Session 3: Guardrail Design and Site-specific Installation Considerations
Course Topics

- Session 2 – Testing Requirements and Performance Characteristics of Common Barrier Systems, Terminals and Crash Cushions
- Session 3 – Guardrail Design and Site-specific Installation Considerations
Session 3 Objectives

- Define Barrier Length of Need (LON) and Explain its Basis
- Evaluate Examples of Field Installations
- Apply a Field Procedure to Check LON Adequacy
- Describe the Basic Principles of an Optimal Barrier Installation
Session 3 Outline

- Length of Need (LON)
- Guardrail Placement
- Special Situations
  - Guardrail over Low Fill Culvert
  - Guardrail Posts in Rock/Mowing Strips
  - Guardrail at Turnout
  - Weathering Steel Guardrail
  - Steel-backed Timber Rail
  - Transitions to Bridge Railings/Parapets
Length of Need (LON) Theory

- **HAZARD**
- **Edge of Traveled Way**
- **LR** = Runout Length
- **θ** = Angle of Departure

**Unknown**
Length of Need (LON) Definition

The length of barrier needed in advance of the primary hazard to intercept and redirect the path of an encroaching vehicle.
Graphical Depiction of LON

LENGTH OF NEED

HAZARD

LENGTH OF BARRIER NEEDED

L_R

Session 3
Proper Length of Need

1 MINIMUM OFFSET / LONGER BARRIER LENGTH

2 FARTHER OFFSET / SHORTER BARRIER RUN NEEDED

3 WHEN SOME OR ALL OF BARRIER IS FLARED / EVEN LESS BARRIER NEEDED
Length of Need

Calculating the length of need \((X)\)

- For straight or nearly straight sections of roadway:
  \[
  X = \frac{L_A + \left(\frac{b}{a}\right) L_1 - L_2}{\left(\frac{b}{a}\right) + \left(\frac{L_A}{L_R}\right)}
  \]

- For parallel installations (no flare):
  \[
  X = \frac{L_A - L_2}{L_A/L_R}
  \]
LON Design for Approach Barrier Layout

Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 5.39, Pg. 5-49
LON Design for Opposing Traffic

Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 5.42, Pg. 5-54
## Suggested Runout Lengths

<table>
<thead>
<tr>
<th>Design Speed (mph)</th>
<th>Over 10,000 veh/day</th>
<th>5,000 to 10,000 veh/day</th>
<th>1,000 to 5,000 veh/day</th>
<th>Under 1,000 veh/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>470</td>
<td>430</td>
<td>380</td>
<td>330</td>
</tr>
<tr>
<td>70</td>
<td>360</td>
<td>330</td>
<td>290</td>
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<td>250</td>
<td>210</td>
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<td>190</td>
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</tr>
<tr>
<td>30</td>
<td>110</td>
<td>90</td>
<td>80</td>
<td>70</td>
</tr>
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</table>

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – TABLE 5.10, Pg. 5-50
Step 1: Identify the Hazard
Step 2: Define the Point of Departure

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U.S. Department of Transportation
Federal Highway Administration

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Step 3: Intersect the Hypotenuse

Length of Barrier Needed

$L_R$
Quick Field Check of LON

1. Stand on roadway edgeline opposite the upstream edge of the hazard.
2. Pace upstream along edgeline appropriate runout length (based on speed of roadway and traffic volume).
3. Turn and look at far lateral edge of hazard.
4. If planned (or existing) guardrail run intercepts this line of sight, it satisfies basic design length of need.
5. Check for “secondary” hazards that could be economically shielded by extending barrier.
6. Check for better terminal location by extending barrier a short distance.
DelDOT Guidelines for Dual Bridges

The need for guardrail at a bridge approach is based on the clear zone requirements for fixed hazards. For twin bridges, the length of approach rail on the median side of each bridge should be long enough to prevent an errant vehicle from impacting the bridge rail end of the other bridge. If it is within, or close to, the design clear zone, the guardrail should be long enough to protect the area between bridges at the edge of the clear zone. Consideration should be given to including a transverse berm between the endwalls of the two bridges.

Ref: DelDOT Roadside Design Manual, Chp.10
Guardrail Placement

Place as far from outside edge of traffic lane as practical
Principle 1: Deflection Distance

Barrier to Hazard Distance Is Critical Element
Deflection Distance
Results of Inadequate Transition Design
Reducing Strong Post W-beam deflection

- Reduce post spacing to 3’-1½”
- Reduce post spacing again to 1’-6¾”
- Nest rail element
Rule of thumb:
Each stiffening method reduces deflection by approximately one half
Stiffened Guardrail – Is it Necessary?
Principle 2: Soil Backing For Fill Locations

2’ measured from back of post

Hinge Point
Guidelines for Guardrail on Fills

Ref: DelDOT Standard Construction Details, B-1 (2010)

<table>
<thead>
<tr>
<th>TYPE</th>
<th>POST SPACING</th>
<th>CLEAR AREA BEHIND POST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6’-3” (1905)</td>
<td>3’-0” (900) MIN</td>
</tr>
<tr>
<td>2</td>
<td>3’-1 ½” (952.5)</td>
<td>2’-0” (200) MIN</td>
</tr>
</tbody>
</table>
Adequate Soil Backing?
Soil Backing Recommendation

1. Slope can be as steep as 2H:1V with 2-ft. backing in strong soil with 6 ft. posts.

2. Backing can be less than 2 ft. with 2H:1V slope in strong soil with 7 ft. posts.

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – FIGURE 5.33, Pg. 5-41
Recent Test Results

Midwest Roadside Safety Facility has tested the MGS System installed at the breakpoint of a 2H:1V slope using both 9 ft. steel posts and 7.5 ft. wood posts. Both designs used a standard 6’-3” post spacing.
Principle 3: Slope in Front of Guardrail
Guardrail on Slopes

10H:1V or Flatter in Front of Barriers
Recommended beam Guardrail placement on slopes

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – FIGURE 5.38, Pg. 5-47
Guardrail Height Measurement

- HEIGHT MEASUREMENT
  - 2 ft. Max
  - 1 ft MAX
Guardrail on Slopes
Guardrail on Slopes

- Any barrier may be placed anywhere on a 10H:1V or flatter slope.
- No barrier should be placed on a slope steeper than 6H:1V (exception for some high tension cable).
- Cable Guardrail may be placed on slopes of 6H:1V or steeper, but its location on these slopes is critical for minimizing penetrations.
- On slopes steeper than 10H:1V but no steeper than 6H:1V, metal beam guardrail should be placed in compliance with Figure 5-38 (AASHTO RDG).
Location of Cable in Swales

CABLE SHOULD NOT BE PLACED BETWEEN 1’ AND 8’ BEYOND THE BOTTOM OF A DITCH
Principle 4: Flare Rate

*Flared barriers* are those that are not parallel to the edge of the traveled way. They are used to:

- Locate terminals farther from the roadway.
- Lessen driver reaction to a roadside obstacle.
- Transition from barrier to an obstacle nearer the roadway (bridge parapet or railing).
- Reduce total length of rail needed.
- Reduce nuisance hits.
Flare Rate

Disadvantages of flared barriers:

- Flare increases the maximum angle at which the barrier can be hit.
- Flare increases the probability that a vehicle will be redirected into or across the roadway after an impact.
- Flared barriers may require more grading to provide a flat area between the traveled way and the barrier.
Flared W-Beam Guardrail Example
### Flare Rate Table

<table>
<thead>
<tr>
<th>Design Speed (mph)</th>
<th>Flare Rate for Barrier Inside Shy Line</th>
<th>Fare Rate for Barrier at or Beyond Shy Line</th>
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</thead>
<tbody>
<tr>
<td>70</td>
<td>30:1</td>
<td>20:1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15:1</td>
</tr>
<tr>
<td>60</td>
<td>26:1</td>
<td>18:1</td>
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<td></td>
<td></td>
<td>14:1</td>
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<tr>
<td>55</td>
<td>24:1</td>
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<td></td>
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<td>12:1</td>
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<tr>
<td>50</td>
<td>21:1</td>
<td>14:1</td>
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<td>11:1</td>
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<tr>
<td>45</td>
<td>18:1</td>
<td>12:1</td>
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<td></td>
<td></td>
<td>10:1</td>
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<tr>
<td>40</td>
<td>16:1</td>
<td>10:1</td>
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<tr>
<td></td>
<td></td>
<td>8:1</td>
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<tr>
<td>30</td>
<td>13:1</td>
<td>8:1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7:1</td>
</tr>
</tbody>
</table>

A – Suggested maximum flare rate for rigid barrier system.
B – Suggested maximum flare rate for semi-rigid barrier system

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – TABLE 5.9, Pg. 5-48
Principle 5: Guardrail and Curbs

- Curbs – may function to channelize traffic, to control drainage, improve delineation, control access, and reduce erosion.
- Curbs are not adequate to prevent a vehicle from leaving the roadway; they are not a barrier.
- Use of any guardrail/curb combination where high-speed, high-angle impacts are likely should be discouraged.
Curbs

- **Vertical** – Intended to discourage vehicles from leaving the roadway and range from 6 to 8 inches high. Should not be used on high-speed facilities.

- **Sloping** – Designed so vehicles can cross them (mountable) readily when the need arises.
  - Steeper than 1H:1V are limited to 4 in.
  - Face slope between 1H:1V & 2H:1V, the height should be limited to 6 in.
Ref: DelDOT Standard Construction Details, C-1 (2010)

1. When P.C.C. curb or integral P.C.C. curb and gutter is placed adjacent to Portland cement concrete pavement, construct the joint as per the longitudinal joint sealant detail on detail P-C-Sheet 3 of SDRP.
2. Joint filler to seal work to be placed under respective curb and gutter.
3. Depress curb at entrances and curb ramps as detailed on this sheet.
4. Depress curb flush with pavement at curb ramps. Maximum slope of curb at curb ramps is 1:12 in the direction of pedestrian travel. See detail C-C Sheet 10 of 4.
5. Depress curb flush with pavement or adjacent area at edge of islands, tapering back to full height at a slope of 1:6.
Guardrail and Curbs

Session 3
Curbs should not be used along High-Speed Roadways
Effects of Terrain

- Curbs
  - Curbs and guardrails should not be used in combination where high-speed, high-angle impacts are likely.
  - If no other alternative is feasible, the effects can be reduced by stiffening the guardrail or using curbs of 4 in. or less in height.
Barrier behind 4” AC Curb
Guardrail/Curb Recommendations

Best: Remove curb
May also: Limit curb height to 4” or
Stiffen guardrail by:

- Adding rail to back of post
- Adding a rubrail
- Reducing the post spacing
- Nesting rail elements
Special Situations

- Guardrail over Low Fill Culverts
- Guardrail Posts in Rock
- Guardrail at Intersections/Turnouts
- Weathering Steel Guardrail
- Steel-backed Timber Rail
- Transitions to Bridge Railings/Parapets
Guardrail over Low Fill Culverts

Ref: DELDOT STANDARD CONSTRUCTION DETAILS, B-16
Example of Guardrail over Culvert
Guardrail Posts in Rock

Drill a 12”-16” diameter hole so that the Guardrail post is a minimum of 20” into the rock (extra length may be cut off/galvanize end) or its full length.

Concrete cannot be used as backfill.

Ref: DelDOT Specifications 720566
Guardrail Posts in Rock

Plan View Steel 200mm Posts
Either hole configuration acceptable

Plan View Wood 250mm Posts
Either hole configuration acceptable

Notes
For overlying soil depths (A) ranging from 0 to 460 mm, the depth of required drilling (B) is equal to 610 mm.

Notes
For overlying soil depths (A) ranging from 460 to the embedment depth of the post, depth of required drilling (B) is equal to either 305 mm or the desired embedment depth minus the depth of soil which ever is less.
Guardrail at Intersections

Short Radius at Intersecting roadways
Guardrail Placement at Intersections

Ref: DELDOT STANDARD CONSTRUCTION DETAILS, B-18

Exhibit Special End Anchorage

Ref: U.S. Department of Transportation
Federal Highway Administration

Session 3
Guardrail Placement at Intersections

- Curved Radius Treatment
  - Treatment for driveways, turnouts, or side roads along what would otherwise be a continuous run of barrier.
  - Common treatment uses shop-bent W-beam panels around the intersection radius, using either standard post spacing or halving the post spacing to create additional stiffness.
  - NCHRP 230 design used weakened wood posts around the radius and removed the bolt from the rail-to-post connection at the center post; acted like a bullnose.
  - Need sufficient unobstructed area behind the radius to allow for the large deflection of the system (should be specified on the detail).
Weathering Steel Guardrail

- Cor-Ten Steel (A-588)
- Powder-coated Steel
Q. Is it OK to use Weathering Steel (sometimes called Cor-Ten, A-588, or Rusting Steel) in longitudinal barriers?

A. … the use of weathering steel Guardrail is not recommended…. However, where aesthetic concerns are primary, weathering steel Guardrail may be used if the owner agency adopts a frequent periodic inspection and replacement schedule….

When exposed to salt spray or de-icing chemicals, weathering steel may not develop the ‘patina’ that slows corrosion. Eventually, significant section loss can result. ..

The lapped splices in w-beams panels can corrode rapidly to the point where the barrier becomes ineffective…

http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/qa_bttabr.cfm#brrs1
Steel-Backed Timber Rail
Steel-Backed Timber Guardrail

Ref: Eastern Federal Lands

U.S. Department of Transportation
Federal Highway Administration

Session 3
Merritt Parkway Guardrail

Ref: Connecticut DOT

Table 1

<table>
<thead>
<tr>
<th>Curve Radius</th>
<th>Splice</th>
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<tbody>
<tr>
<td>20 ft</td>
<td>10 ft</td>
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<tr>
<td>26 ft</td>
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<tr>
<td>30 ft</td>
<td>20 ft</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>No.</th>
<th>Width</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 ft</td>
<td>2 ft</td>
</tr>
<tr>
<td>2</td>
<td>2 ft</td>
<td>3 ft</td>
</tr>
<tr>
<td>3</td>
<td>3 ft</td>
<td>4 ft</td>
</tr>
</tbody>
</table>

Ref: Federal Highway Administration

Session 3
Steel-Backed Log Guardrail
TL-2 Timber Guardrail Terminal
TL-2 Terminal Details

Timber Rail 1
Detail D

Timber Rails 2 - 8
Detail E

Timber Rails 9
Detail F

Timber Posts 1 - 9
Detail H

Splice Plate at Posts 2 - 9
Detail I

Splice Plate at Post 1
Detail G

Filler Plate at Post 10
Detail J

Timber Block
Detail K

Session 3
Steel-Backed Timber Guardrail Transition to Masonry Wall

Ref: Eastern Federal Lands
Transitions to Bridge Railings

Ref: DelDOT Standard Construction Details, B-5
Bridge Transition and Retrofit Design

Type 2-31 Transition

Type 4 Retrofit

Ref: DelDOT Standard Construction Details
Session 3 Outcomes

- Define LON and Evaluate Examples of Field Installations.
- Apply a Field Procedure to Check LON adequacy.
- Understand site characteristics impacting barrier layout and crash performance.