR ZONE DISTANCES (IN FEET FROM EDGE OF DRIVING LANE) | | | | | |
|----------------|-------------|--|------------|-----|------------|----------------|---------|
| | | FILL SLOPES | | | CUT SLOPES | | |
| | | 1:6 OR FLATTER | 1:5 TO 1:4 | 1:3 | 1:3 TO 1:6 | 1:4 OR FLATTER | 1:6 |
| 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 - 28 | ** | 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 | 26 - 36* | ** | 12 - 16 | 16 - 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.

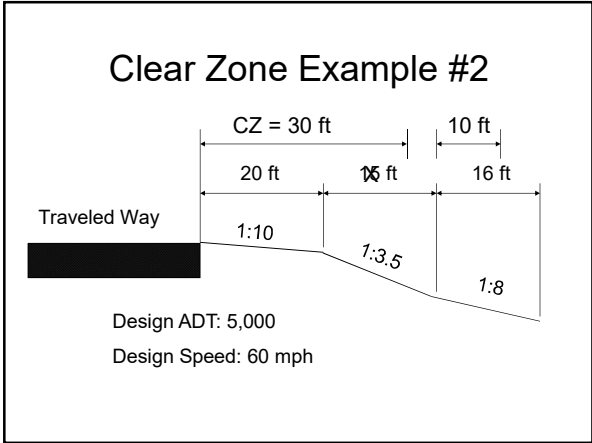
** Since recovery is less likely on the unshielded, reversible 1:3 slopes, fixed objects should not be present in the vicinity of the toe of these slopes.

42

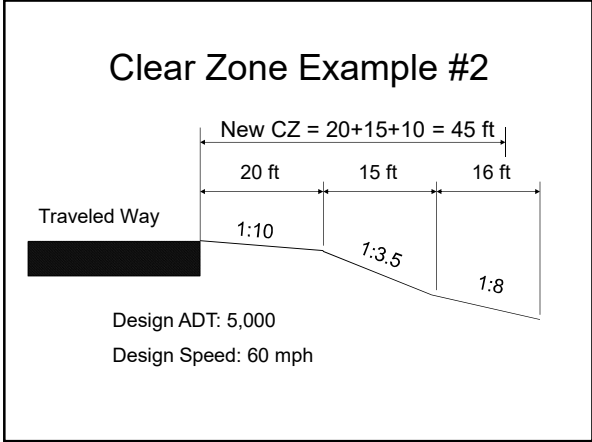




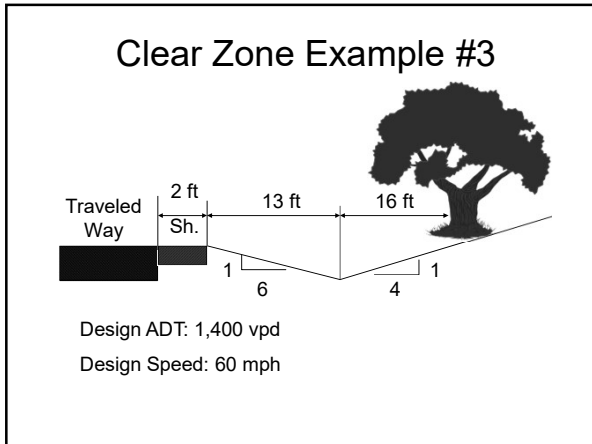
43



44



45



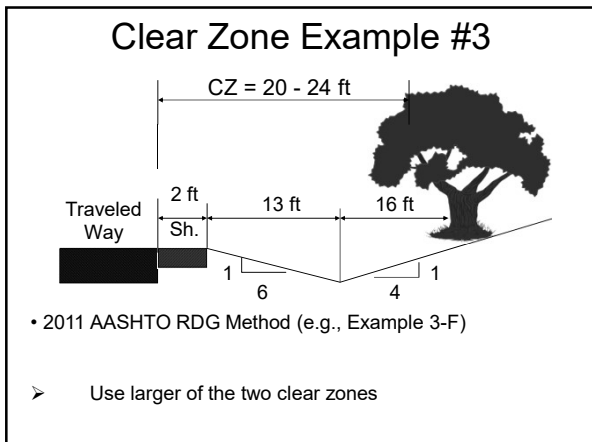
46

| DESIGN SPEED | DESIGN ADT | CLEAR ZONE DISTANCES (IN FEET FROM EDGE OF DRIVING LANE) | | | | | |
|-----------------------|------------|---|------------------|-----|------------------|----------------------|-------|
| | | FILL SLOPES | | | CUT SLOPES | | |
| | | 1:1 OR FLATTER | 1.5 TO 1:4 | 1:3 | 1:4 TO 1:6 | 1:8 OR FLATTER | |
| 40 mph or Lower | 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 | 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 |

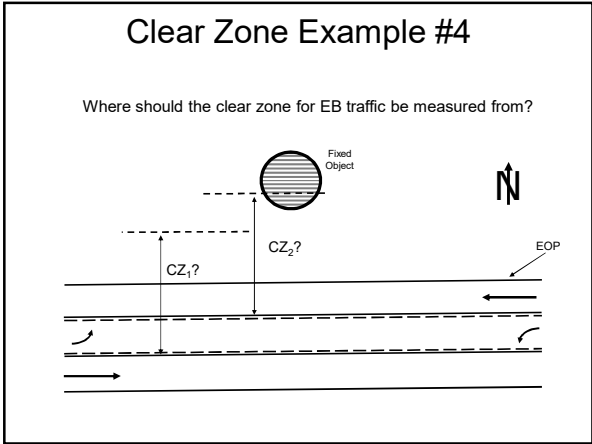
* Where a site specific investigation indicates a high probability of continuing crashes, or such occurrences are indicated by crash history, the designer may provide clear zone distances greater than 30 feet as indicated. Clear zones may be limited to 30 feet for practicality and to provide a consistent 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.

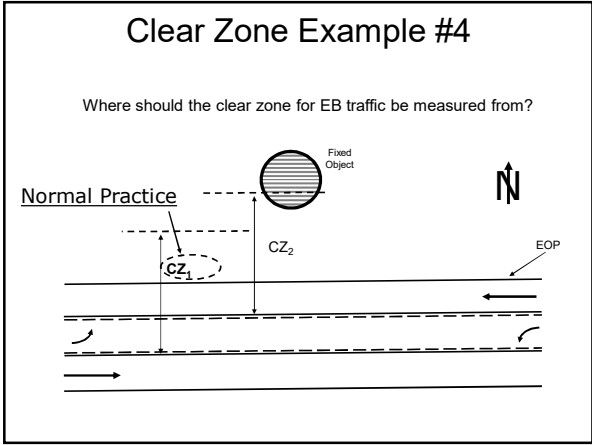
47



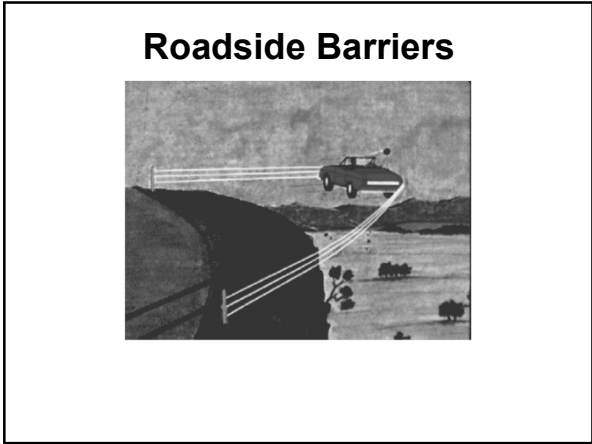
48



49




50



51

Design Options in Order of Preference


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



52


Barrier Types

- Roadside Barriers
- Median Barriers
- Bridge Railings



53

Barrier Classifications

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

54

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)

55

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



56

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



57

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



58

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

59

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

60

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



61

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



62

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



63

Type MGS-8

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



Source: TTI

64



Source: TTI

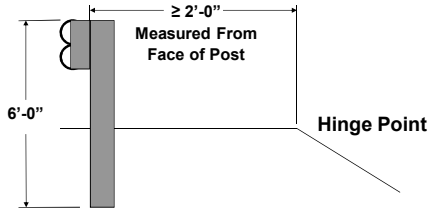
65

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



66

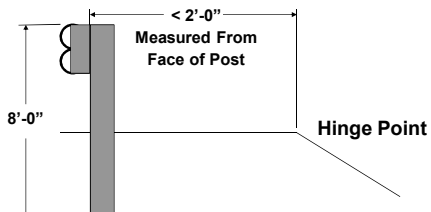
Type B Post Length Requirements



Specified in Standard Plan R-60-Series

67

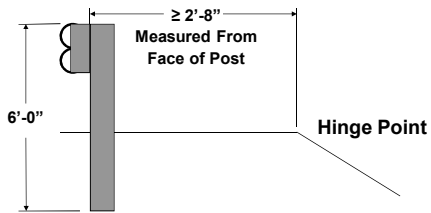
Type B Post Length Requirements



Specified in Standard Plan R-60-Series

68

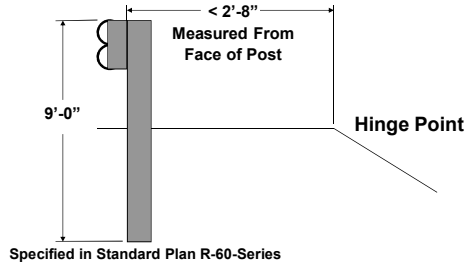
Type MGS-8 Post Length Requirements



Specified in Standard Plan R-60-Series

69

Type MGS-8 Post Length Requirements



70

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



71


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/BD
 - 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

72

Barrier Location

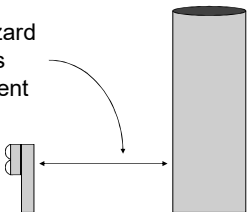
Place Barrier
As Far From
Traveled Way
As Possible



73

Barrier Location

Barrier to Hazard
Distance Is
Critical Element



74

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., 1st) to guardrail deflections listed in table

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

¹ An additional 12" or more to determine when feasible.
² Less than 2'-0" from the shoulder edge point to the face of guardrail post.

75

Terrain Effects



- Curbs
- Slopes

76

Curbs and Guardrail

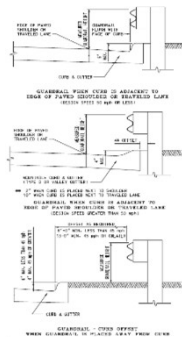


MUST Take Certain Precautions!!

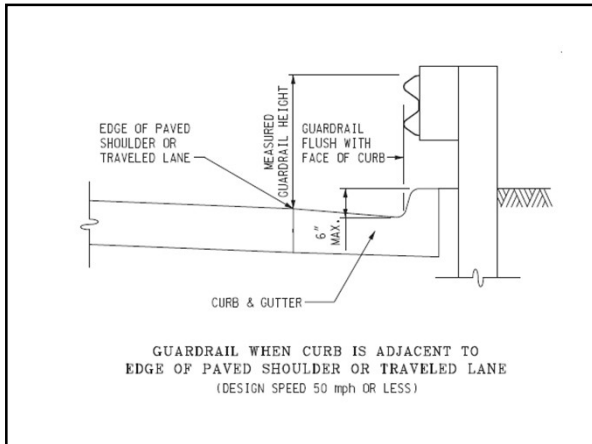
77

MDOT Guidelines Curb & Guardrail

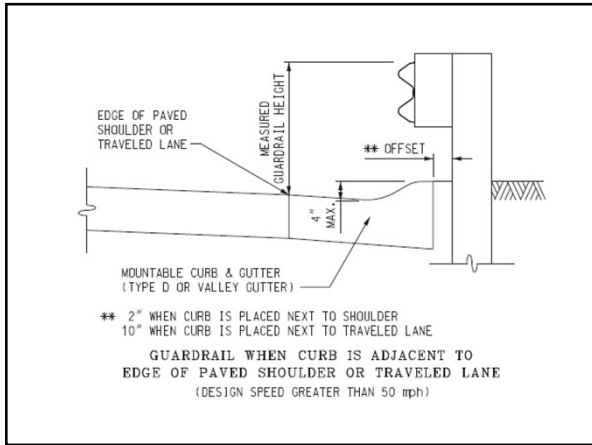
- Section 7.01.34 of the RDM discusses curb & guardrail
- Use only Type D or valley gutter when design speed >50 mph
- Follow offset and max curb height recommendations when guardrail is placed away from curb



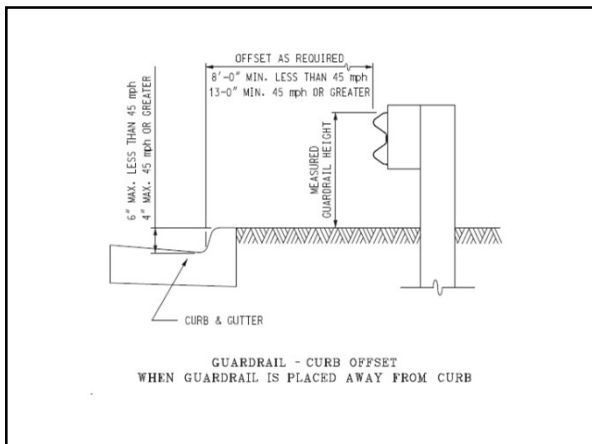
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79



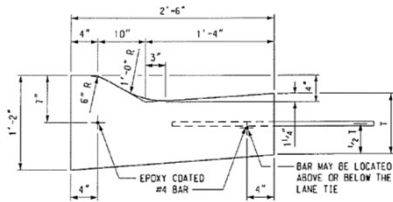
80



81



Type D Curb & Gutter MDOT Standard Plan R-30 Series



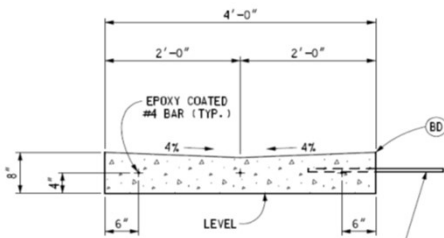
SEE NOTES WHEN PAVEMENT JOINT
IS SEALED WITH NEOPRENE

| DETAIL | DIMENSION | | LANE TIES | CONCRETE CYD / LF1 |
|--------|-----------|----------|-----------|-----------------------|
| | T | | | |
| D1 | 9" | AS SHOWN | 0.0788 | |
| D2 | 9" | OMITTED | 0.0788 | |
| D3 | 10" | AS SHOWN | 0.0826 | |

D

82

Valley Gutter MDOT Standard Plan R-33 Series



NOTE:
LANE TIE AND JOINT TO BE USED WHEN
ADJACENT TO CONCRETE SHOULDER

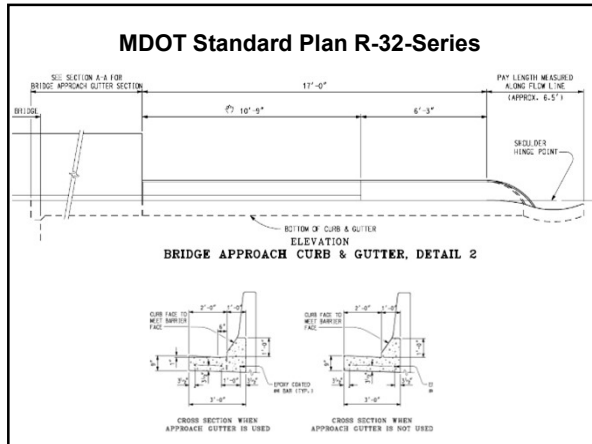
CONCRETE VALLEY GUTTER

83

Looks OK?



84



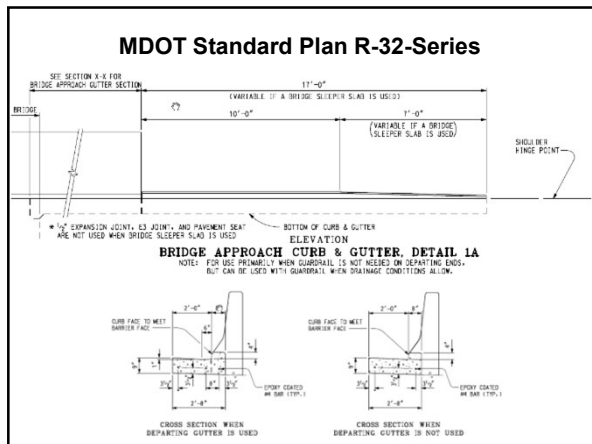
85

Looks OK?

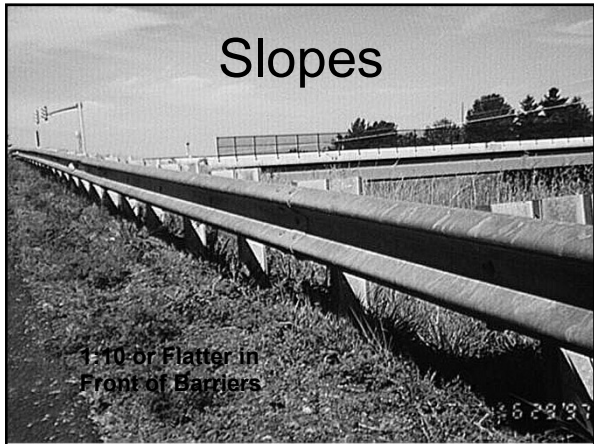
No !!

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

86



87



88

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 - TSMO Division)

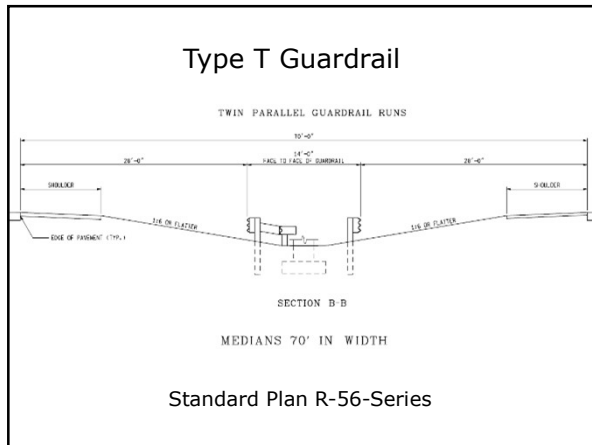
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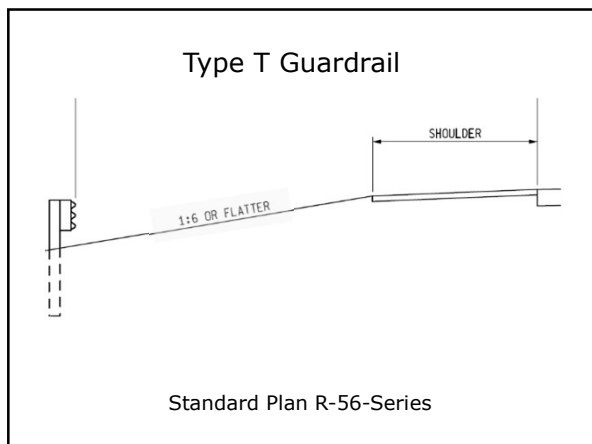
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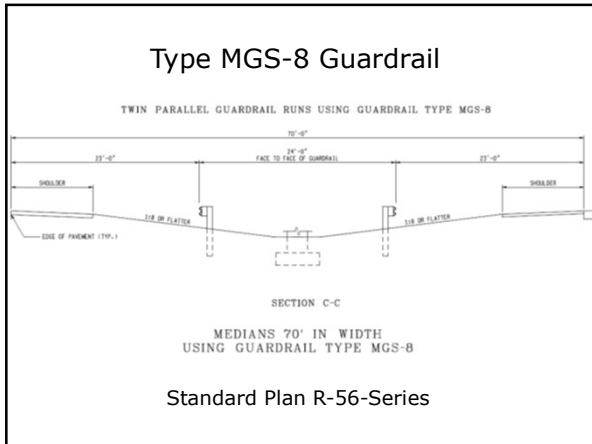
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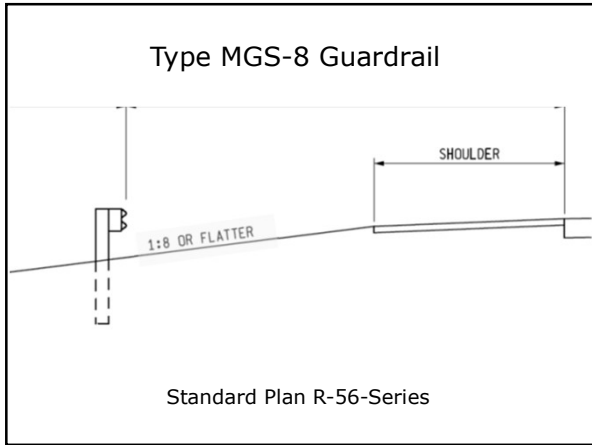
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93



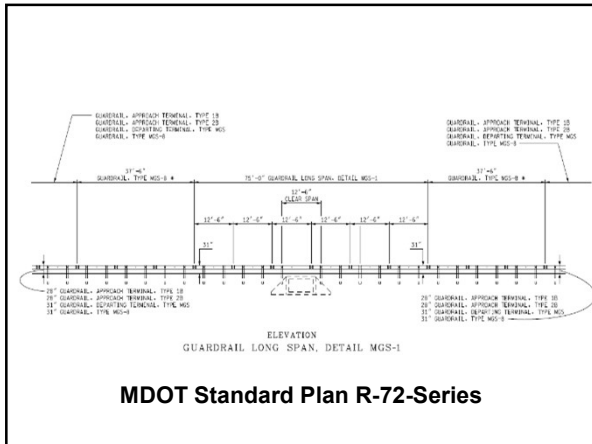
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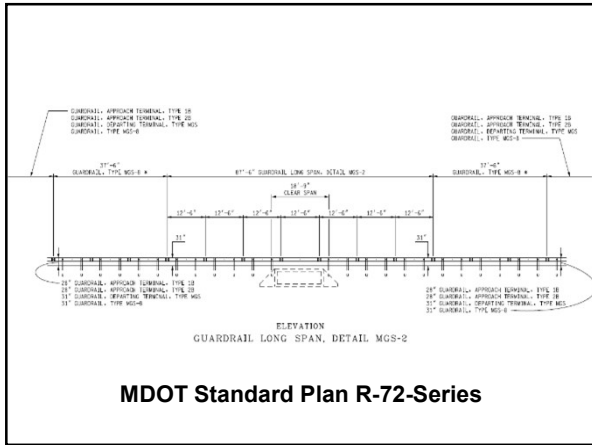
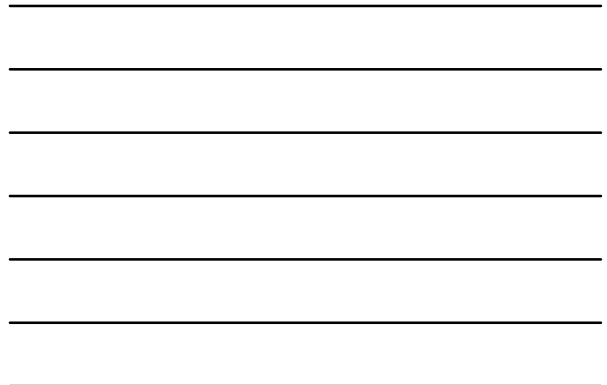
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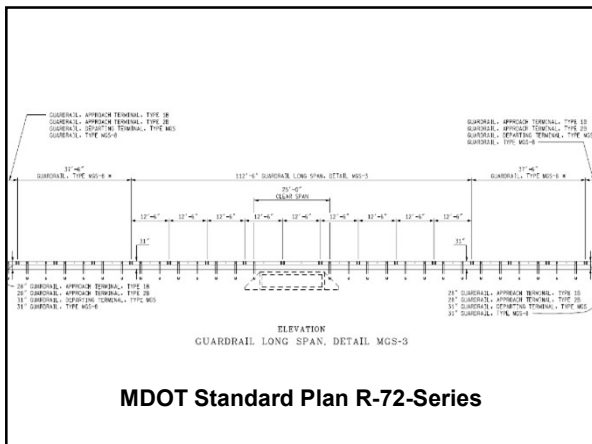
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97



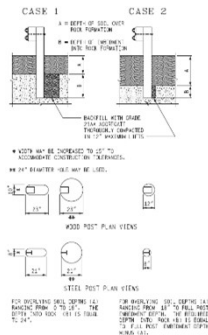
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99

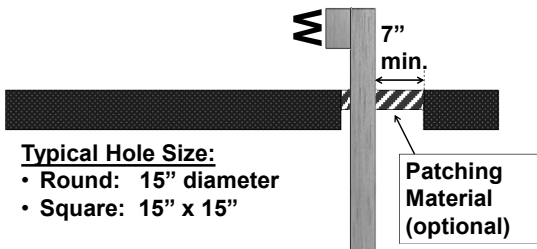


Placing Guardrail in Rock 7.01.33.C



100

Guardrail Posts through Paved Surfaces 7.01.33.D



101

Additional Blockouts on Guardrail Posts 7.01.33.E

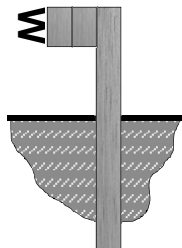
Double Blockouts (up to 16" deep)

- Not permitted on terminals
- No limit to the number of posts in a guardrail run that can have double blockouts

Multiple Blockouts (up to 36" deep)

- Not permitted on terminals
- Limited to one or two posts in a guardrail run
- May use up to four blockouts on one post

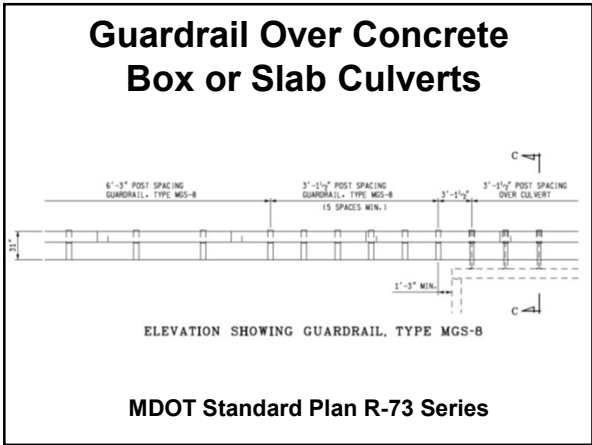
** MUST TAKE SLOPE BEHIND POST INTO CONSIDERATION!!! **



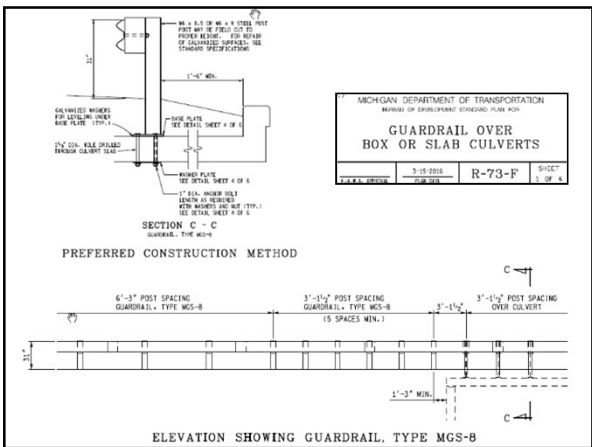
102



103

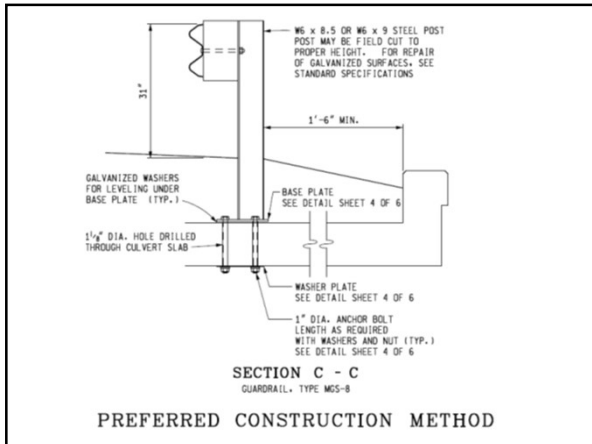


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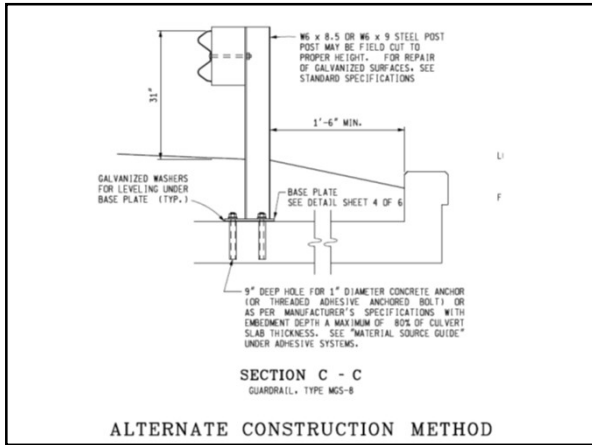


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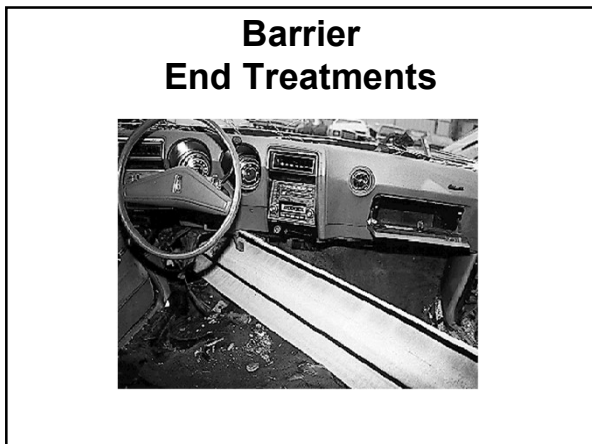




106



107



108

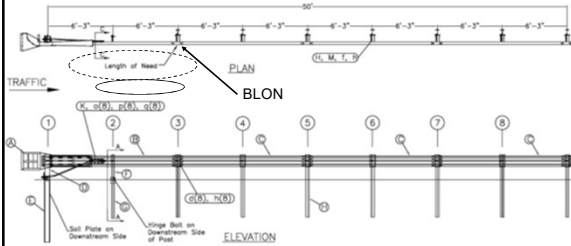
Guardrail Terminals

- Gating
- Non-Gating



109

Example of Gating Guardrail Terminals



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

110

Gating Terminal



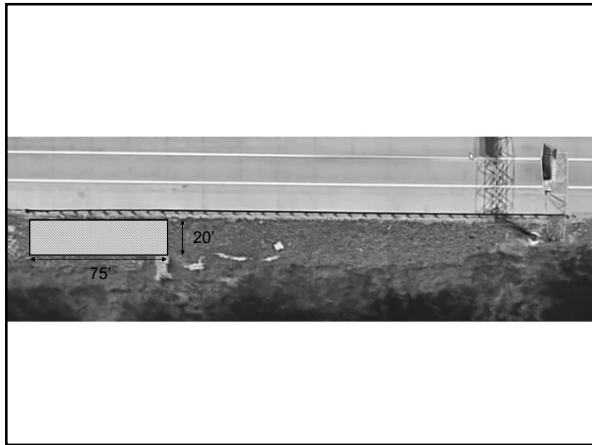
111

Gating Terminals

Section 7.01.25.E of RDM

- The area behind and beyond the terminal should be traversable and free of fixed objects
- A 20' x 75' (minimum) runout area beyond and parallel to the terminal should be provided

112



113

MDOT NCHRP 350 Compliant Guardrail Approach Terminals

Type 1 (Flared) Approach Terminals

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

114

SRT (Slotted Rail Terminal)



115

FLEAT (Flared Energy Absorbing Terminal)



116

MDOT NCHRP 350 Compliant Guardrail Approach Terminals

Type 2 (Parallel) Approach Terminals

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

117

ET (Extruder Terminal)



118



119

SKT (Sequential Kinking Terminal)



120



121

**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

122

**CAT (Crash Cushion
Attenuation Terminal)**

123

FLEAT-MT (Median Terminal)



124

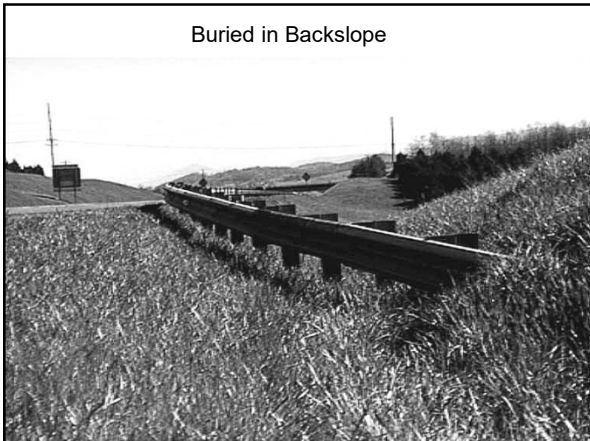
**MDOT
Guardrail Approach Terminals**

Type 4 (Buried in Backslope)

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

125

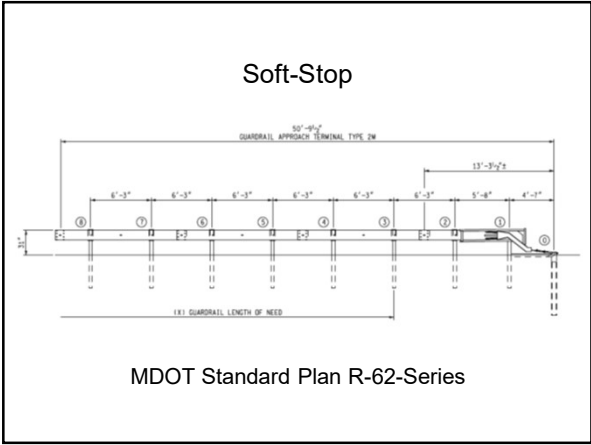
Buried in Backslope



126



127



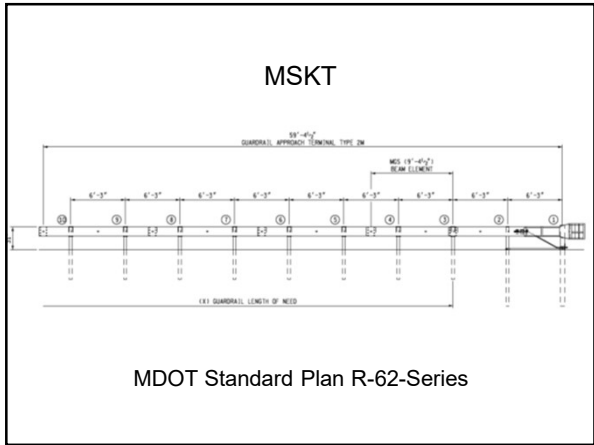
128



129



130

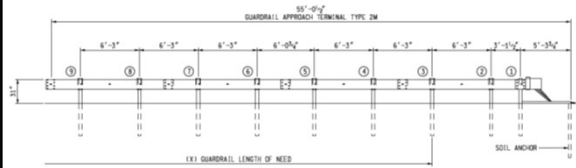


131



132

Max-Tension



MDOT Standard Plan R-62-Series

133

Max-Tension Crash Test Small Car (MASH, TL-3)



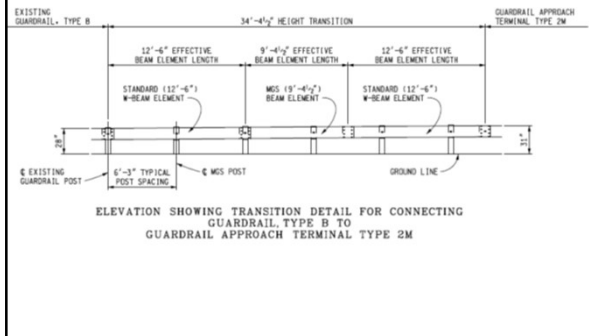
134

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



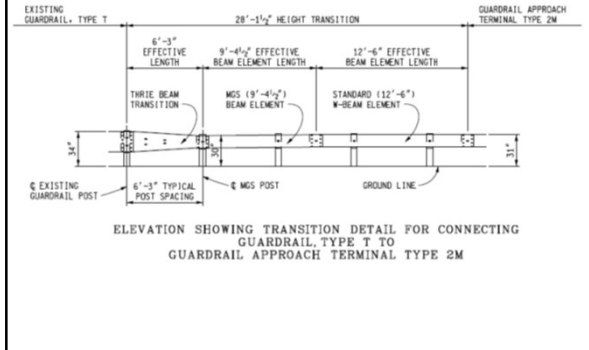
135

MDOT Standard Plan R-60-Series



136

MDOT Standard Plan R-60-Series



137

Guardrail Terminal Action Plan

- Use MASH-compliant, tangent (Type 2) guardrail approach terminals as an interim measure for all new installations and upgrades on projects let after June 30, 2018
 - Until multiple suitable flared terminal becomes available
- Use of NCHRP 350 compliant flared terminals will be permitted on a case-by-case basis
 - Consult with the MDOT Geometric Design Unit, TSMO Division for assistance

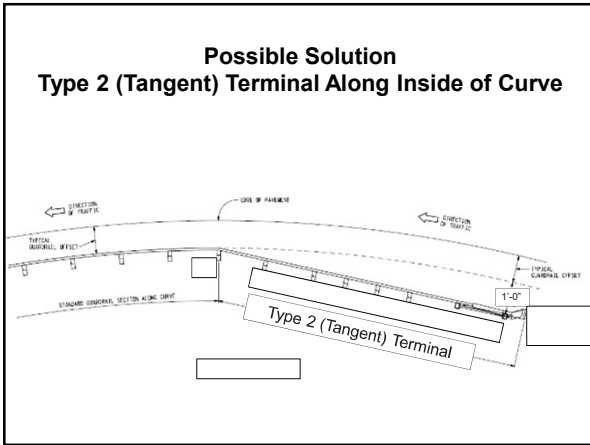
138



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

- Consult with MDOT Geometric Design Unit, TSMO Division

139



140

Guardrail Terminal Action Plan

- Type 2M guardrail terminals will be specified by frequently used special provision (FUSP) and Standard Plan R-62-Series
 - FUSP 12SP-807K-01
 - Design Advisory 2018-01 (Update: MASH-Compliant Terminals)
- Three terminals are approved for use (contractor's choice per the FUSP)
 - MSKT
 - Soft-Stop
 - MAX-Tension
- 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.

141

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.

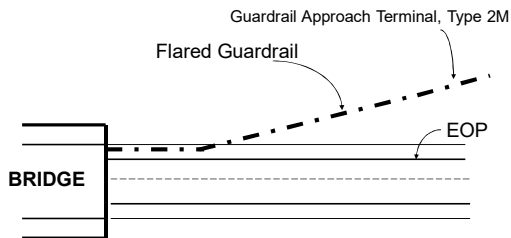
142

Guardrail Terminal Additions & Revisions

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

143

Can a Type 2 Terminal be Attached to Flared Guardrail?



Answer: YES

144

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

145

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., Three-Beam Guardrail)
- Terminal is not flared
- It has a semi-circular end shoe
- Last post does not have an offset block
- No ground strut



146

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



147

Curved Guardrail



148

Curved Guardrail

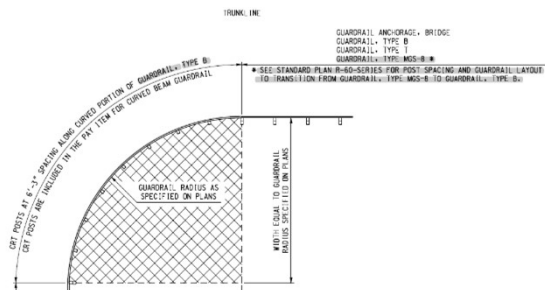
Key Features:

- 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**

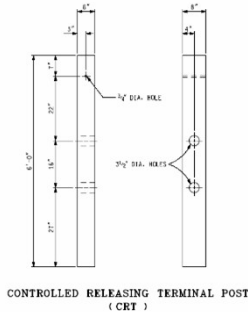
149

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



150

Use CRT Posts Along Curved Portion of Special Detail 21



151

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

152

Purpose of Cable Assembly



153

Grading

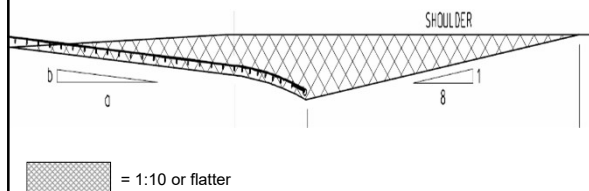
1:10 slope or flatter at least 2'-0" feet behind face of guardrail posts and tapering toward road at 1:8 flare rate in advance of terminal



Note, this applies to ALL guardrail approach terminals

154

Preferred Grading In Vicinity of Terminal



155

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 1:8 grading transition



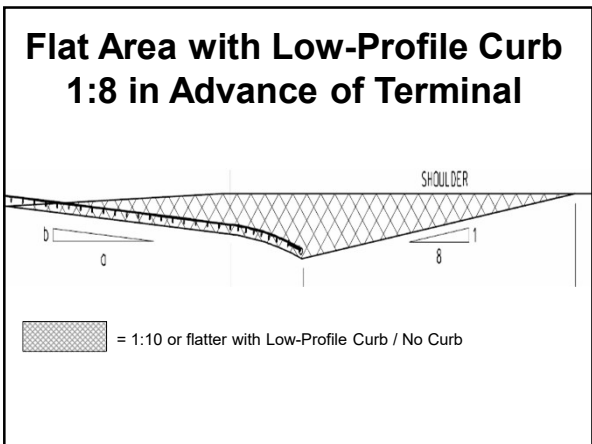
156



157



158



159

Guardrail Anchorages and Transitions



160

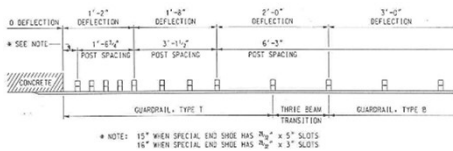
Anchorage & Transitions

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



161

Guardrail Strength Transition



- Typical transition from guardrail to concrete
- Must have gradual change in stiffness
 - Avoid sudden and extreme changes in stiffness


162



163

**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 Series

164

**MDOT Approved
Guardrail Transitions**

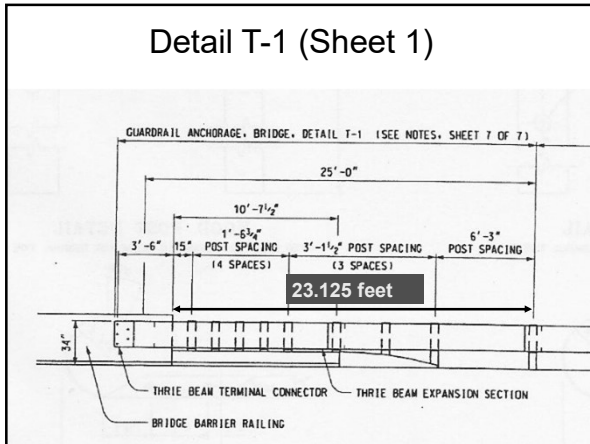
- Guardrail Anchorage
Bridge Detail T-4
- Guardrail Anchorage
Bridge Detail T-5
- Guardrail Anchorage
Bridge Detail T-6



Detailed in MDOT Standard Plan R-67 Series

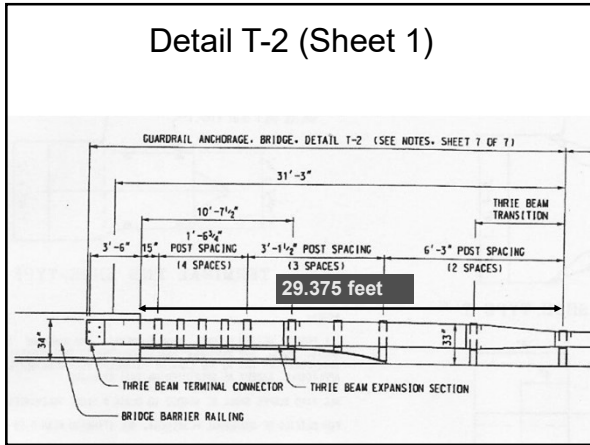
165

Detail T-1 (Sheet 1)



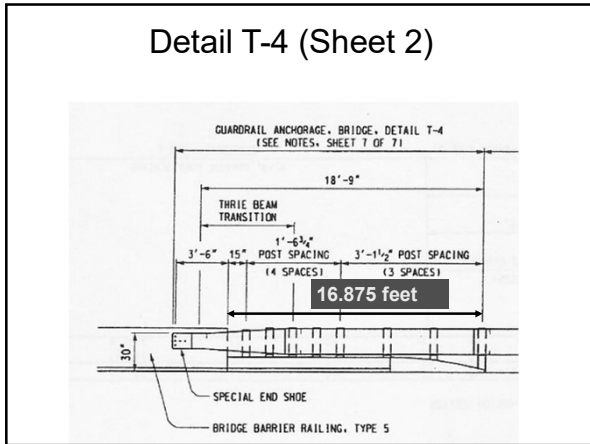
166

Detail T-2 (Sheet 1)



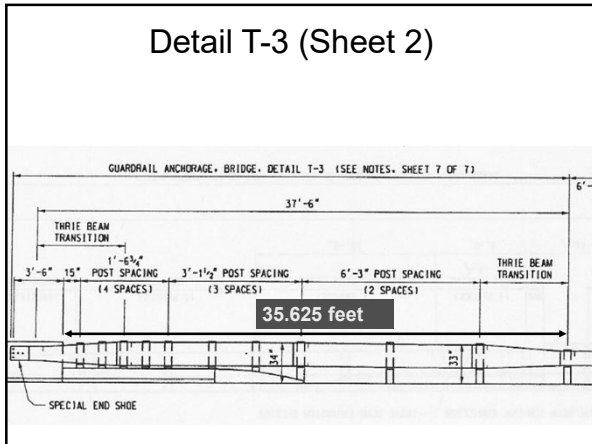
167

Detail T-4 (Sheet 2)



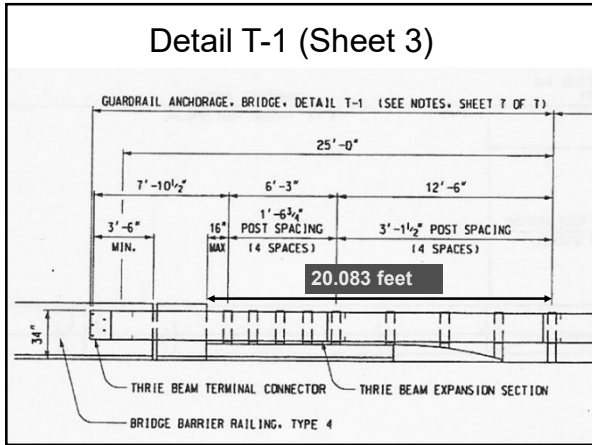
168

Detail T-3 (Sheet 2)



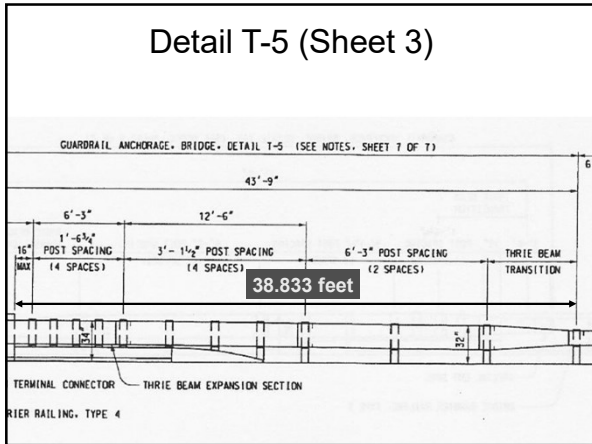
169

Detail T-1 (Sheet 3)



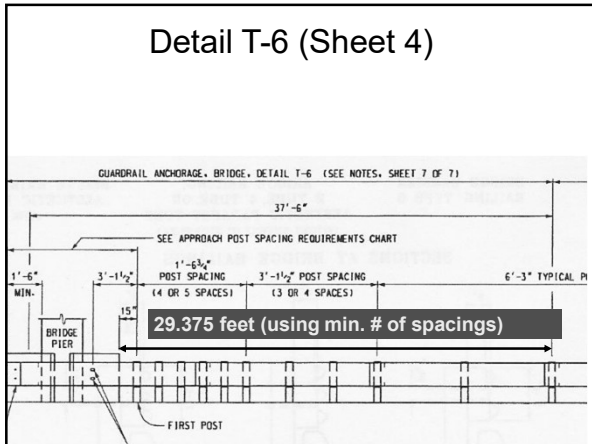
170

Detail T-5 (Sheet 3)



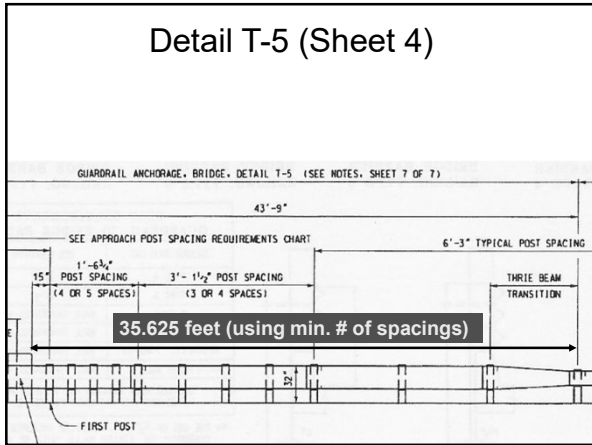
171

Detail T-6 (Sheet 4)



172

Detail T-5 (Sheet 4)



173

MDOT Approved Guardrail Transitions

- Guardrail Anchorage Bridge Detail A-1
- Guardrail Anchorage Bridge Detail A-2



Detailed in MDOT Standard Plan B-22 and B-23 Series

174

MDOT Approved Guardrail Transitions

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



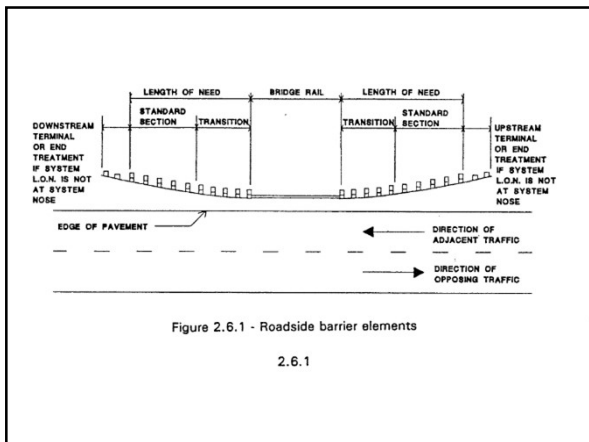
Detailed in MDOT Standard Plan R-71 Series

175

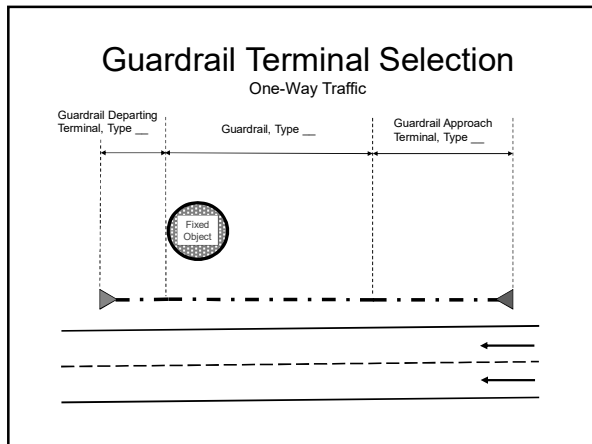
Barrier Design



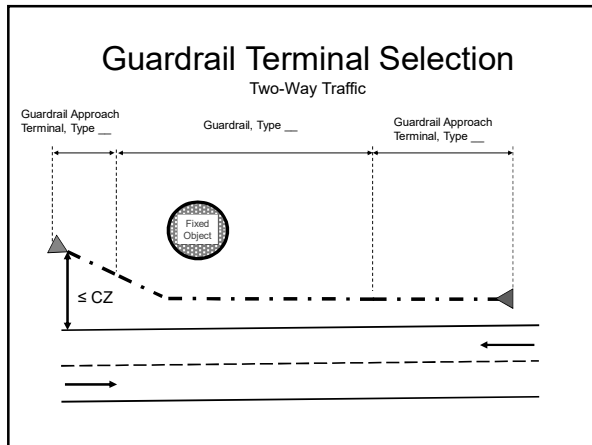
176



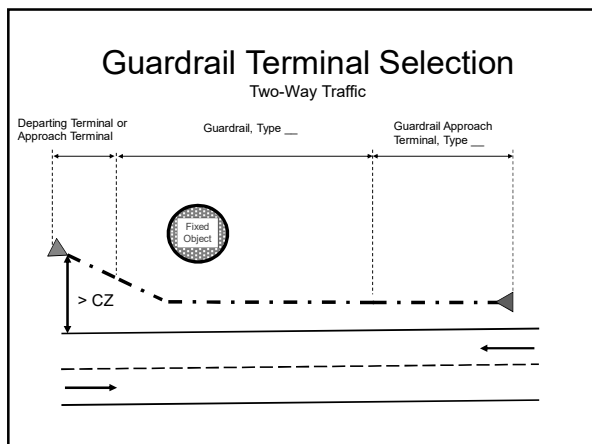
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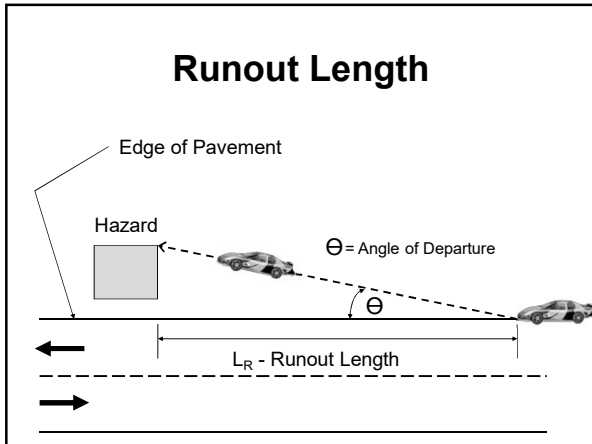
178



179



180



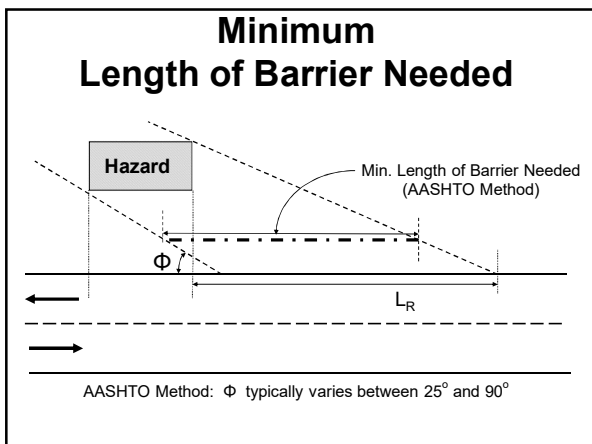
181

Runout Length

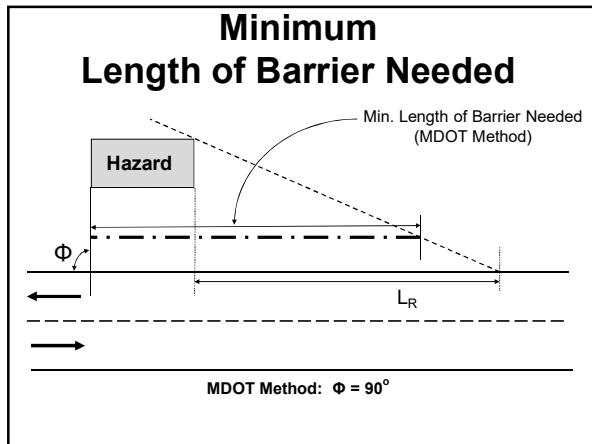
| Design Speed (mph) | Traffic Volume (ADT) veh/day | | | |
|--------------------|------------------------------|-------------------|-----------|------------|
| | Over 10,000 | Over 5,000-10,000 | 1000-5000 | Under 1000 |
| 80 | 470 | 430 | 380 | 330 |
| 70 | 360 | 330 | 290 | 250 |
| 60 | 300 | 250 | 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 permitted for intermediate design speeds
 - Example: DS = 75 mph & ADT = 12,000: $L_R = 415'$

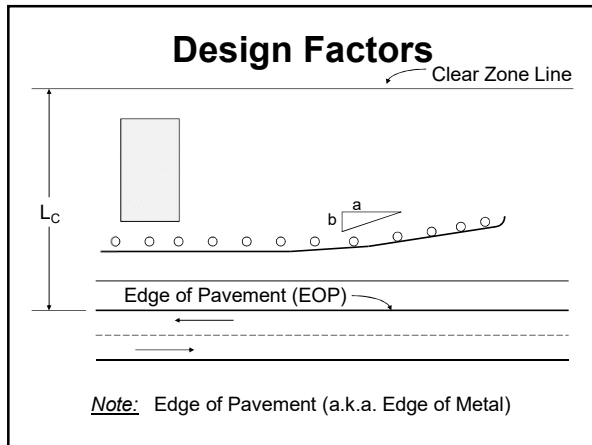
182



183



184



185

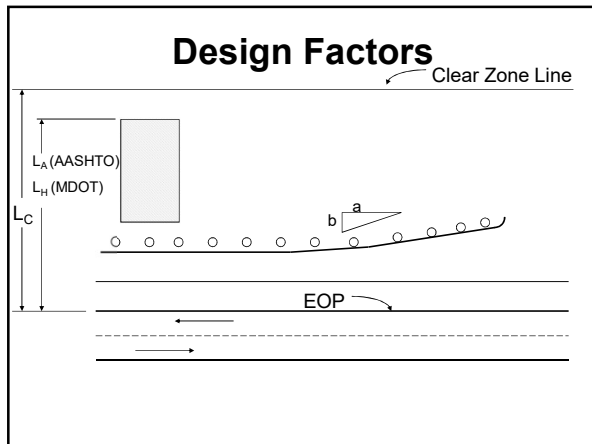
CLEAR ZONE DISTANCES
(IN FEET FROM EDGE OF DRIVING LANE)

| 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 | ** | 9-10 | 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 | 28-30 |
| ≥ 80 mph | under 750 | 18-20 | 20-26 | ** | 10-12 | 14-16 | 14-16 |
| | 750 - 1500 | 24-26 | 26-36* | ** | 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 |

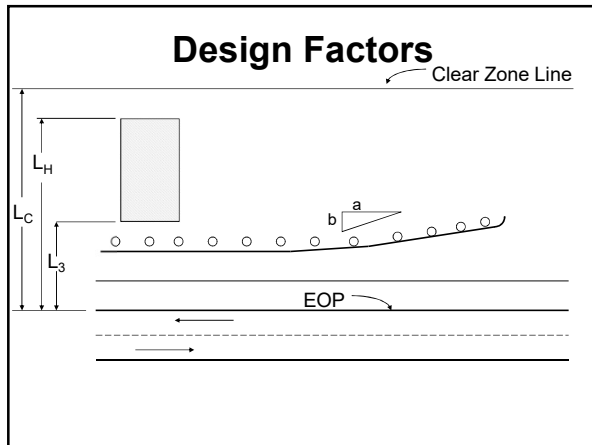
*Where a site specific investigation indicates a high probability of containing crashes, or such occurrences are indicated by crash history, the designer may provide clear zone distances greater than 30 feet as indicated. Clear zones may be limited to 30 feet for practicality and to provide a consistent 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.

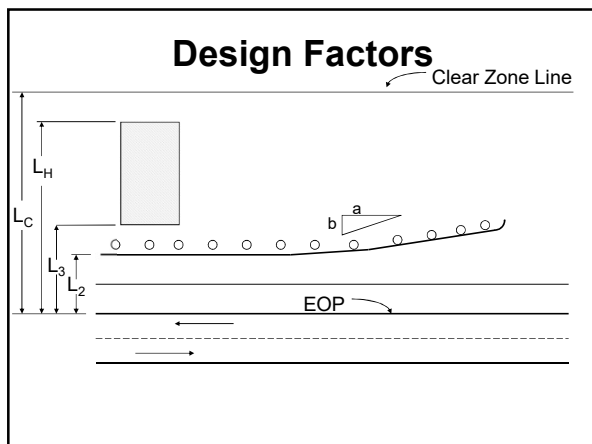
186



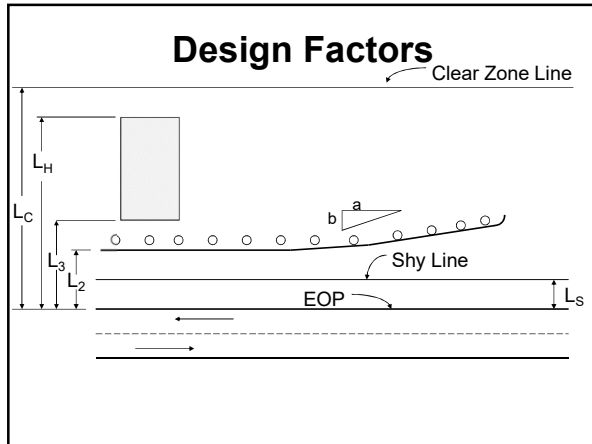
187



188



189



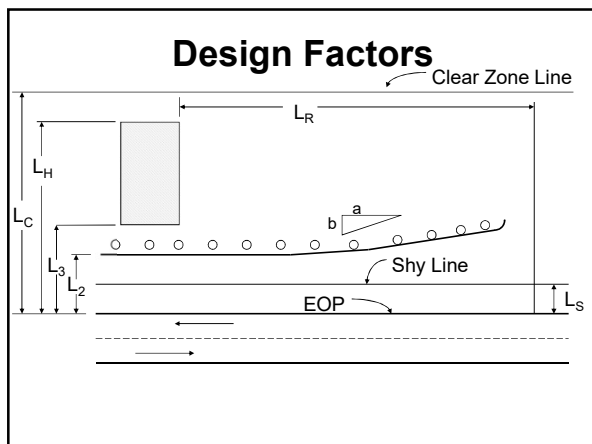
190

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

191



192

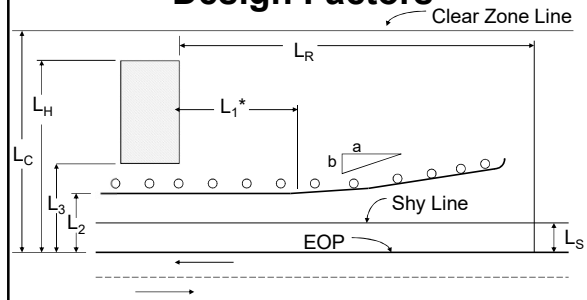
MDOT Runout Length Table

| 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

193

Design Factors

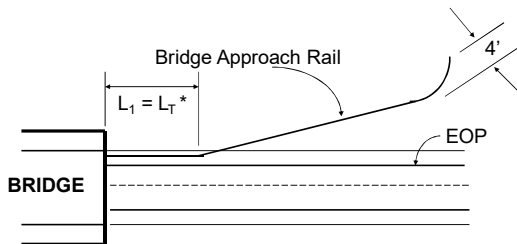


* MDOT Guardrail Worksheet specifies L_1 must be 25' min., but there are exceptions:

- Guardrail bridge anchorages
- Guardrail installations with a large offset between the hazard and the guardrail

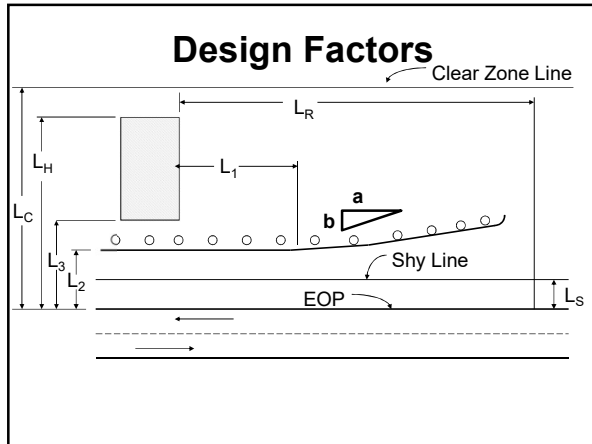
194

Bridge Approach Rail



* Use $L_1 = L_T$ even when $L_T < 25'$

195



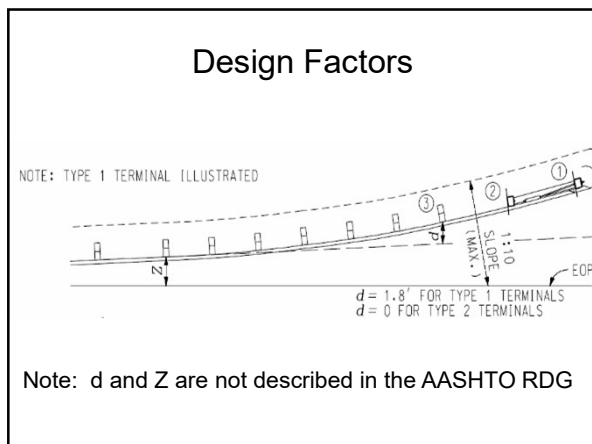
196

AASHTO RDG Table 5-9 Suggested Flare Rates (a:b)

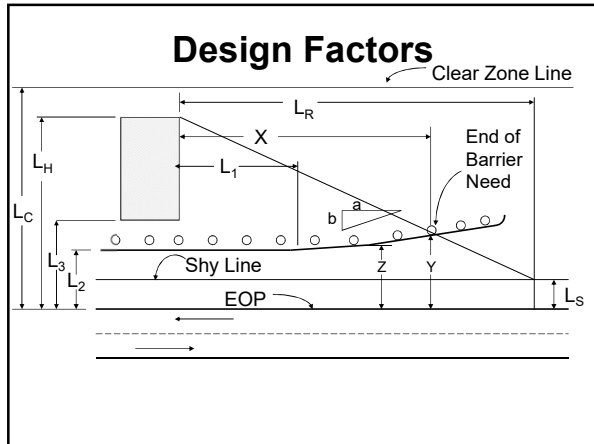
| Barrier Type | Barrier Height (ft) | Suggested Flare Rates (a:b) | |
|--------------|---------------------|-----------------------------|---------|
| | | Maximum | Minimum |
| *** | 42.0 | 1:1 | 1:1 |
| *** | 36.0 | 1:1 | 1:1 |
| ** | 30.0 | 1:1 | 1:1 |
| ** | 24.0 | 1:1 | 1:1 |
| ** | 18.0 | 1:1 | 1:1 |
| ** | 12.0 | 1:1 | 1:1 |
| ** | 6.0 | 1:1 | 1:1 |

*Suggested Maximum Flare Rate for Rigid Barrier Systems
**Suggested Maximum Flare Rate for Semi-Rigid Systems

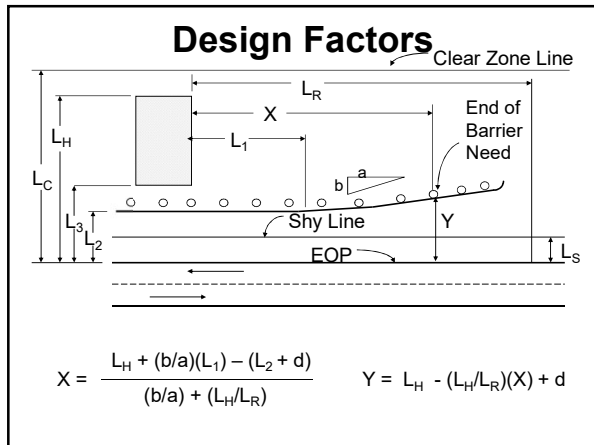
197



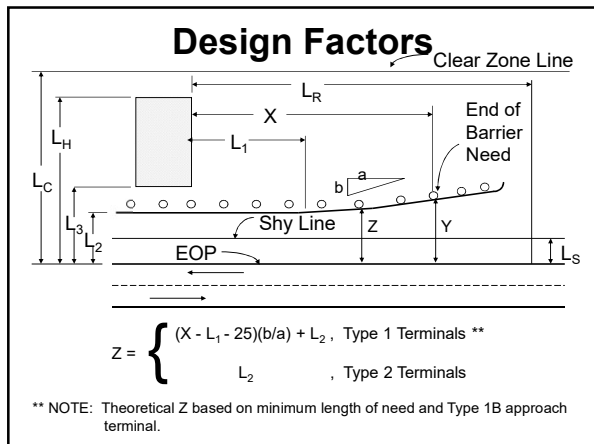
198



199

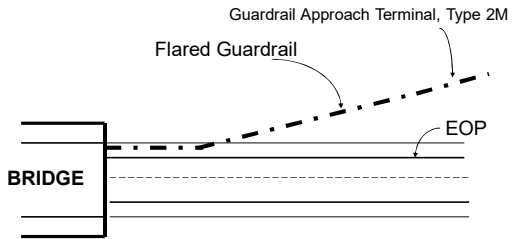


200



201

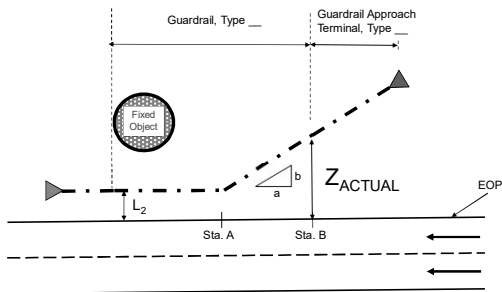
Type 2 Terminal Attached to Flared Guardrail



In this case, $Z \neq L_2$!!

202

Calculating Z_{ACTUAL}

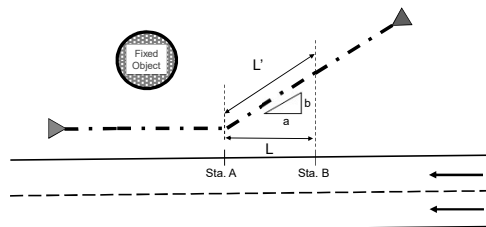


$$Z_{ACTUAL} = L_2 + |(Sta.B - Sta.A)| \times (b/a)$$

203

Calculating Stations A and B

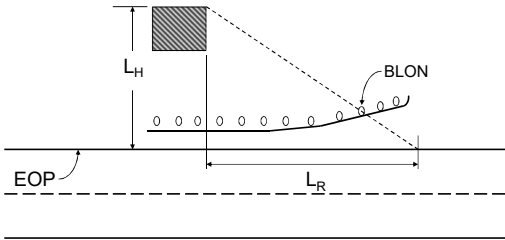
Does Flaring Affect the Calculations?



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

204

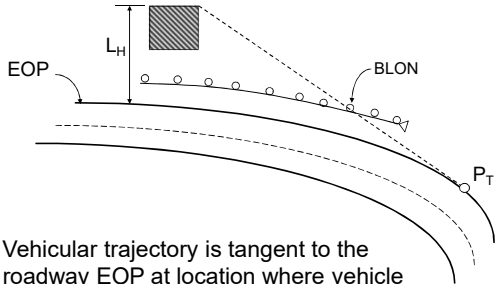
Graphic Solution



Vehicular trajectory must intersect or be located in advance of beginning length of need (BLON) point

205

Horizontal Curve Solution



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

206

Length of Need – Approach End Flared vs. Parallel

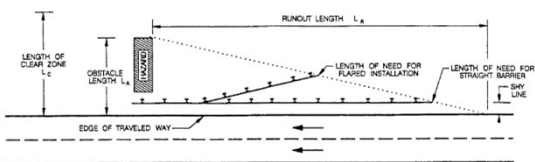
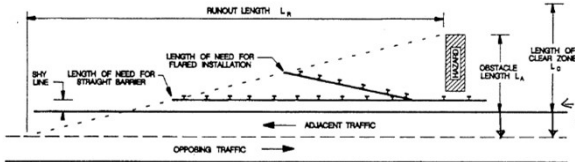


Figure 2.6.5 - Simplified representation of length of need

Flaring the guardrail reduces the length of need (X)

207

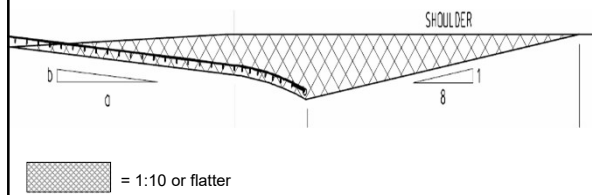
Length of Need – Departing End Flared vs. Parallel



Flaring the guardrail reduces the length of need (X)

208

Grading Requirements

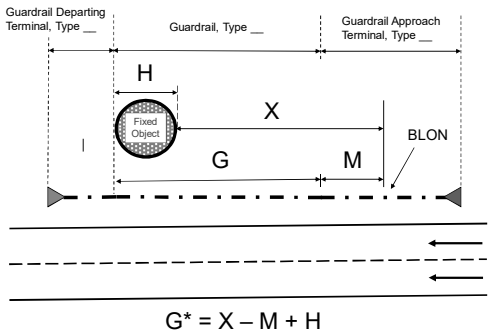


- Grading requirements for flared installations may be impractical or cost-prohibitive
- Decision to install flared or parallel guardrail run is site-specific

209

Calculating Length of Guardrail

Freestanding Guardrail Shielding Fixed Object & One-Way Traffic



210

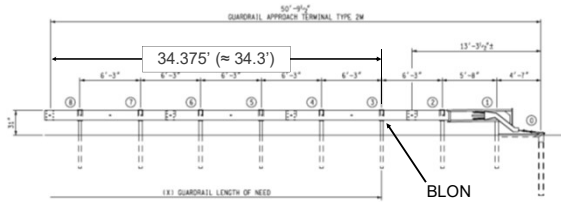
M (Deduction Value) MDOT Guardrail Worksheet

| 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

211

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

212

Calculating Length of Guardrail

Freestanding Guardrail Shielding Fixed Object & One-Way Traffic

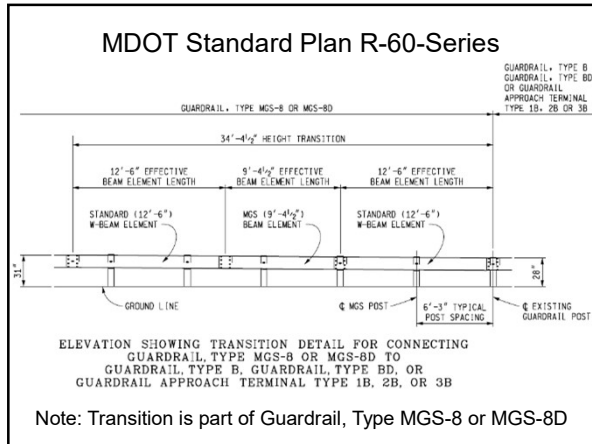
- H = fixed object width
- M = portion of approach terminal located within length of need
 - Deduction values from guardrail worksheet
- G = guardrail quantity

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

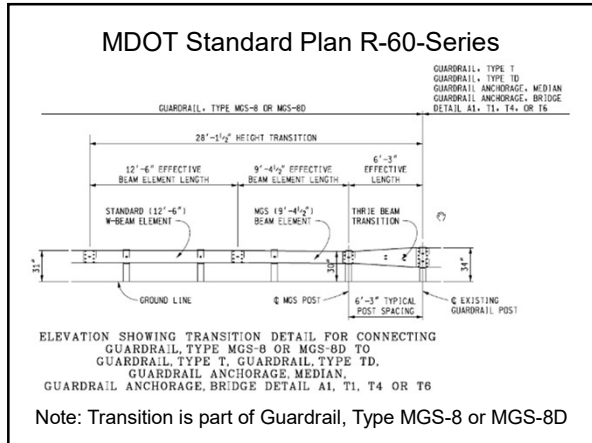
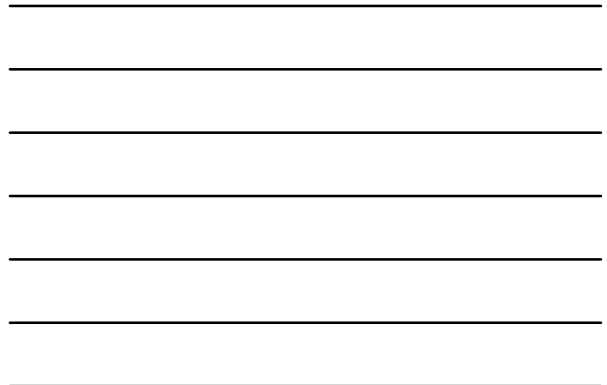
* Important Notes

- 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

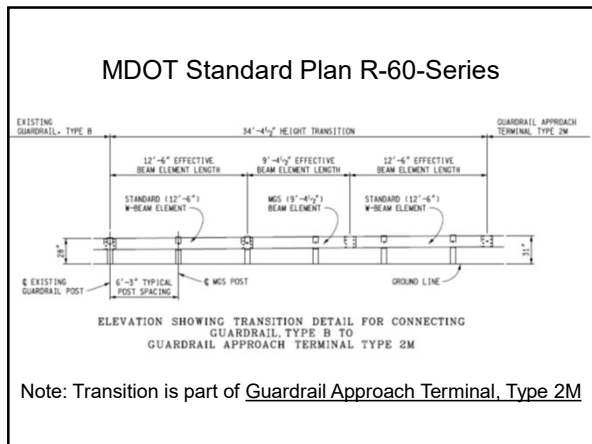
213



214

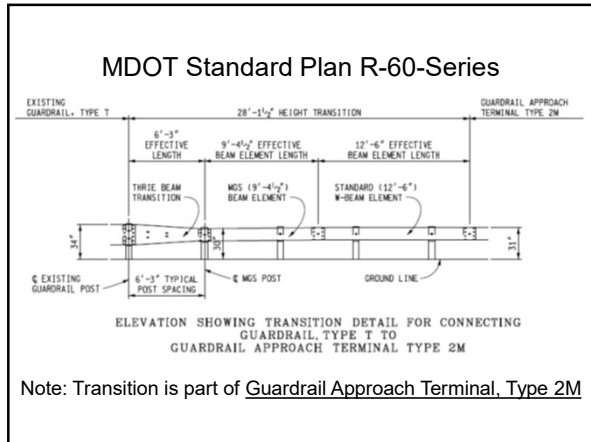


215

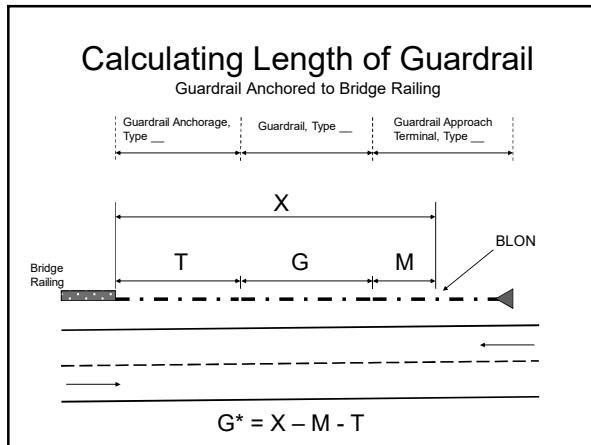


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217



218

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 T-1 through T-6 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

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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

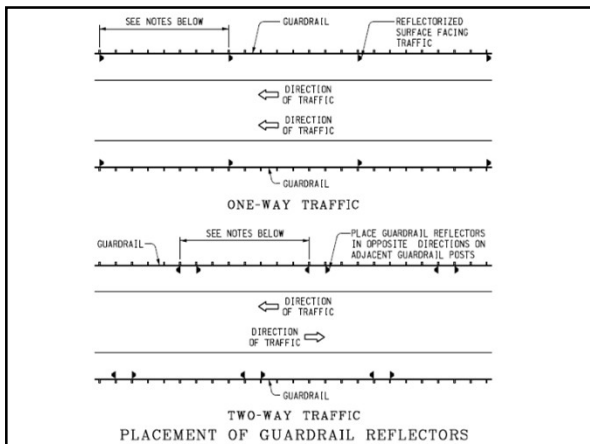
* Total Guardrail Length, including anchorages, but excluding approach terminals

220

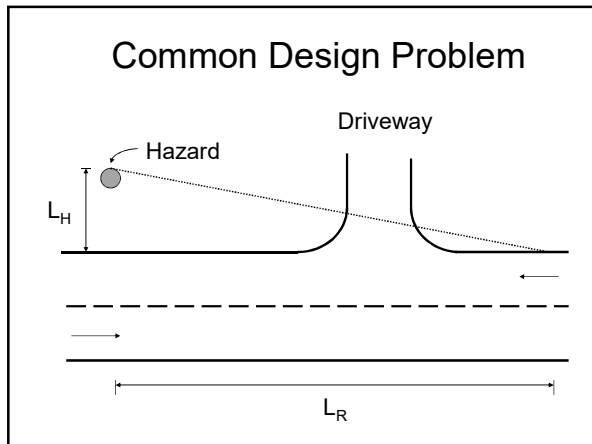
Reflectors

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

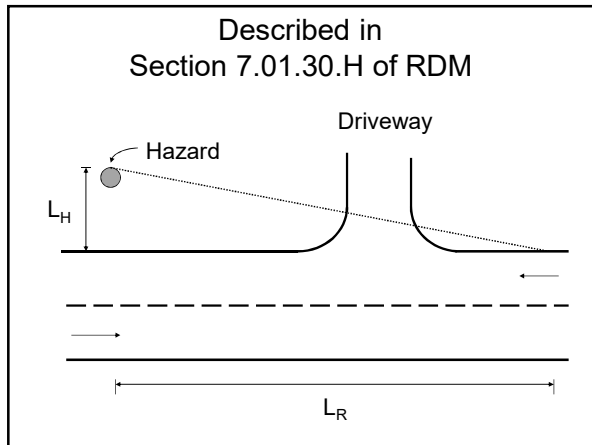
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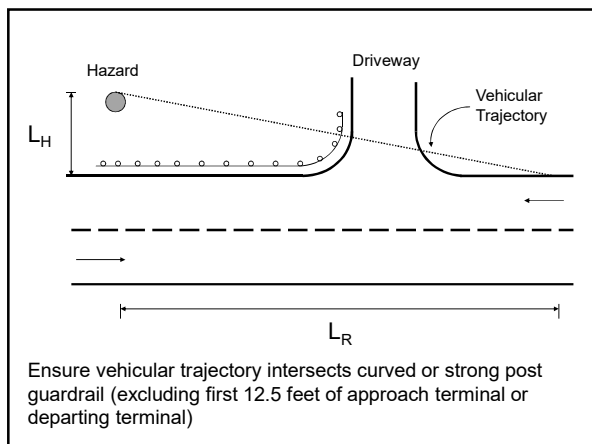
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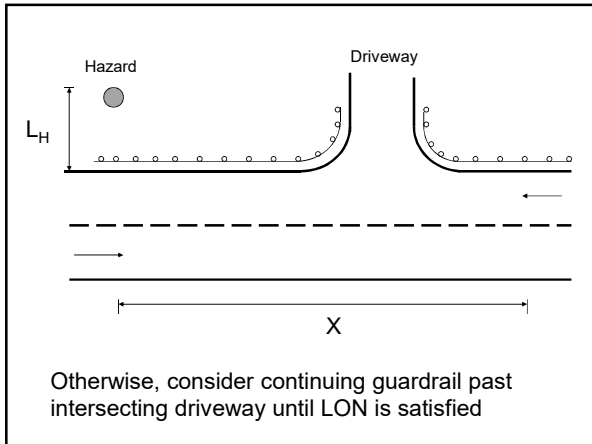
223



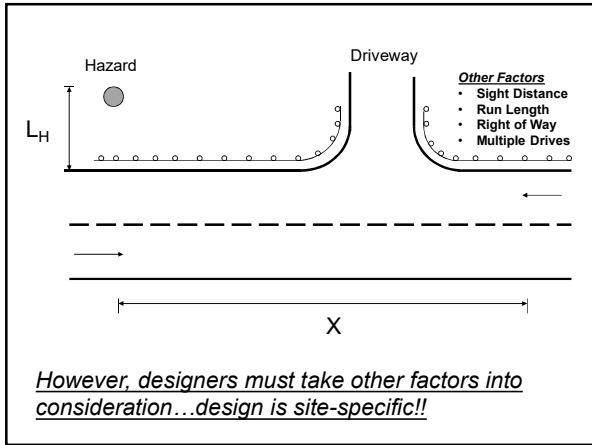
224



225



226



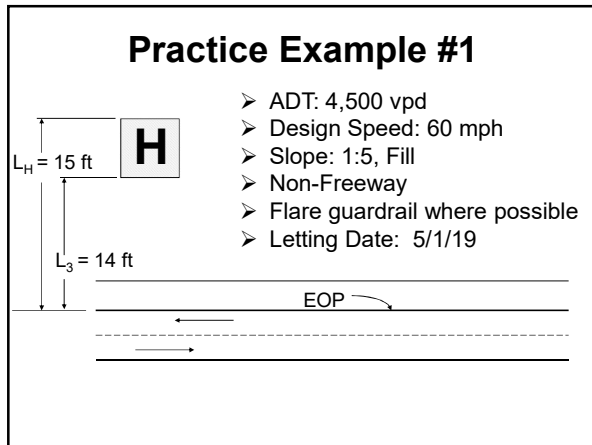
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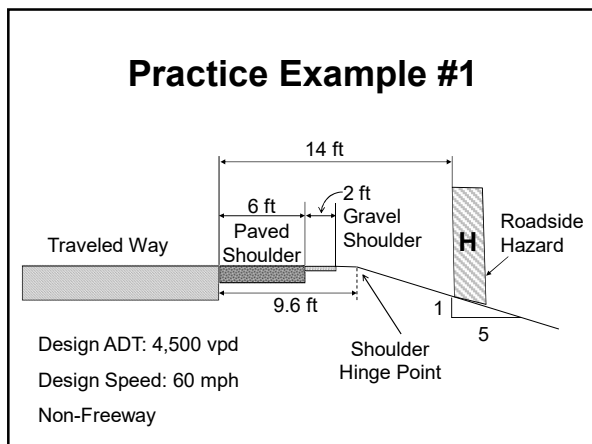
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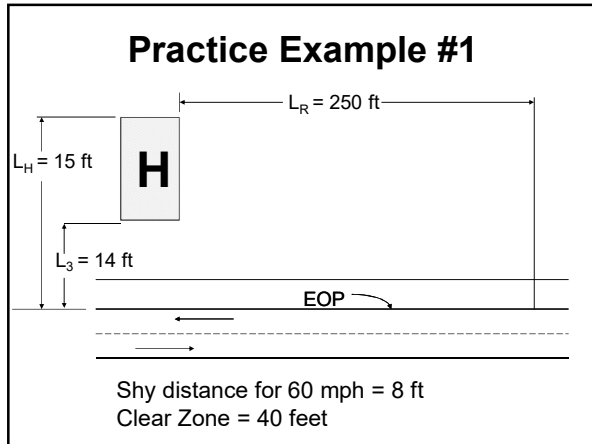
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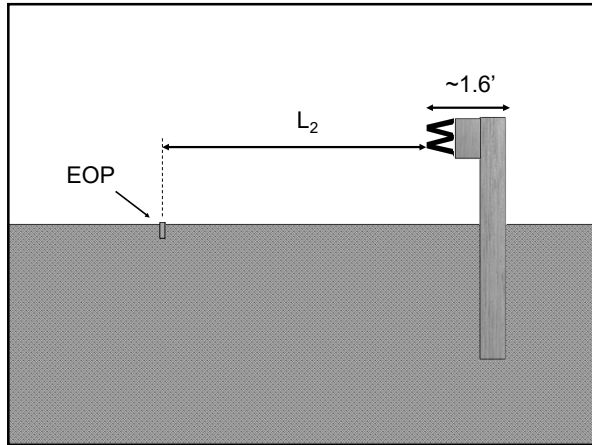
230



231



238



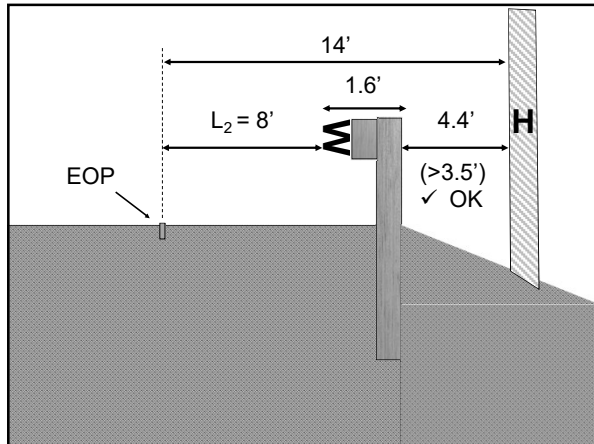
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MDOT Guardrail Deflection Table

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

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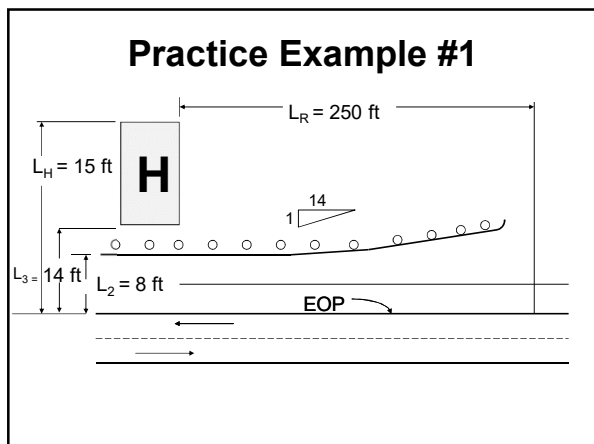
241

**AASHTO RDG Table 5-9
Suggested Flare Rates (a:b)**

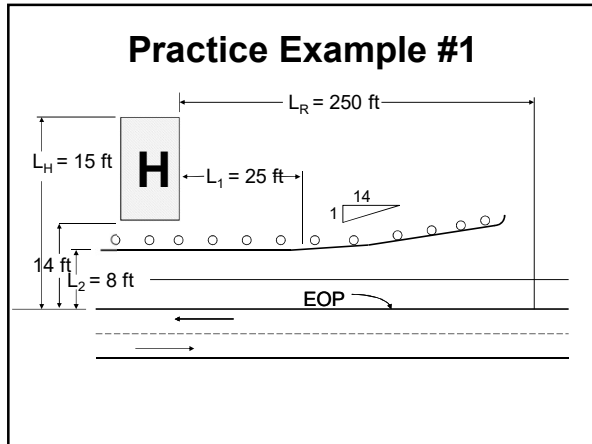
| Barrier Type | Flare Rate (a:b) | Barrier Type | Flare Rate (a:b) |
|--------------|------------------|--------------|------------------|
| *** | 1:1 | *** | 1:1 |
| *** | 1:1 | *** | 1:1 |
| *** | 1:1 | *** | 1:1 |
| *** | 1:1 | *** | 1:1 |
| *** | 1:1 | *** | 1:1 |
| *** | 1:1 | *** | 1:1 |
| *** | 1:1 | *** | 1:1 |
| *** | 1:1 | *** | 1:1 |
| *** | 1:1 | *** | 1:1 |
| *** | 1:1 | *** | 1:1 |

*Suggested Maximum Flare Rate for Rigid Barrier Systems
**Suggested Maximum Flare Rate for Semi-Rigid Systems

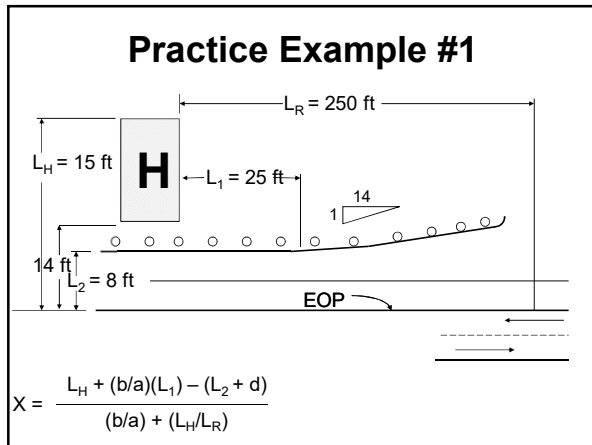
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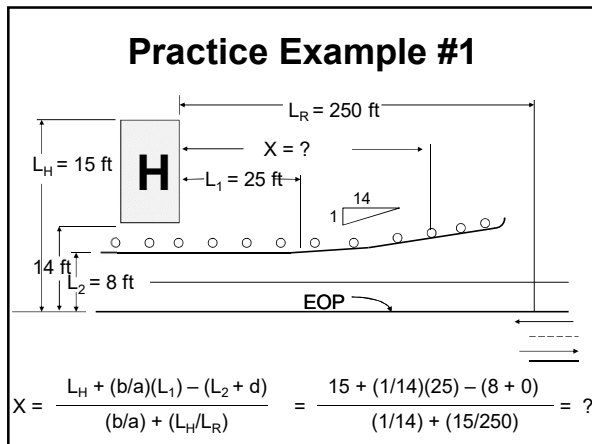
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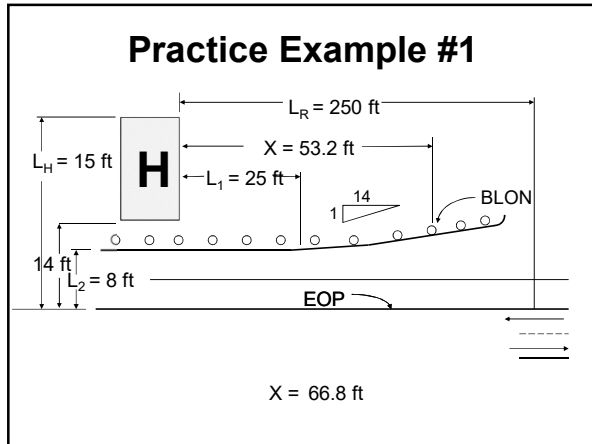
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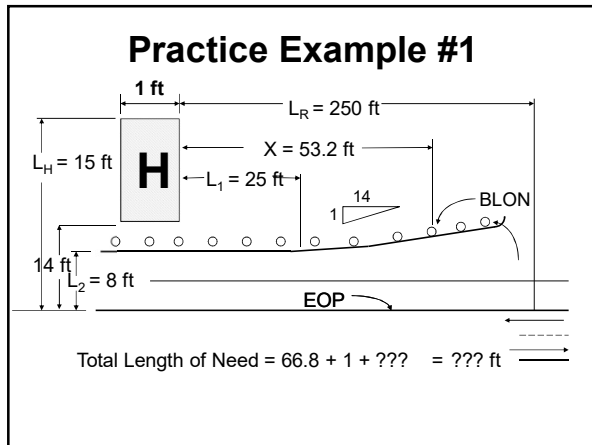
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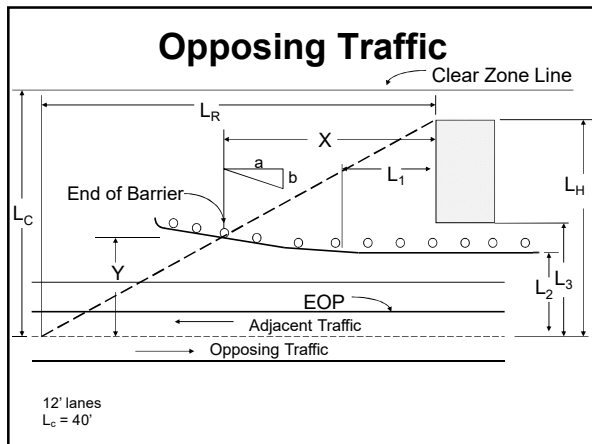
246



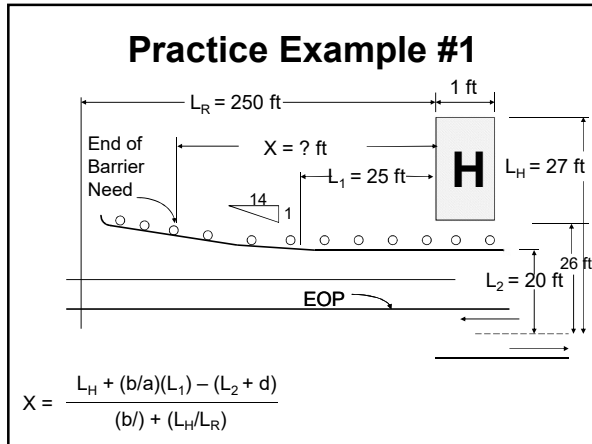
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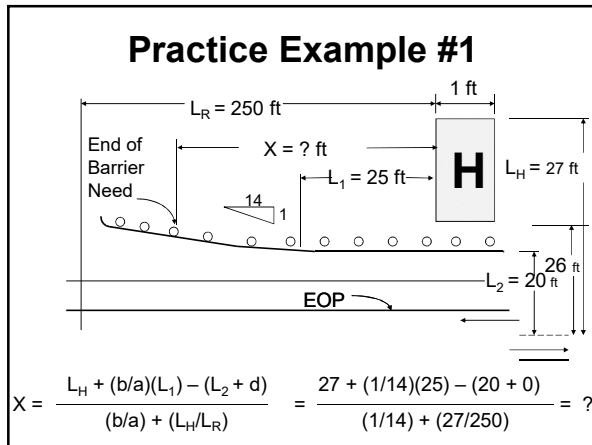
248



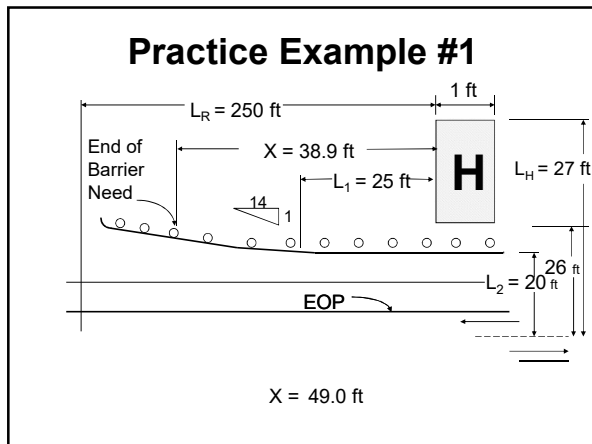
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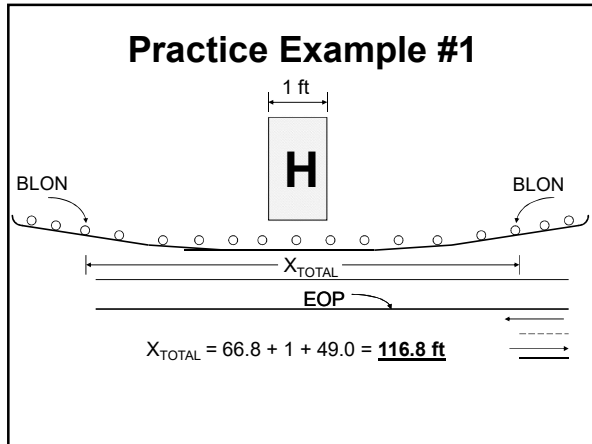
250



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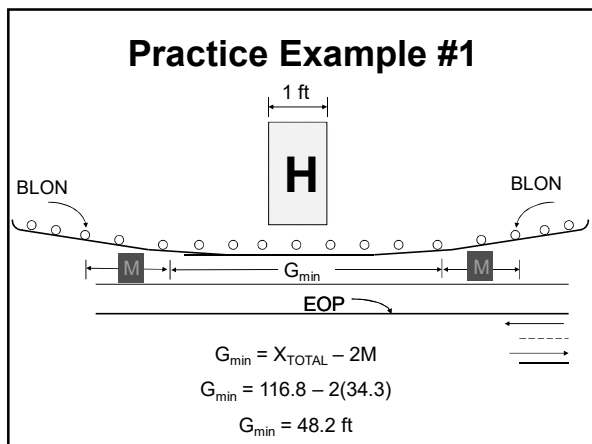


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Deduction Value Type 2M Approach Terminal MDOT Guardrail Worksheet

| 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' |

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255

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*

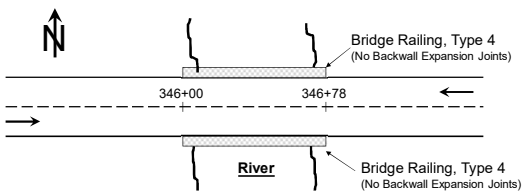
$$N_R = \left(\frac{50}{50} \right) + 1 = 2 \longrightarrow 2$$

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

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

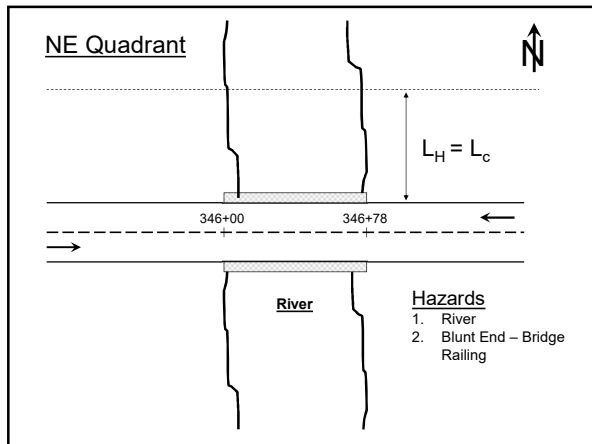
257

Practice Example #2

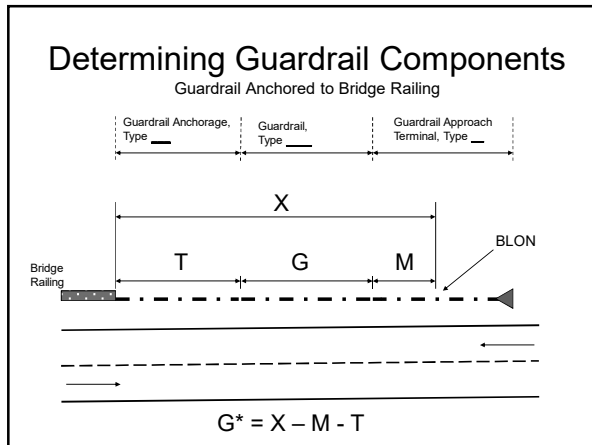


| | |
|--|--|
| <p>Assignment – NE & NW Quadrants Only</p> <ol style="list-style-type: none"> 1. Identify all roadside hazards. 2. Determine if guardrail is needed. 3. If necessary, design guardrail and calculate quantities using guardrail worksheet. | <p>Design Data & Assumptions</p> <ul style="list-style-type: none"> • Rural Two-Lane Road • Design Speed = 55 mph • ADT = 5,000 vpd • River is 6' deep • 1:5 Slope in advance of bridge ends • Flare guardrail where possible • Letting Date: 5/1/19 |
|--|--|

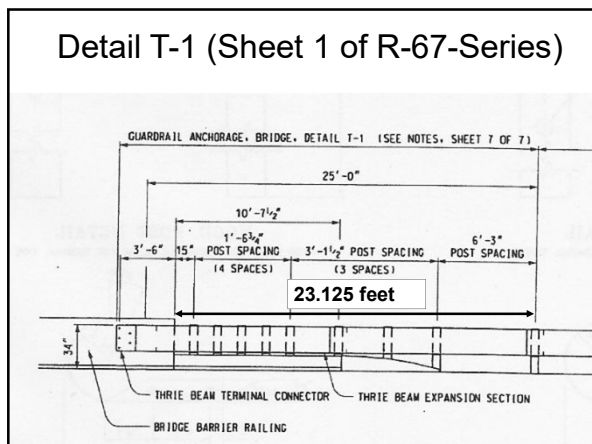
258



259



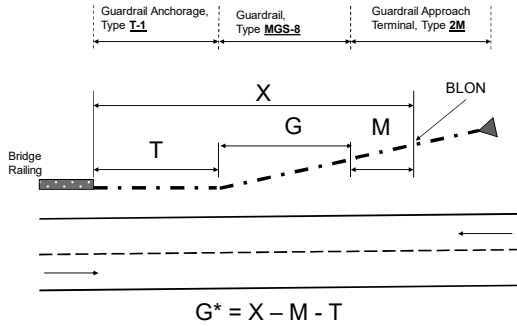
260



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Determining Guardrail Components

Guardrail Anchored to Bridge Railing



262

GUARDRAIL WORKSHEET

ROUTE: Practice Example R2 CONTROL SECTION 99999 JOB # EXAMPLE
 DESIGNED BY: ABC DATE 2005/1/18 CHECKED BY: XYZ DATE 00/01/18
 APPROX. STATION OR W.P. 340+78 DESCRIPTION: Practice Example R2

GUARDRAIL RUN # THE QUAD

IF STATIONING IS NOT AVAILABLE, LOCATE TO NEAREST FIXED OBJECT

NOTE: TYPE 1 TERMINAL ILLUSTRATED

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

| | | | |
|--|------------------------------|-------------------------------|-----------|
| LENGTH OF NEED | $X = 113.76'$ | DESIGN ADT | 5,000 vpd |
| RUNOUT LENGTH (7.01.19) | $L_R = 185'$ | DESIGN SPEED | 55 mph |
| GUARDRAIL TAPER RATE (R-59-SERIES) | $\frac{b}{a} = \frac{1}{12}$ | 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) | $L_3 = 4'$ | $L_8 = 7'$ SHY LINE (7.01.18) | |
| EFFECTIVE TURNED OUT DISTANCE OF ANCHORAGE ... d | $d = 0$ | STATION AT A | -347+01.1 |
| LATERAL EXTENT OF ROADSIDE FEATURE (MEASURED) | $L_H = 30'$ | STATION AT B | -347+66.8 |
| LATERAL OFFSET AT END OF FLARE | $Z = 9.47'$ ** | | |

NOTE: DISTANCE OF OBJECT FROM FACE OF BARRIER MUST BE GREATER THAN THE MAXIMUM DEFLECTION (7.01.20) ** Refer to Calculations and Notes
 $L_9 = L_8$
 REFER TO STANDARD PLAN R-59-SERIES AND DESIGN MANUAL SECTION 7.01.20 FOR GUARDRAIL TERMINALS

SHEET 1 OF 1

263

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

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

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

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

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

| | | | |
|--|------------------------------|-------------------------------|-----------|
| LENGTH OF NEED | $X = 113.76'$ | DESIGN ADT | 5,000 vpd |
| RUNOUT LENGTH (7.01.19) | $L_R = 185'$ | DESIGN SPEED | 55 mph |
| GUARDRAIL TAPER RATE (R-59-SERIES) | $\frac{b}{a} = \frac{1}{12}$ | 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) | $L_3 = 4'$ | $L_8 = 7'$ SHY LINE (7.01.18) | |
| EFFECTIVE TURNED OUT DISTANCE OF ANCHORAGE ... d | $d = 0$ | STATION AT A | -347+01.1 |
| LATERAL EXTENT OF ROADSIDE FEATURE (MEASURED) | $L_H = 30'$ | STATION AT B | -347+66.8 |
| LATERAL OFFSET AT END OF FLARE | $Z = 9.47'$ ** | | |

NOTE: DISTANCE OF OBJECT FROM FACE OF BARRIER MUST BE GREATER THAN THE MAXIMUM DEFLECTION (7.01.20) ** Refer to Calculations and Notes
 $L_9 = L_8$
 REFER TO STANDARD PLAN R-59-SERIES AND DESIGN MANUAL SECTION 7.01.20 FOR GUARDRAIL TERMINALS

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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 |

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** Must interpolate in this case to obtain L_R

265

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

$$X = \frac{L_R - (L_R \cdot d)}{\left(\frac{\text{No Flare (or Type 2 Terminal)}}{L_W}\right) - \frac{L_R}{L_B}}$$

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

$$Z = L_B \text{ (For Type 0 Terminals)}$$

| | | | |
|---|----------------------|---------------------------------|-----------|
| LENGTH OF NEED | $X = 113.76'$ | DESIGN ADT | 5,000 vpd |
| RUNOUT LENGTH (7.01.19) | $L_R = 185'$ | 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) | $L_D = 4'$ | $L_B = 7'$ 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) | $L_E = 30'$ | STATION AT B | -347+66.8 |
| LATERAL OFFSET AT END OF FLARE | $Z = 9.47'$ ** | | |

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AASHTO RDG Table 5-9 Suggested Flare Rates (a:b)

| Design Speed (mph) | 1000-5000 | 5000-10000 | 10000-20000 | 20000+ |
|--------------------|-----------|------------|-------------|--------|
| 80 | 3:1 | 3:1 | 3:1 | 3:1 |
| 70 | 3:1 | 3:1 | 3:1 | 3:1 |
| 60 | 3:1 | 3:1 | 3:1 | 3:1 |
| 50 | 3:1 | 3:1 | 3:1 | 3:1 |
| 40 | 3:1 | 3:1 | 3:1 | 3:1 |
| 30 | 3:1 | 3:1 | 3:1 | 3:1 |

*Suggested Maximum Flare Rate for Rigid Barrier Systems

**Suggested Maximum Flare Rate for Semi-Rigid Systems

267

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

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

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

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

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

LENGTH OF NEED $X = 113.76'$ DESIGN ADT 5,000 vpd
 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 $Z = 9.47'$ **

Used distance to face of bridge railing

268

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

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

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

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

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

LENGTH OF NEED $X = 113.76'$ DESIGN ADT 5,000 vpd
 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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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 TO 1:5 | 1:4 OR FLATTER | 1:6 |
| 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 | ** | 9-10 | 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 | 28-28 |
| ≥ 80 mph | under 750 | 18-20 | 20-26 | ** | 10-12 | 14-16 | 14-16 |
| | 750 - 1500 | 24-26 | 26-36* | ** | 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 containing 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 unobstructed, traversable 1:3 slopes, fixed objects should not be present in the vicinity of the toe of these slopes.

270

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

$$X = \frac{L_H \cdot \left(\frac{b}{a}\right) (L_1) - (L_2 \cdot d)}{\frac{b}{a} + \frac{L_H}{L_B}} \quad X = \frac{L_H - (L_2 \cdot d)}{\left(\frac{\text{No Flare or Type 2 Terminal}}{L_H}\right) \frac{L_H}{L_B}} \quad Z = (X - L_1 - 25) \left(\frac{b}{a}\right) \cdot L_B$$

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

| | | | |
|--|----------------------|---------------------------------|-----------|
| LENGTH OF NEED | $X = 113.76'$ | DESIGN ADT | 5,000 vpd |
| RUNOUT 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) | $L_B = 4'$ | | |
| 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) .. | $L_H = 30'$ | STATION AT B | -347+66.8 |
| LATERAL OFFSET AT END OF FLARE | $Z = 9.47'$ ** | | |

Used distance to face of bridge railing

271

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

$$X = \frac{L_H \cdot \left(\frac{b}{a}\right) (L_1) - (L_2 \cdot d)}{\frac{b}{a} + \frac{L_H}{L_B}} \quad X = \frac{L_H - (L_2 \cdot d)}{\left(\frac{\text{No Flare or Type 2 Terminal}}{L_H}\right) \frac{L_H}{L_B}} \quad Z = (X - L_1 - 25) \left(\frac{b}{a}\right) \cdot L_B$$

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

| | | | |
|--|----------------------|---------------------------------|-----------|
| LENGTH OF NEED | $X = 113.76'$ | DESIGN ADT | 5,000 vpd |
| RUNOUT 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) | $L_B = 4'$ | | |
| 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) .. | $L_H = 30'$ | STATION AT B | -347+66.8 |
| LATERAL OFFSET AT END OF FLARE | $Z = 9.47'$ ** | | |

Using a Type 2M approach terminal, so $d=0$

272

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

$$X = \frac{L_H \cdot \left(\frac{b}{a}\right) (L_1) - (L_2 \cdot d)}{\frac{b}{a} + \frac{L_H}{L_B}} \quad X = \frac{L_H - (L_2 \cdot d)}{\left(\frac{\text{No Flare or Type 2 Terminal}}{L_H}\right) \frac{L_H}{L_B}} \quad Z = (X - L_1 - 25) \left(\frac{b}{a}\right) \cdot L_B$$

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

| | | | |
|--|----------------------|---------------------------------|-----------|
| LENGTH OF NEED | $X = 113.76'$ | DESIGN ADT | 5,000 vpd |
| RUNOUT 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) | $L_B = 4'$ | | |
| 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) .. | $L_H = 30'$ | STATION AT B | -347+66.8 |
| LATERAL OFFSET AT END OF FLARE | $Z = 9.47'$ ** | | |

$L_H = L_C$ in this case, since the river is the hazard and extends beyond the clear zone

273

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

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

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

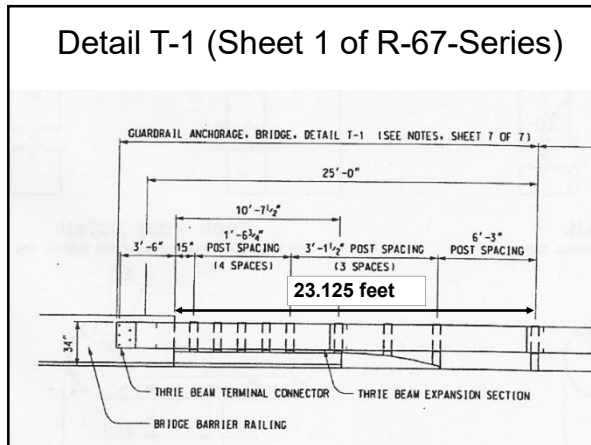
$$Z = (X - L_1 - 25) \left(\frac{b}{a}\right) \cdot L_B$$

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

| | | | |
|--|----------------------|---------------------------------|-----------|
| 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) | $L_g = 4'$ | | |
| CLEAR ZONE (7.01.11) | $L_c = 30'$ | $L_1 = .23.125'$ MIN. | |
| E.O.P. TO ROADSIDE FEATURE (MEASURED) | $L_g = 4'$ | $L_g = 7'$ 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) .. | $L_H = 30'$ | STATION AT B | -347+66.8 |
| LATERAL OFFSET AT END OF FLARE | $Z = 9.47'$ ** | | |

$L_1 < 25'$ in this case because $L_1 = L_T$
(exception to $L_1 = 25'$ min. rule)

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275

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

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

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

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

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

| | | | |
|--|----------------------|---------------------------------|-----------|
| 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) | $L_g = 4'$ | | |
| CLEAR ZONE (7.01.11) | $L_c = 30'$ | $L_1 = .23.125'$ MIN. | |
| E.O.P. TO ROADSIDE FEATURE (MEASURED) | $L_g = 4'$ | $L_g = 7'$ 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) .. | $L_H = 30'$ | STATION AT B | -347+66.8 |
| LATERAL OFFSET AT END OF FLARE | $Z = 9.47'$ ** | | |

$L_2 < L_S$ in this case (i.e., guardrail within shy distance)
This is acceptable

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

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

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

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

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

| | |
|--|--|
| 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-55-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+0.1 |
| LATERAL EXTENT OF ROADSIDE FEATURE (MEASURED) L _B = 30' | STATION AT B = -347+66.8 |
| LATERAL OFFSET AT END OF FLARE Z = 9.47' ** | |

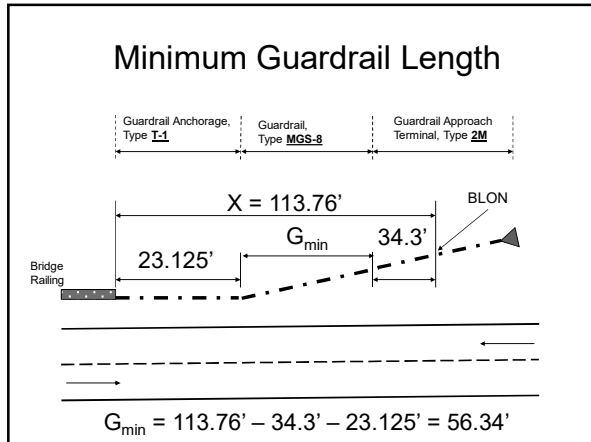
L₁ < 25' in this case because L₁ = L_T
 (exception to L₁ = 25' min. rule)

278

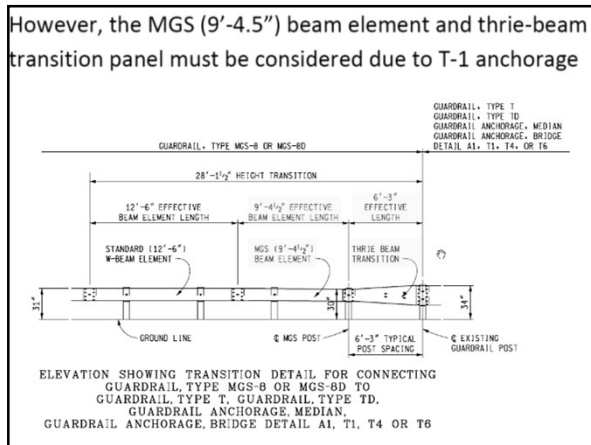
Length of Need (X)

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

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∴ # of 12.5' panels = $\left(\frac{56.34 - 9.375 - 6.25}{12.5}\right) = 3.26 \rightarrow 4$ panels

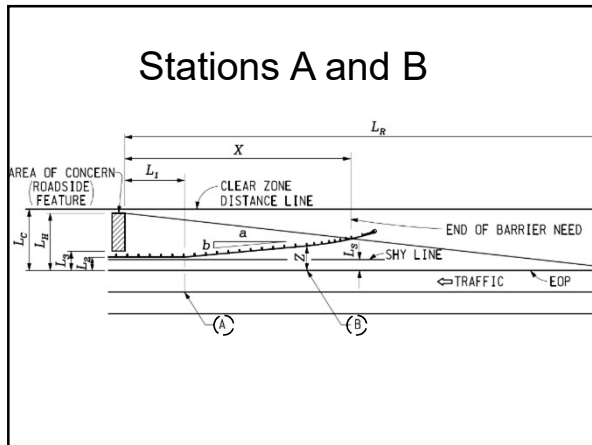
Type MGS-8 guardrail length = $(12.5)(4) + 9.375 + 6.25$

= 65.625 feet

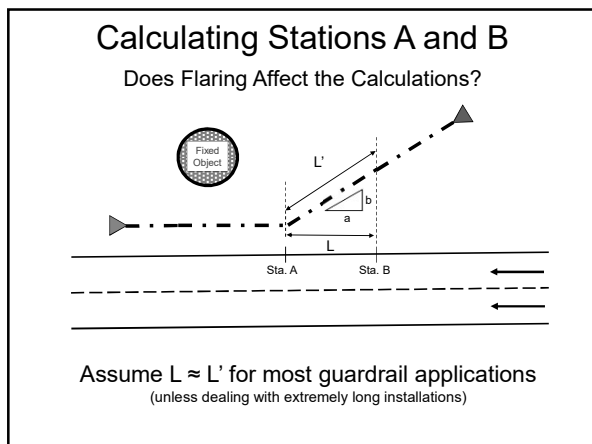
282

Reflectors
 # of reflectors = $\left(\frac{65.625 + 23.125}{50}\right) + 1 = 2.78 \rightarrow$ round up to 3
 *** But two-way roads require reflectors facing both sides ***
 \therefore # of reflectors = $3 \times 2 =$ 6 reflectors

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Stations

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

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

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Calculating Z

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

$$\begin{aligned} Z_{\text{actual}} &= L_2 + (\text{Distance}_{B-A}) \times \left(\frac{b}{a}\right) \\ &= 4 + (65.625) \times \left(\frac{1}{12}\right) = \underline{9.47'} \end{aligned}$$

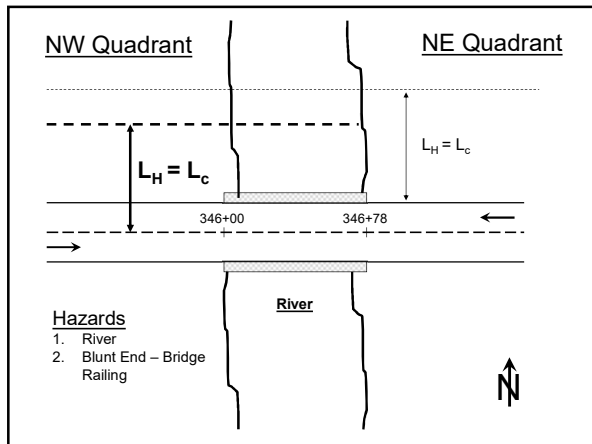
287

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

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| | | | | | |
|---|-----------------------------------|--|-----------|---|--|
| $X = \frac{L_R \cdot \left(\frac{b}{a}\right) (L_1) - (L_2 + d)}{\frac{b}{a} + \frac{L_R}{L_B}}$ | | $X = \frac{L_R - (L_2 + d)}{\left(\frac{\text{No Flare or Type B Terminals}}{L_R}\right)}$ | | $Z = (X - L_1 - 25) \left(\frac{b}{a}\right) \cdot L_B$ | |
| $Z = L_R \text{ (For Type B Terminals)}$ | | | | | |
| LENGTH OF NEED | $X = 64.88'$ | DESIGN ADT | 5,000 vpd | | |
| RUNOUT 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) | $L_2 = 16'$ | | | | |
| CLEAR ZONE (7.01.11) | $L_C = 30'$ | $L_1 = 23.125'$ (5' MIN.) | | | |
| E.O.P. TO ROADSIDE FEATURE (MEASURED) | $L_2 = 16'$ | $L_B = 7'$ (SHY LINE (7.01.18)) | | | |
| EFFECTIVE TURNED OUT DISTANCE OF ANCHORAGE | $d = 0$ | STATION AT A 345+76.9 | | | |
| LATERAL EXTENT OF ROADSIDE FEATURE (MEASURED) | $L_R = 30'$ | STATION AT B 345+48.8 | | | |
| LATERAL OFFSET AT END OF FLARE | $Z = 6.34'$ (measured from EOP)** | | | | |
| NOTE: DISTANCE OF OBJECT FROM BACK OF BARRIER MUST BE GREATER THAN THE MAXIMUM DEFLECTION (7.01.20) | $18.34'$ (measured from CL)** | | | | |
| $L_H \leq L_C$ | | ** Refer to Calculations and Notes | | | |
| REFER TO STANDARD PLAN R-59-SERIES AND DESIGN MANUAL SECTION 7.01.30 FOR GUARDRAIL AT EMBANKMENTS | | | | | |
| SHEET 1 OF 2 | | | | | |

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Length of Need (X)

$$X = \frac{30 + \left(\frac{1}{12}\right) \times (23.125) - 16}{\left(\frac{1}{12}\right) + \left(\frac{30}{185}\right)} = 64.88'$$

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Guardrail Length

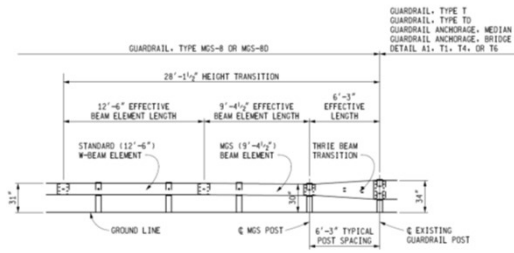
Using a Guardrail Approach Terminal, Type 2M with Guardrail, Type MGS-8 in this case

∴ Min. Guardrail Length = $64.88' - 23.125' - 34.3' = 7.46'$

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However, in this case, the minimum length of Type MGS-8 between the T-1 anchorage and Type 2M approach terminal is 28'-1.5" due to the required height transition section; see MDOT Standard Plan R-60-Series.

∴ Type MGS-8 guardrail length = 28.125 feet



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Reflectors

of reflectors = $(\frac{28.125 + 23.125}{50}) + 1 = 2.02 \rightarrow$ round up to 3

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

∴ # of reflectors = $3 \times 2 =$ 6 reflectors

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| PAY ITEMS | |
|-----------|--|
| 28.125 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 |

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Stations

Station A = (346+00) - 23.125' ≈ 345+76.9

Station B = (346+00) - 23.125 - 28.125' ≈ 345+48.8

296

Calculating Z

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

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

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

or

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

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Guardrail Design Shielding Embankments

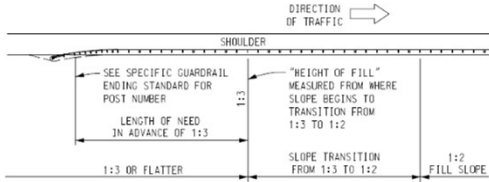


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Guardrail at Embankments

MDOT Method

- Parallel Guardrail Installations
 • Section 7.01.30F of RDM



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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 |

300

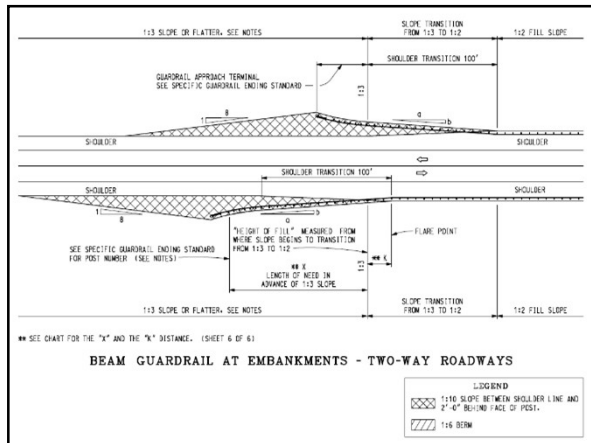
Guardrail at Embankments

MDOT Method

Flared Guardrail Installations

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

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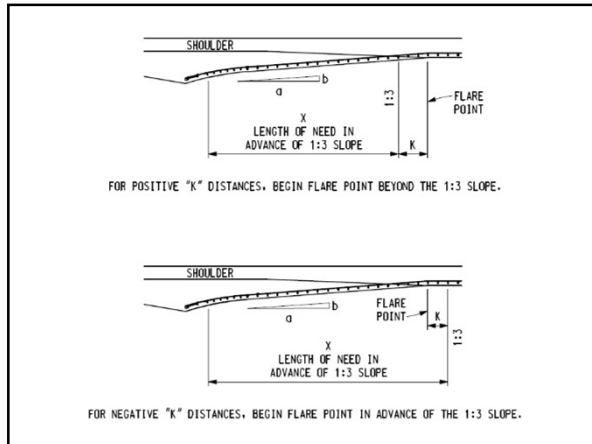


302

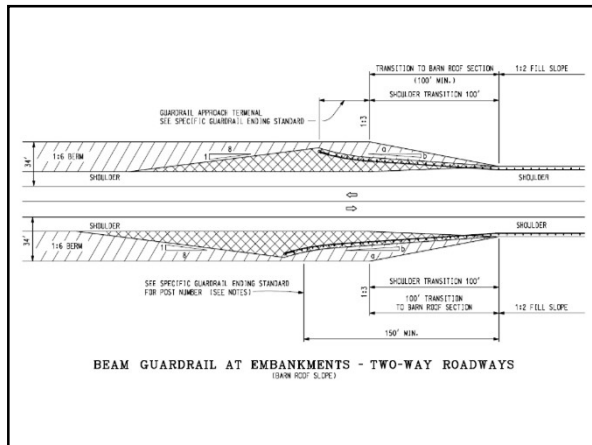
Standard Plan R-59-E X & K Values

| 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 |

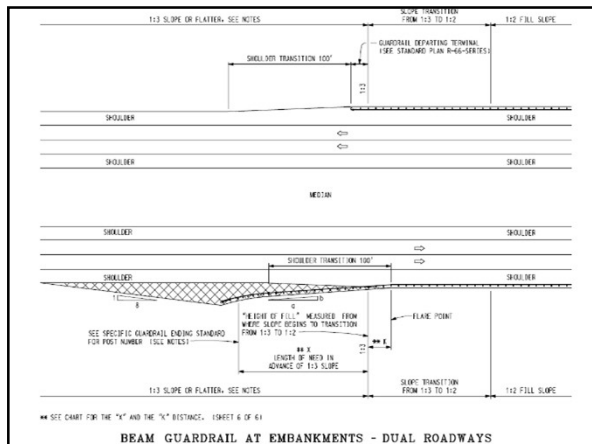
303



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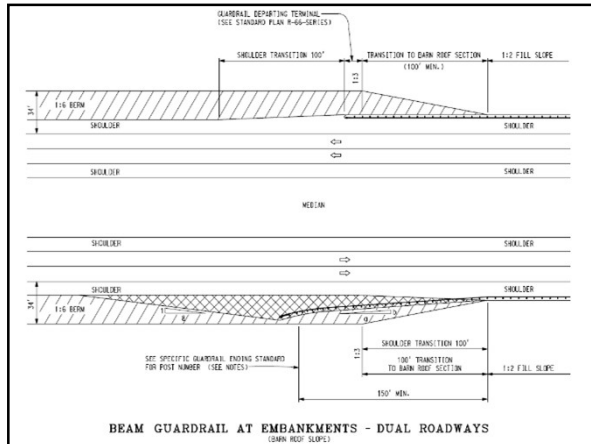


305

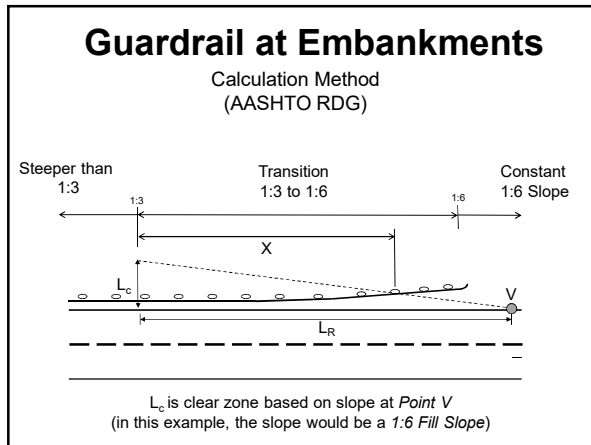


306

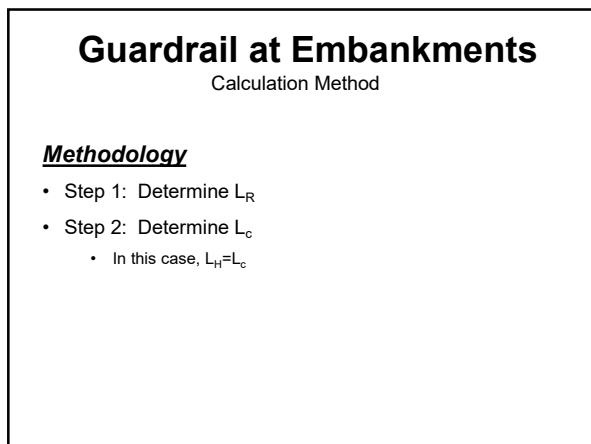




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Guardrail at Embankments

Calculation Method

Methodology

- Step 3: Determine Layout and Terminal
 - Flared or Parallel Guardrail
 - If flared:*
 - Determine flare rate (b/a)
 - Determine location where flare begins
 - Terminal Type:
 - Type 1 (Flared) or Type 2 (Parallel) Terminal

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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

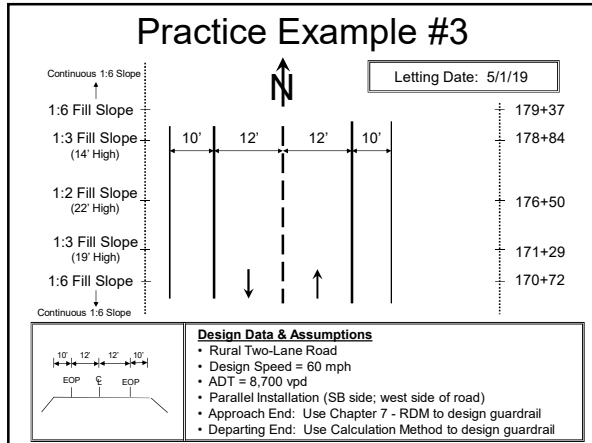
Type 1 Terminal and Flared Guardrail Run

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

Type 2 Terminal and Parallel Guardrail Run

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

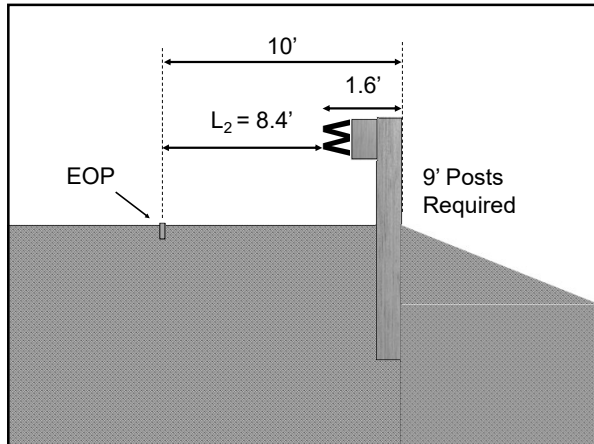
313



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- Type MGS-8 guardrail will be used
- Type 2M guardrail approach terminals will be used
- $L_c = 32'$ (1:6 slope at Sta. 168+79; 250' (L_1) south of Sta. 171+29)
- Assume $L_2 = 8.4'$ (i.e., $10' - 1.6'$); requires use of 9' posts

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Approach End (North End)

Refer to Subsection 7.01.30.F of Michigan Road Design Manual

- Fill Height = 14' at 1:3 Point (Sta. 178+84); Speed = 60 mph

∴ Length of Need in Advance of 1:3 = 205'

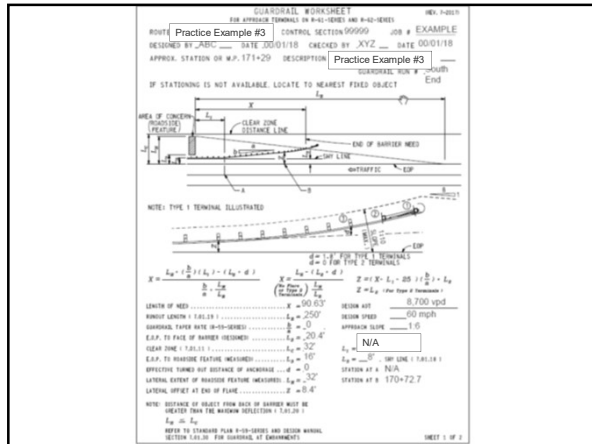
| GUARDRAIL AT EMBANKMENTS (PARALLEL INSTALLATIONS) | | | | |
|--|----|---|------------|--------|
| HEIGHT OF FILL AT 1:3 (ft) | | LENGTH OF NEED IN ADVANCE OF 1:3 (ft) | | |
| OVER | TO | 70 mph | 60 mph | 50 mph |
| 5 | 10 | 147 | 121 | 100 |
| 10 | 12 | 197 | 171 | 122 |
| 12 | 14 | 235 | <u>205</u> | 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 |

317

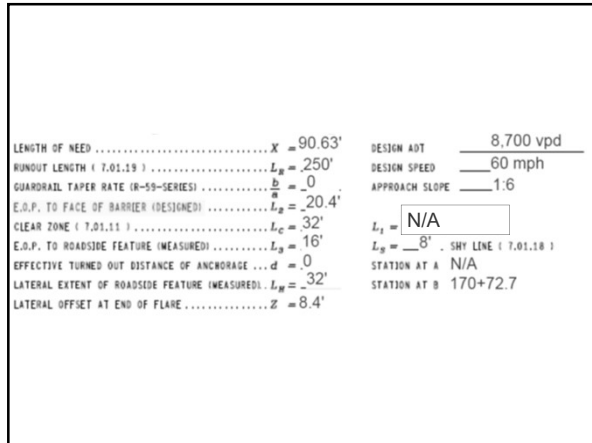
Departing End (South End)

- Shoulder hinge point on west side of road is within northbound (NB) traffic's clear zone
 - Use guardrail worksheet to calculate length of need
- Guardrail ending on south end is within NB traffic's clear zone
 - Must use a crashworthy guardrail terminal (i.e., Type 2M guardrail approach terminal).

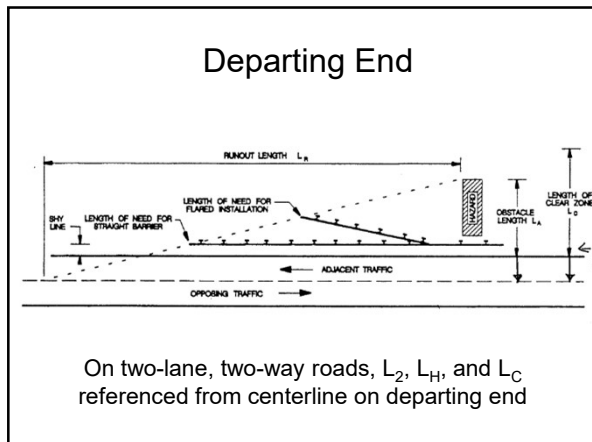
318



319



320



321

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

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

322

Total Guardrail Length

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

$$= 982.03'$$

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

∴ Type MGS-8 Guardrail Length = (12.5)(79) = 987.5 feet

323

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 ***

∴ # of reflectors = 21 x 2 = 42 reflectors

324

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.

325

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

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

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

326

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

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

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

327

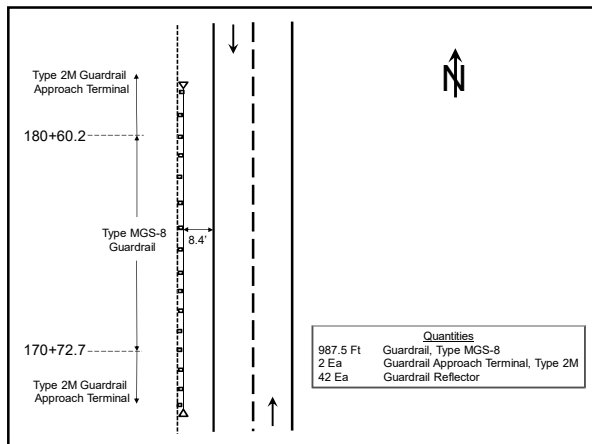
Check: Type MGS-8 Guardrail Length = Sta. B_n – Sta. B_s
 987.5 feet = (180+60.2) – (170+72.7)
 987.5 feet = 987.5 feet ✓

328

Calculating Z

Z = 8.4' (measured from EOP)

329



330
