North Carolina Department of Transportation

# Highway Safety Barrier Installation 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 provide installers, inspectors and maintenance personnel with the information needed to install, inspect or maintain barriers so as to maximize the probability of optimal barrier installations. Specifically, participants should have a better understanding of the following:

- Be knowledgeable of the principles behind good barrier performance
- Identify possible deficiencies in new barrier designs or existing installations.
- Avoid common errors in barrier and terminal installations to optimize crash performance (and reduce liability).
- Some maintenance considerations

## *Target Audience*

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

## *Course Contents*

This course consists of six sessions (listed below).

**Session 1:** Roadside Safety Problem, Clear Zone and Warrants for Barrier – Brief description of the run-off road (ROR) problem in North Carolina, short discussion of the Clear Zone concept, and the challenge of determining when barrier is needed.

**Session 2:** Testing Requirements and Performance Characteristics of Common Barrier Systems – Outlines how selected safety barriers are tested and function under controlled crash tests.

**Session 3:** 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 4:** Guardrail Design, Length of Need and Site-specific Conditions – Provides guidance for selecting the barrier type and creating an optimal design based on the five design principles, a quick field check of Length of Need, and some site-specific special designs.

**Session 5:** Guardrail/End Treatment Installation and Common Errors – Illustrate proper barrier installation and show some common installation errors.

**Session 6:** Maintenance of Systems – Discuss various damage scenarios and their effect on barrier functionality.

# Resources

### NCDOT Guardrail Committee Members Contact Information

| | | | |
|---|---|---|---|
| Vickie Davis | Area Construction Engineer – Division 9 | vdavis@ncdot.gov | (704) 202-0945 |
| Thad Duncan | Division Project Engineer – Division 12 | tfduncan@ncdot.gov | (980) 552-4227 |
| Sam Eddy | Eastern Wake County Maintenance Engineer | sceddy@ncdot.gov | (919) 340-1230 |
| Bucky Galloway | Western Regional Safety Engineer – Division 10-14 | ddgalloway@ncdot.gov | (828) 650-2700 |
| David Harris | State Roadside Environmental Engineer | davidharris@ncdot.gov | (919) 707-2925 |
| Joel Howerton (chair) | State Plans and Standards Engineer | jhowerton@ncdot.gov | (919) 707-6950 |
| Joshua Kellen | State Maintenance Operations – Training and Development | jlkellen@ncdot.gov | (919) 835-8491 |
| Roger Kluckman | Specialty Functions and Support Services Lead | rkluchman@ncdot.gov | (919) 707-6233 |
| Bobby Norris | District Engineer – District 2, Division 7 | bnorris@ncdot.gov | (336) 487-0100 |
| Charles Reinhardt | Division Maintenance Engineer – Division 11 | creinhardt@ncdot.gov | (336) 903-9121 |
| John Rhyne | Division Maintenance Engineer – Division 9 | jprhyne@ncdot.gov | (336) 747-7800 |
| Shawn Troy | Traffic Safety Systems Engineer | stroy@ncdot.gov | (919) 814-4964 |
| Ken Thornewell | Central Work Zone Traffic Control Engineer | kcthornewell@ncdot.gov | (919) 814-5037 |
| Aaron Williams (FHWA) | Western Transportation Engineer | aaron.williams@dot.gov | (919) 747-7024 |

**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 redirected 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."

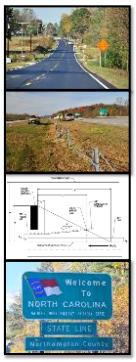
**Working Width**—The distance between the traffic face of the test article before the impact and the maximum lateral position of any major part of the system or vehicle after the impact.

**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: Roadside Safety Problem, Clear Zone and Warrants for Barrier



North Carolina Department of Transportation

**Highway Safety Barrier Installation Training**

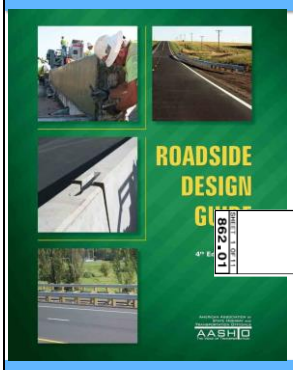
Instructor: Bill Fitzgerald, PE
KLS Engineering, LLC
(703) 858 1356

**Virtual Live Training**
**May 18 – 20, 2021**

THE UNIVERSITY OF NORTH CAROLINA HIGHWAY SAFETY RESEARCH CENTER

KLS Engineering

## Guidance Presented




NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
RALEIGH

STANDARD SPECIFICATIONS
FOR
ROADS AND STRUCTURES

ROADWAY STANDARD DRAWING FOR
**GUARDRAIL PLACEMENT**

1-18

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

862.01

**862D0 X**

JANUARY 2018

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

# Objectives of Course

This course will help you to:

- Evaluate if a traffic barrier MAY be the best treatment to use at a specific site.
- Understand the principles of good barrier system design
- Identify installations that may not adequately shield all the significant hazards or secondary hazards.
- Recognize good installations and common errors for barriers and terminals and know how to avoid them.
- Understand when damaged barrier and/or terminal may no longer be functional.

NCDOT Session 1 1-4

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Session 1:
Roadside Safety Problem, Clear Zone and Warrants for Barrier

NCDOT Session 1 1-5

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## Session 1 Learning Outcomes

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

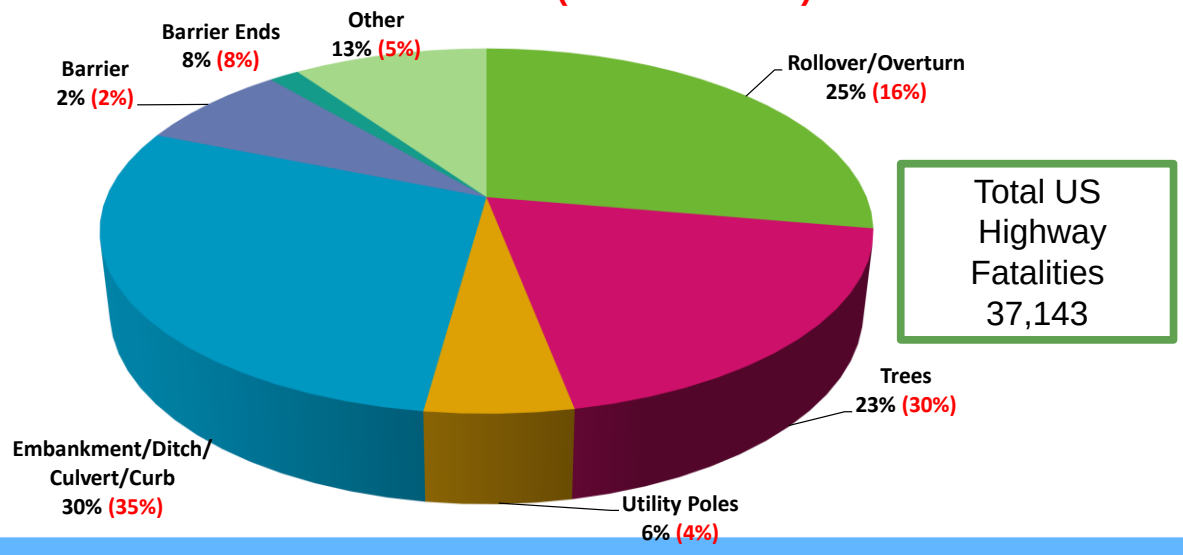
- Describe the primary Roadside Safety Concerns in North Carolina.
- Identify the need for training.
- Define clear zone and barrier warrants.

NCDOT Session 1 1-6

## National Roadway Departure Fatalities

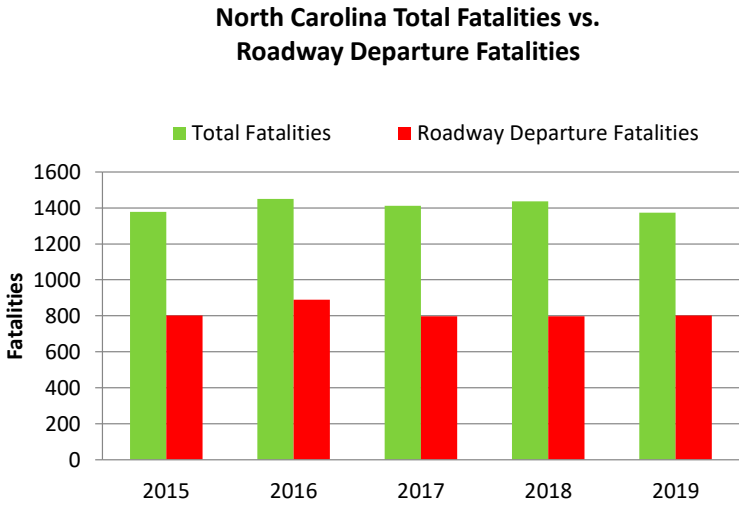
(Single Vehicle Fatal Crashes)

National **(North Carolina)**




NCDOT Session 1 1-7

# North Carolina Crash Data Trend



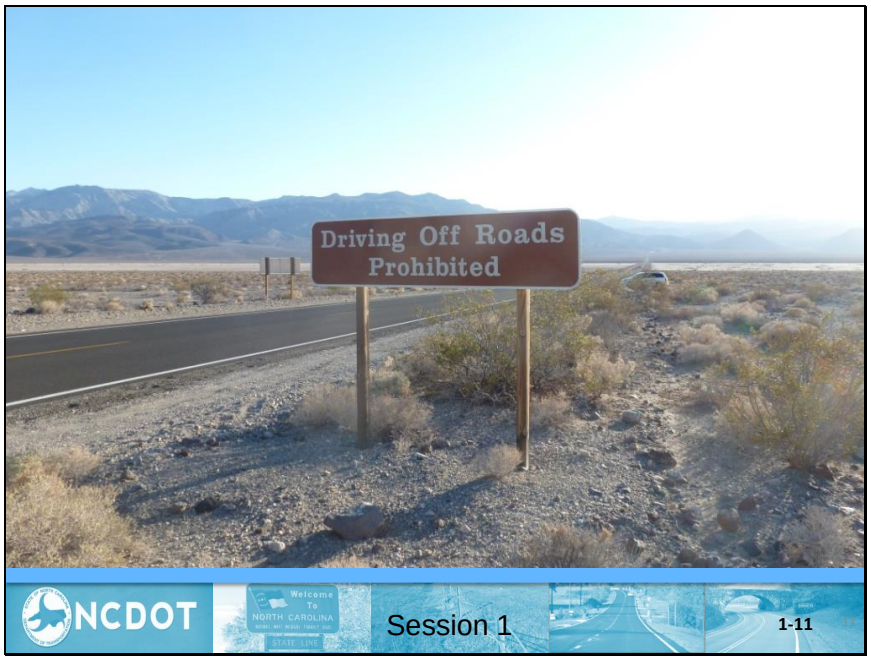

Ref: FARS Data – 2019

NCDOT Session 1 1-8

# Real World Crashes


NCDOT Session 1 1-9


Real World Crashes
NCDOT
Session 1
1-10


Driving Off Roads Prohibited
NCDOT
Session 1
1-11

## Need for Training

Potential consequences of poorly Designed/Installed barrier systems include:

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

NCDOT Session 1 1-12

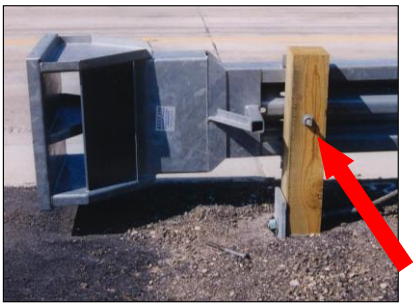
## Need for Training

Must have a strong connection between systems

NCDOT Session 1 1-13

## Need for Training

Examples of improper installation of systems:

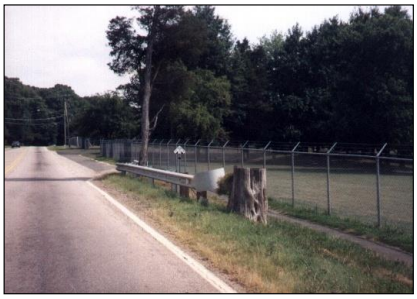


Fatal Flaw

NCDOT Session 1 1-14

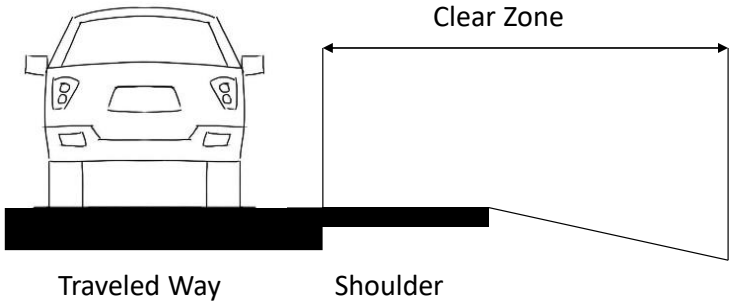
## Need for Training

Examples of improper installation of systems:



NCDOT Session 1 1-15

# 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



# Clear Zone Principle

**Get**

**MAXIMUM,**

**COST-EFFECTIVE**

**width**


As Wide as Practical
Do not compromise available clear zone
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 1
1-18

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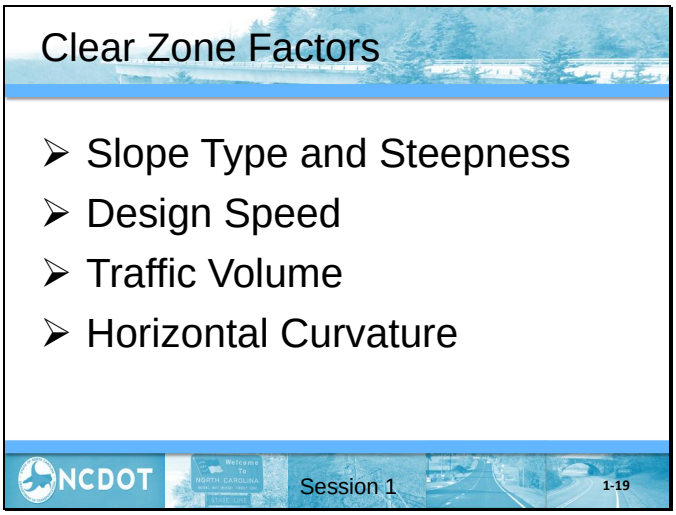
Clear Zone Factors
Slope Type and Steepness
Design Speed
Traffic Volume
Horizontal Curvature
NCDOT
Session 1
1-19

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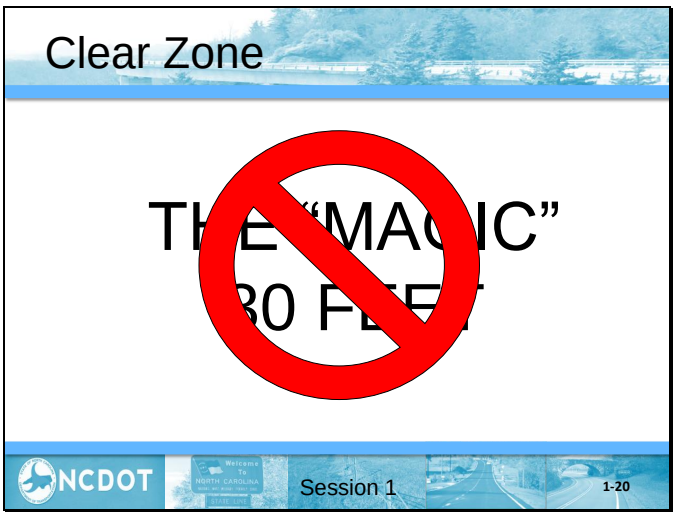



# NCDOT Design Clear Zone Table

| 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

# 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.

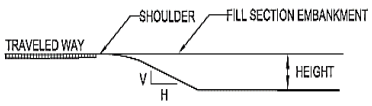
NCDOT Session 1 1-22

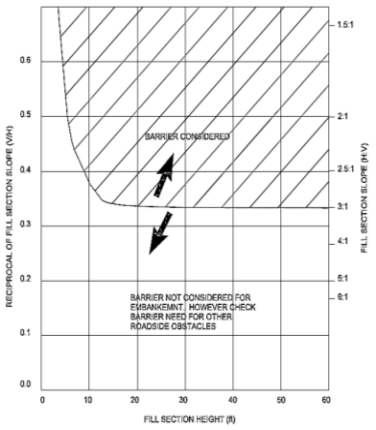
## Potential Hazards

- Bridge Piers / Abutments / Railing Ends
- Drainage Structures / Ditches
- Sign and Luminaire Supports
- Permanent Bodies of Water
- Steep Embankments



## Embankment Guidelines




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


NCDOT
Session 1
1-26

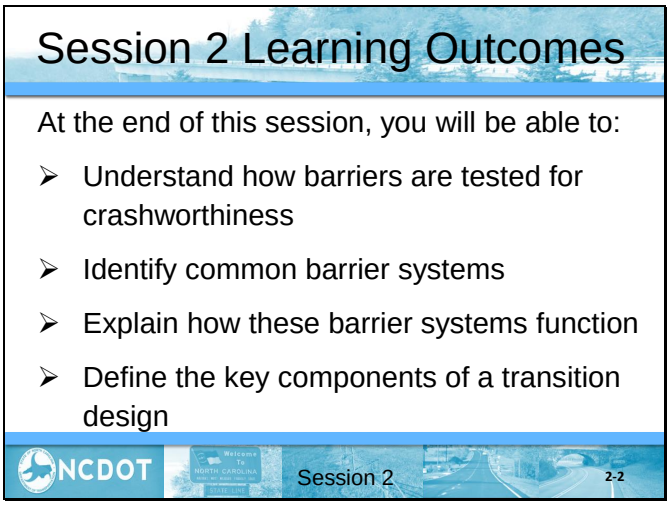

NCDOT
Session 1
1-27


## Review Learning Outcomes

- Describe the primary Roadside Safety Concerns in North Carolina.
- Identify the need for training.
- Define clear zone and barrier warrants.

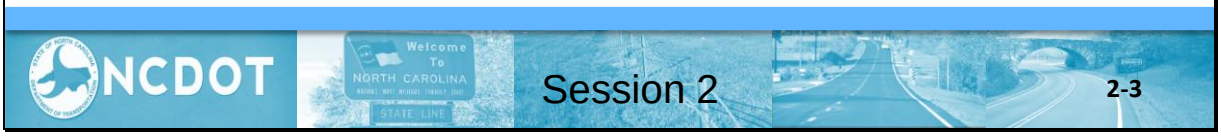
# Session 2: Testing Requirements and Performance Characteristics of Common Barrier Systems


North Carolina Department of Transportation
Highway Safety Barrier Installation Training
Session 2:
Testing Requirements and Performance Characteristics of Common Barrier Systems
NCDOT
Session 2
2-1


Session 2 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 2
2-2

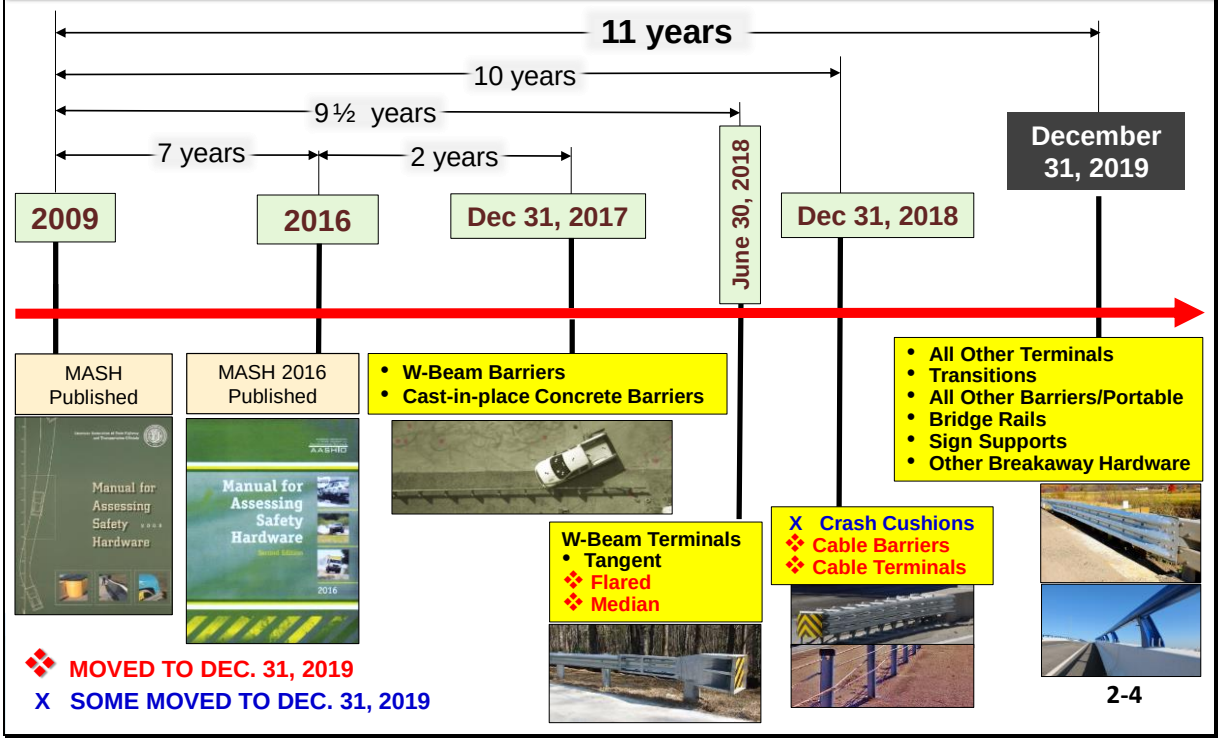
# Crash Testing Guidelines

- 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



# MASH Implementation Timeline

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




# 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 2 2-5

## NCHRP 350 comparison with MASH Crew Cab Truck


NCDOT Session 2 2-6

## 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 2 2-7

## Standard Barrier Systems

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

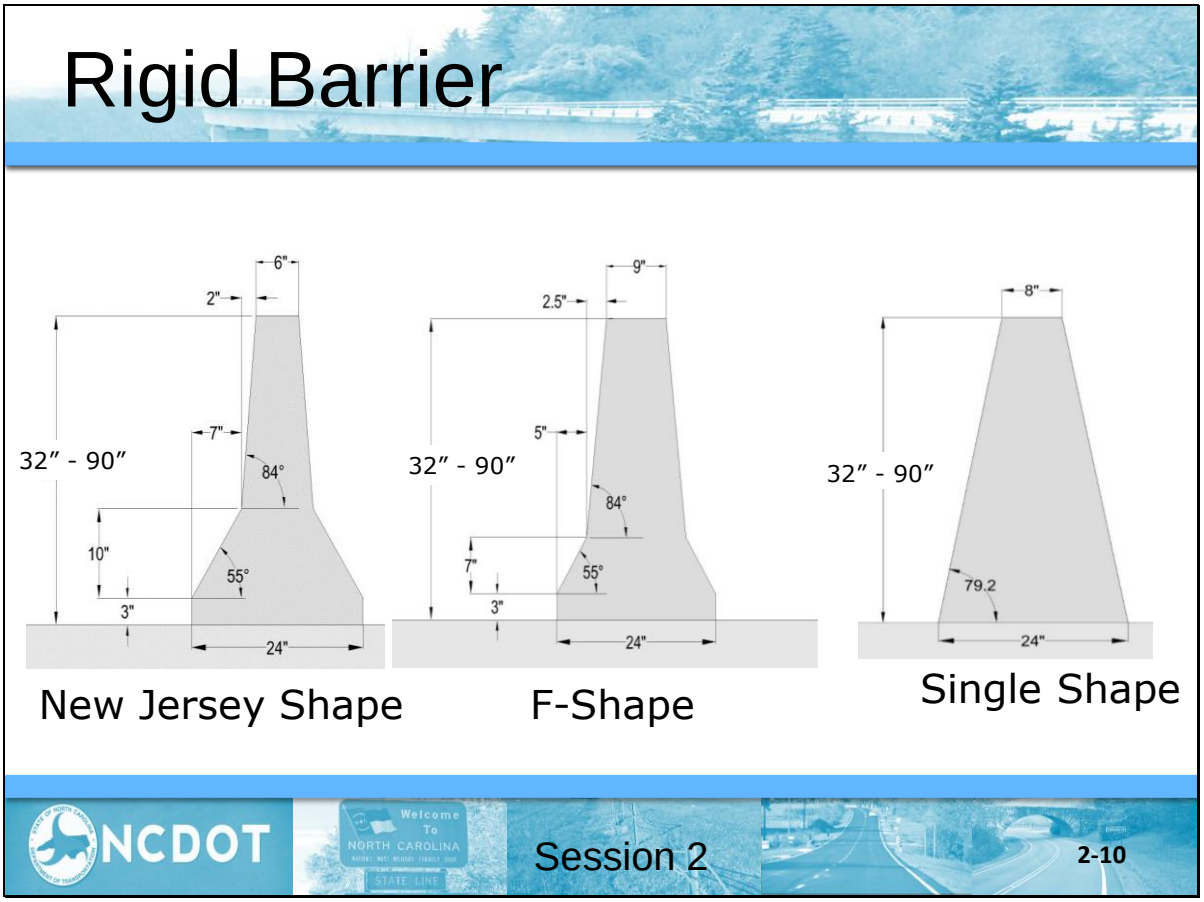


## Barrier Systems: Rigid Barriers

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.

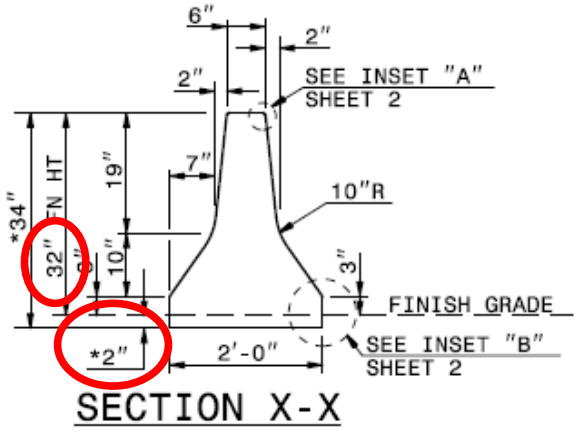
Examples include:

- 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 2
2-10


MASH Testing
of 32" New
Jersey Shaped
Concrete
Barrier
Video Clip

# Rigid Barrier – New Jersey Shape




SECTION X-X

TYPE IV - NO GLARE SCREEN PERMITTED

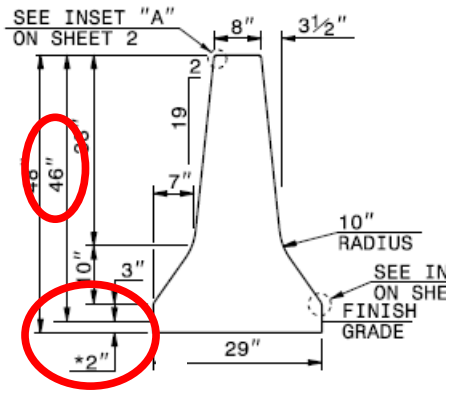
854.01 SHEET 1 OF 4

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.

- Type IV typically used
- Types II & III for bifurcated cross-sections
- 2" min Embedment minimizes Deflection
- When large trucks are not an issue

# Rigid Barrier – New Jersey Shape




2" min Embedment minimizes Deflection

Considered TL- 5

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

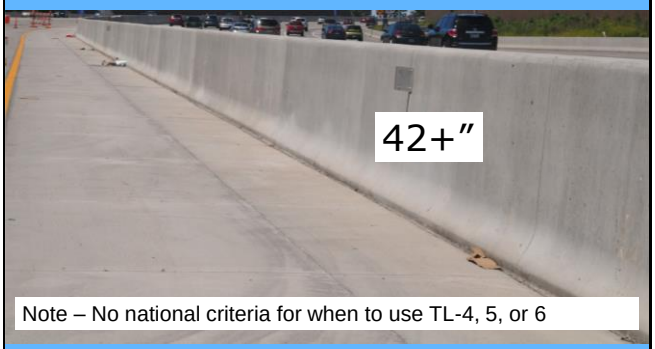
SECTION X-X

**TYPE - T**

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

NCDOT Session 2 2-13

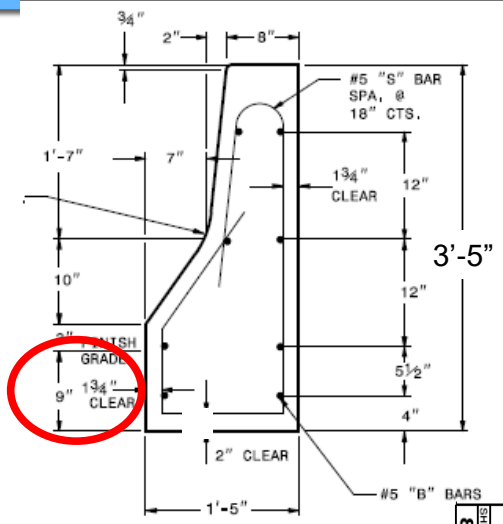
# Rigid Barrier




Note – No national criteria for when to use TL-4, 5, or 6

NCDOT Session 2 2-14

# Rigid Barrier – New Jersey Shape




DETAIL X-X
CROSS SECTIONAL VIEW

9" min Provides Fixity

SHEET 5 OF 8 857.01

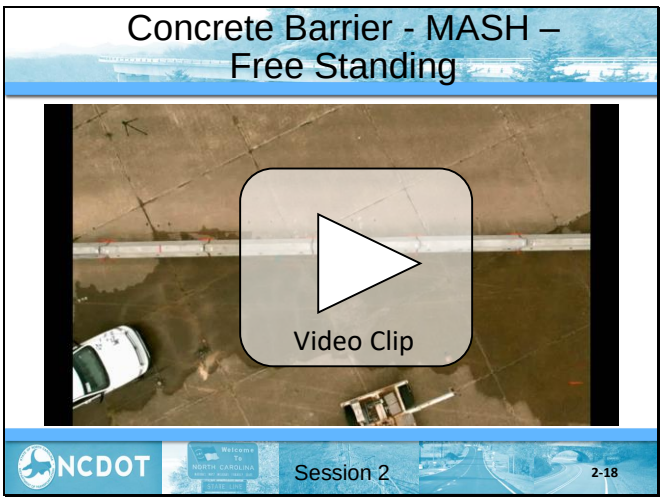
ROADWAY STANDARD DRAWING FOR
**PRECAST REINFORCED CONCRETE BARRIER**
41" SINGLE FACED

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



# Rigid Barrier: TL-5


NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 2
2-17


Concrete Barrier - MASH – Free Standing
Video Clip
NCDOT
Session 2
2-18

# 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 it 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 Blocks: 6" x 8" recycle plastic or composite.

NCDOT Session 2 2-20

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


NCDOT Session 2 2-21

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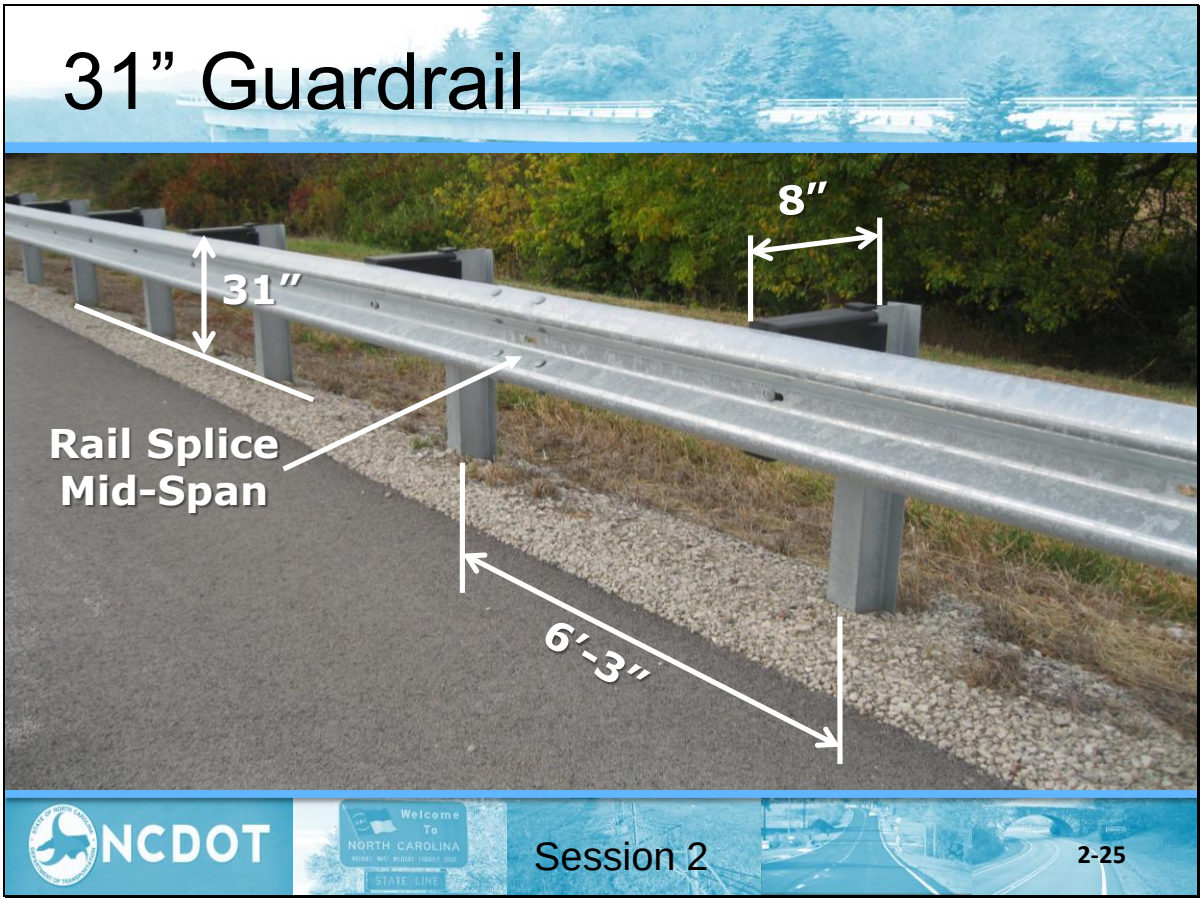
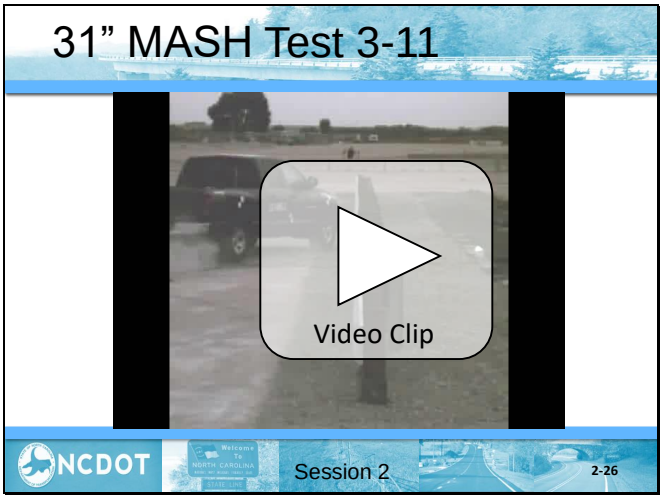
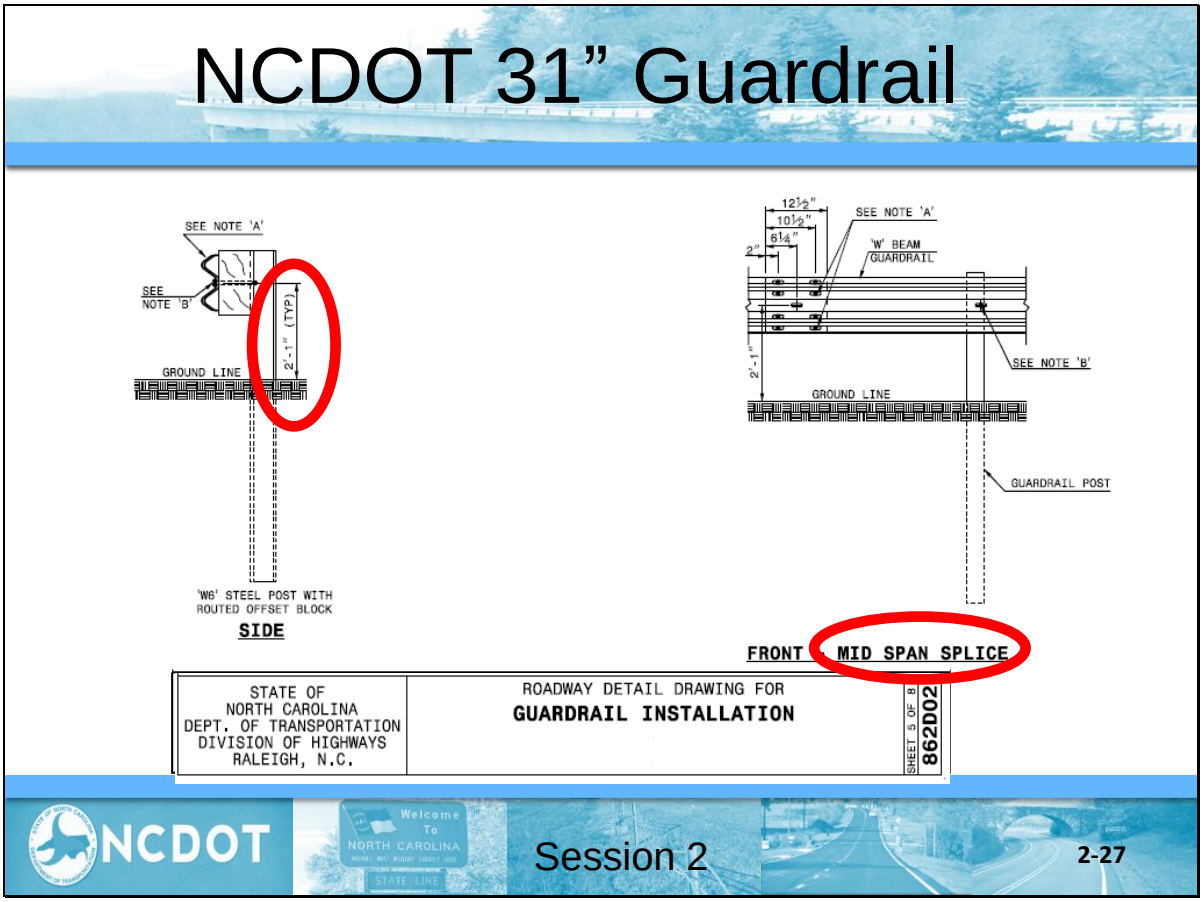
## Barrier Systems: Semi-Rigid

- **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

NCDOT Session 2 2-24


31” Guardrail
8”
31”
Rail Splice
Mid-Span
6’-3”
NCDOT
Session 2
2-25


31” MASH Test 3-11
Video Clip
NCDOT
Session 2
2-26


NCDOT 31” Guardrail
SEE NOTE 'A'
SEE NOTE 'B'
2'-1" (TYP.)
GROUND LINE
'W6' STEEL POST WITH ROUTED OFFSET BLOCK
SIDE
12½"
10½"
6¼"
2"
SEE NOTE 'A'
'W' BEAM GUARDRAIL
SEE NOTE 'B'
2'-1"
GROUND LINE
GUARDRAIL POST
FRONT
MID SPAN SPLICE
STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.
ROADWAY DETAIL DRAWING FOR
GUARDRAIL INSTALLATION
SHEET 5 OF 8
862D02
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 2
2-27

## 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

NCDOT Session 2 2-28

## 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 2 2-29

# Barrier Systems: Flexible Barriers

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

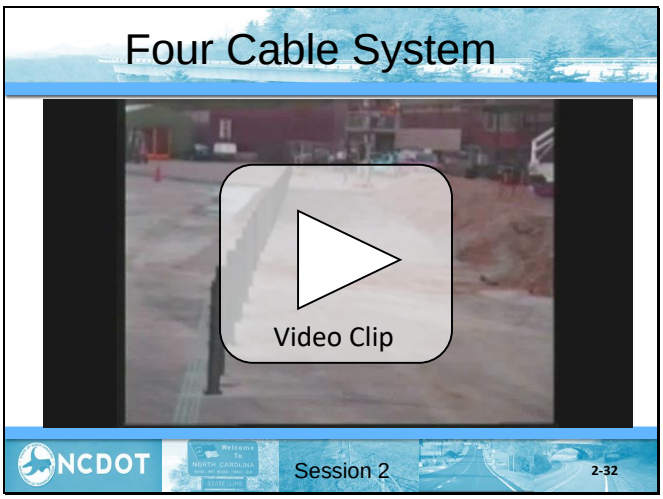


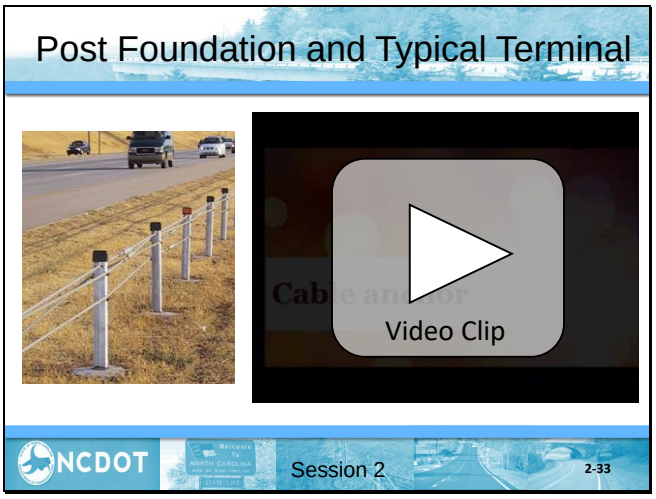
## High-Tension Cable Systems

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

★ = APL

Currently, NO system has passed all MASH 2016 testing


Four Cable System
Video Clip
NCDOT
Session 2
2-32


Post Foundation and Typical Terminal
Video Clip
NCDOT
Session 2
2-33


HTC On 4:1 Slope
Video Clip
Maximum Offset 4'
NCDOT
Session 2
2-34

# 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 2 2-35

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MASH 27” W-Beam Median Barrier Test


NCDOT Session 2 2-36

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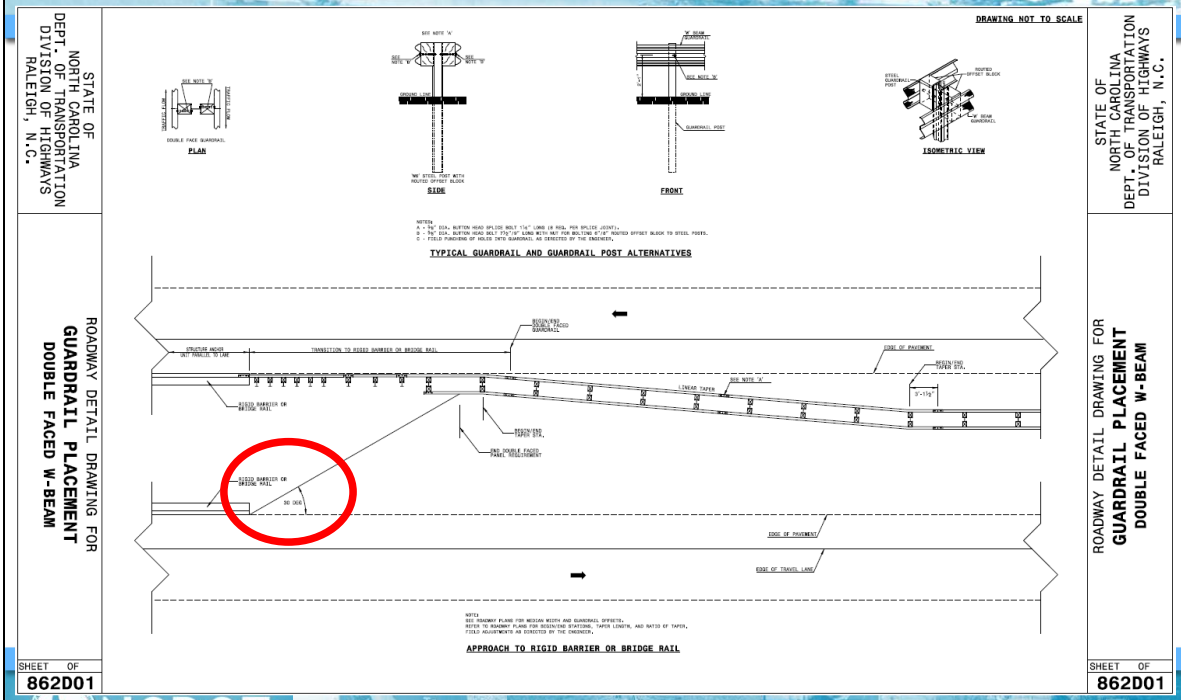
## MASH 31" Median Barrier Test




## MASH 31" Median Barrier



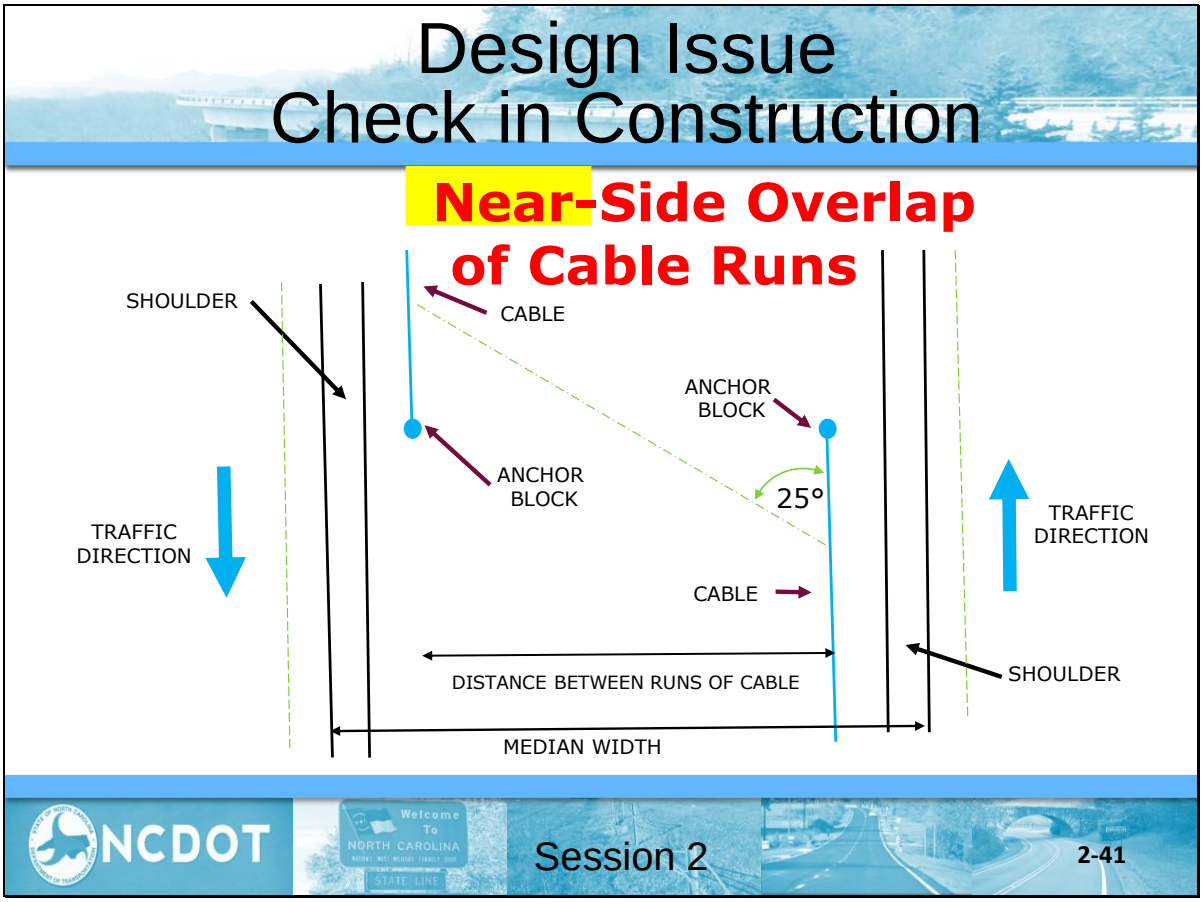
## Flexible Median Barriers

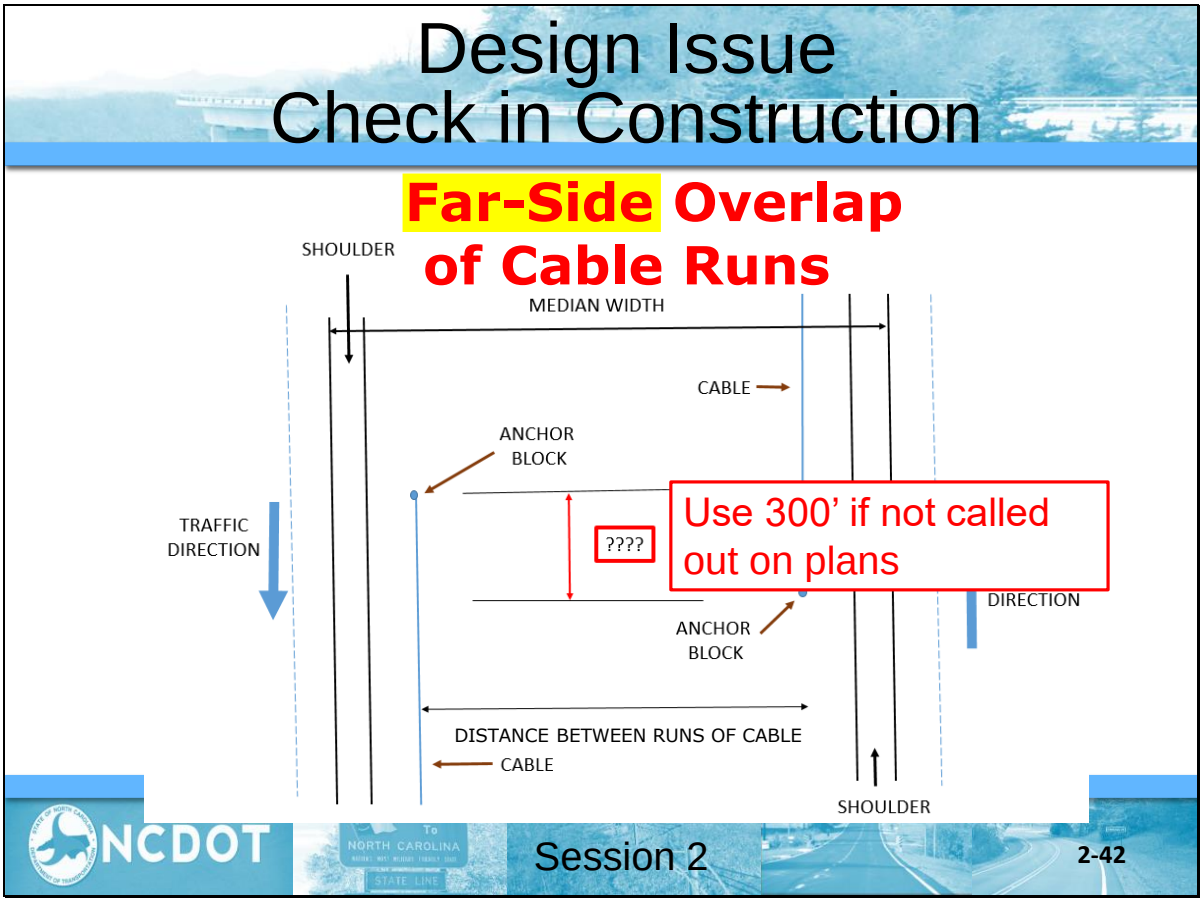
Advantage of high tension cable is it may remain effective after impact.

NCDOT Session 2 2-39

## Flexible Median Barriers

NCDOT Session 2 2-40

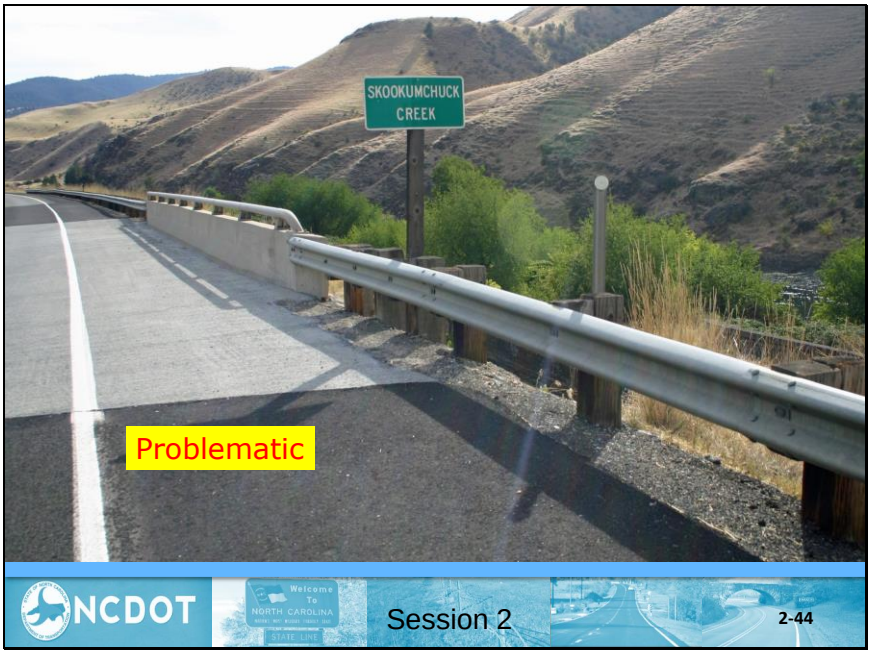

Design Issue
Check in Construction
Near-Side Overlap
of Cable Runs
SHOULDER
CABLE
ANCHOR
BLOCK
ANCHOR
BLOCK
25°
TRAFFIC
DIRECTION
TRAFFIC
DIRECTION
CABLE
DISTANCE BETWEEN RUNS OF CABLE
SHOULDER
MEDIAN WIDTH
NCDOT
Session 2
2-41


Design Issue
Check in Construction
Far-Side Overlap
of Cable Runs
SHOULDER
MEDIAN WIDTH
CABLE
ANCHOR
BLOCK
TRAFFIC
DIRECTION
????
Use 300' if not called
out on plans
DIRECTION
ANCHOR
BLOCK
DISTANCE BETWEEN RUNS OF CABLE
CABLE
SHOULDER
NCDOT
Session 2
2-42

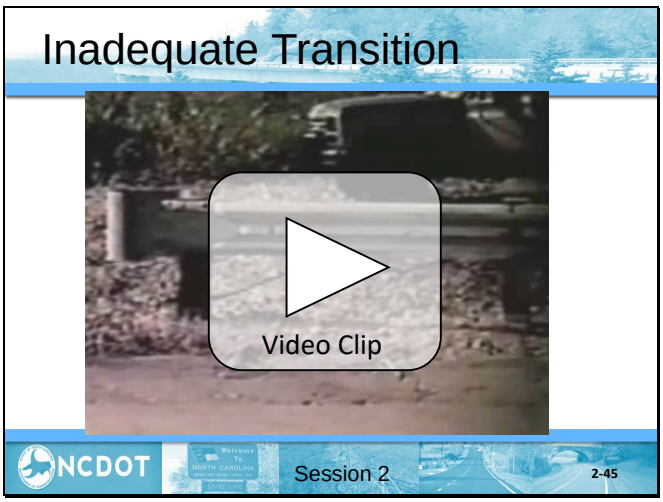
## Transition Sections

- 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 2 2-43




NCDOT Session 2 2-44

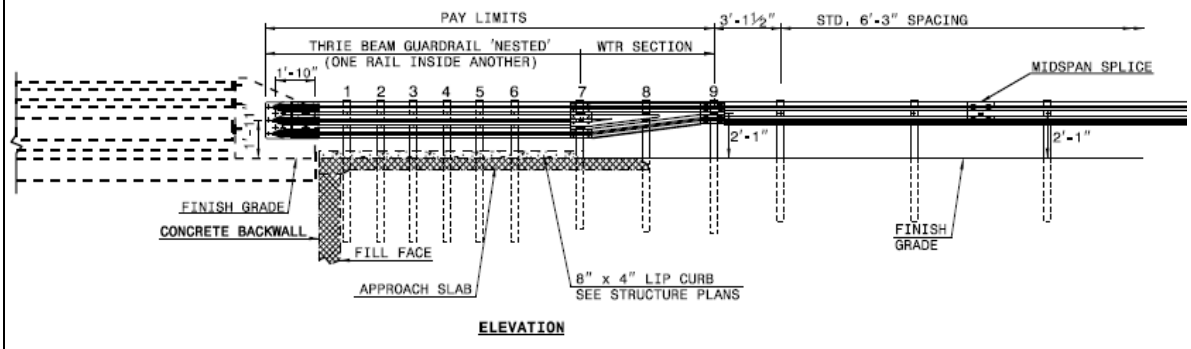



# Transition Sections

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

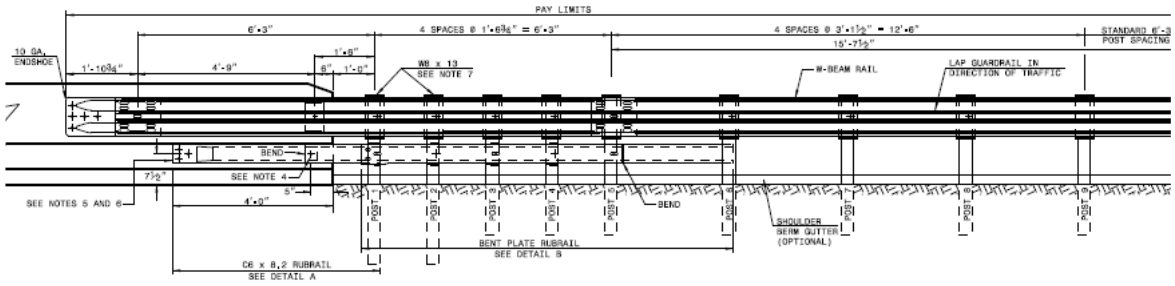



| 862.03 SHEET 1 OF 7 | ROADWAY STANDARD DRAWING FOR<br>**STRUCTURE ANCHOR UNITS**<br>GUARDRAIL ANCHOR UNIT, TYPE III<br>FOR ATTACHMENT TO RAIL ON BRIDGE | 1-18 STATE OF<br>NORTH CAROLINA<br>DEPT. OF TRANSPORTATION<br>DIVISION OF HIGHWAYS<br>RALEIGH, N.C. |
|---|---|---|

NCDOT Session 2 2-47


NCDOT Transition – Previous Standard
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 2
2-48

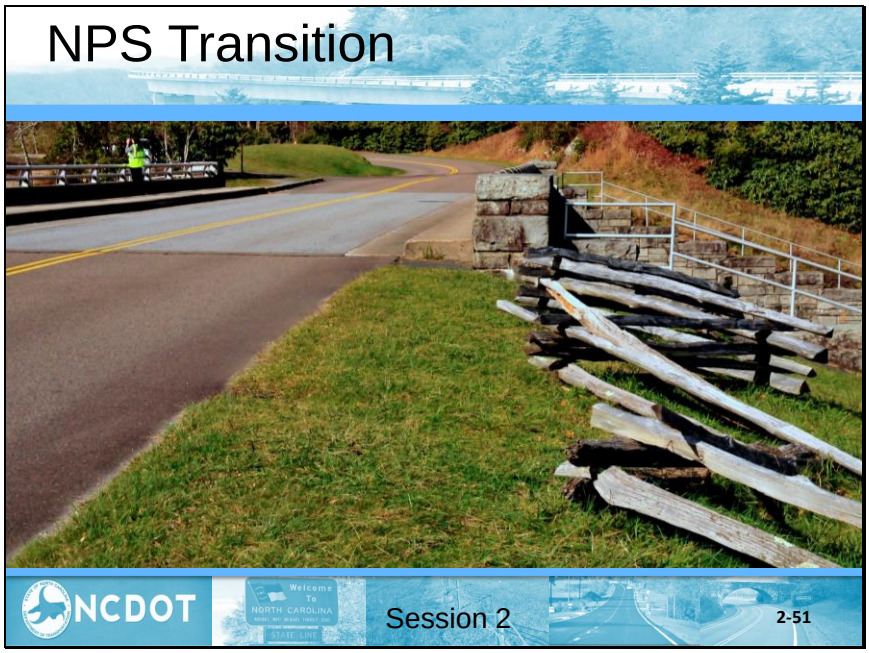
# NCDOT Transition – Direct




**ELEVATION**

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

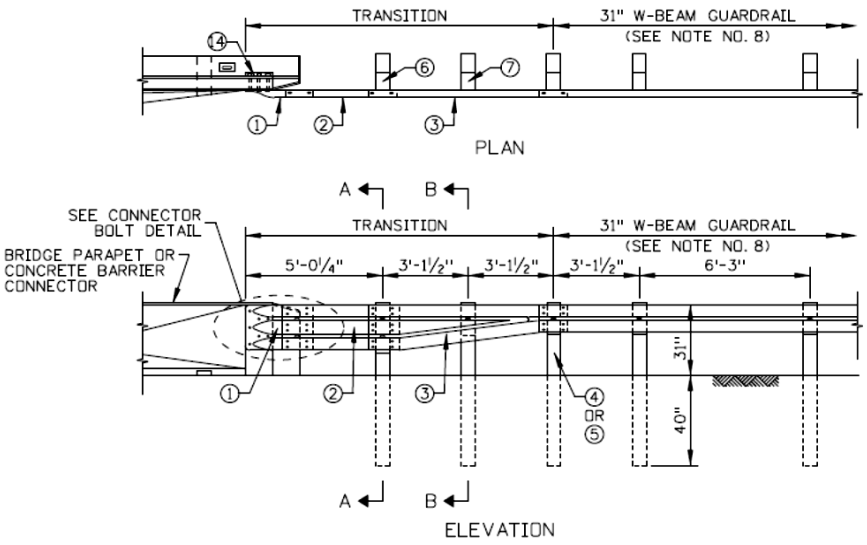

NCDOT Transition – With Curb
NCDOT
Session 2
2-50


NPS Transition
NCDOT
Session 2
2-51

## 31” Transition


NCDOT Session 2 2-52

## Transition – 31”, TL-2




LOW SPEED GUARDRAIL TRANSITION

NCDOT Session 2 2-53

# 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)



## 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

# Session 3: Testing Requirements and Performance Characteristics of End Treatments and Impact Attenuators

North Carolina Department of Transportation

**Highway Safety Barrier Installation Training**

## Session 3:

## Testing Requirements and Performance Characteristics of End Treatments and Impact Attenuators

NCDOT Session 3 3-1

## Session 3 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

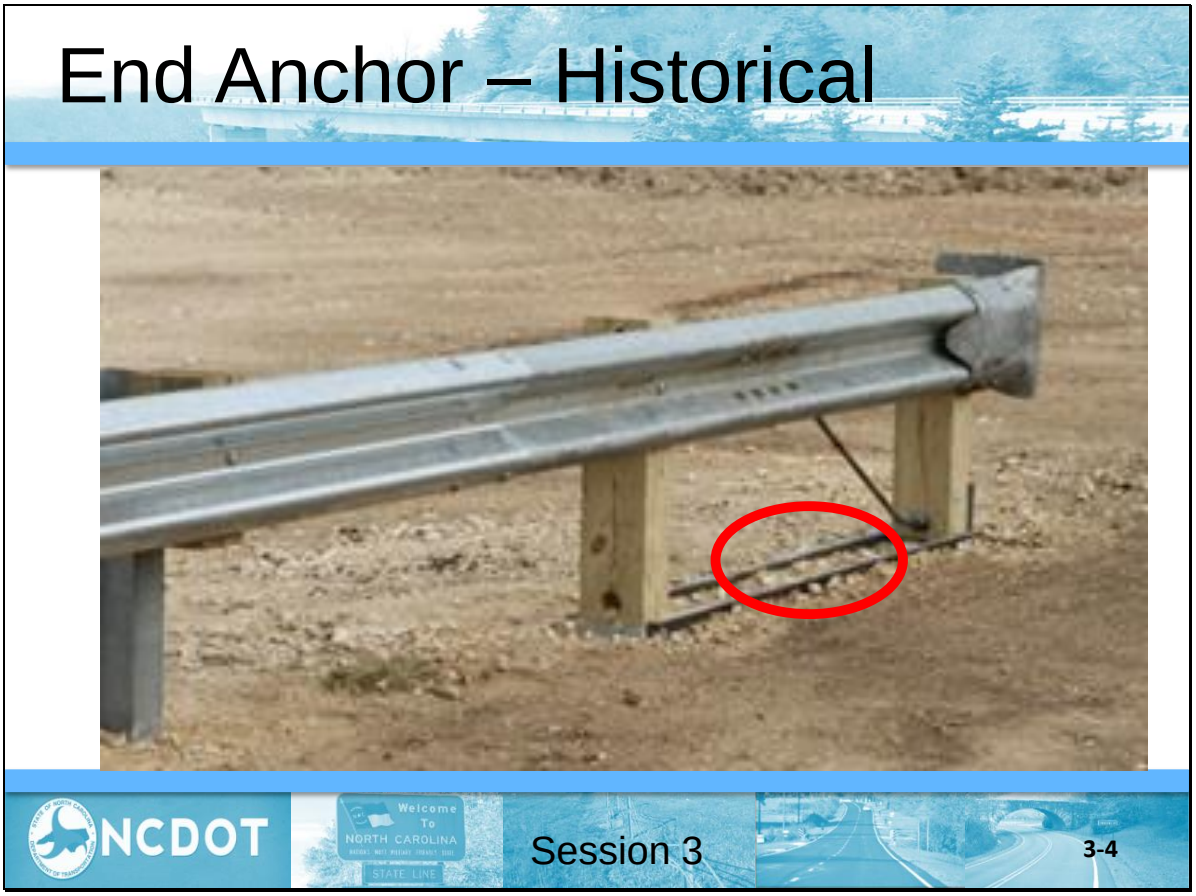
NCDOT Session 3 3-2

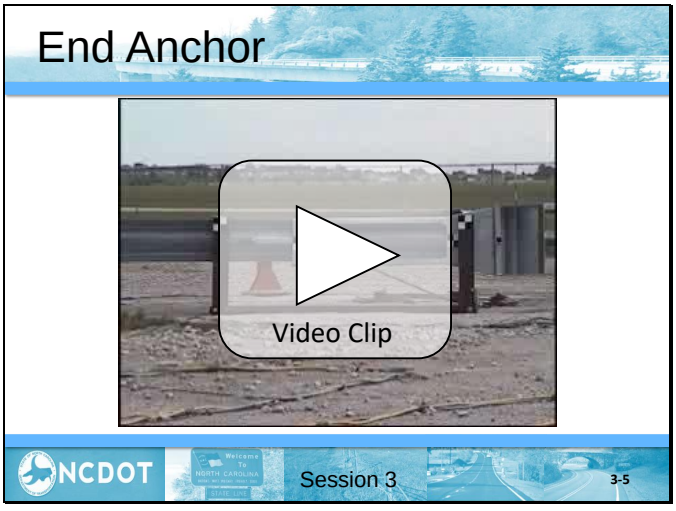
## Guardrail End Treatments

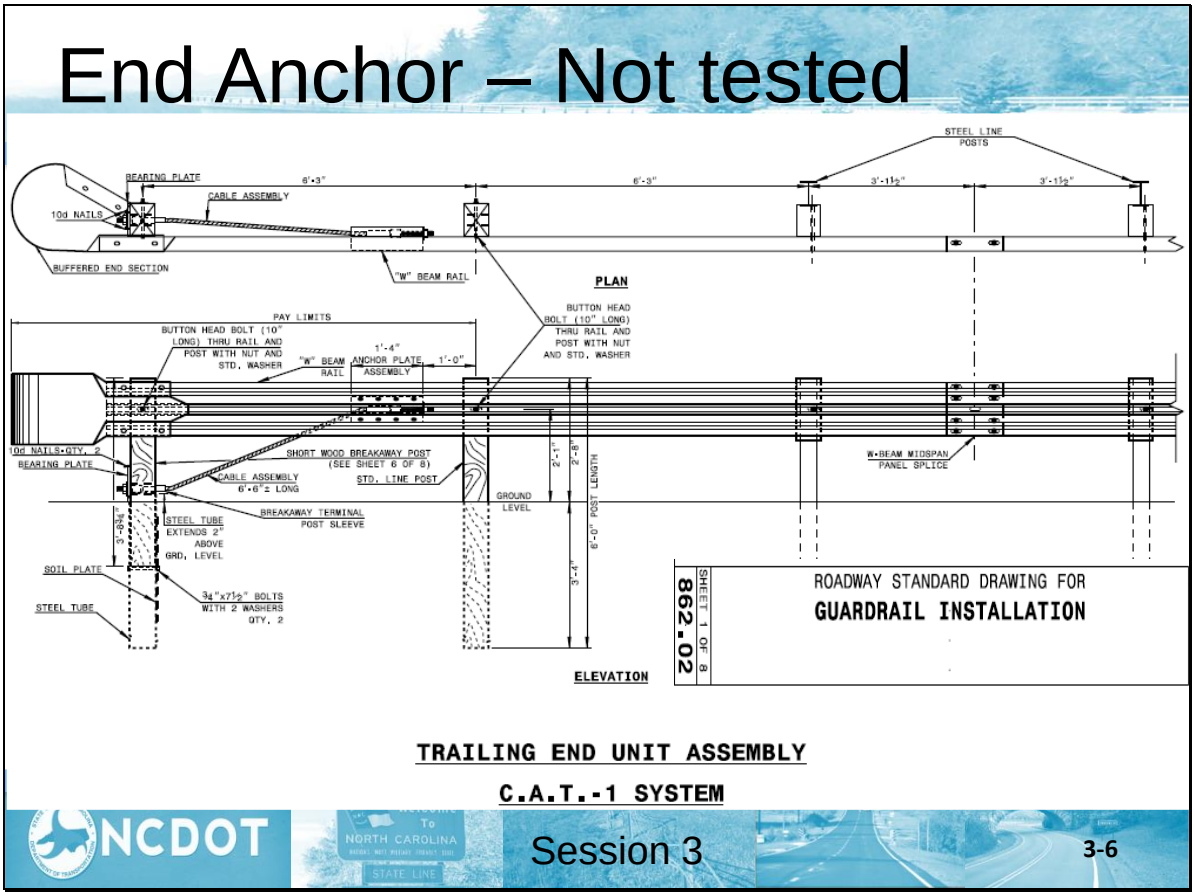
A barrier end treatment must serve two functions:

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

NCDOT Session 3 3-3


End Anchor – Historical
NCDOT
Session 3
3-4


End Anchor
Video Clip
NCDOT
Session 3
3-5


End Anchor – Not tested
STEEL LINE POSTS
BEARING PLATE
CABLE ASSEMBLY
10d NAILS
BUFFERED END SECTION
"W" BEAM RAIL
PLAN
PAY LIMITS
BUTTON HEAD BOLT (10" LONG) THRU RAIL AND POST WITH NUT AND STD. WASHER
"W" BEAM RAIL
ANCHOR PLATE ASSEMBLY
BUTTON HEAD BOLT (10" LONG) THRU RAIL AND POST WITH NUT AND STD. WASHER
10d NAILS-QTY. 2
BEARING PLATE
SHORT WOOD BREAKAWAY POST (SEE SHEET 6 OF 8)
STD. LINE POST
CABLE ASSEMBLY 6'-6"± LONG
BREAKAWAY TERMINAL POST SLEEVE
STEEL TUBE EXTENDS 2" ABOVE GRD. LEVEL
SOIL PLATE
STEEL TUBE
¾"x7½" BOLTS WITH 2 WASHERS QTY. 2
GROUND LEVEL
W-BEAM MIDSPAN PANEL SPLICE
ELEVATION
SHEET 1 OF 8
862.02
ROADWAY STANDARD DRAWING FOR
GUARDRAIL INSTALLATION
TRAILING END UNIT ASSEMBLY
C.A.T.-1 SYSTEM
NCDOT
Session 3
3-6

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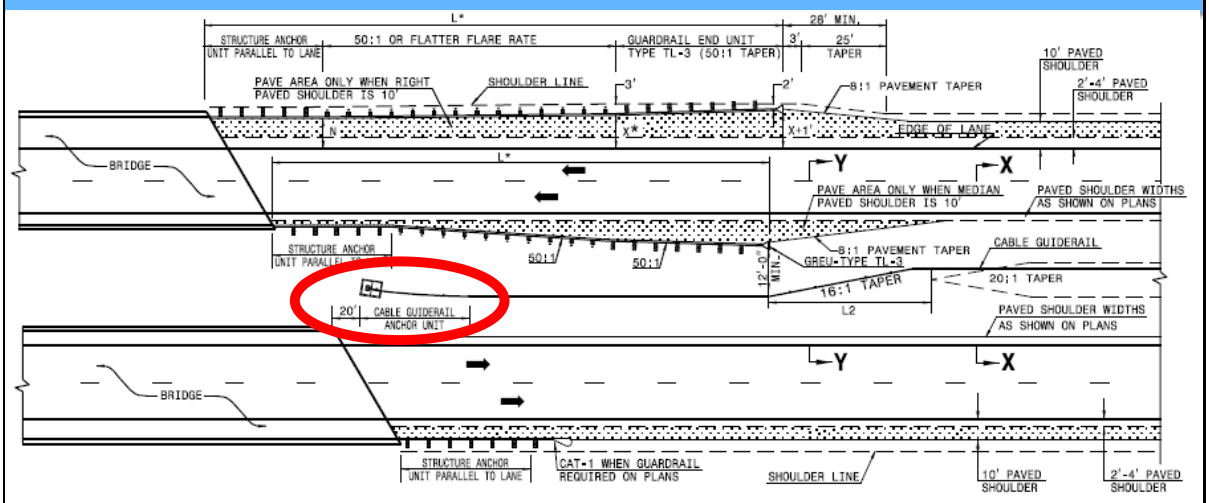
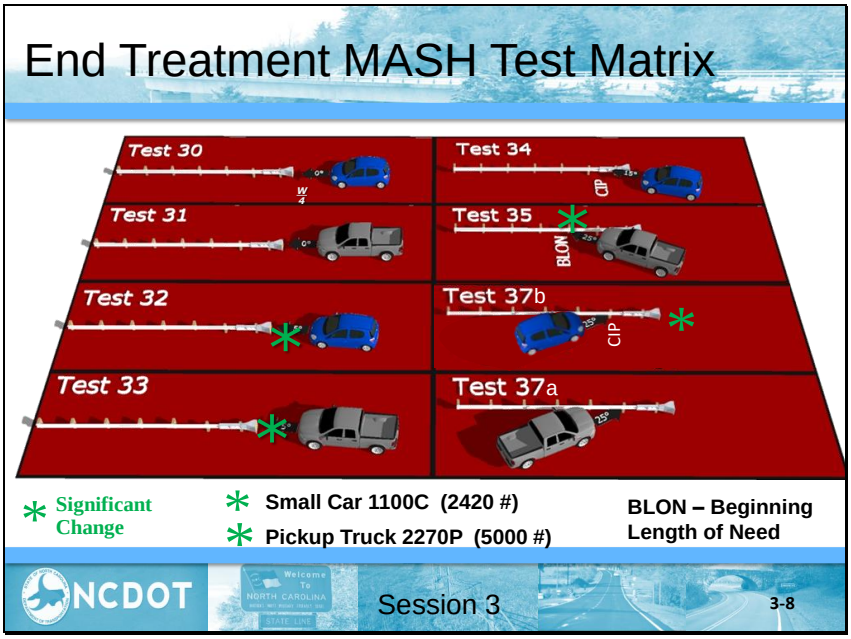
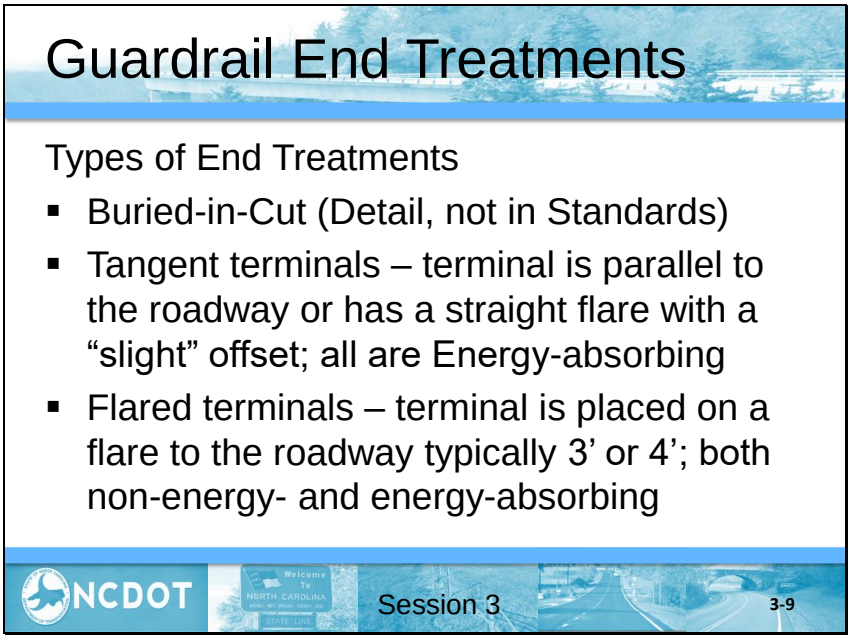
# Cable Guiderail Anchor Unit Placement




NCDOT Session 3 3-7


End Treatment MASH Test Matrix
Test 30
Test 34
Test 31
Test 35
Test 32
Test 37b
Test 33
Test 37a
CIP
BLON
Significant Change
Small Car 1100C (2420 #)
Pickup Truck 2270P (5000 #)
BLON – Beginning Length of Need
NCDOT
Session 3
3-8

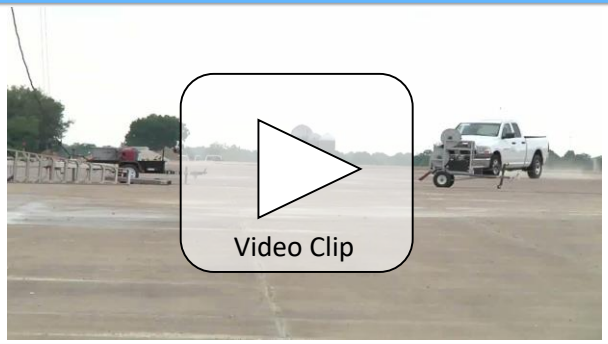

Guardrail End Treatments
Types of End Treatments
Buried-in-Cut (Detail, not in Standards)
Tangent terminals – terminal is parallel to the roadway or has a straight flare with a “slight” offset; all are Energy-absorbing
Flared terminals – terminal is placed on a flare to the roadway typically 3’ or 4’; both non-energy- and energy-absorbing
NCDOT
Session 3
3-9

# 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

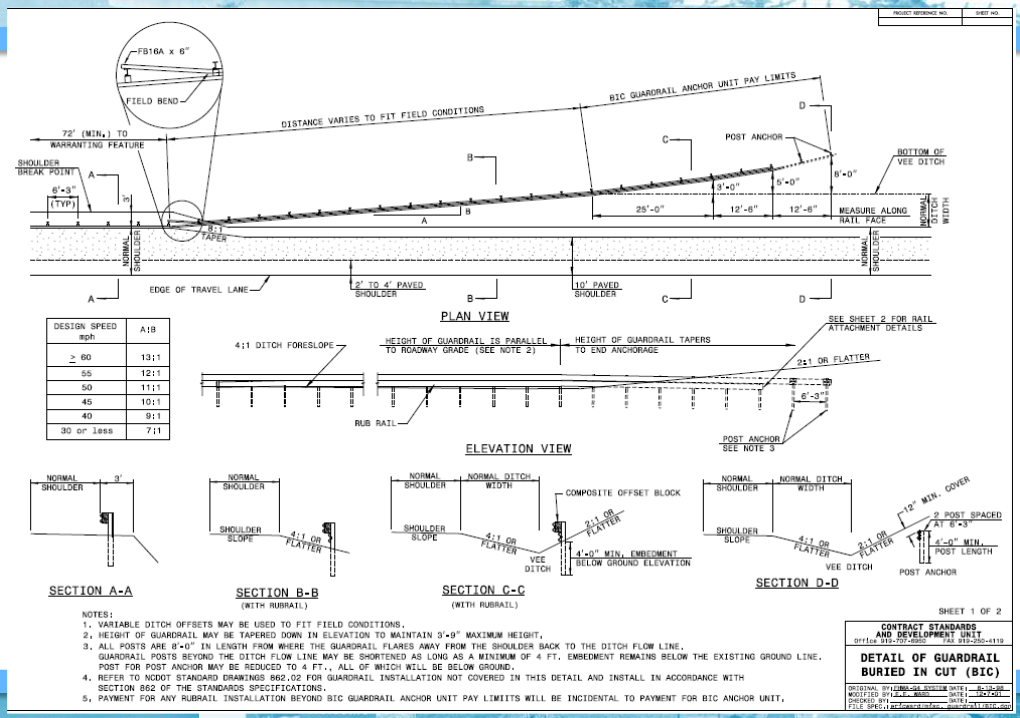
NCDOT Session 3 3-10

MASH
Buried in Cut End Treatment

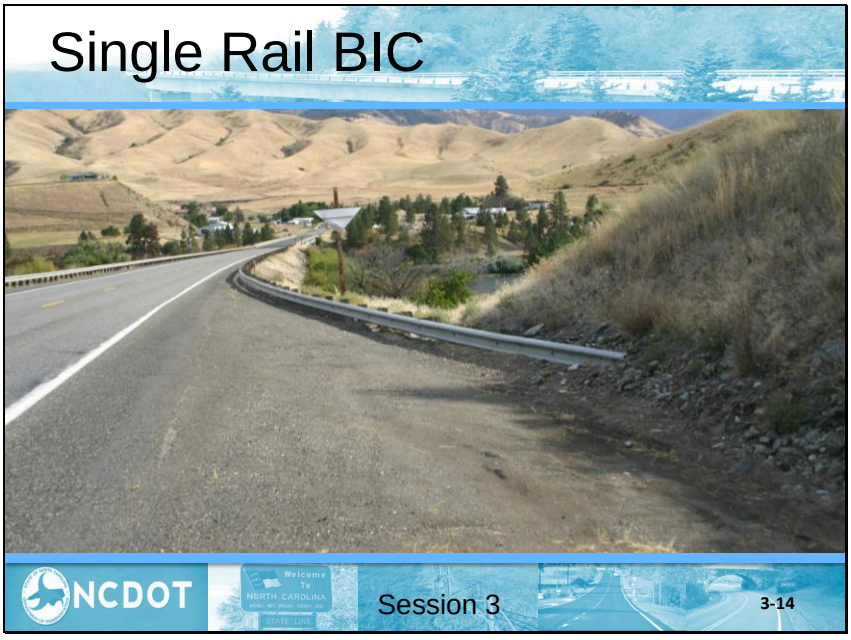



NCDOT Session 3 3-11

# Buried in Cut (350 – to be Updated)




BIC Looking Across Roadway
NCDOT
Session 3
3-13


Single Rail BIC
NCDOT
Session 3
3-14


BIC Considerations – 10:1 Slope for Single
Video Clip
NCDOT
Session 3
3-15


BIC Considerations - LON
Any concerns with this installation?
NCDOT
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Session 3
3-16

## End Treatments - Terminology

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

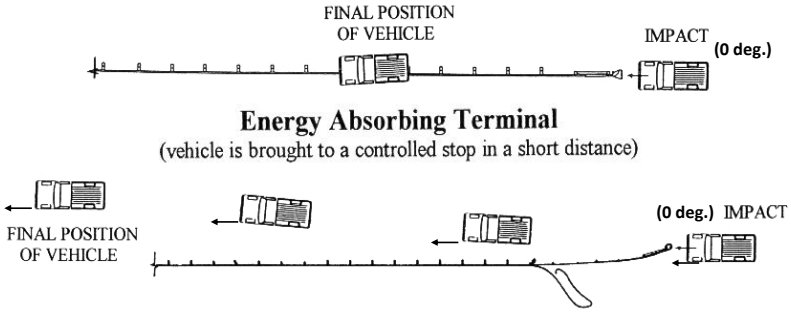
(AT-1 – Anchor Terminal – no cable)

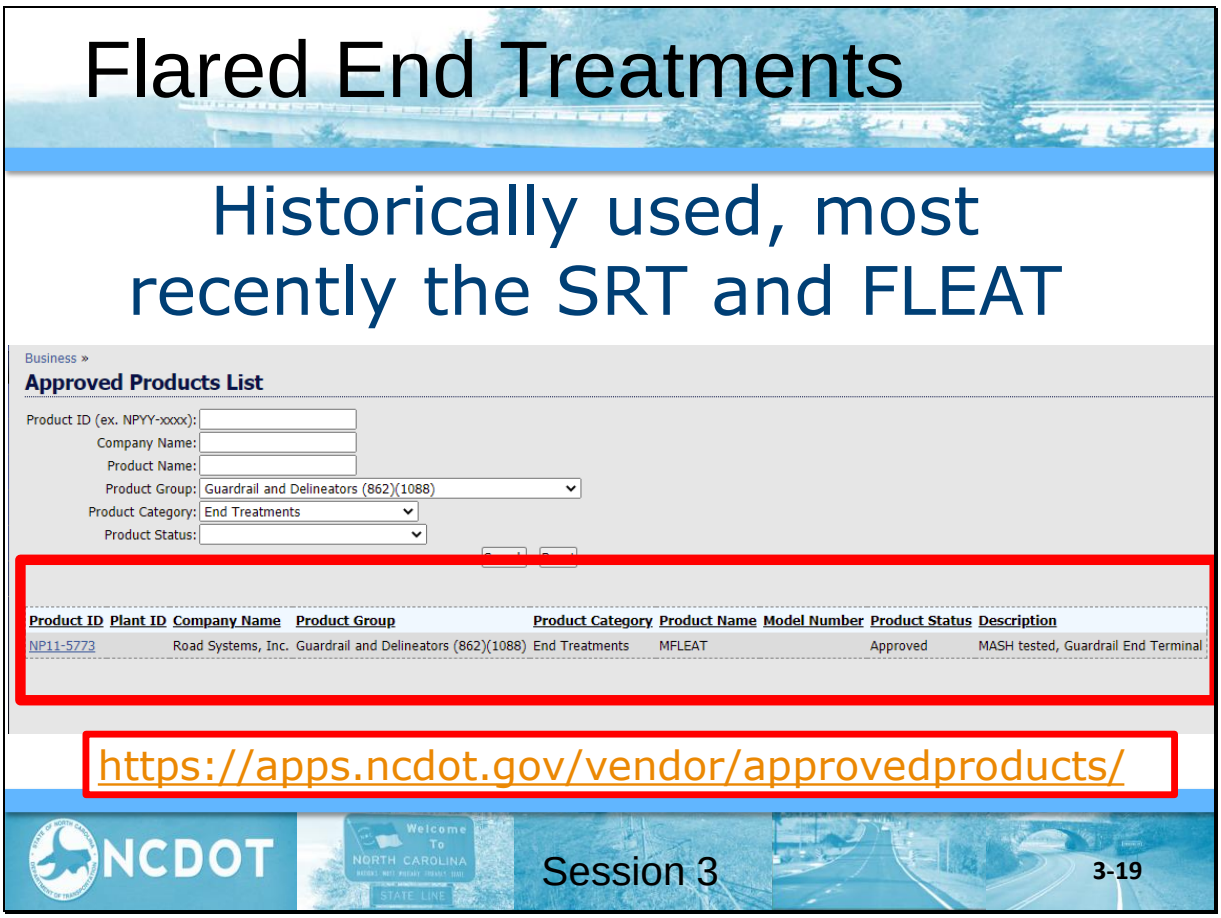
GREA – Guardrail End Anchor – crashworthy Pre-MASH devices

GREU – Guardrail End Unit – crashworthy MASH approved devices



## End Treatments




Flared End Treatments
Historically used, most recently the SRT and FLEAT
Business »
Approved Products List
Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group: Guardrail and Delineators (862)(1088)
Product Category: End Treatments
Product Status:
Product ID Plant ID Company Name Product Group Product Category Product Name Model Number Product Status Description
NP11-5773 Road Systems, Inc. Guardrail and Delineators (862)(1088) End Treatments MFLEAT Approved MASH tested, Guardrail End Terminal
https://apps.ncdot.gov/vendor/approvedproducts/
NCDOT
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Session 3
3-19

## 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 3 3-20

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MASH
MFLEAT


NCDOT Session 3 3-21

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## Flared End Treatment: Non-energy-Absorbing

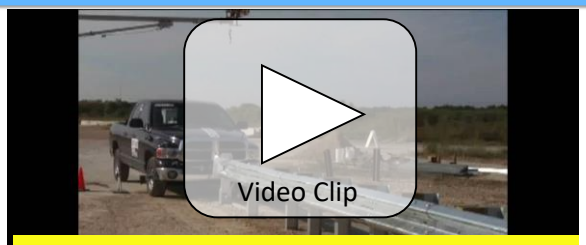
- MASH SRT (Slotted Rail Terminal)
  - W-Beam rails on a straight line and horizontal slots in rail
  - Offset - 4’; 31” Height
  - 37’-6” long, BLON at Post 4
  - Cable-anchored system

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

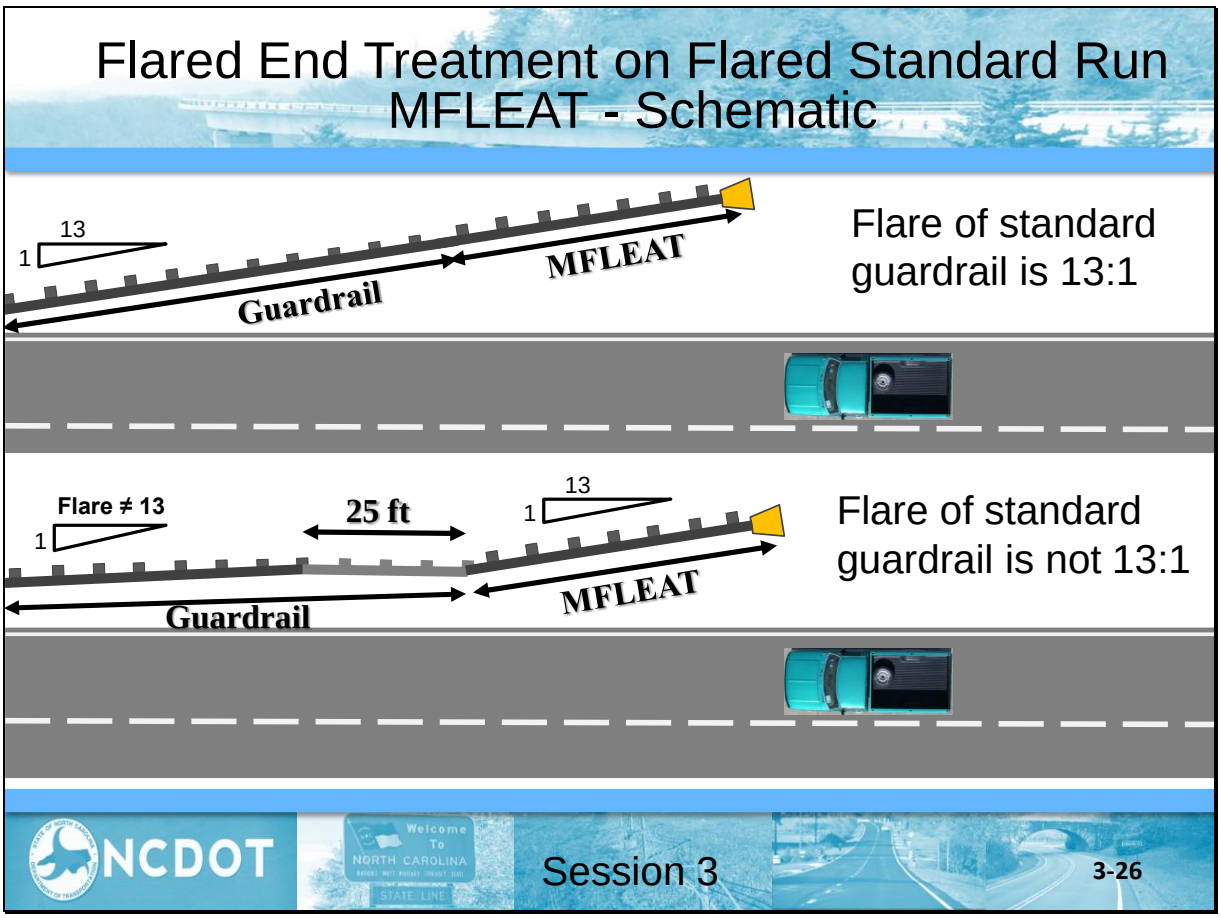

## Flared End Treatments on Flared Standard Run

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
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STATE LINE
Session 3
3-26

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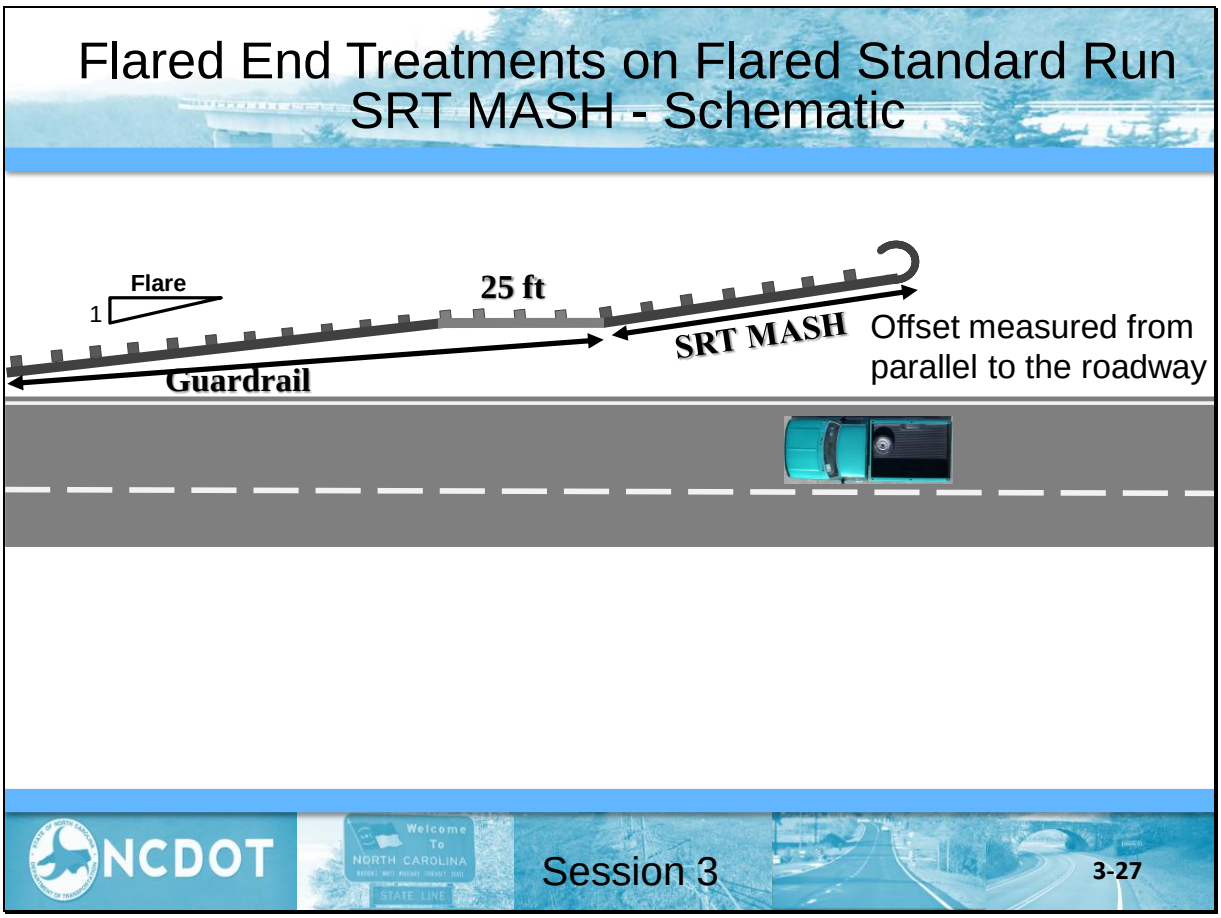
Flared End Treatments on Flared Standard Run
SRT MASH - Schematic
Flare
1
25 ft
SRT MASH
Guardrail
Offset measured from parallel to the roadway
NCDOT
Session 3
3-27

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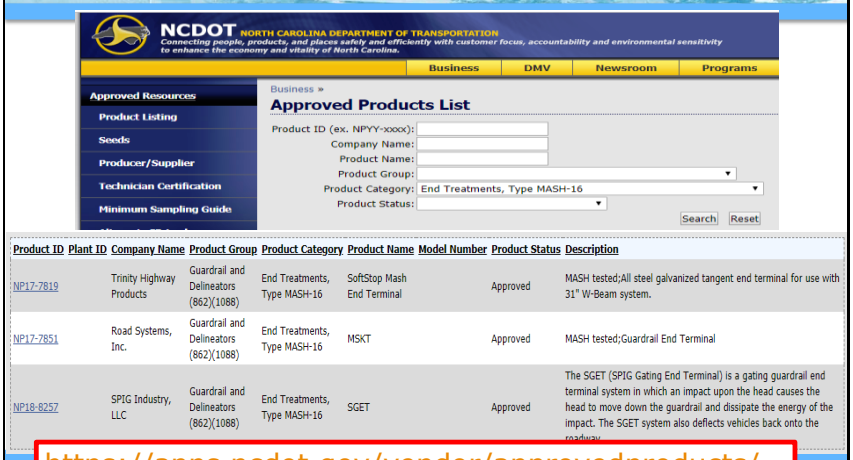
## Flared End Treatment Selection

- 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)

NCDOT Session 3 3-28

## Tangent End Treatment




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

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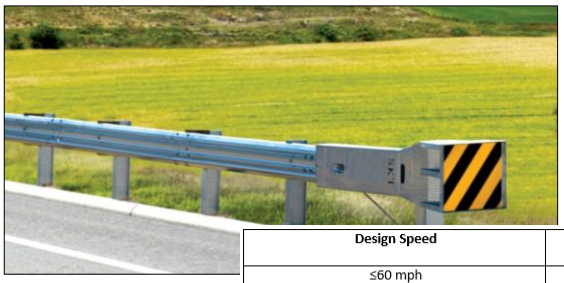
## Tangent End Treatment: Energy Absorbing

- **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 |

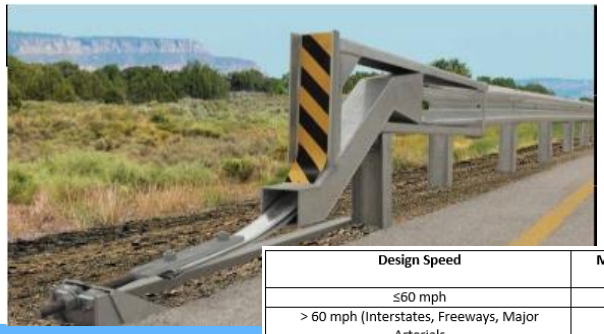
NCDOT Session 3 3-30

## MASH MSKT


NCDOT Session 3 3-31

## Tangent End Treatment: Energy Absorbing

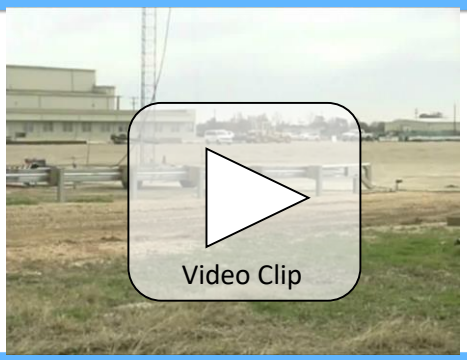
- Soft Stop (MASH 16)
  - Impact head slides along panels, crushing them vertically, absorbing the energy of the vehicle in shallow angle impacts – **works in tension**
  - TL-3 at 51' long; BLON at 16'-6"; 31" only



| 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 |

NCDOT Session 3 3-32

## MASH Soft Stop




NCDOT Session 3 3-33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STATE LINE
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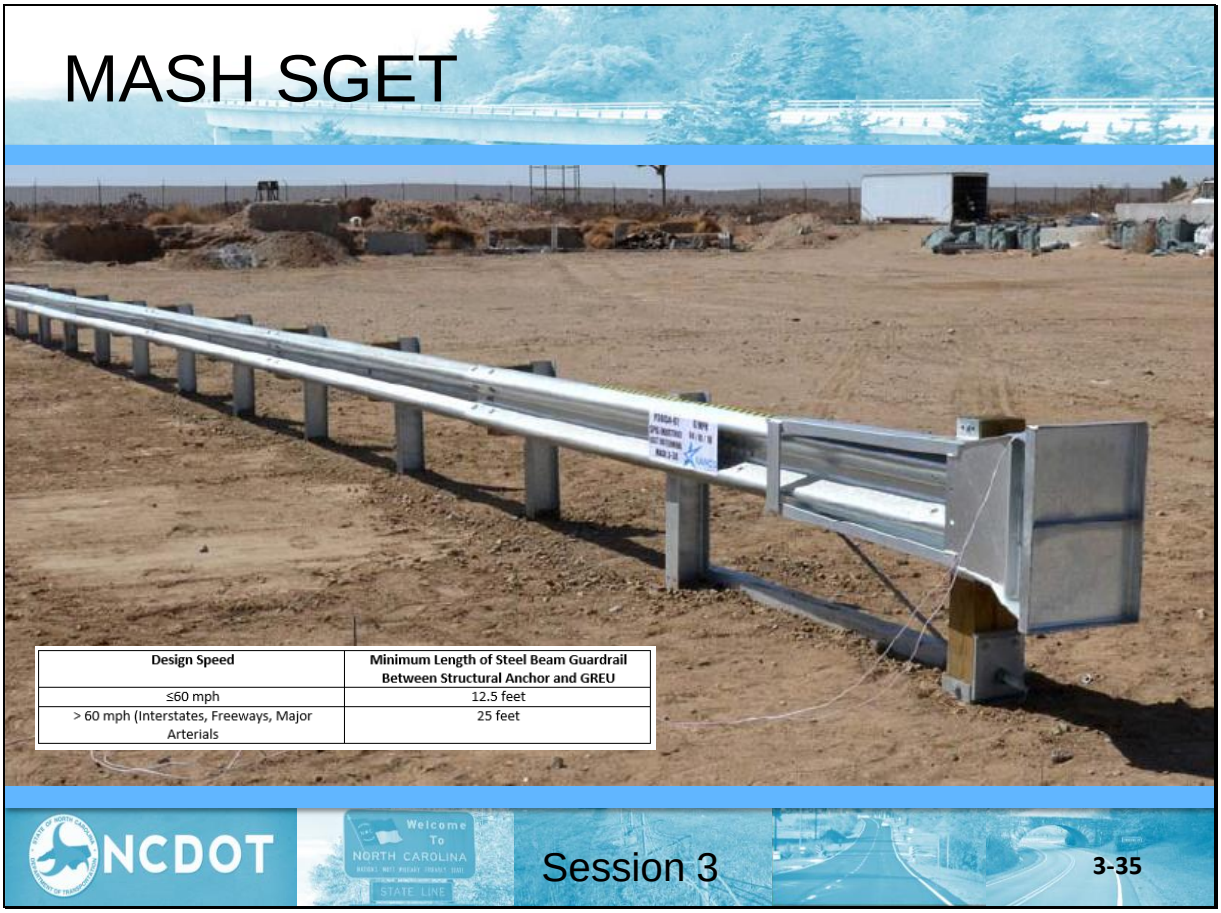

MASH SGET
Design Speed
Minimum Length of Steel Beam Guardrail Between Structural Anchor and GREU
≤60 mph
12.5 feet
> 60 mph (Interstates, Freeways, Major Arterials
25 feet
NCDOT
Session 3
3-35


MASH SGET – Test 3-31
NCDOT
Session 3
3-36

## 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 3 3-37

## MASH MAX-Tension


NCDOT Session 3 3-38

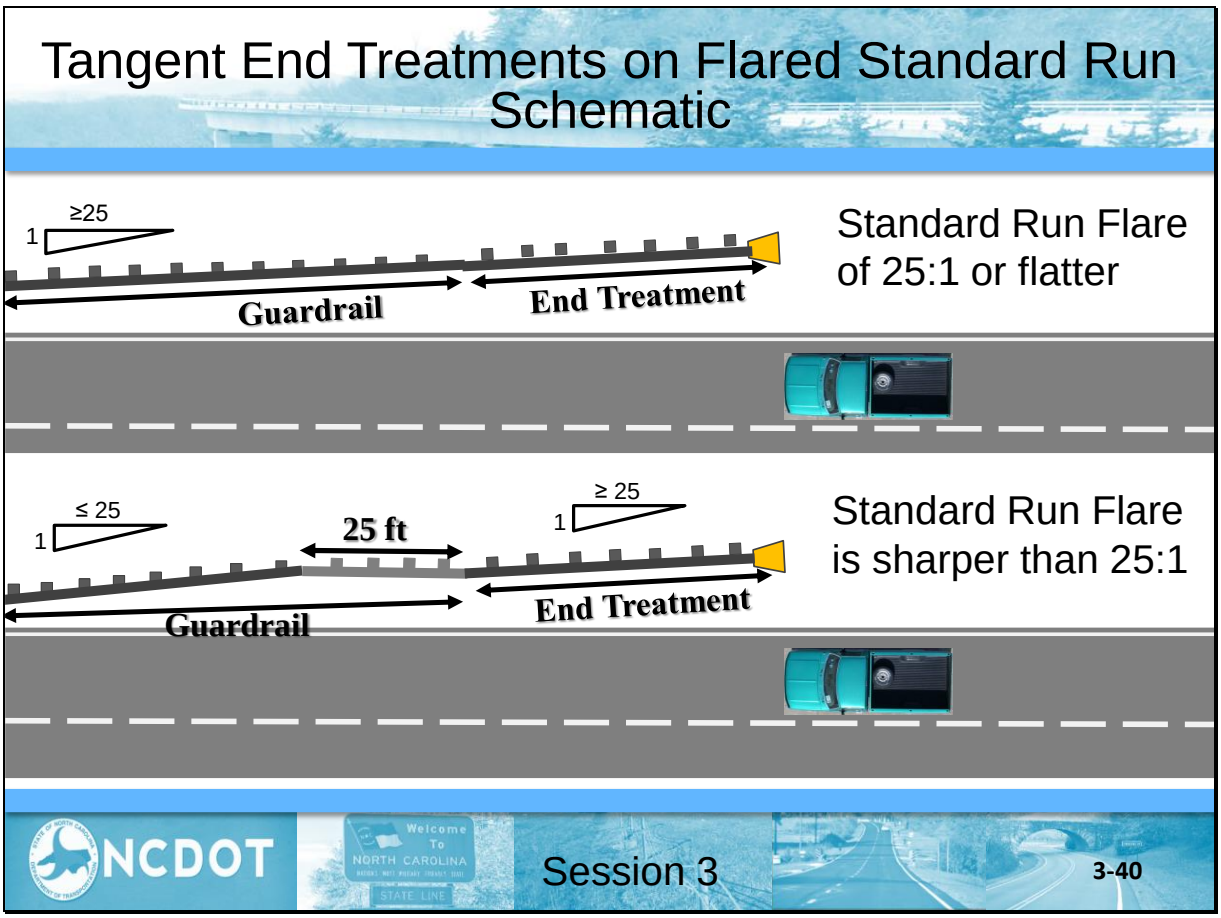
# Tangent End Treatments on Flared Standard Run

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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STATE LINE
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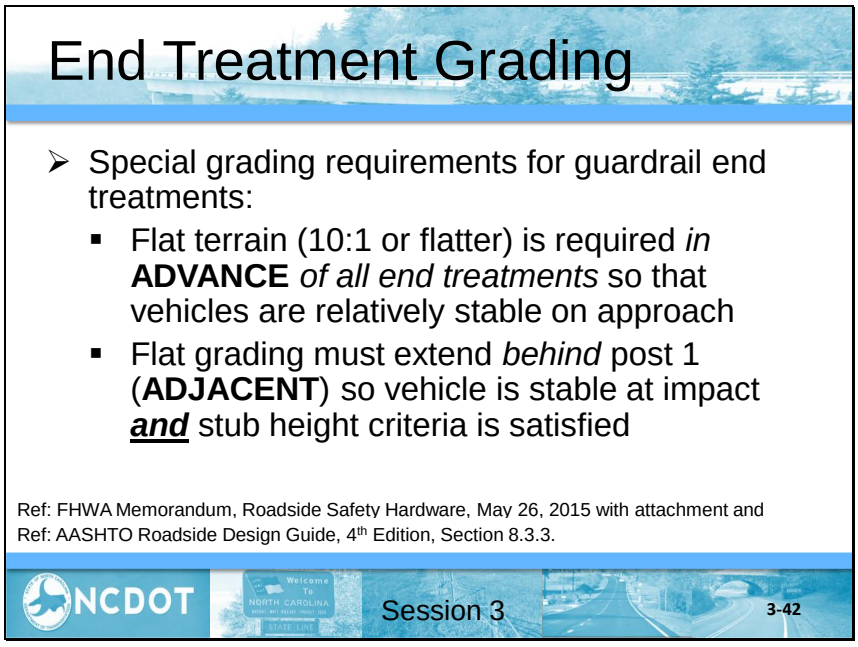
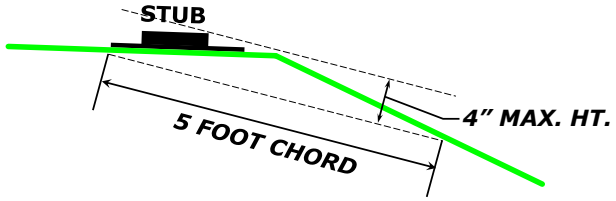
INSTALLATION
MUST HAVE MANUFACTURER'S SHOP DRAWINGS AND INSTALLATION MANUAL TO INSTALL / INSPECT ANY OF THE PROPRIETARY END TREATMENTS
NCDOT
Session 3
3-41


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.
NCDOT
Session 3
3-42

## Stub Height Criteria




***RDG Figure 4.1***

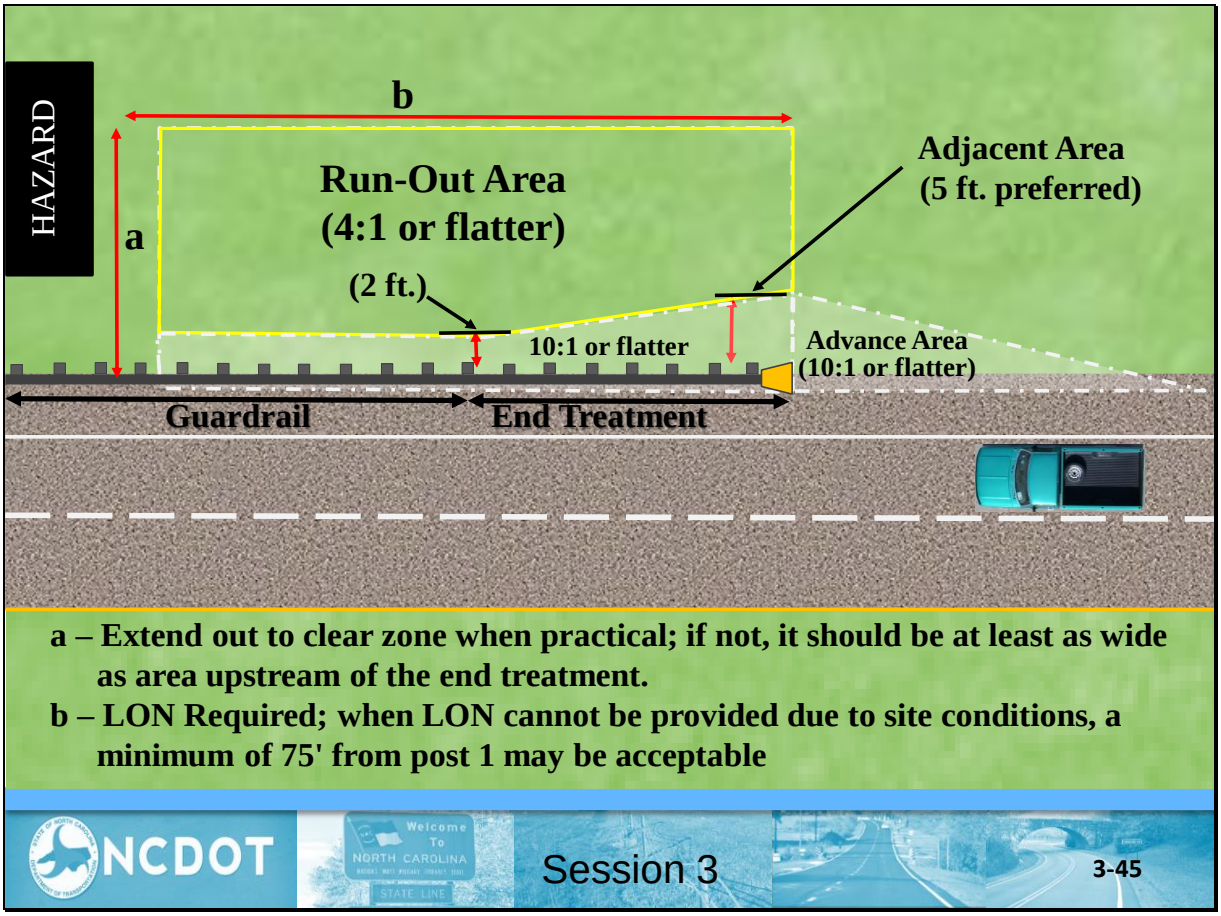
Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 4.1



## 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)
Adjacent Area
(5 ft. preferred)
(2 ft.)
10:1 or flatter
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
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Session 3
3-45

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# Flared End Treatment Grading - AASHTO

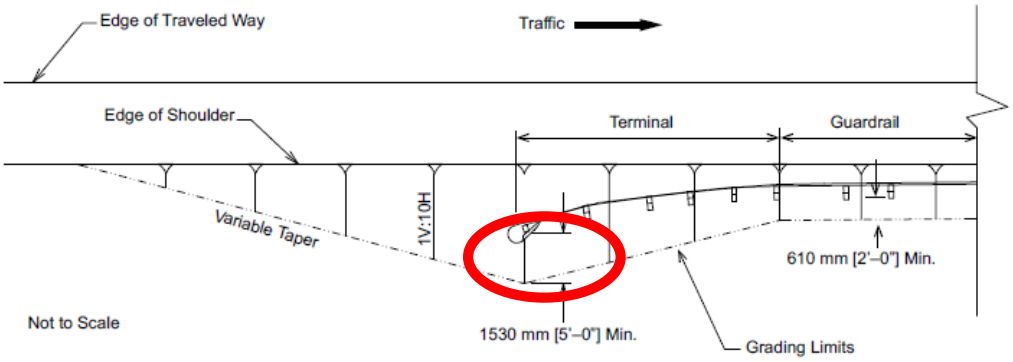


**Figure 8-2. Grading for Flared Guardrail Terminal**

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

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


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STATE LINE
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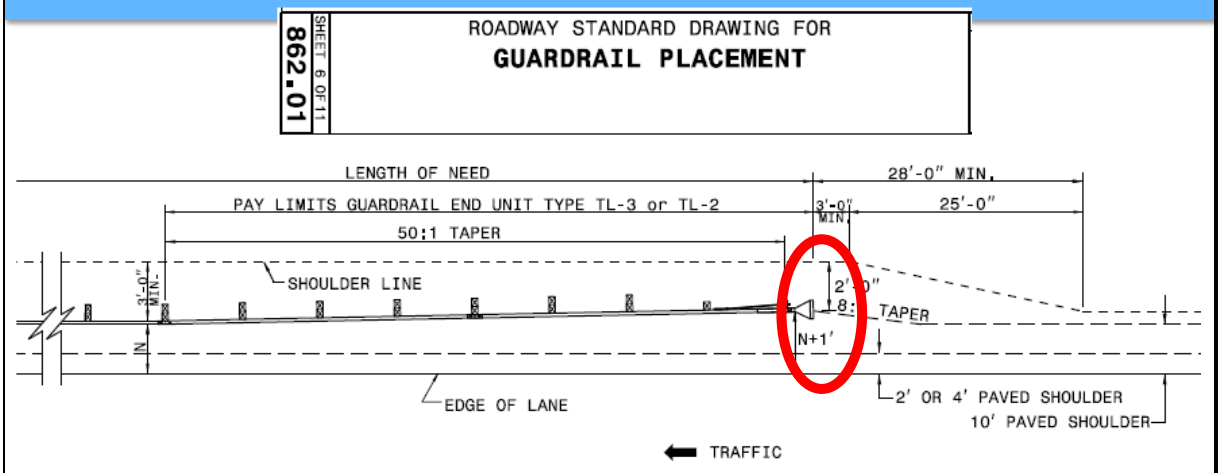
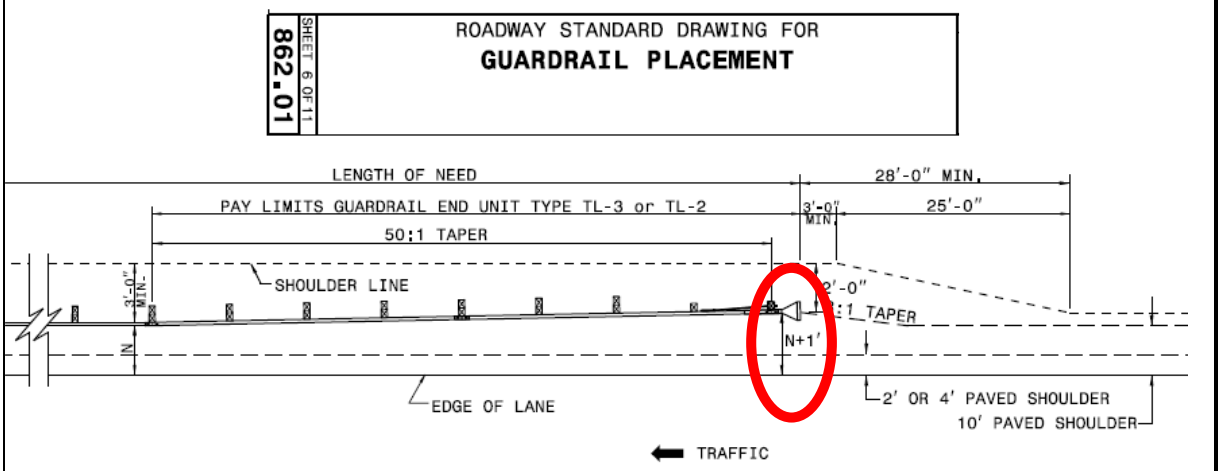
# Tangent End Treatment Grading - NCDOT




Need special Borrow bid item for 3R projects

Need Special Provision for Density

# Tangent End Treatment Offset - NCDOT






## Thing to Remember about End Treatments

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

## Thing to Remember about End Treatments

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

NCDOT Session 3 3-51

## EXISTING END TREATMENTS

NCDOT Session 3 3-52

# 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 3 3-53

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# 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 3 3-54

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# Turndown


NCDOT Session 3 3-55

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## Non-crashworthy End Treatment
### BCT Terminal

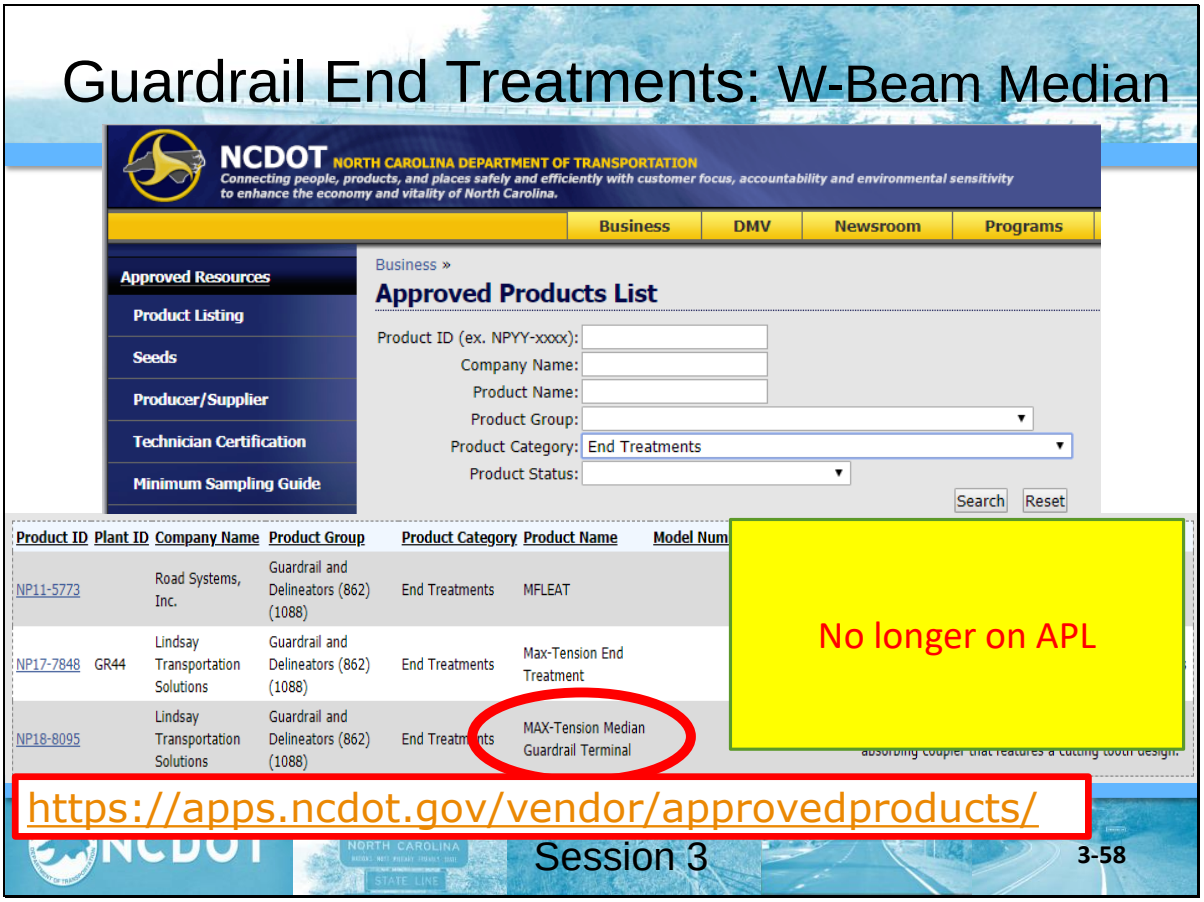
- Breakaway Cable Terminal (BCT) NCHRP 230
  - W-Beam rail with a parabolic curve and 4-ft offset.
  - No impact head or ground strut between the two end posts.
  - Only two breakaway posts.
  - Rail bolted to all posts.

For Identification Only

NCDOT Session 3 3-56

## Non-crashworthy End Treatment
### BCT Terminal


NCDOT Session 3 3-57


Guardrail End Treatments: W-Beam Median
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
Product Status:
Search
Reset
Product ID | Plant ID | Company Name | Product Group | Product Category | Product Name | Model Num
NP11-5773 | | Road Systems, Inc. | Guardrail and Delineators (862) (1088) | End Treatments | MFLEAT
NP17-7848 | GR44 | Lindsay Transportation Solutions | Guardrail and Delineators (862) (1088) | End Treatments | Max-Tension End Treatment
NP18-8095 | | Lindsay Transportation Solutions | Guardrail and Delineators (862) (1088) | End Treatments | MAX-Tension Median Guardrail Terminal
No longer on APL
https://apps.ncdot.gov/vendor/approvedproducts/
Session 3
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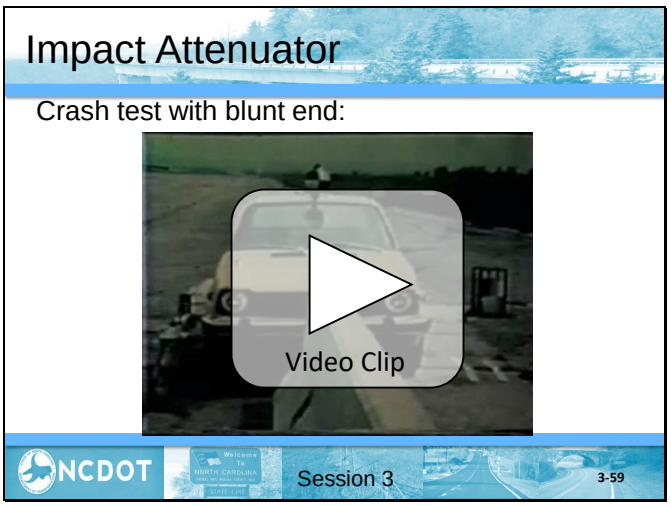
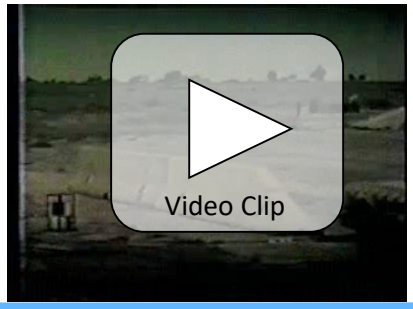

Impact Attenuator
Crash test with blunt end:
Video Clip
NCDOT
Session 3
3-59

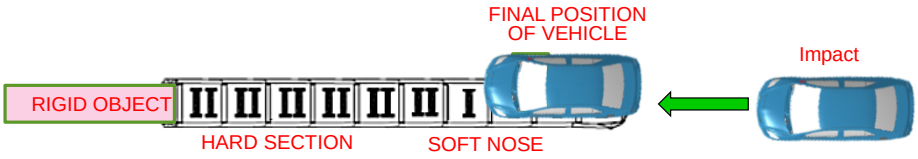
## Impact Attenuator

Crash test with ramped end:

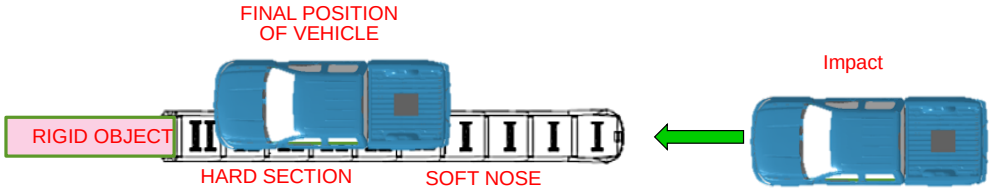



NCDOT Session 3 3-60

## 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**

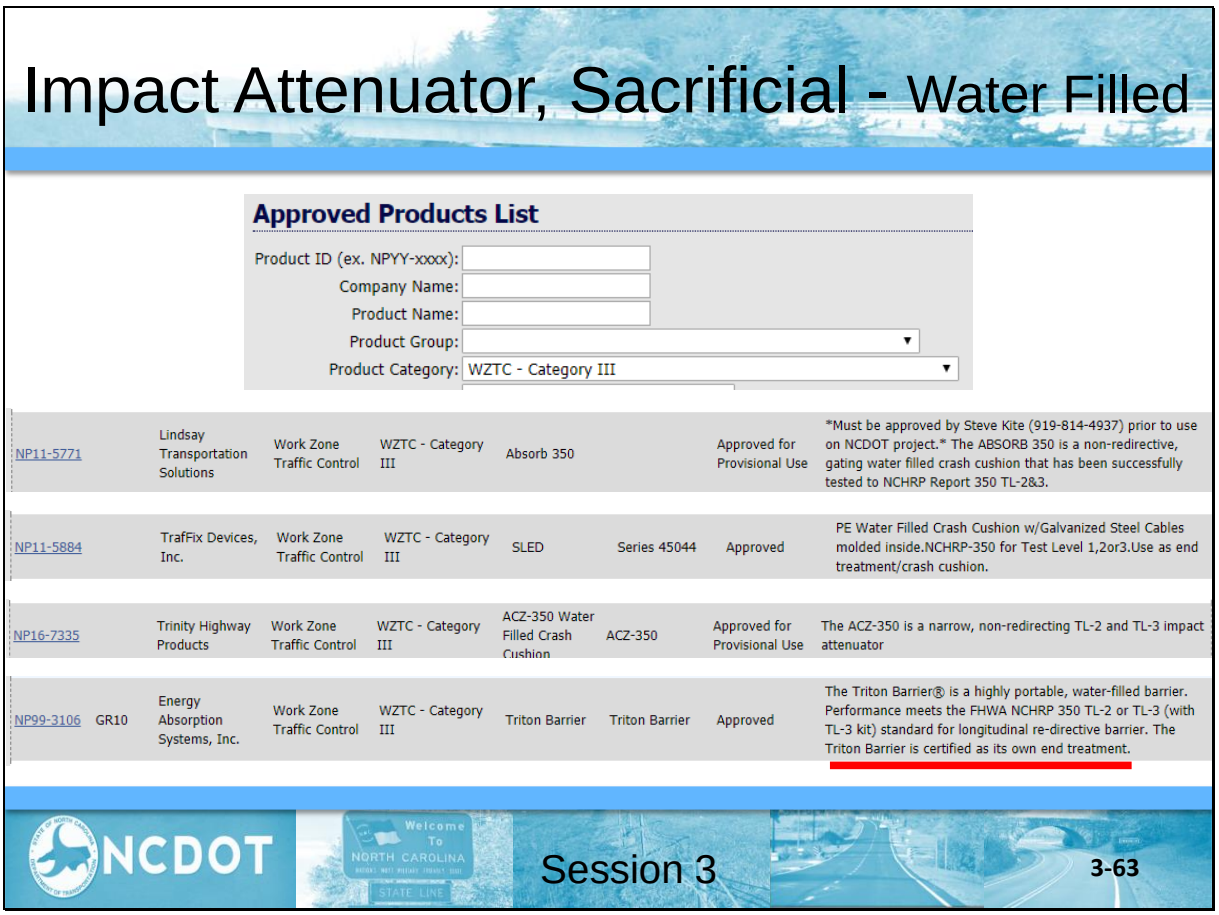
NCDOT Session 3 3-61

# 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
Welcome To NORTH CAROLINA STATE LINE
Session 3
3-63

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## Impact Attenuator, Sacrificial - Water Filled

Absorb M (MASH)

ACZ-350

Sled (MASH)


TRITON barrier CET

NCDOT Session 3 3-64

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## Water Filled


NCDOT Session 3 3-65

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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.



Impact Attenuator, Sacrificial – Sand Barrel

➢ Sand Barrels:

Energite

TrafFix Big Sandy (MASH)

Not Normally Used

CrashGard (MASH)

## Sand Barrels – Good Application


NCDOT Session 3 3-68

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## Sand-Filled Array


NCDOT Session 3 3-69

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## NCDOT Impact Attenuator Selection

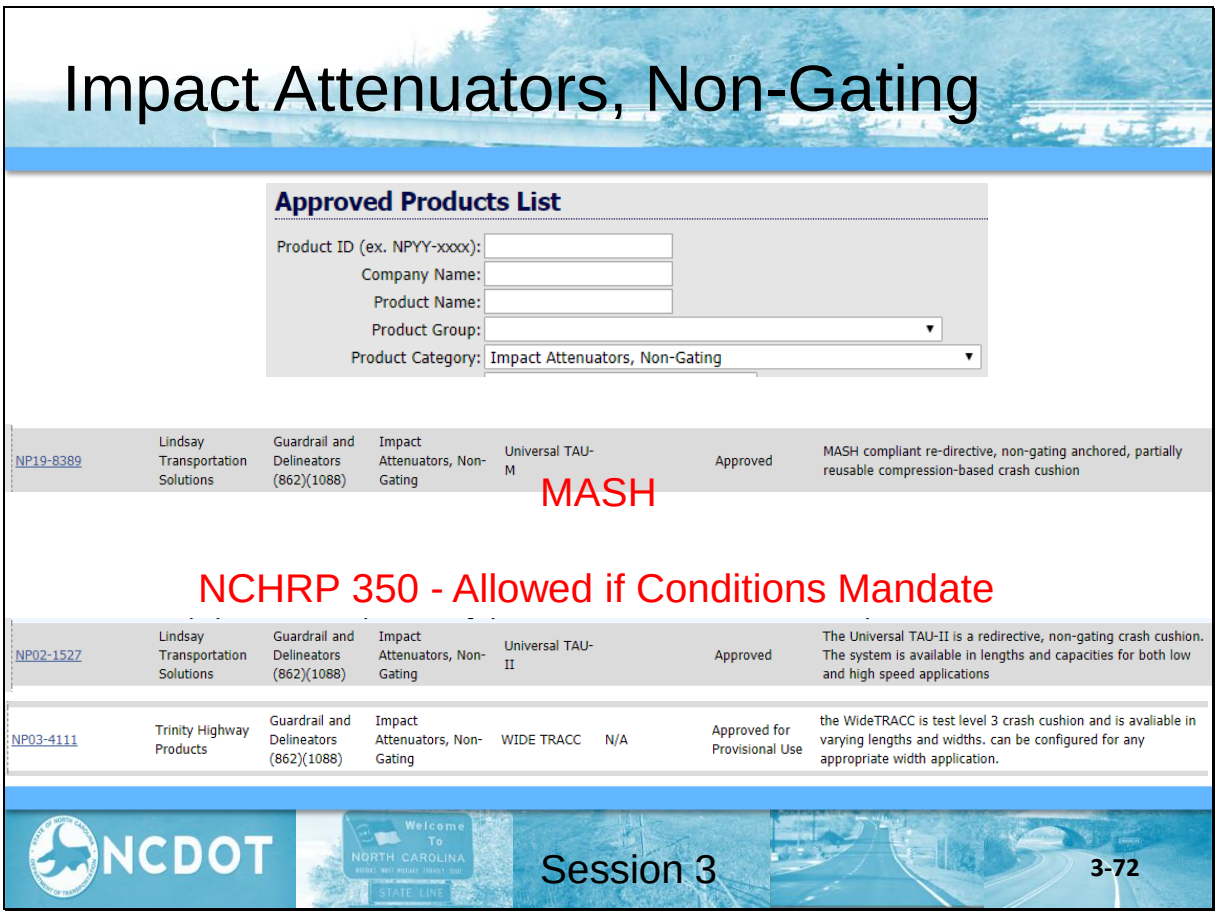
**"For median width less than or equal to 40' use NON-GATING IAU's. For median width greater than 40' may use GATING or NON-GATING IAU's"**



## 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 3
3-72

# 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 or self-restoring (R) absorbing cartridges, steel diaphragms and two cables at the bottom to provide redirection.

NCDOT Session 3 3-73

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## Impact Attenuators, Non-Gating - Typical


NCDOT Session 3 3-74

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# 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 |
| 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 |

MASH

NCDOT Session 3 3-75

# Impact Attenuators, Life Cycle

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

NCDOT Session 3 3-76

# Example – Low Cost


NCDOT Session 3 3-77

## Impact Attenuators, Life Cycle

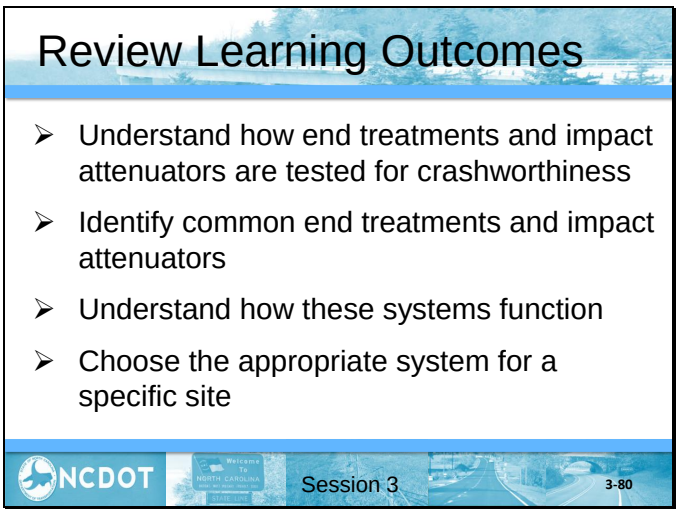
- QuadGuard Elite (MASH)
  - Uses High Density Polyethylene cylinders to absorb energy
  - Essentially for use in locations where a high number of hits is anticipated.

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

NCDOT Session 3 3-78

## Example - Self Restoring


NCDOT Session 3 3-79


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 3
3-80

# Session 4: Guardrail Design, Length of Need, and Site-specific Installation Considerations

North Carolina Department of Transportation
**Highway Safety Barrier Installation Training**

# Session 4: Guardrail Design, Length of Need, and Site-specific Installation Considerations

NCDOT Session 4 4-1

## Session 4 Learning Outcomes

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

- Understand the design principles affecting an optimal barrier installation
- Apply a field procedure to check Length of Need
- Be familiar with special designs to address site-specific installation considerations

NCDOT Session 4 4-2

## Guardrail Placement

**Place AS FAR AWAY as Possible**

*without affecting function*

NCDOT Session 4 4-3

## 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 4 4-4

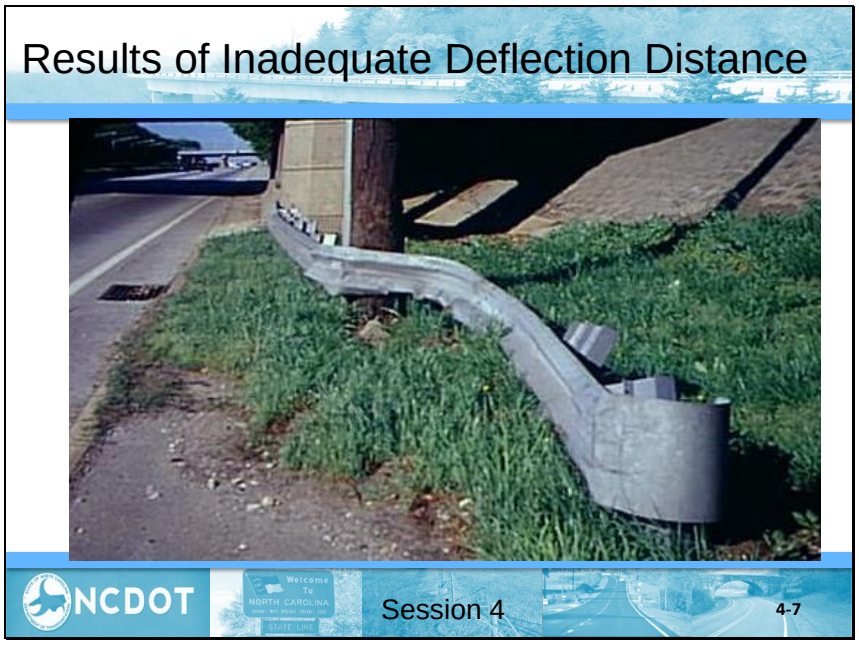
# Principle 1: Deflection

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

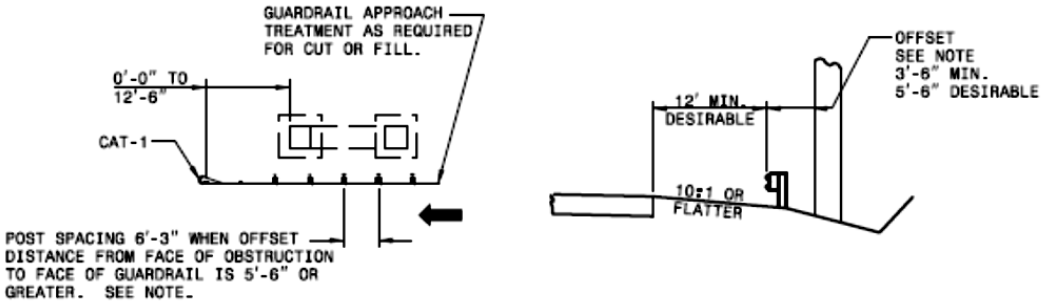
- If the barrier is shielding a vertical rigid object, the distance between the barrier and the object should be sufficient to avoid the vehicle impacting or snagging on the object.
- Note that, even for rigid barriers with no lateral deflection, large vehicles may roll behind the top of the barrier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

NCDOT Session 4 4-5


Deflection
NCDOT
Session 4
4-6


Results of Inadequate Deflection Distance
NCDOT
Session 4
4-7

# 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

NCDOT Session 4 4-8

## Quarter Post (1'- 6 ¾") 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 (3'- 1 ½") post guardrail; 25' of quarter post guardrail

NCDOT Session 4 4-9

## Principle 2: Slope in Front of Barrier

Any barrier may be placed anywhere on a 10H:1V or flatter slope.

NCDOT Session 4 4-10

## Guardrail on Slopes

- Any barrier may be placed anywhere on a 10H:1V or flatter slope.
- Cable barrier may be placed on slopes of 6H:1V or flatter, but restrictions apply when placed in a swale. Special HTCB designs are available for placement on 4:1 slopes.

NCDOT Session 4 4-11

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## Principle 2: Slope in Front of Barrier


NCDOT Session 4 4-12

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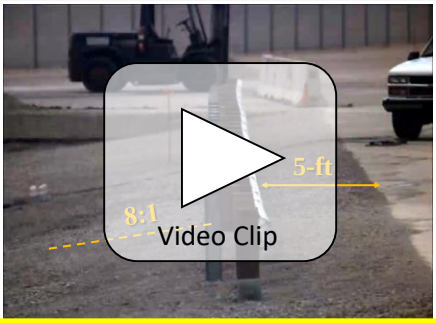
## NCHRP 350 TL-3 31" on 8:1 Slope

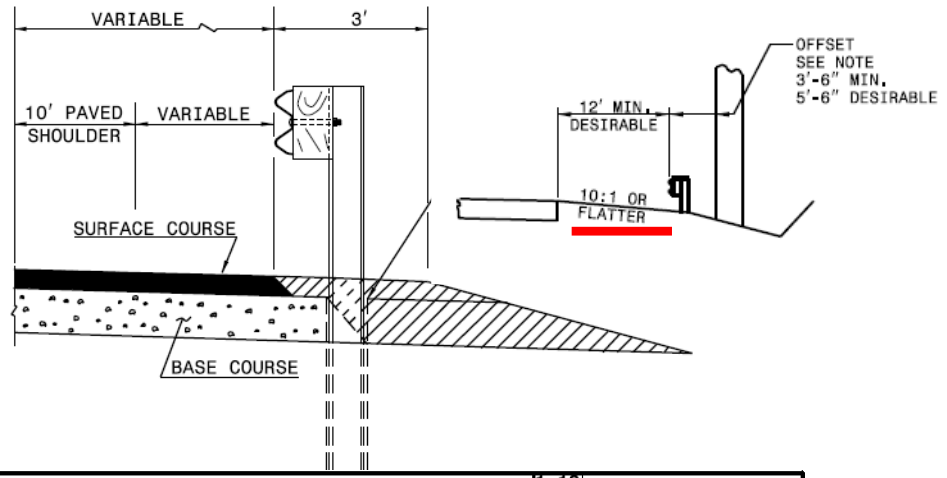



Vehicle is contained and redirected but shows instability



## Slope in Front of Barrier

IMPLIED – FLAT




862.01 SHEET 10 OF 11

ROADWAY STANDARD DRAWING FOR
**GUARDRAIL PLACEMENT**

1-18

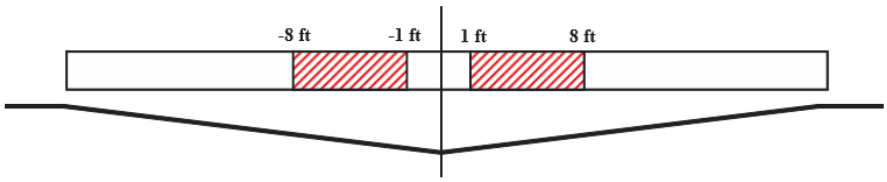
STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

## Barrier in Sloped Median
## - Old System (29") ONLY -



# 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

## Location of Cable in Swales

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

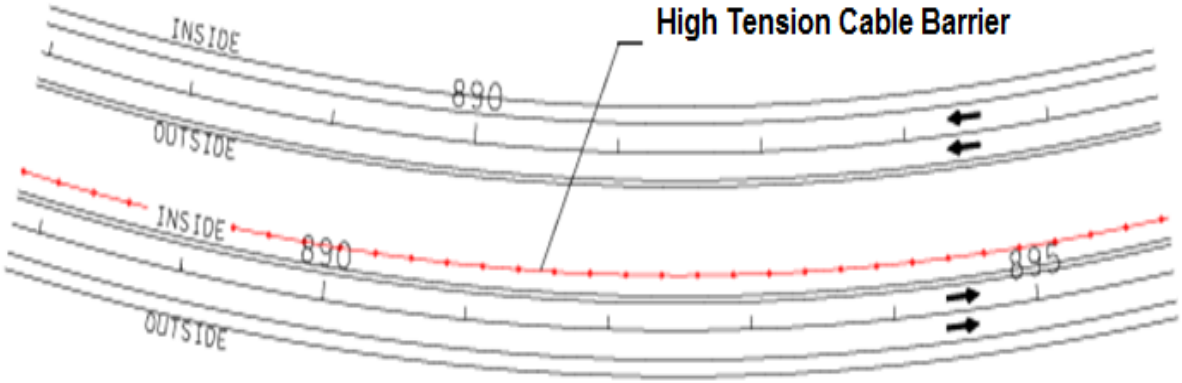

CABLE SHOULD NOT BE PLACED BETWEEN 1' AND 8' BEYOND THE BOTTOM OF A DITCH

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

NCDOT Session 4 4-17

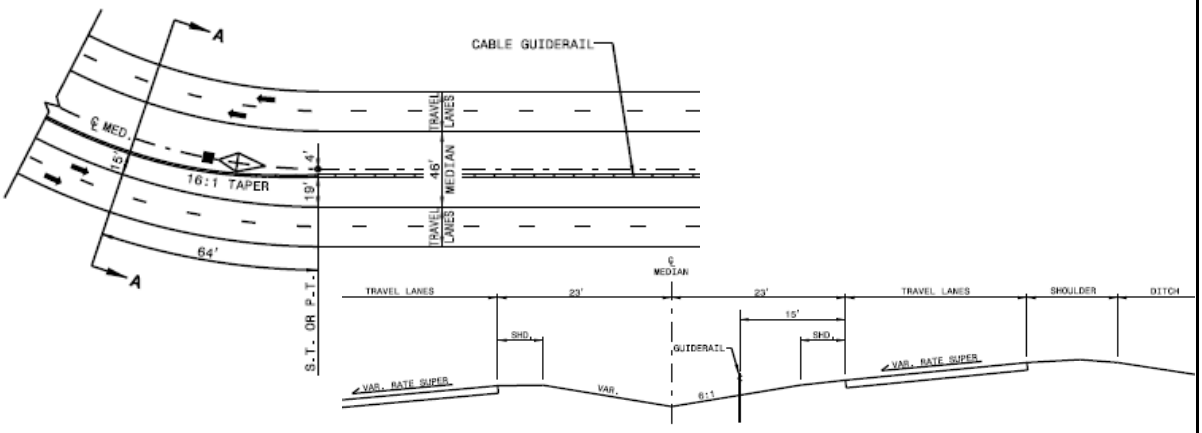
## Barrier in Sloped Median

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




NCDOT Session 4 4-18

# Barrier in a Curved Median




SHEET 3 OF 12
865.01

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

NCDOT Session 4 4-19

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# Principle 3: Guardrail and Curbs

NCDOT Session 4 4-20

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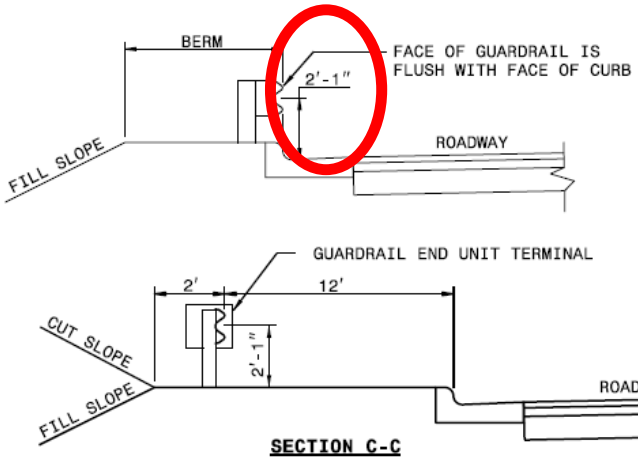
## Guardrail and Curbs – 29”


NCDOT Session 4 4-21

## NCDOT Guardrail and Curbs



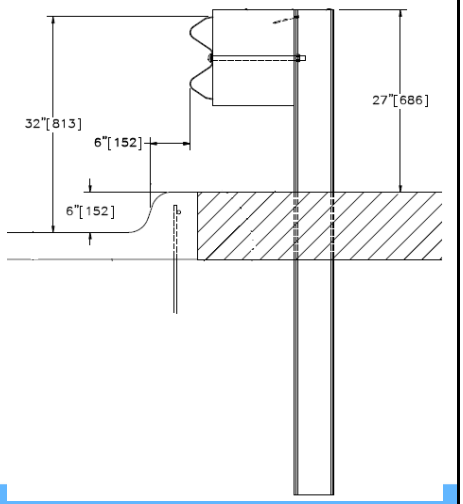

| | | |
|---|---|---|
| 862.01 SHEET 11 OF 11 | ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT** GUARDRAIL TREATMENT AT CURB AND GUTTER | 1-18 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C. |

Ref: NCDOT Standard Drawings, 862.01 Sht. 11

NCDOT Session 4 4-22

# 31” and Curbs

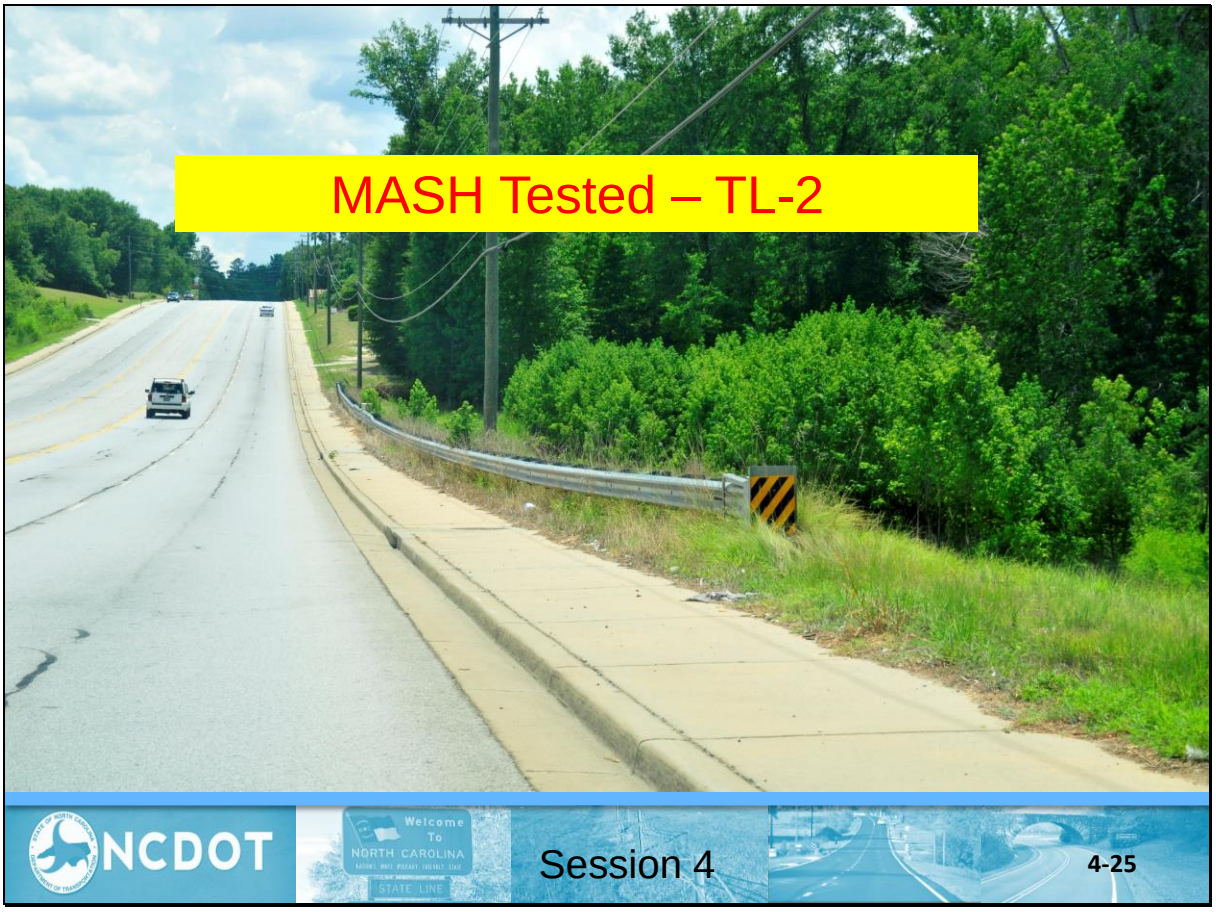
Successfully tested to MASH placed 6” behind a 6” high curb at TL-3




NCDOT Session 4 4-23

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


NCDOT Session 4 4-24


MASH Tested – TL-2
NCDOT
Welcome To NORTH CAROLINA STATE LINE
Session 4
4-25


MASH TL-2 31” 6 ft. behind curb
Video Clip
NCDOT
Session 4
4-26


End Treatments and Curbs
CURRENTLY UNDER STUDY –
DO NOT BURY BEARING PLATE
2” maximum height recommended
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Session 4
4-27

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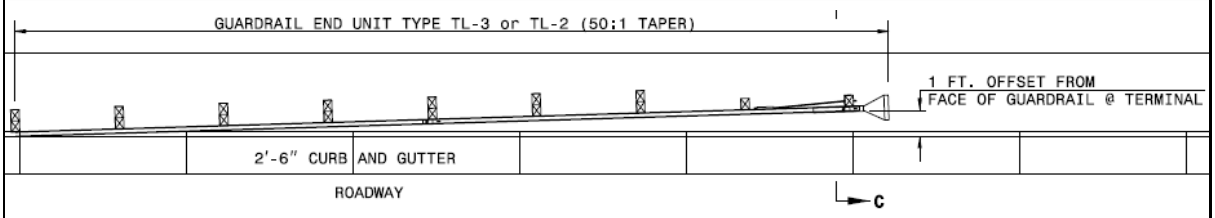
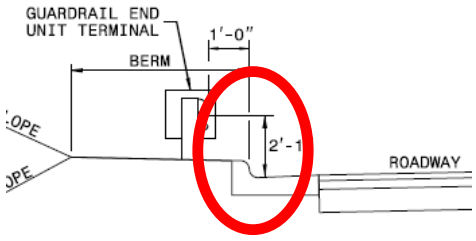
# End Treatments and Curbs - NCDOT




GUARDRAIL AT FACE OF CURB




SECTION C-C

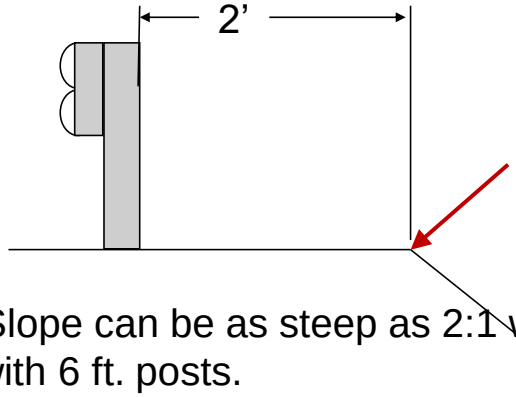
Careful with Breakaway Cable Anchorage Terminals – Don't let Bearing Plate be buried

Ref: NCDOT Standard Drawings, 862.01 Sht. 11



## Principle 4: Soil Backing For Fill Locations

# Soil Backing Recommendation

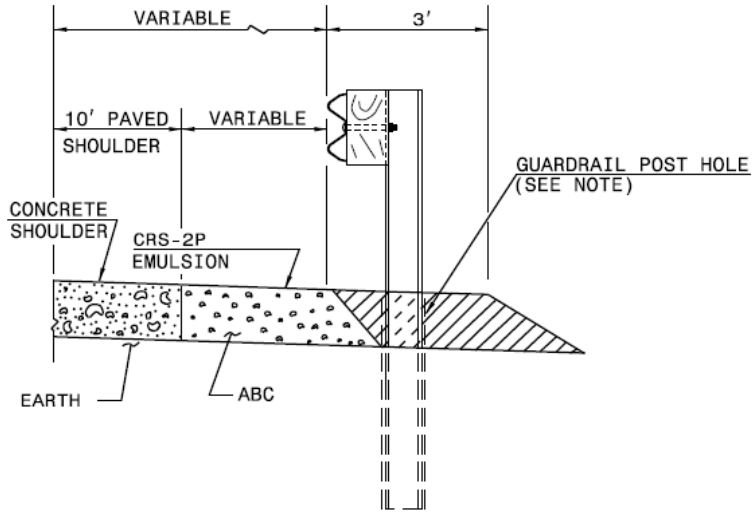



## Historical Guidance

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




862.01 SHEET 10 OF 11

ROADWAY STANDARD DRAWING FOR
**GUARDRAIL PLACEMENT**

1-18

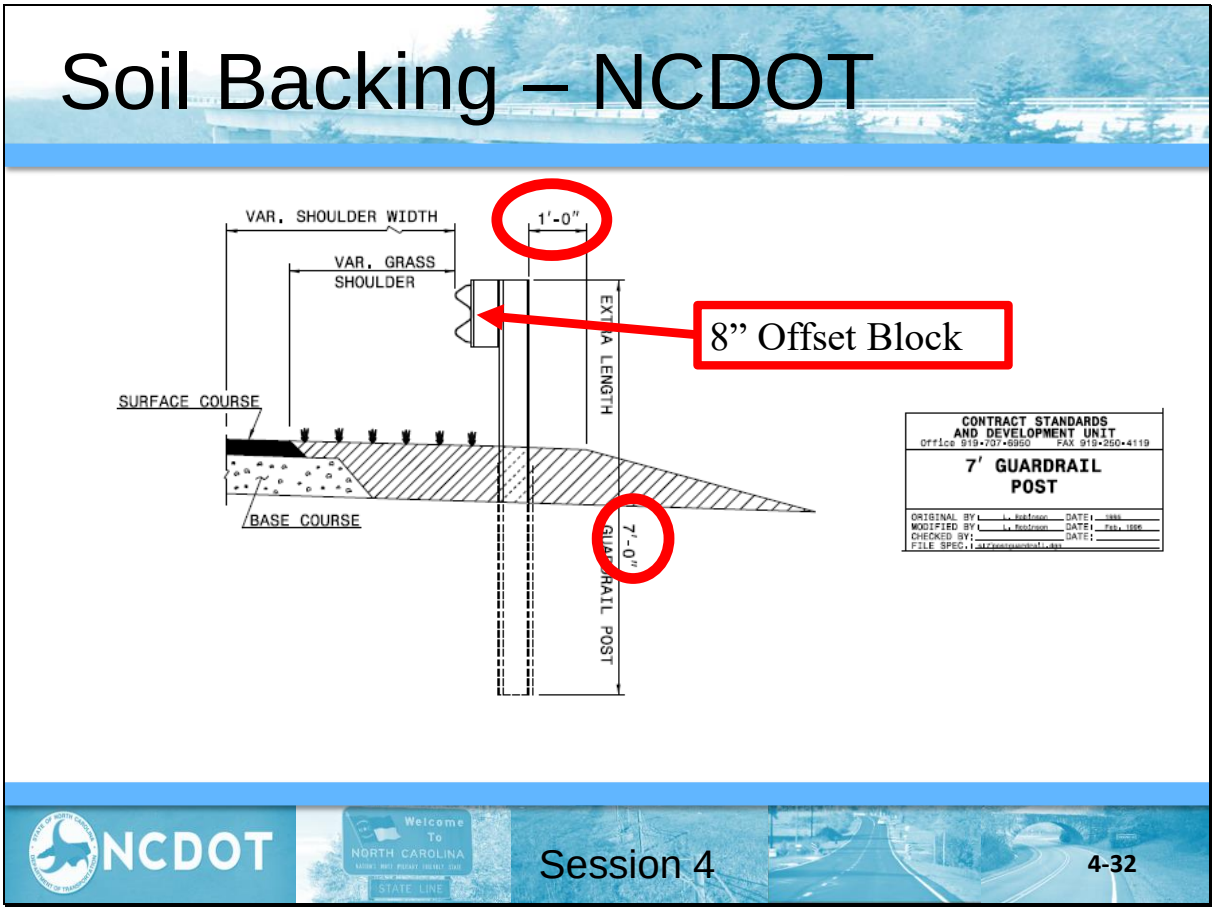
STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

NCDOT

Session 4

4-31

# Soil Backing – NCDOT




NCDOT Session 4 4-32

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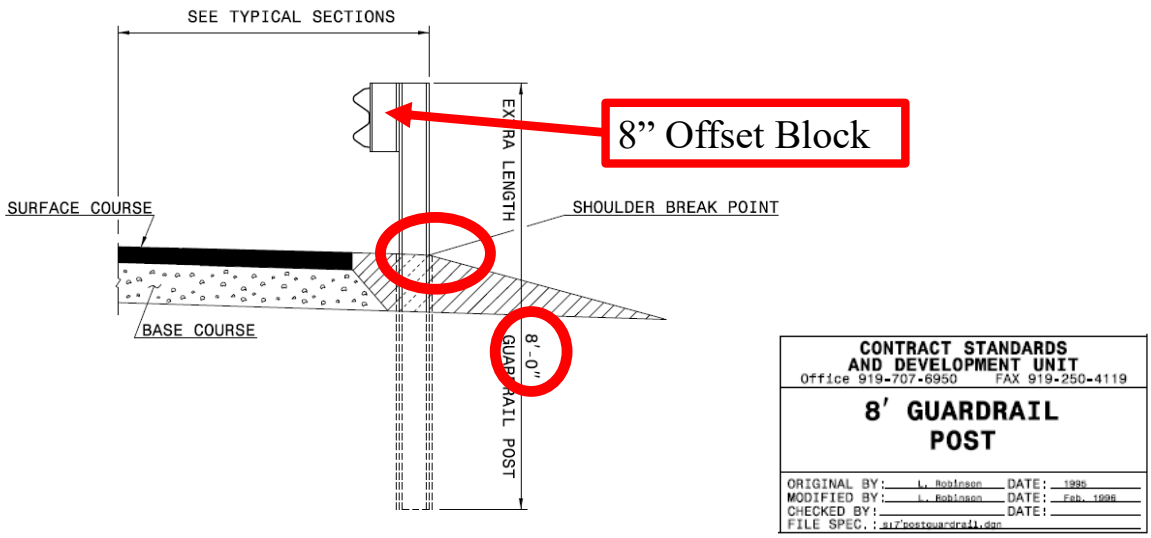
# Soil Backing – NCDOT




NCDOT Session 4 4-33

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# 31” with Posts on a 2:1 Slope

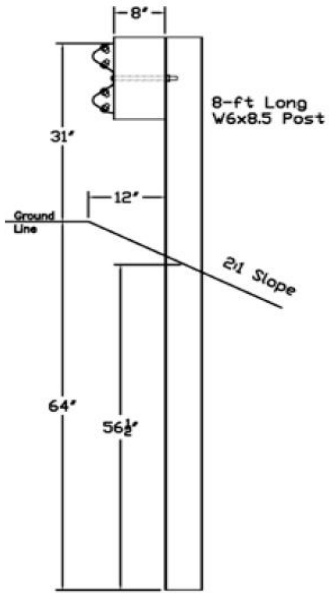
31” with face of rail at slope break point of 2:1 slope

**Posts**

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

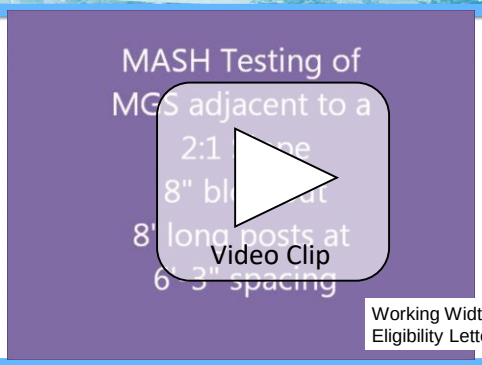
**Offset Blocks**

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




NCDOT Session 4 4-34

# 31” with Posts on a 2:1 Slope




NCDOT Session 4 4-35


Principle 5: Flare Rate
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Session 4
4-36

# 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)

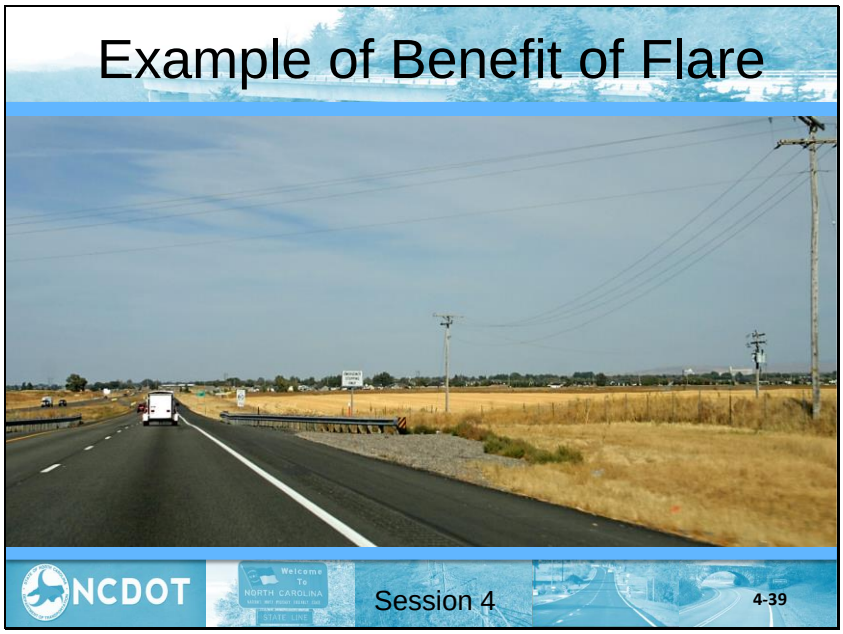
# Suggested Flare Rates

**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.

NCDOT Session 4 4-38


Example of Benefit of Flare
NCDOT
Session 4
4-39


Possibly Excessive Flare and
Slope Steeper than 10:1
NCDOT
Session 4
4-40

# 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

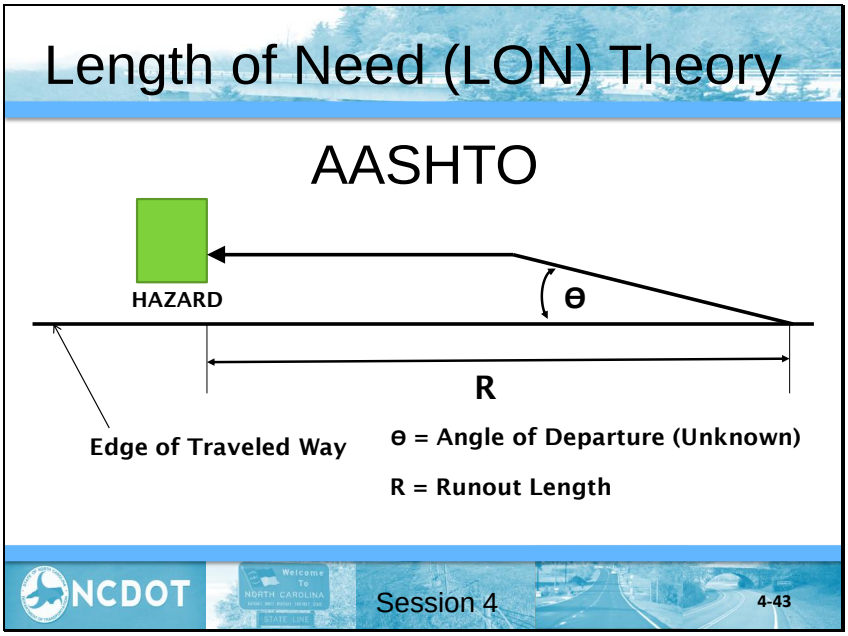
NCDOT guidance is to provide 25' of parallel guardrail in advance of any end treatment requiring a kink.

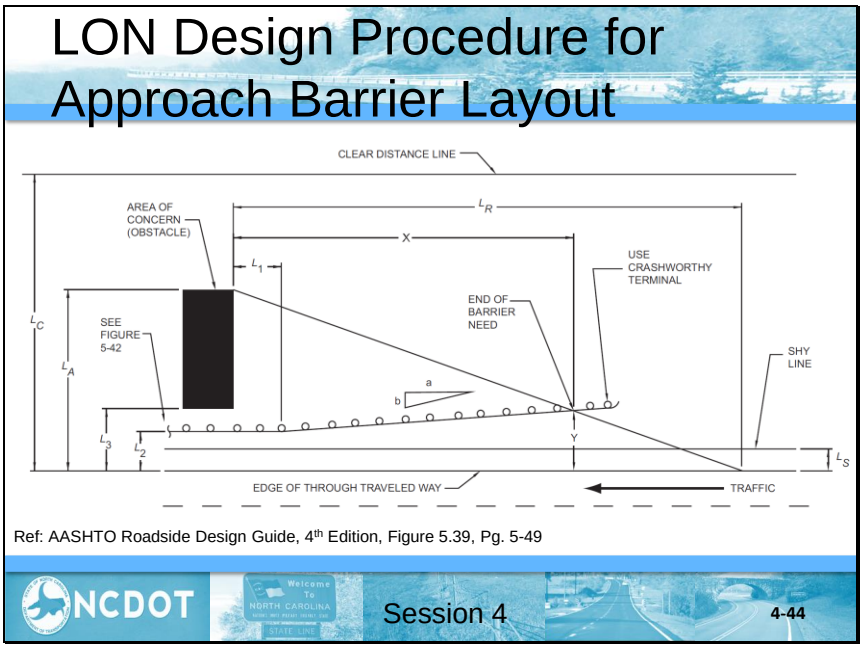


## Length of Need (LON) Definition

### AASHTO

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


Length of Need (LON) Theory
AASHTO
HAZARD
θ
R
Edge of Traveled Way
θ = Angle of Departure (Unknown)
R = Runout Length
NCDOT
Session 4
4-43


LON Design Procedure for Approach Barrier Layout
CLEAR DISTANCE LINE
AREA OF CONCERN (OBSTACLE)
$L_R$
X
$L_1$
USE CRASHWORTHY TERMINAL
END OF BARRIER NEED
SEE FIGURE 5-42
$L_C$
$L_A$
a
b
SHY LINE
$L_3$
$L_2$
Y
$L_S$
EDGE OF THROUGH TRAVELED WAY
TRAFFIC
Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 5.39, Pg. 5-49
NCDOT
Session 4
4-44

## 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:

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

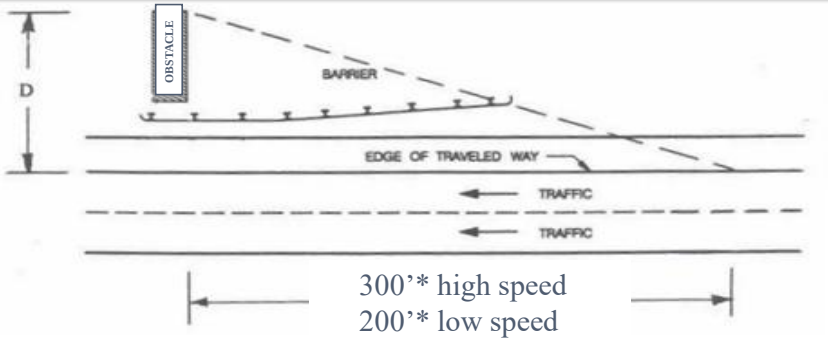
Ref: AASHTO Roadside Design Guide, 4th Edition, Equation 5-1 and 5-2, Pg 5-51



## Quick Field Check of LON

1. Stand on roadway edgeline opposite the upstream edge of the hazard.
2. Beginning at the upstream face of hazard, walk upstream along the edge of traveled way a distance 300' (High Speed, 200' Low)
3. From this position, sight to the upstream, back edge of hazard (limit to 30' offset)
4. End treatment of barrier should lie near (± 30') the line of sight.

# 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')

NCDOT Session 4 4-47

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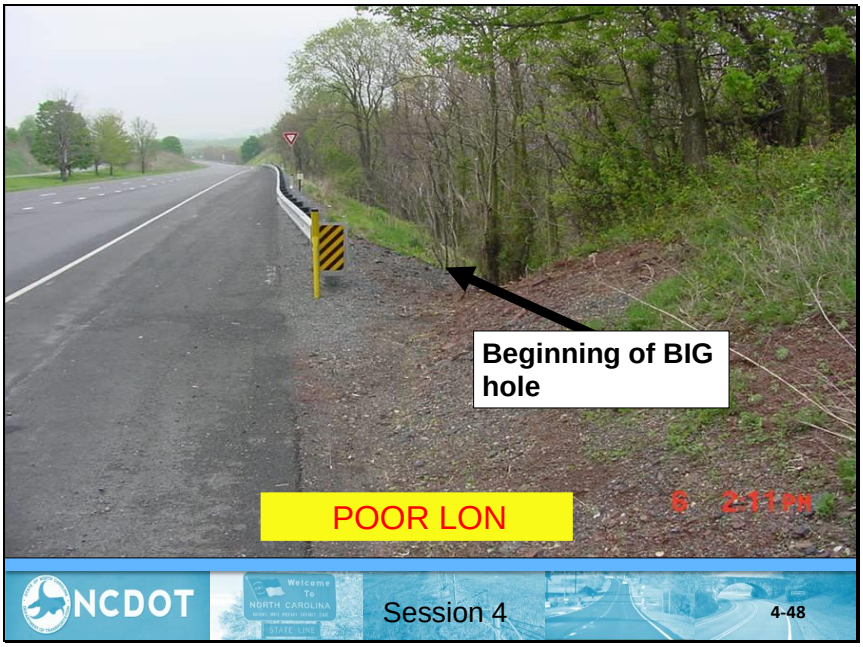
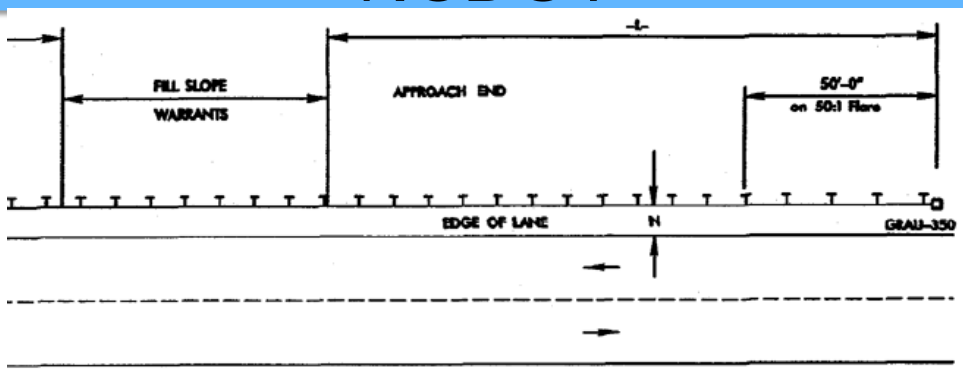

Beginning of BIG hole
POOR LON
NCDOT
Session 4
4-48


Length of Need – Adequate?
NCDOT
Session 4
4-49


Length of Need – Adequate?
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 4
4-50

# 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

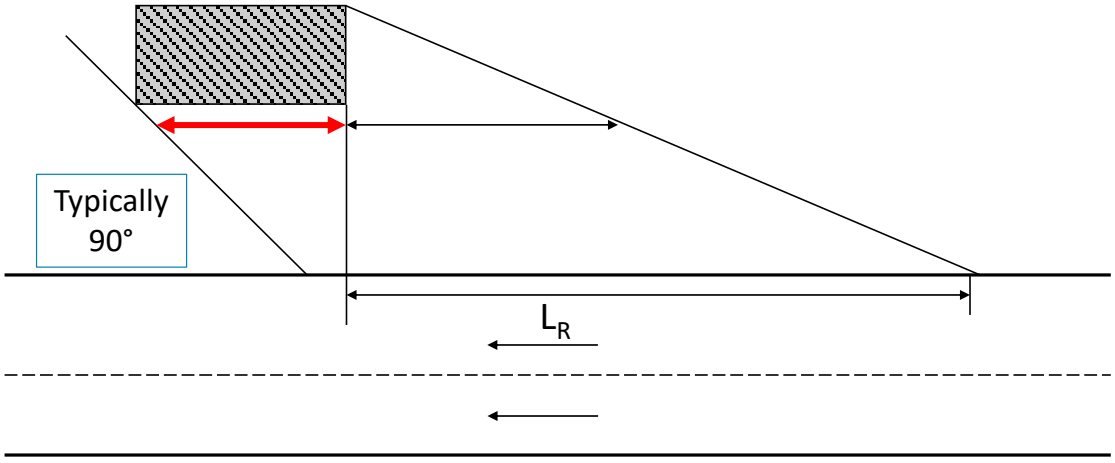
| DESIGN SPEED (MPH) | 70 | 60 | 50 | 40 |
|---|---|---|---|---|
| "L (FT.) | 150' | 125' | 100' | 75' |

DETAIL 3 – 2C

**These are quite short compared to AASHTO**

## Downstream Termination One Direction Traffic

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






## 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
CLARIDGE NURSERY
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 4
4-54

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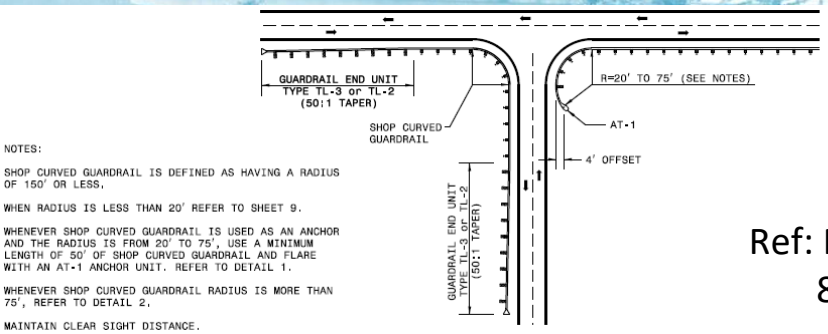
# Guardrail Placement at Intersections




NOTES:

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

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

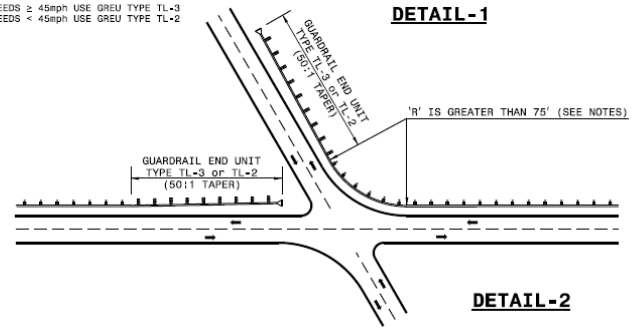
WHENEVER SHOP CURVED GUARDRAIL IS USED AS AN ANCHOR AND THE RADIUS IS FROM 20' TO 75', USE A MINIMUM LENGTH OF 50' OF SHOP CURVED GUARDRAIL AND FLARE WITH AN AT-1 ANCHOR UNIT. REFER TO DETAIL 1.

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



_____

_____

Test 3:33 on a 2:1 Slope at **50 mph** ONLY

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NCDOT
Welcome To
NORTH CAROLINA
STATE LINE
Session 4
4-57

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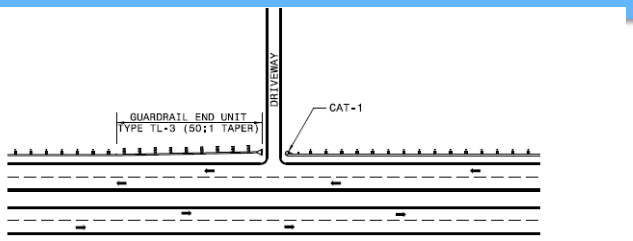
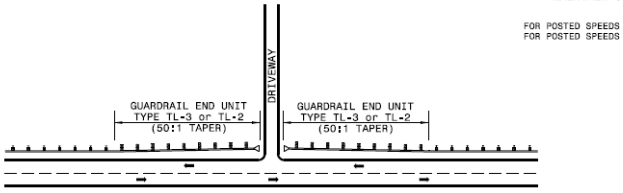
# Guardrail Placement at Driveways




**DETAIL-3**
DIVIDED HIGHWAY

NOTE: USE DETAIL
20' OR LAR(
BE UTILIZE
MAINTAIN C

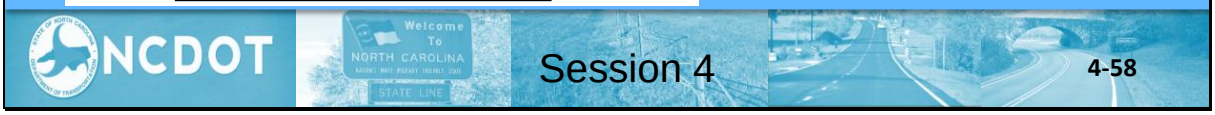
FOR POSTED SPEEDS
FOR POSTED SPEEDS




**DETAIL-4**
UNDIVIDED HIGHWAY

**GUARDRAIL TREATMENT AT DRIVEWAYS**

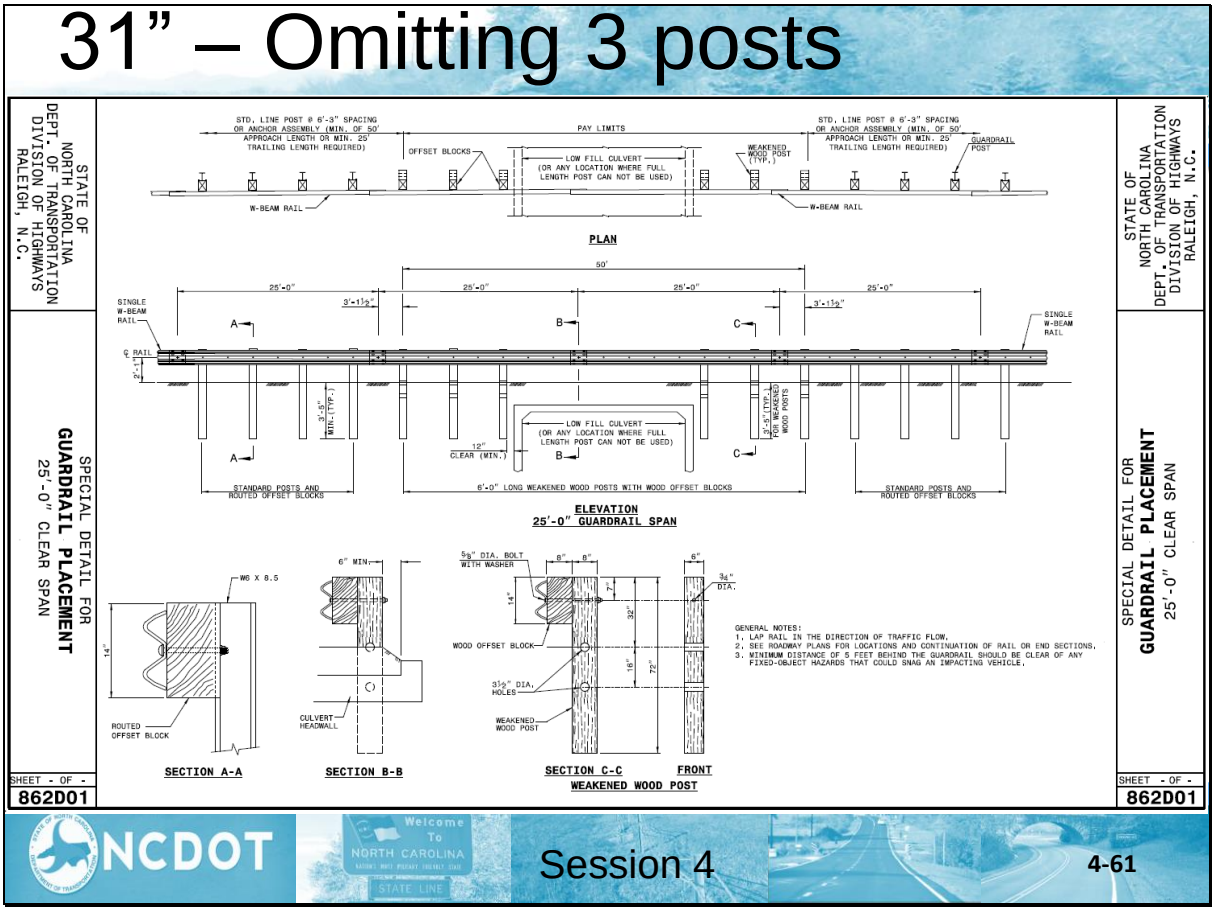
Ref: NCDOT Standard 862.01, Sht 9

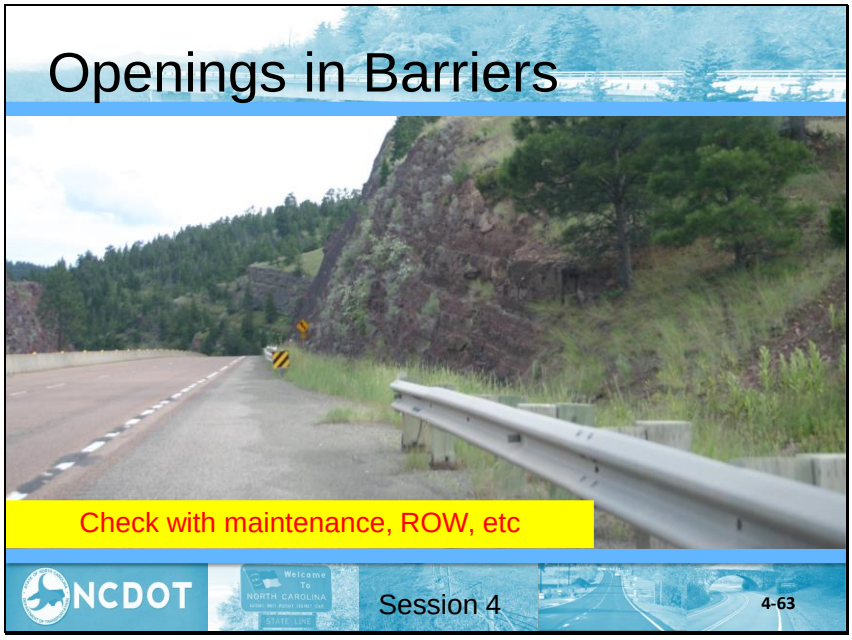


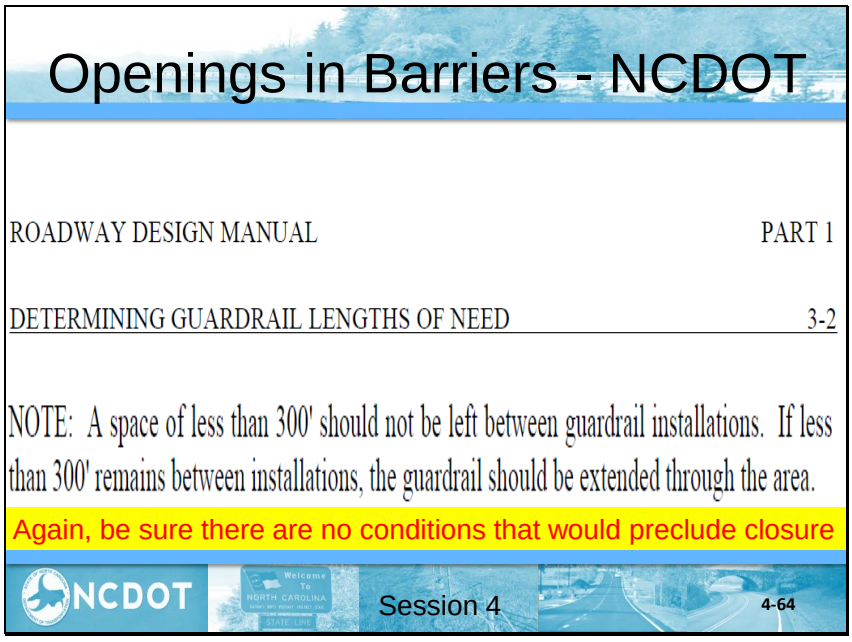

Omitting posts – old 29” guardrail
NCDOT
Session 4
4-59


31” – Omitting 3 posts
Video Clip
Working Width - 94”
Eligibility Letter B-189
NCDOT
Session 4
4-60

# 31” – Omitting 3 posts





Openings in Barriers
Check with maintenance, ROW, etc
NCDOT
Session 4
4-63


Openings in Barriers - NCDOT
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
NCDOT
Session 4
4-64

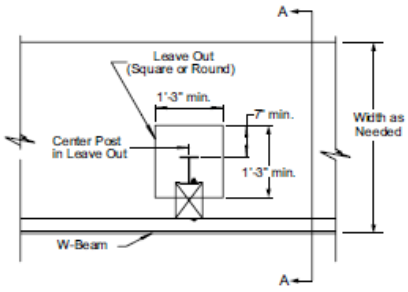
## Extra Offset Blocks – National Guidance

- 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.

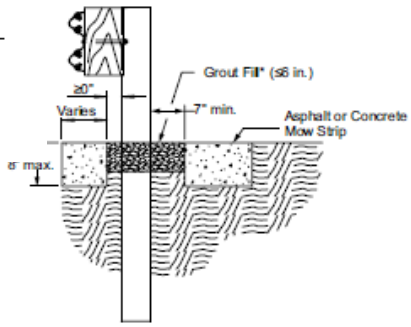
Ref: AASHTO Roadside Design Guide – 3rd Edition, Section 5.4.1.6



## Leaveouts in Structural Pavement



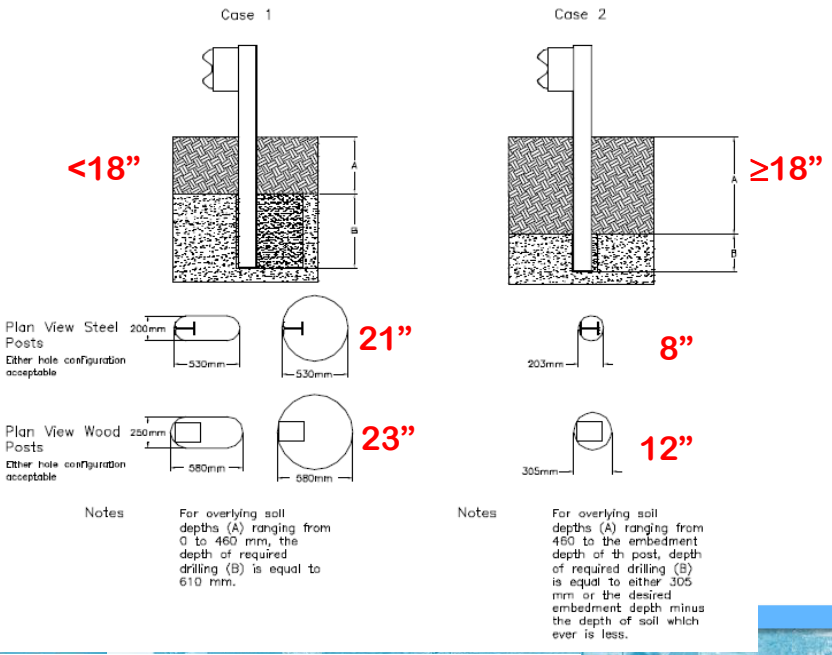

Steel Post Detail




Section A-A

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

# Guardrail Posts in Rock - AASHTO




Eligibility Letter B-64B

4-67

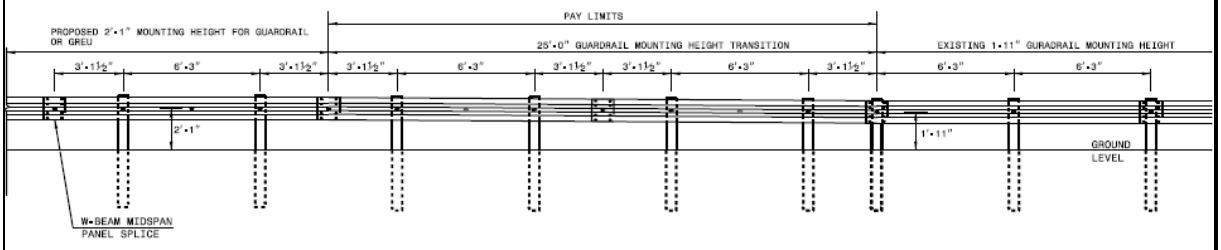
# Guardrail Posts in Rock - NCDOT

**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**

| 862.02 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. |
|---|---|---|

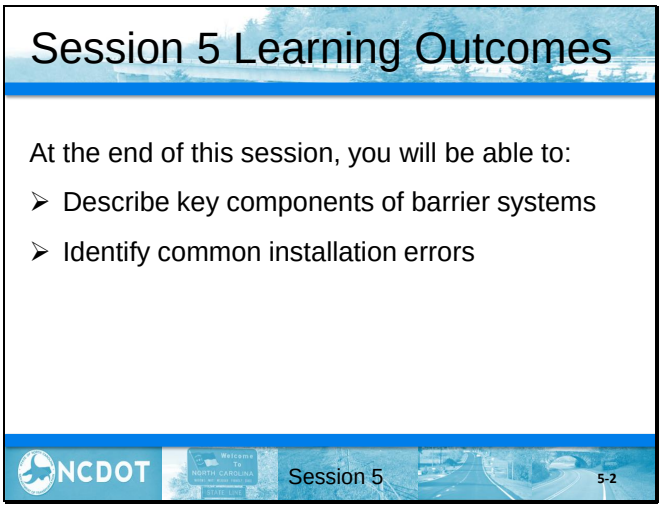


## Review Learning Outcomes

- Understand the design principles affecting an optimal barrier installation
- Apply a field procedure to check Length of Need
- Be familiar with special designs to address site-specific installation considerations

# Session 5: Installation/Common Errors of Systems


North Carolina Department of Transportation
Highway Safety Barrier Installation Training
Session 5:
Installation/Common
Errors of System
NCDOT
Session 5
5-1


Session 5 Learning Outcomes
At the end of this session, you will be able to:
Describe key components of barrier systems
Identify common installation errors
NCDOT
Session 5
5-2

# Barrier Components

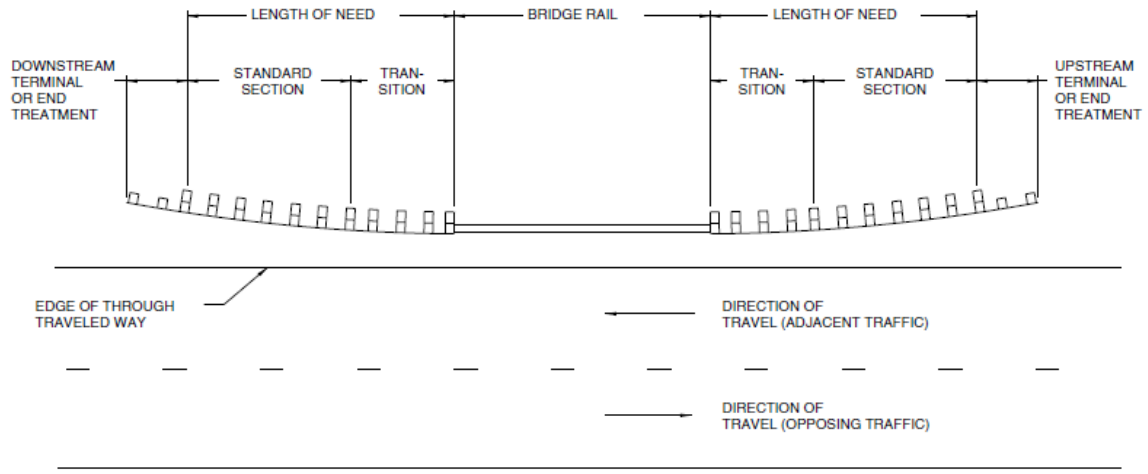



**Figure 5-4. Definition of Roadside Barriers**

REF: AASHTO Roadside Design Guide, 4th Edition, Figure 5-4

NCDOT Session 5 5-3

## Key Components of Barrier Systems

1. Standard Run of Barrier
2. Transition to a Stiffer System
3. End Treatment
4. Impact Attenuator

NCDOT Session 5 5-4

## 1. Standard Run of Barrier

a. Barrier Design Principles
b. Height Measurement
c. Tension Continuity
d. Other Considerations
e. Barriers in Work Zones

NCDOT Session 5 5-5

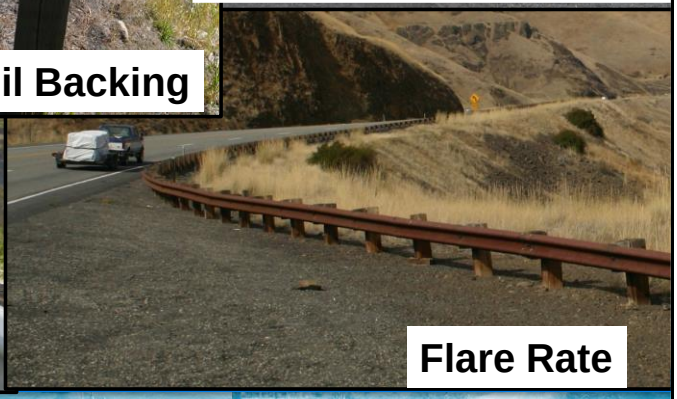
## a. Barrier Design Principles


Deflection


Soil Backing


Slope in Front of Barrier

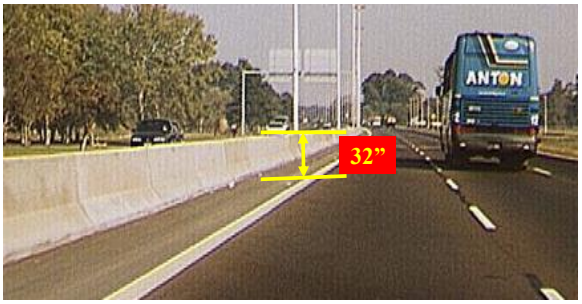

Barriers and Curbs


Flare Rate

NCDOT Session 5 5-6

## b. Height Measurement

- Concrete Barrier Standards
  - Roadside & Median Barrier - 32” Jersey shape from Finished Grade (46” for Type T)




NCDOT Session 5 5-7

## b. Height Measurement

- High Tension Cable Barrier
  - Dependent on Manufactured System

NCDOT Session 5 5-8

## b. Height Measurement

- High Tension Cable Barrier
  - If the agency uses foundations, insure top is at proper height. This will effect the height of the cable.

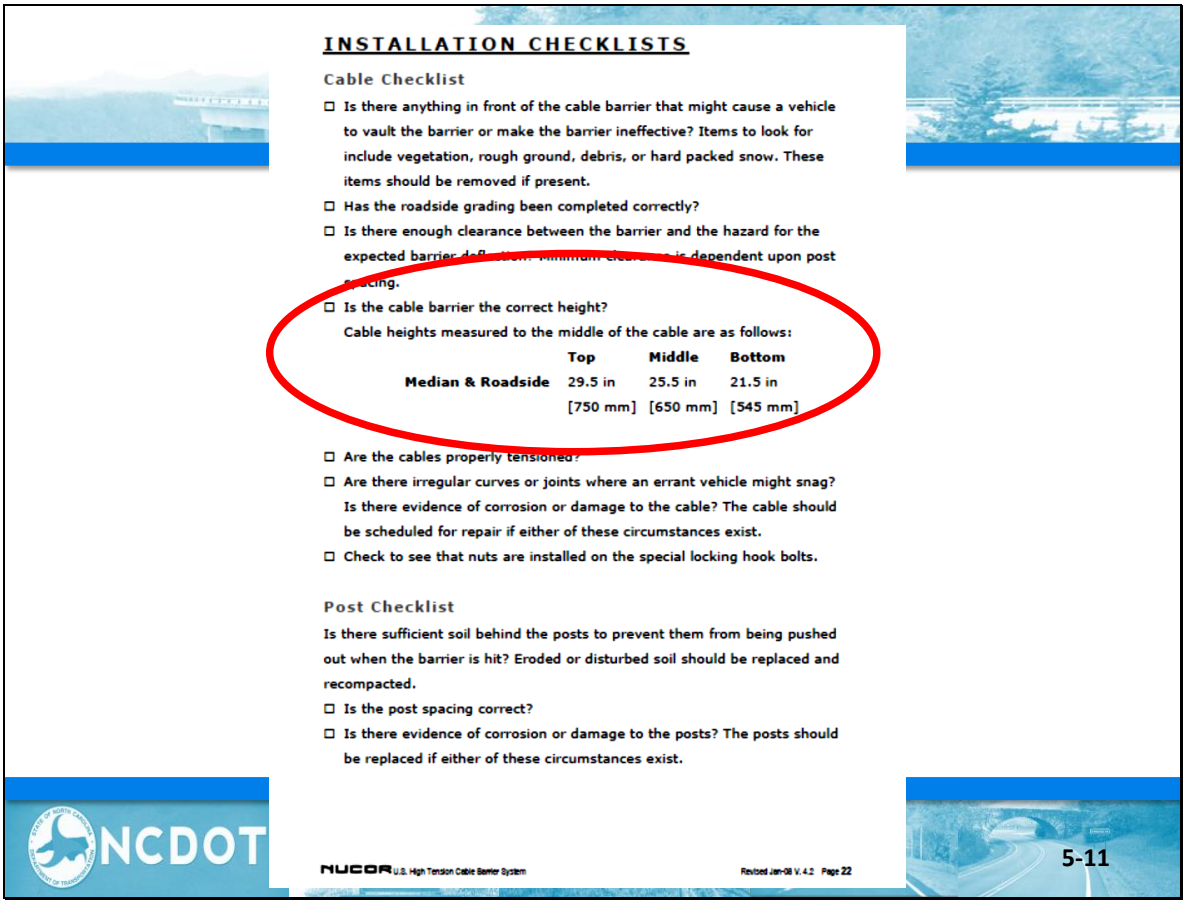


NCDOT Session 5 5-9

## High Tension Cable Systems

- The installation requirements are specific to the manufacturer. Referral to the manufacturer's installation manual is essential.
- The next slide shows an example of a installation checklist from a manufacturer's manual.

NCDOT Session 5 5-10

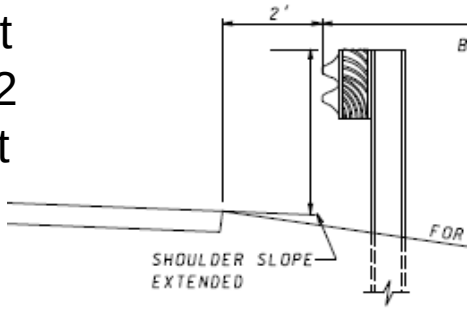

INSTALLATION CHECKLISTS
Cable Checklist
☐ Is there anything in front of the cable barrier that might cause a vehicle to vault the barrier or make the barrier ineffective? Items to look for include vegetation, rough ground, debris, or hard packed snow. These items should be removed if present.
☐ Has the roadside grading been completed correctly?
☐ Is there enough clearance between the barrier and the hazard for the expected barrier deflection? Minimum clearance is dependent upon post spacing.
☐ Is the cable barrier the correct height?
Cable heights measured to the middle of the cable are as follows:
Top Middle Bottom
Median & Roadside 29.5 in 25.5 in 21.5 in
[750 mm] [650 mm] [545 mm]
☐ Are the cables properly tensioned?
☐ Are there irregular curves or joints where an errant vehicle might snag? Is there evidence of corrosion or damage to the cable? The cable should be scheduled for repair if either of these circumstances exist.
☐ Check to see that nuts are installed on the special locking hook bolts.
Post Checklist
Is there sufficient soil behind the posts to prevent them from being pushed out when the barrier is hit? Eroded or disturbed soil should be replaced and recompacted.
☐ Is the post spacing correct?
☐ Is there evidence of corrosion or damage to the posts? The posts should be replaced if either of these circumstances exist.
NCDOT
NUCOR U.S. High Tension Cable Barrier System
Revised Jan-08 V. 4.2 Page 22
5-11

# Old Guardrail - Height Measurement

For slopes 10:1 or flatter, the height is measured from the ground directly beneath the rail

For slopes steeper than 10:1 but no steeper than 6:1, and within 2 feet of the breakpoint, the height is measured from the shoulder slope extended as shown

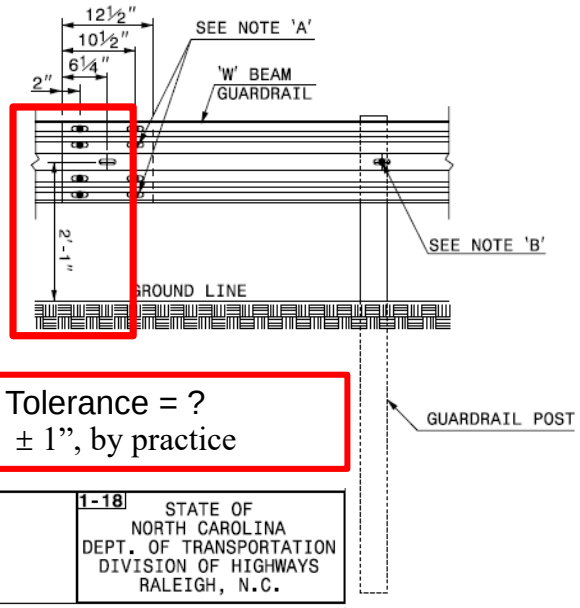
**Only for the 27 3/4" Guardrail**




PLACEMENT ON SLOPE

# 31” W-Beam Height Measurement

- 31” W-Beam




Remember: our terminology is referring to TOP of Rail

Ground slope is 10:1 or FLATTER

Tolerance = ?
± 1”, by practice

862.02 SHEET 5 OF 8

ROADWAY STANDARD DRAWING FOR
**GUARDRAIL INSTALLATION**

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

NCDOT

Session 5

5-13

# b. Height Measurement

**Rail too high**

**Rail too low**

NCDOT

Session 5

5-14

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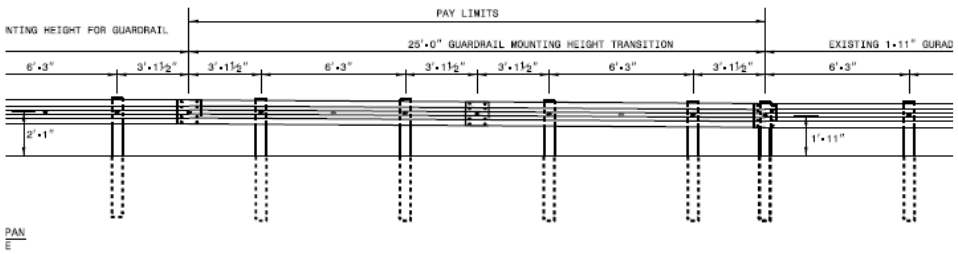
# b. Height Transition Measurement



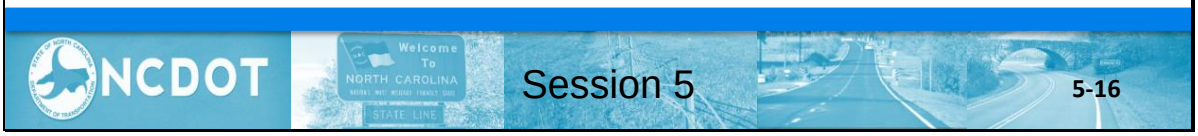

**ELEVATION VIEW**

**NOTE: IF EXISTING GUARDRAIL IS LOWER THAN 1'-11", USE AN ADDITIONAL 12'-6" LONG SECTION OF GUARDRAIL. FOR EVERY 1" OF HEIGHT DIFFERENCE, TO TRANSITION FROM EXISTING GUARDRAIL TO PROPOSED 2'-1" GUARDRAIL**

| 862.02 SHEET 4 OF 8 | ROADWAY STANDARD DRAWING FOR **GUARDRAIL INSTALLATION** |
|---|---|

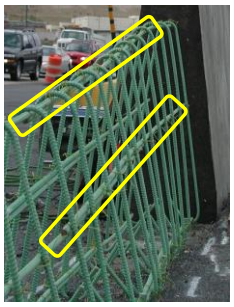
# c. Tension Continuity

- Concrete Barrier
  - Continuous reinforcement and/or anchored to/in the pavement, and for PCB, the connection pin and loops
- W-Beam
  - Splices with 8 bolts tying panels together, and some type of end anchor or structural tie to a rigid object/bridge rail (transition)
- High Tension Cable
  - Proprietary systems typically use a type of turn buckle between successive cables and end terminal anchors.



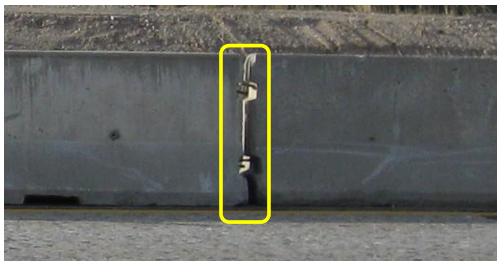
## c. Tension Continuity

Cast In Place Concrete Barrier



Horizontal bars maintain continuity for cast in place barrier

Precast Concrete Barrier



Missing connection pin
NO TENSION

NCDOT Session 5 5-17

## c. Tension Continuity

- W-Beam
  - 8 bolts tying panels together
  - structural connection to a rigid barrier with 4 (min) thru bolts

NCDOT Session 5 5-18

## c. Tension Continuity

- Thrie Beam Connection
  - 5 bolts required for a structural connection to a rigid barrier

NCDOT Session 5 5-19

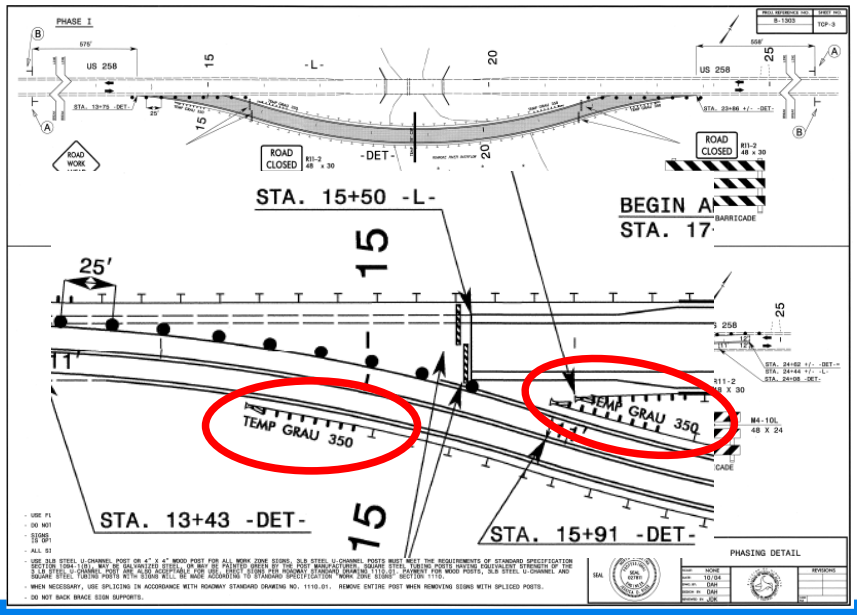
## c. Tension Continuity

Missing bolts

No Structural connection

NCDOT Session 5 5-20

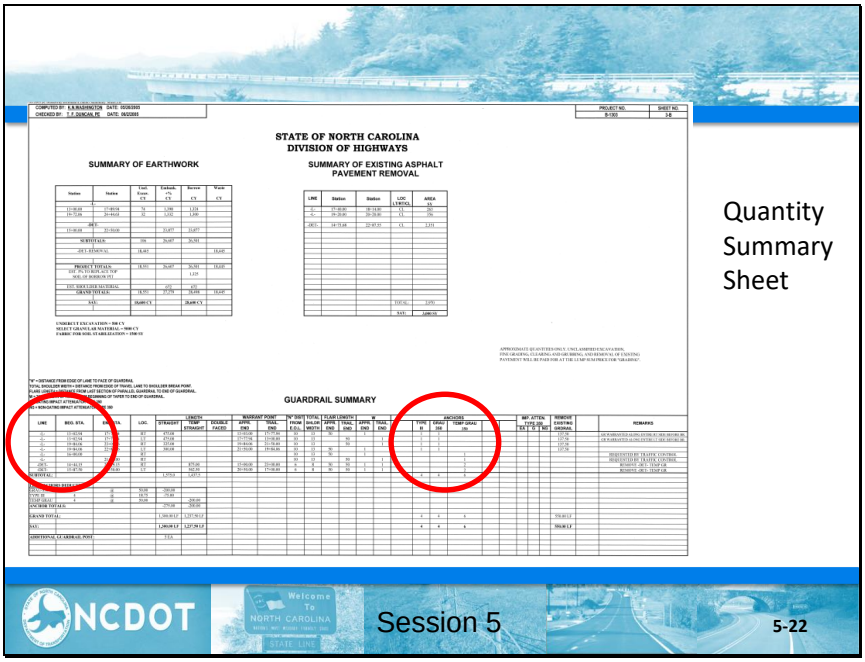
# Temporary Barrier – Need for Tension




Traffic Management Plan



Participant Notebook Page 5-14




## Quantity Summary Sheet – blow-up

| LINE | BEG. STA. | END STA. |
|---|---|---|
| -L- | 13+02.94 | 17+77.94 |
| -L- | 13+02.94 | 17+77.94 |
| -L- | 19+84.06 | 23+09.06 |
| -L- | 19+84.06 | 22+84.06 |
| -L- | 16+00.00 | |
| -L- | | 21+50.00 |
| -DET- | 14+44.15 | 23+09.15 |
| -DET- | 15+87.50 | 23+50.00 |
| SUBTOTAL: | | |

| W | | 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)

# d. Other Considerations

- Lapping
  - For one-way traffic, all guardrail panels should be lapped in the direction of traffic with the upstream panel lapping the downstream panel including terminal elements and end sections. (Some exceptions, i.e. CAT)
  - For two-way traffic always mount guardrail going with adjacent traffic, meaning rail laps will be opposite on each side of the road.

Structural Anchor Standards reference “LAP”

## d. Other Considerations

Correctly Lapped

NCDOT Session 5 5-25

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_____

## d. Other Considerations

**Typically NO WASHERS**
**Unless called for in the plans**

NCDOT Session 5 5-26

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## d. Other Considerations

Valley delineators could impede the bolt head pulling thru rail

NCDOT Session 5 5-27

## d. Other Considerations

Drilling of holes into the rail FOR THE RAIL TO POST CONNECTION is not recommended.

Better to bolt offset block to post, no rail attachment, for one or two consecutive posts.

NCDOT Session 5 5-28

## d. Other Considerations

**Cutting a slot, hole or a rail section with a torch is NOT PERMISSIBLE**

Using a torch on the rail element may compromise the strength of the rail.

Tests results have shown this becomes a weak point in the rail and can cause ripping and rupturing.

NCDOT Session 5 5-29

## e. Barriers in Work Zones

Barrier should be in GOOD condition

NCDOT Session 5 5-30

## e. Barriers in Work Zones

Flare rate appears to be too excessive here

NCDOT Session 5 5-31

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## 2. Transition

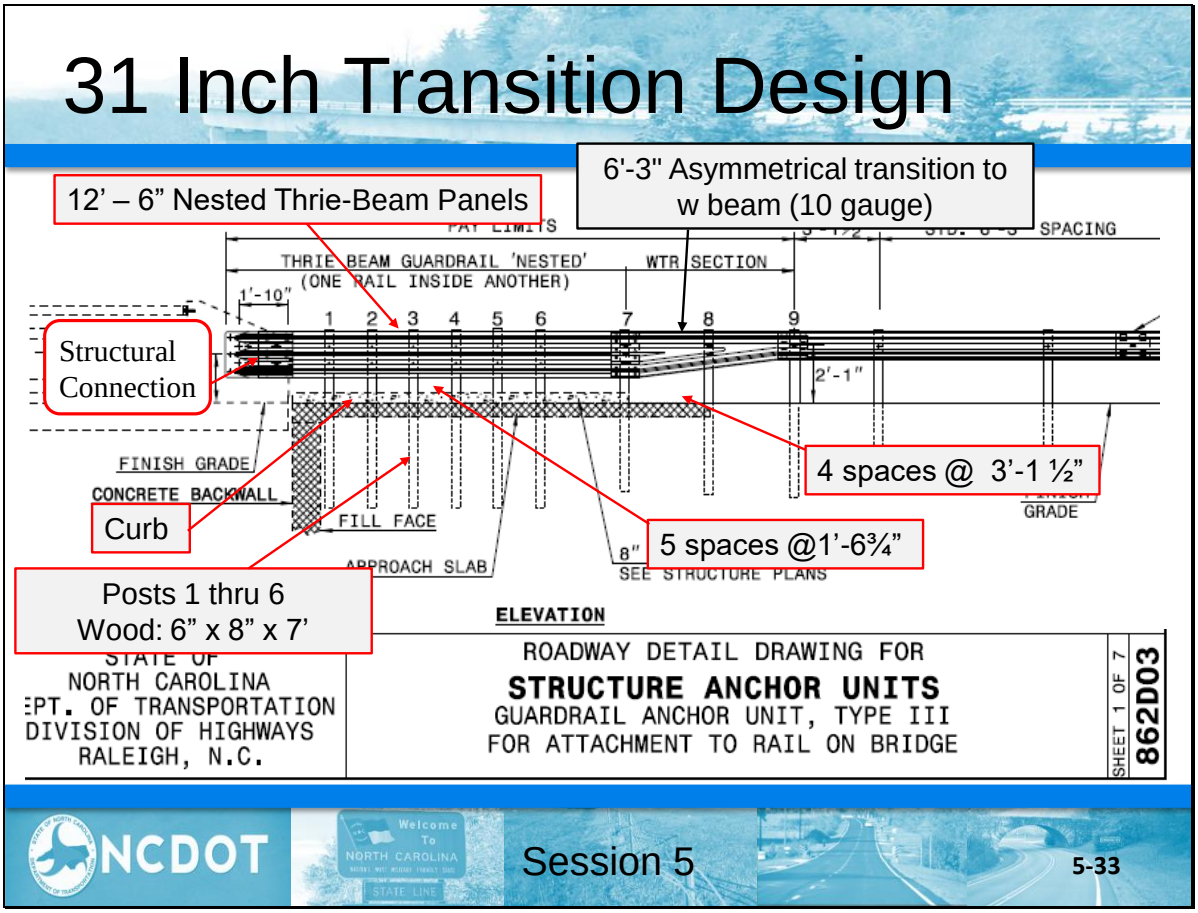
Old 29” Guardrail Standard

NCDOT Session 5 5-32

_____

_____

# 31 Inch Transition Design



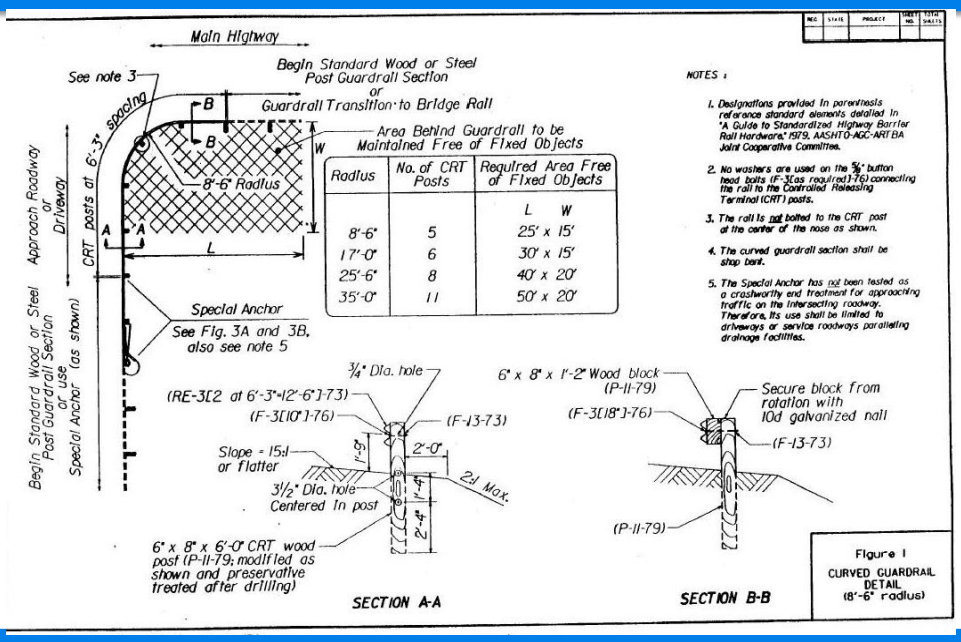

NCDOT Session 5 5-33

## Transition

Structural Connection

NCDOT Session 5 5-34

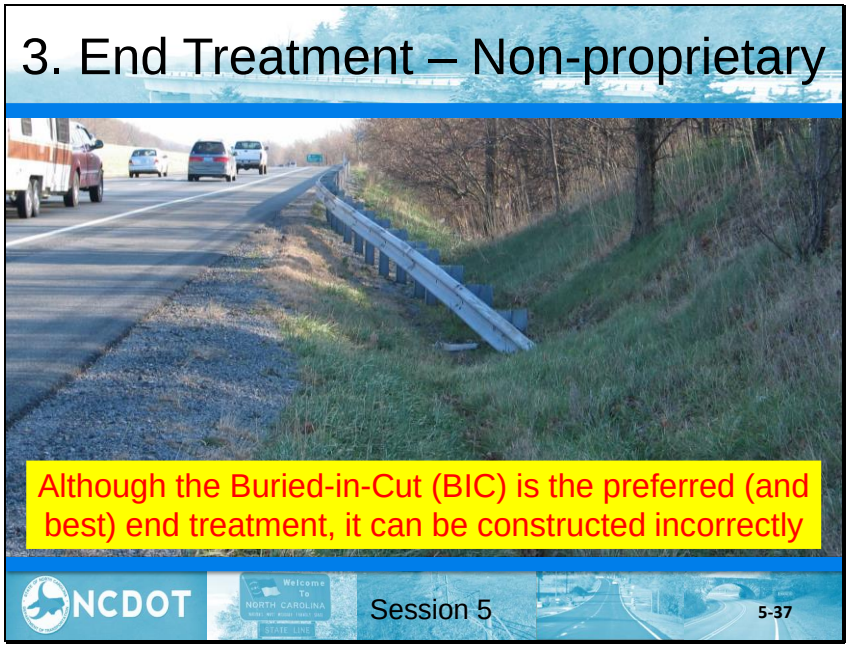
# Special Barrier Design – at Access

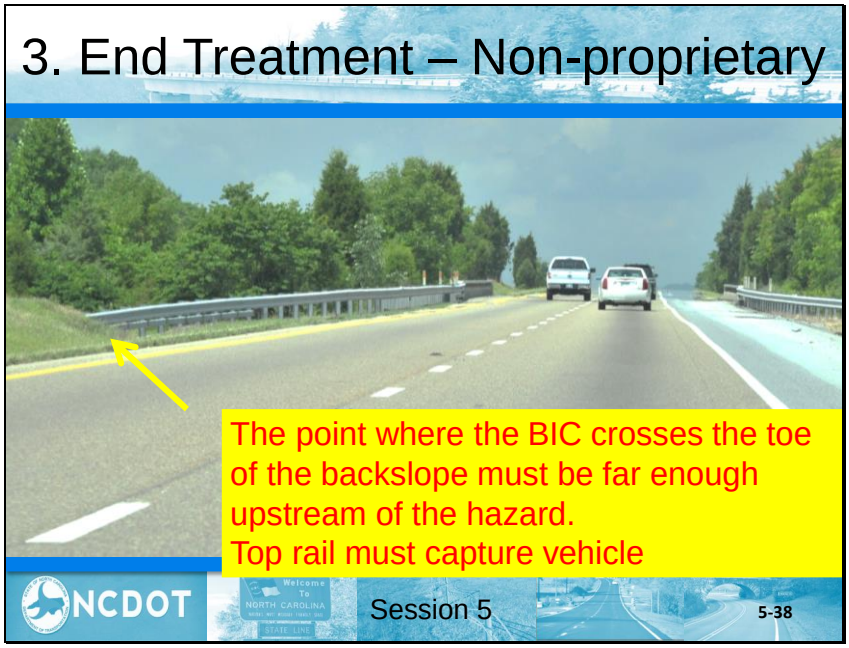





## 3. End Treatments

a. Manufacturers Manuals
b. Post types
c. Panel requirements
d. Grading
e. Breakaway Cable **Anchorage**
f. Other Common Errors
g. Delineation


3. End Treatment – Non-proprietary
Although the Buried-in-Cut (BIC) is the preferred (and best) end treatment, it can be constructed incorrectly
NCDOT
Session 5
5-37


3. End Treatment – Non-proprietary
The point where the BIC crosses the toe of the backslope must be far enough upstream of the hazard.
Top rail must capture vehicle
NCDOT
Session 5
5-38

## 3. End Treatment

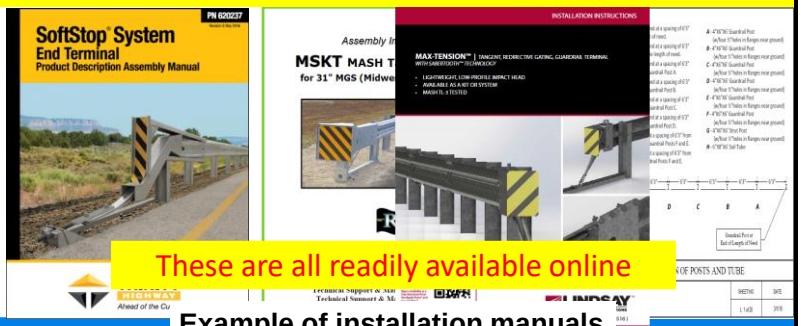
**RULE #1: Follow manufacturers instructions and standard plans.**

NCDOT Session 5 5-39

## 3. End Treatment

a. Manufacturers Manuals

Must follow manufacturer's installation instructions and State standards.




These are all readily available online

**Example of installation manuals**

NCDOT Session 5 5-40

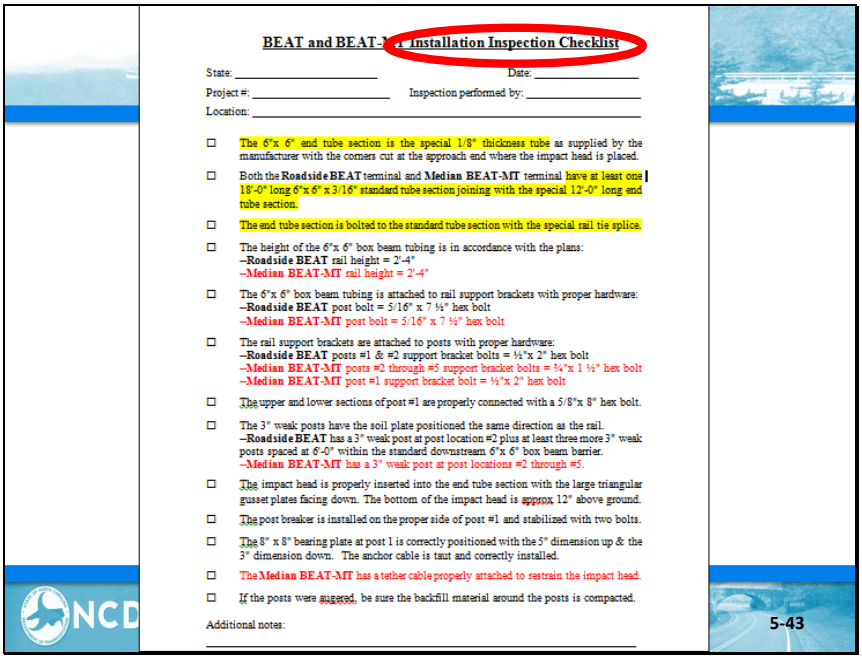
**TAKE ADVANTAGE OF MANUFACTURER TRAINING FOR DETAILED INSTRUCTION ON INSTALLING ANY OF THE PROPRIETARY END TREATMENTS**



# Additional Resources

- Manufacturers website – online training, installation manuals, etc.
- Maine DOT's Guardrail Inspection Series videos http://www.dot.state.mn.us/design/roadsidesafety/links.html


FLEAT and SRT videos are also available



**BEAT and BEAT-MT Installation Inspection Checklist**

State: _____ Date: _____

Project #: _____ Inspection performed by: _____

Location: _____

- ☐ The 6"x 6" end tube section is the special 1/8" thickness tube as supplied by the manufacturer with the corners cut at the approach end where the impact head is placed.
- ☐ Both the **Roadside BEAT** terminal and **Median BEAT-MT** terminal have at least one 18'-0" long 6"x 6" x 3/16" standard tube section joining with the special 12'-0" long end tube section.
- ☐ The end tube section is bolted to the standard tube section with the special rail tie splice.
- ☐ The height of the 6"x 6" box beam tubing is in accordance with the plans:
  –**Roadside BEAT** rail height = 2'-4"
  –**Median BEAT-MT** rail height = 2'-4"
- ☐ The 6"x 6" box beam tubing is attached to rail support brackets with proper hardware:
  –**Roadside BEAT** post bolt = 5/16" x 7 ½" hex bolt
  –**Median BEAT-MT** post bolt = 5/16" x 7 ½" hex bolt
- ☐ The rail support brackets are attached to posts with proper hardware:
  –**Roadside BEAT** posts #1 & #2 support bracket bolts = ½"x 2" hex bolt
  –**Median BEAT-MT** posts #2 through #5 support bracket bolts = ¾"x 1 ½" hex bolt
  –**Median BEAT-MT** post #1 support bracket bolt = ½"x 2" hex bolt
- ☐ The upper and lower sections of post #1 are properly connected with a 5/8"x 8" hex bolt.
- ☐ The 3" weak posts have the soil plate positioned the same direction as the rail.
  –**Roadside BEAT** has a 3" weak post at post location #2 plus at least three more 3" weak posts spaced at 6'-0" within the standard downstream 6"x 6" box beam barrier.
  –**Median BEAT-MT** has a 3" weak post at post locations #2 through #5.
- ☐ The impact head is properly inserted into the end tube section with the large triangular gusset plates facing down. The bottom of the impact head is approx. 12" above ground.
- ☐ The post breaker is installed on the proper side of post #1 and stabilized with two bolts.
- ☐ The 8" x 8" bearing plate at post 1 is correctly positioned with the 5" dimension up & the 3" dimension down. The anchor cable is taut and correctly installed.
- ☐ The **Median BEAT-MT** has a tether cable properly attached to restrain the impact head.
- ☐ If the posts were augered, be sure the backfill material around the posts is compacted.

Additional notes: _____

5-43

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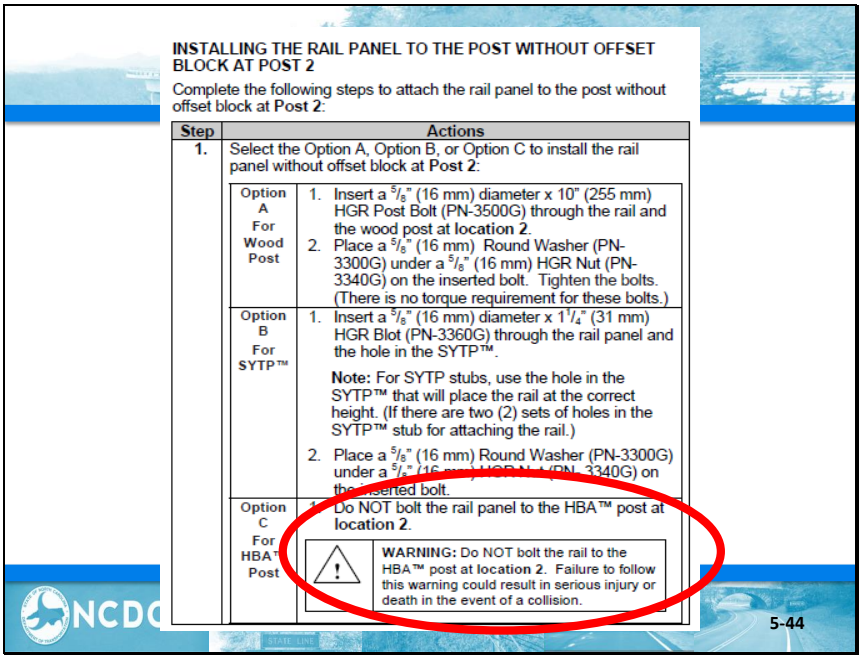

**INSTALLING THE RAIL PANEL TO THE POST WITHOUT OFFSET BLOCK AT POST 2**

Complete the following steps to attach the rail panel to the post without offset block at **Post 2**:

| Step | Actions |
|---|---|
| 1. | Select the Option A, Option B, or Option C to install the rail panel without offset block at **Post 2**: |
| | **Option A For Wood Post**<br>1. Insert a $^{5}/_{8}$" (16 mm) diameter x 10" (255 mm) HGR Post Bolt (PN-3500G) through the rail and the wood post at **location 2**.<br>2. Place a $^{5}/_{8}$" (16 mm) Round Washer (PN-3300G) under a $^{5}/_{8}$" (16 mm) HGR Nut (PN-3340G) on the inserted bolt. Tighten the bolts. (There is no torque requirement for these bolts.) |
| | **Option B For SYTP™**<br>1. Insert a $^{5}/_{8}$" (16 mm) diameter x $1^{1}/_{4}$" (31 mm) HGR Blot (PN-3360G) through the rail panel and the hole in the SYTP™.<br>**Note:** For SYTP stubs, use the hole in the SYTP™ that will place the rail at the correct height. (If there are two (2) sets of holes in the SYTP™ stub for attaching the rail.)<br>2. Place a $^{5}/_{8}$" (16 mm) Round Washer (PN-3300G) under a $^{5}/_{8}$" (16 mm) HGR Nut (PN-3340G) on the inserted bolt. |
| | **Option C For HBA™ Post**<br>1. Do NOT bolt the rail panel to the HBA™ post at **location 2**.<br>**WARNING:** Do NOT bolt the rail to the HBA™ post at **location 2**. Failure to follow this warning could result in serious injury or death in the event of a collision. |

5-44

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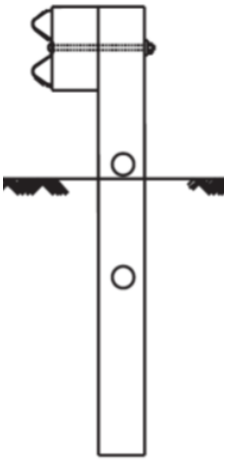
# 3. End Treatment

## b. Post Types

Each manufacturer may have several different types of post, even for the same system - both currently approved and previously used.

Must consult with the installation manual of the specific model being worked with for proper post type.

Only one generic special post for terminals – the CRT post with large holes to weaken it.



**Controlled Release Terminal (CRT) Post**

## 3. End Treatment

c. Panel Types

Each system may have one or more different rail panels.

Must consult with the installation manual of the specific system for proper panel type



## 3. End Treatment

c. Panel Types

SRT Rail with a FLEAT impact head

## 3. End Treatment

d. Grading

Check grading compliance with Standard Drawing (or plan details).

Check grading material for proper density. (Material must be compacted so it won't erode.)

NCDOT Session 5 5-48

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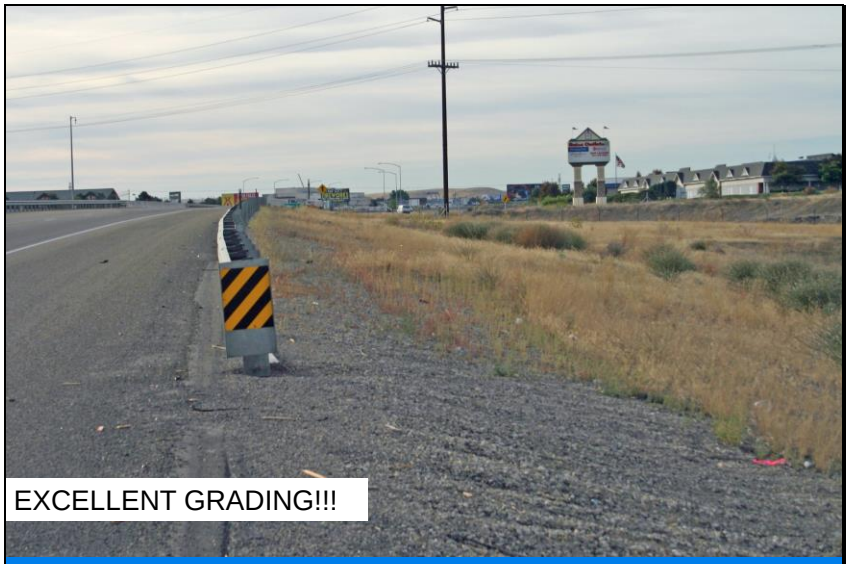

EXCELLENT GRADING!!!

NCDOT Session 5 5-49

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EXCELLENT GRADING??? What about BAD stub height?
Would have been easily made excellent
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 5
5-50

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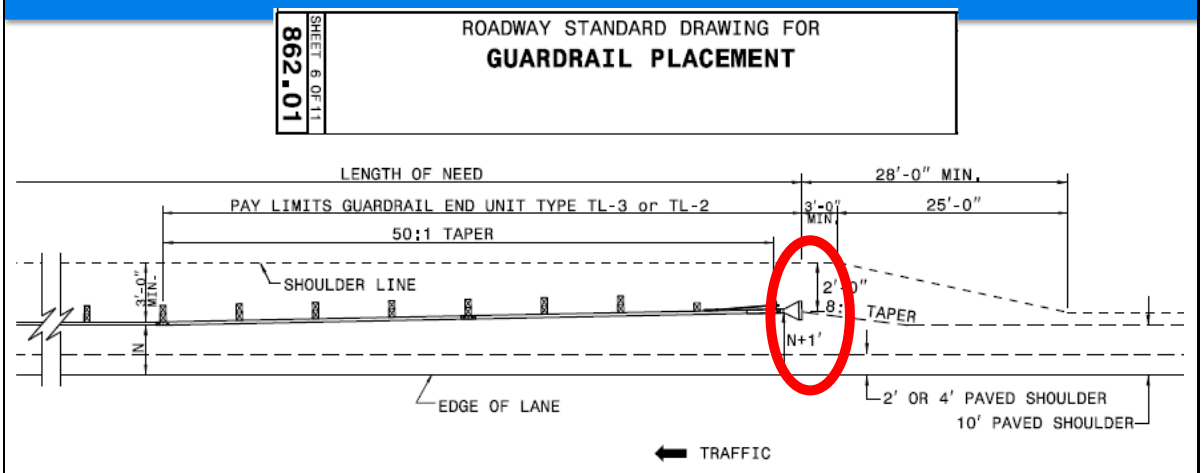
# Tangent Terminal Grading - NCDOT




Need special Borrow bid item for 3R projects

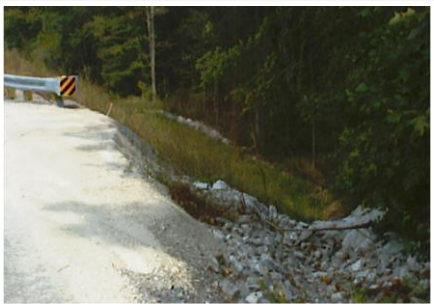
Need Special Provision for Density



## 3. End Treatment

d. Grading

*Improper Grading*



A common error with all end treatment types.

## 3. End Treatment

d. Grading

Telltales of poor grading

- Soil tubes/foundation posts installed too high
- Soil plate showing
- Strut too high

(Also bearing plate misaligned)

Common Error applies to both energy absorbing and non energy absorbing terminals

NCDOT Session 5 5-53

## Substandard Grading – DOCUMENT

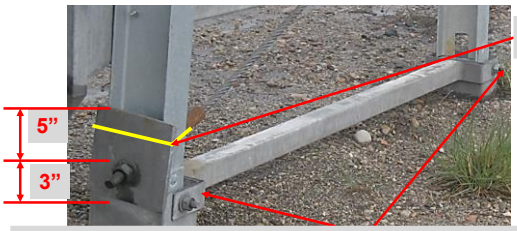
NCDOT Session 5 5-54

# 3. End Treatment

## e. Breakaway Cable Anchorage (BCA) Assembly

Bearing Plate & Strut

- Should be in up position and secured to post.
- Strut secured at posts required locations.




**Strut secured at breakaway posts 1 & 2**



# 3. End Treatment

## e. Breakaway Cable Anchorage Assembly

Wrong Bearing Plate

Missing Bearing Plate

## 3. End Treatment

e. Breakaway Cable Anchorage Assembly

Buried and upside down bearing plate – won't release

NCDOT Session 5 5-57

## 3. End Treatment

e. Breakaway Cable Anchorage Assembly

Upside down bearing plate – may not release

NCDOT Session 5 5-58

# 3. End Treatment

## e. Breakaway Cable Anchorage Assembly

Most systems require an anchor bracket and anchor cable.

- Anchor block must release from rail if system has impact head
- Non-energy absorbing system does not have to release from rail.

Energy absorbing

Non-energy absorbing



# 3. End Treatment

## e. Breakaway Cable Anchorage Assembly

- Check the type and combination of breakaway posts against the State standards and the manufacturer's instructions.
- Not all posts in all terminals use a offset block.
- Check to see that the correct cable anchor bracket is used and it is properly attached to the rail.

Wrong anchor bracket

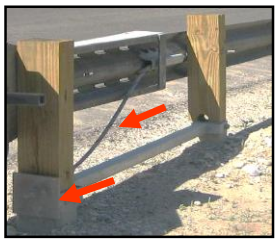
Anchor bracket not attached

# 3. End Treatment

## e. Breakaway Cable Anchorage Assembly

Anchor Cable

- Should be taut, lift up 1” or less
- Tightened by holding cable at bottom, not allowing cable twist.



NCDOT Session 5 5-61

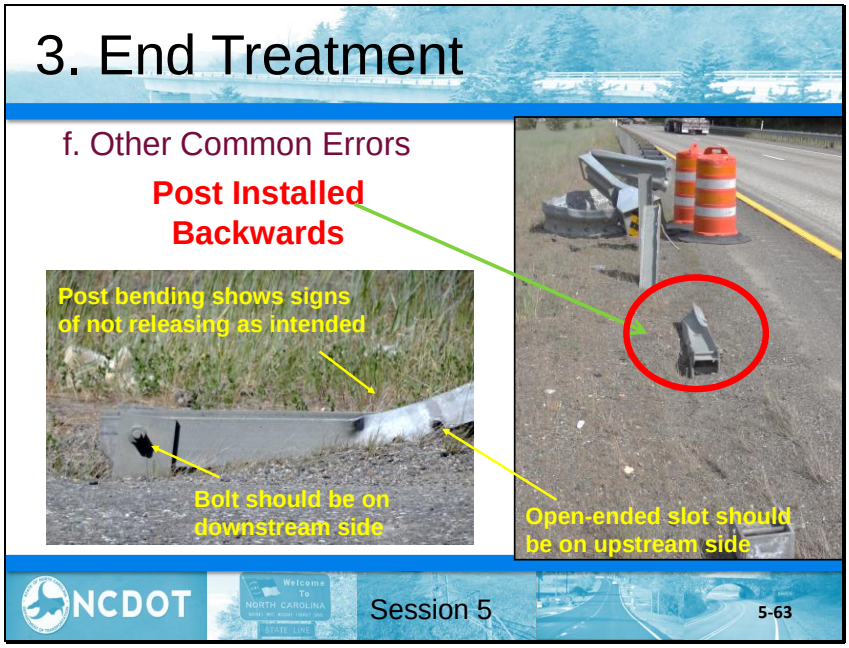
# 3. End Treatment

## f. Other Common Errors

Terminals with an impact head: the end of the first W-beam rail section should be pushed against the throat area of the impact head so the end of the rail cannot be seen.

FATAL FLAW

NCDOT Session 5 5-62


3. End Treatment
f. Other Common Errors
Post Installed Backwards
Post bending shows signs of not releasing as intended
Bolt should be on downstream side
Open-ended slot should be on upstream side
NCDOT
Session 5
5-63


3. End Treatment
f. Other Common Errors
End treatments with an impact head should be parallel* with the top of the rail.
* For Softstop see manufacturers manual
NCDOT
Session 5
5-64

## 3. End Treatment

f. Other Common Errors

Energy Absorbing (compression based) Terminals MUST be installed on a straight line

Manufacturers of Tension-based systems also require straight line

NCDOT Session 5 5-65

## 3. End Treatment

f. Other Common Errors


NCDOT Session 5 5-66

## 3. End Treatment

f. Other Common Errors

FLEAT head on SRT rail - HORRIBLE

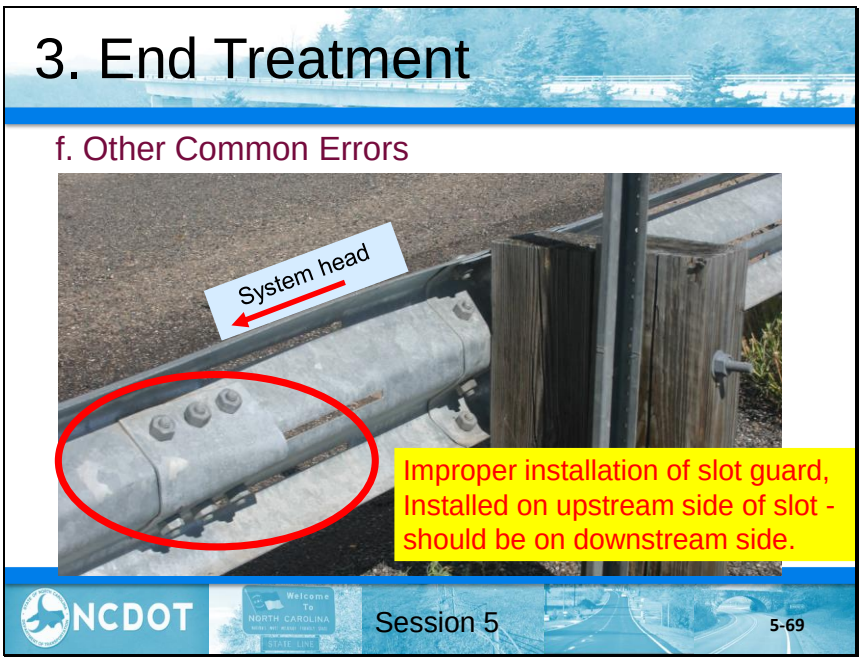
NCDOT Session 5 5-67

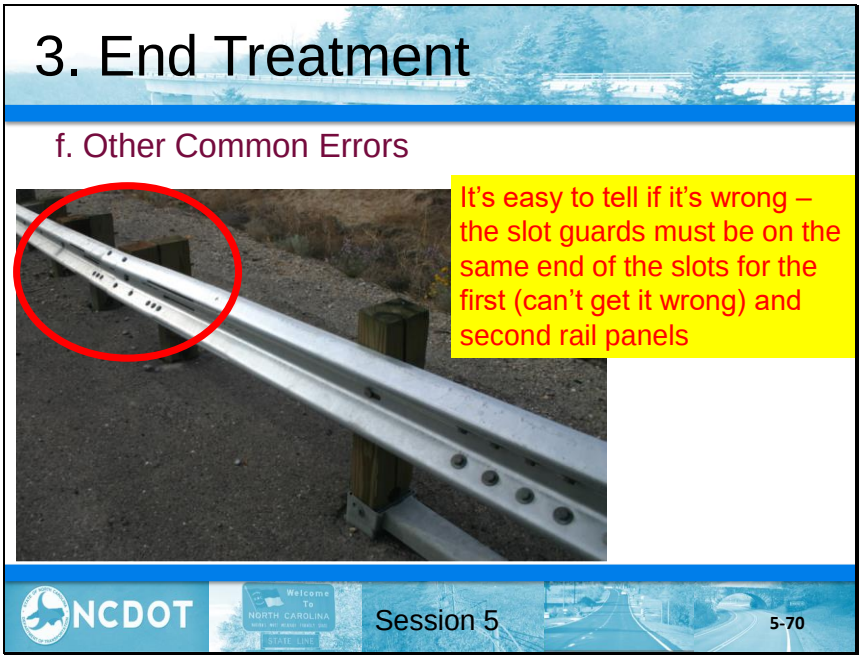
## 3. End Treatment

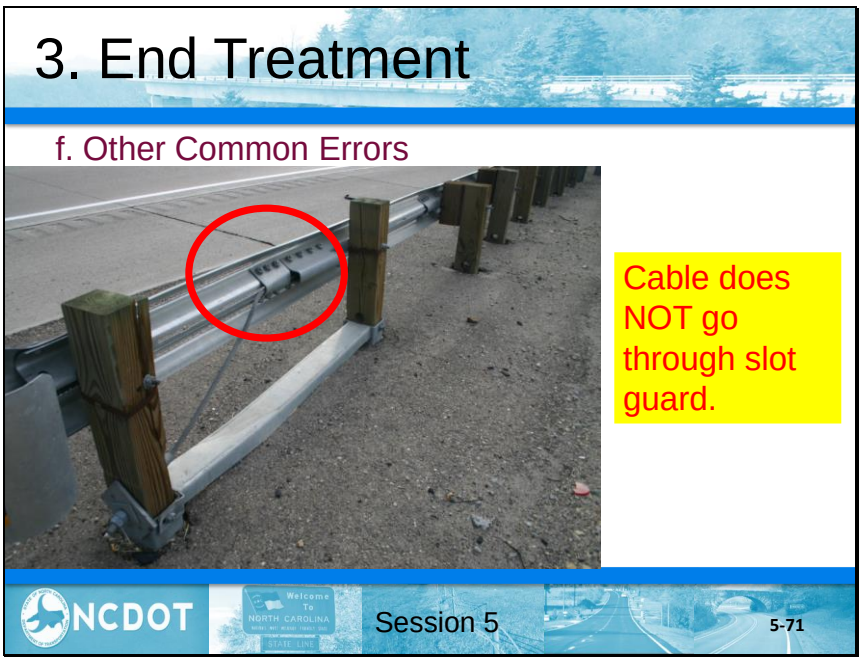
f. Other Common Errors

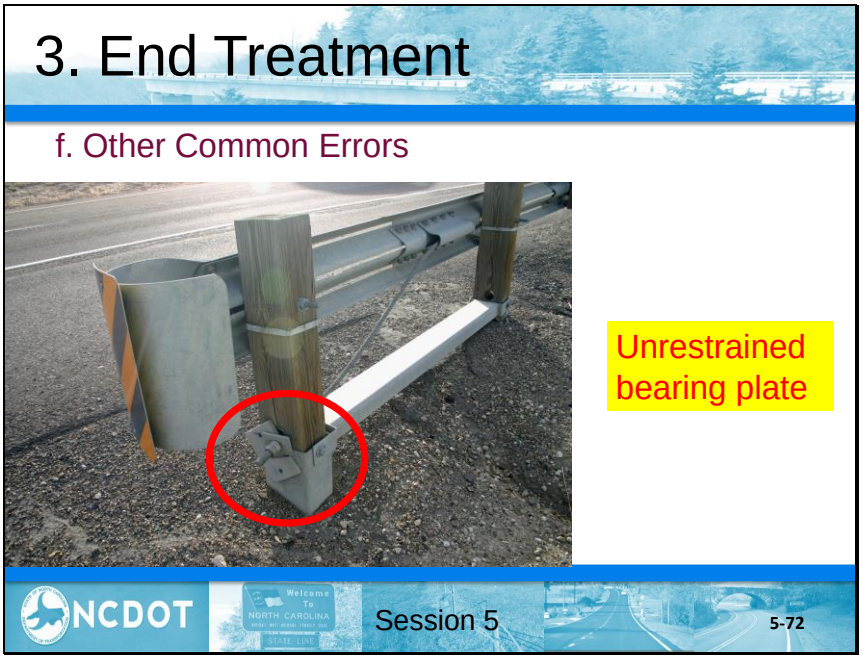
Whether construction or maintenance, never would have THREE slotted rails.

NCDOT Session 5 5-68


3. End Treatment
f. Other Common Errors
System head
Improper installation of slot guard, Installed on upstream side of slot - should be on downstream side.
NCDOT
Session 5
5-69


3. End Treatment
f. Other Common Errors
It's easy to tell if it's wrong – the slot guards must be on the same end of the slots for the first (can't get it wrong) and second rail panels
NCDOT
Session 5
5-70


3. End Treatment
f. Other Common Errors
Cable does NOT go through slot guard.
NCDOT
Session 5
5-71


3. End Treatment
f. Other Common Errors
Unrestrained bearing plate
NCDOT
Session 5
5-72

## 3. End Treatment

### f. Other Common Errors

Bolt only impact head to post #1, NOT rail panel.

- Wood Post – Lag Screws (screwed in only)
- Steel Post – Hex Bolts

Refer to manufacturer's installation instructions.

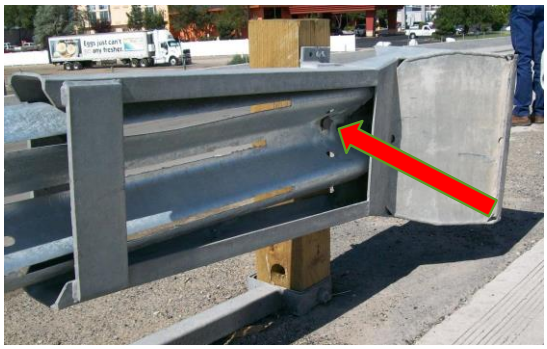
NCDOT Session 5 5-73

## 3. End Treatment

### f. Other Common Errors

**NO** rail to post connection at post 1 of systems with impact heads.

Note the WRONG rail for this terminal.



NCDOT Session 5 5-74

## 3. End Treatment

### f. Other Common Errors

DO NOT place any washers or delineators on the face of a guardrail terminal unless specifically called for or allowed in manufacturer's installation instructions

NCDOT Session 5 5-75

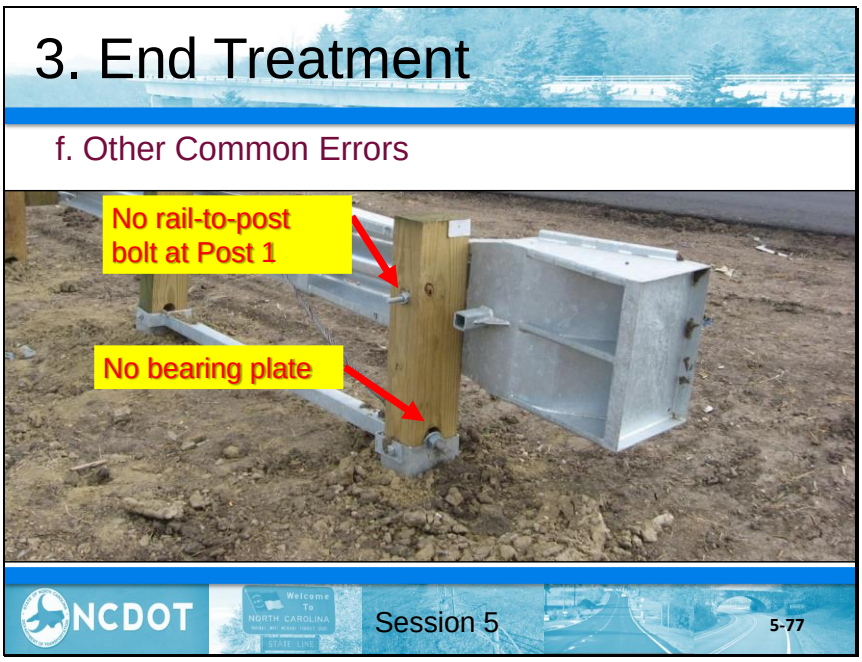
## 3. End Treatment

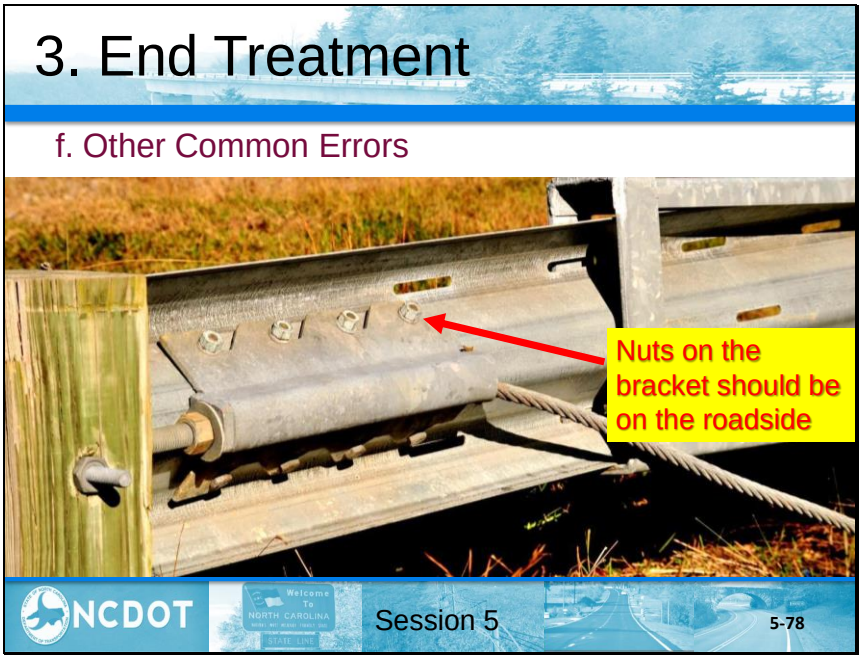
### f. Other Common Errors

Improper bolt @ post 2

Refer to manufacturer's installation instructions.

NCDOT Session 5 5-76


3. End Treatment
f. Other Common Errors
No rail-to-post bolt at Post 1
No bearing plate
NCDOT
Session 5
5-77


3. End Treatment
f. Other Common Errors
Nuts on the bracket should be on the roadside
NCDOT
Session 5
5-78

## 3. End Treatment

f. Other Common Errors

Excessive flare on a end treatment.

NCDOT Session 5 5-79

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## 3. End Treatment

f. Other Common Errors

**Improper Application** – Hazard within terminal length

NCDOT Session 5 5-80

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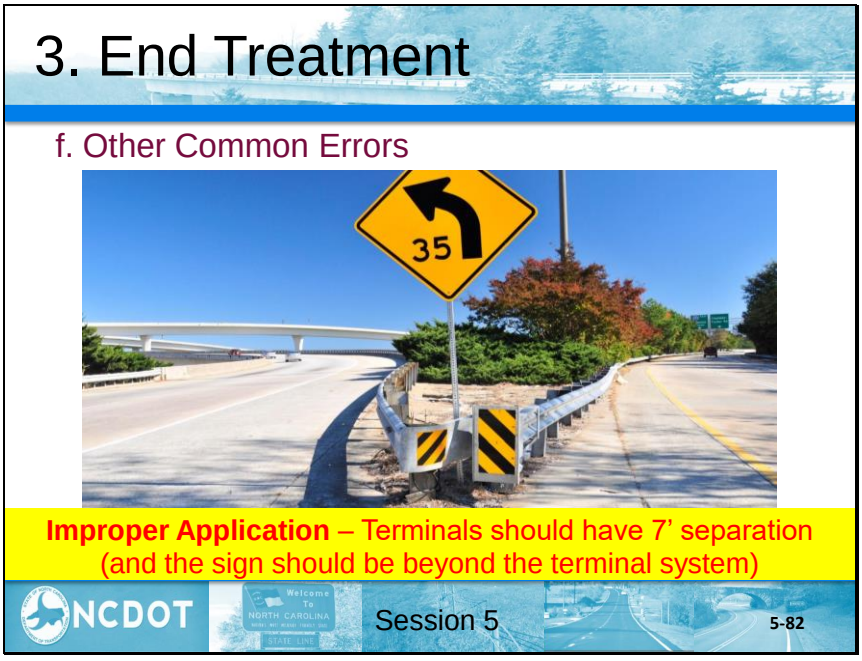
3. End Treatment
f. Other Common Errors
BIG HOLE
Improper Application – no runout for a non-energy absorbing terminal…LON (as well as grading)
NCDOT
Session 5
5-81


3. End Treatment
f. Other Common Errors
35
Improper Application – Terminals should have 7' separation (and the sign should be beyond the terminal system)
NCDOT
Session 5
5-82

## 3. End Treatment

g. Delineation



## General Details for End Treatments

- USE MANUALS
- Stub height (Desirable Grading)
- Straight Line (25:1 Flare max; NCDOT 50:1)
- Rail Lap (Absolutely for Telescoping Devices)
- No Delineators within System
- Anchor Details (ex. – SOFTSTOP strut)

Check Length of Need – Field Procedure

# 4. Impact Attenuators

a. Manufacturers Manuals
b. Grading


NCDOT Session 5 5-85

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## 4. Impact Attenuators

a. Manufacturers Manuals

Must follow manufacturer's installation instructions and State standards.



These are all readily available online

NCDOT Session 5 5-86

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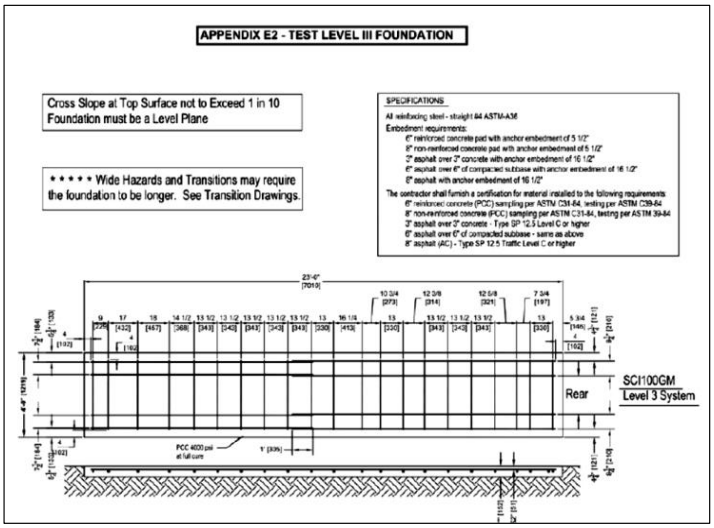
# 4. Impact Attenuators

## a. Manufacturers Manuals

Construct concrete pad if called for per manufacturer's requirements or state standards.

Clean out drilled holes WELL!!

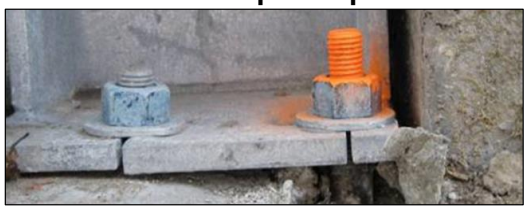


# 4. Impact Attenuators

## a. Manufacturers Manuals

- Anchor bolts are required to secure the system to concrete pad. Number of bolts and length of bolts vary with systems.
- Bolts are typically required to be epoxied into concrete pad.
- Bolts may have a torque value.

**Full bolt depth required**



**Cutting bolt prohibited**

Must follow manufacturer's installation instructions.

NCDOT Session 5 5-88

# 4. Impact Attenuators

## a. Manufacturers Manuals

- Backup varies among systems.
- May be connected to a barrier or may be a stand alone



Must follow manufacturer's installation instructions.



# 4. Impact Attenuators

## a. Manufacturers Manuals

- When system is placed in a bidirectional application a transition is required to prevent back side snagging



Must follow manufacturer's installation instructions.

# 4. Impact Attenuators

## a. Manufacturers Manuals

- Place appropriate delineation on front of system



Must follow manufacturer's installation instructions and state guidance



# 4. Impact Attenuators

## b. Grading

Grading should be so an errant vehicle impacts the system in a stabled condition – same as end treatments

**Suspect Grading**

Must follow manufacturer's installation instructions.

# 4. Impact Attenuators

Ex: results of improper torque values applied to fender panels.

Must follow manufacturer's installation instructions.

## General Details for Impact Attenuators

- **USE MANUALS**
- TRANSITION if necessary
- GRADING – 10:1 or flatter
- Clean out Foundation Holes – Brush
- Lap for Translation
- Rear Panels Must Clear Object
- Torque – per Manual
- Softer Modules in Front

NCDOT Session 5 5-94

## Review Learning Outcomes

- Describe key components of barrier systems
- Identify common installation errors

NCDOT Session 5 5-95

# Session 6: Maintenance of Systems

North Carolina Department of Transportation
**Highway Safety Barrier Installation Training**

# Session 6: Maintenance of Systems

NCDOT Session 6 6-1

## Session 6 Learning Outcomes

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

- Recognize how damaged barrier MAY BE assessed for maintenance response.
- Understand when a damaged barrier end treatment MAY no longer function.
- Effectively delineate/treatment of damaged hardware prior to repair.

NCDOT Session 6 6-2

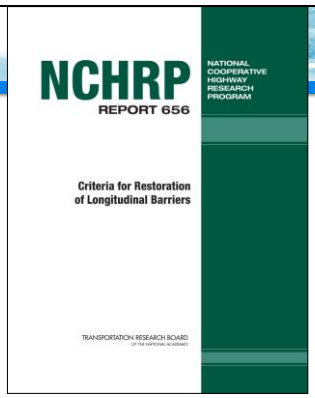
## Introduction

- Barriers should be routinely observed.
- Barrier may need to be repaired after crashes or long term exposure.


NCDOT Session 6 6-3

## Need To Repair



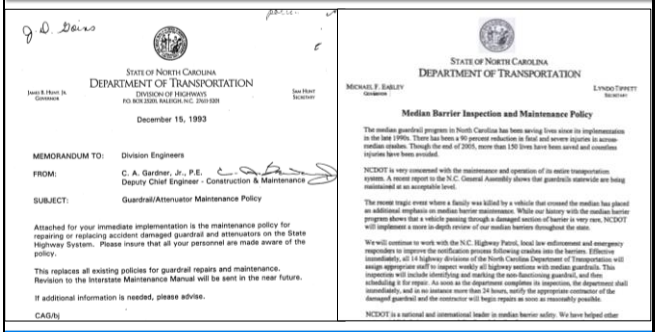




Available for purchase


Available online



## NCDOT Policies



STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
P.O. BOX 25201, RALEIGH, N.C. 27611-5201

December 15, 1993

MEMORANDUM TO: Division Engineers

FROM: C. A. Gardner, Jr., P.E.
Deputy Chief Engineer - Construction & Maintenance

SUBJECT: Guardrail/Attenuator Maintenance Policy

Attached for your immediate implementation is the maintenance policy for repairing or replacing accident damaged guardrail and attenuators on the State Highway System. Please insure that all your personnel are made aware of the policy.

This replaces all existing policies for guardrail repairs and maintenance. Revision to the Interstate Maintenance Manual will be sent in the near future.

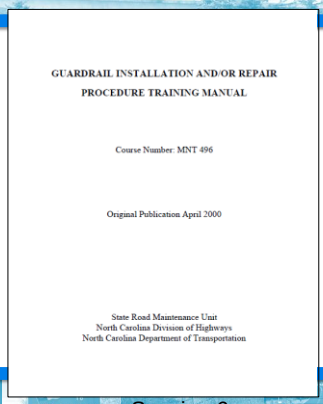
If additional information is needed, please advise.

CAG/hj

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

Median Barrier Inspection and Maintenance Policy

## NCDOT Guidance



GUARDRAIL INSTALLATION AND/OR REPAIR
PROCEDURE TRAINING MANUAL

Course Number: MNT 496

Original Publication April 2000

State Road Maintenance Unit
North Carolina Division of Highways
North Carolina Department of Transportation

NCDOT Session 6 6-7

## Timing of Repair

**RESPONSE TO NOTIFICATION OF DAMAGE**

Attenuator or guardrail damaged by accident is to be scheduled for repair/replacement as soon as possible after the condition is known. If the damaged area is determined by the engineer to present a traffic hazard by nature of the damage itself, or by exposing traffic to some previously protected situation, the area will be properly marked by barricade, warning lights, cones, truck mounted attenuator, etc., as appropriate until such time as repair has been completed.

REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

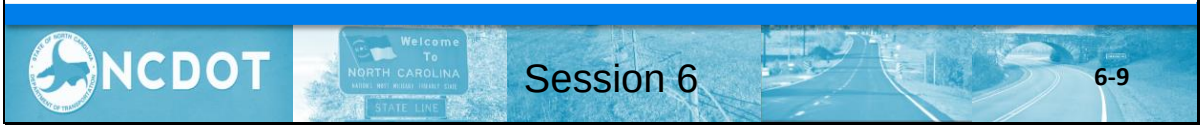
NCDOT Session 6 6-8

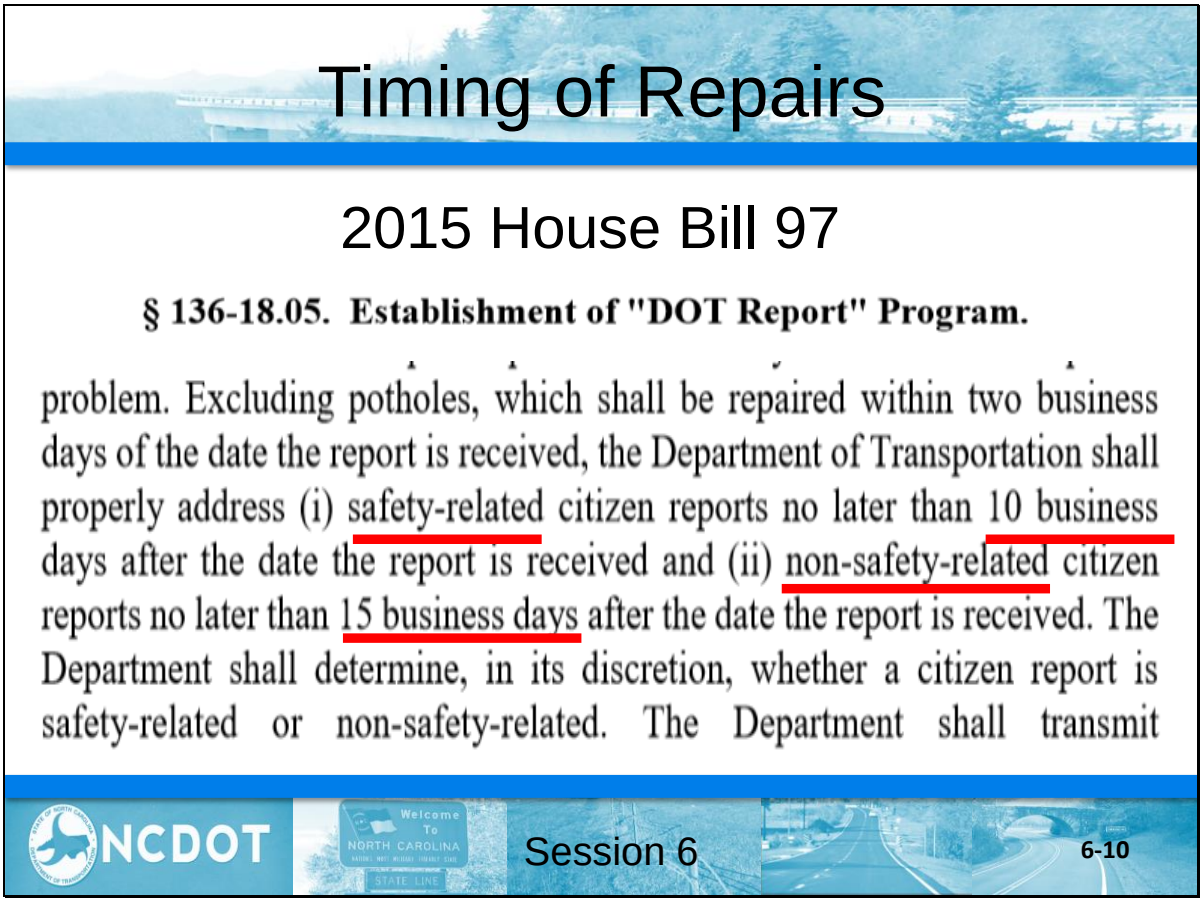
# Timing of Repair (cont'd)

**RESPONSE TO NOTIFICATION OF DAMAGE (cont'd)**

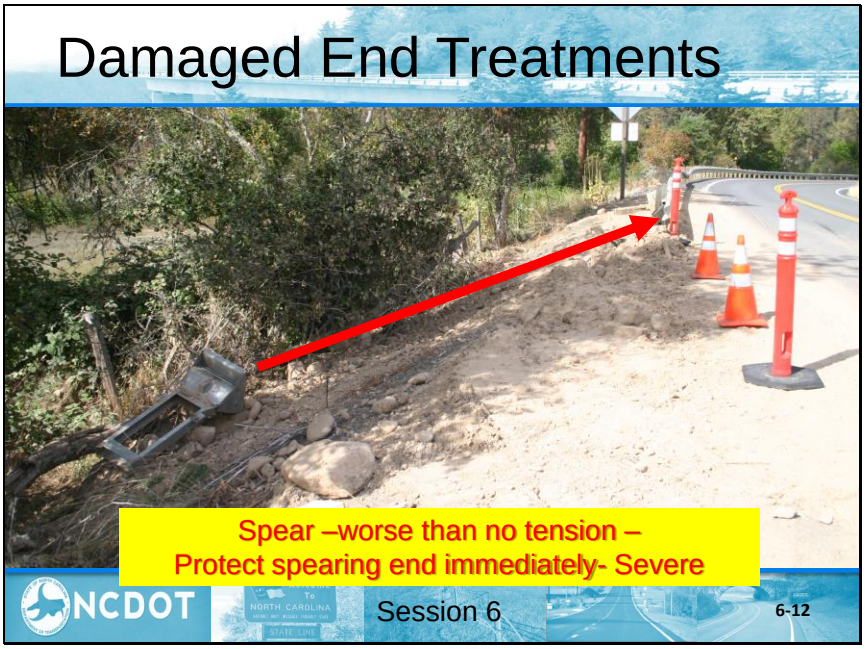
Examples would be straight pieces of rail exposed by the destruction of an anchor unit, bridge abutment exposed, sign post protection rail destroyed, or areas where rail has been damaged so badly it has to be removed. If there is any question as to the need for delineating such hazards, then the areas should be properly marked.

REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993




Timing of Repairs
2015 House Bill 97
§ 136-18.05. Establishment of "DOT Report" Program.
problem. Excluding potholes, which shall be repaired within two business days of the date the report is received, the Department of Transportation shall properly address (i) safety-related citizen reports no later than 10 business days after the date the report is received and (ii) non-safety-related citizen reports no later than 15 business days after the date the report is received. The Department shall determine, in its discretion, whether a citizen report is safety-related or non-safety-related. The Department shall transmit
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 6
6-10


Damaged End Treatments
Spear –worse than no tension –
must be treated (drop rail) immediately- Severe
NCDOT
Session 6
6-11


Damaged End Treatments
Spear –worse than no tension –
Protect spearing end immediately- Severe
NCDOT
Session 6
6-12


Damaged End Treatments
Added end section still leaves blunt end
NCDOT
Session 6
6-13


Temporary Barrier Delineation
Delineate damaged areas while evaluating damage. Make repairs as soon as practical.
NCDOT
Session 6
6-14

# Temporary Barrier Delineation

For Cable barrier, removal of damaged posts will eliminate a spearing obstacle for opposing traffic.

NCDOT Session 6 6-15

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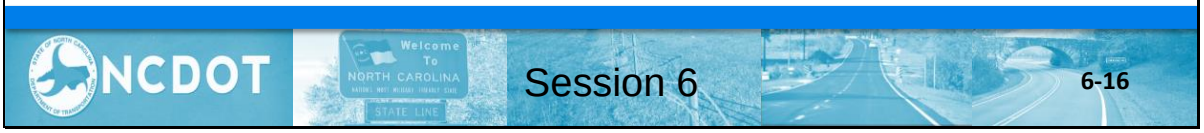
# For HTC Barrier, Keep the Cable Intact

Alternatives to cutting the cable include:

- Removing the vehicle by towing it in the opposite direction from which it hit the system.
- Loosening the cables at the turnbuckles.
- Release the cables at the anchor.
- Cutting the turnbuckle (preferred method to cutting the cable). The adjacent posts on either side of the turnbuckle need to be removed. Be sure that all personnel are clear of the cable and always cut the center of the turnbuckle, between two undamaged posts away from the impact area.



# Evaluate the Site

**DECISION TO REPAIR/REPLACE OR ELIMINATE GUARDRAIL**

Consideration should be given to eliminating the need for the rail by flattening the slope and/or eliminating the hazard. The warrants in the Roadway Design Manual and the drawings in the Roadway Standard Drawings Manual should be used in this determination. The department that eliminates the hazard is responsible for coordinating the removal of the guardrail by the county road maintenance personnel.

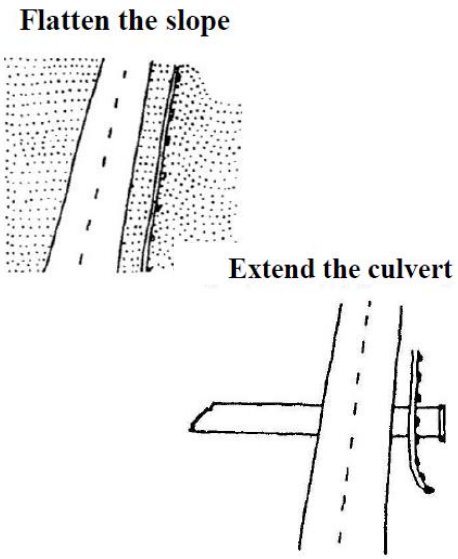
REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

# Evaluate the Site

**5.2 – Repair or Eliminate**

Before repairing the guardrail, consider if it can be eliminated. If the slope can be flattened or the hazard relocated, the barrier is not necessary.

If the roadside obstacle is no longer there, the guardrail is itself a hazard and should be removed




REF: NCDOT GUARDRAIL INSTALLATION AND/OR REPAIR PROCEDURE TRAINING MANUAL. April 2000

# Determine Extent of Damage

**SAFETY-RELATED ????**

**Safety-related DEFINITELY**

When guardrail has been hit, determine the extent or severity of damage. If the damage is minor or so slight that it will function to shield the hazard, schedule the repair with other work. If the damage is severe, schedule it for repair as soon as possible. Until then, clear debris from the road and shoulder, then set out barrels or barricades to warn motorists.

REF: NCDOT GUARDRAIL INSTALLATION AND/OR REPAIR PROCEDURE TRAINING MANUAL. April 2000

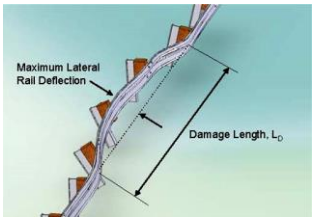
NCDOT Session 6 6-19

## Guardrail – Damage Modes

**Severely Damaged**

- Rail beam has been severed
- Beam is crushed more than 18” out of line or
- Three or more posts have been broken

**Severe damaged needs to be repaired as soon as possible**




REF: NCDOT GUARDRAIL INSTALLATION AND/OR REPAIR PROCEDURE TRAINING MANUAL. April 2000



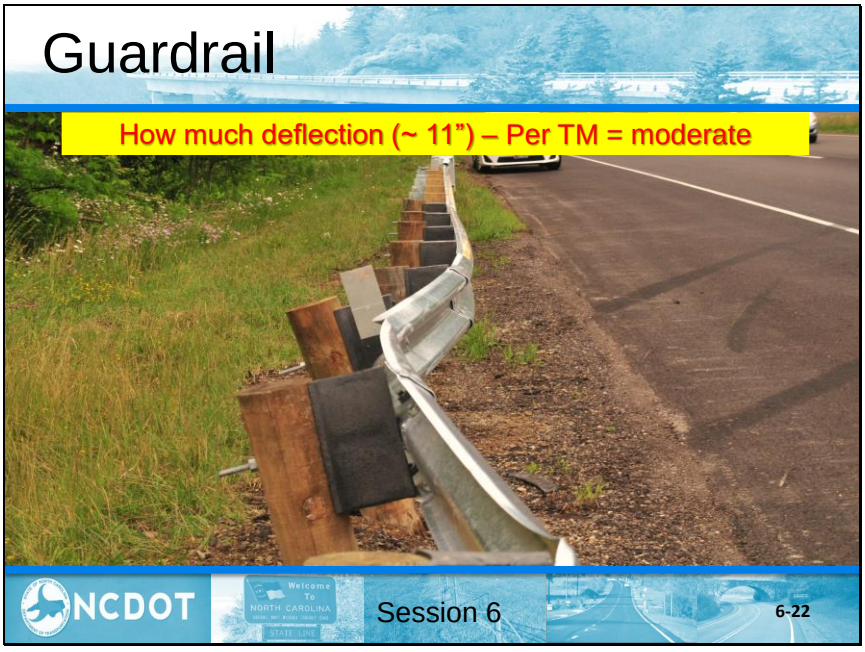
## Guardrail – Damage Modes

**Moderate Damaged.** Repair later if the guardrail will still function properly.

**Minor Damage** is aesthetic. Repairs may not be needed at all.

**Supervisor needs to make decision – is moderate “safety-related” or not; this was intent of NCHRP 656**

REF: NCDOT GUARDRAIL INSTALLATION AND/OR REPAIR PROCEDURE TRAINING MANUAL. April 2000


Guardrail
How much deflection (~ 11") – Per TM = moderate
NCDOT
Session 6
6-22


Bends within compressive terminal may cause unwanted buckling – little energy absorption – Safety-related
NCDOT
Session 6
6-23


Post separation – Severe or moderate?
If height is too low (?"), penetration is likely - Severe
NCDOT
Session 6
6-24


No tension continuity – Severe
NCDOT
Session 6
6-25


## Cable Rail – Damage Modes

**Severely Damaged**

- Any cable is broken or pulled loose from the anchor or
- Cable is sagging to the point that it would not function properly when hit or
- Four or more posts have been knocked down.

**Severe damaged needs to be repaired as soon as possible**

REF: NCDOT GUARDRAIL INSTALLATION AND/OR REPAIR PROCEDURE TRAINING MANUAL. April 2000

## Cable Rail


NCDOT Session 6 6-28

## End Treatments – Damage Modes

**Severely Damaged**

- One or more broken posts
- Rail that has been torn loose or
- Damaged cable assembly.

**Severe damaged needs to be repaired as soon as possible**

REF: NCDOT GUARDRAIL INSTALLATION AND/OR REPAIR PROCEDURE TRAINING MANUAL. April 2000

NCDOT Session 6 6-29

# End Treatments

**This could act like a spear if not repaired expeditiously - Severe**

**You need to have the manufacturer's installation manual to repair these systems.**

NCDOT Session 6 6-30

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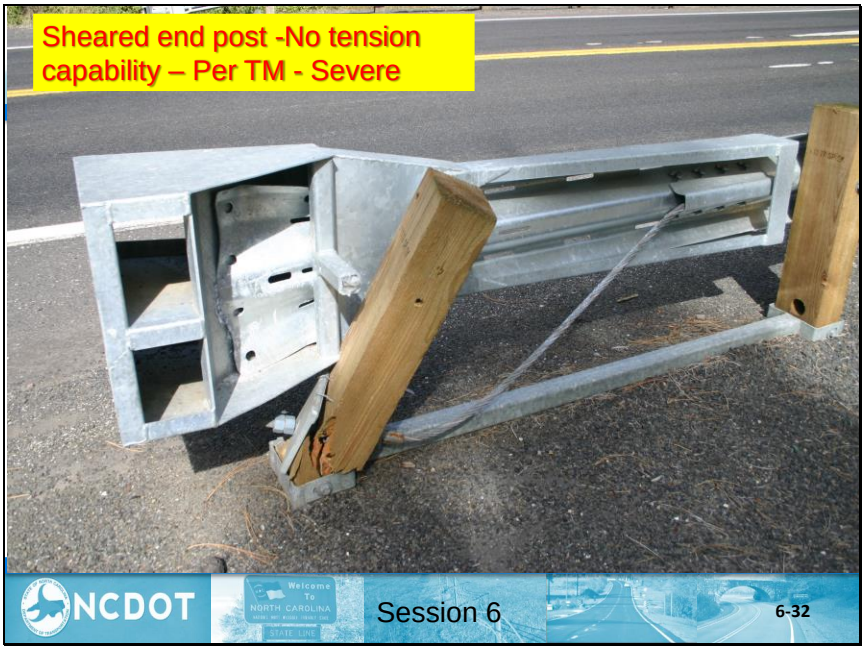
# End Treatments

- Check for nuisance hits on end treatments to be sure post #1 is not damaged.
- Even with claims of “reusability” – use best judgment and closely examine all salvageable parts.
- Impact Heads may be re-usable based on state policy and manufacturers recommendations (generally say no).

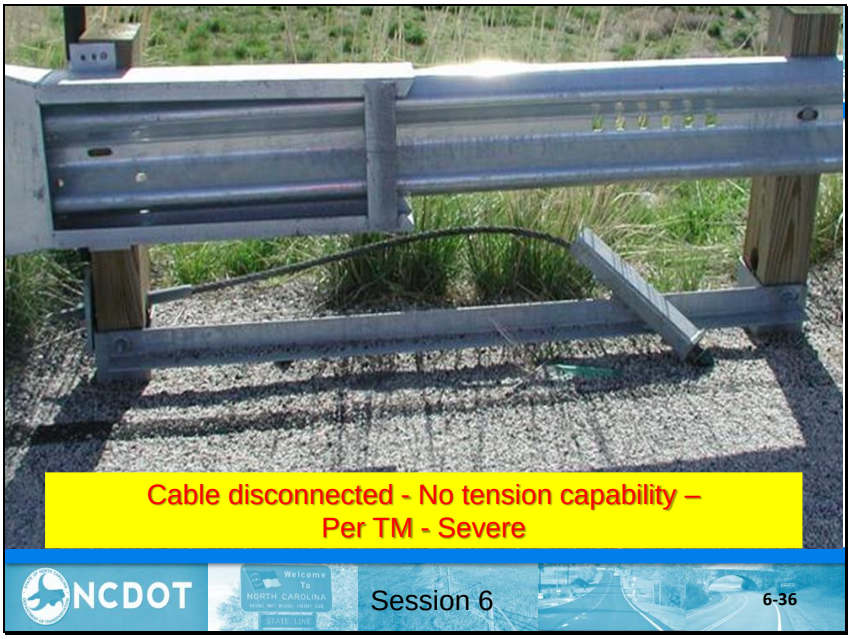
NCDOT Session 6 6-31


Sheared end post -No tension capability – Per TM - Severe
NCDOT
Session 6
6-32

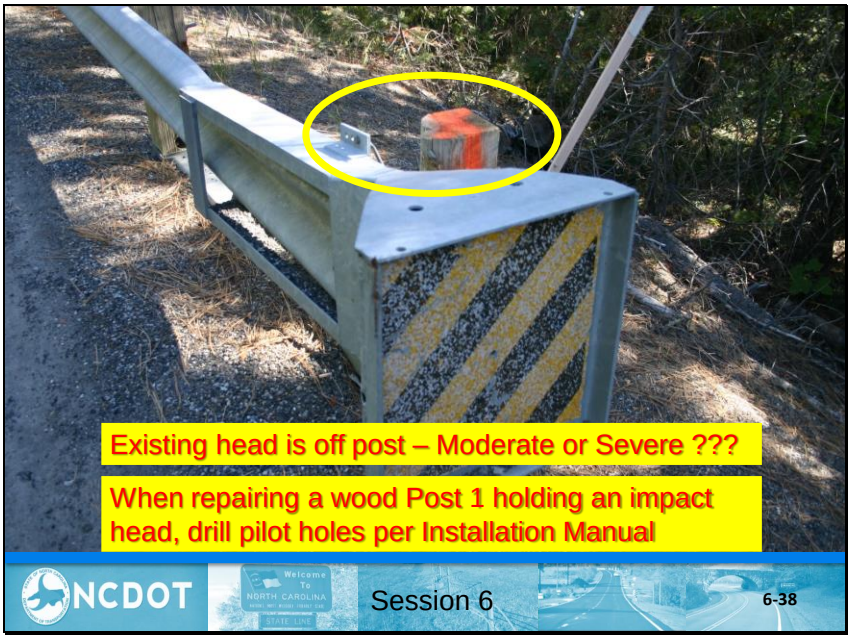

No tension capability and possible spear – Severe
Non-Energy Absorbing Terminal WRONG here – no Runout
Don't know why memorial is here
NCDOT
Session 6
6-33


SRT first rail only – not as tested. Light pole nearby may also be a problem. Severity - ????
NCDOT
Session 6
6-34


Impact head not parallel to rail – don't know how serious – Doubt Severe; Just POOR workmanship
NCDOT
Session 6
6-35


Cable disconnected - No tension capability –
Per TM - Severe
NCDOT
Session 6
6-36


Foundation tubes too high – Severity depends on
how excessive the height is
NCDOT
Session 6
6-37


Existing head is off post – Moderate or Severe ???
When repairing a wood Post 1 holding an impact head, drill pilot holes per Installation Manual
NCDOT
Session 6
6-38

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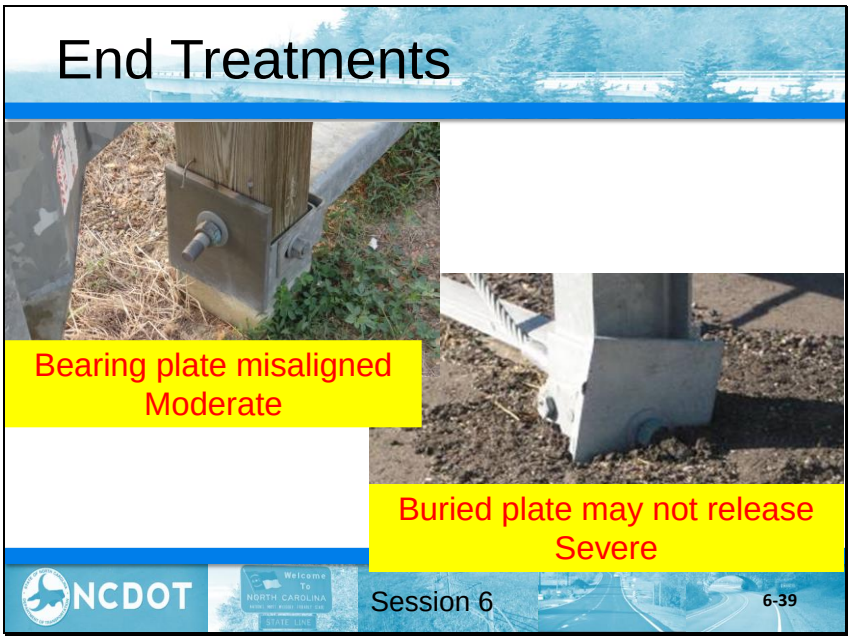
End Treatments
Bearing plate misaligned
Moderate
Buried plate may not release
Severe
NCDOT
Session 6
6-39

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Missing bearing plate and cable - No tension capability – (Also the head should be parallel to top of rail) – Per TM - Severe
NCDOT
Session 6
6-40

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Rail not engaged with head
Severe
NCDOT
Session 6
6-41

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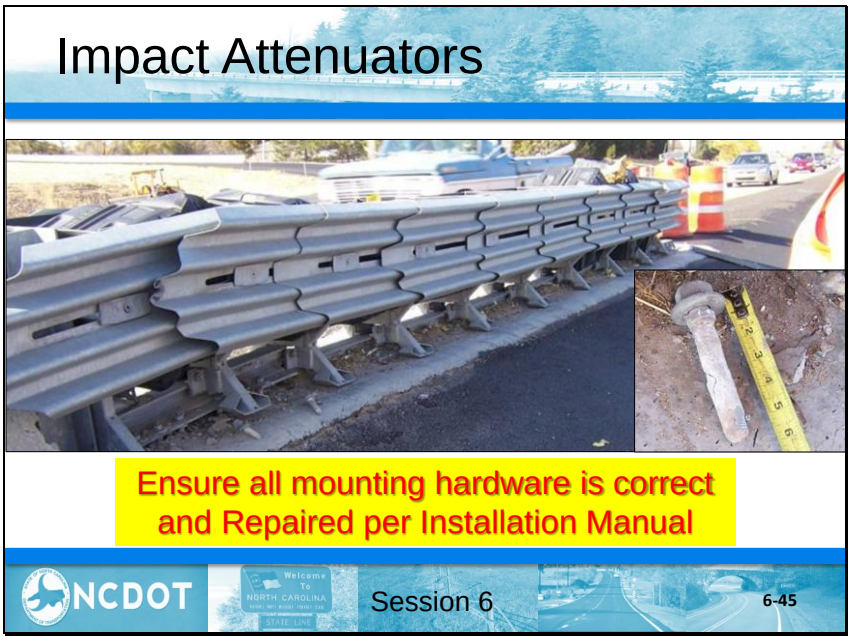
Damaged End Treatments
No tension, impact head damaged - Severe
NCDOT
Session 6
6-42


Urgency of Repair ???
Some reserve capacity – Moderate or Severe???
Have manufacturer's Installation Manual available.
NCDOT
Session 6
6-43


Urgency of Repair ???
This is a blunt end until repaired - Severe
Have manufacturer's Installation Manual available.
NCDOT
Session 6
6-44


Impact Attenuators
Ensure all mounting hardware is correct
and Repaired per Installation Manual
NCDOT
Session 6
6-45

## Impact Attenuators

Typical QuadGuard Cartridges

Typical Universal TAU Cartridges

Place proper cartridges in the correct system & in the proper order

NCDOT Session 6 6-46

## Impact Attenuators

Place sand container in the correct position with the correct amount of sand.

NCDOT Session 6 6-47

# Replace In-Kind vs. Upgrade

**REPLACEMENT/REPAIR OF GUARDRAIL COMPONENTS**

**A. *Rail (Steel)***

The accident damaged section of rail shall be replaced/repaired to the current design standard as practical. It should be noted when only a portion of a rail system is damaged, consideration should be given to replacing the remaining undamaged length to current standards. However, when the undamaged length of remaining rail is less than 100 feet, the entire rail system shall be replaced to current design standards.

For pre-31" guardrail, the repaired guardrail should be to the latest 29" standard, especially related to height.

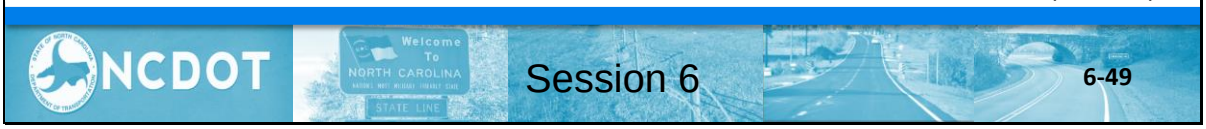
REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

# Replace In-Kind vs. Upgrade

**A short section of weak post rail should be replaced by standard blocked out W-beam rail**

Damaged sections of rail must be repaired to the current design standard as practical. For example, if an old weak post guardrail system that is shielding a hazard has been hit, the damaged section should be replaced by the standard blocked out W-beam system. Note that a 50' transition will be needed from the old weak post rail to the new strong post rail to minimize pocketing effects.

REF: NCDOT GUARDRAIL INSTALLATION AND/OR REPAIR PROCEDURE TRAINING MANUAL. April 2000 p 25



# Replace In-Kind vs. Upgrade

**REPLACEMENT/REPAIR OF GUARDRAIL COMPONENTS**

**B. *Rail (Cable)***

The damaged section of cable rail shall be replaced/repaired to the current design standard.

It should be noted that periodic inspections of the cable tension is required to insure its proper function. Additionally, large vegetation shall not be allowed to grow within 15 feet of the cable as the system is designed to deflect 15 feet under impact.

REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

# Replace In-Kind vs. Upgrade

**REPLACEMENT/REPAIR OF GUARDRAIL COMPONENTS**

**C. Terminal End Section**

The accident damaged end section shall be replaced/repaired to the current design standard except as follows:

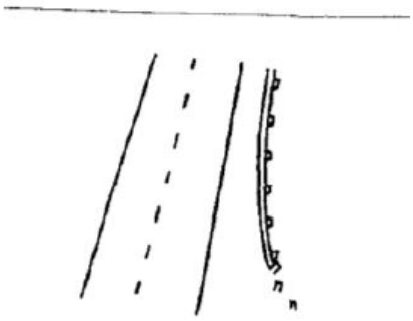
Exceptions:

- When only the guardrail end section (buffer or terminal end design) has been damaged (bent), with no post damage, it may be repaired with like kind.
- When adequate shoulder width cannot be obtained economically to meet the current design standard contact Roadway Design for an alternate design.

REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

# Replace In-Kind vs. Upgrade

**If any posts of a sub-standard end treatment have been broken, it should be upgraded**



REF: NCDOT GUARDRAIL INSTALLATION AND/OR REPAIR PROCEDURE TRAINING MANUAL. April 2000

# Replace In-Kind vs. Upgrade

**REPLACEMENT/REPAIR OF GUARDRAIL COMPONENTS**

**D. Structure Anchor Unit**

The accident damaged guardrail attached to a structure (ex: bridge, concrete barrier, etc.) shall be replaced/repaired in accordance with current design standard. If field conditions prevent the use of standard design and it is structurally sound to attach to the structure, assistance in the design of an acceptable replacement and/or repair is available through the Road Maintenance Unit as needed.

REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

NCDOT Session 6 6-53

# Replace In-Kind vs. Upgrade

***REPLACEMENT/REPAIR OF IMPACT ATTENUATORS***

Damaged or malfunctioning attenuators shall be replaced/repaired to the current design standard.

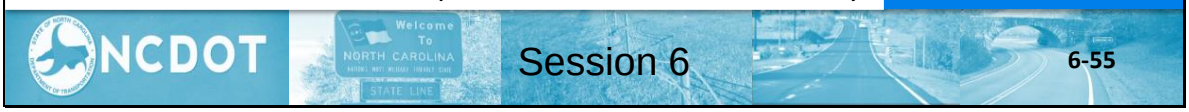
Attenuators should be inventoried by type and location and maintained on a regular schedule (every 6 months) to insure proper function.

REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

# Median Barrier Inspection/Maintenance

- Requires weekly inspection by each NCDOT highway division.
- All non-functioning section of median barrier identified and marked.
- Appropriate contractor notified of damaged section within 24 hours.
- Repair work to begin “as soon as reasonably possible”

Ref: NCDOT Median Barriers Inspection and Maintenance Policy



# Inspect Repairs

**Inspection once the repairs are completed, as well as periodic inspection.**

**6.3 – Maintenance Tips**

- Before repairing guardrail, consider eliminating it.
- When barrier must be repaired, check the design.
- Keep large vegetation away from the guardrail.
- Watch for material buildup under and in front of the rail.
- Loosen cable turnbuckle in cooler weather, and tighten in warmer weather. ???? – to Spec

REF: NCDOT GUARDRAIL INSTALLATION AND/OR REAIR PROCEDURE TRAINING MANUAL. April 2000P

NCDOT Session 6 6-56

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## Review Learning Outcomes

- Recognize how damaged barrier MAY BE assessed for maintenance response.
- Understand when a damaged barrier end treatment MAY no longer function.
- Effectively delineate/treatment of damaged hardware prior to repair.

NCDOT Session 6 6-57

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