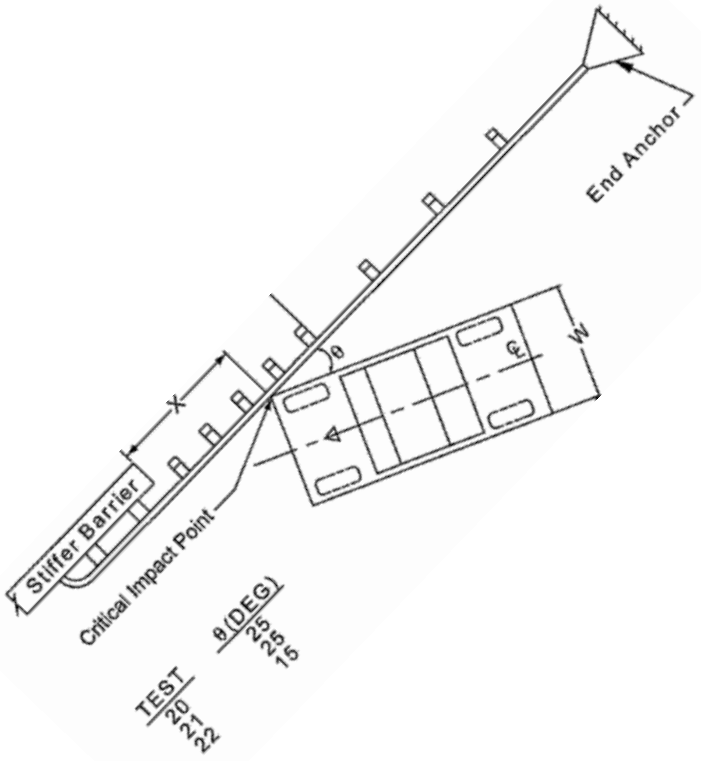
North Carolina Department of Transportation

Highway Safety Barrier Design Training

Participant Notebook

Virtual Live Training
May 18-20, 2021



KLS Engineering

THE UNIVERSITY OF NORTH CAROLINA HIGHWAY SAFETY RESEARCH CENTER

INTRODUCTION

Course Goal and Outcomes

The overall course goal is to make design engineers sensitive to the safety consequences of decisions made concerning roadside barrier safety features. Specifically, participants should be able to perform the following after attending this course:

- Apply the clear zone concept.
- Determine when roadside and median barriers are required.
- Design roadside and median barriers.
- Select the most appropriate end treatments/impact attenuators.

Target Audience

The target audience for this training includes North Carolina DOT and local transportation agency program personnel (LTAP), and consultants having direct responsibilities for specifying and designing traffic barriers (including transitions to other systems), end treatments and impact attenuators.

Course Contents

This course consists of six sessions (listed below) and concludes with a workshop exercises.

Session 1: Introduction and Pre-Assessment – Includes a brief overview of the run off the road (ROR) problem as it exists in North Carolina and tests the participants' pre-training familiarity with barrier design principles.

Session 2: Clear Zone and Barrier Guidelines – Explains the clear zone concept and examines the sometimes difficult decision of when a barrier is required to shield a hazard.

Session 3: Testing Requirements and Performance Characteristics of Common Barrier Systems – Outlines how selected safety barriers are tested and function under controlled crash tests.

Session 4: Testing Requirements and Performance Characteristics of End Treatments and Impact Attenuators– Identifies how selected safety features are tested and function under controlled crash tests.

Session 5: Design Principles – Provides guidance for selecting the barrier type and creating an optimal design based on the five design principles.

Session 6: Length of Need and Special Considerations – Explains what Length of Need is based on and how it is calculated, and identifies design options to use in special situations. LON exercise.

Resources

NCDOT Guardrail Committee Members Contact Information

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North Carolina Department of Transportation (NCDOT)

- Roadway Standard Drawings
  https://connect.ncdot.gov/resources/Specifications/Pages/2018-Roadway-Standard-Drawings.aspx
- Special Provisions
  https://connect.ncdot.gov/resources/Specifications/Pages/2018-Specifications-and-Special-Provisions.aspx
- Product Evaluation Program
  https://connect.ncdot.gov/resources/Products/Pages/default.aspx
- Approved Product List
  https://apps.ncdot.gov/vendor/approvedproducts/

- Maintenance Operations Manual - https://inside.ncdot.gov/TransportationServices/SMFM/Pages/Maintenance-Operations-Manual.aspx
    - Operational Maintenance Activities, MN-27: Policy for Repair / Replacement of Damaged Barriers - https://inside.ncdot.gov/TransportationServices/SMFM/Lists/ManualFoward/DispForm.aspx?ID=16
    - Guardrail/Attenuator Maintenance policy - https://inside.ncdot.gov/TransportationServices/SMFM/Documents/DE19931215.PDF
    - Damage to State Property Notification Process - https://inside.ncdot.gov/TransportationServices/SMFM/Documents/RF20010320A.PDF
    - Median Barrier Inspection and Maintenance Policy - https://inside.ncdot.gov/TransportationServices/SMFM/Documents/DE20070105.pdf
    - NCGS 136-18.05 Establishment of DOT Report Program - https://www.ncleg.gov/EnactedLegislation/Statutes/PDF/BySection/Chapter_136/GS_136-18.05.pdf
    - Joint Implementation Agreement for Manual for Assessing Safety Hardware (MASH) - https://inside.ncdot.gov/TransportationServices/SMFM/StateMaintenanceFleetManagement/Joint%20Implementation%20Agreement%20for%20MASH%20-%20Jan%207%202016.pdf
    - MASH Guardrail Units (GREU) - https://inside.ncdot.gov/TransportationServices/SMFM/Documents/05-26-2017%20MASH%20Complaint%20GREU%20Installation.pdf
    - Eligibility of Crash Cushion Devices (MASH 16 Sunset Date) - https://inside.ncdot.gov/TransportationServices/SMFM/StateMaintenanceFleetManagement/Eligibility%20of%20Crash%20Cushion%20devices%20(Manual%20for%20Assessing%20Safety%20Hardwa.._%20(002).pdf

Federal Highway Administration (FHWA) https://www.fhwa.dot.gov/

- FHWA Hardware Policy and Guidance http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/
- FHWA Longitudinal Barriers http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/
- FHWA Resource Charts http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/resource_charts/
- W-Beam Guardrail Repair Guide https://safety.fhwa.dot.gov/local_rural/training/fhwasa08002/

American Association of State Highway and Transportation Officials (AASHTO) https://www.transportation.org/

- AASHTO, Roadside Design Guide, 2011
- AASHTO, Manual for Assessing Safety Hardware, 2016 (MASH16)

Task Force 13 website http://www.tf13.org/

- Guide to Standardized Highway Barrier Hardware

Roadside Safety Pooled Fund sites:

- MwRSF: http://mwrsf-qa.unl.edu/
- TTI: http://www.roadsidepooledfund.org/

TERMINOLOGY

Several terms will be used throughout the course; to ensure no misunderstanding, they are defined here:

Effective barrier: barrier that will satisfactorily perform under the barrier test conditions; i.e. smooth redirection

Hazard: an area of concern such as a terrain feature or an obstacle that should be considered for mitigation

Warranting hazard: a hazard that by itself would be determined to be shielded

Secondary hazard: a hazard that by itself would not normally be shielded (such as a typical tree or utility pole)

Head-on versus End-on impact: a head-on impact is essentially at zero degrees to the line of barrier; an end-on impact is hitting the end of the barrier at ANY angle.

Upstream versus Downstream: the upstream point is what the travelling vehicle comes to first; the downstream is as the vehicle is leaving

GLOSSARY

Adjacent Grading—Adjacent grading refers to the area on which the terminal is installed and the area immediately behind it.

Advance Grading—Advance grading refers to the area over which a vehicle may travel before any contact with a barrier terminal is made.

Anchorage—A device which anchors a flexible or semi-rigid barrier to the ground so as to develop the barrier's tensile strength during an impact. Anchorages differ from terminals in that they are not considered crashworthy.

Area of Concern—An object or roadside condition that may warrant safety treatment.

Barricade—A device which provides a visual indicator of a hazardous location or the desired path a motorist should take. It is not intended to contain or redirect an errant vehicle.

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

Bi-directional—For the purposes of classifying crash cushions, bi-directional describes the capability of a crash cushion to safely operate the median of a divided highway or an undivided roadway, where it will be exposed to impacts from two different directions of traffic. A bi-directional crash cushion is considered. A bi-directional crash cushion is also a uni-directional crash cushion. A crash cushion is considered to be bi-directional when it has been qualified through a reverse-direction crash test.

Breakaway—A design feature which allows a device such as a sign, luminaire, or traffic signal support to yield or separate upon impact The release mechanism may be a slip plane, plastic hinges, fracture elements, or a combination of these.

Bridge Railing—A longitudinal barrier whose primary function is to prevent an errant vehicle form going over the side of the bridge structure.

Clearance—Lateral distance from edge of traveled way to a roadside object or feature.

Clear Runout Area—The area at the toe of a non-recoverable slope available for safe use by an errant vehicle.

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

Conservation of Momentum Principle—A concept of crash cushion design which involves the dissipation of the kinetic energy of an impacting vehicle by transferring the vehicles momentum to the variable masses of materials in the crash cushion, such as sand contained in sand barrels.

Cost-effective—An item or action taken that is economical in terms of tangible benefits produced for the money spent.

Crash Cushion—Device that prevents an errant vehicle from impacting a fixed object by gradually decelerating the vehicle to a safe stop or by redirecting the vehicle away from the obstacle.

Crash Tests—vehicular impact tests by which the structural and safety performance of roadside barriers and other highway appearances may be determined. Three evaluation criteria are considered, namely (1) structural adequacy, (2) impact severity, and (3) vehicular post-impact trajectory.

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

Design Speed—A selected speed used to determine the various geometric design features of the roadway. The assumed design speed should be a logical one with respect to the topography, anticipated operating speed, the adjacent land use, and the functional classification of the highway.

Drainage Feature—Roadside items whose primary purpose is to provide adequate roadway drainage such as curbs, culverts, ditches, and drop inlets.

End Treatment—The designed modification of the end of a roadside or median barrier.

Flare—The variable offset distance of a barrier to move it farther from the traveled way; generally in reference to the upstream end of the barrier.

Frangible—A structure quality or feature that makes the structure readily or easily broken upon impact.

Fuse Plate—The plate which provides structural reinforcement to the sign post hinge to resist wind loads but which will release or fracture upon impact of a vehicle with the post.

Glare Screen—A device used to shield a driver's eye from the headlights of an oncoming vehicle.

Hinge—The weakened section of a sign post designed to allow the post to rotate upward when impacted by a vehicle.

Impact Angle—For a longitudinal barrier, it is the angle between a tangent to the face of the barrier and tangent to the vehicle's path at impact. For a crash cushion, it is the angle between the axis of symmetry of the crash cushion and a tangent to the vehicles path of impact.

Impact Attenuator—See Crash Cushion.

Length of Need—Total length of a longitudinal barrier needed to shield an area of concern.

Length of Need (LON) Point—That point on the terminal or longitudinal barrier at which it will contain and redirect an impacting vehicle along the face of the terminal barrier.

Level of Performance—The degree to which a longitudinal barrier, including bridge railing, is designed for containment and redirection of different types of vehicles.

Longitudinal barriers—A barrier whose primary function is to prevent penetration and to safely redirect an errant vehicle away from a roadside or median obstacle.

Low Maintenance/Self Restoring Crash Cushions—Crash Cushions that either suffer very little, if any damage, upon impact and are easily pulled back into their full operating condition, or they partially rebound after an impact and may only need an inspection to ensure that no parts have been damaged, misaligned, or otherwise disabled.

Median—The portion of a divided highway separating the traveled ways for traffic in opposite directions.

Multidirectional—The capability of the fracture mechanism of a breakaway support or the plates of a split-base support to work when struck from any direction. These are also referred to as omni-directional.

Median Barrier—A longitudinal barrier used to prevent an errant vehicle from crossing the median.

Non-Recoverable Slope—A slope which is considered traversable but on which an errant vehicle will continue to the bottom of the slope. Embankment slopes between 3H:1V and 4H:1V may be considered traversable but non-recoverable if they are smooth and free of fixed objects.

Offset—Lateral distance from the edge of traveled way to a roadside object or feature.

Omni-directional—See Multidirectional.

Operating Speed—The highest speed at which reasonably prudent drivers can be expected to operate vehicles on a section of highway under low traffic densities and good weather. This speed may be higher or lower than posted or legislated speed limits or nominal design speeds where alignment, surface, roadside development, or other features affect vehicle operations.

Operational Barrier—One that has performed satisfactorily in full-scale crash tests and has demonstrated satisfactory in-service performance.

Performance Level—See Level of Performance.

Recoverable Slope—A slope on which a motorist may, to a greater or lesser extent, retain, or regain control of a vehicle. Slopes flatter than 4H:1V are generally considered recoverable.

Recovery Area—Generally synonymous with clear zone.

Reusable Crash Cushions—Reusable crash cushions have some major components that may be able to survive most impacts intact and can be salvaged when the unit is being repaired.

Roadside—That area between the outside shoulder edge and the right-of-way limits. The area between roadways of a divided highway may also be considered roadside.

Roadside Barrier—A longitudinal barrier used to shield roadside obstacles or no-traversable terrain features. It may occasionally be used to protect pedestrians or “bystanders” from vehicle traffic.

Roadside Signs—Roadside signs can be divided into 3 main categories: overhead signs, large roadside signs, and small roadside signs. Large roadside signs may be defined as those greater than or equal to $50ft^2$ in area. Small roadside signs may be defined as those less than $50ft^2$ in area.

Roadway—The portion of a highway, including shoulders for vehicular use.

Rounding—The introduction of a vertical curve between two transverse slopes to minimize the abrupt slope change and to maximize vehicle stability and maneuverability.

Runout Distance Grading—Refers to the area into which a vehicle may travel after impacting a terminal ahead of its LON point.

Sacrificial Crash Cushions—Sacrificial crash cushions are crashworthy roadside safety devices designed for a single impact. These system’s major comments are destroyed in impacts and must be replaced, but many of the other parts of the system can be reused.

Severity Index—A severity index (SI) is a number from zero to ten used to categorize accidents by the probability of their resulting in property damage, personal injury, or a fatality, or any combination of these possible outcomes. The resultant number can then be translated into an accident cost and the relative effectiveness of alternate safety treatments can be estimated.

Shielding—The introduction of a barrier or crash cushion between the vehicle and an obstacle or area of concern to reduce the severity of impacts of errant vehicles.

Shy Distance—The distance from the edge of the traveled way beyond which a roadside object will not be perceived as an obstacle by the typical driver to the extent that the driver will change the vehicle's placement or speed.

Slip Base—A structural element at or near the bottom of a post or pole which will allow release of the post from its base upon impact while resisting wind loads.

Slope—The relative steepness of the terrain expressed as a ratio or percentage. Slopes may be categorized as positive (backslopes) or negative (foreslopes) or as a parallel or cross slope (in relation to the direction of traffic).

Staged Attenuation Device—A crash cushion that is designed to be progressively stiffer as an impacting vehicle deforms or penetrates it.

Temporary Barrier—Temporary barriers are used to prevent vehicular access into construction or maintenance work zones and to redirect an impacting vehicle so as to minimize damage to the vehicle and injury to the occupants while providing worker protection.

Terminal—A terminal is essentially a crashworthy anchorage, a device used to anchor a flexible or semi-rigid barrier to the ground. Being crashworthy, terminals are normally used at the end of a barrier that is located within the clear zone or that is likely to be impacted by errant vehicles.

Traffic Barrier—A device used to prevent a vehicle from striking a more severe obstacle or feature located on the roadside or in the median or to prevent crossover median accidents. As defined herein, there are four classes of traffic barriers, namely; roadside barriers, median barriers, bridge railings, and crash cushions.

Transition—A section of barrier between two different barriers, or more commonly, where a roadside barrier connects to a bridge railing or to a rigid object such as a bridge pier. The transition should produce a gradual stiffening of the approach rail so vehicular pocketing, snagging, or penetration at the connection can be minimized.

Traveled Way—The portion of the roadway for the movement of vehicles, exclusive of shoulders.

Through Traveled Way—The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

Traversable Slope—A slope from which a motorist will be unlikely to steer back to the roadway but may be able to slow and stop safely. Slopes between 3H:1V and 4H:1V generally fall into this category.

Uni-directional—For the purposes of classifying crash cushions, uni-directional describes the capability of a crash cushion to operate in a location where it will be exposed to traffic impacts from only one direction. Such locations may include gore areas, or roadside locations on a divided highway. A crash

cushion is considered to be uni-directional unless it has been qualified as bi-directional through a reverse-direction crash test.

Vehicle—A motorized unit for use in transporting passengers or freight, ranging from an 820-kg [1,800-lb] automobile to a 36000-kg [80,000-lb] van-type tractor trailer.

Warrants—The criteria by which the need for a safety treatment improvement can be determined.

Work-Energy Principle—"A concept of crash cushion design which involves the reduction of an impacting vehicle's kinetic energy to zero, the condition of a stopped vehicle, through the conversion of kinetic energy into other forms of energy."

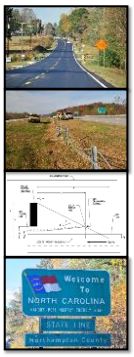
Working Width—The distance between the traffic face of the test article before the impact and the maximum lateral position of any major part of the system or vehicle after the impact.

Zone of Intrusion (ZOI)—The region measured above and behind the face of a barrier system where an impacting vehicle or any major part of the system may extend during an impact.

Acronyms

AASHTO – American Association of State Highway Transportation Officials
ADT – Average Daily Traffic
BLON – Beginning Length of Need
BIC – Buried In Cut
CIP – Critical Impact Point
CM – Countermeasure
FARS – Fatal Analysis Reporting System
FHWA – Federal Highway Administration
HTC – High Tension Cable
LON – Length of Need
MASH – Manual for Assessing Safety Hardware
MGS – Midwest Guardrail System
NCHRP – National Cooperative Highway Research Program
NHTSA – National Highway Transportation Safety Administration
PE – Preliminary Engineering
RDG – Roadside Design Guide
ROW – Right of Way
SHSP – Strategic Highway Safety Plan
SPWB – Strong Post W-Beam
TL – Test Level
TTI – Texas Transportation Institute
VMT – Vehicle Miles Traveled
WZ – Work Zone

Session 1: Introduction and Pre-Assessment



North Carolina Department of Transportation

Highway Safety Barrier Design Training

Instructor: Bill Fitzgerald, PE
KLS Engineering, LLC
(703) 858 1356

Virtual Live Training

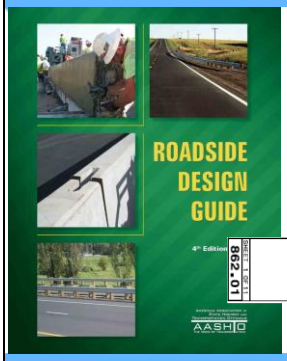
May 18 – 19, 2021

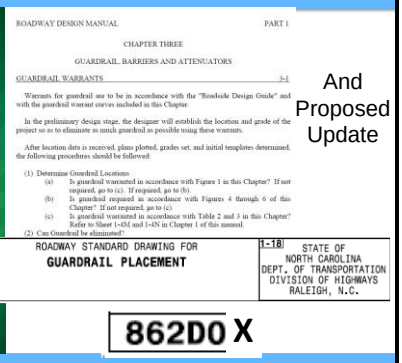
THE UNIVERSITY OF NORTH CAROLINA HIGHWAY SAFETY RESEARCH CENTER

KLS Engineering

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

Guidance Presented




ROADWAY DESIGN MANUAL PART 1

CHAPTER THREE

GUARDRAIL, BARRIERS AND ATTENUATORS

GUARDRAIL WARRANTS 3-1

Warrants for guardrail are to be in accordance with the "Roadside Design Guide" and with the guardrail warrant curves included in this Chapter.

In the preliminary design stage, the designer will establish the location and grade of the project so as to eliminate as much guardrail as possible using these warrants.

After location data is received, plans plotted, grades set, and initial templates determined, the following procedures should be followed:

(1) Determine Guardrail Locations
(a) Is guardrail warranted in accordance with Figure 1 in this Chapter? If not required, go to (c). If required, go to (b).
(b) Is guardrail required in accordance with Figures 4 through 6 of this Chapter? If not required, go to (c).
(c) Is guardrail warranted in accordance with Table 2 and 3 in this Chapter? Refer to Sheet 1-EM and 1-EN in Chapter 1 of this manual.
(2) Can Guardrail be eliminated?

ROADWAY STANDARD DRAWING FOR
GUARDRAIL PLACEMENT

1-18 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

862D0 X

And Proposed Update

NCDOT Session 1 1-2

Ground Rules

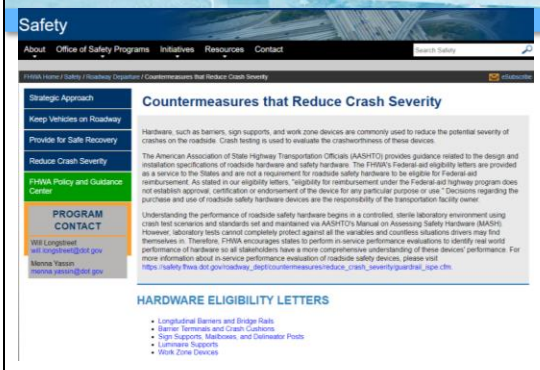
- Be on time
- Participate
- Restrict sidebar conversations
- Turn off cellphones

Virtual Training – participate with yes/no answers to questions
Use chat box to submit your questions/comments

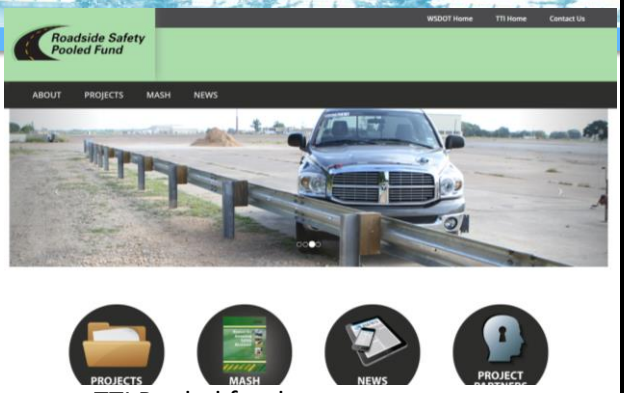
Terminology: Page v

NCDOT Session 1 1-3

Additional Resources

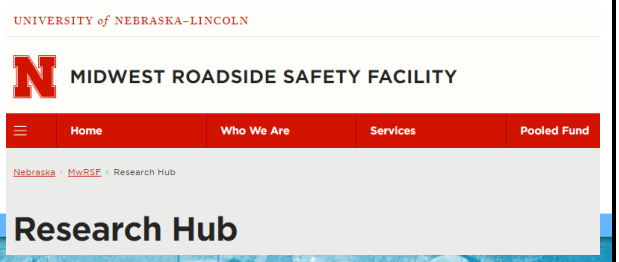


FHWA Eligibility Letters
https://safety.fhwa.dot.gov/roadway_dept/countermeasures/reduce_crash_severity/



TTI Pooled funds, etc.
https://www.roadsidepooledfund.org

https://mwrsf.unl.edu/researchhub



Objectives of Course

At the course you will be able to:

- Identify when a traffic barrier MAY be the best treatment to use at a specific site.
- Select a barrier that will adequately shield the identified hazard(s).
- Assess the topography of the site to provide for an optimal barrier system installation.

Session 1:
Introduction and Pre-assessment

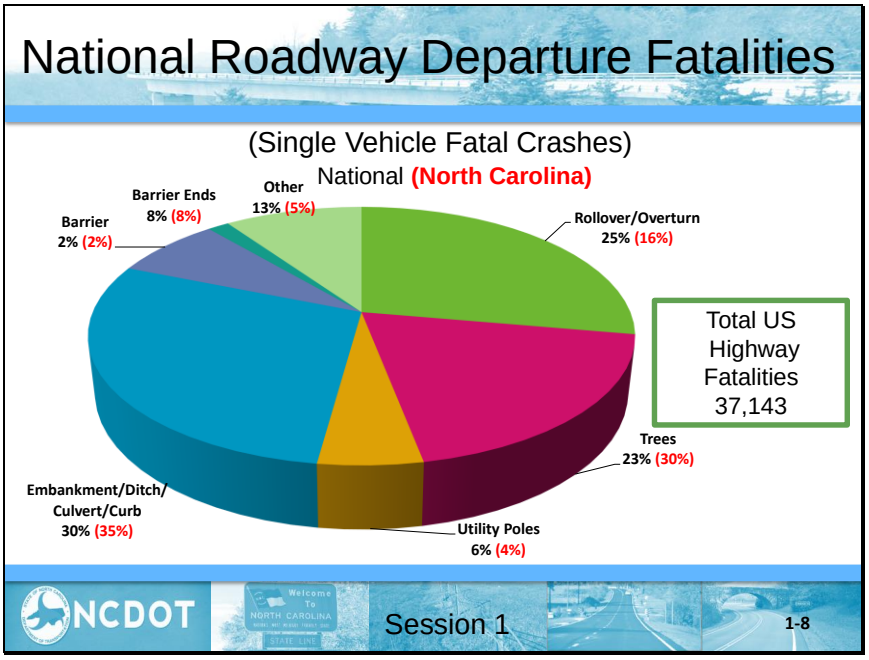
NCDOT Session 1 1-6

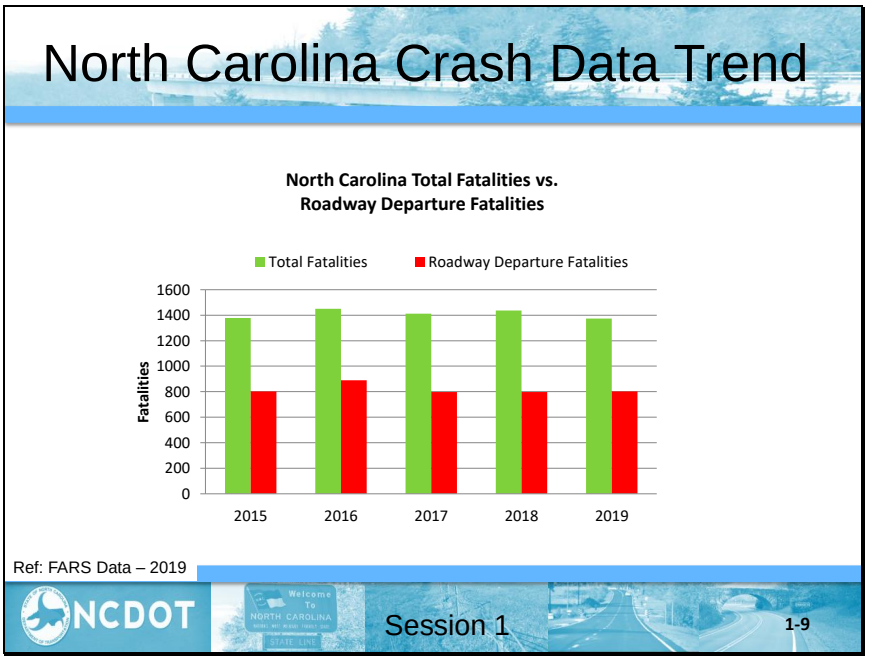
Session 1 Learning Outcomes

At the end of this session, you will be able to:

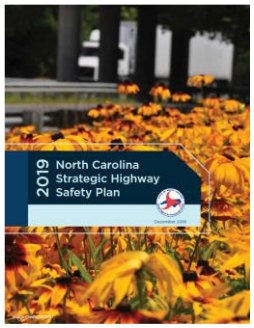
- Identify the primary Roadside Safety Concerns in North Carolina.
- Assess your current knowledge of Barrier Design Principles.

NCDOT Session 1 1-7


National Roadway Departure Fatalities
(Single Vehicle Fatal Crashes)
National (North Carolina)
Barrier Ends 8% (8%)
Other 13% (5%)
Barrier 2% (2%)
Rollover/Overturn 25% (16%)
Total US Highway Fatalities 37,143
Trees 23% (30%)
Embankment/Ditch/ Culvert/Curb 30% (35%)
Utility Poles 6% (4%)
NCDOT
Session 1
1-8


North Carolina Crash Data Trend
North Carolina Total Fatalities vs. Roadway Departure Fatalities
Total Fatalities
Roadway Departure Fatalities
Fatalities
1600
1400
1200
1000
800
600
400
200
0
2015
2016
2017
2018
2019
Ref: FARS Data – 2019
NCDOT
Session 1
1-9

North Carolina Strategic Highway Safety Plan



Lane Departure STRATEGIES

1. Keep vehicles from leaving their travel lane.
2. Reduce the potential for and severity crashes when vehicles leave their lane.
3. Support & enhance driver education & awareness programs.

North Carolina Strategic Highway Safety Plan

Strategy 2:
Reduce the potential for and severity of crashes when vehicles leave their lane.

Supporting Actions

- Continue to apply and evaluate the effectiveness of low-cost treatments such as Safety Edge℠ technology, clear zone maintenance, median barriers, and guardrail.


Real World Crashes
Video Clip
NCDOT
Session 1
1-12

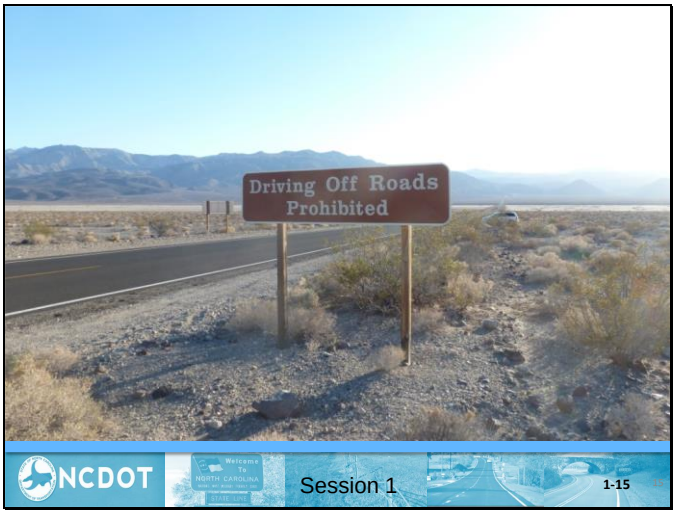

Real World Crashes
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 1
1-13

Need for Training

Potential consequences of poorly designed barrier systems include:

- Systems may not function as designed.
- Crash severities may be increased.

NCDOT Session 1 1-14



NCDOT Session 1 1-15

Need for Training

The next 9 slides show locations where barrier was installed. For each photo, decide at a glance whether you believe it to be:

1. Good example,
2. Bad example, or
3. Cannot decide without more information.

We will discuss these slides in further detail in later applicable sessions, so please record and save your responses.

NCDOT Session 1 1-16


NCDOT
Session 1
1-17

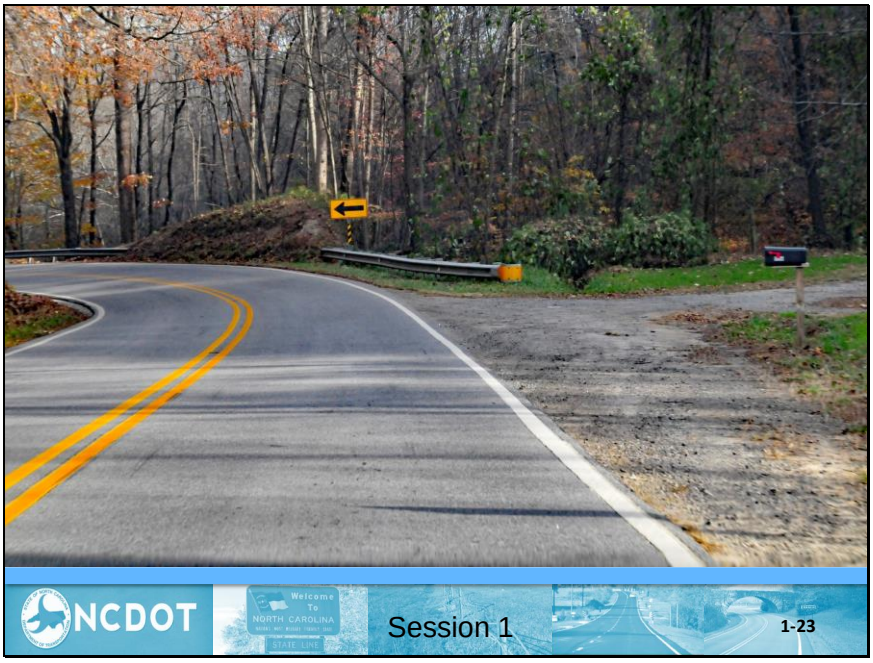

NCDOT
Session 1
1-18


NCDOT
Session 1
1-19

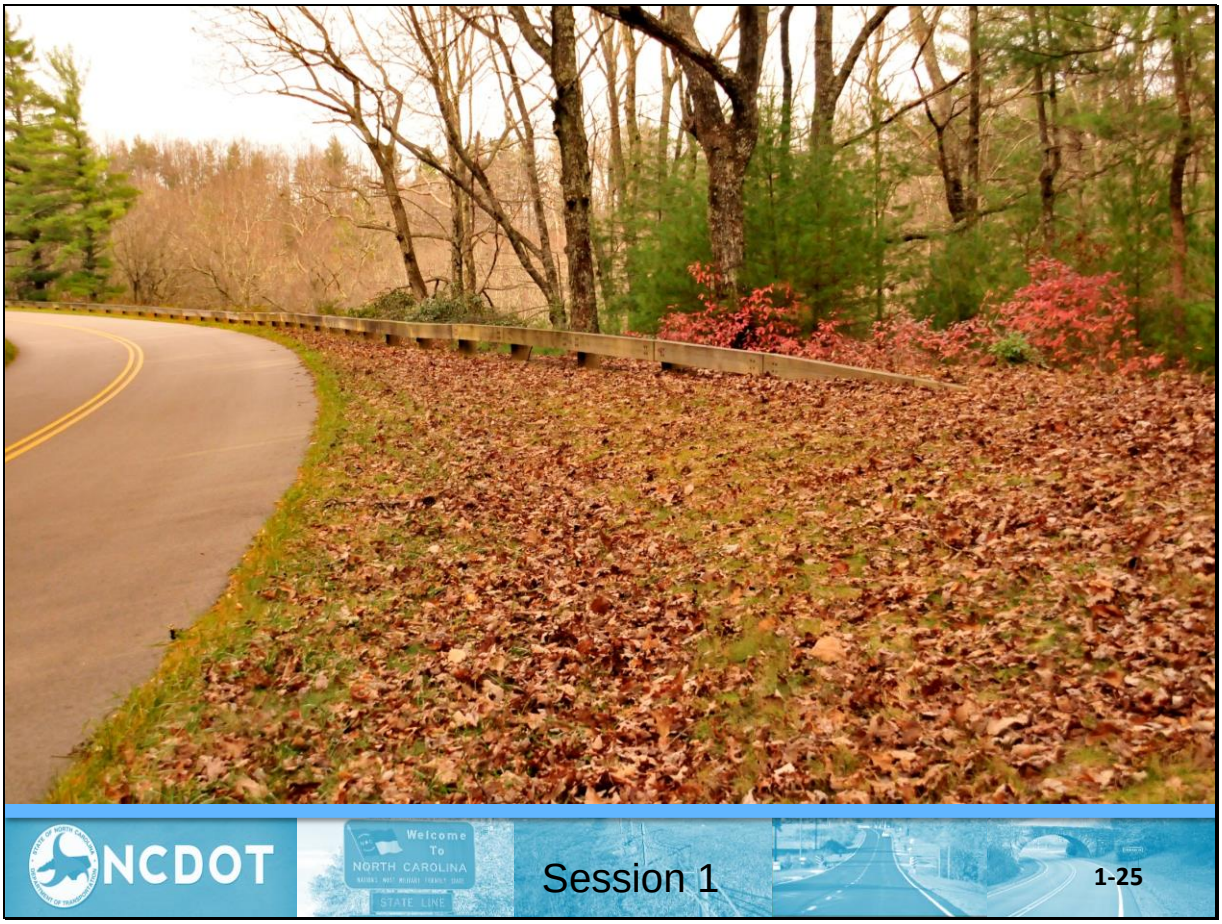

NCDOT
Session 1
1-20


EXIT
466
NCDOT
Session 1
1-21


EXIT
265 B
NCDOT
Session 1
1-22


NCDOT
Session 1
1-23

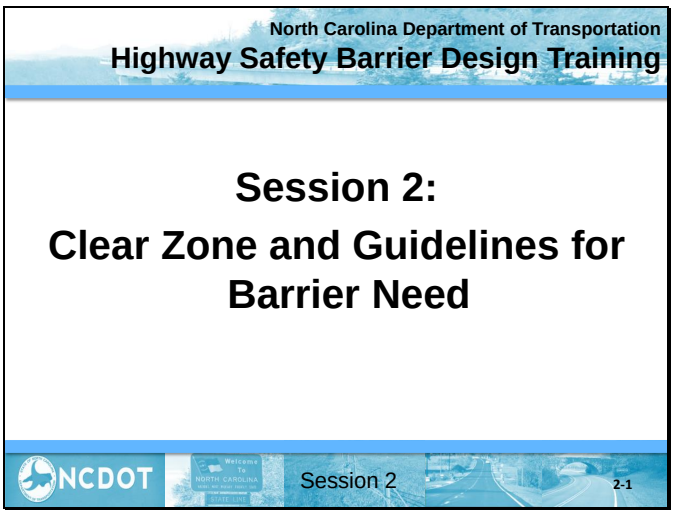

NCDOT
Session 1
1-24

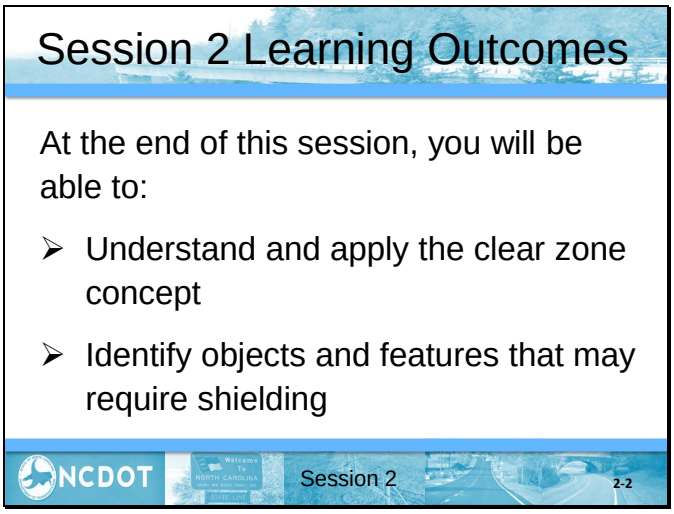


Review Learning Outcomes

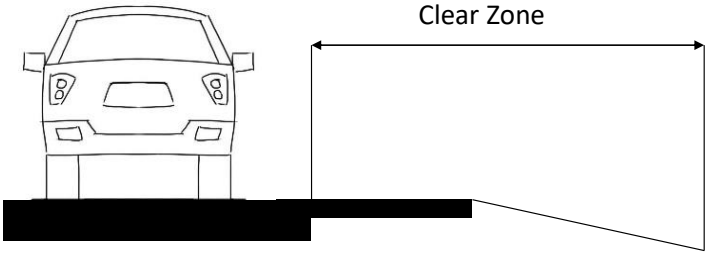
- Identify the primary Roadside Safety Concerns in North Carolina.
- Assess your current knowledge of Barrier Design Principles.

Session 2: Clear Zone and Guidelines for Barrier Need


North Carolina Department of Transportation
Highway Safety Barrier Design Training
Session 2:
Clear Zone and Guidelines for Barrier Need
NCDOT
Session 2
2-1


Session 2 Learning Outcomes
At the end of this session, you will be able to:
Understand and apply the clear zone concept
Identify objects and features that may require shielding
NCDOT
Session 2
2-2

Clear Zone: A Definition



The unobstructed, traversable area provided beyond the edge of the through traveled way for the recovery of errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function like through lanes.

Ref: AASHTO Roadside Design Guide, 4th Edition, Glossary

NCDOT Session 2 2-3

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Clear Zone Principle

Get

MAXIMUM,

COST-EFFECTIVE

width

NCDOT Session 2 2-4

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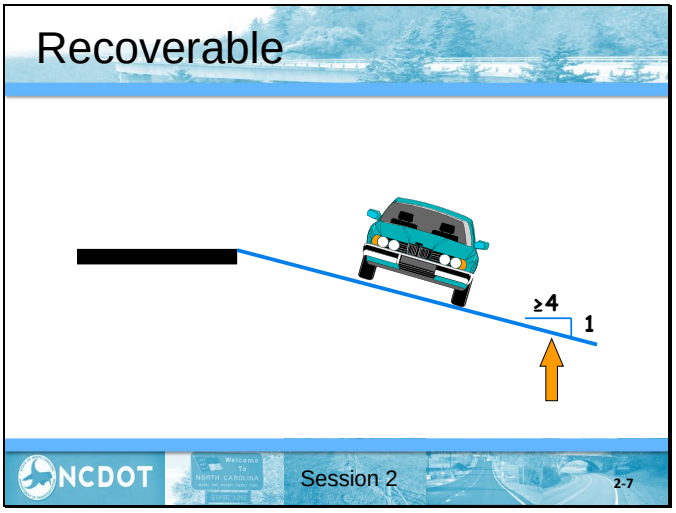
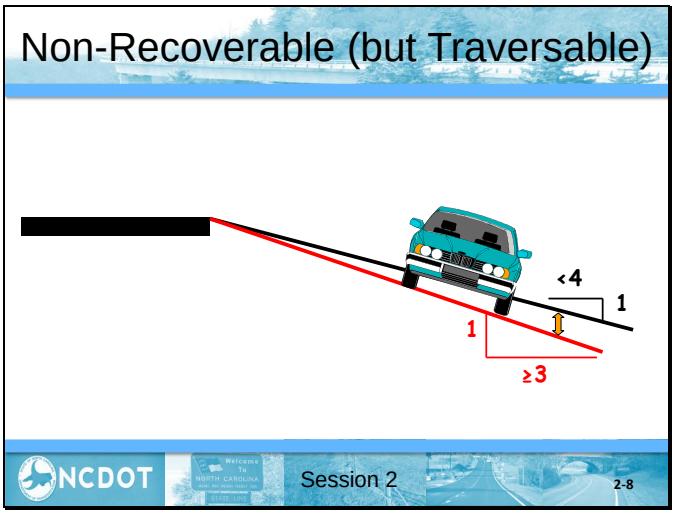
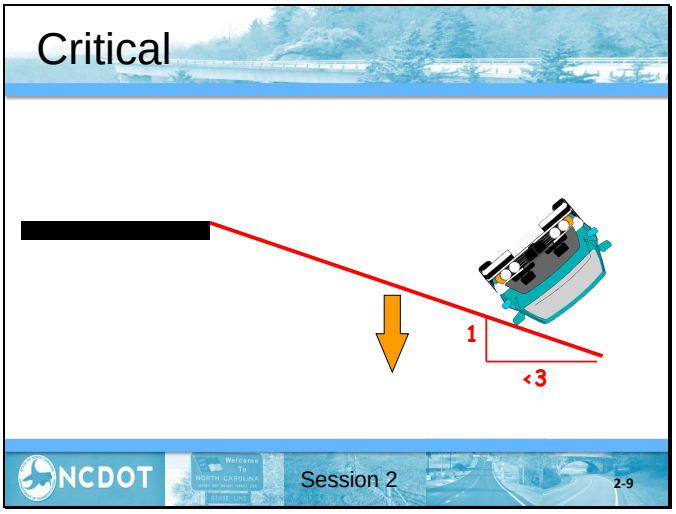
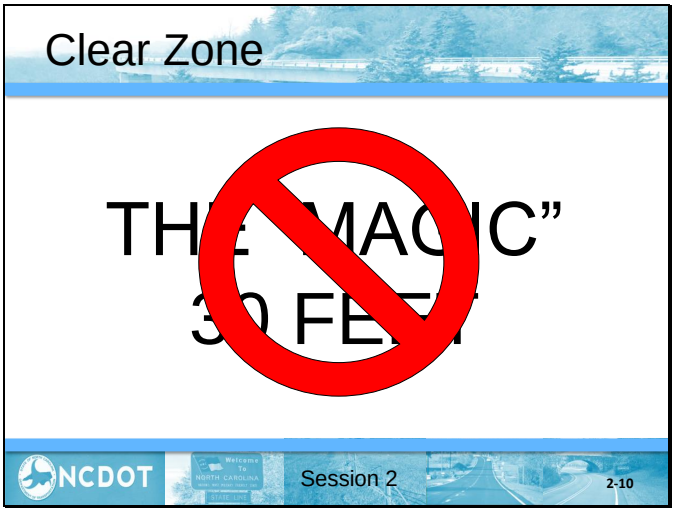
Clear Zone Factors

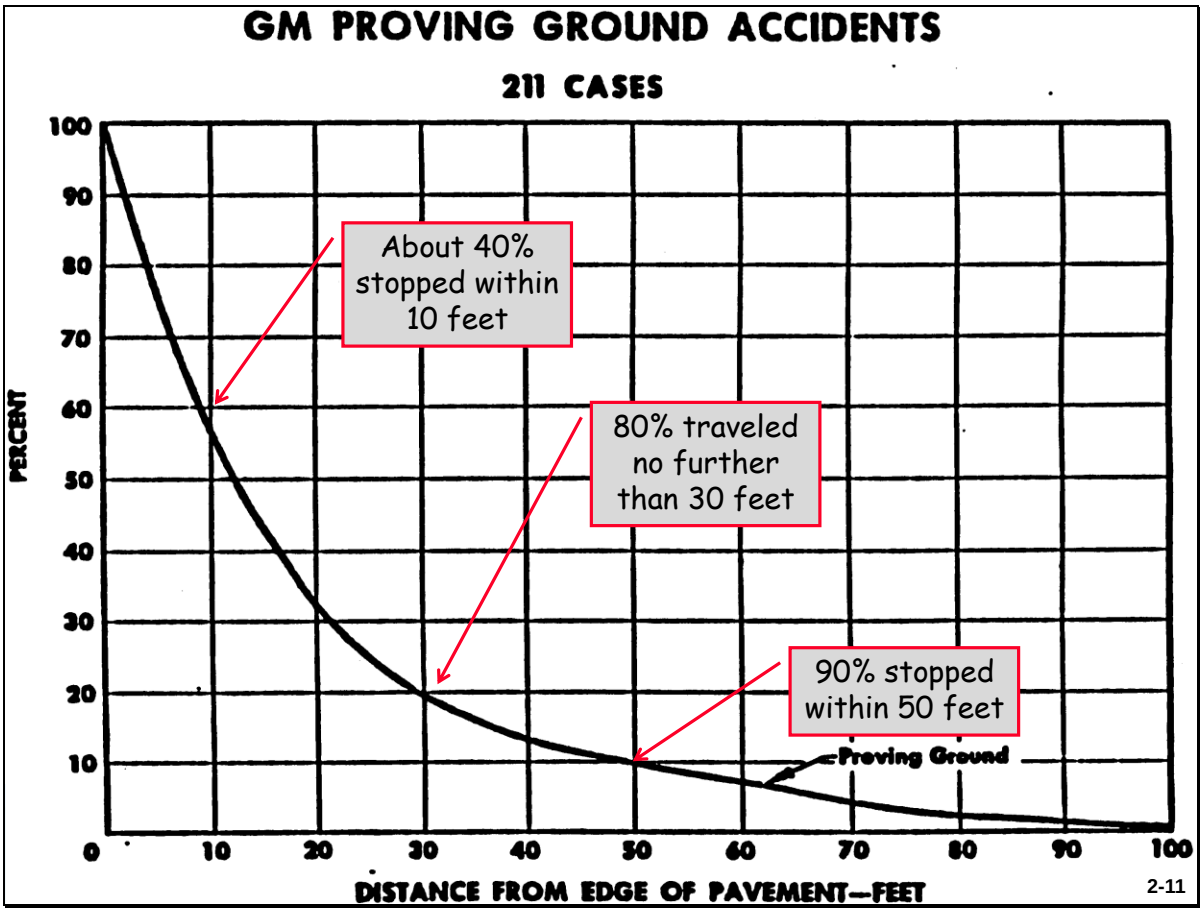
- Slope Type and Steepness
- Design Speed
- Traffic Volume
- Horizontal Curvature


Recoverable
≥4
1
NCDOT
Session 2
2-7


Non-Recoverable (but Traversable)
<4
1
1
≥3
NCDOT
Session 2
2-8


Critical
1
<3
NCDOT
Session 2
2-9


Clear Zone
NCDOT
Session 2
2-10

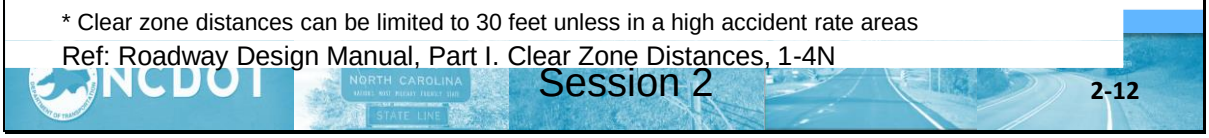

GM PROVING GROUND ACCIDENTS
211 CASES
About 40% stopped within 10 feet
80% traveled no further than 30 feet
90% stopped within 50 feet
Proving Ground
PERCENT
DISTANCE FROM EDGE OF PAVEMENT—FEET
2-11

NCDOT Design Clear Zone Table

Design Speed	Design ADT	Foreslopes			Backslopes		
		1V:6H or flatter	1V:5H to 1V:4H	1V:3H	1V:3H	1V:5H to 1V:4H	1V:6H 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	10-12	10-12
	1500-6000	12-14	14-16	**	12-14	12-14	12-14
	OVER 6000	14-16	16-18	**	14-16	14-16	14-16
45-50 mph	UNDER 750	10-12	12-14	**	8-10	8-10	10-12
	750-1500	14-16	16-20	**	10-12	12-14	14-16
	1500-6000	16-18	20-26	**	12-14	14-16	16-18
	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
65-70 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

* Clear zone distances can be limited to 30 feet unless in a high accident rate areas

Ref: Roadway Design Manual, Part I. Clear Zone Distances, 1-4N



Important Distinction

Available Clear Zone = Area Existing for recovery

Design Clear Zone = A selected value used for design to provide recovery area for a majority of errant drivers

Do not compromise available clear zone

NCDOT Session 2 2-13

Example Clear Zones

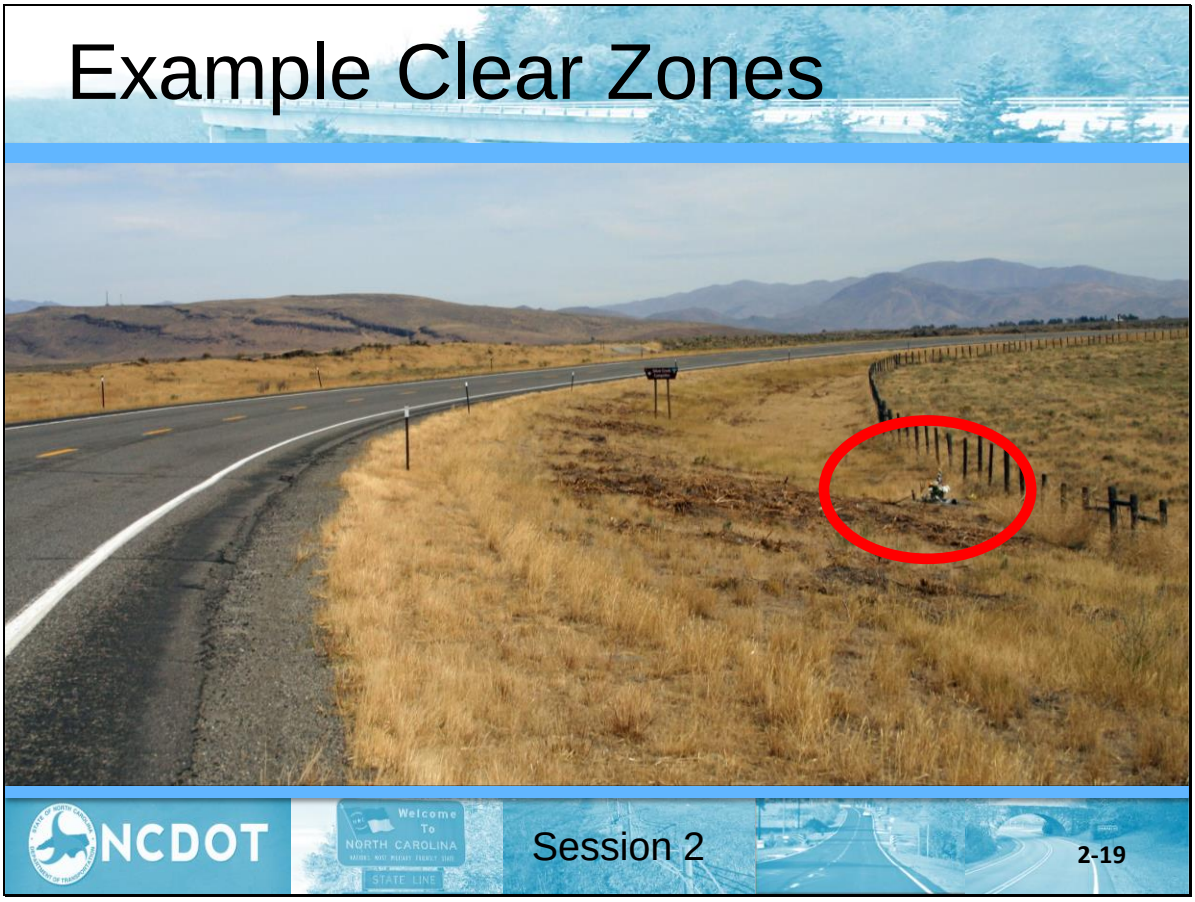
NCDOT Session 2 2-14


Example Clear Zones
NCDOT
Session 2
2-15


Example Clear Zones
NCDOT
Session 2
2-16


Example Clear Zones
NCDOT
Session 2
2-17


Example Clear Zones
NCDOT
Session 2
2-18


Example Clear Zones
NCDOT
Welcome To NORTH CAROLINA STATE LINE
Session 2
2-19

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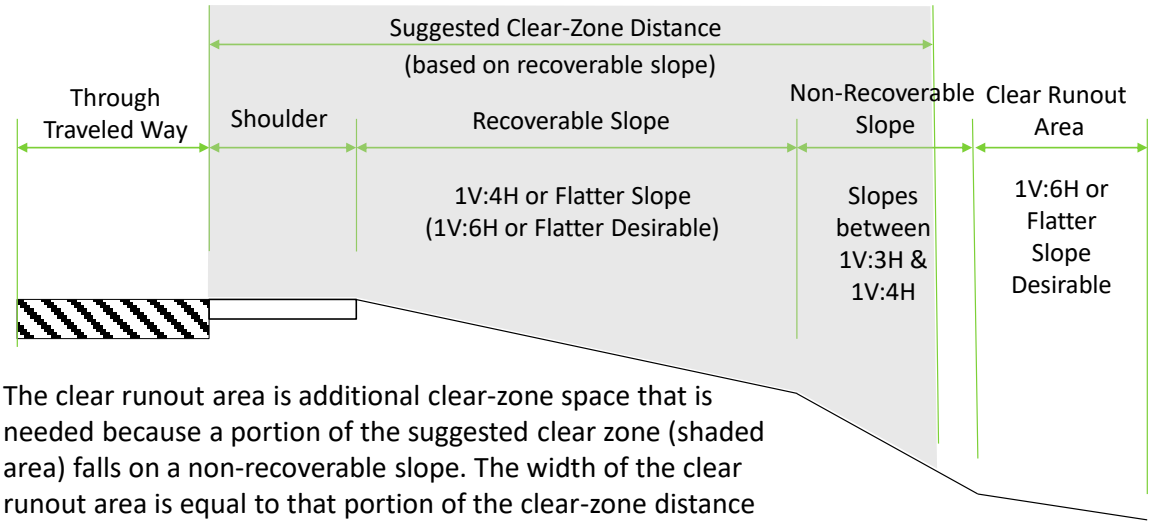
Clear Zone Adjustments for Non-uniform Slopes

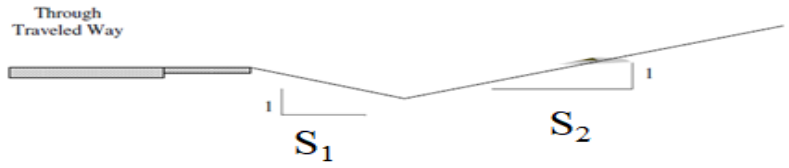


The clear runout area is additional clear-zone space that is needed because a portion of the suggested clear zone (shaded area) falls on a non-recoverable slope. The width of the clear runout area is equal to that portion of the clear-zone distance that is located on the non-recoverable slope – min 10'.

Ref: AASHTO Roadsid FIGURE 1 SIMILAR 1-4M F-1

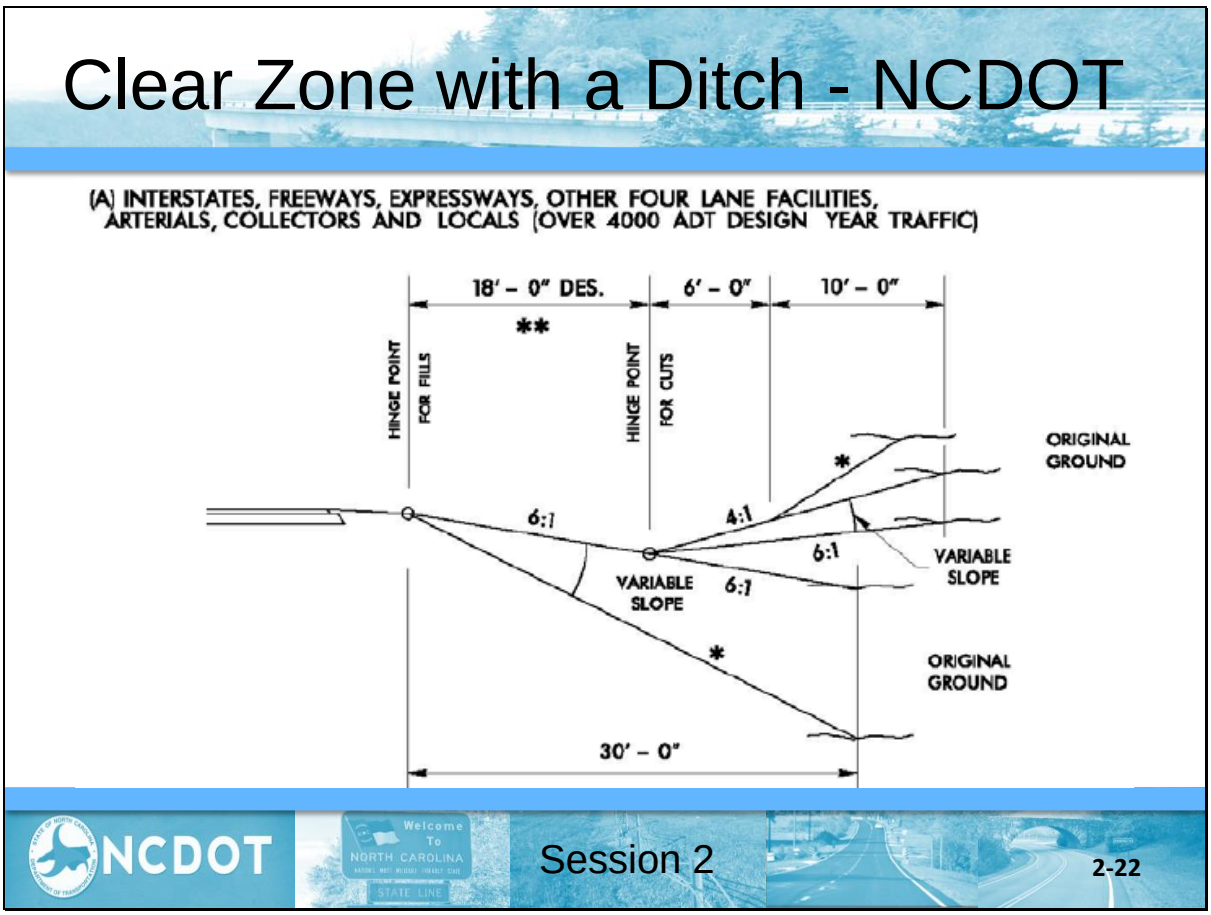
NCDOT Session 2 2-20

Clear Zone with a Ditch



- The combination of S_1 and S_2 needs to fall within the preferred area of Figure 3.6 of the RDG for the clear zone to extend beyond the ditch bottom
- If the combination is outside and S_1 is recoverable, the clear zone stops at the ditch bottom
- If S_1 is not recoverable, the clear zone stops at the top of the S_1 slope

Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 3.6, Pg. 3-9


Clear Zone with a Ditch - NCDOT
(A) INTERSTATES, FREEWAYS, EXPRESSWAYS, OTHER FOUR LANE FACILITIES, ARTERIALS, COLLECTORS AND LOCALS (OVER 4000 ADT DESIGN YEAR TRAFFIC)
18' – 0" DES.
6' – 0"
10' – 0"
**
HINGE POINT FOR FILLS
HINGE POINT FOR CUTS
ORIGINAL GROUND
*
6:1
4:1
6:1
VARIABLE SLOPE
VARIABLE SLOPE
6:1
*
ORIGINAL GROUND
30' – 0"
NCDOT
Welcome To NORTH CAROLINA STATE LINE
Session 2
2-22

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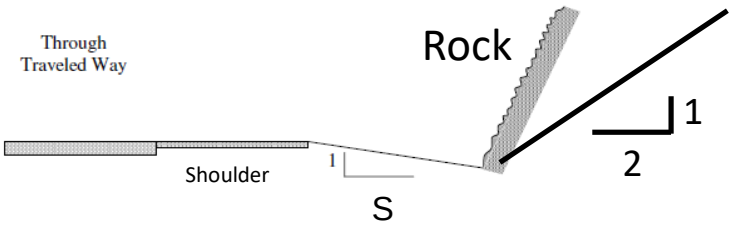
Clear Zone with a steep Cut Slope



S (≥4) Recoverable	Clear Zone extends to the base of the cut. If this distance is less than the design clear zone: • For a **smooth** rock cut – it can be considered a natural barrier. (Note a 2:1 smooth slope is not normally shielded) • For a **jagged** rock cut – it is considered as any other significant obstacle within the design clear zone.
S (<4) Non-Recoverable	Clear Zone ends at the edge of shoulder.

Ref: AASHTO Roadside Design Guide, 4th Edition, Pg.3-24

NCDOT Session 2 2-23

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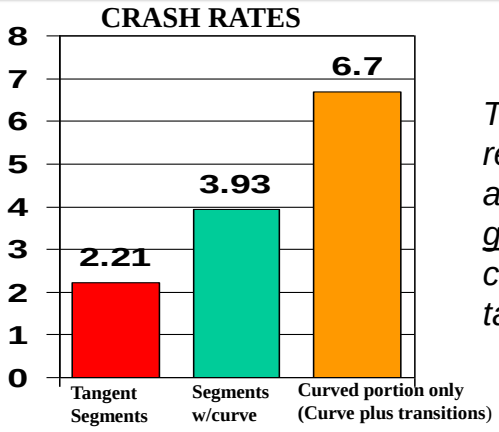
….Curves Present Particular Safety Problems



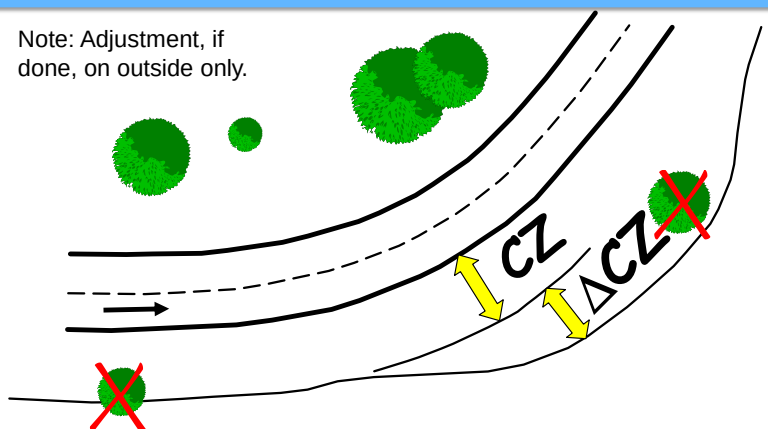
The risk of a reported crash is about <u>three times greater</u> on a curve than on a tangent

Source: Glennon, et al, 1985 study for FHWA

NCDOT Session 2 2-24

Horizontal Curves - AASHTO

Note: Adjustment, if done, on outside only.



Ref: AASHTO Roadside Design Guide, 4th Edition, Pg. 3-3

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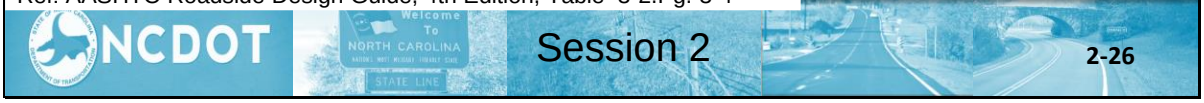
Horizontal Curve Adjustments

K_{CZ} (Curve Correction Factor)(U.S. Customary Units)

Radius (ft)	Design Speed (mph)					
	40	45	50	55	65	70
2,950	1.1	1.1	1.1	1.2	1.2	1.2
2,300	1.1	1.1	1.2	1.2	1.2	1.3
1,970	1.1	1.2	1.2	1.2	1.3	1.4
1,640	1.1	1.2	1.2	1.3	1.3	1.4
1,475	1.2	1.2	1.3	1.3	1.4	1.5
1,315	1.2	1.2	1.3	1.3	1.4	-
1,150	1.2	1.2	1.3	1.4	1.5	-
985	1.2	1.3	1.4	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	-	-	-	-	-

Ref: AASHTO Roadside Design Guide, 4th Edition, Table 3-2.Pg. 3-4



Horizontal Curves - NCDOT

The Roadside Design Guide states: "The designer **may** choose to modify…". Again, not normally done unless crash history indicates a problem.

Need approval by Roadway Design Unit

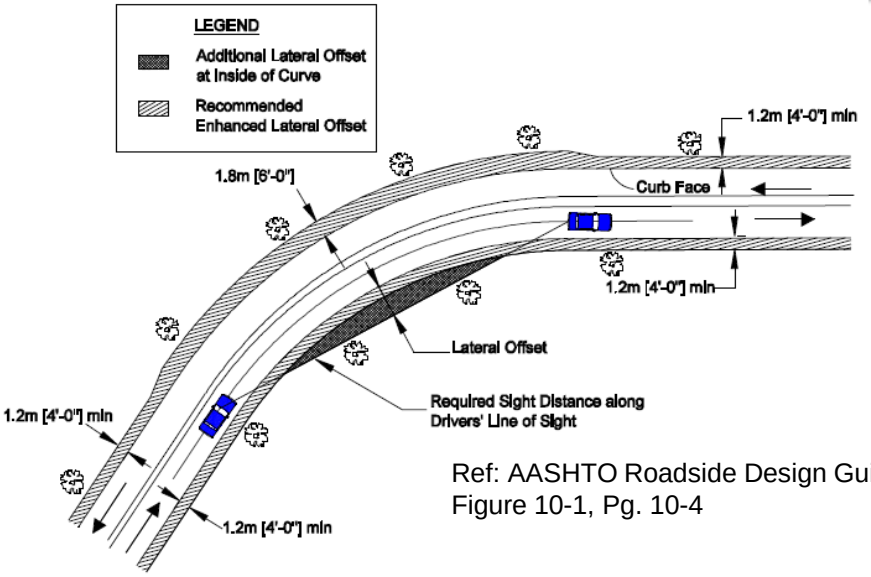
Remember - As Wide as Practical

Clear Zone and Curbs

The minimum lateral offset of 1.5 ft should be provided beyond the face of curbs to any vertical objects.
This is called the Lateral Offset and ***should not be construed as an acceptable clear zone distance.***

Ref: AASHTO Roadside Design Guide, Section 10.2.1.1 Curbs

Clear Zone in an Urban Area



Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 10-1, Pg. 10-4

Figure 10-1. Lateral Offset for Objects at Horizontal Curves on Curbed Facilities

NCDOT Session 2 2-29

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Order of Preference

1. Remove hazard
2. Redesign hazard (make traversable)
3. Relocate hazard (move away from traffic)
4. Reduce Impact Severity (use breakaway design)
5. SHIELD hazard
6. Delineate hazard so motorist can avoid

Ref: AASHTO Roadside Design Guide, 4th Edition – Pg. 1-4

NCDOT Session 2 2-30

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Order of Preference - NCDOT

4.10 Traffic Barriers
4.10.1 General Considerations

The preferred method of addressing roadside hazards is as follows:

1. Remove the hazard;
2. Remove embankment hazard (flatten slopes);
3. Shift hazard away from traffic;
4. Reduce the impact severity by using breakaway posts;
5. Protect the hazard;
6. Delineate the hazard so motorists are aware of the hazard.

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Welcome To NORTH CAROLINA
STATE LINE
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AASHTO Barrier Warrants

Obstacle	Guidelines
Bridge piers, abutments, and railing ends	Shielding generally required
Boulders	Judgment decision based on nature of fixed object and likelihood of impact
Culverts, pipes, headwalls	Judgment decision based on size, shape and location of obstacle
Foreslopes and backslopes (smooth)	Shielding not generally required
Foreslopes and backslopes (rough)	Judgment decision based on likelihood of impact
Ditches (parallel)	Refer to Figures 3-6 and 3-7
Ditches (transverse)	Shielding generally required if likelihood of head-on impact is high
Embankment	Judgment decision based on fill height and slope (see Figure 5-1)
Retaining Walls	Judgment decision based on relative smoothness of wall and anticipated maximum angle of impact
Sign/Luminaire supports	Shielding generally required for non-breakaway supports
Traffic signal supports	Isolated traffic signals within clear zone on high-speed rural facilities may warrant shielding
Trees	Judgment decision based on site-specific circumstances
Utility poles	Shielding may be needed on a case by case basis.
Permanent bodies of water	Judgment decision based on location and depth of water and likelihood of encroachment.

Ref: AASHTO Roadside Design Guide, 4th Edition Chapter 5 Table 5-2, Pg. 5-9

NCDOT Guidance

ROADWAY DESIGN MANUAL PART 1

CHAPTER THREE

GUARDRAIL, BARRIERS AND ATTENUATORS

GUARDRAIL WARRANTS 3-1

Warrants for guardrail are to be in accordance with the "Roadside Design Guide" and with the guardrail warrant curves included in this Chapter.

In the preliminary design stage, the designer will establish the location and grade of the project so as to eliminate as much guardrail as possible using these warrants.

After location data is received, plans plotted, grades set, and initial templates determined, the following procedures should be followed:

(1) Determine Guardrail Locations
- (a) Is guardrail warranted in accordance with Figure 1 in this Chapter? If not required, go to (c). If required, go to (b).
- (b) Is guardrail required in accordance with Figures 4 through 6 of this Chapter? If not required, go to (c).
- (c) Is guardrail warranted in accordance with Table 2 and 3 in this Chapter? Refer to Sheet 1-4M and 1-4N in Chapter 1 of this manual.

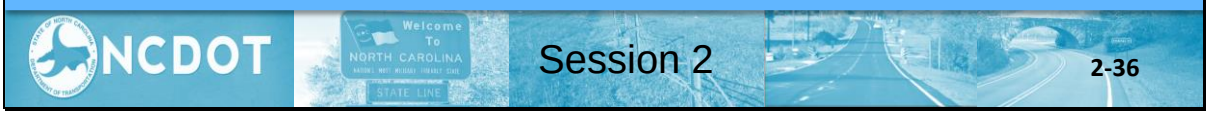
(2) Can Guardrail be eliminated?

NCDOT Session 2 2-35

NCDOT Guidance - Proposed

Obstacles* within the Clear Zone	Guideline
Embankments	engineering judgment - see note 1
Shoulder Drop-off with slope Steeper than 1:1 - greater than 2 feet height	guardrail required
Shoulder Drop-off with slope Steeper than 1:1 - less than 2 feet height	Guardrail not required
Bridge Piers, Abutments	Guardrail required - see note 2
Culverts, Pipes, Headwalls	Guardrail required - see note 3
Sign Supports	Guardrail required for non-breakaway supports
Traffic Signal Supports	Engineering judgement based on each location
Utility Poles	Engineering judgement based on each location
Rough Rock Cuts	Guardrail required
Large Boulders	Guardrail required
Streams or Permanent Bodies of Water less than 2 feet in depth	Guardrail not required
Streams or Permanent Bodies of Water greater than 2 feet in depth	Guardrail required
Landscaping	Engineering judgement based on each location - see note 4

* Obstacles may be nontraversable hazards or fixed objects
Note 1 - see RDG Figure 5-1
Note 2 - Subregional Tier Guideline allows for reduced lengths (see STG for details)
Note 3 - section 5-2 original RDM need new information location
Note 4 - Landscaping plans should be reviewed for potential hazards

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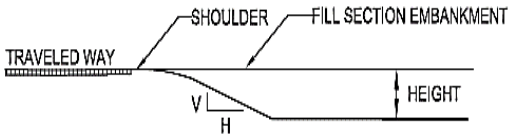
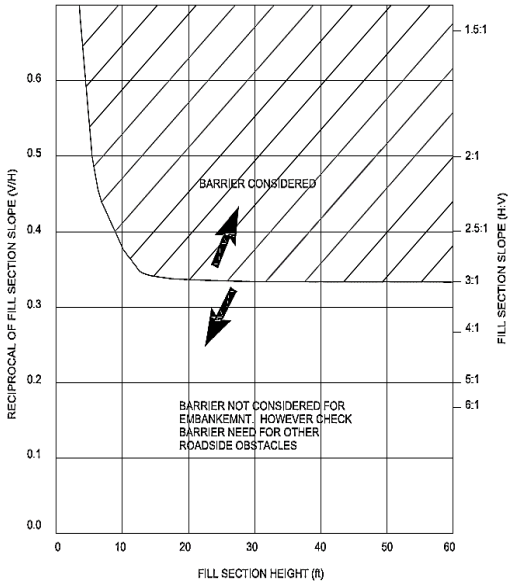
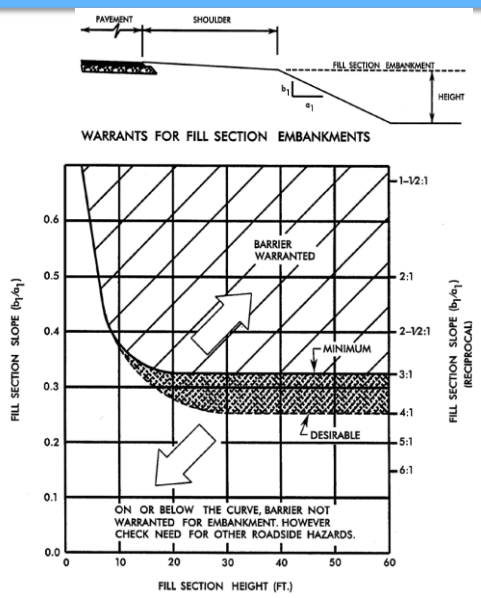
Embankment Guidelines



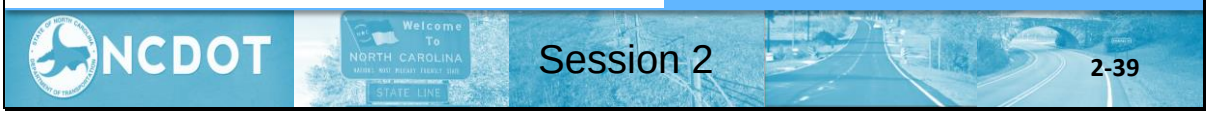


Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 5.1b, Pg. 5-6

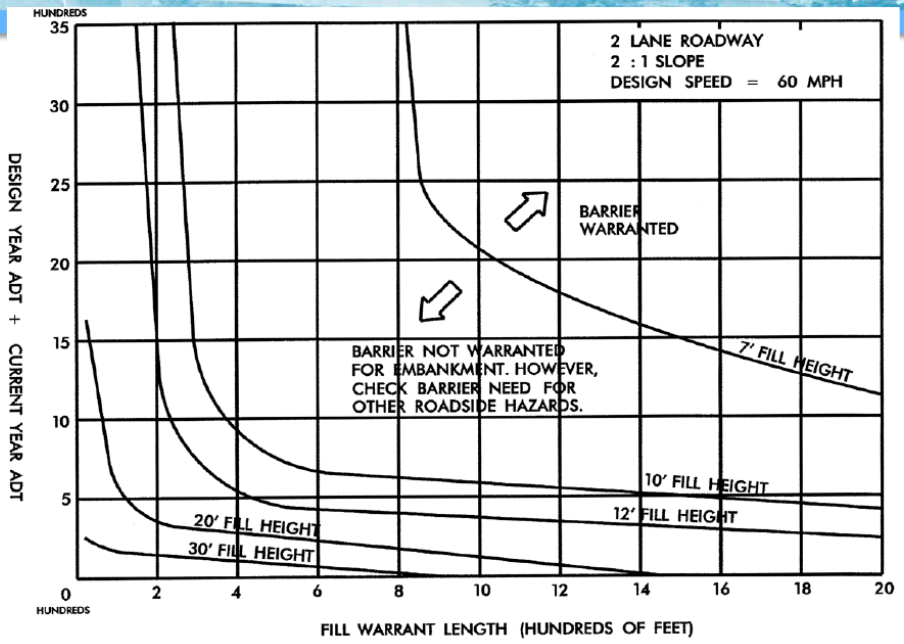
NC Embankment Warrants



Ref: NCDOT Roadway Design Manual, Part 1, Chapter 3



Modified Embankment Warrants



Ref: NCDOT Roadway Design Manual, Part 1, Chapter 3, Figure 5

Is barrier warranted at the locations shown in the next eight photos?

Do not consider effectiveness of existing barrier (if any).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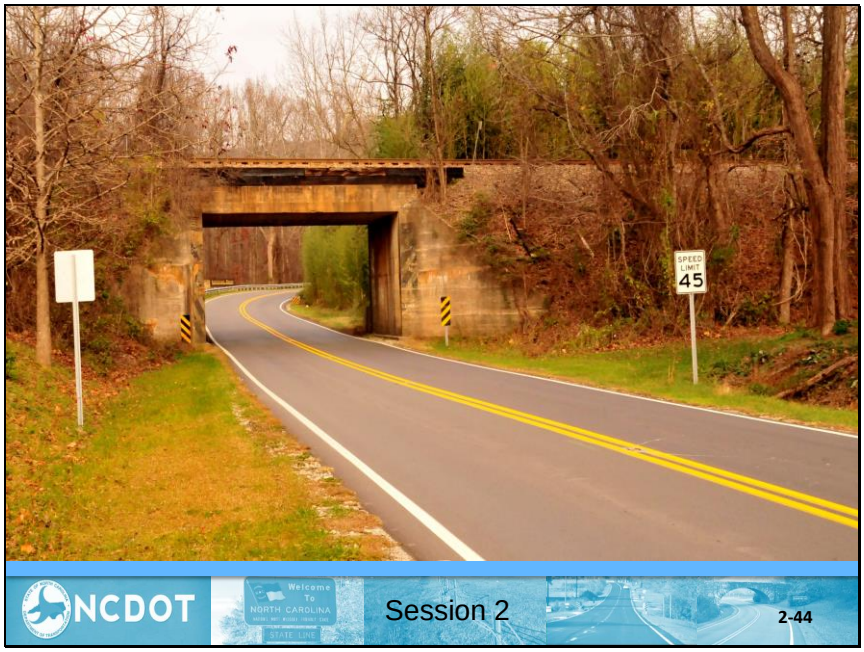
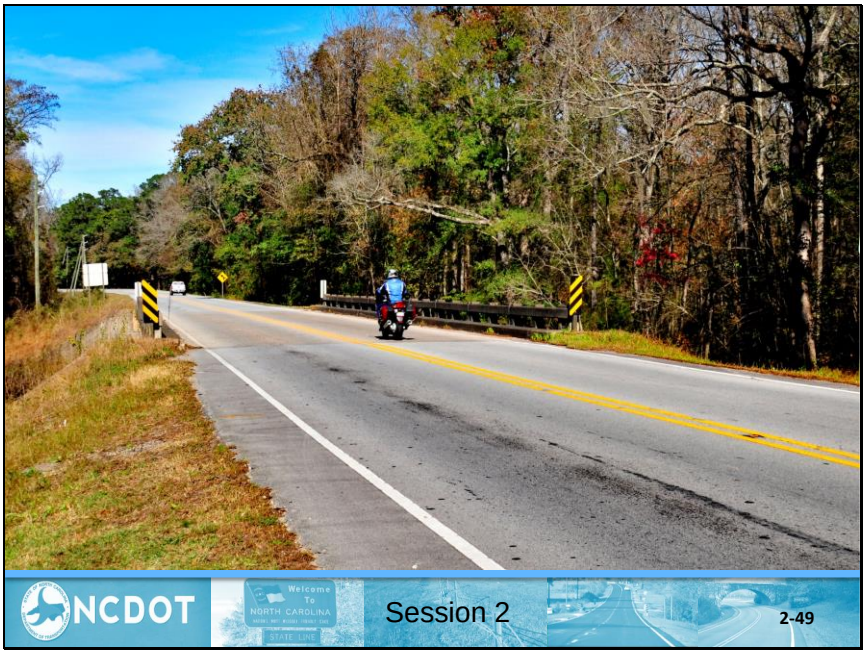

SPEED LIMIT
45
NCDOT
Session 2
2-44


NORTH
EAST
NCDOT
Session 2
2-45


EXIT 14
NCDOT
Session 2
2-46


NCDOT
Session 2
2-47


Laurel Fork
NCDOT
Session 2
2-48


NCDOT
Session 2
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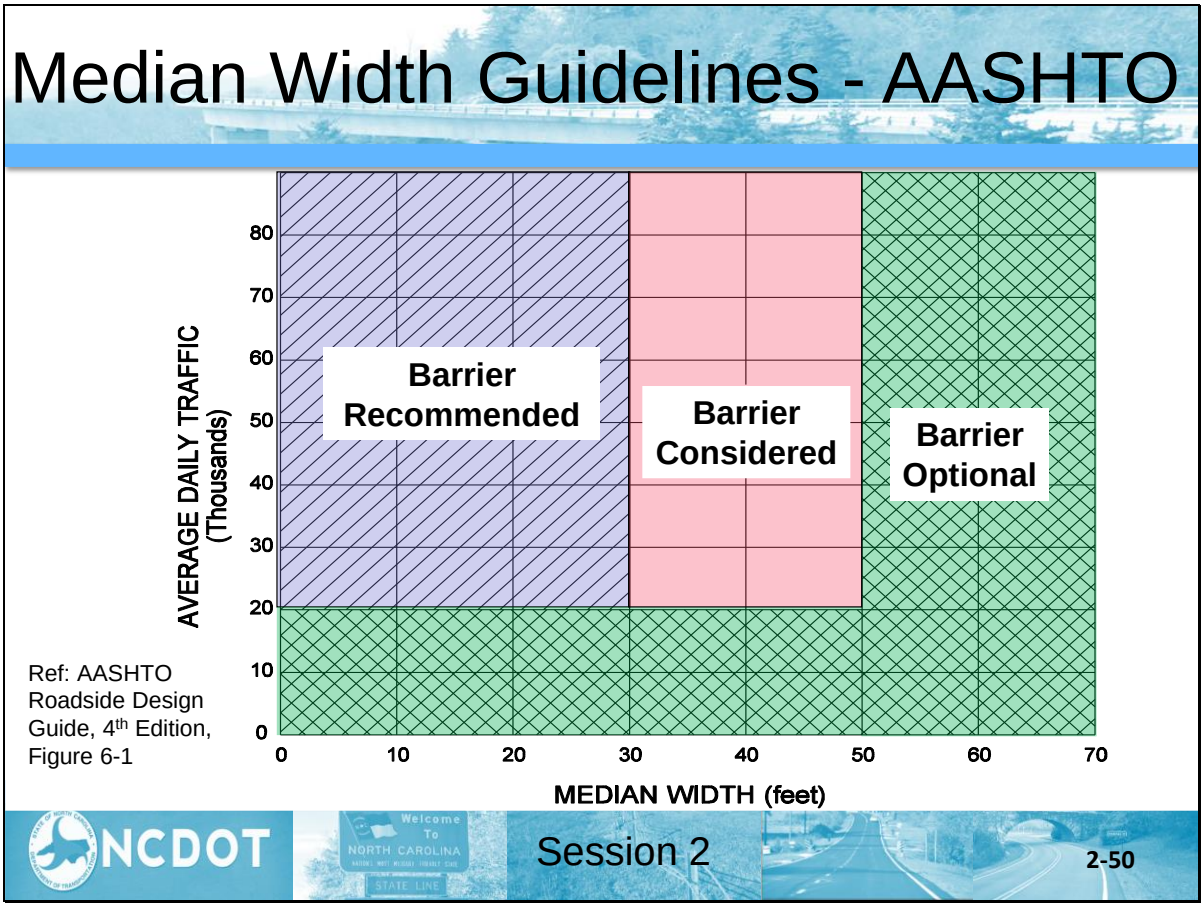
Median Width Guidelines - AASHTO
AVERAGE DAILY TRAFFIC (Thousands)
80
70
60
50
40
30
20
10
0
Barrier Recommended
Barrier Considered
Barrier Optional
0
10
20
30
40
50
60
70
MEDIAN WIDTH (feet)
Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 6-1
NCDOT
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STATE LINE
Session 2
2-50

Median Width Guidelines - NCDOT

ROADWAY DESIGN MANUAL PART 1

GUARDRAIL / GUIDERAIL TREATMENT IN MEDIAN LOCATIONS 3-6

Guidelines for typical Median Guardrail / Guiderail Installations:

Incorporate median guardrail / guiderail on all freeway projects with median widths of 70 feet or less.

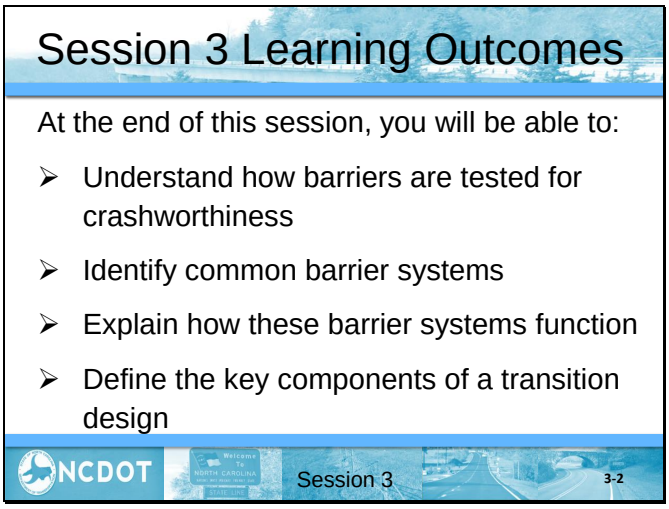
Two types of installations will be used: Cable guiderail or steel beam guardrail with 6'- 3" post spacing (semi-rigid guardrail).

Review Learning Outcomes

- Understand and apply the clear zone concept
- Identify objects and features that may require shielding

Session 3: Testing Requirements and Performance Characteristics of Common Barrier Systems


North Carolina Department of Transportation
Highway Safety Barrier Design Training
Session 3:
Testing Requirements and Performance Characteristics of Common Barrier Systems
NCDOT
Session 3
3-1


Session 3 Learning Outcomes
At the end of this session, you will be able to:
Understand how barriers are tested for crashworthiness
Identify common barrier systems
Explain how these barrier systems function
Define the key components of a transition design
NCDOT
Session 3
3-2

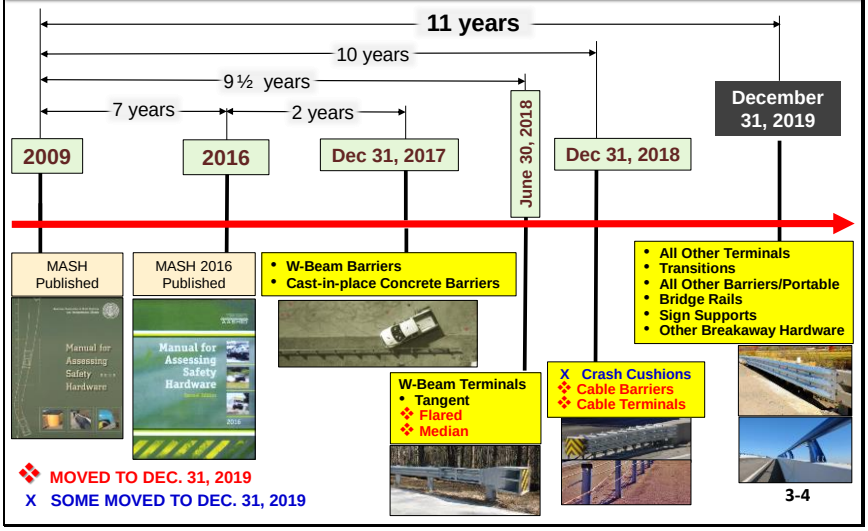
Crash Testing Guidelines

- In 1993, crash testing and evaluation criteria were published as NCHRP Report 350
- In 2009, the Manual for Assessing Safety Hardware (MASH) was published by AASHTO. It was used by FHWA as the testing standard for all new products
- In 2016, an update to MASH was adopted and a timetable for implementation of new installations complying with this edition was signed between FHWA and AASHTO

NCDOT Session 3 3-3

MASH Implementation Timeline

(AASHTO/FHWA Joint MASH Implementation Agreement Issued January 7, 2016)



3-4

MASH Test Conditions

Selection of a performance level is based on speed and traffic mix.

- **TL-1**, **TL-2**, and **TL-3**: crash tests with small car and pickup truck with a 25˚ impact angle at 31, 44, and 62 mph, respectively.

2,420 lbs.
1100C

5,000 lbs.
2270P

NCDOT Session 3 3-5

NCHRP 350 comparison with MASH Crew Cab Truck

NCDOT Session 3 3-6

MASH Test Conditions (cont'd)

- **TL- 4**: TL-3 + 15˚ impact angle, 56 mph Single-Unit Truck
- **TL- 5**: TL-3 + 15˚ impact angle, 50 mph Tractor-Van Trailer
- **TL- 6**: TL-3 + 15˚ impact angle, 50 mph Tractor-Tank Trailer

22,000 lbs.

80,000 lbs.

80,000 lbs.

NCDOT Session 3 3-7

Functional Requirement of Barrier

1. Contain Vehicle
   - No Penetration
   - No Vaulting/Under-riding
2. Redirect Vehicle Smoothly (low exit angle) with no snagging/overturning, and no excessive rotation (75 degree max)
3. Tolerable Occupant Impact Forces
4. Minimum Occupant Compartment Deformation and no Debris Intrusion

NCDOT Session 3 3-8

Standard Barrier Systems

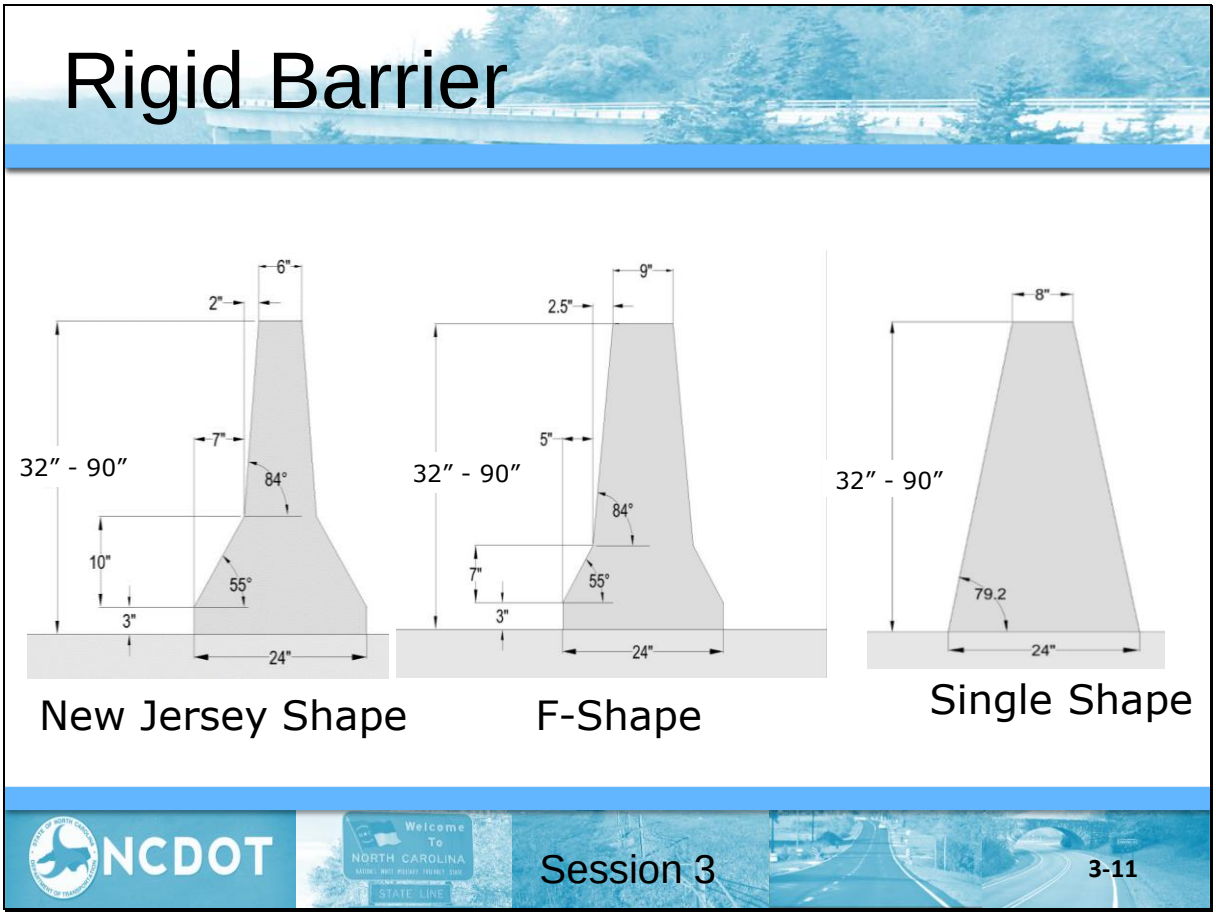
- Rigid Systems
- Semi-Rigid Systems
- Flexible Systems
- Median Barrier Systems

Barrier Systems: Rigid Barriers

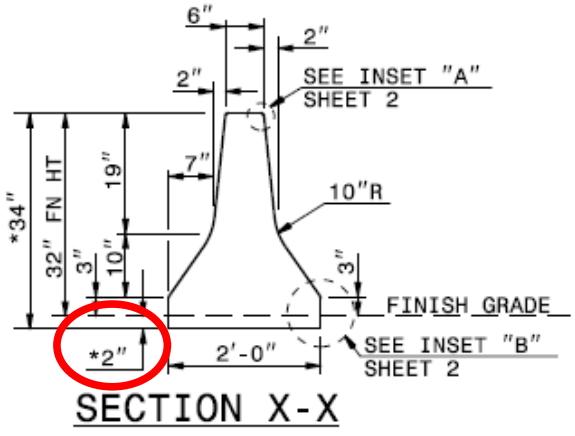
Rigid Barrier Systems have little (between 0 to 1 ft.) deflection under the TL-3 pickup impact. They are generally anchored by some acceptable means.

Examples include:

- New Jersey Safety Shape Concrete Barrier
- F-shape Concrete Barrier
- Single or Slope Concrete Barrier
- Vertical Wall


Rigid Barrier
6"
2"
7"
84°
32" - 90"
10"
55°
3"
24"
New Jersey Shape
9"
2.5"
5"
84°
32" - 90"
7"
55°
3"
24"
F-Shape
8"
32" - 90"
79.2
24"
Single Shape
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 3
3-11

Rigid Barrier – New Jersey Shape



SECTION X-X

TYPE IV - NO GLARE SCREEN PERMITTED

Type IV typically used

Types II & III for bifurcated cross-sections

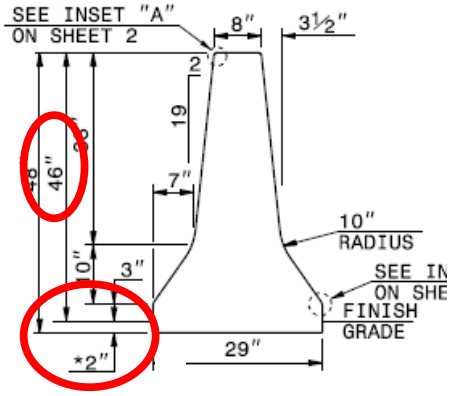
2" min Embedment minimizes Deflection

When large trucks are not an issue

854.01 SHEET 1 OF 4	ROADWAY STANDARD DRAWING FOR **DOUBLE FACED CONCRETE BARRIER** TYPES I, II, III & IV	1-18 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

NCDOT Session 3 3-12

Rigid Barrier – New Jersey Shape



2" min Embedment minimizes Deflection

Considered TL- 5

For use when conditions warrant (typical urban, high truck volume

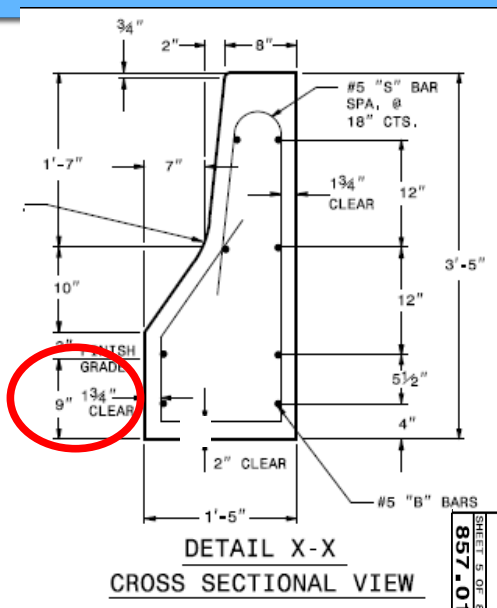
SECTION X-X

TYPE - T

854.02 SHEET 1 OF 4	ROADWAY STANDARD DRAWING FOR **DOUBLE FACED CONCRETE BARRIER** TYPE T, T1 AND T2	1-18 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

NCDOT Session 3 3-13

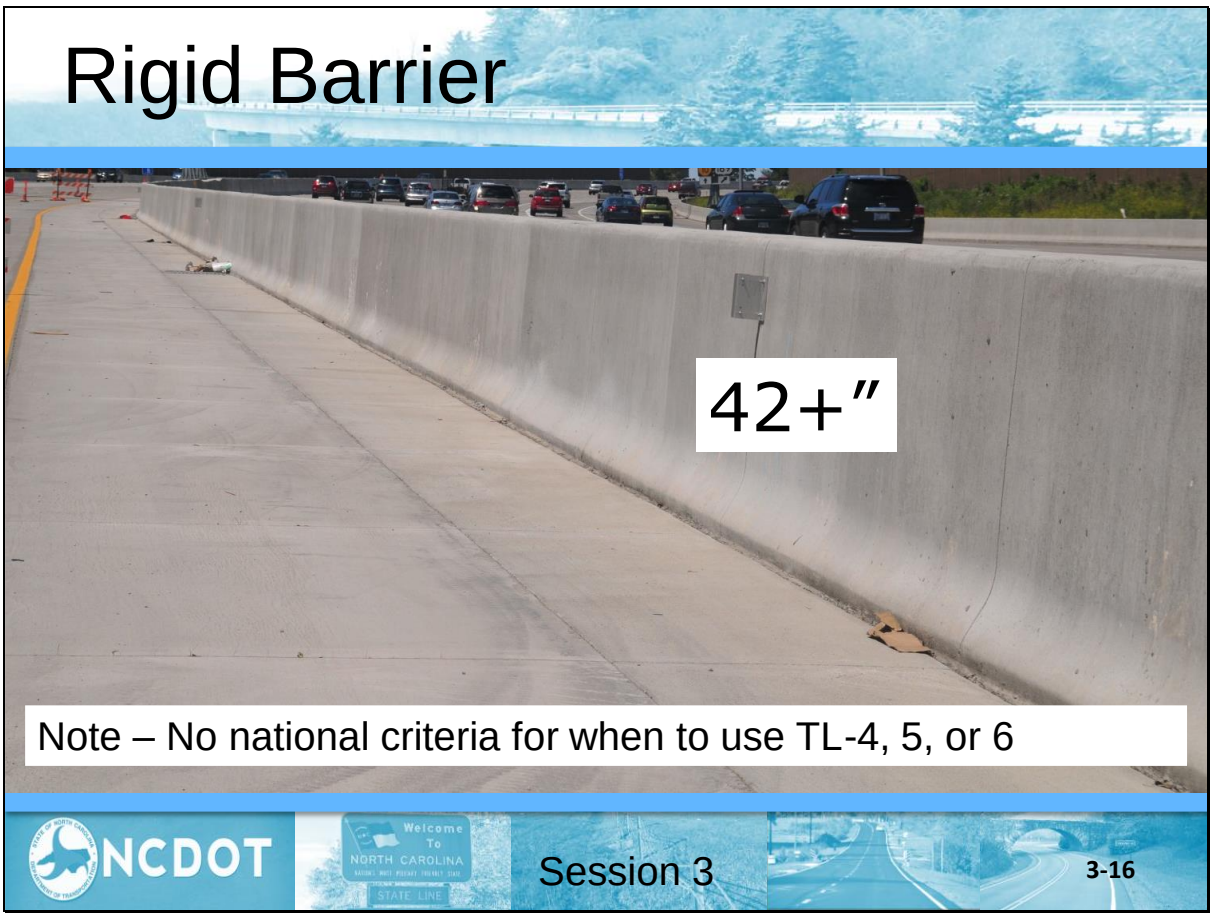
Rigid Barrier – New Jersey Shape



DETAIL X-X
CROSS SECTIONAL VIEW

9" min Provides Fixity

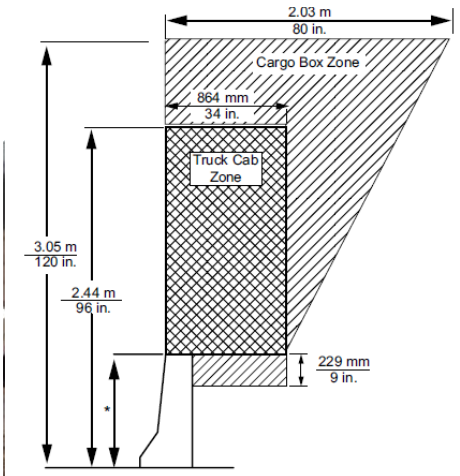
SHEET 5 OF 8	ROADWAY STANDARD DRAWING FOR	1-18	STATE OF NORTH CAROLINA
857.01	**PRECAST REINFORCED CONCRETE BARRIER** 41" SINGLE FACED		DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.


Rigid Barrier
42+”
Note – No national criteria for when to use TL-4, 5, or 6
NCDOT
Session 3
3-16


Rigid Barrier: TL-5
Video Clip
NCDOT
Session 3
3-17

Zone of Intrusion

Zone of Intrusion (ZOI) - the region measured above and behind the face of a barrier system where an impacting vehicle or any major part of the system may extend during an impact.



*Review TL-4 barrier heights fell in a range of 737 mm (29 in.) to 1.07 m (42 in.)

Figure 5-31. Zone of Intrusion for TL-4 Barriers per NCHRP Report 350

AASHTO LRFD Bridge Specification (7th Edition)

3.6.5.1 Where the design choice is to redirect or absorb the collision load, protection shall consist of one of the following:

- An embankment;
- A structurally independent, crashworthy ground-mounted 54.0-in. high barrier, located within 10.0 ft from the component being protected; or
- A 42.0-in. high barrier located at more than 10.0 ft from the component being protected.

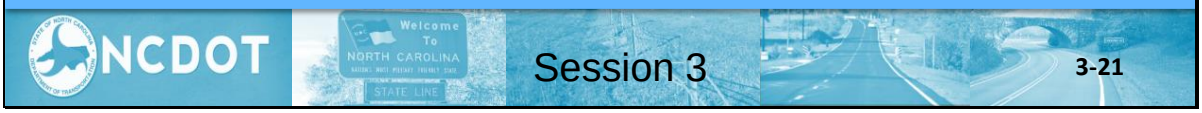
Such barrier shall be structurally and geometrically capable of surviving the crash test for Test Level 5, as specified in Section 13.

Barrier Systems: Semi-Rigid

Semi-Rigid Barrier Systems have deflections of a few feet (between 2 to 5 ft.) under the TL-3 pickup impact.

Typically consist of beam and post elements.

TERMINOLOGY: Call new system 31" (shows 2'-1" to bolt on standards)



Barrier Systems: Semi-Rigid

- W-Beam Steel Guardrail – **350 Guardrail (29")**
  - 12" wide W-beam rail section (12-gauge thickness).
  - Posts are spaced at 6'-3" centers, and the nominal rail height is 27" – 30"
  - Rail splice at the post.
  - Steel posts: W6 x 8.5/9.0 x 6'-0" long.
  - Offset Block: 6" x 8" recycle plastic or composite.

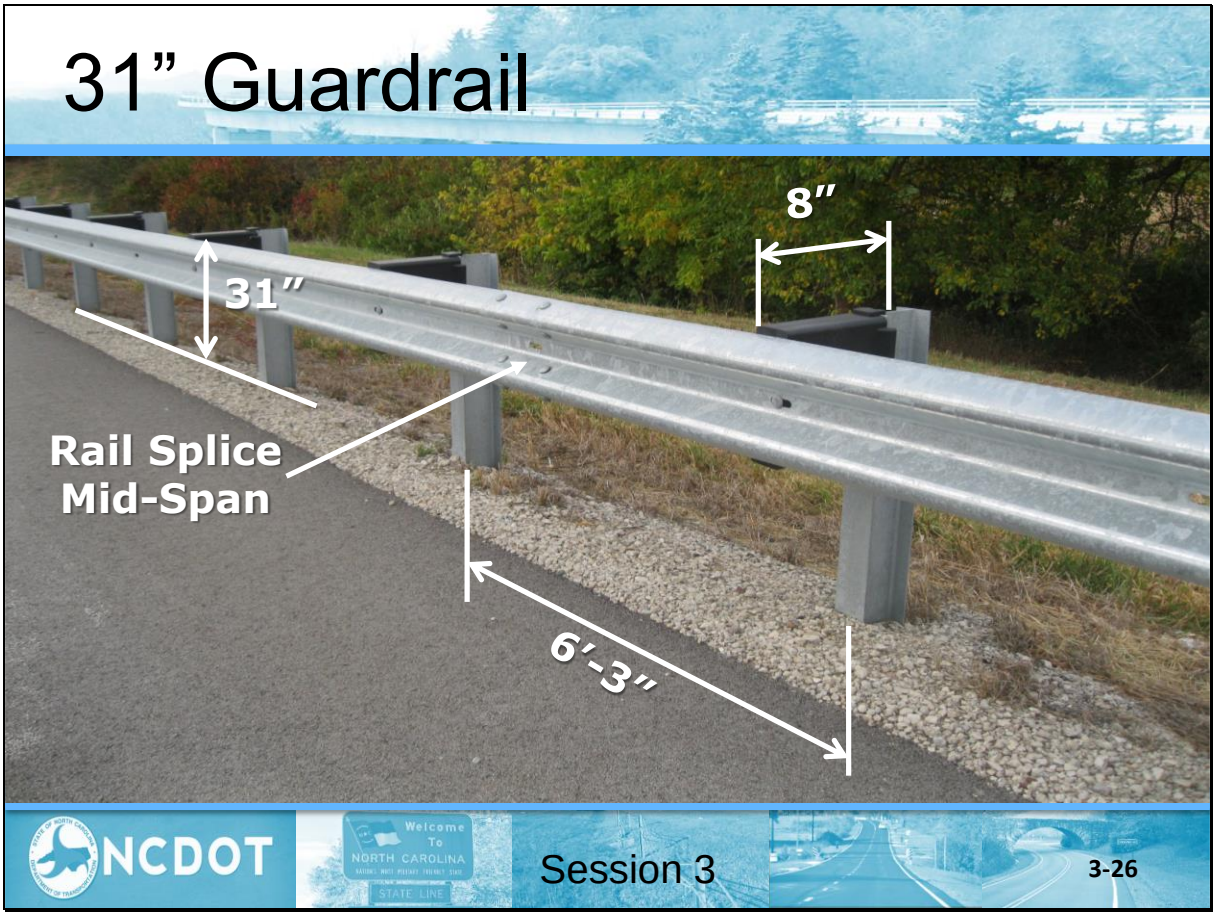
NCDOT Session 3 3-22

Guardrail with Wood Post & Wood Offset Block 27 5/8" Height

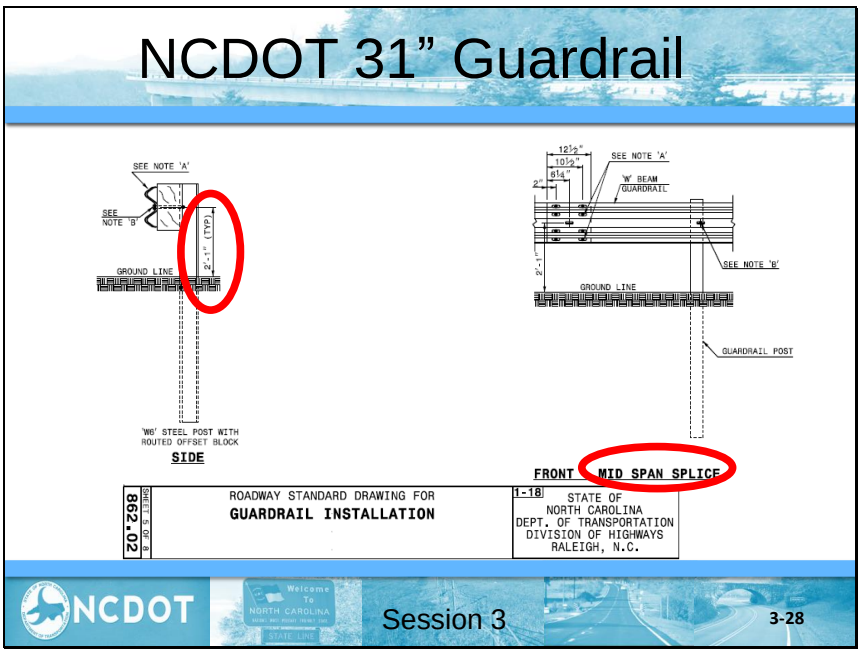
NCDOT Session 3 3-23

Barrier Systems: Semi-Rigid

- **31"** (shown in standards as 2'-1")
  - 31" Height to Top of Rail
  - Rail Splice mid-span.
  - Post spacing 6'-3"
  - Steel posts, W6 x 8.5/9.0 x 6'
  - Offset Block: 8" recycled plastic or composite


31” Guardrail
8”
31”
Rail Splice
Mid-Span
6’-3”
NCDOT
Welcome To NORTH CAROLINA
Session 3
3-26


31” MASH Test 3-11
Video Clip
NCDOT
Session 3
3-27


NCDOT 31” Guardrail
SEE NOTE 'A'
SEE NOTE 'B'
GROUND LINE
2'-1" (TYP.)
'W6' STEEL POST WITH ROUTED OFFSET BLOCK
SIDE
SEE NOTE 'A'
'W' BEAM GUARDRAIL
SEE NOTE 'B'
GROUND LINE
GUARDRAIL POST
FRONT
MID SPAN SPLICE
SHEET 5 OF 8
862.02
ROADWAY STANDARD DRAWING FOR
GUARDRAIL INSTALLATION
1-18
STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.
NCDOT
Session 3
3-28


Existing Guardrail Height
Must be ≥ 27” to remain in place within the Transportation Improvement Program (TIP)
NCDOT
Session 3
3-29

Barrier Systems: Flexible Barriers

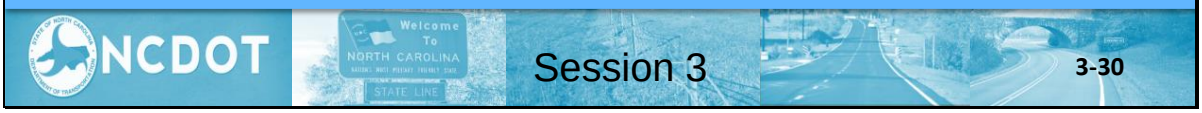
Flexible Barrier Systems typically have relatively large deflections

Examples of Flexible Barriers include:

- Weak post W-beam
- Low tension cable
- High tension cable

No longer in standards

To be removed from standards when MASH available



Barrier Systems: Flexible Barriers

- Low Tensioned Cable Barrier
  - Generic System
  - 3 cables design (center cable on opposite side of the post for median application).
  - Design deflection of approximately 12 ft.
  - Generic crashworthy terminal.

NCDOT Session 3 3-31

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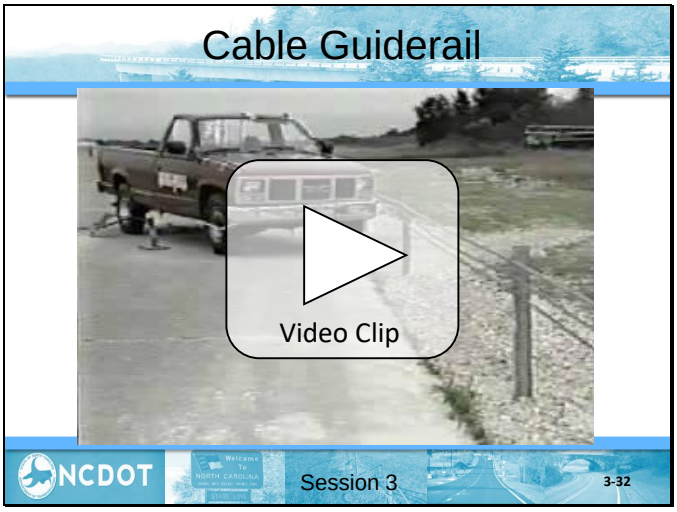
_____



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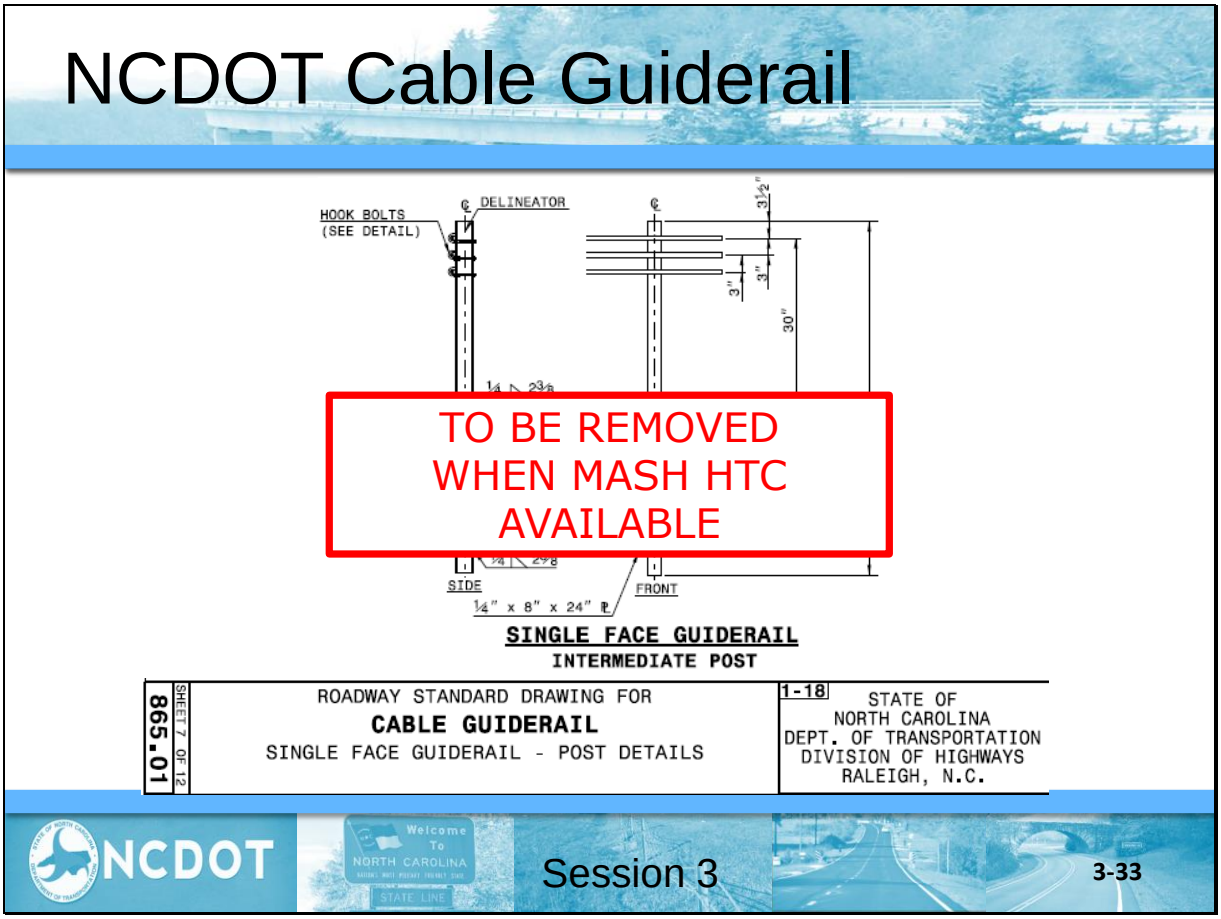
NCDOT Cable Guiderail



NCDOT Session 3 3-33

_____

_____

Barrier Systems: Flexible Barriers

Advantages of cable systems include:

- Low initial cost
- Lower deceleration forces
- Effective vehicle containment and redirection
- Installation conditions flexibility
- SNOW

NCDOT Session 3 3-34

Barrier Systems: Flexible Barriers

- High Tensioned Cable (HTC) Barrier
  - Five different proprietary designs available
  - Each requires a unique proprietary terminal
  - Somewhat reduced deflections
  - Generally easier maintenance
  - Can retain effectiveness after most impacts

NCDOT Session 3 3-35

High-Tension Cable (HTC) Systems

- Brifen ★★
- Safence
- CASS (Trinity Steel) ★
- Nucor
- Gibraltar ★

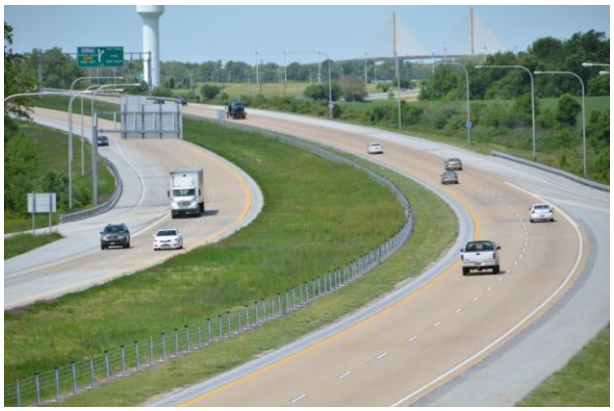
★ = APL

Currently, NO system has passed all MASH 2016 testing

NCDOT Session 3 3-36

Brifen USA

http://www.brifenusa.com



- Interweaving cables creates a “mini-anchor” at each post due to friction as the tensioned cables weave past each post.
- 3 or 4 cable design available.

NCDOT Session 3 3-37

Gibraltar

http://www.gibraltartx.com

- Has hairpin type connection to post.
- Posts to cable connection is alternate side-to-side
- 3 or 4-cable design available.

NCDOT Session 3 3-38

Trinity Industries

http://www.highwayguardrail.co

(Cable Safety System-CASS)

- 3 or 4 cable design available.

NCDOT Session 3 3-39

Four Cable System

NCDOT Session 3 3-40

Post Foundation and Typical Terminal

NCDOT Session 3 3-41

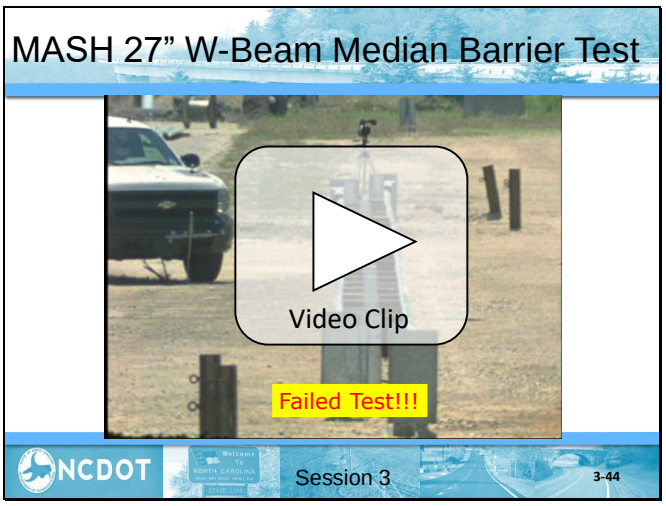
HTC On 4:1 Slope

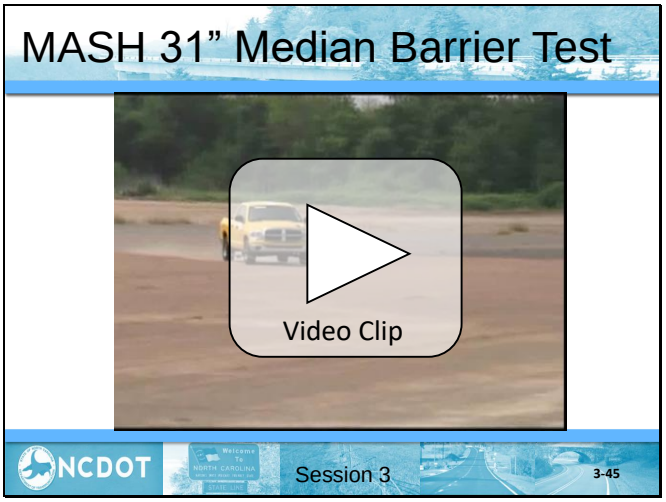
NCDOT Session 3 3-42

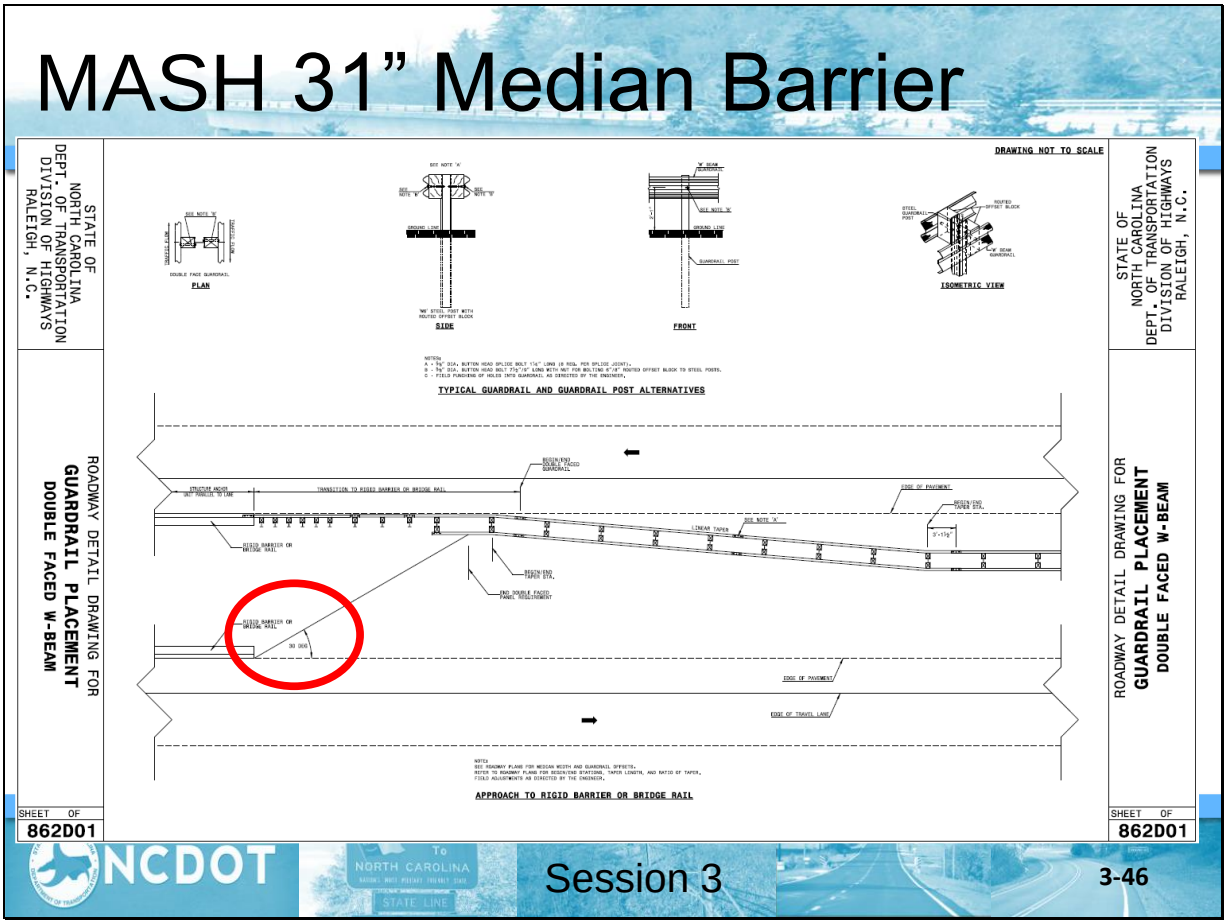
Barriers in the Median

- Used to separate opposing traffic on a divided highway or to separate through traffic from local traffic.
- Many barriers approved for roadside applications can be modified for use in the median.
- Width of the median is an important consideration.
- Also must consider the dynamic deflection of the barrier to avoid intrusion into opposing traffic.
- There are terminals designed specifically to shield the ends of median barriers.

NCDOT Session 3 3-43


MASH 27” W-Beam Median Barrier Test
Video Clip
Failed Test!!!
NCDOT
Session 3
3-44

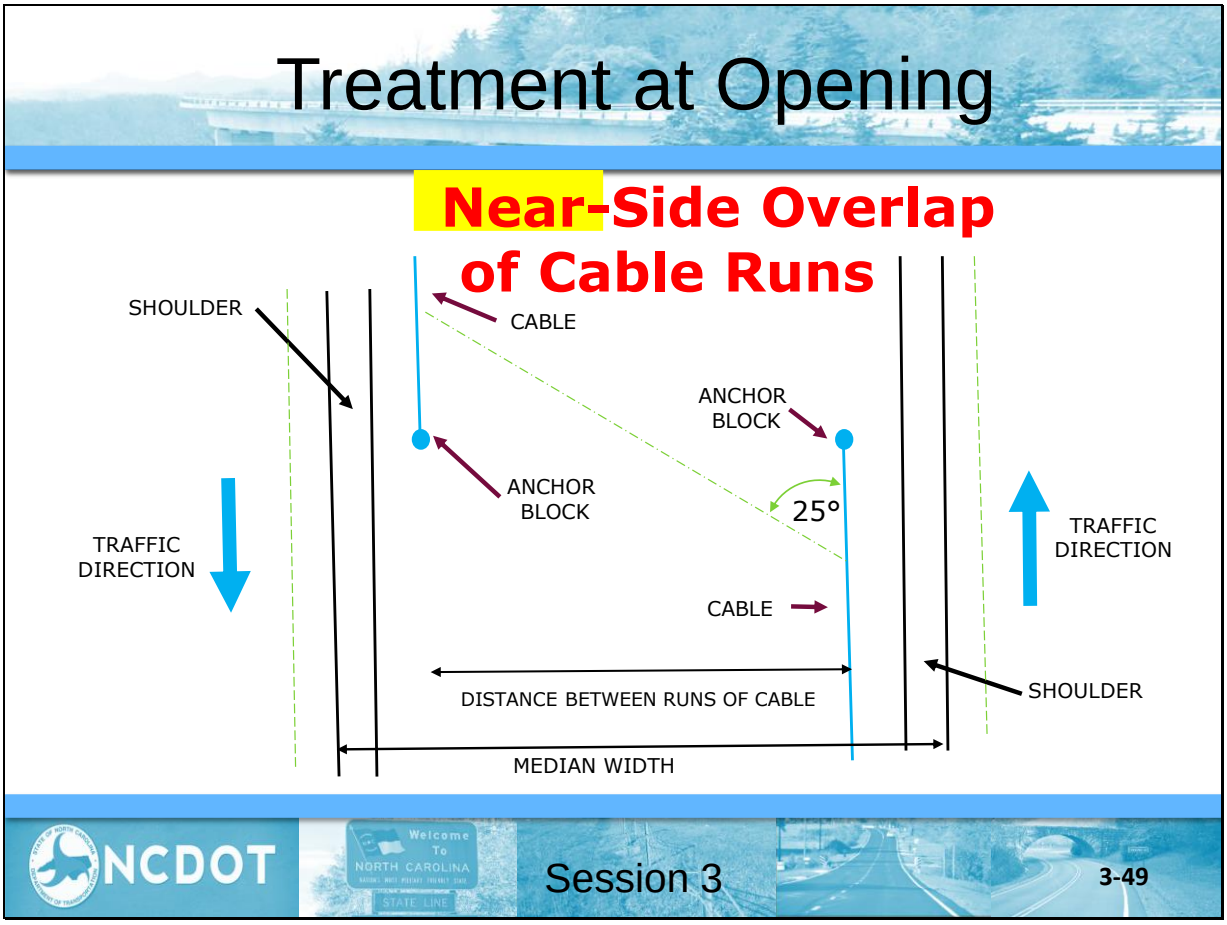

MASH 31” Median Barrier Test
Video Clip
NCDOT
Session 3
3-45

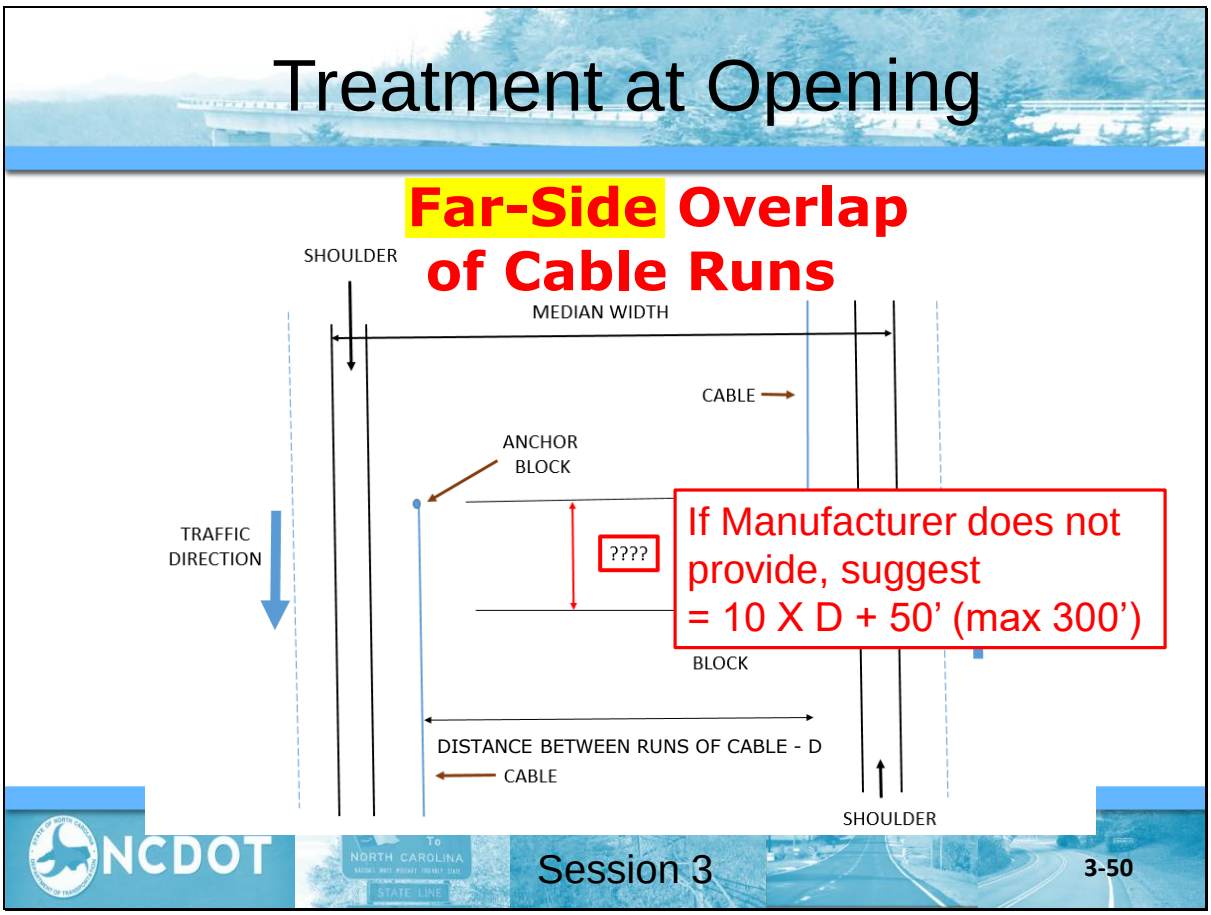


Flexible Median Barriers

Advantage of high tension cable is it may remain effective after impact.


Flexible Median Barriers
NCDOT
Welcome To NORTH CAROLINA STATE LINE
Session 3
3-48


Treatment at Opening
Near-Side Overlap of Cable Runs
SHOULDER
CABLE
ANCHOR BLOCK
ANCHOR BLOCK
25°
TRAFFIC DIRECTION
TRAFFIC DIRECTION
CABLE
DISTANCE BETWEEN RUNS OF CABLE
SHOULDER
MEDIAN WIDTH
NCDOT
Session 3
3-49


Treatment at Opening
Far-Side Overlap of Cable Runs
SHOULDER
MEDIAN WIDTH
CABLE
ANCHOR BLOCK
TRAFFIC DIRECTION
????
If Manufacturer does not provide, suggest
= 10 X D + 50' (max 300')
BLOCK
DISTANCE BETWEEN RUNS OF CABLE - D
CABLE
SHOULDER
NCDOT
Session 3
3-50

Transition Sections

- When a softer (more flexible) barrier precedes a stiffer barrier, a gradual stiffening must occur between the two systems.
- An effective transition must provide the following:
  - Adequate connection (TENSION continuity)
  - Adequate length to gradually increase stiffness.

NCDOT Session 3 3-51

Inadequate Transition

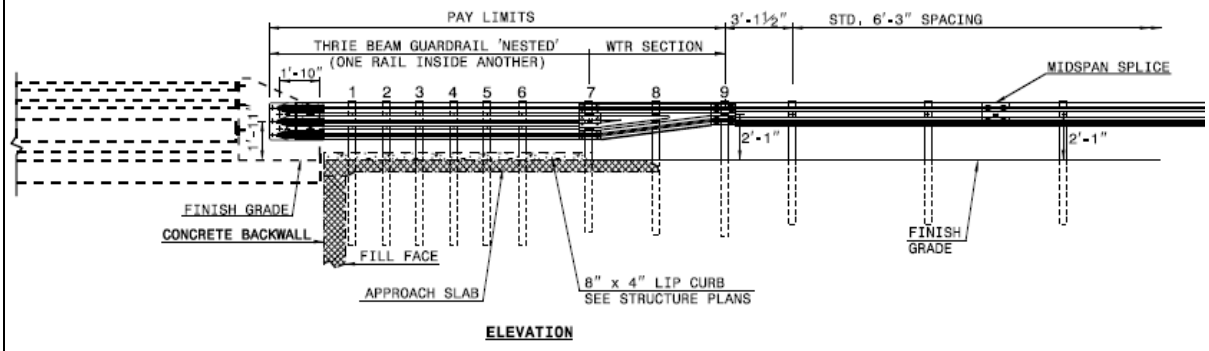
NCDOT Session 3 3-52

Transition Sections

Successfully crash-tested transitions include the following essential elements (in addition to a structural connection):

- Additional and/or Larger Posts
- Nested rail (w-beam or Thrie-beam)
- Curbs (only as crash-tested transition unit), Rub Rails, and/or Flared Parapet Wall to Prevent Snagging

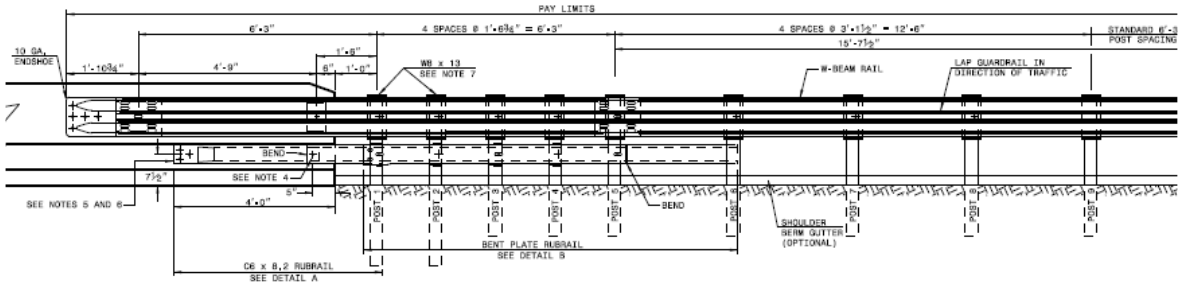
NCDOT Transition – Thrie-beam



SHEET 1 OF 7 862.03	ROADWAY STANDARD DRAWING FOR **STRUCTURE ANCHOR UNITS** GUARDRAIL ANCHOR UNIT, TYPE III FOR ATTACHMENT TO RAIL ON BRIDGE	1-18 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

NCDOT Transition – Previous Standard

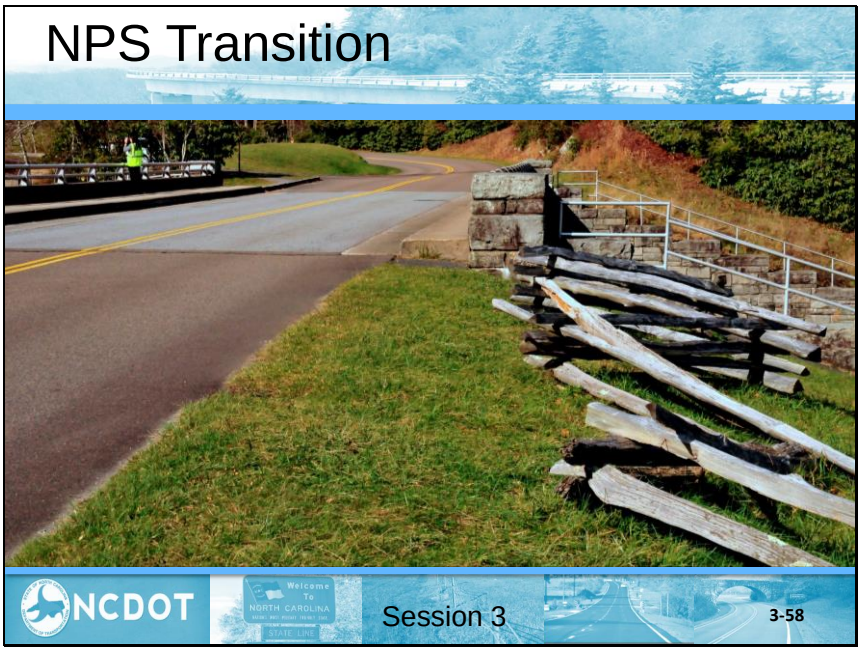
NCDOT Transition – Direct



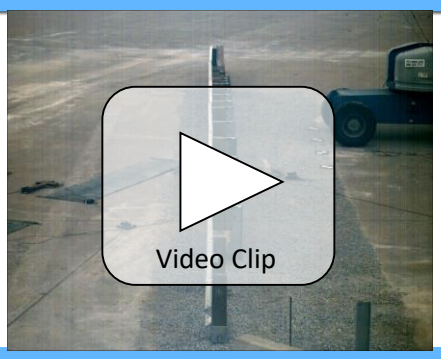
ELEVATION

SHEET 4 OF 7 862.03	ROADWAY STANDARD DRAWING FOR **STRUCTURE ANCHOR UNIT** GUARDRAIL ANCHOR UNIT TYPE B-77 FOR F-SHAPE BARRIER	1-18 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.


NCDOT Transition – With Curb
NCDOT
Session 3
3-57

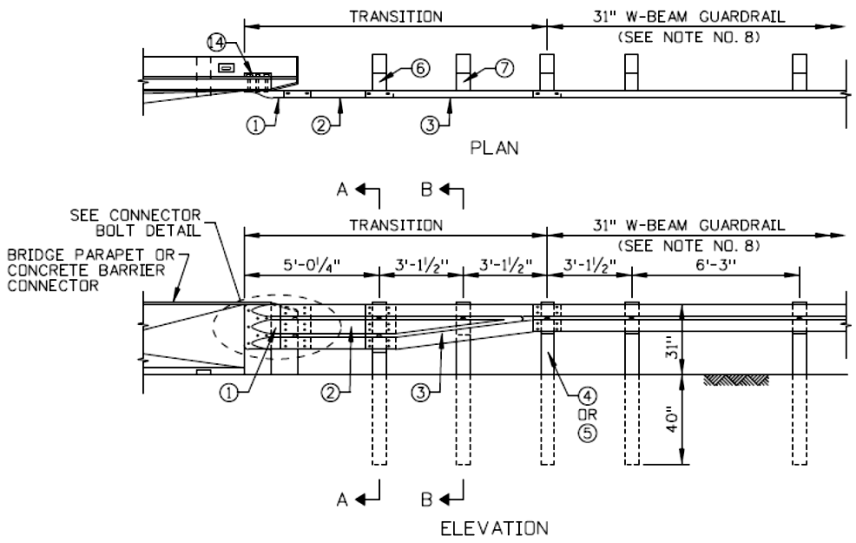

NPS Transition
NCDOT
Session 3
3-58

31" Transition



NCDOT Session 3 3-59

Transition – 31", TL-2



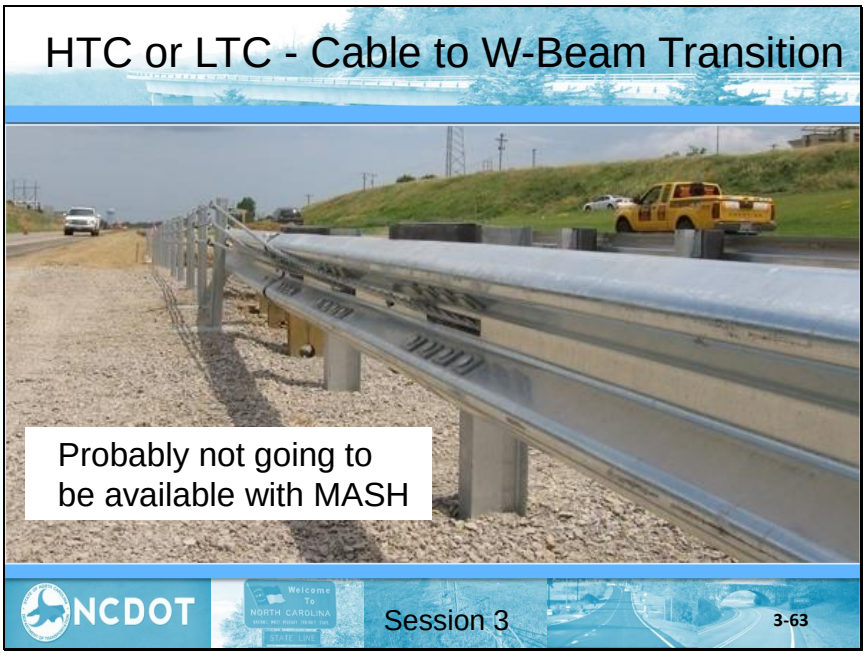
LOW SPEED GUARDRAIL TRANSITION

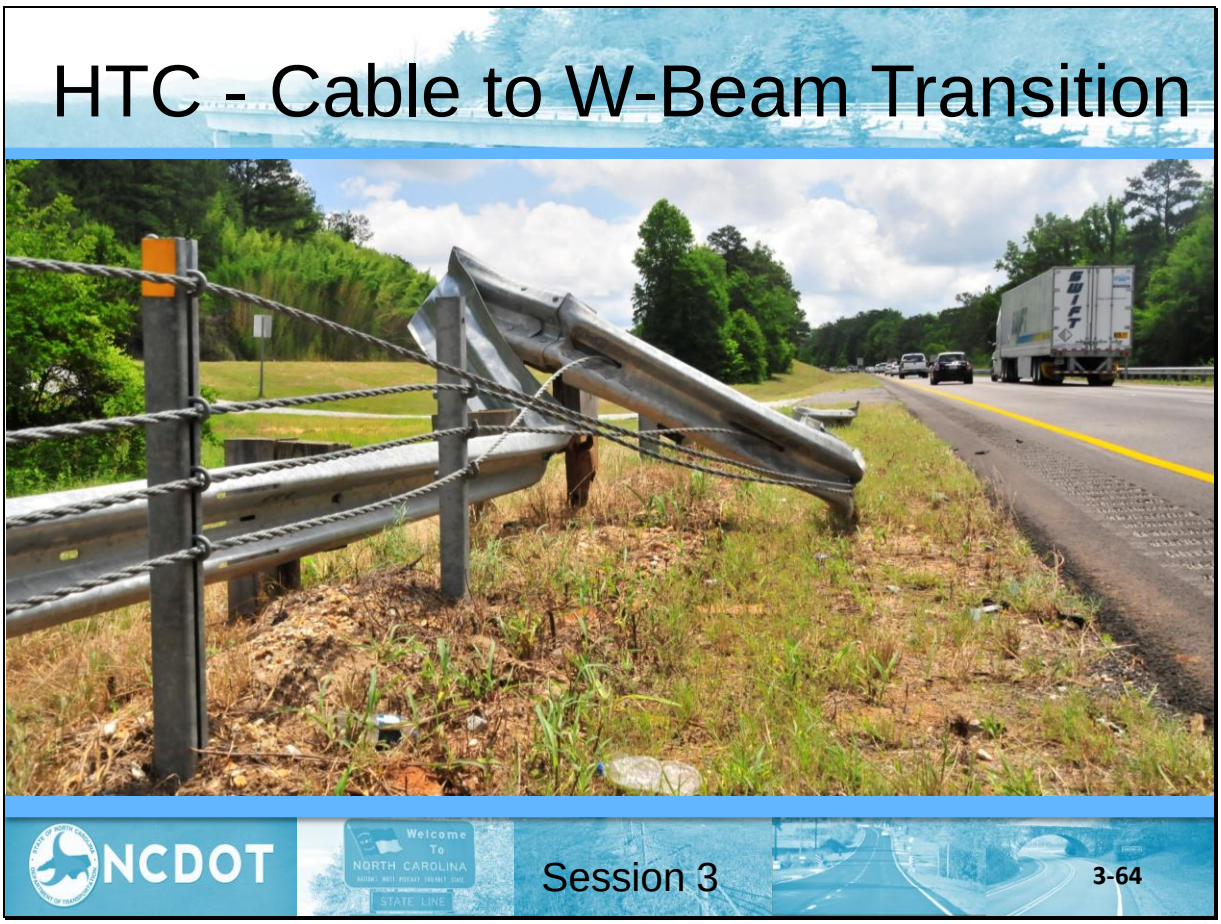
NCDOT Session 3 3-60

Connections to Low Parapets or Combination Rails

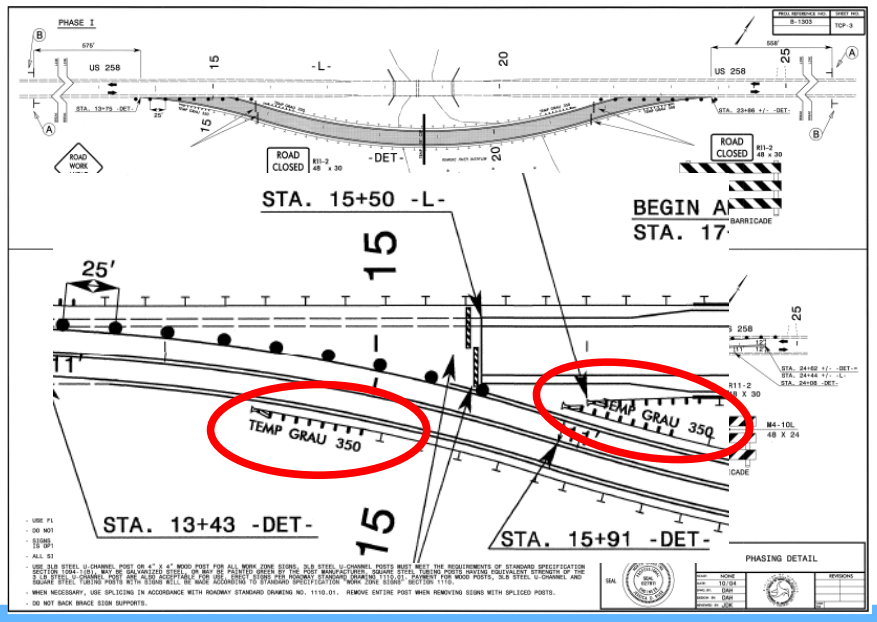
If the concrete parapet or portion of a combination rail is less than the transition height (31”), a steel plate may be applicable to adjust the height.


Transition: HTC to Guardrail (Spatial)
NCDOT
Session 3
3-62

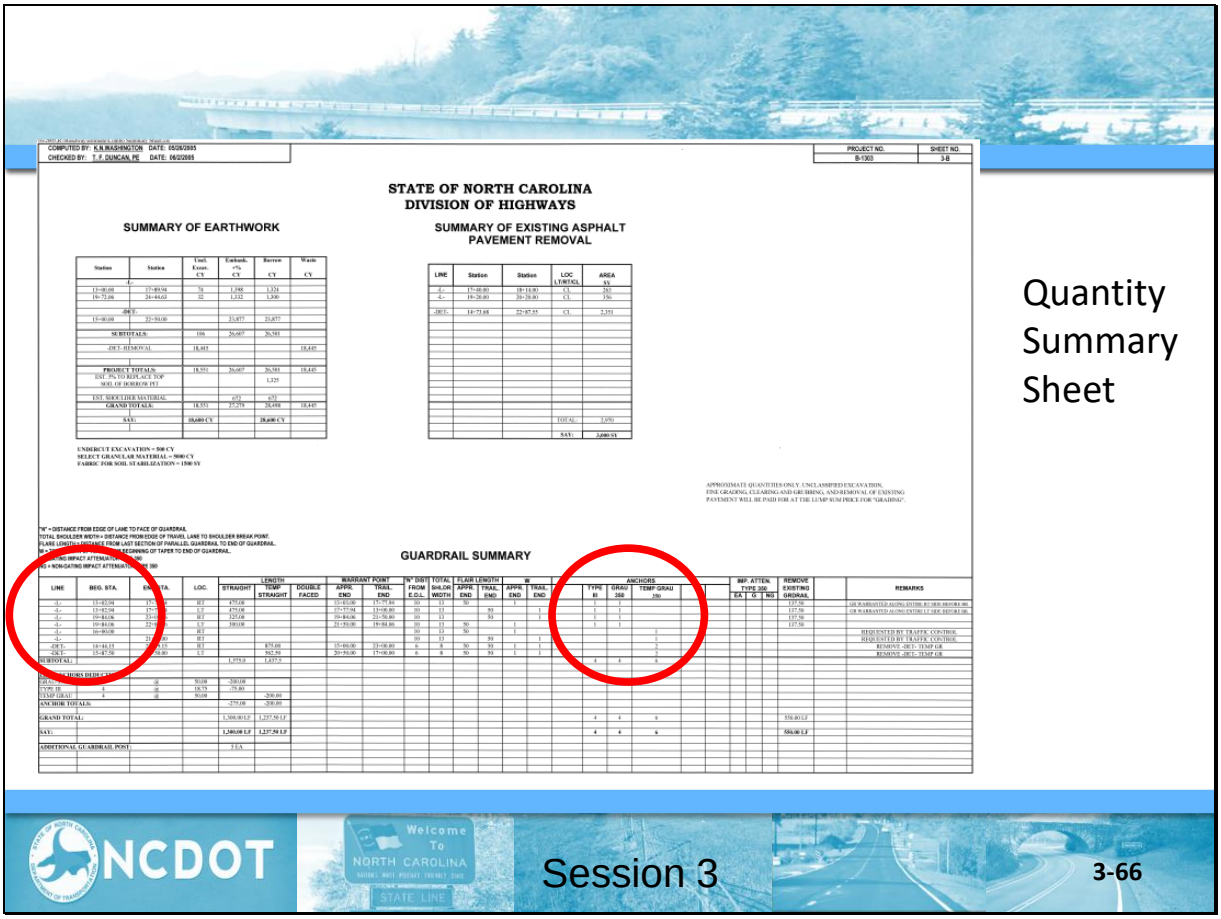

HTC or LTC - Cable to W-Beam Transition
Probably not going to be available with MASH
NCDOT
Session 3
3-63


HTC - Cable to W-Beam Transition
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 3
3-64

Temporary Barrier – Need for Tension



Traffic Management Plan


STATE OF NORTH CAROLINA
DIVISION OF HIGHWAYS
SUMMARY OF EARTHWORK
SUMMARY OF EXISTING ASPHALT PAVEMENT REMOVAL
GUARDRAIL SUMMARY
Quantity Summary Sheet
NCDOT
Welcome To NORTH CAROLINA
Session 3
3-66

Quantity Summary Sheet – blow-up

LINE	BEG. STA.	END STA.
-L-	13+02.94	17+77.14
-L-	13+02.94	17+77.14
-L-	19+84.06	23+09.66
-L-	19+84.06	22+84.66
-L-	16+00.00	
-L-		21+52.00
-DET-	14+44.15	23+09.15
-DET-	15+87.50	21+50.00
SUBTOTAL:		

W BEAM		ANCHORS		
APPR. END	TRAIL. END	TYPE III	GRAU 350	TEMP GRAU 350
1		1	1	
	1	1	1	
	1	1	1	
1		1	1	
1				1
	1			1
1	1			2
1	1			2
		4	4	6

Need to re-establish tension in any altered guardrail – include in plan sheets

★ Placement of GRAU (GREU) must abide by standard application criteria (Deflection and LON)

NCDOT Session 3 3-67

Review Learning Outcomes

- Understand how barriers are tested for crashworthiness
- Identify common barrier systems
- Explain how these barrier systems function
- Define the key components of a transition design

NCDOT Session 3 3-68

Session 4: Testing Requirements and Performance Characteristics of End Treatments and Impact Attenuators

North Carolina Department of Transportation
Highway Safety Barrier Design Training

Session 4:

Testing Requirements and Performance Characteristics of End Treatments and Impact Attenuators

NCDOT Session 4 4-1

Session 4 Learning Outcomes

At the end of this session, you will be able to:

- Understand how end treatments and impact attenuators are tested for crashworthiness
- Identify common end treatments and impact attenuators
- Understand how these systems function
- Choose the appropriate system for a specific site

NCDOT Session 4 4-2

Guardrail End Treatments

A barrier end treatment must serve two functions:

- Provide the necessary TENSION of the guardrail system for downstream impacts
- Be crashworthy when impacted end-on.

NCDOT Session 4 4-3

Cable Anchor Terminal – MASH

- 2 Design Tested
- Both have a strut between last 2 posts

TxDOT Design
9'- 4 ½ " rail element
Rail ends at last post

MwRSF Design
12'- 6" rail
Rail extends past last post

NCDOT Session 4 4-4

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Cable Anchor Terminal - Tension

NCDOT Session 4 4-5

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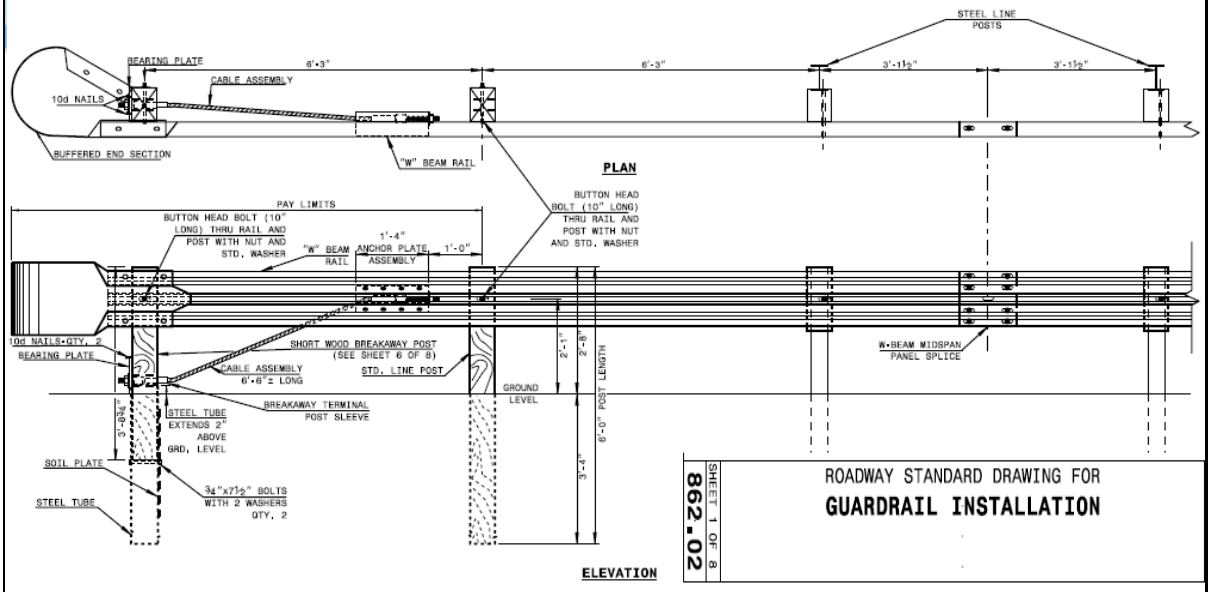
NC Cable Anchor – Not tested



TRAILING END UNIT ASSEMBLY

C.A.T.-1 SYSTEM

NCDOT Session 4 4-6

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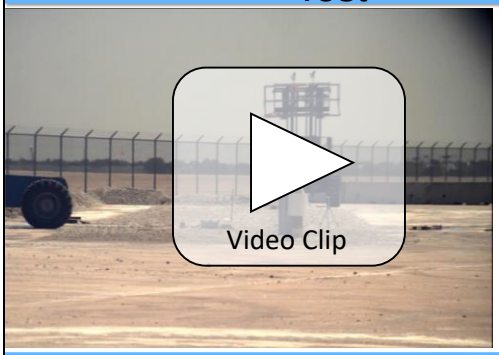
Guardrail Cable Anchor Terminal Test



Impacted at 6th post from the end

Vehicle deflected up to 10' behind the barrier

NCDOT Session 4 4-7

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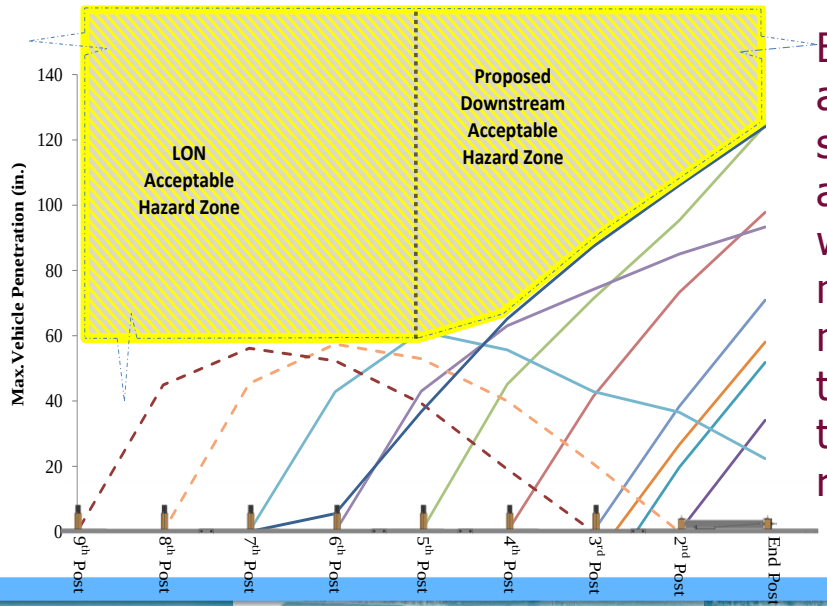
Guardrail Cable Anchor Terminal Test Analysis



Based on test and simulations, additional working width may be needed from the 6th post to the end of the rail.

NCDOT

Session 4

4-8

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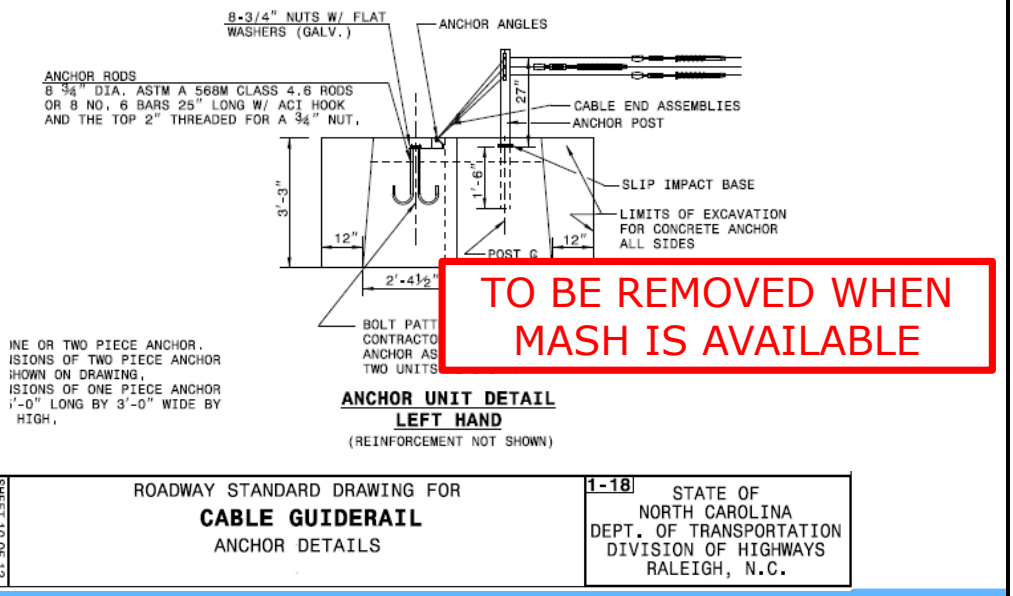
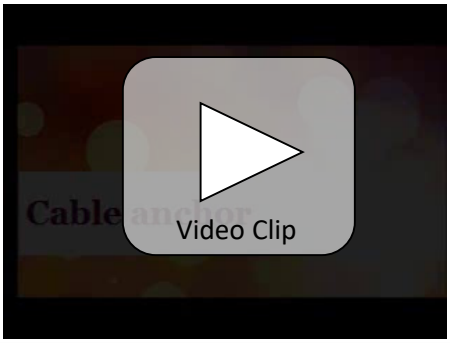
Cable Guiderail terminal - LTC



NCDOT Session 4 4-9

Cable Guiderail terminal - HTC



NCDOT Session 4 4-10


PRE-ASSESSMENT PHOTO
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 4
4-11

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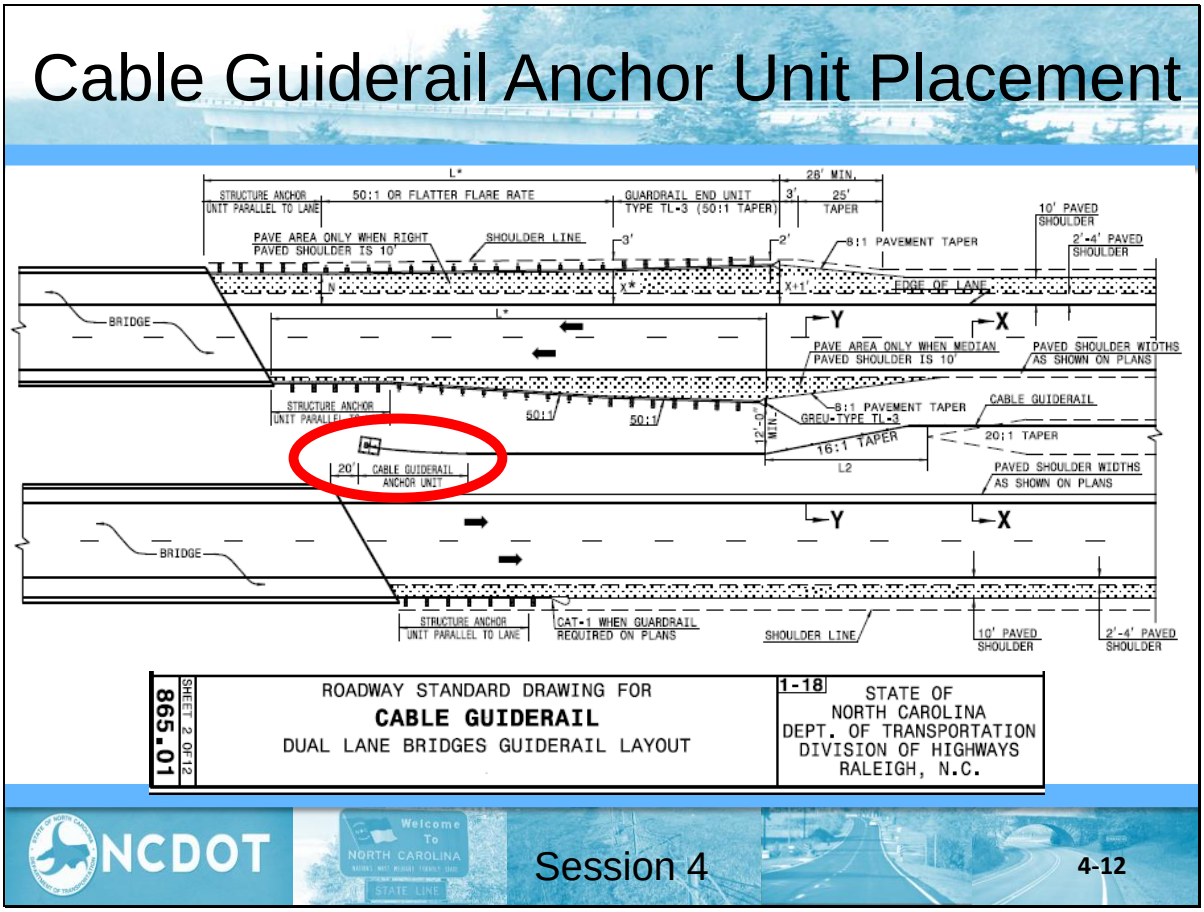
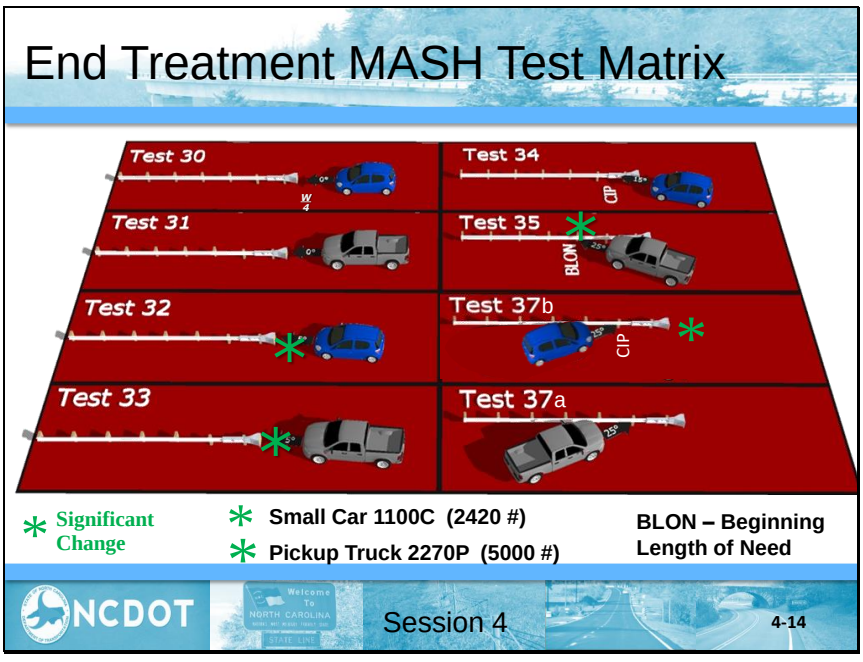

Cable Guiderail Anchor Unit Placement
STRUCTURE ANCHOR UNIT PARALLEL TO LANE
50:1 OR FLATTER FLARE RATE
GUARDRAIL END UNIT TYPE TL-3 (50:1 TAPER)
28' MIN.
25' TAPER
PAVE AREA ONLY WHEN RIGHT PAVED SHOULDER IS 10'
SHOULDER LINE
8:1 PAVEMENT TAPER
10' PAVED SHOULDER
2'-4' PAVED SHOULDER
EDGE OF LANE
BRIDGE
PAVE AREA ONLY WHEN MEDIAN PAVED SHOULDER IS 10'
PAVED SHOULDER WIDTHS AS SHOWN ON PLANS
CABLE GUIDERAIL
GREU-TYPE TL-3
16:1 TAPER
20:1 TAPER
20' CABLE GUIDERAIL ANCHOR UNIT
CAT-1 WHEN GUARDRAIL REQUIRED ON PLANS
ROADWAY STANDARD DRAWING FOR
CABLE GUIDERAIL
DUAL LANE BRIDGES GUIDERAIL LAYOUT
865.01
1-18
STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.
NCDOT
Session 4
4-12

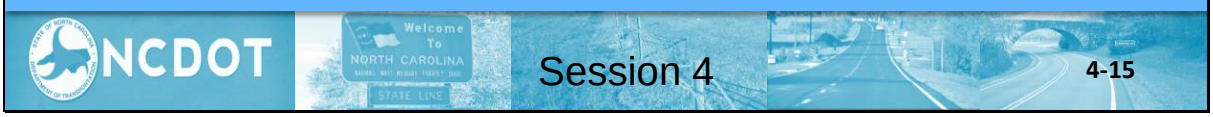

PRE-ASSESSMENT PHOTO
NCDOT
Session 4
4-13


End Treatment MASH Test Matrix
Test 30
Test 31
Test 32
Test 33
Test 34
Test 35
Test 37b
Test 37a
W 4
CIP
BLON
CIP
Significant Change
Small Car 1100C (2420 #)
Pickup Truck 2270P (5000 #)
BLON – Beginning Length of Need
NCDOT
Session 4
4-14

Guardrail End Treatments

Types of End Treatments

- Buried-in-Cut (Detail, not in Standards)
- Tangent terminals – terminal is parallel to the roadway or has a straight flare with a "slight" offset; all are Energy-absorbing
- Flared terminals – terminal is placed on a flare to the roadway typically 3' or 4'; both non-energy- and energy-absorbing

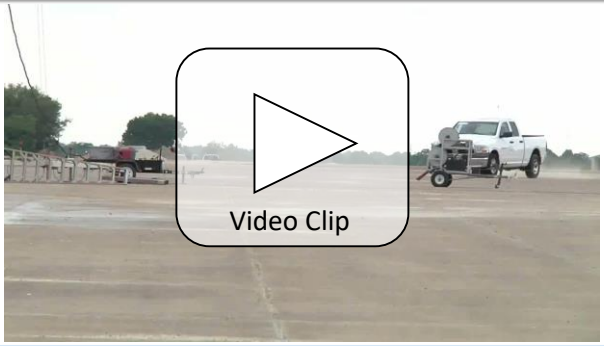


Buried in Cut End Treatment

- Key design considerations:
  - For slopes steeper than 10:1, keep the height of the w-beam rail constant relative to the roadway grade until the barrier crosses the ditch flow line (but a max height of 47")
  - Use a flare rate, either 13:1 or appropriate for the design speed,
  - Add a w-beam rubrail when the distance between the bottom of the w-beam rail and the ground exceeds ~19",
  - Use an anchor of steel posts capable of developing the full tensile strength of the w-beam rail and buried 1' below ground

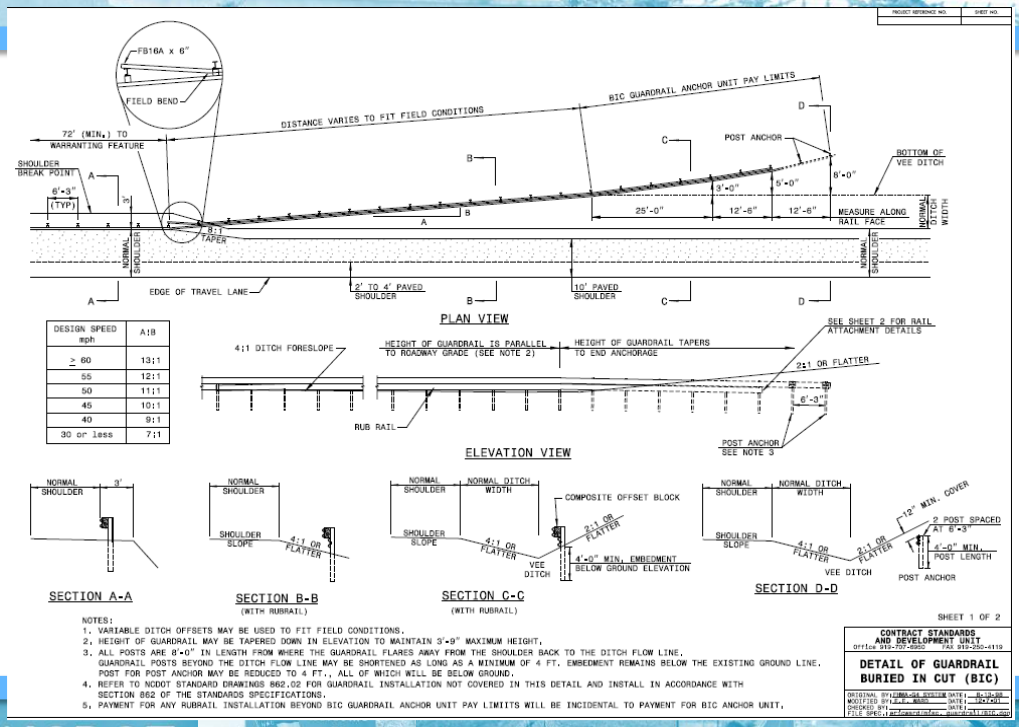
NCDOT Session 4 4-16

MASH
Buried in Cut End Treatment



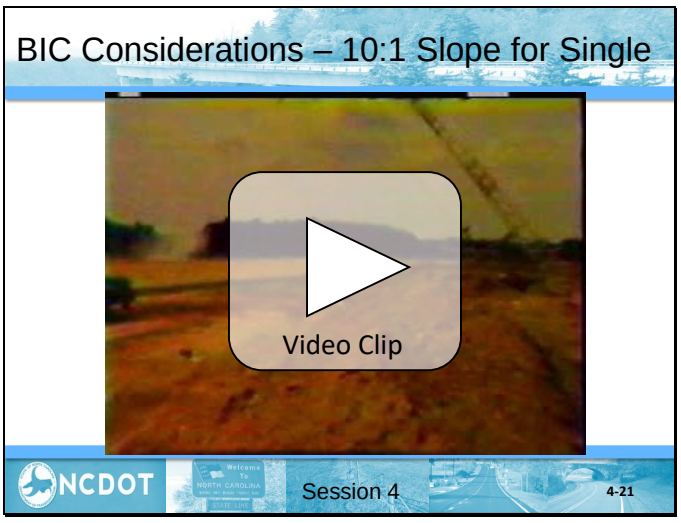
NCDOT Session 4 4-17

Buried in Cut (350 – to be Updated)




BIC Looking Across Roadway
NCDOT
Session 4
4-19


Single Rail BIC
NCDOT
Session 4
4-20


BIC Considerations – 10:1 Slope for Single
Video Clip
NCDOT
Session 4
4-21


BIC Considerations - LON
Any concerns with this installation?
NCDOT
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Session 4
4-22

End Treatments - Terminology

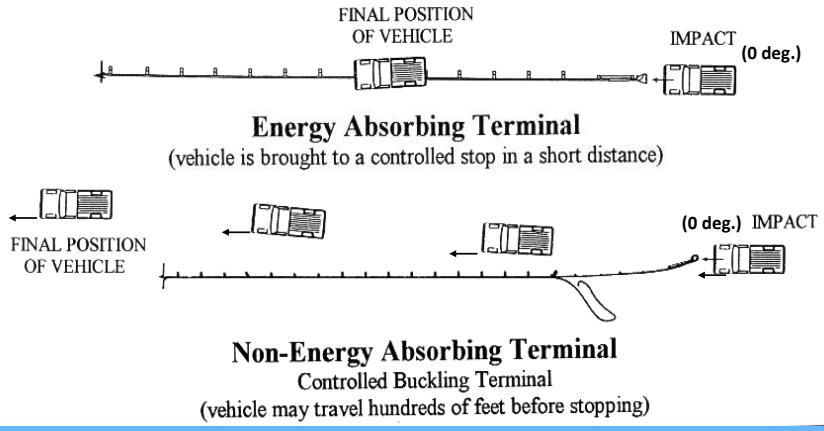
CAT-1 – Cable Anchor Terminal – non-crashworthy device to develop Tension where there is no opportunity for end-on impacts

(AT-1 – Anchor Terminal – no cable)

GREA – Guardrail End Anchor – crashworthy Pre-MASH devices

GREU – Guardrail End Unit – crashworthy MASH approved devices

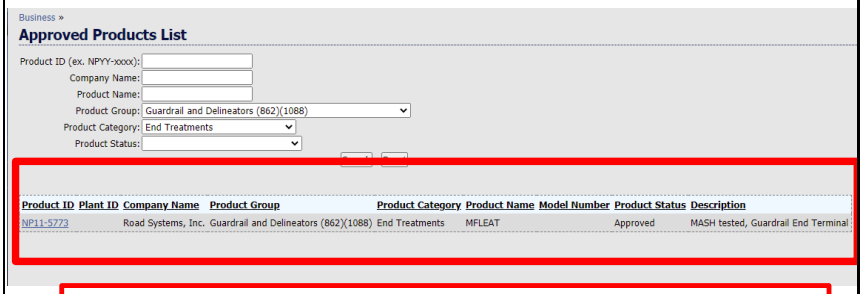
End Treatments



NCDOT Session 4 4-25

Flared End Treatments

Historically used, most recently the SRT and FLEAT



https://apps.ncdot.gov/vendor/approvedproducts/

NCDOT Session 4 4-26

Flared End Treatment: Energy Absorbing

- **MFLEAT** *MASH Version of FLEAT (MASH 16)*
  - Curls the rail (by kinking) tightly towards the roadway.
  - Steel post system; BLON at 4th Post
  - TL-3 at 39’ 7” straight flared length. 3-ft. offset.
  - Cable-anchored, compression system

BLON – Beginning Length of Need

Ref: FHWA Eligibility Letter CC-143 dated 04/10/19

NCDOT Session 4 4-27

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MASH MFLEAT

NCDOT Session 4 4-28

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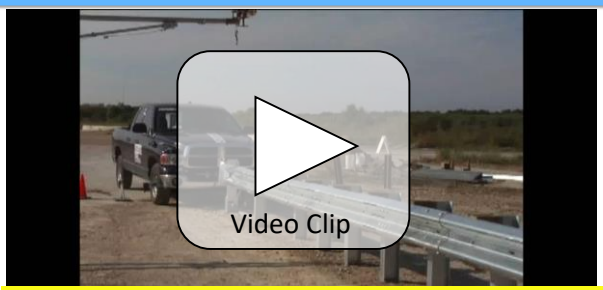
Flared End Treatment: Non-energy-Absorbing

- MASH SRT (Slotted Rail Terminal)
  - W-Beam rails on a straight line and horizontal slots in rail
  - Offset - 4’; 31” Height
  - 37’-6” long, BLON at Post 4
  - Cable-anchored system

Not currently on APL

Ref: FHWA Eligibility Letter CC-140 dated 12/19/17

MASH Test 3-31: SRT



Because of the non-energy absorption, no hazard should exist within 150’ downstream of post #1


NOT GOOD!!!!!
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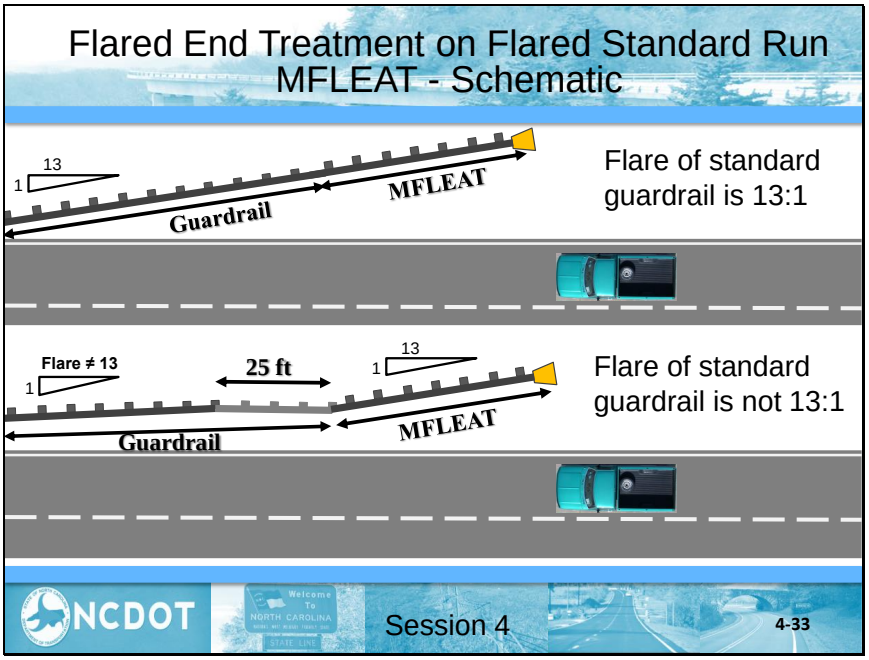
Session 4
4-31

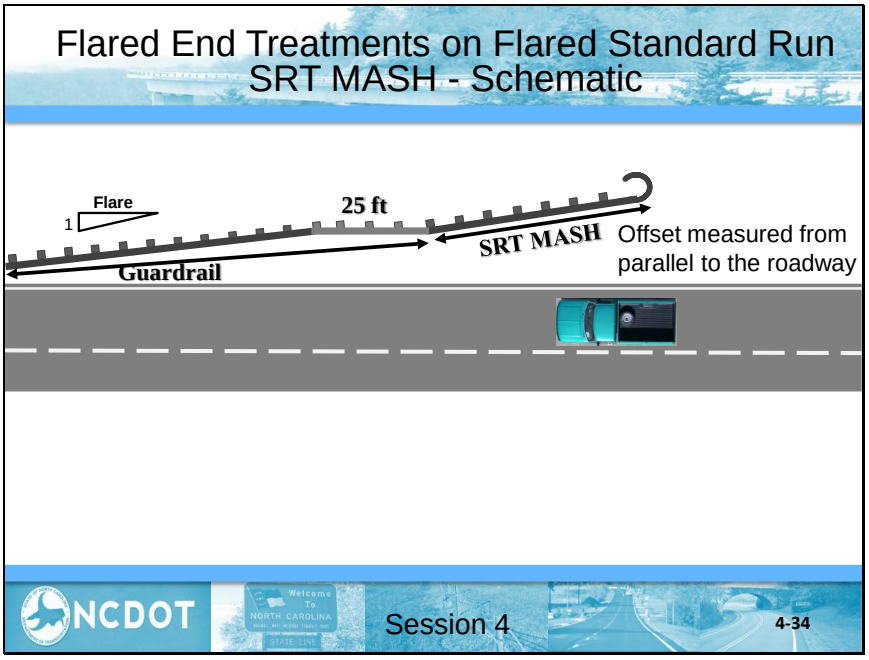
Flared End Treatments on Flared Standard Run

The flare of the end treatment is measured from a line parallel to the ROADWAY:

- For Energy Absorbing (MFLEAT) which has a 13:1 flare, there may need to be a “kink” either toward or away from the roadway, depending on the flare of the standard guardrail
- For the SRT MASH, the offsets are measured from a line parallel to the roadway.

NCDOT guidance is to provide 25’ of parallel guardrail in advance of any end treatment requiring a kink.

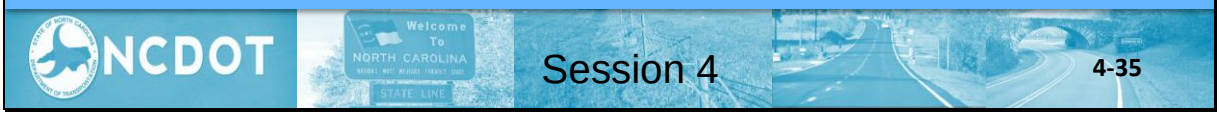

Flared End Treatment on Flared Standard Run
MFLEAT - Schematic
13
1
Guardrail
MFLEAT
Flare of standard guardrail is 13:1
Flare ≠ 13
1
25 ft
13
1
Guardrail
MFLEAT
Flare of standard guardrail is not 13:1
NCDOT
Session 4
4-33

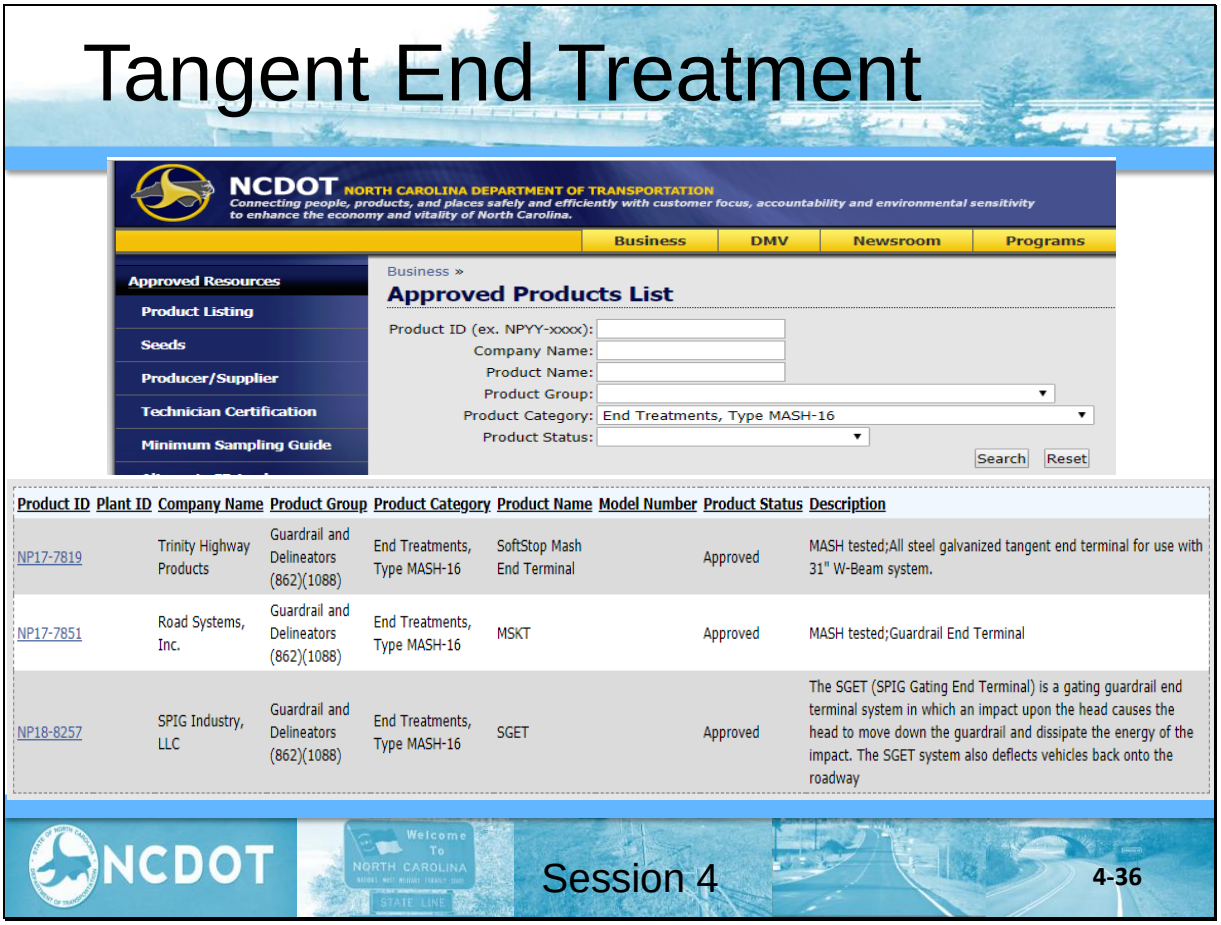

Flared End Treatments on Flared Standard Run
SRT MASH - Schematic
Flare
1
25 ft
Guardrail
SRT MASH
Offset measured from parallel to the roadway
NCDOT
Session 4
4-34

Flared End Treatment Selection

- The contractor may choose any system on the Approved Product List meeting the design requirements
  - One is energy absorbing (currently MFLEAT)
  - One could be non-energy absorbing (SRT)

  What is **important** is to understand how the system works –a **FLARED** system should only be allowed if criteria have been met (LON and grading)




Tangent End Treatment
NCDOT NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
Connecting people, products, and places safely and efficiently with customer focus, accountability and environmental sensitivity to enhance the economy and vitality of North Carolina.
Business
DMV
Newsroom
Programs
Approved Resources
Product Listing
Seeds
Producer/Supplier
Technician Certification
Minimum Sampling Guide
Business »
Approved Products List
Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: End Treatments, Type MASH-16
Product Status:
Search
Reset
Product ID | Plant ID | Company Name | Product Group | Product Category | Product Name | Model Number | Product Status | Description
NP17-7819 | Trinity Highway Products | Guardrail and Delineators (862)(1088) | End Treatments, Type MASH-16 | SoftStop Mash End Terminal | | Approved | MASH tested;All steel galvanized tangent end terminal for use with 31" W-Beam system.
NP17-7851 | Road Systems, Inc. | Guardrail and Delineators (862)(1088) | End Treatments, Type MASH-16 | MSKT | | Approved | MASH tested;Guardrail End Terminal
NP18-8257 | SPIG Industry, LLC | Guardrail and Delineators (862)(1088) | End Treatments, Type MASH-16 | SGET | | Approved | The SGET (SPIG Gating End Terminal) is a gating guardrail end terminal system in which an impact upon the head causes the head to move down the guardrail and dissipate the energy of the impact. The SGET system also deflects vehicles back onto the roadway
NCDOT
Welcome To NORTH CAROLINA STATE LINE
Session 4
4-36

Tangent End Treatment: Energy Absorbing

- **MSKT** *MASH Version of SKT (MASH 16)*
  - Kinks Guardrail when hit head-on or at a shallow angle
  - Steel post system; BLON at 3rd Post
  - TL-3 at 47' long; attachment to 31" Guardrail
  - Cable-anchored system, Compression system

Design Speed	Minimum Length of Steel Beam Guardrail Between Structural Anchor and GREU
≤60 mph	12.5 feet
> 60 mph (Interstates, Freeways, Major Arterials	25 feet

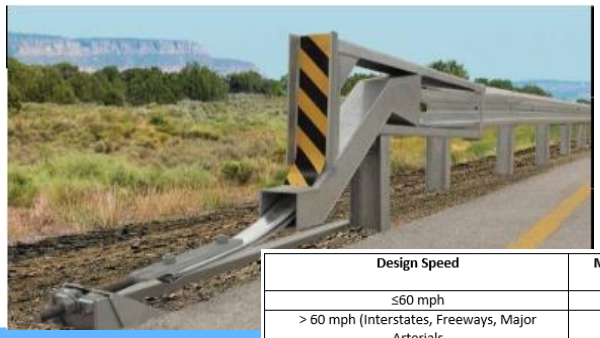
NCDOT Session 4 4-37

MASH MSKT

NCDOT Session 4 4-38

Tangent End Treatment: Energy Absorbing

- Soft Stop (MASH 16)
  - Impact head slides along panels, crushing them vertically, absorbing the energy of the vehicle in shallow angle impacts – **works in tension**
  - TL-3 at 51’ long; BLON at 16’-6”; 31” only



Design Speed	Minimum Length of Steel Beam Guardrail Between Structural Anchor and GREU
≤60 mph	12.5 feet
> 60 mph (Interstates, Freeways, Major Arterials	25 feet


MASH Soft Stop
Video Clip
NCDOT
Session 4
4-40


NCDOT
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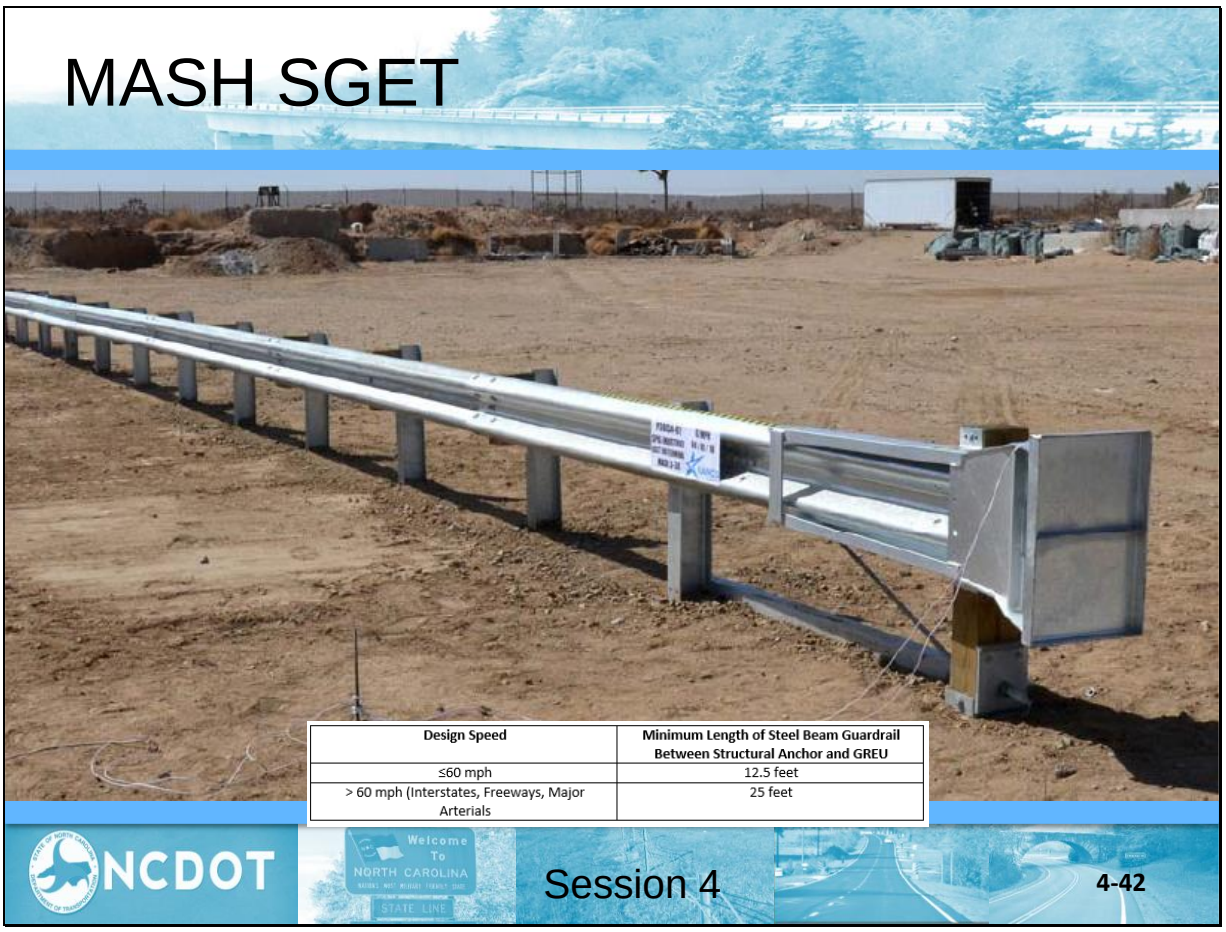
Session 4
4-41


MASH SGET
Design Speed
Minimum Length of Steel Beam Guardrail Between Structural Anchor and GREU
≤60 mph
12.5 feet
> 60 mph (Interstates, Freeways, Major Arterials
25 feet
NCDOT
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STATE LINE
Session 4
4-42


MASH SGET – Test 3-31
Video Clip
NCDOT
Session 4
4-43

Tangent End Treatment: Energy Absorbing

- MAX-Tension (MASH 16)
  - The MAX system utilizes tensioned cables, telescoping panels, and a cutting tooth to absorb the kinetic energy and safely contain or redirect impacting – **works primarily in tension**
  - TL-3 at 50' long; BLON at 9'-4 ½"; 31" only

Not on current APL

Design Speed	Minimum Length of Steel Beam Guardrail Between Structural Anchor and GREU
≤60 mph	12.5 feet
> 60 mph (Interstates, Freeways, Major Arterials	25 feet

NCDOT Session 4 4-44

MASH MAX-Tension

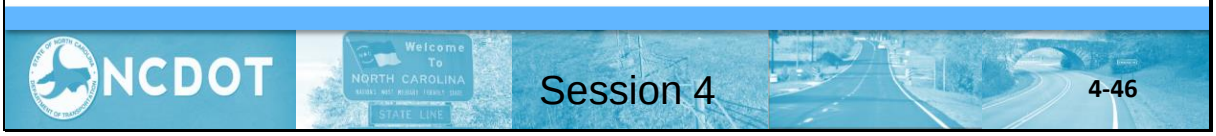
NCDOT Session 4 4-45

Tangent End Treatments – End Offset Proposed

4.10.9 Guardrail Anchor Units

The following are commonly used anchor units with a brief description.

Guardrail End Unit – Test Level 2 and Test Level 3 (GREU-TL-2 and TL-3) - the GREU – TL-2 and TL-3 are tangential end units. These units will be flared over the last 50 feet to provide a 1-foot offset.



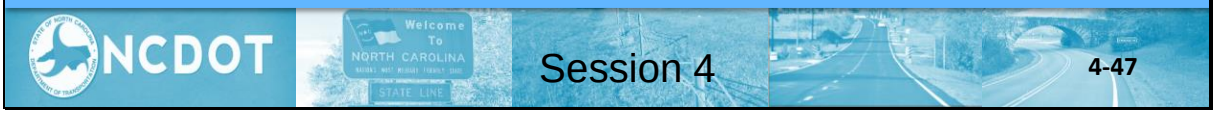
Tangent End Treatments on Flared Standard Run

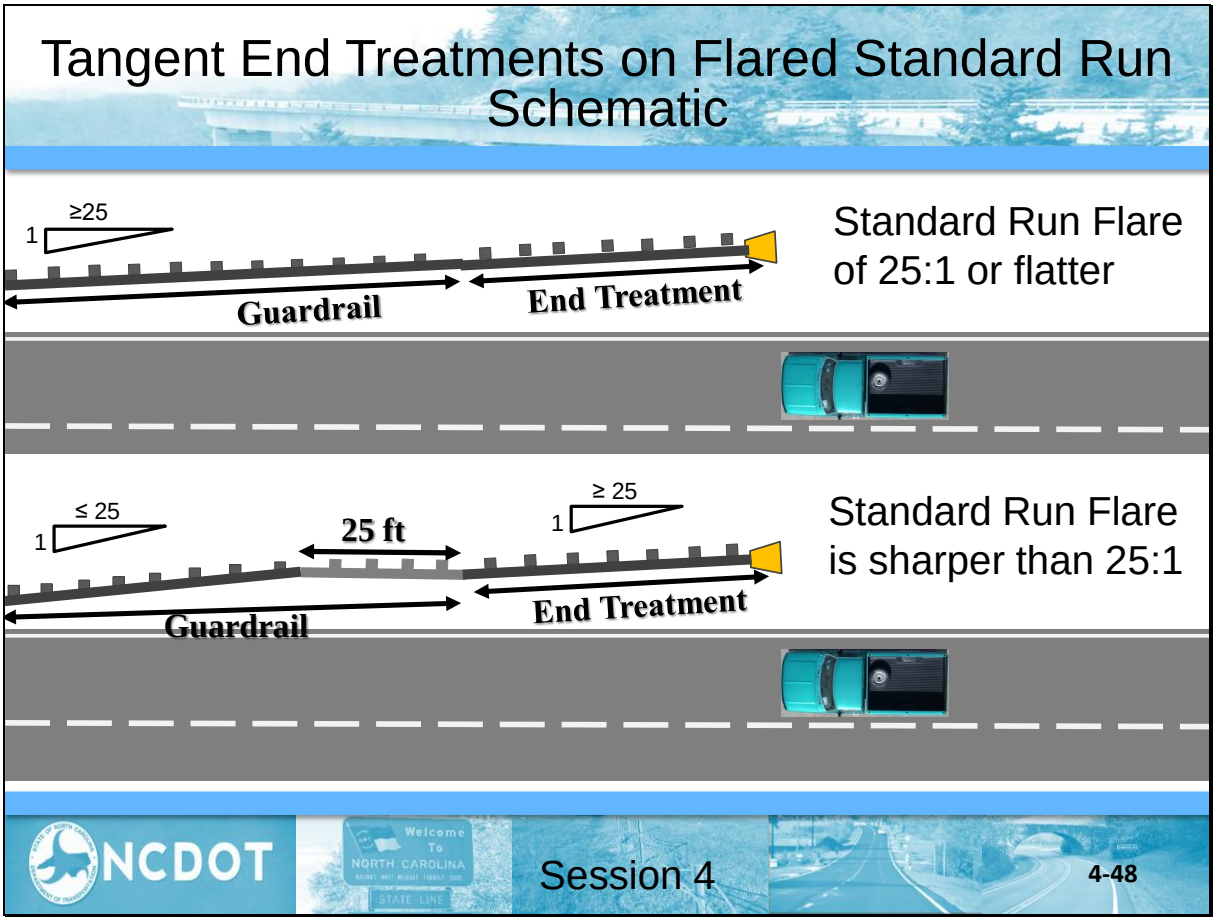
The offset of the end treatment is measured from a line parallel to the ROADWAY:

- If the standard flare is 25:1 or flatter, the end treatment may be placed on the standard flare line extended

- If the standard flare is sharper than 25:1, a kink in the run must be provided so the end treatment is no sharper than 25:1

NCDOT guidance is to provide 25' of parallel guardrail in advance of any end treatment requiring a kink.




Tangent End Treatments on Flared Standard Run Schematic
≥25
1
Guardrail
End Treatment
Standard Run Flare of 25:1 or flatter
≤ 25
1
25 ft
≥ 25
1
Guardrail
End Treatment
Standard Run Flare is sharper than 25:1
NCDOT
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Session 4
4-48

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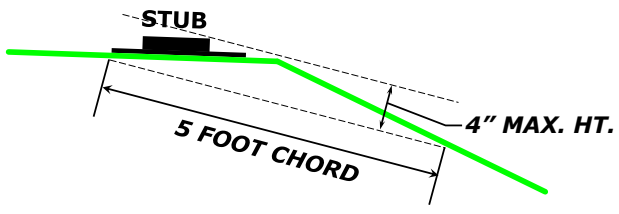
End Treatment Grading

- Special grading requirements for guardrail end treatments:
  - Flat terrain (10:1 or flatter) is required *in* **ADVANCE** *of all end treatments* so that vehicles are relatively stable on approach
  - Flat grading must extend *behind* post 1 (**ADJACENT**) so vehicle is stable at impact ***and*** stub height criteria is satisfied

Ref: FHWA Memorandum, Roadside Safety Hardware, May 26, 2015 with attachment and
Ref: AASHTO Roadside Design Guide, 4th Edition, Section 8.3.3.

Stub Height Criteria



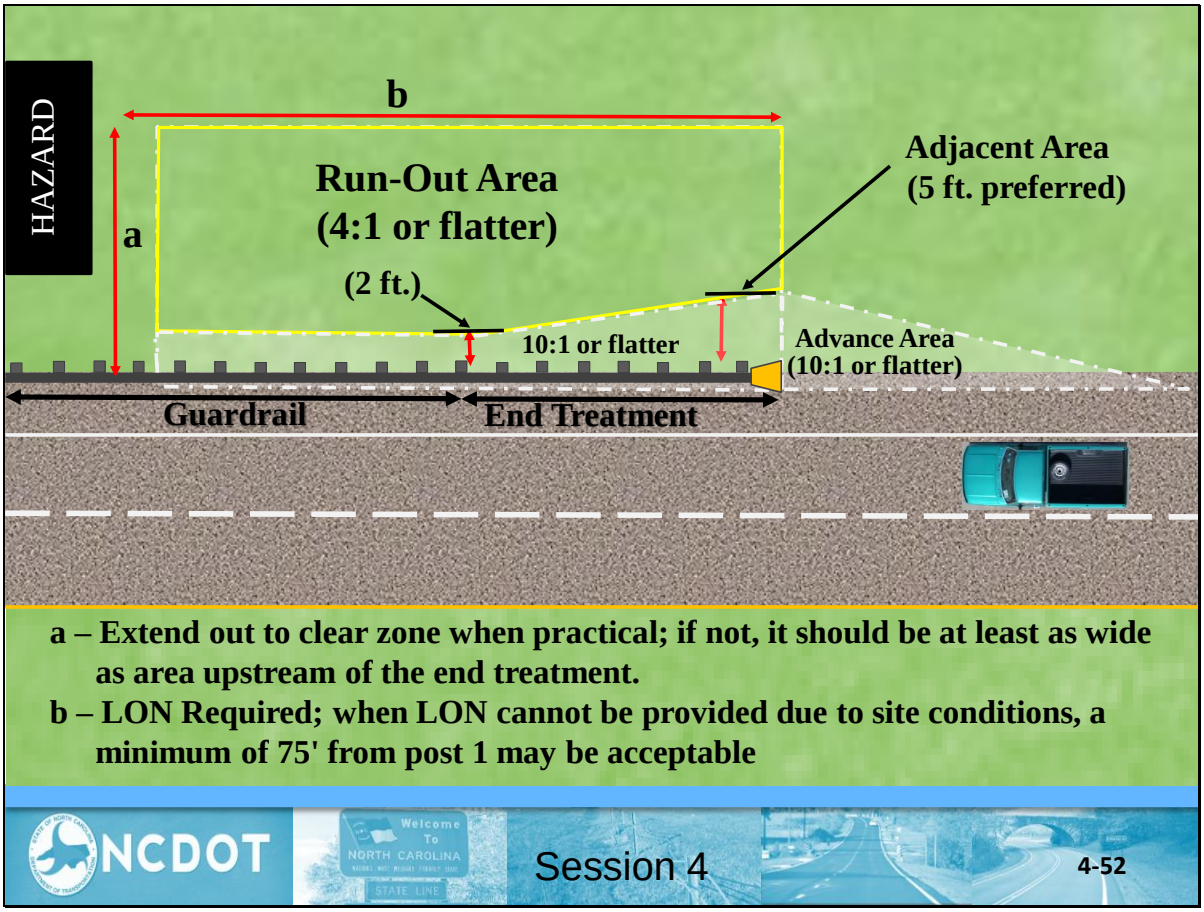
RDG Figure 4.1

Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 4.1

End Treatment Grading Requirements

- **Runout Distance Grading** - refers to the area into which a vehicle may travel after impacting a terminal ahead of its length-of-need point.
  - The lateral runout distance directly behind a terminal ideally should be at least as wide as the roadside clear distance immediately upstream of terminal.
  - The minimum recovery obstacle-free area behind and beyond a terminal should be approximately 75 ft. long.

Ref: AASHTO Roadside Design Guide, 4th Edition, Section 8.3.3.


HAZARD
b
a
Run-Out Area
(4:1 or flatter)
(2 ft.)
10:1 or flatter
Adjacent Area
(5 ft. preferred)
Advance Area
(10:1 or flatter)
Guardrail
End Treatment
a – Extend out to clear zone when practical; if not, it should be at least as wide as area upstream of the end treatment.
b – LON Required; when LON cannot be provided due to site conditions, a minimum of 75' from post 1 may be acceptable
NCDOT
Session 4
4-52

Flared End Treatment Grading - AASHTO

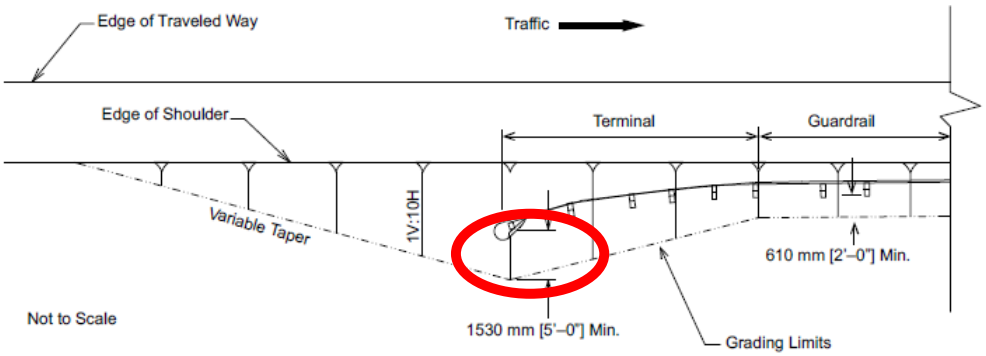
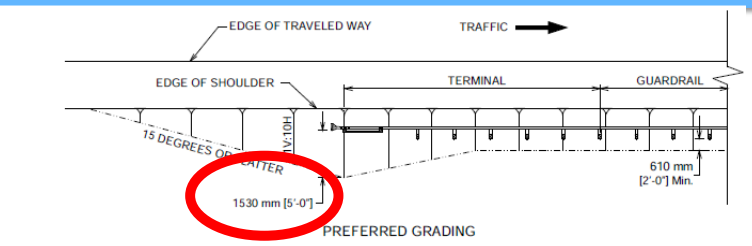


Figure 8-2. Grading for Flared Guardrail Terminal

End Treatments (Anchorages, Terminals, and Crash Cushions) 8-5

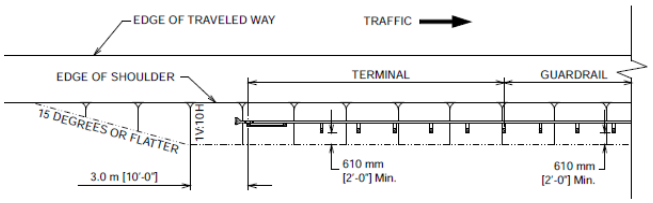
Must have this full grading if a flared end treatment is used

Tangent End Treatment Grading - AASHTO



PREFERRED GRADING

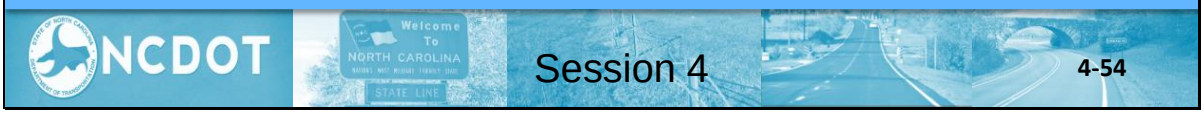
NOT TO SCALE



ALTERNATIVE GRADING

Note: The preferred grading layout should be used when practical. However, if necessary because of site limitations, the alternative grading layout may be used when upgrading an existing terminal.

Figure 8-3. Grading for Tangent Guardrail Terminal




PRE-ASSESSMENT PHOTO
NCDOT
Welcome To NORTH CAROLINA STATE LINE
Session 4
4-55

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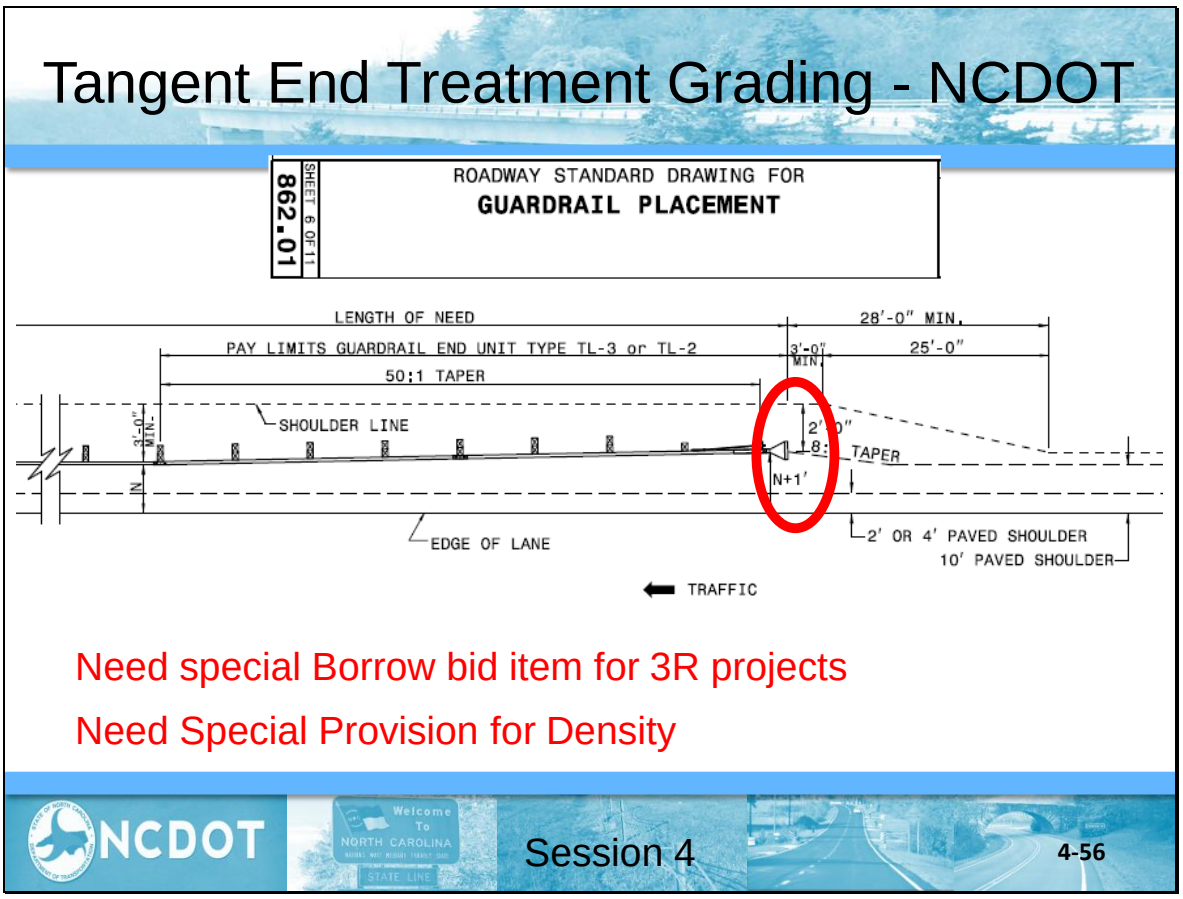
Tangent End Treatment Grading - NCDOT



Need special Borrow bid item for 3R projects

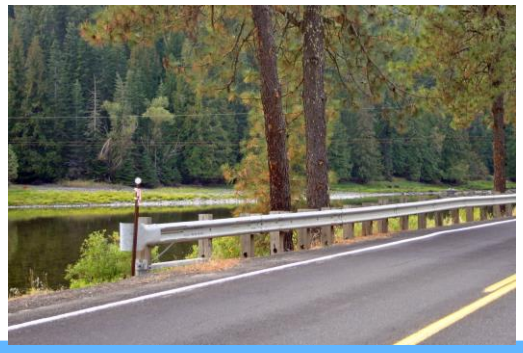
Need Special Provision for Density


PRE-ASSESSMENT PHOTO
No Stub problem, but could be better
NCDOT
Session 4
4-57


Substandard Grading – DOCUMENT
NCDOT
Session 4
4-58

Thing to Remember about End Treatments

Non-Energy Absorbing End Treatments will not shield objects directly behind and within End Treatment limits

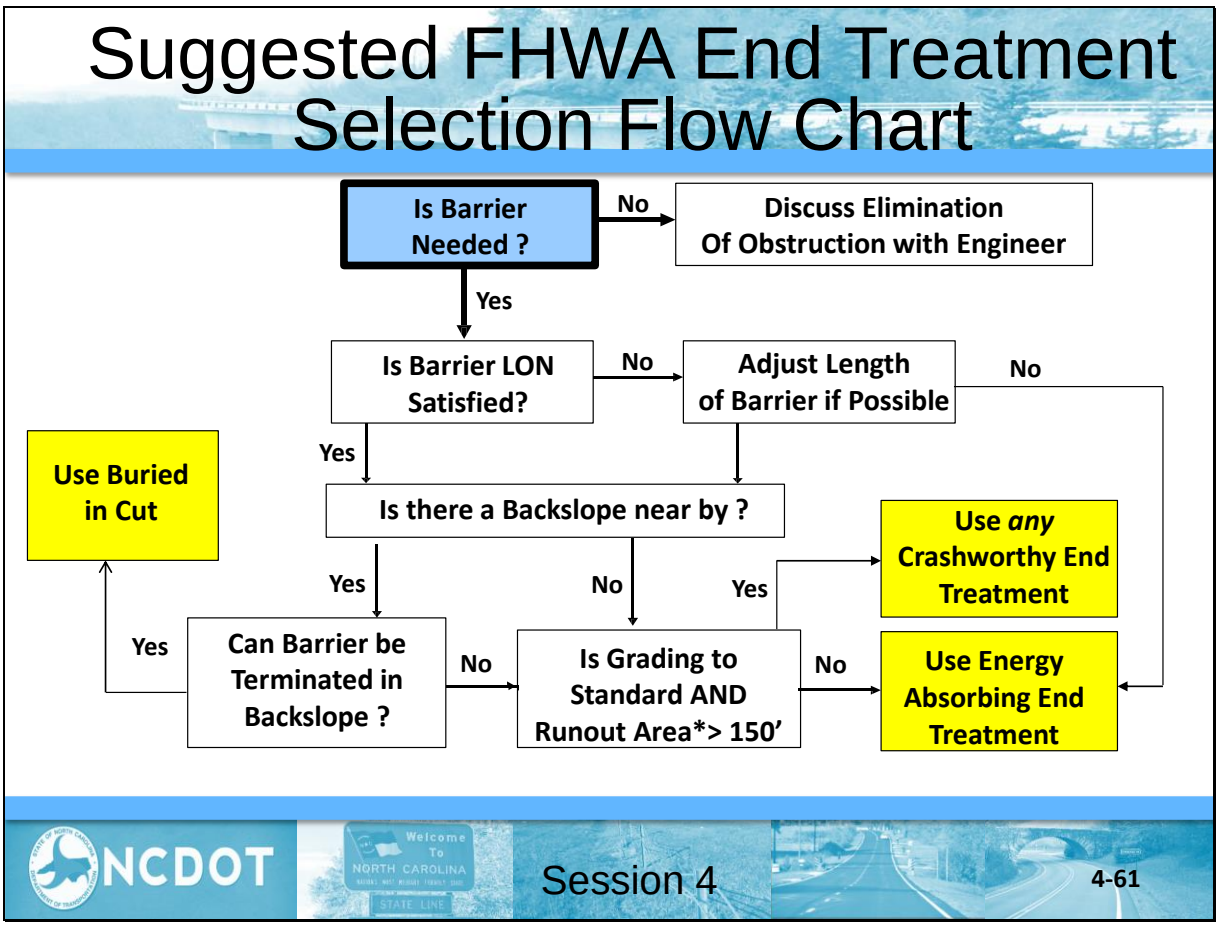


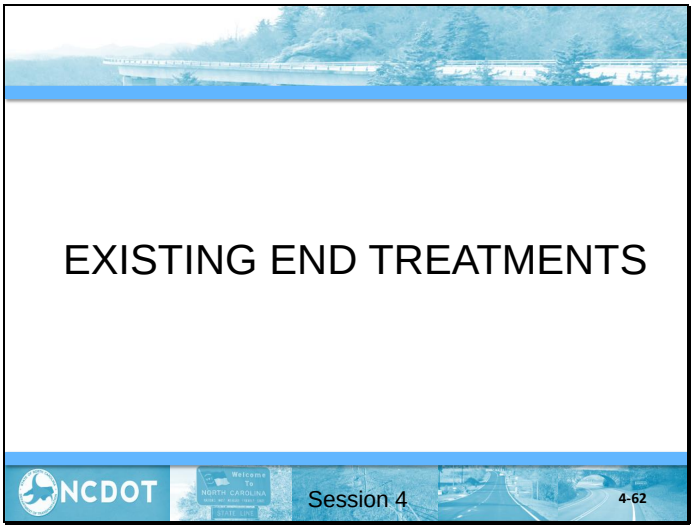
NCDOT Session 4 4-59

Thing to Remember about End Treatments

Even Energy Absorbing End Treatment will not shield objects directly behind and within End Treatment limits

NCDOT Session 4 4-60


Suggested FHWA End Treatment Selection Flow Chart
Is Barrier Needed ?
No
Discuss Elimination Of Obstruction with Engineer
Yes
Is Barrier LON Satisfied?
No
Adjust Length of Barrier if Possible
No
Yes
Use Buried in Cut
Is there a Backslope near by ?
Use any Crashworthy End Treatment
Yes
No
Yes
Yes
Can Barrier be Terminated in Backslope ?
No
Is Grading to Standard AND Runout Area*> 150'
No
Use Energy Absorbing End Treatment
NCDOT
Session 4
4-61


EXISTING END TREATMENTS
NCDOT
Session 4
4-62

Tangent Guardrail End Treatment
Energy Absorbing

- SKT 350 (Sequential Kinking Terminal)(NCHRP 350)
  - Kinks panels when hit head-on or at a shallow angle
  - Wood or Steel post system (many options)
  - TL-3 at 50' long; BLON at 3rd Post
  - Cable-anchored, Compression system

Ref: FHWA Eligibility Letter CC-88 dated 3/8/05

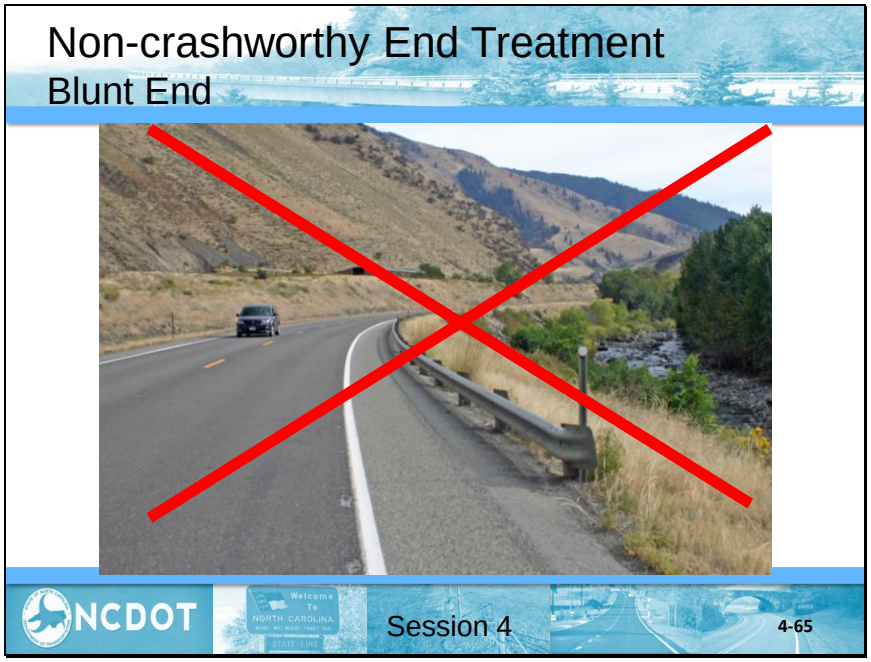
NCDOT Session 4 4-63

Tangent Guardrail End Treatment
Energy Absorbing

- ET Plus (Guardrail Extruder Terminal)(NCHRP 350)
  - Flattens the rail element when hit head-on
  - Weakened wood or steel posts (several options available)
  - 50' long; attaches to either height w-beam system
  - BLON at 3rd Post
  - Cable-anchored, compression system

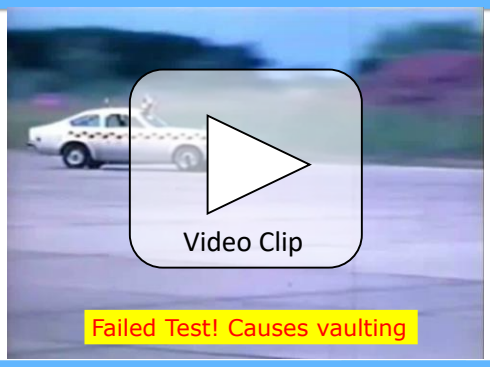
Ref: FHWA Eligibility Letter CC-12Q dated 3/15/10

NCDOT Session 4 4-64


Non-crashworthy End Treatment
Blunt End
NCDOT
Session 4
4-65


Non-crashworthy End Treatment
Turndown
NCDOT
Session 4
4-66

Turndown



Non-crashworthy End Treatment
BCT Terminal

- Breakaway Cable Terminal (BCT) NCHRP 230
  - W-Beam rail with a parabolic curve and 4-ft offset.
  - No impact head or ground strut between the two end posts.
  - Only two breakaway posts.
  - Rail bolted to all posts.

For Identification Only

Non-crashworthy End Treatment
BCT Terminal

NCDOT Session 4 4-69

Guardrail End Treatments: Non-energy Absorbing – For Identification Only

- MELT – Modified Eccentric Loader Terminal
  - W-Beam rail with an accentuated parabolic curve and 4-ft offset.
  - Strut between the steel tubes foundation of the two end posts.
  - 37'-6" long with 8 breakaway posts; BLON at Post #3.
  - No rail-to-post bolts except at posts 1 and 8 and beyond.

For Identification Only

(NCHRP 350 TL-2)

NCDOT Session 4 4-70

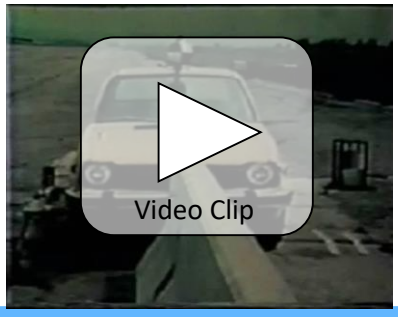
Guardrail End Treatments: W-Beam Median

Only one MASH gating, double sided end treatment available on the market

No longer on NCDOT APL

Impact Attenuator

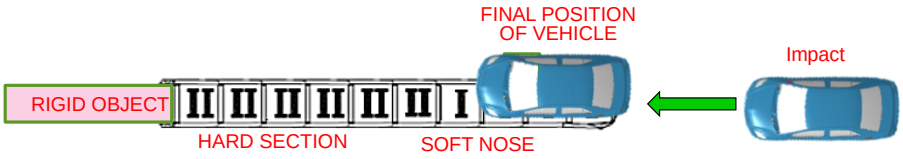
Crash test with blunt end:



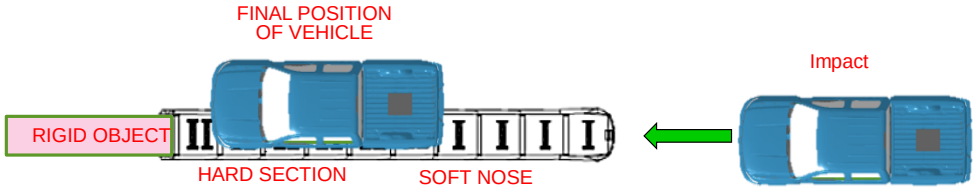
Impact Attenuator

Crash test with ramped end:

Impact Attenuator Theory



Soft nose to bring a small car to a controlled stop



Harder back section to bring a pick-up truck to a controlled stop

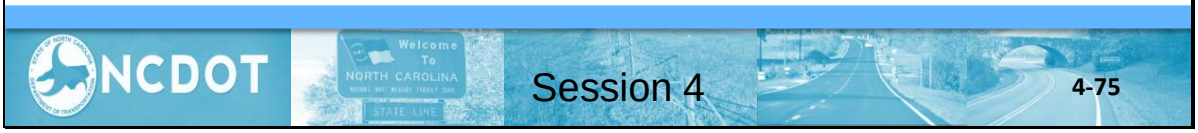
NCDOT Session 4 4-74

Impact Attenuator, Sacrificial - Water Filled

- Water-filled Barriers

  Absorb M (MASH) / Sled(MASH) / ACZ 350 / TRITON CET

  - Individual crash cushion designs vary by manufacturer, but they all function in a similar manner.
  - Vehicles impacting the nose at an angle will **not** be redirected.
  - No appreciable re-directive capability under most impact conditions.
  - Typically used in work zones to shield temporary concrete barrier.



Impact Attenuator, Sacrificial - Water Filled

Approved Products List

Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: WZTC - Category III

NP11-5771		Lindsay Transportation Solutions	Work Zone Traffic Control	WZTC - Category III	Absorb 350		Approved for Provisional Use	*Must be approved by Steve Kite (919-814-4937) prior to use on NCDOT project.* The ABSORB 350 is a non-redirective, gating water filled crash cushion that has been successfully tested to NCHRP Report 350 TL-2&3.
NP11-5884		TrafFix Devices, Inc.	Work Zone Traffic Control	WZTC - Category III	SLED	Series 45044	Approved	PE Water Filled Crash Cushion w/Galvanized Steel Cables molded inside.NCHRP-350 for Test Level 1,2or3.Use as end treatment/crash cushion.
NP16-7335		Trinity Highway Products	Work Zone Traffic Control	WZTC - Category III	ACZ-350 Water Filled Crash Cushion	ACZ-350	Approved for Provisional Use	The ACZ-350 is a narrow, non-redirecting TL-2 and TL-3 impact attenuator
NP99-3106	GR10	Energy Absorption Systems, Inc.	Work Zone Traffic Control	WZTC - Category III	Triton Barrier	Triton Barrier	Approved	The Triton Barrier® is a highly portable, water-filled barrier. Performance meets the FHWA NCHRP 350 TL-2 or TL-3 (with TL-3 kit) standard for longitudinal re-directive barrier. The Triton Barrier is certified as its own end treatment.

NCDOT Session 4 4-76

Impact Attenuator, Sacrificial - Water Filled

Absorb M (MASH)

ACZ-350

Sled (MASH)

TRITON barrier CET

NCDOT Session 4 4-77

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Water Filled

NCDOT Session 4 4-78

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Impact Attenuator, Sacrificial – Sand Barrel

Non-Redirective and Gating

- Individual barrel designs vary in shape by manufacturer, but they all function the same
- Arrays of sand barrels may be designed to shield any shape hazard
- Impacting vehicles will not be redirected.
- Since no re-directive capability, the corner of the hazard must be reasonably shielded.

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Impact Attenuator, Sacrificial – Sand Barrel

➢ Sand Barrels:

Energite

TrafFix Big Sandy (MASH)

Not Normally Used

CrashGard (MASH)

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Sand Barrels – Good Application

NCDOT Session 4 4-81

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Sand-Filled Array

NCDOT Session 4 4-82

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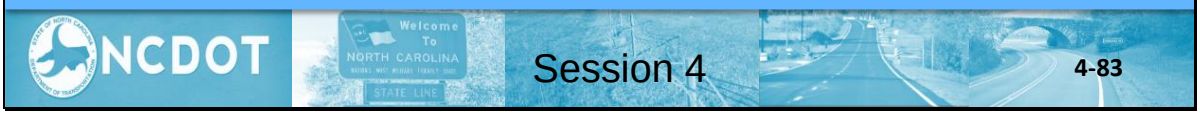
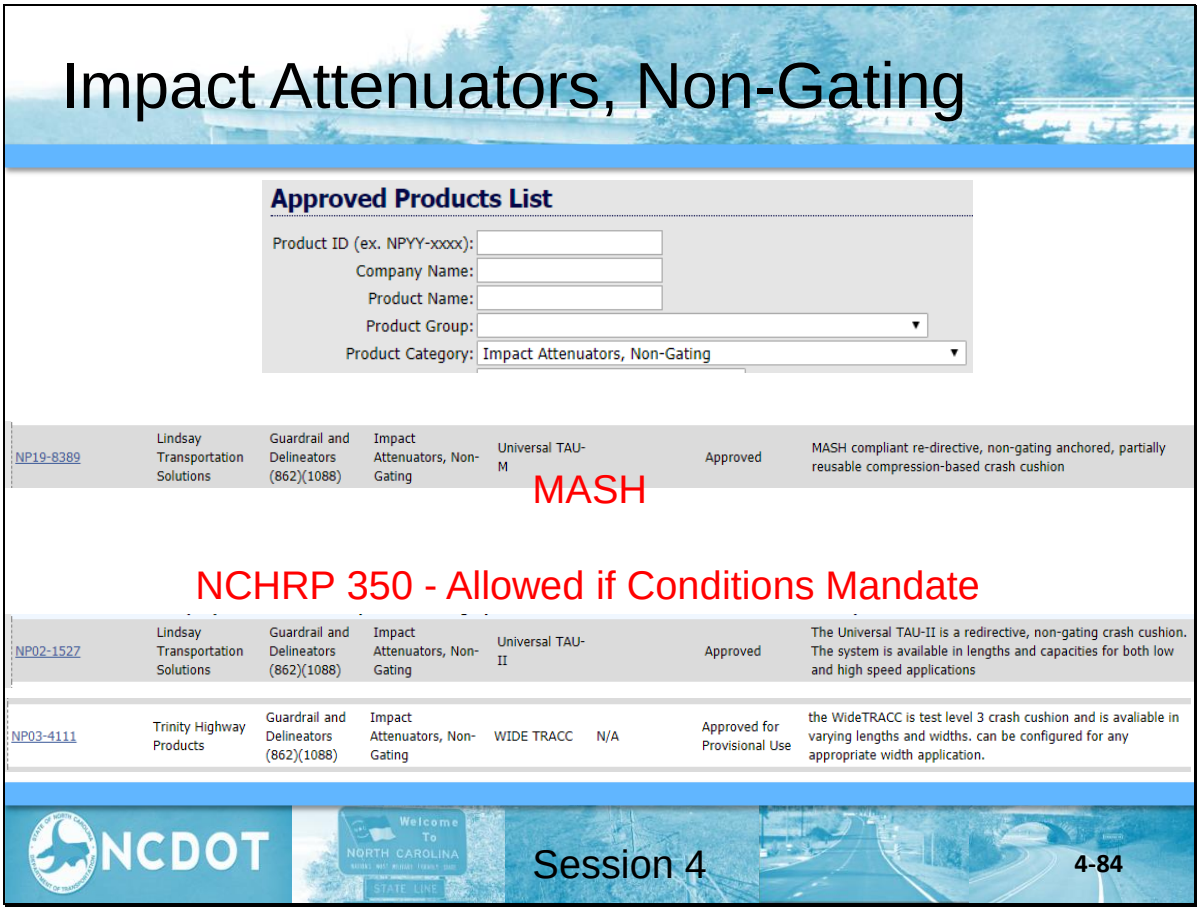
Impact Attenuators, Non-Gating

Non-gating as follows:

- Contains and redirects vehicles impacting along the sides of the device essentially its entire length
- Contains vehicles impacting the nose either head-on or at a 15º angle.
- Approved for TL-2 (350) & TL-3 systems.
- Designed to shield a point hazard; either attached or stand alone.




Impact Attenuators, Non-Gating
Approved Products List
Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: Impact Attenuators, Non-Gating
NP19-8389 Lindsay Transportation Solutions Guardrail and Delineators (862)(1088) Impact Attenuators, Non-Gating Universal TAU-M Approved MASH compliant re-directive, non-gating anchored, partially reusable compression-based crash cushion
MASH
NCHRP 350 - Allowed if Conditions Mandate
NP02-1527 Lindsay Transportation Solutions Guardrail and Delineators (862)(1088) Impact Attenuators, Non-Gating Universal TAU-II Approved The Universal TAU-II is a redirective, non-gating crash cushion. The system is available in lengths and capacities for both low and high speed applications
NP03-4111 Trinity Highway Products Guardrail and Delineators (862)(1088) Impact Attenuators, Non-Gating WIDE TRACC N/A Approved for Provisional Use the WideTRACC is test level 3 crash cushion and is avaliable in varying lengths and widths. can be configured for any appropriate width application.
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Session 4
4-84

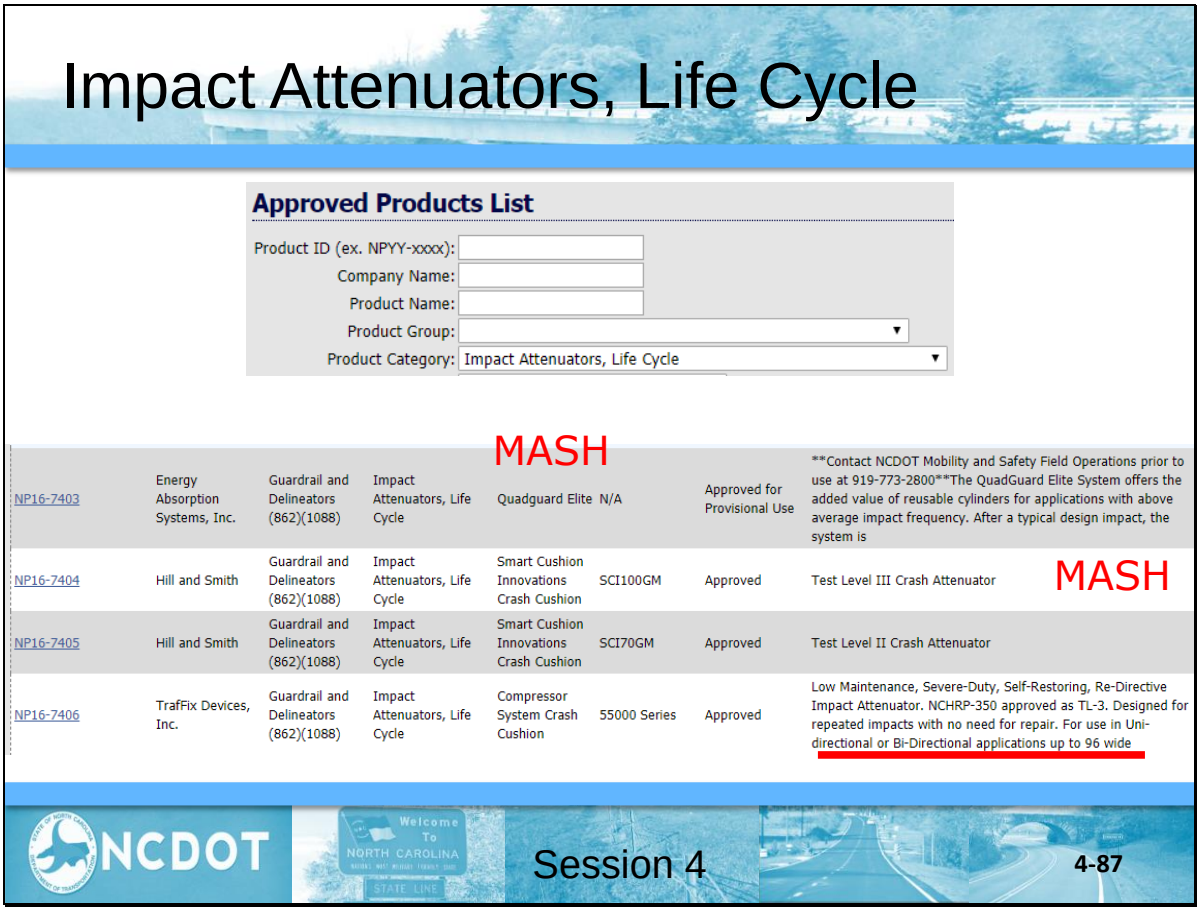
Impact Attenuators, Non-Gating

- TAU-M (MASH) and TAU IIR Systems (NCHRP 350)
  - Can be attached directly to a W-beam or Thrie-beam median barrier as well as to a concrete safety shape.
  - Designed to attach to a median barrier.
  - Common set of parts for 36” to 102” widths in 6” increments (350)
  - Consists of Thrie-beam panels, expendable (MASH) or self-restoring (R) (350) absorbing cartridges, steel diaphragms and two cables at the bottom to provide redirection.

NCDOT Session 4 4-85

Impact Attenuators, Non-Gating - Typical

NCDOT Session 4 4-86


Impact Attenuators, Life Cycle
Approved Products List
Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: Impact Attenuators, Life Cycle
MASH
NP16-7403 Energy Absorption Systems, Inc. Guardrail and Delineators (862)(1088) Impact Attenuators, Life Cycle Quadguard Elite N/A Approved for Provisional Use **Contact NCDOT Mobility and Safety Field Operations prior to use at 919-773-2800**The QuadGuard Elite System offers the added value of reusable cylinders for applications with above average impact frequency. After a typical design impact, the system is
NP16-7404 Hill and Smith Guardrail and Delineators (862)(1088) Impact Attenuators, Life Cycle Smart Cushion Innovations Crash Cushion SCI100GM Approved Test Level III Crash Attenuator
MASH
NP16-7405 Hill and Smith Guardrail and Delineators (862)(1088) Impact Attenuators, Life Cycle Smart Cushion Innovations Crash Cushion SCI70GM Approved Test Level II Crash Attenuator
NP16-7406 TrafFix Devices, Inc. Guardrail and Delineators (862)(1088) Impact Attenuators, Life Cycle Compressor System Crash Cushion 55000 Series Approved Low Maintenance, Severe-Duty, Self-Restoring, Re-Directive Impact Attenuator. NCHRP-350 approved as TL-3. Designed for repeated impacts with no need for repair. For use in Uni-directional or Bi-Directional applications up to 96 wide
NCDOT
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Session 4
4-87

Impact Attenuators, Life Cycle

- SCI Smart Cushion (MASH)
  - Variable Reaction Force
  - Re-usable with minimal component replacement
  - Needs repair before next hit

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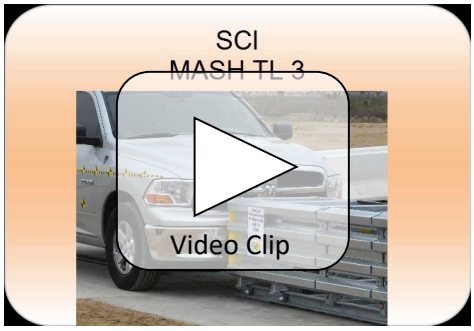
Example – Low Cost



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Impact Attenuators, Life Cycle

- QuadGuard Elite (MASH)
  - Uses High Density Polyethylene cylinders to absorb energy
  - Essentially for use in locations where a high number of hits is anticipated.

REF: FHWA Eligibility Letter CC-57E dated 12/18/15

NCDOT Session 4 4-90

Example - Self Restoring

NCDOT Session 4 4-91

Very Appropriate Use

NCDOT Session 4 4-92

Review Learning Outcomes

- Understand how end treatments and impact attenuators are tested for crashworthiness
- Identify common end treatments and impact attenuators
- Understand how these systems function
- Choose the appropriate system for a specific site

NCDOT Session 4 4-93

Session 5: Design Principles

North Carolina Department of Transportation

Highway Safety Barrier Design Training

Session 5: Design Principles

Session 5 Learning Outcomes

At the end of this session, you will be able to:

Understand the design principles affecting an optimal barrier installation.

Order of Preference - NCDOT

4.10 Traffic Barriers
4.10.1 General Considerations

The preferred method of addressing roadside hazards is as follows:

1. Remove the hazard;
2. Remove embankment hazard (flatten slopes);
3. Shift hazard away from traffic;
4. Reduce the impact severity by using breakaway posts;
5. Protect the hazard;
6. Delineate the hazard so motorists are aware of the hazard.

Guardrail Placement

Place AS FAR AWAY as Possible

without affecting function

NCDOT Session 5 5-5

Barrier Design Principles

1. Deflection
2. Slope in Front of Barrier
3. Guardrail and Curb
4. Soil Backing for Fill Locations
5. Flare Rate

NCDOT Session 5 5-6

Principle 1: Deflection

Adequate room must be left behind the barrier to allow for lateral deflection in an impact.

- If the barrier is shielding a vertical rigid object, the distance between the barrier and the object should be sufficient to avoid the vehicle impacting or snagging on the object.
- Note that, even for rigid barriers with no lateral deflection, large vehicles may roll behind the top of the barrier even if the barrier itself does not deflect.

Deflection Distance

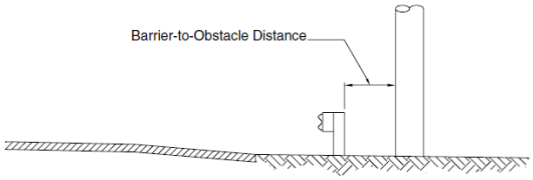
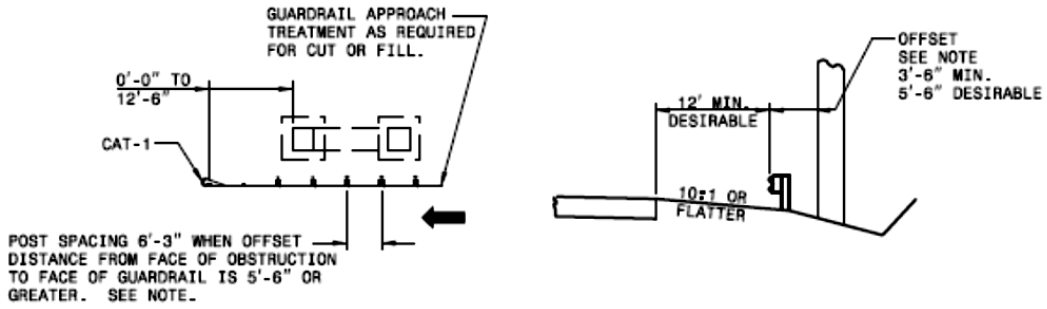


Figure 5-33. Recommended Barrier Placement for Optimum Performance

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – Figure 5-33

Deflection

Deflection Distance - NCDOT



NOTE: WHEN OFFSET DISTANCE FROM FACE OF OBSTRUCTION TO FACE OF GUARDRAIL IS BETWEEN 3'-6" AND 5'-6", BEGIN 3'-1½" POST SPACING AT A POINT 25' BEFORE REACHING THE OBSTRUCTION AND CARRY THROUGHOUT ITS LENGTH. IF THE OFFSET IS LESS THAN 3'-6" USE CONCRETE BARRIER.

DETAIL OF RIGHT SIDE GUARDRAIL AT UNDERPASS

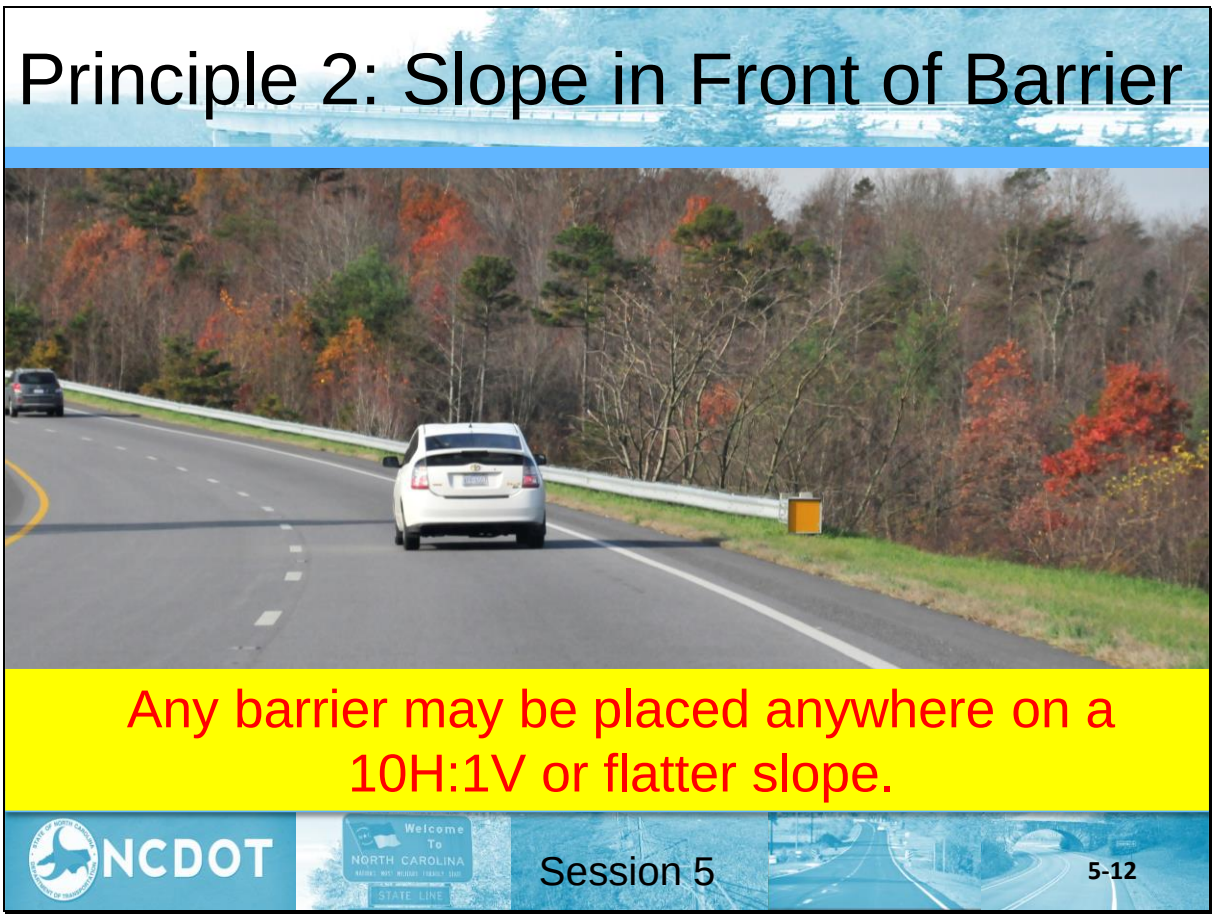
Ref: NCDOT Standard Drawing 862.01, Sht 1

Quarter Post Spacing

Successfully tested to MASH

Deflection distance = 19”; therefore offset from face of rail is 3’

Must start stiffening at 50’ before hard point: 25’ of half post guardrail; 25’ of quarter post guardrail


Principle 2: Slope in Front of Barrier
Any barrier may be placed anywhere on a 10H:1V or flatter slope.
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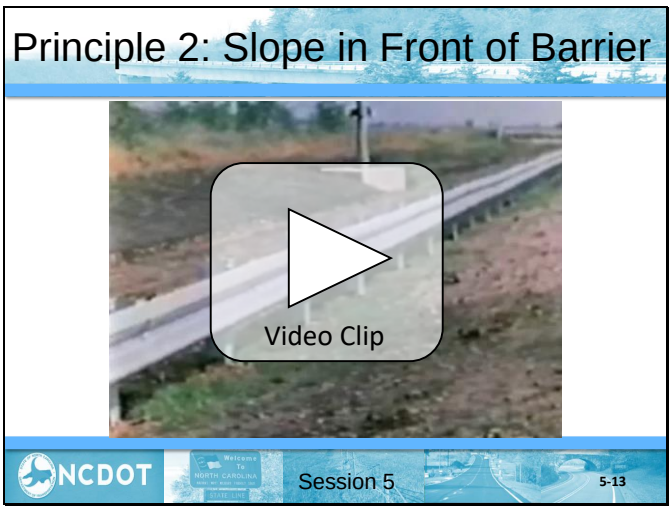
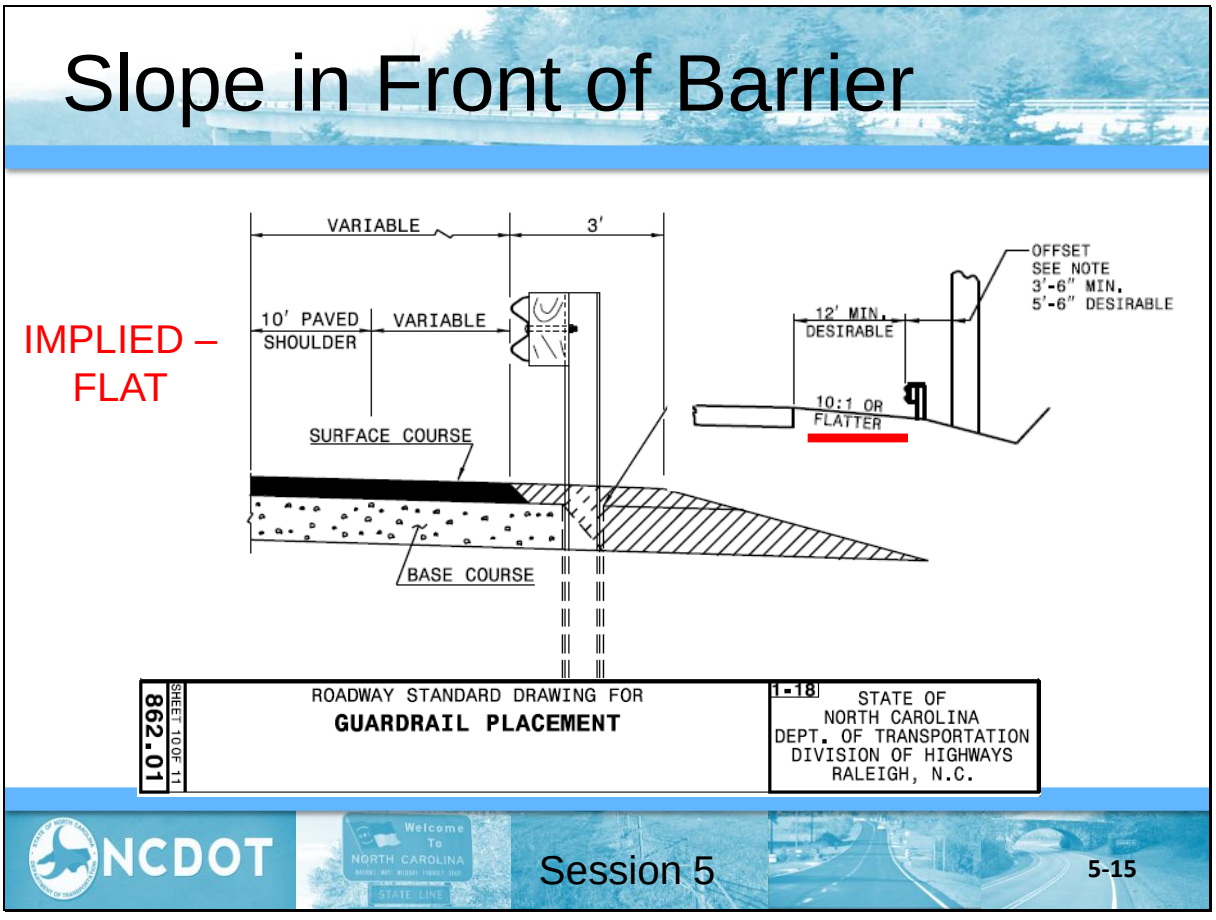
Welcome To NORTH CAROLINA STATE LINE
Session 5
5-12


Principle 2: Slope in Front of Barrier
Video Clip
NCDOT
Session 5
5-13

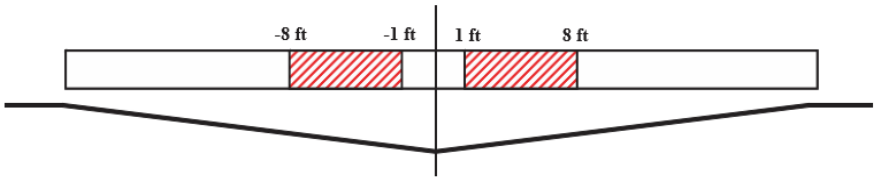

NCHRP 350 TL-3 31” on 8:1 Slope
5-ft
8:1
Video Clip
Vehicle is contained and redirected but shows instability
NCDOT
Session 5
5-14


Slope in Front of Barrier
IMPLIED – FLAT
VARIABLE
3′
10′ PAVED SHOULDER
VARIABLE
SURFACE COURSE
BASE COURSE
OFFSET SEE NOTE 3′-6″ MIN. 5′-6″ DESIRABLE
12′ MIN. DESIRABLE
10:1 OR FLATTER
ROADWAY STANDARD DRAWING FOR
GUARDRAIL PLACEMENT
862.01
SHEET 10 OF 11
1-18
STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.
NCDOT
Session 5
5-15


Barrier in Sloped Median
- Old System (29”) ONLY -
NCDOT
Welcome To NORTH CAROLINA STATE LINE
Session 5
5-16

Slope in Front of Cable Barrier

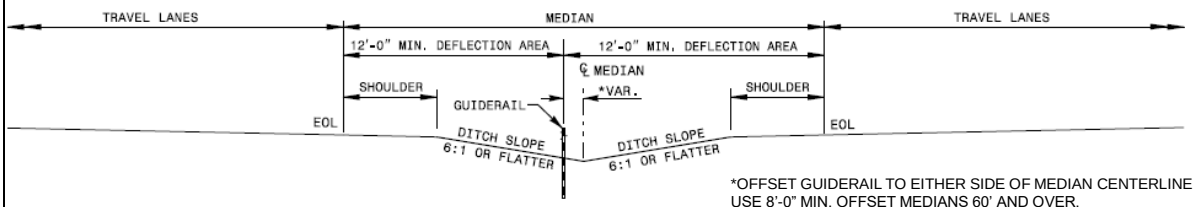
- Cable barrier may be placed anywhere on a 10:1 or flatter slope.
- Cable barrier may be placed on slopes of 6:1, but not in the area from 1 ft. to 8 ft. from the ditch bottom.



(a) Medians shallower than 6H:1V slope (NCHRP Report 711)

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – 6.6.1.1, Pg. 6-18

NCDOT Slope/Swale Guidance - LTC



*OFFSET GUIDERAIL TO EITHER SIDE OF MEDIAN CENTERLINE
USE 8'-0" MIN. OFFSET MEDIANS 60' AND OVER.
USE 4'-0" MIN. OFFSET FOR MEDIANS LESS THAN 60'

TYPICAL SECTION
(DEFLECTION AREA ON MEDIAN SLOPES)
DOUBLE FACE GUIDERAIL APPLICATION

USE 4′-0″ MIN. OFFSET FOR MEDIANS LESS THAN 60′.

Strongly Discouraged

865.01 SHEET 4 OF 12
ROADWAY STANDARD DRAWING FOR
CABLE GUIDERAIL
DESIGN AND PLACEMENT

Location of Cable in Swales

MASH 2016 requires testing with a mid-sized vehicle because of this problem (NC experience)

CABLE SHOULD NOT BE PLACED BETWEEN 1' AND 8' BEYOND THE BOTTOM OF A DITCH

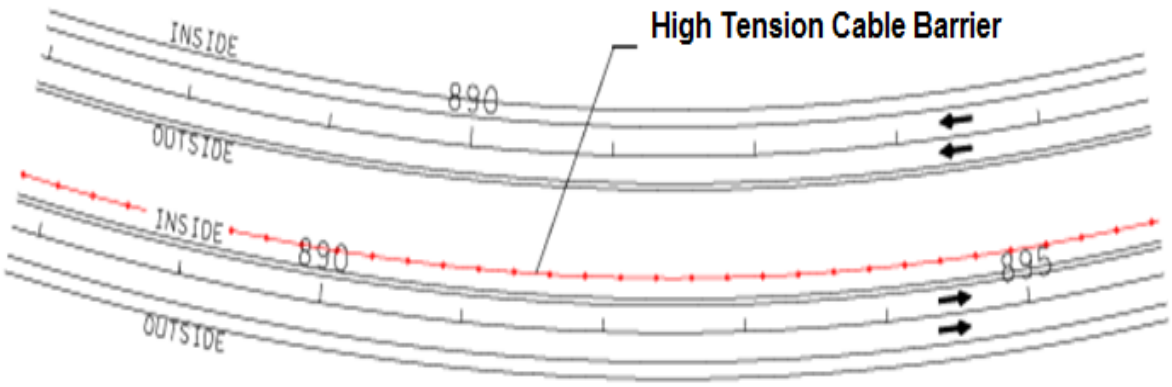
Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – 6.6.1.1, Pg. 6-18


PRE-ASSESSMENT PHOTO
EXIT 466
NCDOT
Session 5
5-20


Barrier in Sloped Median
NCDOT
Session 5
5-21

Barrier in a Curved Median

Which Side of the Median Should the Cable Barrier be Placed?



NCDOT Session 5 5-22

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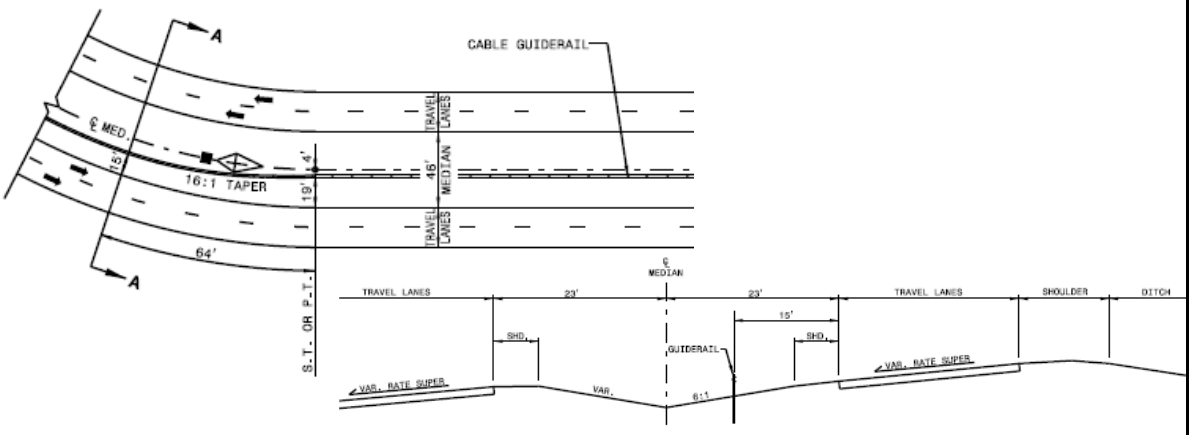
Barrier in a Curved Median



SECTION A-A

865.01 SHEET 3 OF 12

ROADWAY STANDARD DRAWING FOR
CABLE GUIDERAIL
46' MEDIAN GUIDERAIL TRANSITIONS WITH SUPERELEVATION AND/OR FALSE SUMPS

NCDOT

Session 5

5-23


Principle 3: Guardrail and Curbs
NCDOT
Session 5
5-24


PRE-ASSESSMENT PHOTO
6” Curb not acceptable for old 29” System on HS
NCDOT
Session 5
5-25

Guardrail and Curbs

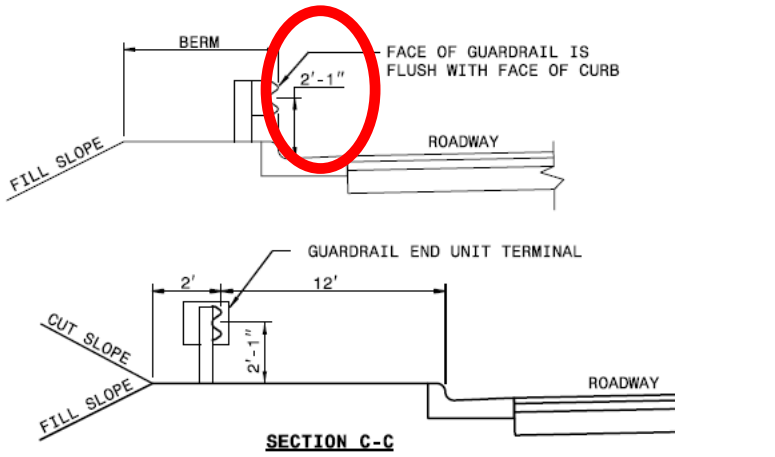
- Curbs may function to channelize traffic, to control drainage, improve delineation, control access, and reduce erosion.
- Curbs are not adequate to prevent a vehicle from leaving the roadway; they are not a barrier.
- Use of any guardrail/curb combination where high-speed, high-angle impacts are likely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

NCDOT Session 5 5-26

Guardrail and Curbs – 29”

NCDOT Session 5 5-27

NCDOT Guardrail and Curbs

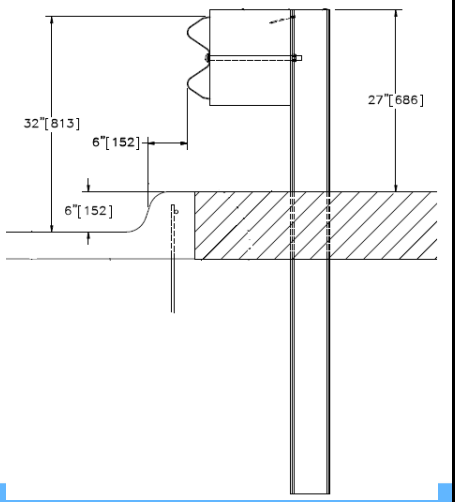


SHEET 11 OF 11		
862.01	ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT** GUARDRAIL TREATMENT AT CURB AND GUTTER	1-18 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

Ref: NCDOT Standard Drawings, 862.01 Sht. 11

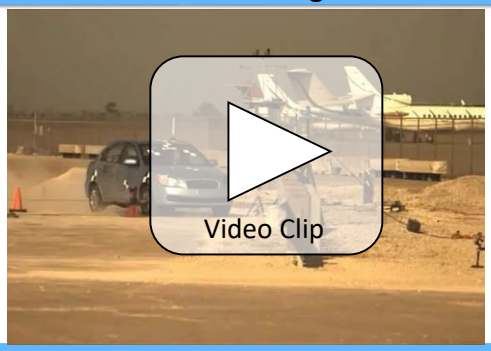
31” and Curbs

Successfully tested to MASH placed 6” behind a 6” high curb at TL-3



NCDOT Session 5 5-29

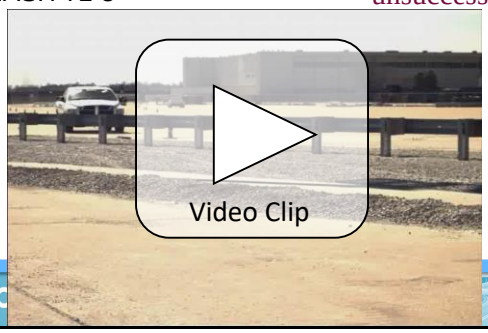
MASH TL-3 31”
Placed 6” behind 6” high Curb



NCDOT Session 5 5-30

31” and Curbs

- The 31” was tested with a 6” curb, 8’ in front of the rail at MASH TL-3 unsuccessful



5-31

End Treatments and Curbs

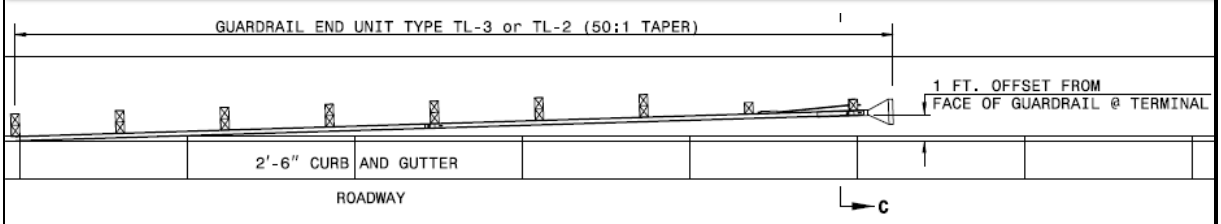
As stated previously, the GRAU-350 is a tangential end unit. However, these units will be flared over the last 50 feet to provide a 1-foot offset. This minimal flare allows the terminal to be offset so that no component of the unit extends beyond the face of the guardrail. The tangential end unit should not be flared greater than a 50:1 flare rate.
No curb is allowed within the limits of this unit.

GUARDRAIL ANCHOR UNITS 3-2E

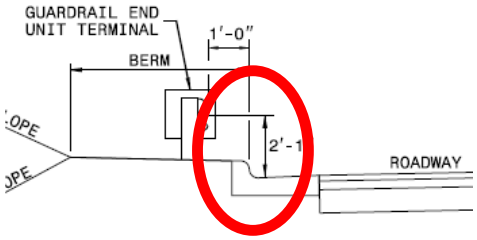
NCDOT Session 5 5-32


End Treatments and Curbs
CURRENTLY UNDER STUDY –
DO NOT BURY BEARING PLATE
2” maximum height recommended
NCDOT
Session 5
5-33

End Treatments and Curbs - NCDOT



GUARDRAIL AT FACE OF CURB



SECTION C-C

Careful with BCA Terminal Anchor – Don't let Bearing Plate be buried

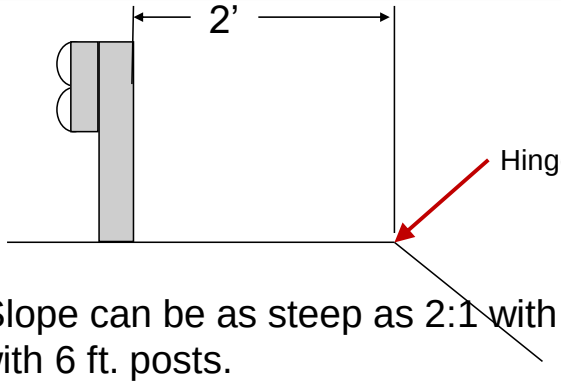
Ref: NCDOT Standard Drawings, 862.01 Sht. 11


NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 5
5-35


MASH TL-2 31” 6 ft. behind curb
Video Clip
NCDOT
Session 5
5-36


Principle 4: Soil Backing For Fill Locations
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 5
5-37

Soil Backing Recommendation

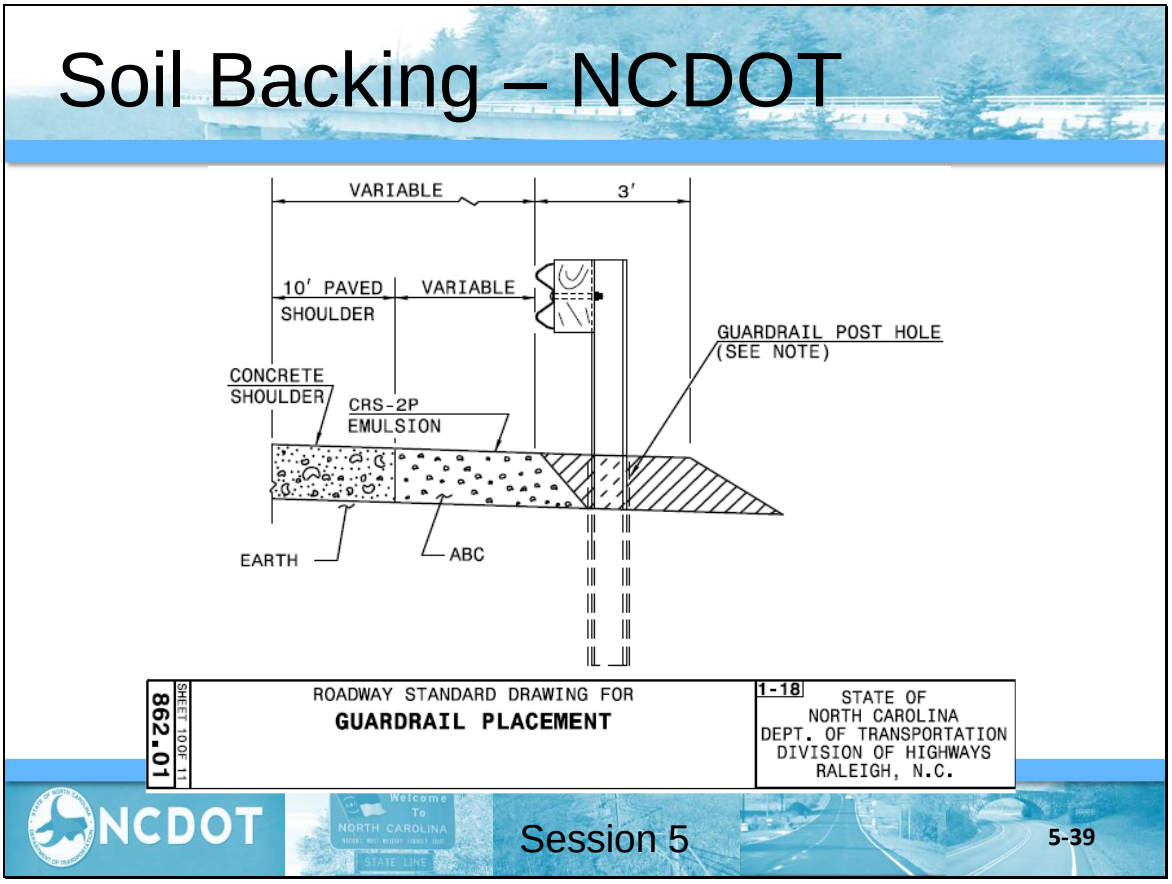


Historical Guidance

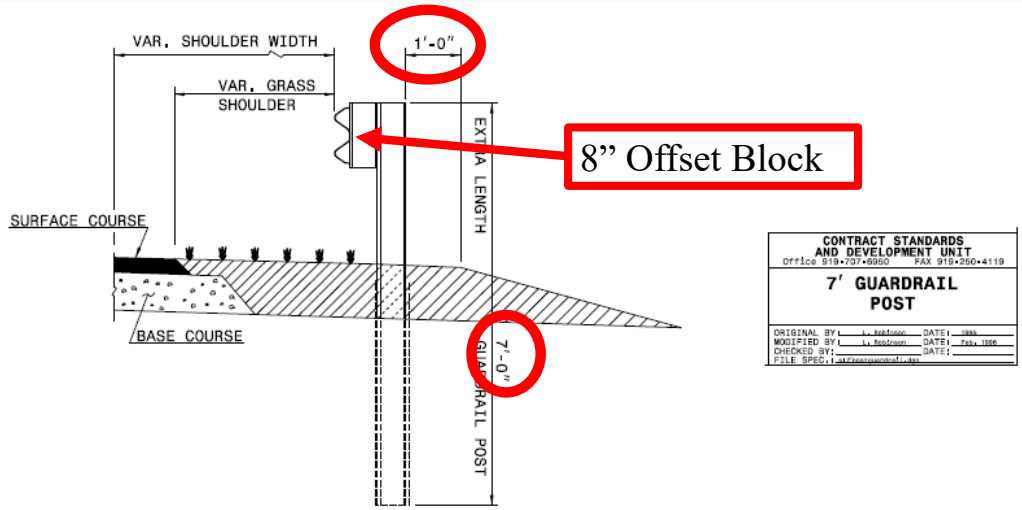
1. Slope can be as steep as 2:1 with 2-ft. backing in strong soil with 6 ft. posts.
2. Backing can be less than 2 ft. with 2:1 slope in strong soil with 7 ft. posts. NCHRP 350 requires half post spacing – ONLY applies to 29” system

Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 5.33, Pg. 5-41

Soil Backing – NCDOT



Soil Backing – NCDOT



NCDOT Session 5 5-40

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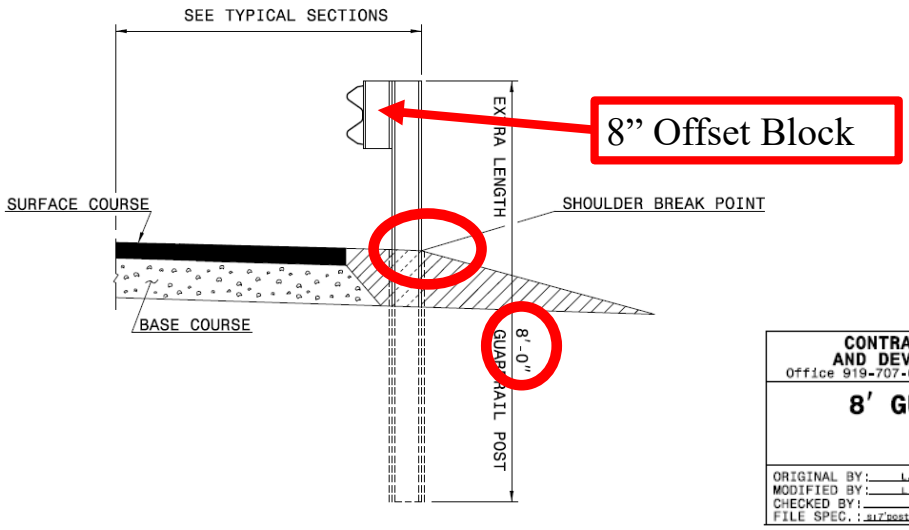
Soil Backing – NCDOT



CONTRACT STANDARDS
AND DEVELOPMENT UNIT
Office 919-707-6950 FAX 919-250-4119

8' GUARDRAIL POST

ORIGINAL BY: L. Robinson DATE: 1995
MODIFIED BY: L. Robinson DATE: Feb. 1996
CHECKED BY: DATE:
FILE SPEC.: sir7'postguardrail.dgn

NCDOT Session 5 5-41

31” with Posts on a 2:1 Slope

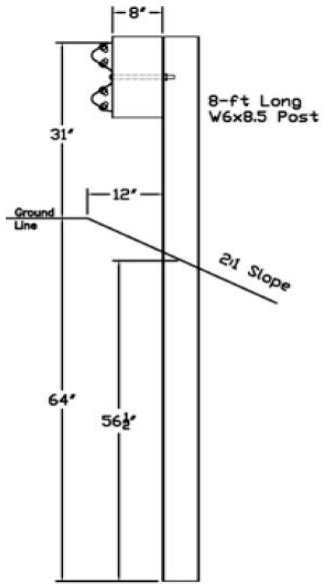
31” with face of rail at slope break point of 2:1 slope

Posts

- 8’ long W6x9 posts tested
- Not recommended with Wood posts at this time
- 6’-3” post spacing

Offset Blocks

- 8” Offset block tested
- Not recommended without offset block at this time



31” with Posts on a 2:1 Slope

Working Width – 55.2”
Eligibility Letter B-261


Principle 5: Flare Rate
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 5
5-44

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Flare Rate

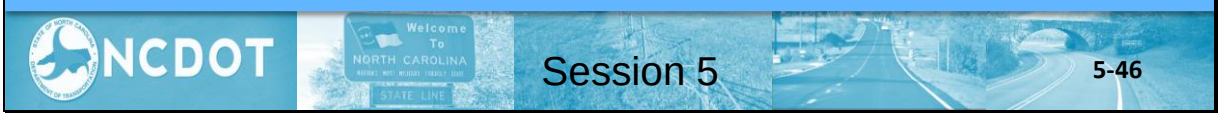
Flared barriers are those that are not parallel to the edge of the traveled way. They are used to:

- Locate end treatments farther from the roadway.
- Lessen driver reaction to a roadside obstacle.
- Reduce total length of rail needed.
- Reduce nuisance hits.
- When tying to a bridge rail from a farther offset (in advance of transition)

Flare Rate

Trade offs and restrictions of flared barriers:

- Flare increases the angle at which the barrier can be hit.
- Flare may increase the angle of redirection after an impact.
- Flared barriers can only be placed on 10:1 or flatter slopes.
- Maximum flare rate varies with design speed
  NCDOT flare rate typically 50:1



Tangent End Treatments on Flared Standard Run - Repeat

The offset of the end treatment is measured from a line parallel to the ROADWAY:

If the standard flare is 25:1 or flatter, the end treatment may be placed on the standard flare line extended

If the standard flare is sharper than 25:1, a kink in the run must be provided so the end treatment is no sharper than 25:1

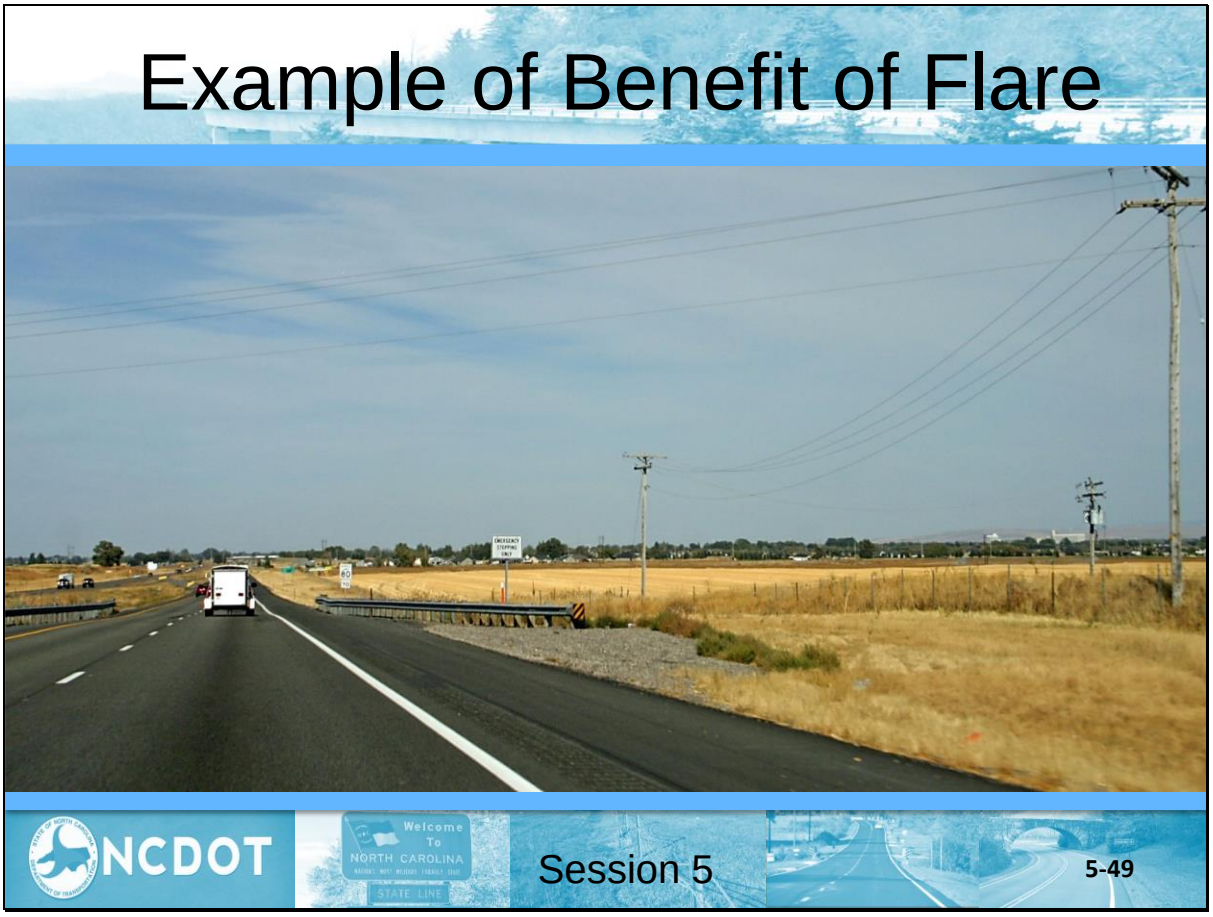
NCDOT guidance is to provide 25' of parallel guardrail in advance of any end treatment requiring a kink.

Suggested Flare Rates

Table 5-9. Suggested Flare Rates for Barrier Design

Design Speed		Flare Rate for Barrier Inside Shy Line	Flare Rate for Barrier at or Beyond Shy Line	
km/h	[mph]		Rigid Barrier	Semi -Rigid Barrier
110	[70]	30:1	20:1	15:1
100	[60]	26:1	18:1	14:1
90	[55]	24:1	16:1	12:1
80	[50]	21:1	14:1	11:1
70	[45]	18:1	12:1	10:1
60	[40]	16:1	10:1	8:1
50	[30]	13:1	8:1	7:1

Notes:
A = Suggested maximum flare rate for rigid barrier system.
B = Suggested maximum flare rate for semi-rigid barrier system.
The MGS has been tested in accordance with NCHRP Report 350 TL-3 at 5:1 flare.
Flatter flare rates for the MGS installations also are acceptable. The MGS should be installed using the flare rates shown or flatter for semi-rigid barriers beyond the shy line when installed in rock formations.


Example of Benefit of Flare
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 5
5-49

Review Learning Outcomes

Understand the design principles affecting an optimal barrier installation.

NCDOT Session 5 5-51

Session 6: Length of Need and Special Considerations

North Carolina Department of Transportation
Highway Safety Barrier Design Training

Session 6: Length of Need and Special Considerations

NCDOT Session 6 6-1

Session 6 Learning Outcomes

At the end of this session, you will be able to:

- Define the Length of Need and apply the design principles for an optimal installation
- Modify guardrail for special situations

NCDOT Session 6 6-2

Order of Preference - NCDOT

4.10 Traffic Barriers
4.10.1 General Considerations

The preferred method of addressing roadside hazards is as follows:

1. Remove the hazard;
2. Remove embankment hazard (flatten slopes);
3. Shift hazard away from traffic;
4. Reduce the impact severity by using breakaway posts;
5. Protect the hazard;
6. Delineate the hazard so motorists are aware of the hazard.

NCDOT Session 6 6-3

Length of Need (LON) Definition

AASHTO

The length of effective barrier needed IN ADVANCE OF the hazard to intercept and redirect an encroaching vehicle.

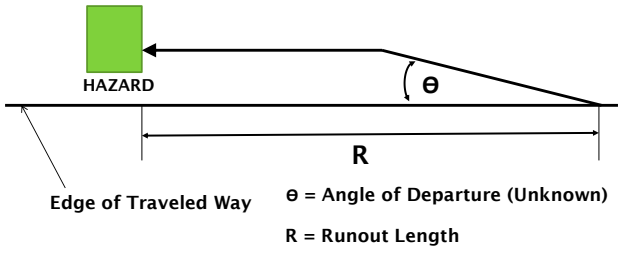
Length of Need (LON) Definition

NCDOT

The length of effective barrier in advance of the obstacle **NOT TO INCLUDE ANY** of the GREU.

Length of Need (LON) Theory

AASHTO



Runout Lengths - NCDOT

Proposed - replace with AASHTO RDG values

LR = RUNOUT LENGTH
N = NORMAL SHOULDER WIDTH (WIDTH OF SHOULDER FROM EDGE OF TRAVEL LANE TO FACE OF GUARDRAIL)

DETAIL 3-2A

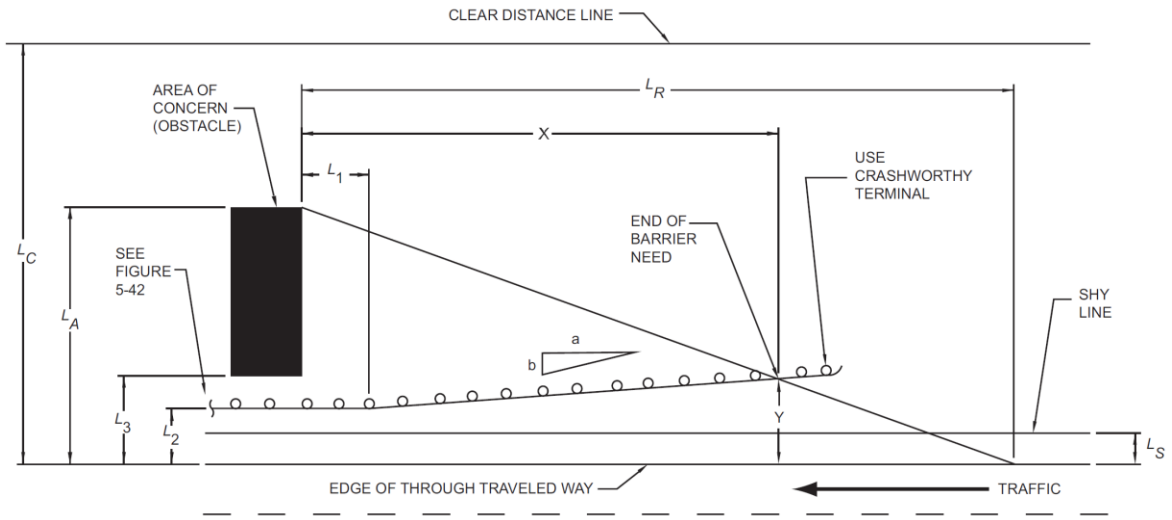
Runout Lengths - AASHTO

Table 5-10(b). Suggested Runout Lengths for Barrier Design (U.S. Customary Units)

Design Speed (mph)	Runout Length (L_R) Given Traffic Volume (ADT) (ft)			
	Over 10,000	5,000 to 10,000	1,000 to 5,000	Under 1,000
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

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – TABLE 5.10, Pg. 5-50

LON Design Procedure for Approach Barrier Layout



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

Length of Need – AASHTO

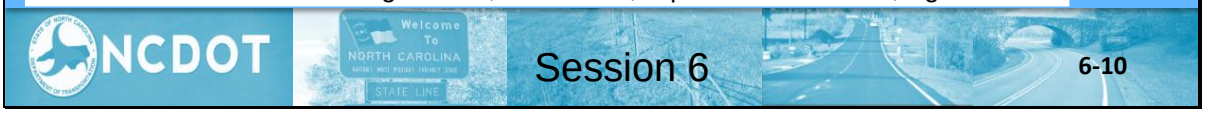
- Calculating the length of need (X) for straight or nearly straight sections of roadway:
  - For flared guardrail installations:

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

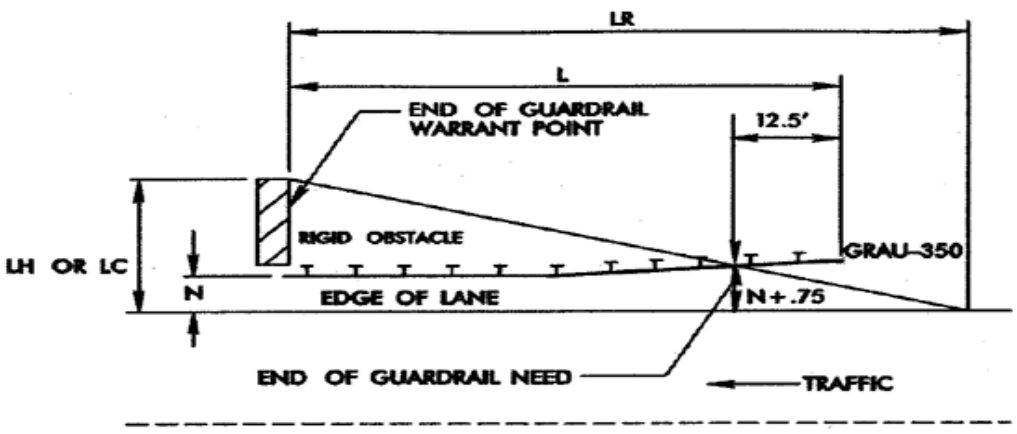
  - For parallel guardrail installations:

$$X = \frac{L_A - L_2}{L_A/L_R}$$

Ref: AASHTO Roadside Design Guide, 4th Edition, Equation 5-1 and 5-2, Pg 5-51



Length of Need – NCDOT



ROADWAY DESIGN MANUAL PART 1

DETAIL 3-2A

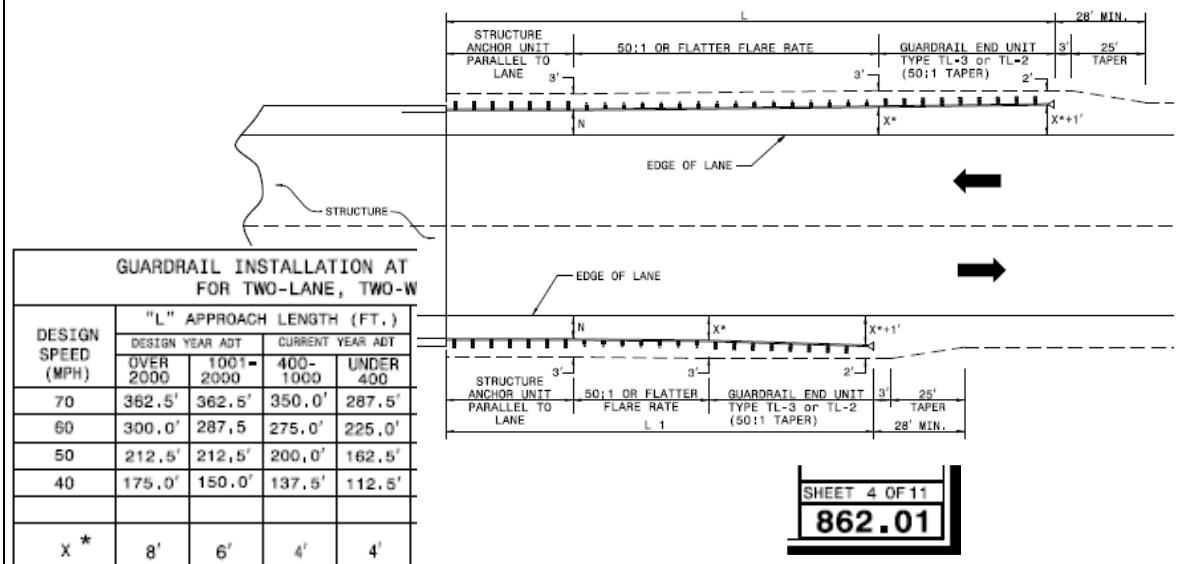
Length of Need – NCDOT

- Calculating the length of need (L) for straight or nearly straight sections of roadway (parallel installation):

$$L = \frac{LH - (N + 0.75)}{LH/LR} \quad + 12.50$$

The formulas and details are derived from Chapter 5 in the Roadside Design Guide.

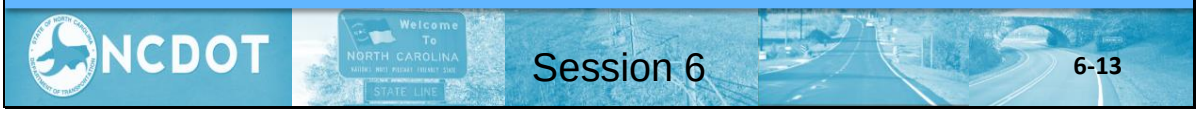
Length of Need for Bridge Approach NCDOT



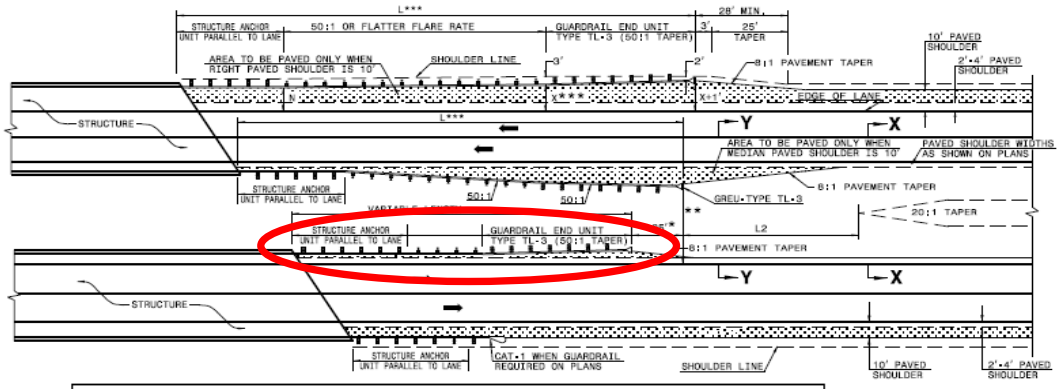
GUARDRAIL INSTALLATION AT
FOR TWO-LANE, TWO-W

DESIGN SPEED (MPH)	"L" APPROACH LENGTH (FT.)			
	DESIGN YEAR ADT		CURRENT YEAR ADT	
	OVER 2000	1001-2000	400-1000	UNDER 400
70	362.5'	362.5'	350.0'	287.5'
60	300.0'	287.5	275.0'	225.0'
50	212.5'	212.5'	200.0'	162.5'
40	175.0'	150.0'	137.5'	112.5'
X *	8'	6'	4'	4'

SHEET 4 OF 11
862.01



Length of Need for Bridge Approach
NCDOT – Dual Bridges



DIMENSIONS FOR LENGTH OF GUARDRAIL APPROACHING DUAL LANE BRIDGES

MEDIAN WIDTH	-L-***						-L2-
	70 MPH	60 MPH	50 MPH				DIM.
30'	300.0'	250.0'	150.0'				80.0'
36'	300.0'	250.0'	150.0'				60.0'
40' & ABOVE	300.0'	250.0'	150.0'				40.0'

SHEET 3 OF 11
862.01

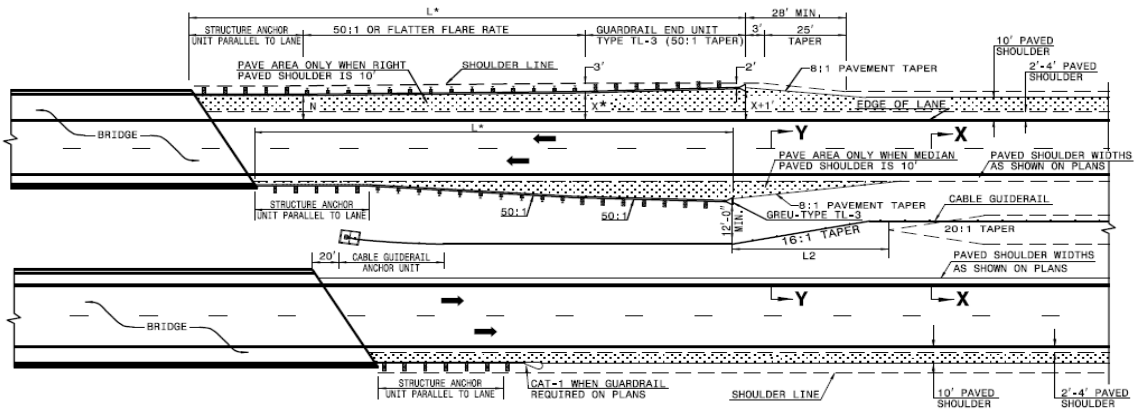
THE DESIGN LAYOUT FOR LENGTHS SHOWN ON THIS STANDARD ARE MINIMUM DESIGN LENGTHS.

NCDOT

Session 6

6-14

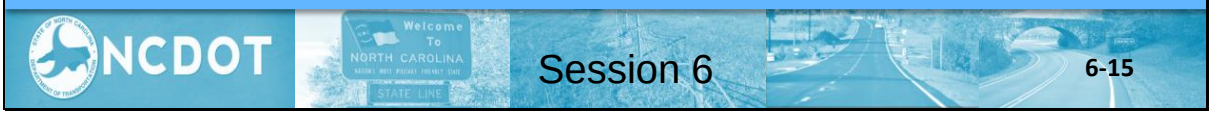
Length of Need for Bridge Approach NCDOT – with Cable Barrier



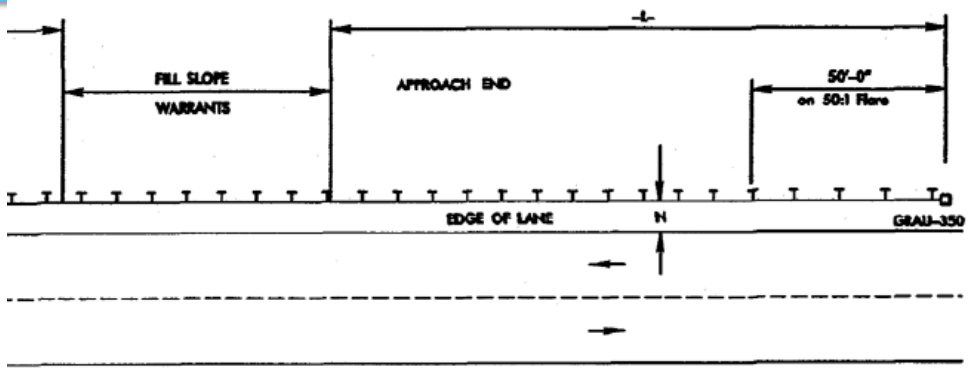
DIMENSIONS FOR LENGTH OF GUARDRAIL APPROACHING DUAL LANE BRIDGES							
MEDIAN WIDTH	-L-*						-L2-
	70 MPH	60 MPH	50 MPH				DIM.
46' & ABOVE	300.0'	250.0'	150.0'				40.0'

SHEET 2 OF12
865.01

THE DESIGN LAYOUT FOR LENGTHS SHOWN ON THIS STANDARD ARE MINIMUM DESIGN LENGTHS.



Length of Need for Fill Slope NCDOT



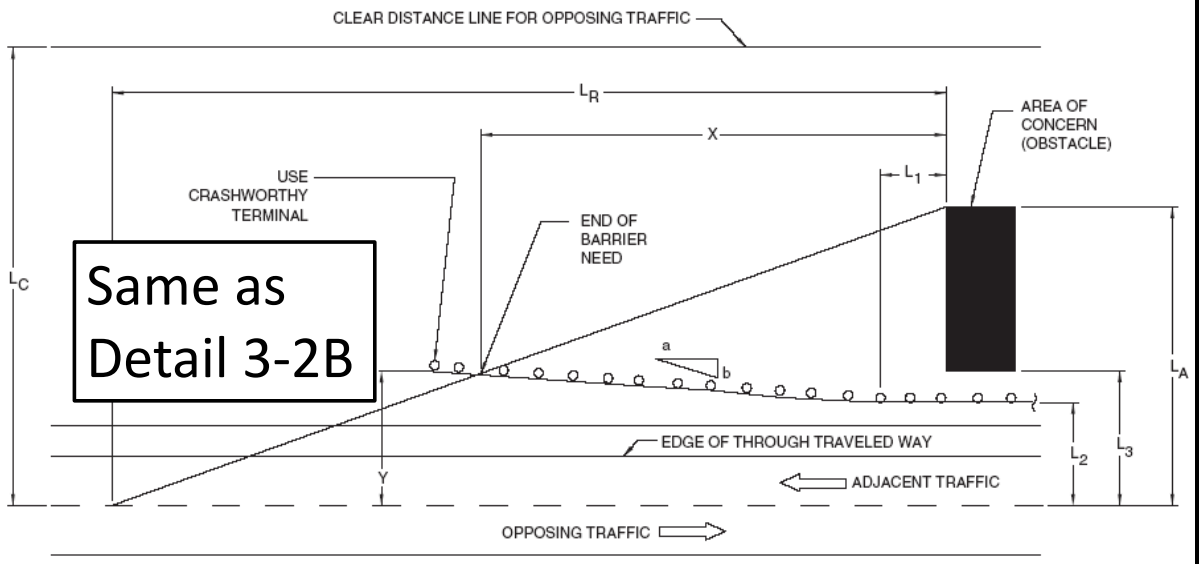
"L" OR LENGTH OF NEED ON THE APPROACH SIDE OF THE GUARDRAIL FOR A FILL SLOPE WARRANT FOR ANY CLASSIFICATION OF ROADWAY

DESIGN SPEED (MPH)	70	60	50	40
"L (FT.)	150'	125'	100'	75'

DETAIL 3 - 2C

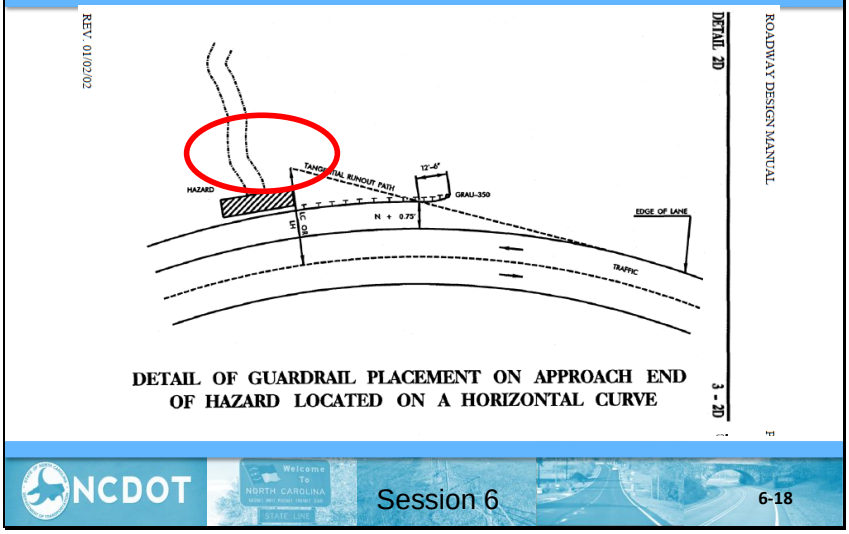
These are quite short compared to AASHTO

LON Design for Opposing Traffic

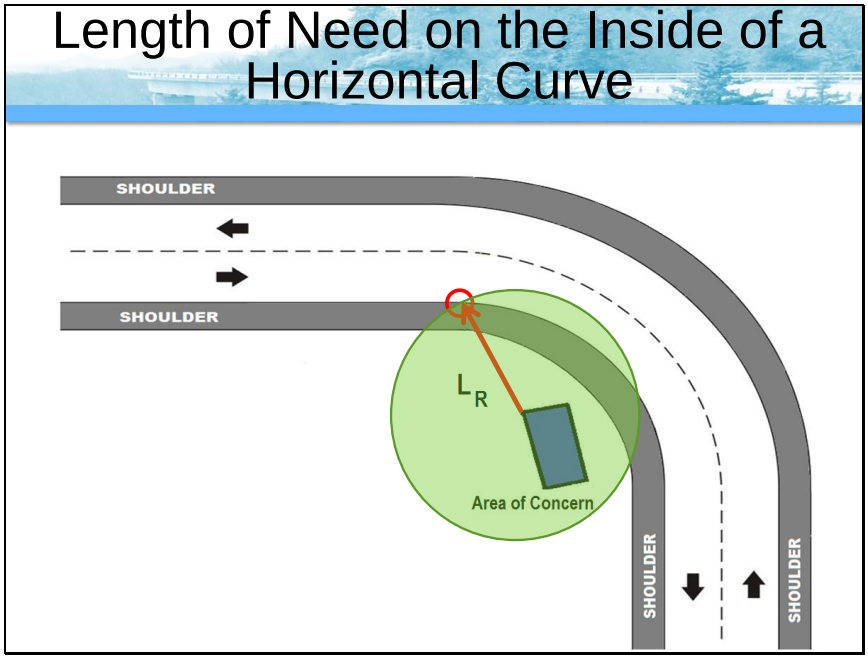


Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 5.42, Pg. 5-54

Length of Need on the Outside of a Horizontal Curve



Length of Need on the Inside of a Horizontal Curve

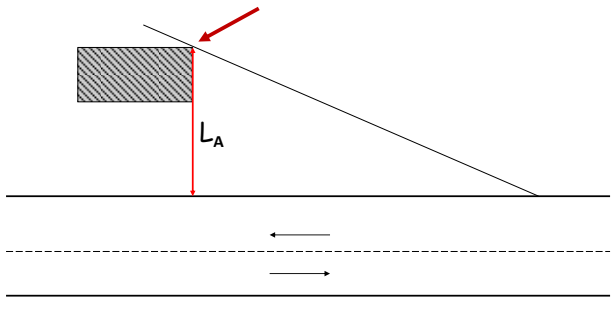


Energy–Absorbing terminal on a curve

Energy-Absorbing terminals must be installed in a straight line over the length of the terminal proper. This may require the barrier to be extended in advance of the curve.

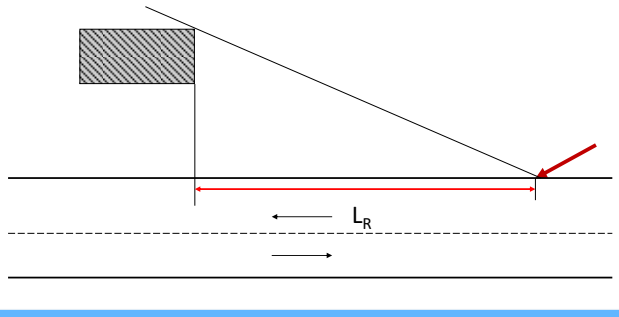
NCDOT Session 6 6-20

Step 1: Identify the Hazard

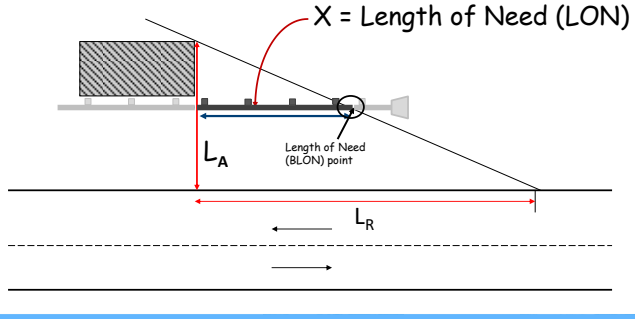


NCDOT Session 6 6-21

Step 2: Define the Point of Departure



Step 3: Intersect the Hypotenuse



Length of Need – Adequate?


Length of Need – Adequate?
NCDOT
Session 6
6-25


Length of Need – Adequate?
NCDOT
Session 6
6-26


Length of Need – Adequate?
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6-27


Length of Need – Adequate?
NCDOT
Session 6
6-28

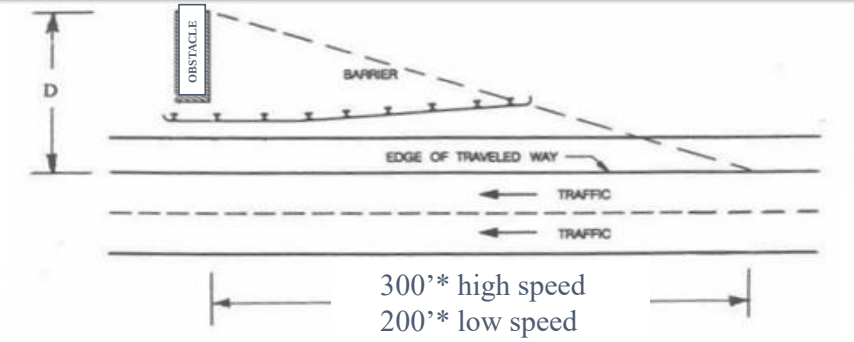

EXIT
265 B
PRE-ASSESSMENT PHOTO
NCDOT
Session 6
6-29


Length of Need – Adequate?
NCDOT
Session 6
6-30

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 ALL hazards that should be shielded in this area
6. Check for better terminal location by extending barrier a short distance (especially on curves!!!)

Length of Need Field Check

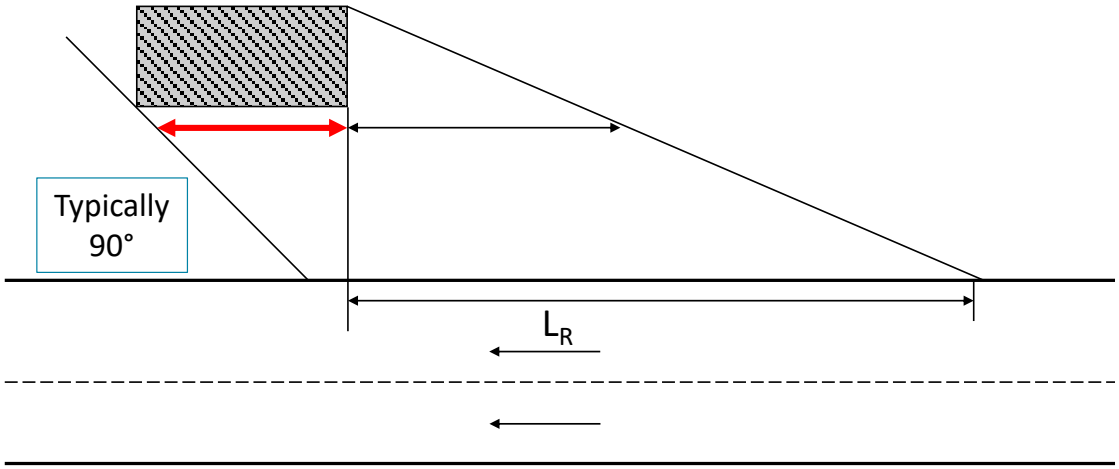


Procedure

- Identify upstream face of hazard
- Identify back of hazard D – limit to 30'
- Walk upstream along the white edge line, beginning at the upstream side of the hazard, 300'* for high speed, or 200'* for low speed (45 mph or less)
- Sight from this position to the upstream face, back edge of hazard (limited to 30')
- End of terminal should intercept line of sight (± ≈30')

Downstream Termination One Direction Traffic

An anchor (CAT-1) plus 25’ of rail must be ADDED at the end



Guardrail Placement

Place as far from traffic as practical
(without affecting performance)

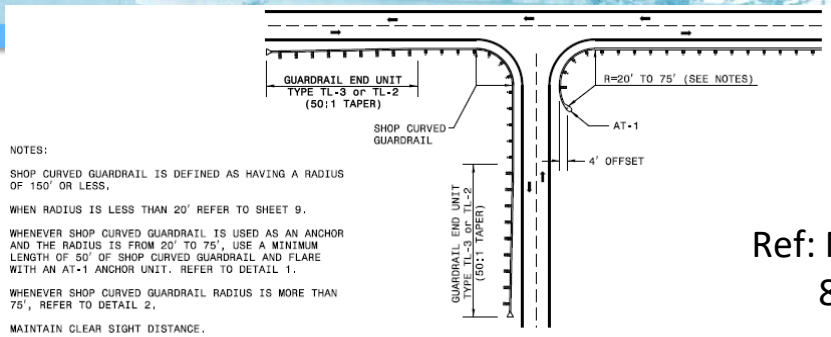
Guardrail Placement in Special Situations

- Guardrail Placement at Intersections
- Long Span (Omitted Post{s})
- Gaps between runs of barrier
- Extra Offset Blocks
- Leaveouts for Posts in Structural Pavement
- Guardrail Post in Rock


Guardrail Placement at Intersections
J. R. DEANS MEMORIAL BRIDGE
NCDOT
Session 6
6-37


HWY 221
NCDOT
Session 6
6-38

Guardrail Placement at Intersections



NOTES:

SHOP CURVED GUARDRAIL IS DEFINED AS HAVING A RADIUS OF 150' OR LESS.

WHEN RADIUS IS LESS THAN 20' REFER TO SHEET 9.

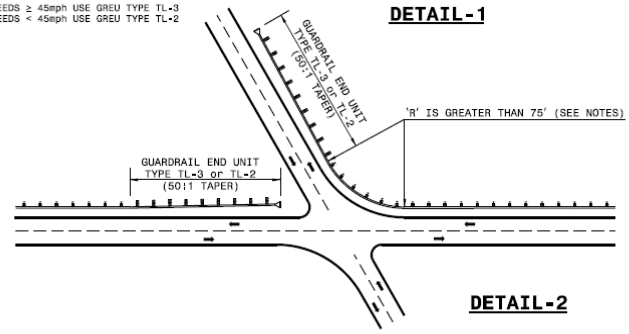
WHENEVER SHOP CURVED GUARDRAIL IS USED AS AN ANCHOR AND THE RADIUS IS FROM 20' TO 75', USE A MINIMUM LENGTH OF 50' OF SHOP CURVED GUARDRAIL AND FLARE WITH AN AT-1 ANCHOR UNIT. REFER TO DETAIL 1.

WHENEVER SHOP CURVED GUARDRAIL RADIUS IS MORE THAN 75', REFER TO DETAIL 2.

MAINTAIN CLEAR SIGHT DISTANCE.

FOR POSTED SPEEDS ≥ 45mph USE GREU TYPE TL-3
FOR POSTED SPEEDS < 45mph USE GREU TYPE TL-2

DETAIL-1



DETAIL-2

GUARDRAIL TREATMENT AT INTERSECTIONS

Ref: NCDOT Standard 862.01, Sht 8

NCDOT Session 6 6-39

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NCDOT Session 6 6-40

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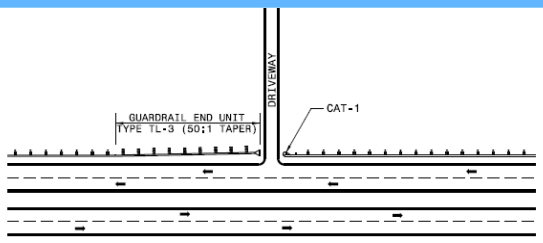
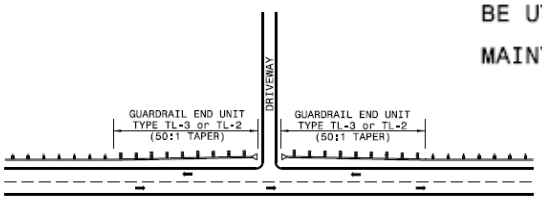
Guardrail Placement at Driveways



DETAIL-3
DIVIDED HIGHWAY

NOTE: USE DETAIL 3 & 4 WHENEVER 20′ OR LARGER RADIUS CANNOT BE UTILIZED.

MAINTAIN CLEAR SIGHT DISTANCE.



DETAIL-4
UNDIVIDED HIGHWAY

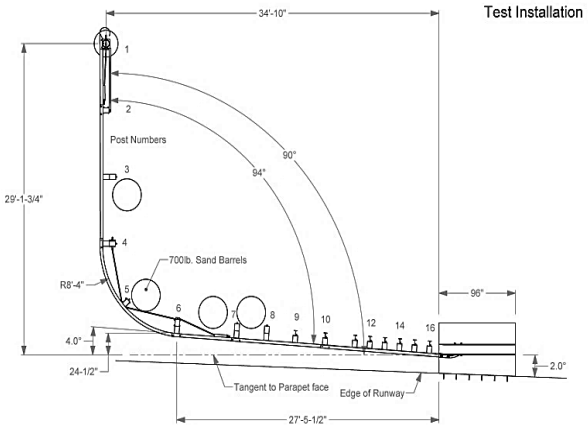
GUARDRAIL TREATMENT AT DRIVEWAYS

Ref: NCDOT Standard 862.01, Sht 9

NCDOT Session 6 6-41

NCDOT Session 6 6-42

TxDOT MASH TL-3 Short Radius



On-going Research by Pool Fund – No Eligibility Letter

TxDOT MASH TL-3 Short Radius

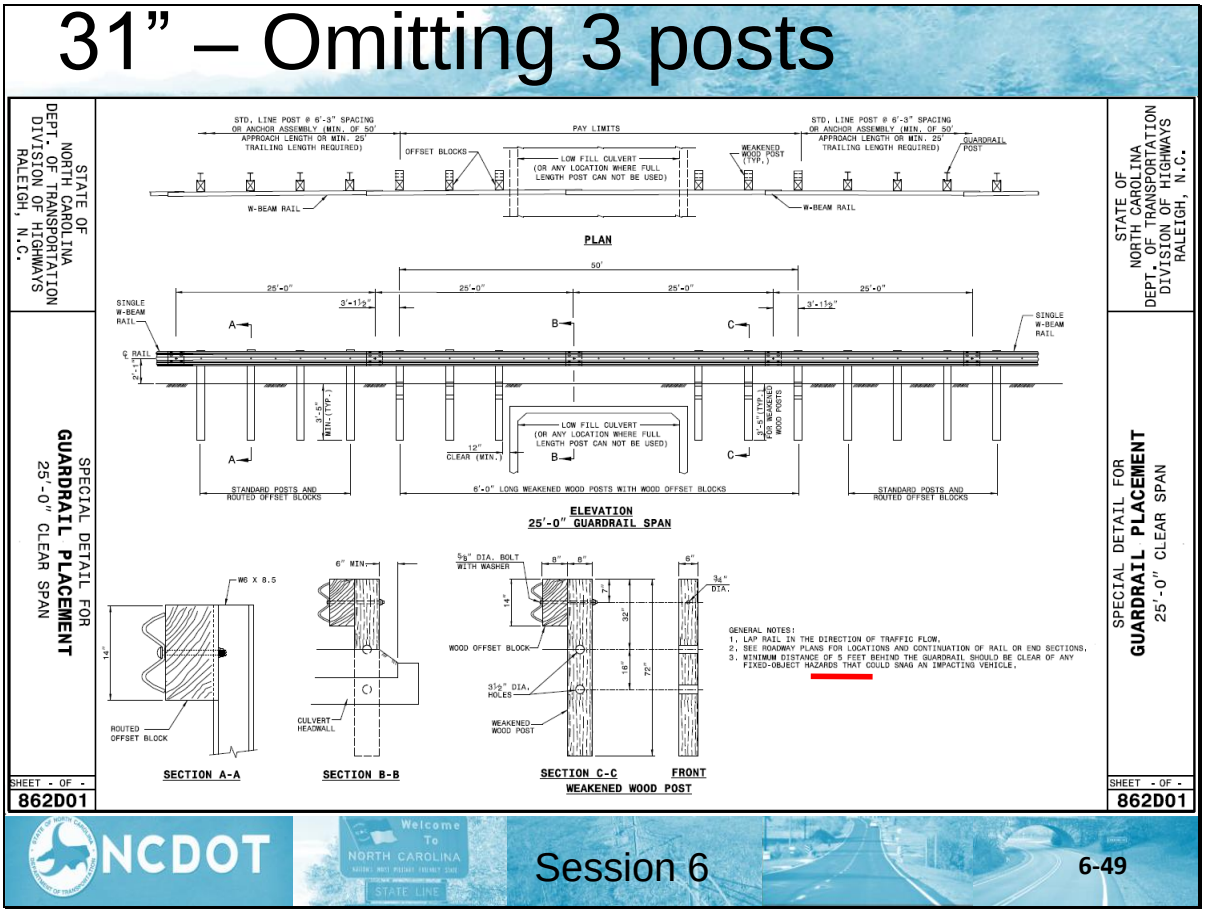

MASH TL-3 Short Radius - NCHRP
Video Clip
NCDOT
Session 6
6-45


Test 3-33 on a 2:1 Slope at **50 mph** ONLY
Video Clip
NCDOT
Session 6
6-46


Omitting posts – old 29” guardrail
NCDOT
Session 6
6-47

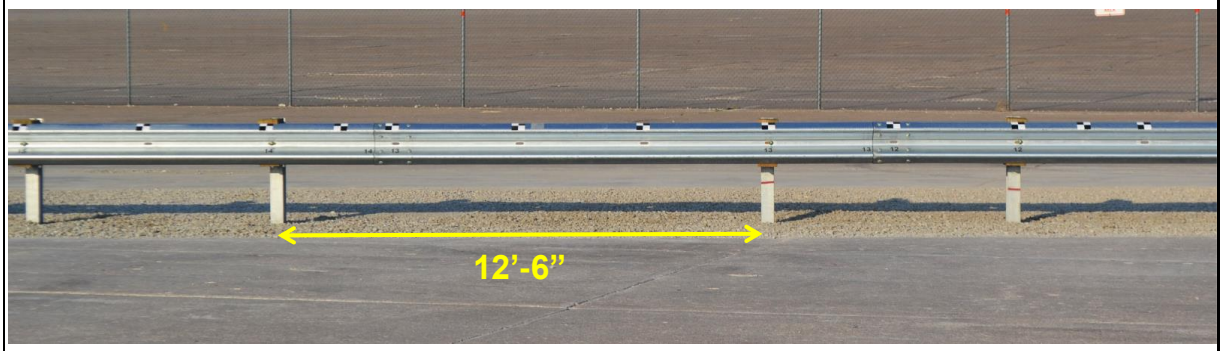

31” – Omitting 3 posts
Video Clip
Working Width – 94”
Eligibility Letter B-189
NCDOT
Session 6
6-48

31” – Omitting 3 posts



MGS - Omitting 1 post – Future??

- No post modifications
- Can be used with wood or steel posts
- Can be used with 8” and 12” blockouts but not with the non-blocked system

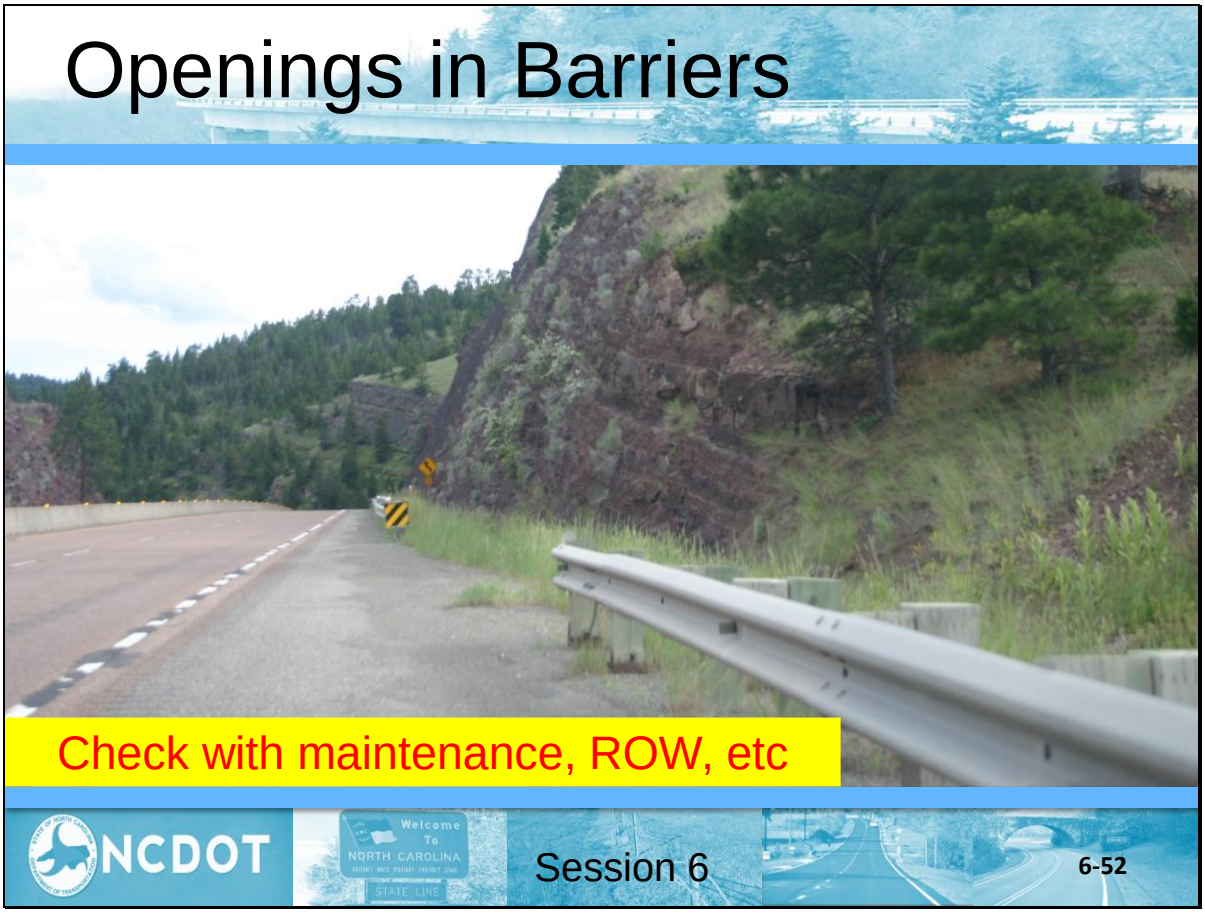


NCDOT Session 6 6-50

MGS - Omitting 1 post – Future??

Working Width 50.1”
Limit 1 per 50’

Session 6 6-51


Openings in Barriers
Check with maintenance, ROW, etc
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 6
6-52

_____

_____

Openings in Barriers - NCDOT

Proposed – Same criteria (4.10.2.2)

ROADWAY DESIGN MANUAL PART 1

DETERMINING GUARDRAIL LENGTHS OF NEED 3-2

NOTE: A space of less than 300' should not be left between guardrail installations. If less than 300' remains between installations, the guardrail should be extended through the area.

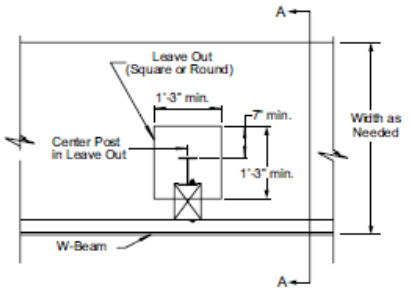
Again, be sure there are no conditions that would preclude closure

Extra Offset Blocks – National Guidance

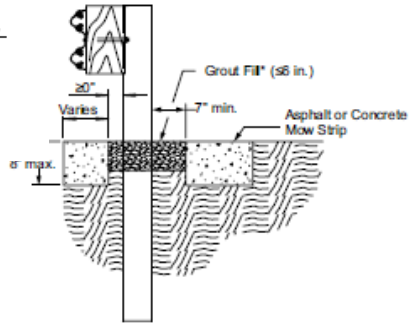
- Two Offset blocks (up to 16" deep) may be used at any time, for any number of posts.
- Three Offset blocks may be used at one or two posts in a section of guardrail.

Ref: AASHTO Roadside Design Guide – 3rd Edition, Section 5.4.1.6

Leaveouts in Structural Pavement



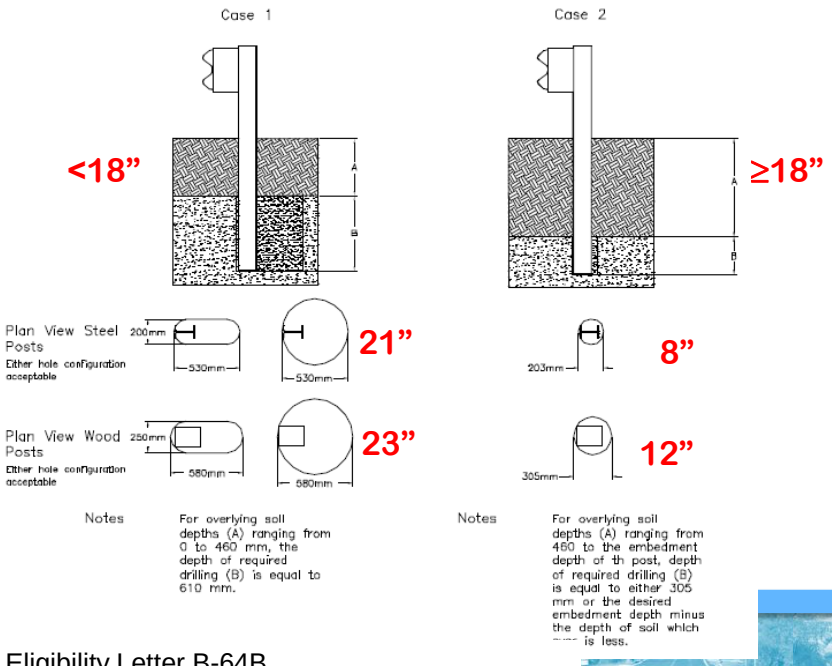
Steel Post Detail



Section A-A

Ref: AASHTO Roadside Design Guide – 4th Edition, Figure 5-52

Guardrail Posts in Rock AASHTO



Eligibility Letter B-64B

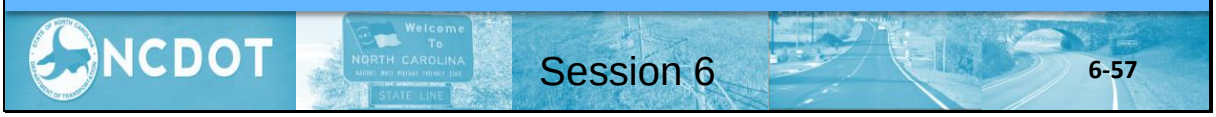
6-56

Guardrail Posts in Rock - NCDOT

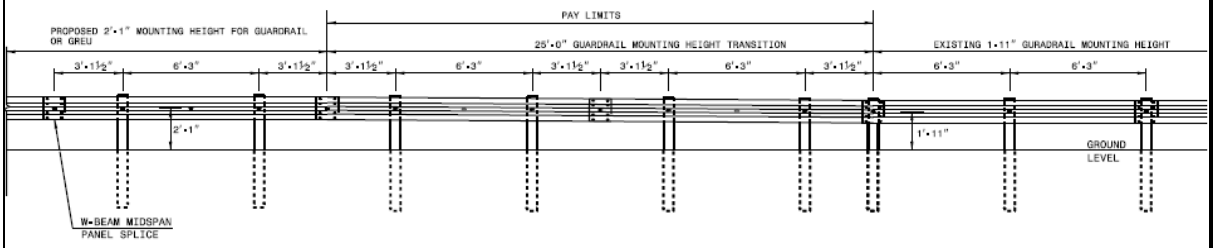
SECTION 862
GUARDRAIL

862-3 CONSTRUCTION METHODS

Where rock interferes with the proper installation of the post, excavate a shaft in the rock at least 9 inches wide, parallel to the roadway, by 23 inches long, perpendicular to the roadway and 24 inches deep. Place the post against the roadside edge of the shaft and fill in behind the post with Class VI select material, up to the top elevation of the rock. Fill the remainder of



Height Transition – 31” to/from Old Guardrail



ELEVATION VIEW

TRANSITION FROM OR 1′-11″ TO 2′-1″ W-BEAM GUARDRAIL MOUNTING HEIGHT

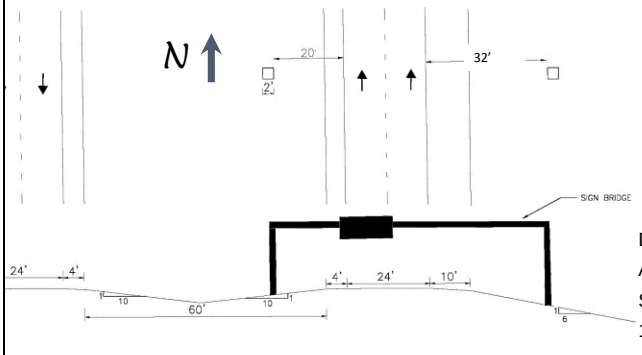
SHEET 4 OF 8	ROADWAY STANDARD DRAWING FOR **GUARDRAIL INSTALLATION**	1-18 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.
862.02		

NCDOT

Session 6

6-58

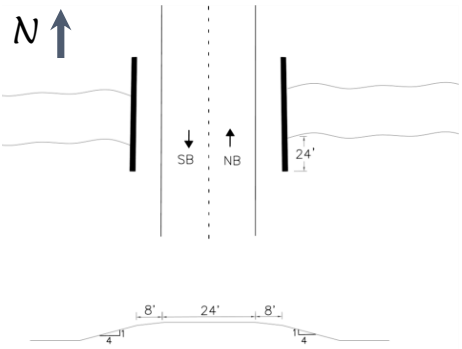
Design Workshop #1 - LON



Design speed: 70 mph
ADT: 53,000
Side slope:
10:1 Left, 6:1 Right

DETERMINE TREATMENTS FOR NB TRAFFIC

Design Workshop #2: LON for Bridge on Rural Road

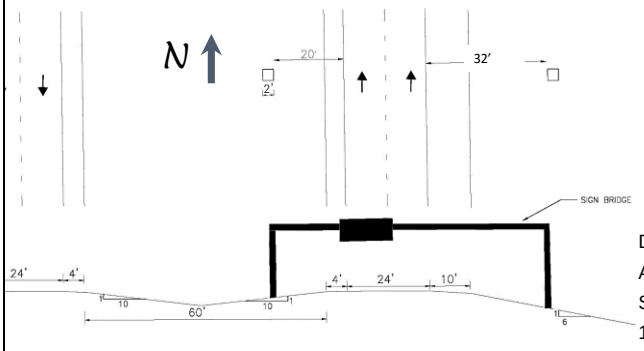


Bridge on Rural Road with Two-way Traffic

Design Speed 60 mph
AADT 2,250
Lane width: 12 ft.
Shoulder width: 8 ft.
Side slope: 4:1

Design for both sides of road, NB

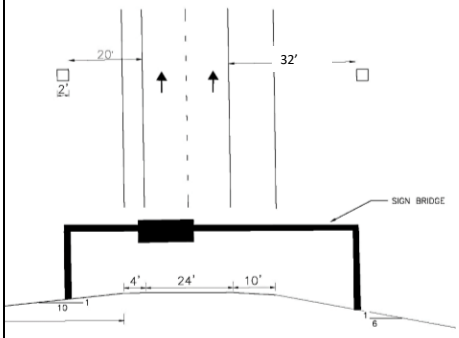
Design Workshop #1 - LON



Design speed: 70 mph
ADT: 53,000
Side slope:
10:1 Left, 6:1 Right

DETERMINE TREATMENTS FOR NB TRAFFIC

Design Workshop #1 - LON



Determine Design Clear Zone

The Clear Zone is a look up value from NCDOT Design Manual

Design speed: 70 mph
ADT: 53,000
Side slope: 10:1 or 6:1

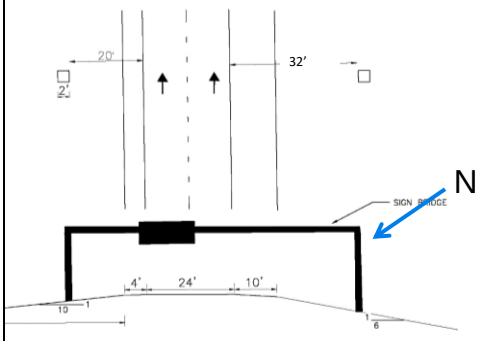
Design Clear Zone Distance – Fill

Design Speed (mph)	Design ADT	Foreslopes		
		1V:6H or flatter	1V:5H to 1V:4H	1V:3H
40 mph	UNDER 750	7-10	7-10	b
	750-1500	10-12	12-14	b
	1500-6000	12-14	14-16	b
	OVER 6000	14-16	16-18	b
45-50 mph	UNDER 750	10-12	12-14	b
	750-1500	14-16	16-20	b
	1500-6000	16-18	20-26	b
	OVER 6000	20-22	24-28	b
55 mph	UNDER 750	12-14	14-18	b
	750-1500	16-18	20-24	b
	1500-6000	20-22	24-30	b
	OVER 6000	22-24	26-32[a]	b
60 mph	UNDER 750	16-18	20-24	b
	750-1500	20-24	26-32[a]	b
	1500-6000	26-30	32-40[a]	b
	OVER 6000	30-32[a]	36-44[a]	b
65-70 mph	UNDER 750	18-20	20-26	b
	750-1500	24-26	28-36[a]	b
	1500-6000	[illegible]	34-42[a]	b
	OVER 6000	30-34[a]	38-46[a]	b

Design Speed 70 mph
AADT = 53,000

LC = 32 ft.

Example – LON

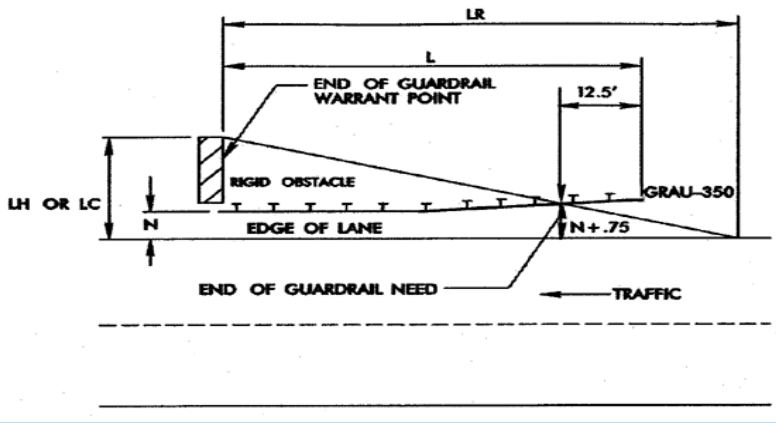


Identify ALL the hazards

NOT SHIELDED

Sign supports – both sides

Calculating the Length of Need (L)



NCDOT Session 6 6-65

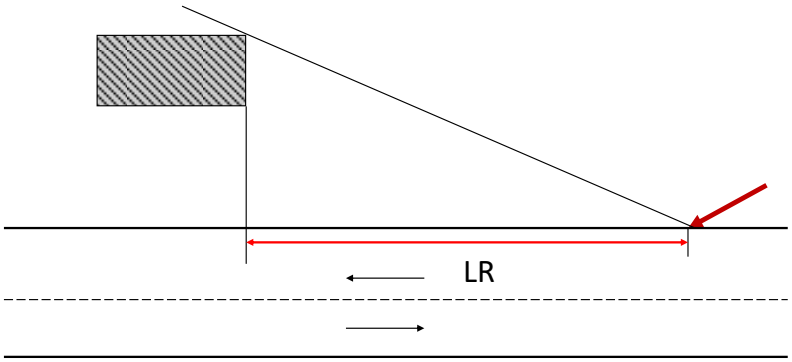
Length of Need – NCDOT

- Calculating the length of need (L) for straight or nearly straight sections of roadway for parallel installation:

$$L = \frac{LH - N}{LH/LR}$$

NCDOT Session 6 6-66

Step 2: Define the Point of Departure



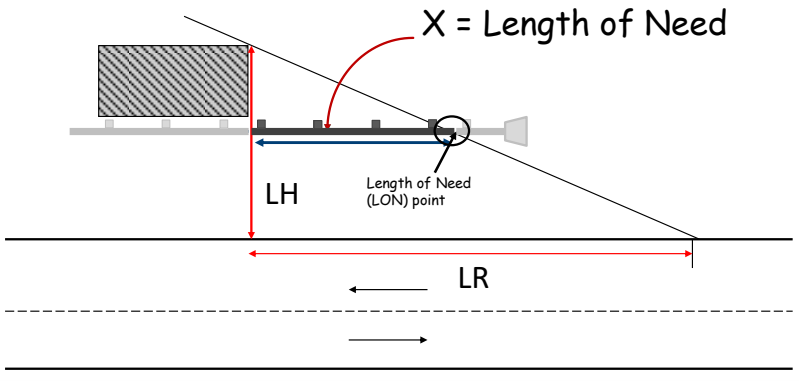
Look up LR:

Design Speed 70 mph
AADT = 53,000

Design Speed (mph)	Runout Length (L_R) Given Traffic Volume (ADT) (ft)			
	Over 10,000	5,000 to 10,000	1,000 to 5,000	Under 1,000
80	470	430	380	330
70	360	330	290	250
60	300	250	210	200
50	230	190	160	150
40	160	**LR = 360 ft.**	110	100
30	110	90	80	70

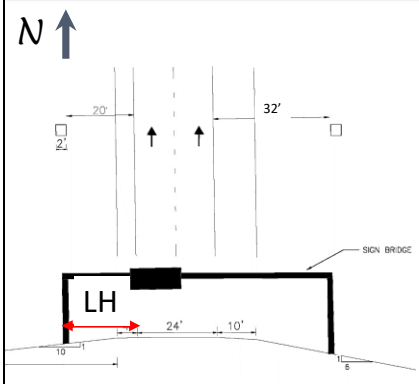
AASHTO Runout Lengths – LR

Step 3: Intersect the Hypotenuse



NCDOT Session 6 6-69

Example – LON



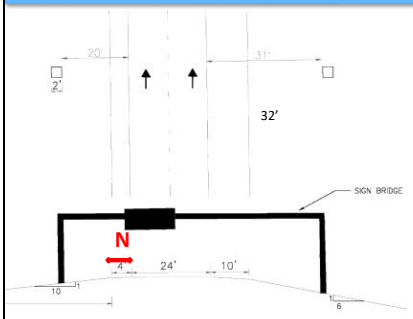
Determine LH – distance to the backside of hazard

For the back of the sign support:

LH = 20 + 2 = 22'

NCDOT Session 6 6-70

Find N

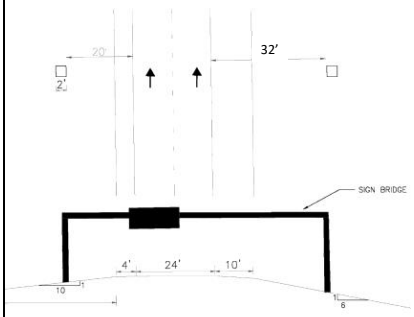


N – Guardrail offset from edge of travel lane.

N = 6 ft.

N = The distance from the edge of the travel lane to the face of the guardrail.
N = Minimum shoulder width for locals and collectors.
N = Usable shoulder width plus 2' for arterials, interstates and freeways.

Calculate LON – Determine Bid Item



LH = 22 ft N = 6 ft LR = 360

Using the formula L =

$$L = \frac{LH - N}{LH/LR}$$

$$= \frac{22 - 6}{22/360}$$

= 262 ft.

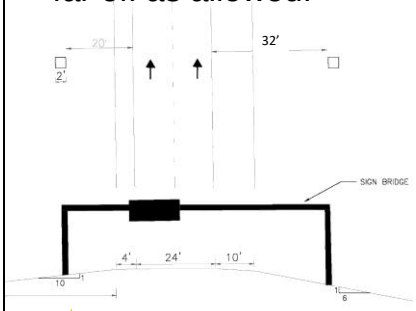
Does **NOT** include Terminal: GREU (50±')

Add 2' for length of hazard; add 25' for CAT-1 effectiveness; convert to panel lengths by dividing by 12.5, rounding up to whole number, and multiplying by 12.5

A CAT-1 must be added

Calculate LON – Additional Offset

If guardrail is placed as far off as allowed:



LH = 22 ft N = (20'-5.5') =14.5' LR = 360'

Using the formula L =

$$L = \frac{LH - N}{LH/LR}$$

$$= \frac{22 - 14.5}{22/360}$$

$$= 123 \text{ ft.}$$

A CAT-1 must be added

★★ BIG savings by offsetting the barrier: 123' VS 262' ★★

Example – LON

TALKING POINTS

What if the situation were a dual bridge? Normal design sets L_A to L_C, in this case 32'; but if the designer chose to shield the ENTIRE opening, L_A would be 64'(to the opposite bridge rail).

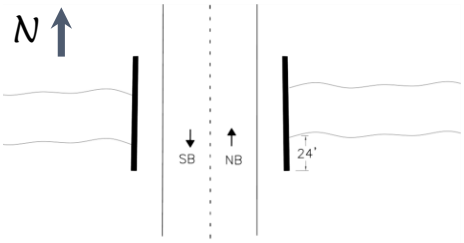
How much more barrier would that require?

Placing the barrier at the 6' offset and parallel, the two lengths are:

For L_A = 32' (and L_2 = 6'), L = 293'

For L_A = 64' (and L_2 = 6'), L = 326'

Design Workshop #2: LON for Bridge on Rural Road

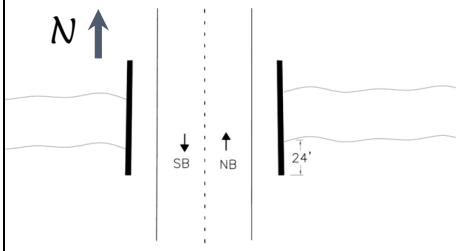


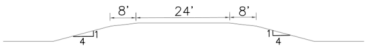
Design for both sides of road, NB

Bridge on Rural Road with Two-way Traffic

Design Speed 60 mph
AADT 2,250
Lane width: 12 ft.
Shoulder width: 8 ft.
Side slope: 4:1

Design Workshop #2: LON for Bridge on Rural Road





Determine Design Clear Zone

The Clear Zone is a look up value from NCDOT Design Manual

Design speed: 60 mph
AADT: 1250
Side slope: 4:1

Design Clear Zone Distance – Fill

Design Speed (mph)	Design ADT	Foreslopes		
		1V:6H or flatter	1V:5H to 1V:4H	1V:3H
40 mph	UNDER 750	7-10	7-10	b
	750-1500	10-12	12-14	b
	1500-6000	12-14	14-16	b
	OVER 6000	14-16	16-18	b
45-50 mph	UNDER 750	10-12	12-14	b
	750-1500	14-16	16-20	b
	1500-6000	16-18	20-26	b
	OVER 6000	20-22	24-28	b
55 mph	UNDER 750	12-14	14-18	b
	750-1500	16-18	20-24	b
	1500-6000	20-22	24-30	b
	OVER 6000	22-24	26-32[a]	b
60 mph	UNDER 750	16-18	20-24	b
	750-1500	20-24	[illegible]	b
	1500-6000	26-30	32-40[a]	b
	OVER 6000	30-32[a]	[illegible]	b
65-70 mph	UNDER 750	18-20	20-26	b
	750-1500	24-26	28-36[a]	b
	1500-6000	28-32[a]	34-42[a]	b
	OVER 6000	30-34[a]	38-46[a]	b

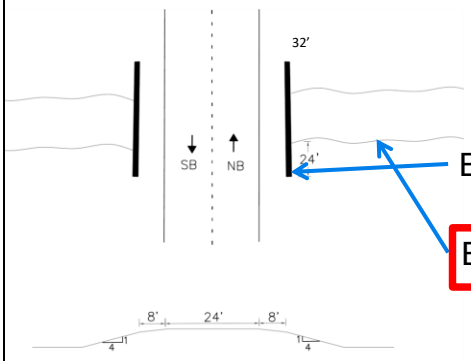
Design Speed 60 mph
AADT = 2250

LC = 32 ft.

For Both Sides

NCDOT Session 6 6-77

Example #2: LON for Bridge on Rural Road Near Side



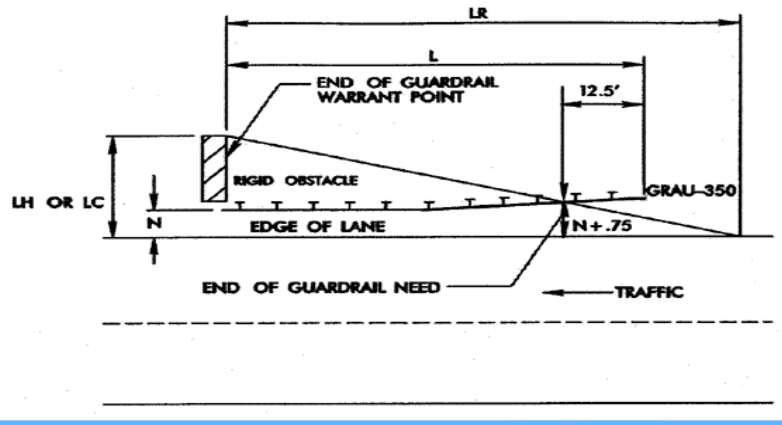
Identify ALL the hazards

End of the Bridge Parapet

Bank of the River

NCDOT Session 6 6-78

Calculating the Length of Need (L)

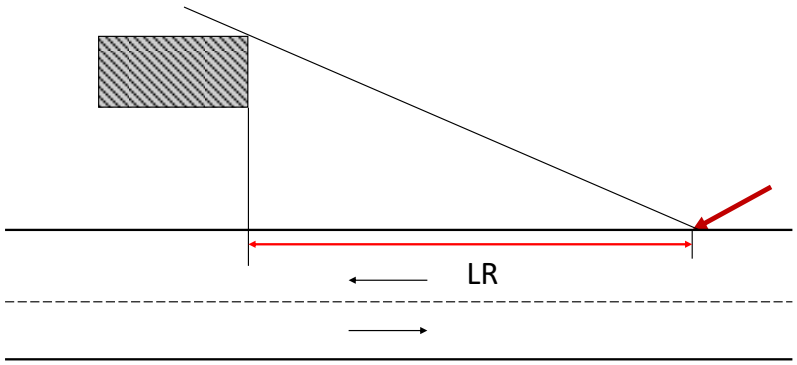


Length of Need – NCDOT

- Calculating the length of need (L) for straight or nearly straight sections of roadway for parallel installation:

$$L = \frac{LH - N}{LH/LR}$$

Step 2: Define the Point of Departure



NCDOT Session 6 6-81

Look up L_R:

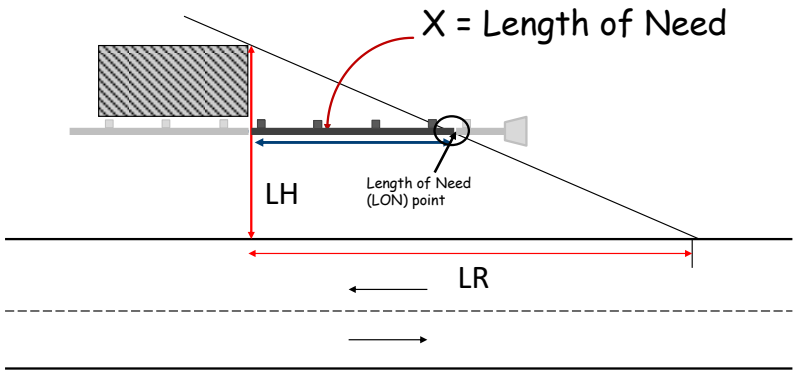
Design Speed 70 mph
AADT = 53,000

Design Speed (mph)	Runout Length (L_R) Given Traffic Volume (ADT) (ft)			
	Over 10,000	5,000 to 10,000	1,000 to 5,000	Under 1,000
80	470	430	380	330
70	360	330	290	250
60	300	250	210	200
50	230	190	160	150
40	160	**LR = 210 ft.**	110	100
30	110	90	80	70

AASHTO Runout Lengths – L_R

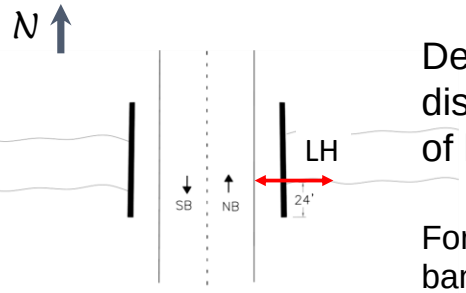
NCDOT Session 6 6-82

Step 3: Intersect the Hypotenuse



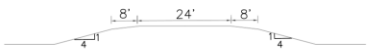
NCDOT Session 6 6-83

Example #2: LON for Bridge on Rural Road Near Side



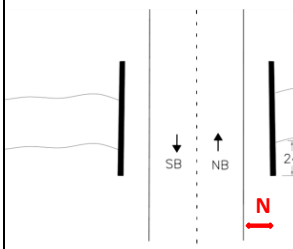
Determine LH – distance to the backside of hazard

For controlling hazard (the bank), LH = LC = 32'



NCDOT Session 6 6-84

Find N



N – Guardrail offset from edge of travel lane.

N = 8 ft.

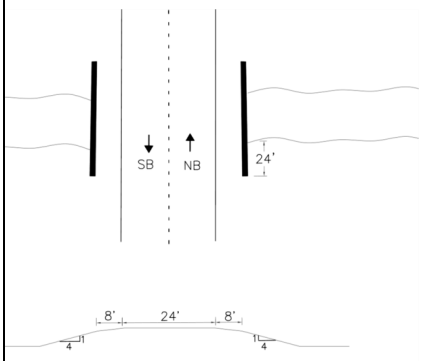
"N" WIDTH FOR LOCALS AND COLLECTORS				
ADT	DESIGN YEAR			
	UNDER 400	400-1500	1501-2000	OVER 2000
LOCALS AND COLLECTORS	2'	5'	6'	8'

N = The distance from the edge of the travel lane to the face of the guardrail.

N = Minimum shoulder width for locals and collectors.

N = Usable shoulder width plus 2' for arterials, interstates and freeways.

Calculate LON – Determine Bid Item
Near Side



LH = 32 ft N = 8 ft LR = 210

Using the formula L =

$$L = \frac{LH - N}{LH/LR}$$

$$= \frac{32 - 8}{32/210}$$

= 158 ft.

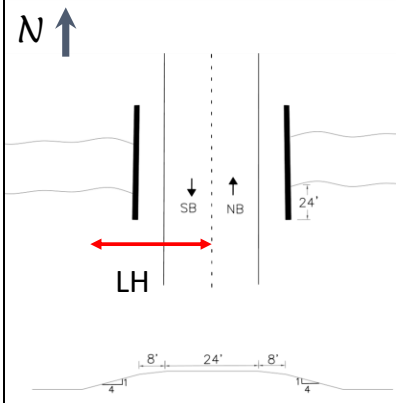
Does **NOT** include Terminal: GREU (50±')

Need a Structure Anchor Unit: 18.75'

24' of Bridge Parapet is Effective Barrier

Therefore 158-19-24 = 115 LF of standard barrier is required; convert to panel lengths by dividing by 12.5, rounding up to whole number, and multiplying by 12.5

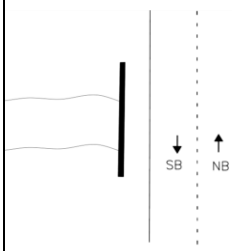
Example #2: LON for Bridge on Rural Road **Far** Side



Determine LH – distance to the backside of hazard **FROM CENTERLINE**

For controlling hazard (the bank), LH = LC = 32'

Find N



N – Guardrail offset from edge of travel lane.

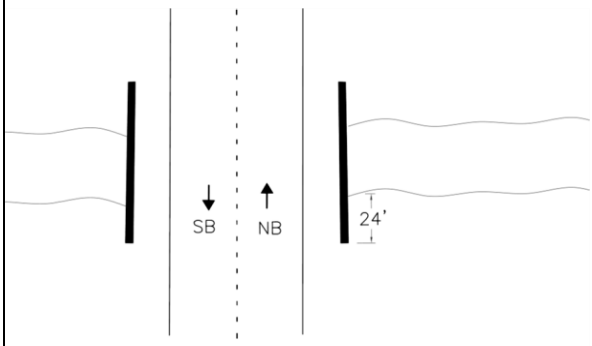
N = ~~8 ft.~~ = 12 + 8 = 20 ft.

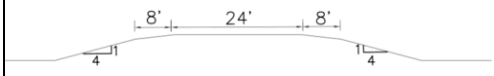
"N" WIDTH FOR LOCALS AND COLLECTORS				
ADT	DESIGN YEAR			
	UNDER 400	400-1500	1501-2000	OVER 2000
LOCALS AND COLLECTORS	2'	5'	6'	8'

N = The distance from the edge of the travel lane to the face of the guardrail.
N = Minimum shoulder width for locals and collectors.
N = Usable shoulder width plus 2' for arterials, interstates and freeways.

Calculate LON – Determine Bid Item

Far Side





LH = 32 ft N = 20 ft LR = 210

Using the formula L =

$$L = \frac{LH - N}{LH/LR}$$

$$= \frac{32 - 20}{32/210}$$

$$= 79 \text{ ft.}$$

Does NOT include Terminal: GREU (50±')

Need a Structure Anchor Unit: 18.75'

24' of Bridge Parapet is Effective Barrier

Therefore 79-24-19 = 36 LF of standard barrier is required (If L had been less than 43', one panel would be needed between the GREU and the structural Anchor Unit.)

Review Learning Outcomes

- Define the Length of Need and apply the design principles for an optimal installation
- Modify guardrail for special situations