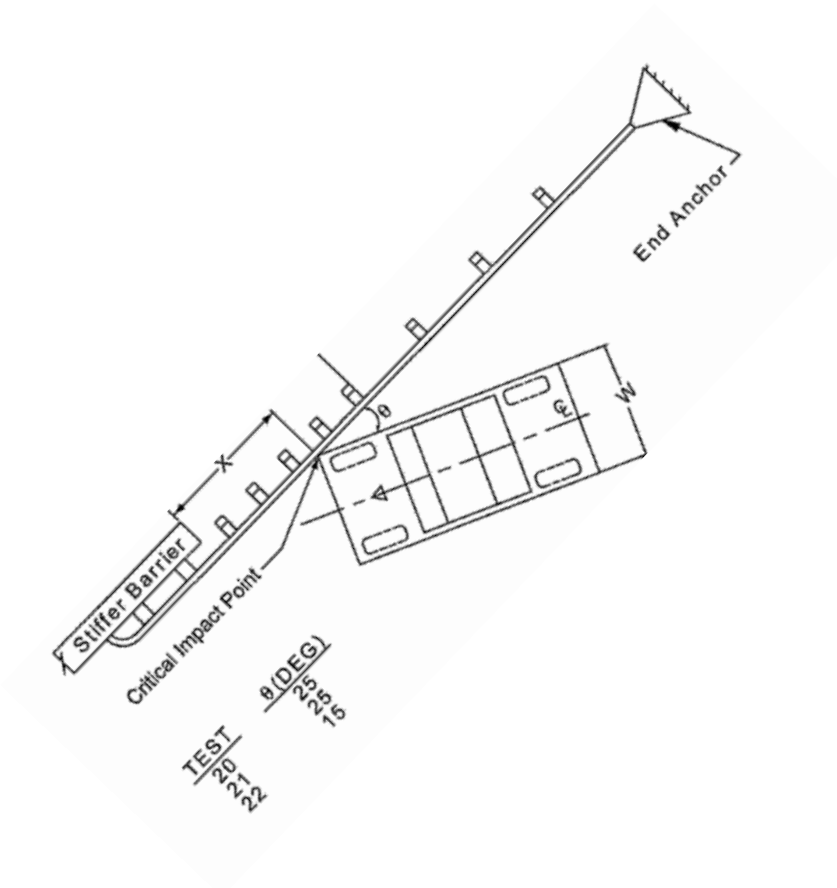
North Carolina Department of Transportation

Highway Safety Barrier Design Training

Participant Notebook

October 30-31, 2023



KLS Engineering

THE UNIVERSITY OF NORTH CAROLINA HIGHWAY SAFETY RESEARCH CENTER

INTRODUCTION

Course Goal and Outcomes

The overall course goal is to make design engineers knowledgeable of the many different considerations concerning roadside safety barrier design leading to optimal barrier installations. Specifically, participants should be able to perform the following after attending this course:

- Apply the clear zone concept.
- Determine when roadside and median barriers MAY be warranted.
- Design roadside and median barriers resulting in optimal barrier performance.
- Select the most appropriate end treatments/impact attenuators.

Target Audience

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

Course Contents

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

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

Session 2: Clear Zone and Guidelines for Barrier Need – Explains the clear zone concept and its application, and examines the sometimes-difficult decision of when a barrier should be used to shield a hazard.

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

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

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

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

Workshop: Tests the participants' post-training knowledge of barrier design principles by providing an opportunity for attendees to demonstrate the overall effectiveness of the training in a workshop.

Resources

NCDOT Guardrail Committee Members Contact Information

Vickie Davis	Area Construction Engineer – Division 9	vdavis@ncdot.gov	(704) 202-0945
Christopher Deyton	Division Maintenance Engineer – Division 13	cdeyton@ncdot.gov	(828) 250-3000
Sam Eddy	Maintenance Management Engineer Supervisor	sceddy@ncdot.gov	(919) 835-8209
Nicole Hackler	State Plans and Standards Engineer	nmhackler@ncdot.gov	(919) 707-6950
David Harris	State Roadside Environmental Engineer	davidharris@ncdot.gov	(919) 707-2925
Christopher Hoffman	Training and Development Engineer	cahoffman@ncdot.gov	(919) 835-8429
Raymond Honbarrier	Maintenance Systems Manager	rchonbarrier@ncdot.gov	(919) 835-8226
Bobby Liverman	Assistant Division Maintenance Engineer – Division 4	blliverman@ncdot.gov	(252) 640-6404
Bobby Norris	District Engineer – District 2, Division 7	bnorris@ncdot.gov	(336) 487-0100
Tim Nye	Senior Traffic Safety Project Engineer	tsnye1@ncdot.gov	(919) 814-4961
Dale Privette (FHWA)	FHWA Safety and Transportation Engineer	dale.privette@dot.gov	(919) 814-4961
John Rhyne	Division Maintenance Engineer – Division 9	jprhyne@ncdot.gov	(336) 747-7800
Shawn Troy	State Traffic Safety Engineer	stroy@ncdot.gov	(919) 814-5010
Ken Thornewell	Central Work Zone Traffic Control Engineer	kcthornewell@ncdot.gov	(919) 814-5037
Jordan Woodard (chair)	Design Development and Support Group Lead	jawoodard4@ncdot.gov	(919) 707-6208

North Carolina Department of Transportation (NCDOT)

- Roadway Design Manual 2023
  https://connect.ncdot.gov/projects/Roadway/pages/RDM.aspx
- Roadway Standard Drawings
  https://connect.ncdot.gov/resources/Specifications/Pages/2024-Roadway-Standard-Drawings.aspx
- Special Provisions
  https://connect.ncdot.gov/resources/Specifications/Pages/2024-Specifications-and-Special-Provisions.aspx
- Approved Product List
  https://apps.ncdot.gov/vendor/approvedproducts/

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/
- W-Beam Guardrail Repair Guide
  https://safety.fhwa.dot.gov/local_rural/training/fhwasa08002/

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

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

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

- Guide to Standardized Highway Barrier Hardware

Roadside Safety Pooled Fund sites:

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

TERMINOLOGY

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

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

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

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

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

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

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

GLOSSARY

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Impact Attenuator—See Crash Cushion.

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

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

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

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

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

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

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

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

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

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

Omni-directional—See Multidirectional.

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

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

Performance Level—See Level of Performance.

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

Recovery Area—Generally synonymous with clear zone.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

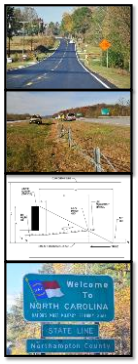
Working Width—The distance between the traffic face of the test article before the impact and the maximum lateral position of any major part of the system or vehicle after the impact.

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

Acronyms

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

Session 1: Introduction and Pre-Assessment



North Carolina Department of Transportation

Highway Safety Barrier Design Training

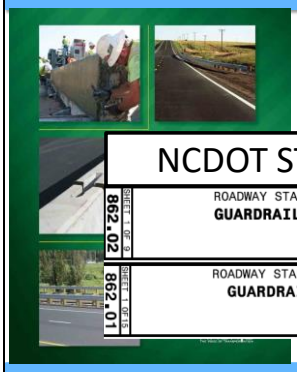
Instructor: Bill Fitzgerald, PE
KLS Engineering, LLC
(703) 973 9109

October 30-31, 2023

THE UNIVERSITY OF NORTH CAROLINA HIGHWAY SAFETY RESEARCH CENTER

KLS Engineering

Guidance Presented



NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
ROADWAY DESIGN MANUAL

NCDOT STANDARD DRAWINGS

862.02 SHEET 1 OF 9
ROADWAY STANDARD DRAWING FOR
GUARDRAIL INSTALLATION
1-24
STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

862.01 SHEET 1 OF 15
ROADWAY STANDARD DRAWING FOR
GUARDRAIL PLACEMENT
1-24
STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

Ground Rules

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

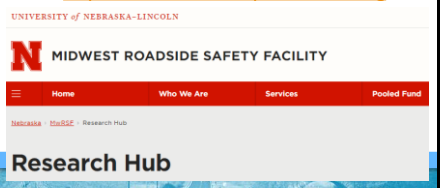
Terminology: Page v

Additional Resources

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

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

https://mwrsf.unl.edu/researchhub



NCDOT Session 1 1-4

Objectives of Course

At the end of this 1½ - day course you should be able to:

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

NCDOT Session 1 1-5

Session 1:
Introduction and Pre-assessment

NCDOT Session 1 1-6

Session 1 Learning Outcomes

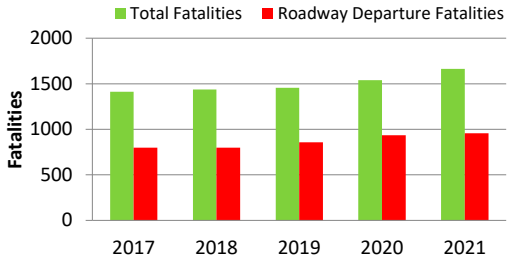
At the end of this session, you should be able to:

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

NCDOT Session 1 1-7

North Carolina Crash Data Trend

North Carolina Total Fatalities vs. Roadway Departure Fatalities



Total US Highway Fatalities 2021 42,939

In 2021, 57.6 percent of all fatalities involved roadway departures

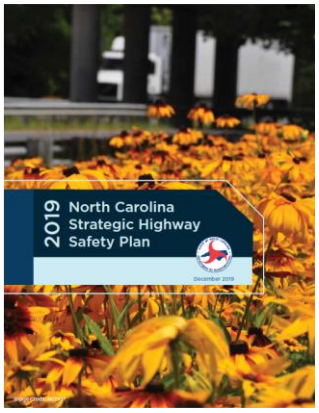
Ref: FARS Data – 2017 to 2021

North Carolina Crash Data - Fatalities

	5-Yr. Total
Culvert/Curb/Ditch	764
Trees	652
Rollover	298
Guardrail End/Face	165
Embankment	156
Utility Pole/Light Pole	125
Concrete Barrier	23
Cable Barrier	21

Ref: FARS Data – 2017 to 2021

North Carolina Strategic Highway Safety Plan



Lane Departure STRATEGIES

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

NCDOT Session 1 1-10

North Carolina Strategic Highway Safety Plan

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

Supporting Actions

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

NCDOT Session 1 1-11


Real World Crashes
Video Clip
NCDOT
Session 1
1-12

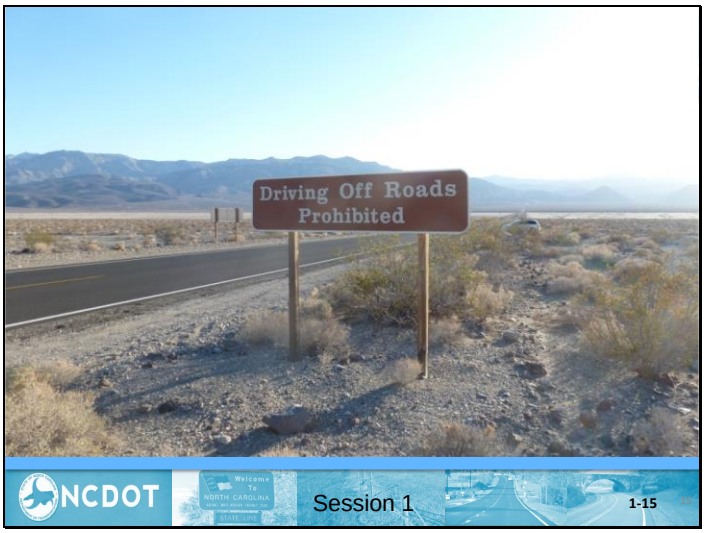

Real World Crashes
NCDOT
Welcome To NORTH CAROLINA STATE LINE
Session 1
1-13

Need for Training

Potential consequences of poorly designed barrier systems include:

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

NCDOT Session 1 1-14



NCDOT Session 1 1-15

Need for Training

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

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

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

NCDOT Session 1 1-16


NCDOT
Session 1
1-18


NCDOT
Session 1
1-19


NCDOT
Session 1
1-20


EXIT
466
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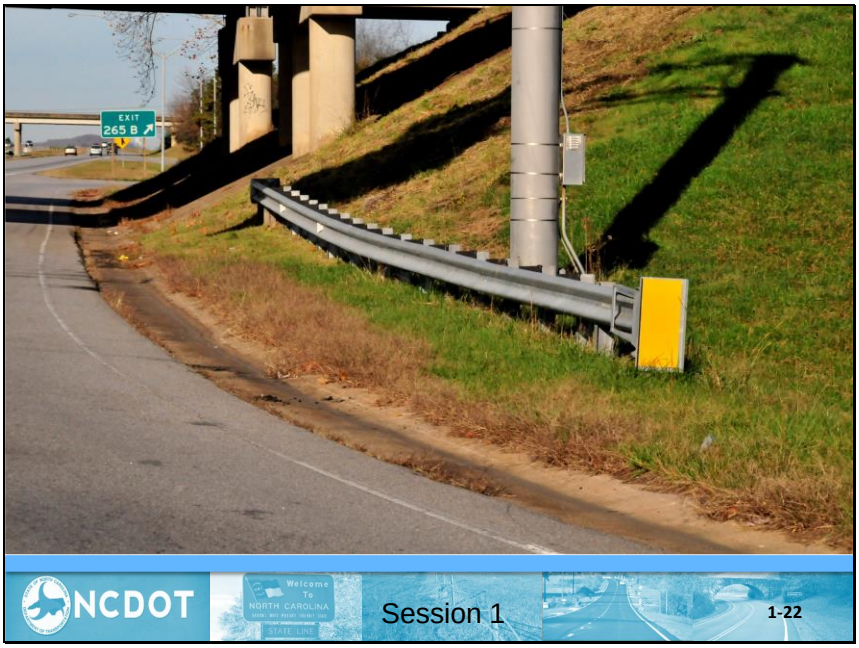
Session 1
1-21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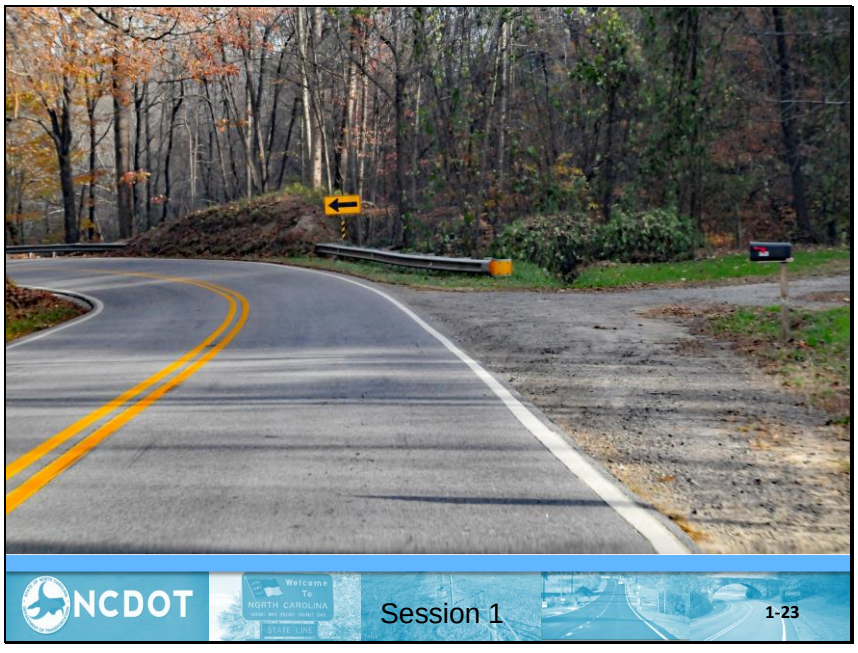
Session 1
1-22


NCDOT
Session 1
1-23


NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 1
1-24

Review Learning Outcomes

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

NCDOT Session 1 1-26

Session 2: Clear Zone and Guidelines for Barrier Need

North Carolina Department of Transportation
Highway Safety Barrier Design Training

Session 2:
Clear Zone and Guidelines for Barrier Need

Session 2 Learning Outcomes

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

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

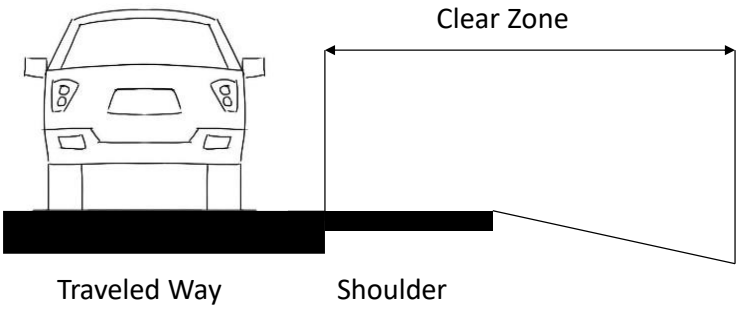
Three Essential Elements of Good Roadside Design

Engineering Judgment

Evaluate **Risk**

Document

Clear Zone: Definition



4.6.1 Clear Zones

The unobstructed traversable area provided beyond the edge of the traveled way is termed the clear zone. This area is used for the recovery of errant vehicles and includes shoulders, bike lanes, and auxiliary lanes.

NCDOT Session 2 2-4

Clear Zone Principle

Get

MAXIMUM,

COST-EFFECTIVE width

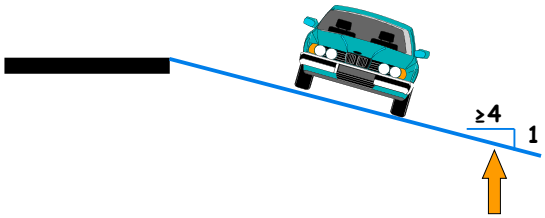
NCDOT Session 2 2-5

Clear Zone Factors

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

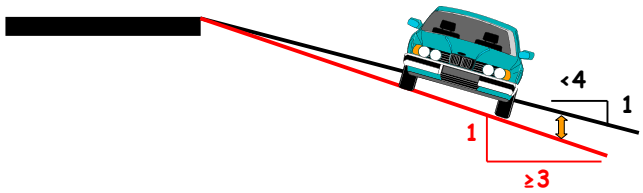
NCDOT Session 2 2-7

Recoverable



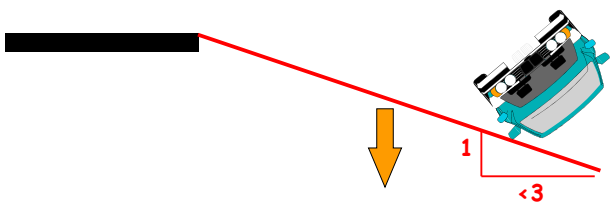
NCDOT Session 2 2-8

Non-Recoverable (but Traversable)

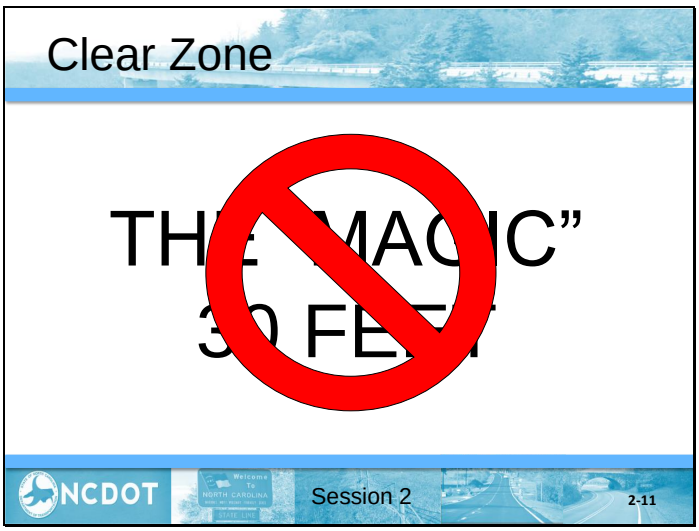


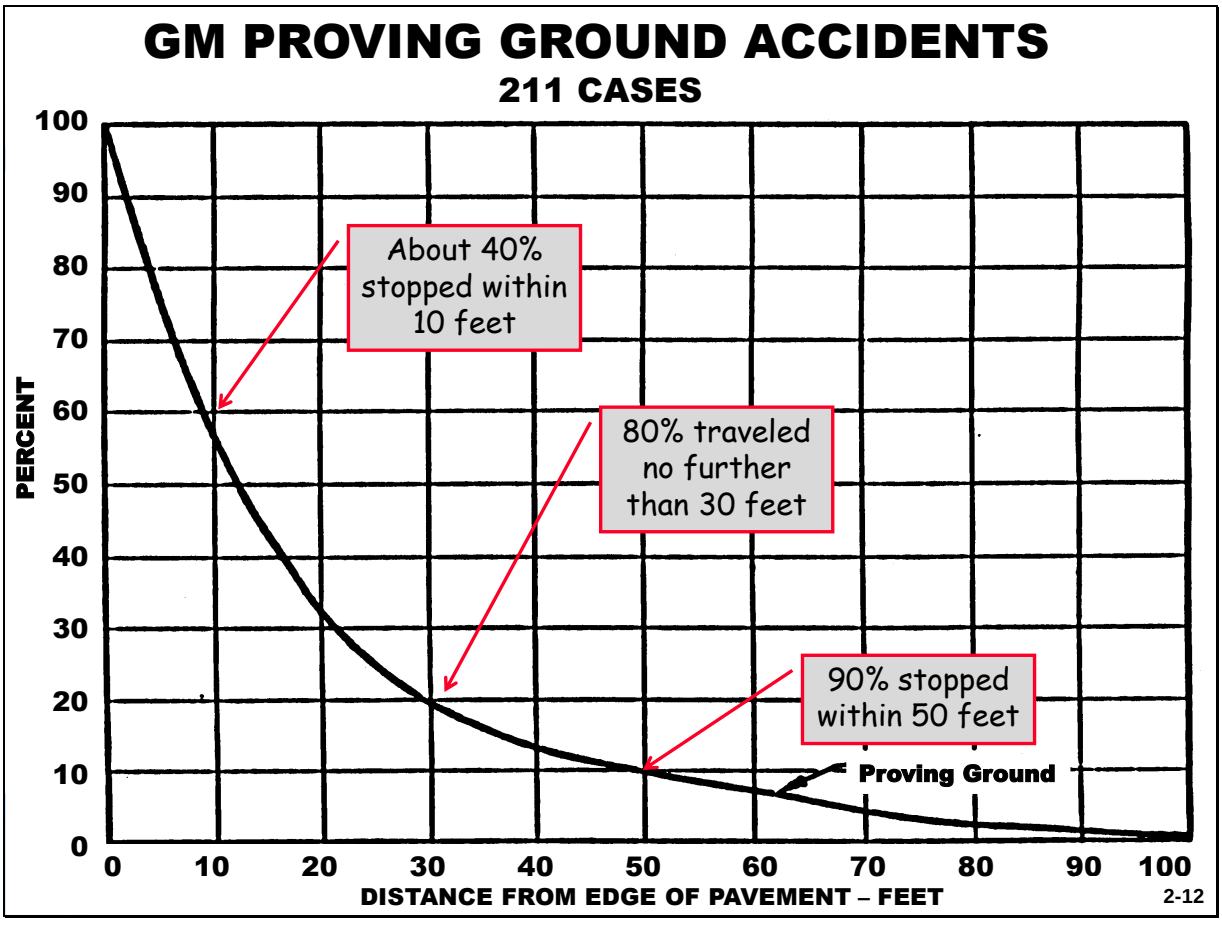
NCDOT Session 2 2-9

Critical



NCDOT Session 2 2-10


Clear Zone
NCDOT
Session 2
2-11


GM PROVING GROUND ACCIDENTS
211 CASES
PERCENT
100
90
80
70
60
50
40
30
20
10
0
About 40% stopped within 10 feet
80% traveled no further than 30 feet
90% stopped within 50 feet
Proving Ground
0
10
20
30
40
50
60
70
80
90
100
DISTANCE FROM EDGE OF PAVEMENT – FEET
2-12

NCDOT Design Clear Zone Table

Table 4-5 Suggested Clear-Zone Distances from Edge of Through Traveled Lane

Design Speed (mph)	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	UNDER 750[c]	7-10	7-10	See Note b	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	UNDER 750[c]	10-12	12-14	See Note b	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	UNDER 750[c]	12-14	14-18	See Note b	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[a]		16-18	20-22	22-24
60	UNDER 750[c]	16-18	20-24	See Note b	10-12	12-14	14-16
	750-1500	20-24	26-32[a]		12-14	16-18	20-22
	1500-6000	26-30	32-40[a]		14-18	18-22	24-26
	OVER 6000	30-32[a]	36-44[a]		20-22	24-26	26-28
65-70[d]	UNDER 750[c]	18-20	20-26	See Note b	10-12	14-16	14-16
	750-1500	24-26	28-36[a]		12-16	18-20	20-22
	1500-6000	28-32[a]	34-42[a]		16-20	22-24	26-28
	OVER 6000	30-34[a]	38-46[a]		22-24	26-30	28-30

NCDOT

Session 2

2-13

Important Distinction

Available Clear Zone = Area Existing for recovery

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

Do not compromise available clear zone

NCDOT Session 2 2-14

Example Clear Zones

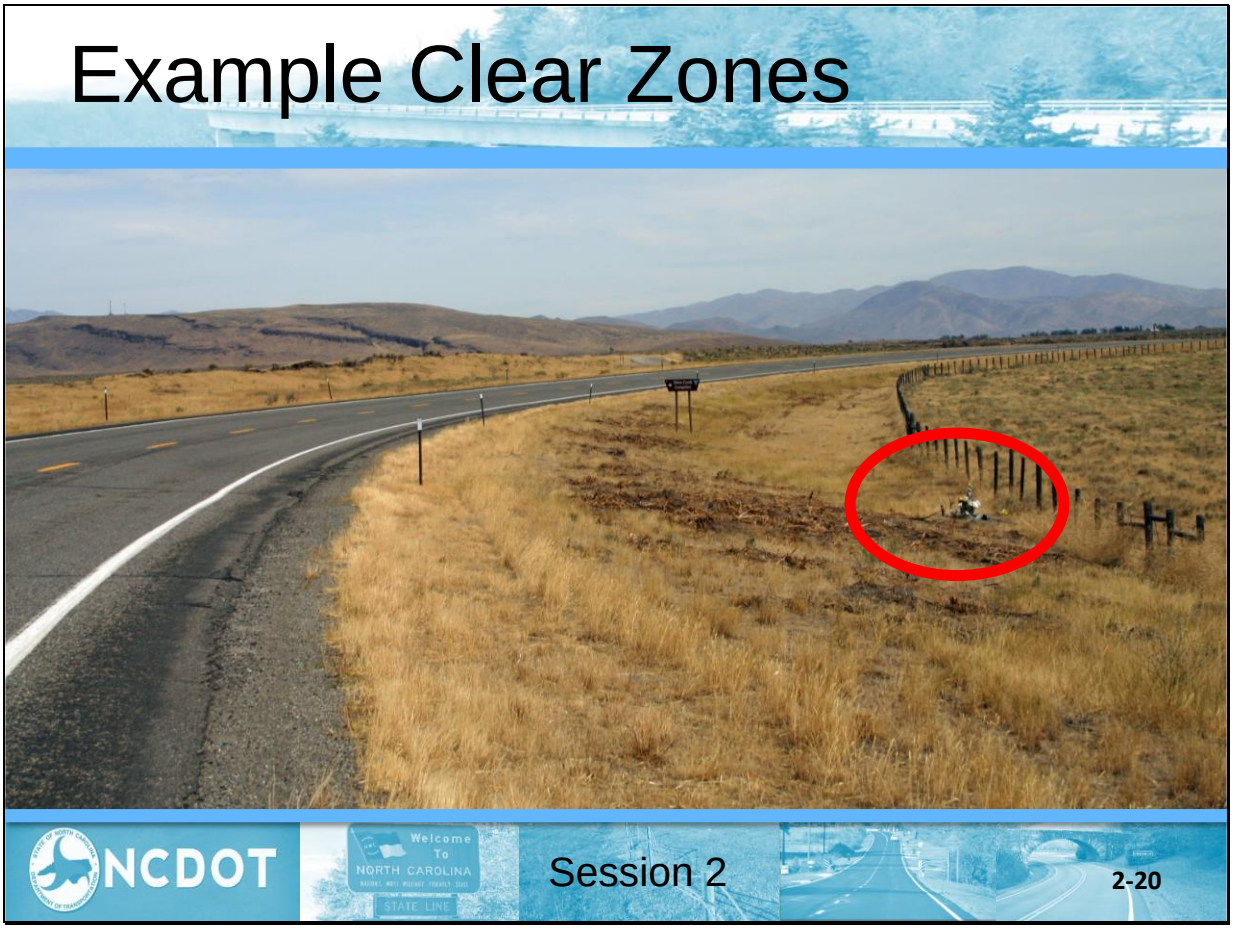
NCDOT Session 2 2-15

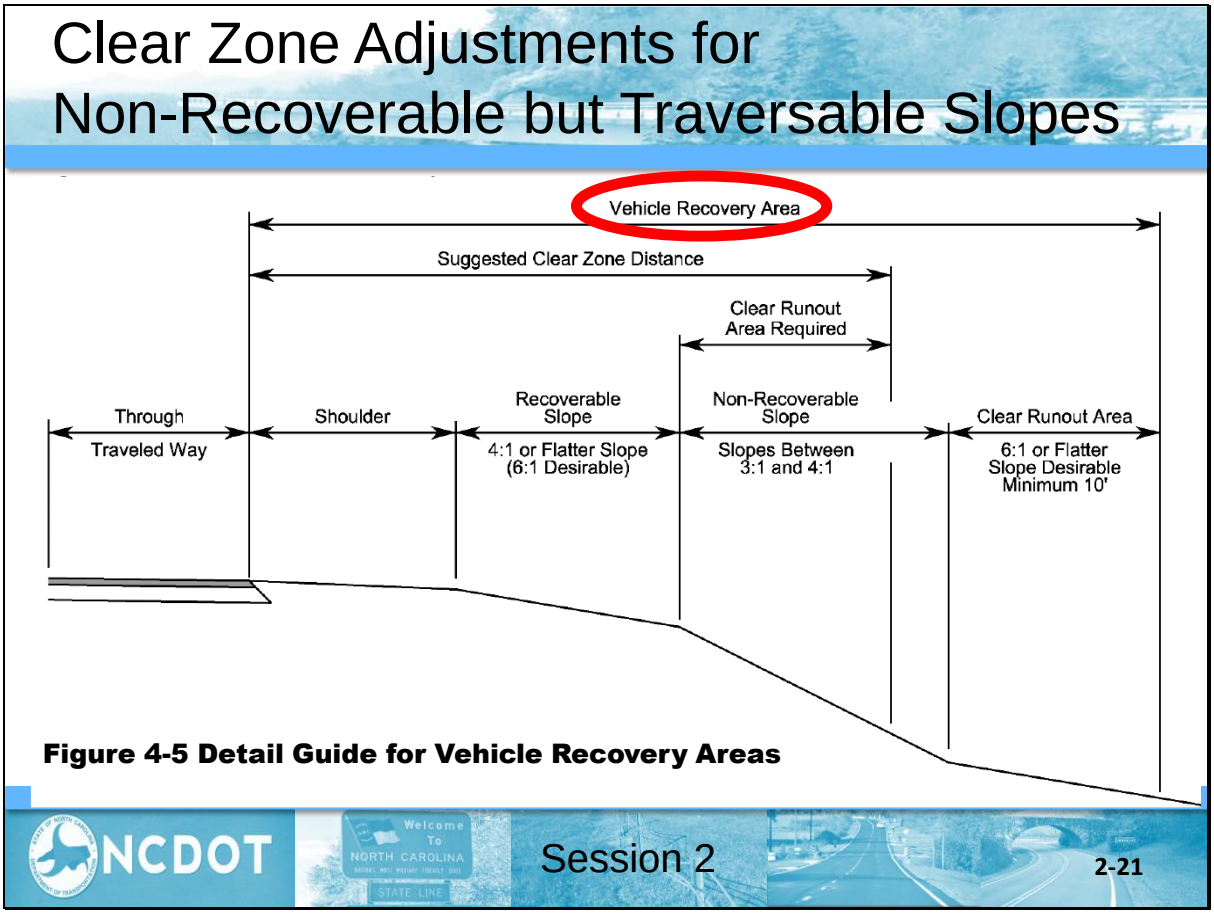

Example Clear Zones
NCDOT
Session 2
2-16


Example Clear Zones
NCDOT
Session 2
2-17

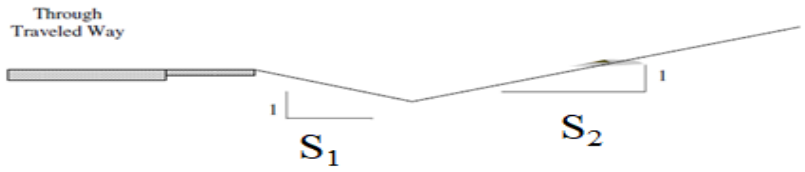

Example Clear Zones
NCDOT
Session 2
2-18


Example Clear Zones
NCDOT
Session 2
2-19


Example Clear Zones
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 2
2-20


Clear Zone Adjustments for
Non-Recoverable but Traversable Slopes
Vehicle Recovery Area
Suggested Clear Zone Distance
Clear Runout
Area Required
Through
Traveled Way
Shoulder
Recoverable
Slope
4:1 or Flatter Slope
(6:1 Desirable)
Non-Recoverable
Slope
Slopes Between
3:1 and 4:1
Clear Runout Area
6:1 or Flatter
Slope Desirable
Minimum 10'
Figure 4-5 Detail Guide for Vehicle Recovery Areas
NCDOT
Session 2
2-21

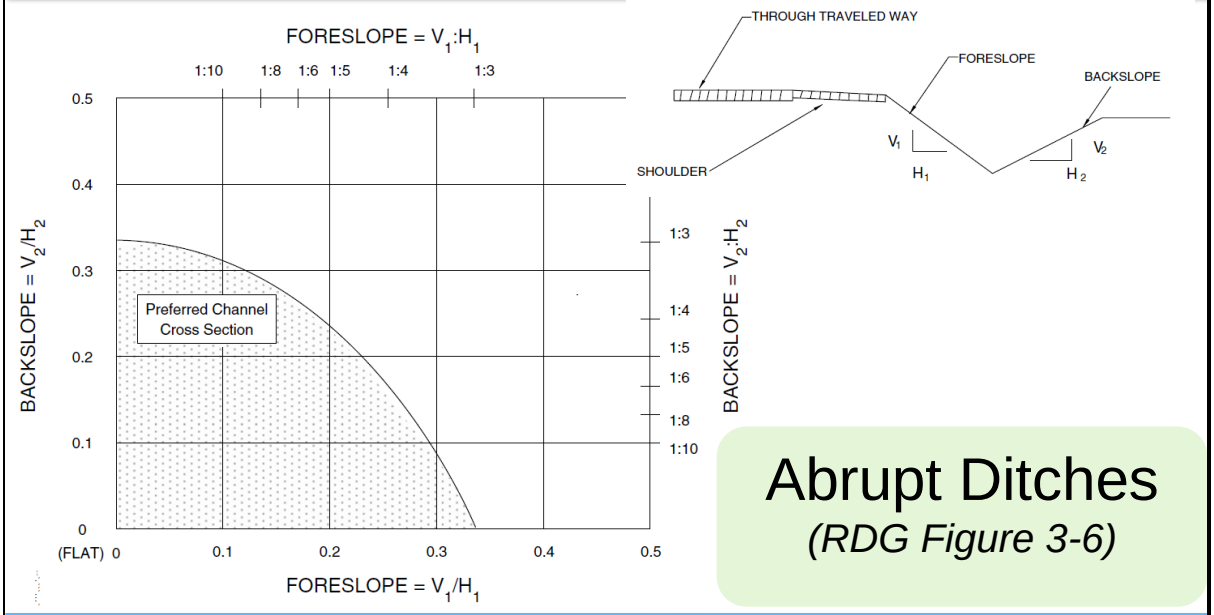
Clear Zone with a Ditch



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

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

AASHTO Ditch Guidance

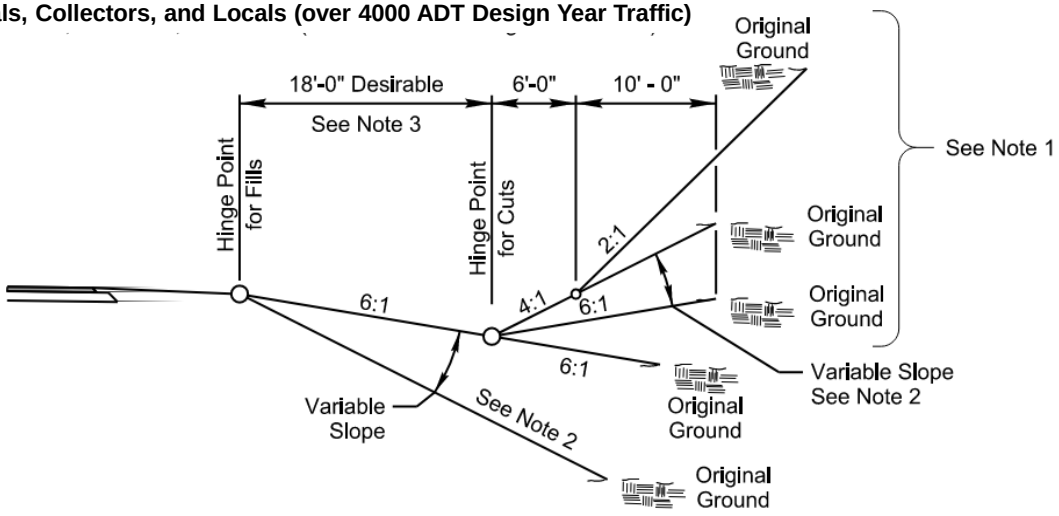


Abrupt Ditches
(RDG Figure 3-6)

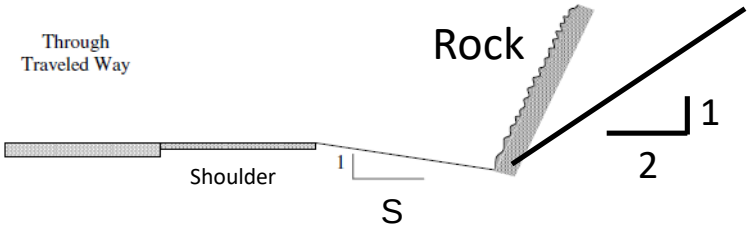
Clear Zone with a Ditch - NCDOT

4.4.6 Sideslopes

(A) Interstates, Freeways, Expressways, other Multi-Lane Facilities, Arterials, Collectors, and Locals (over 4000 ADT Design Year Traffic)

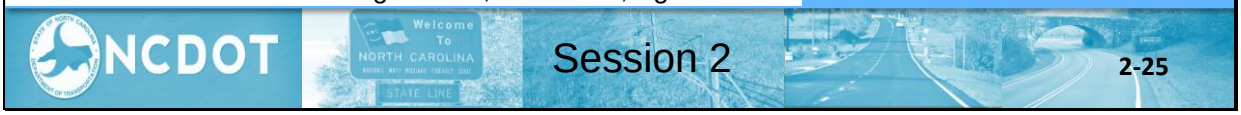


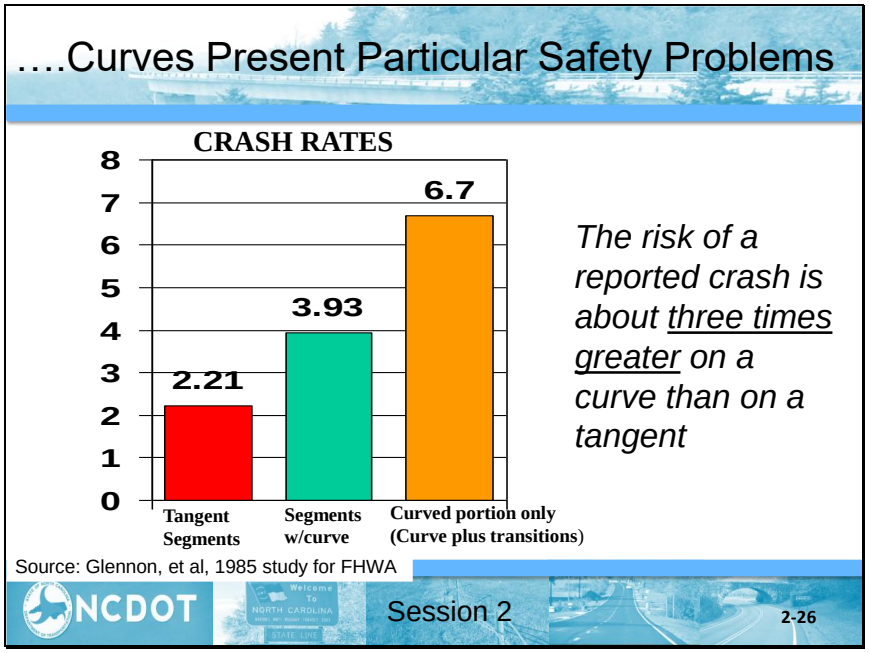
Clear Zone with a steep Cut Slope

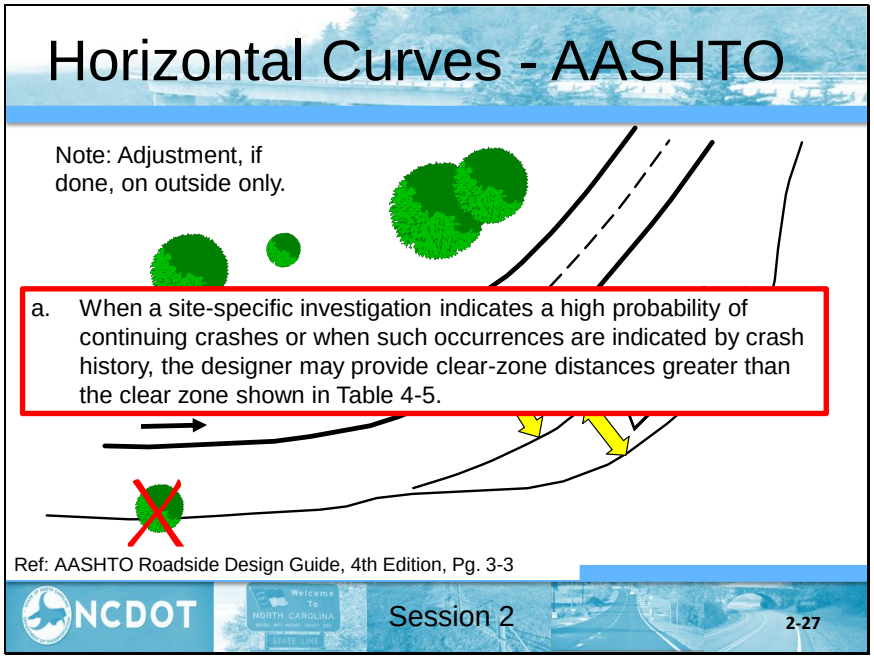


S (≥4) Recoverable	Clear Zone extends to the base of the cut. If this distance is less than the design clear zone: • For a **smooth** rock cut – it can be considered a natural barrier. (Note a 2:1 smooth slope is not normally shielded) • For a **jagged** rock cut – it is considered as any other significant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

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




….Curves Present Particular Safety Problems
CRASH RATES
8
7
6
5
4
3
2
1
0
2.21
3.93
6.7
Tangent Segments
Segments w/curve
Curved portion only (Curve plus transitions)
The risk of a reported crash is about three times greater on a curve than on a tangent
Source: Glennon, et al, 1985 study for FHWA
NCDOT
Session 2
2-26

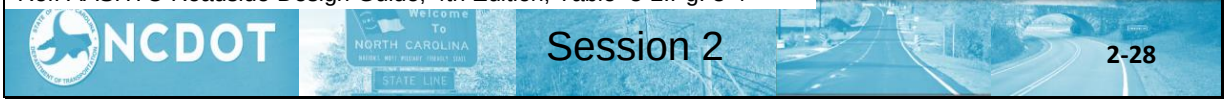

Horizontal Curves - AASHTO
Note: Adjustment, if done, on outside only.
a. When a site-specific investigation indicates a high probability of continuing crashes or when such occurrences are indicated by crash history, the designer may provide clear-zone distances greater than the clear zone shown in Table 4-5.
Ref: AASHTO Roadside Design Guide, 4th Edition, Pg. 3-3
NCDOT
Session 2
2-27

Horizontal Curve Adjustments

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

Radius (ft)	Design Speed (mph)					
	40	45	50	55	65	70
2,950	1.1	1.1	1.1	1.2	1.2	1.2
2,300	1.1	1.1	1.2	1.2	1.2	1.3
1,970	1.1	1.2	1.2	1.2	1.3	1.4
1,640	1.1	1.2	1.2	1.3	1.3	1.4
1,475	1.2	1.2	1.3	1.3	1.4	1.5
1,315	1.2	1.2	1.3	1.3	1.4	-
1,150	1.2	1.2	1.3	1.4	1.5	-
985	1.2	1.3	1.4	1.5	1.5	-
820	1.3	1.3	1.4	1.5	-	-
660	1.3	1.4	1.5	-	-	-
495	1.4	1.5	-	-	-	-
330	1.5	-	-	-	-	-

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



Horizontal Curves - NCDOT

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

Need approval by Roadway Design Unit

Remember - As Wide as Practical

NCDOT Session 2 2-29

Clear Zone and Curbs

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

Ref: AASHTO Roadside Design Guide, Section 10.2.1.1 Curbs

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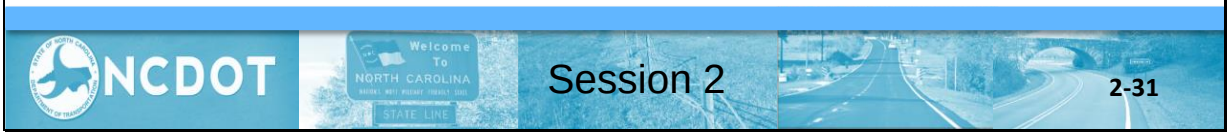
Clear Zone in an Urban Area

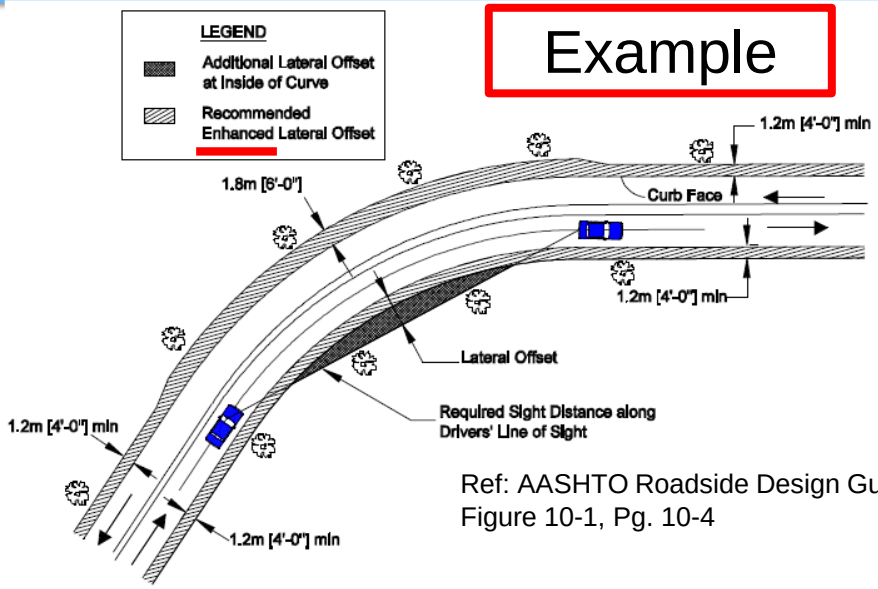
Table 4-5 Suggested Clear-Zone Distances from Edge of Through Traveled Lane

c. For roadways with low volumes, it may not be practical to apply even the minimum values found in Table 4-5. Refer to RDG Chapter 12 for additional considerations for low-volume roadways and RDG Chapter 10 for additional guidance for urban applications.



Clear Zone in an Urban Area

Example



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

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

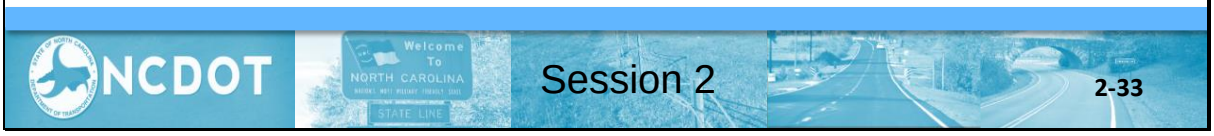
NCDOT Session 2 2-32

Order of Preference

4.6 Roadside Design

6.1 General Considerations

- Remove obstacle
- Redesign obstacle to be safely traversed
- Relocate obstacle
- Reduce impact severity with a breakaway device
- Shield obstacle with barrier that will redirect vehicle or use crash cushion
- Delineate obstacle if other options are not appropriate



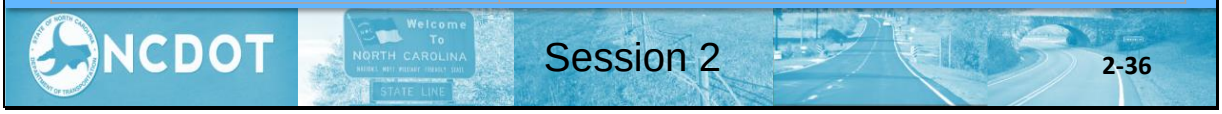

Barriers Must Be
Less of a Hazard
6.2.1 Barrier Warrants
impacts to the protective barrier will be less severe than impact with the roadside hazard.
Session 2
2-34


Session 2
2-35

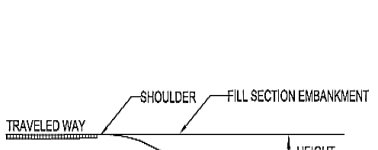
NCDOT Barrier Guidelines

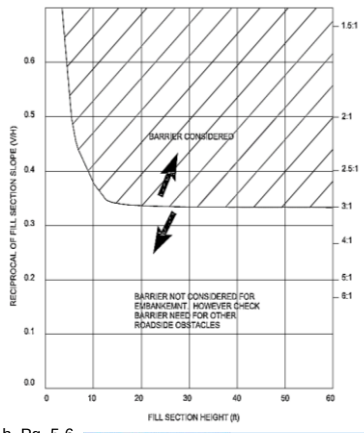
Table 6-1 Barrier Guidelines for Non-Traversable Terrain and Roadside Obstacles [a,b]

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



Embankment Guidelines





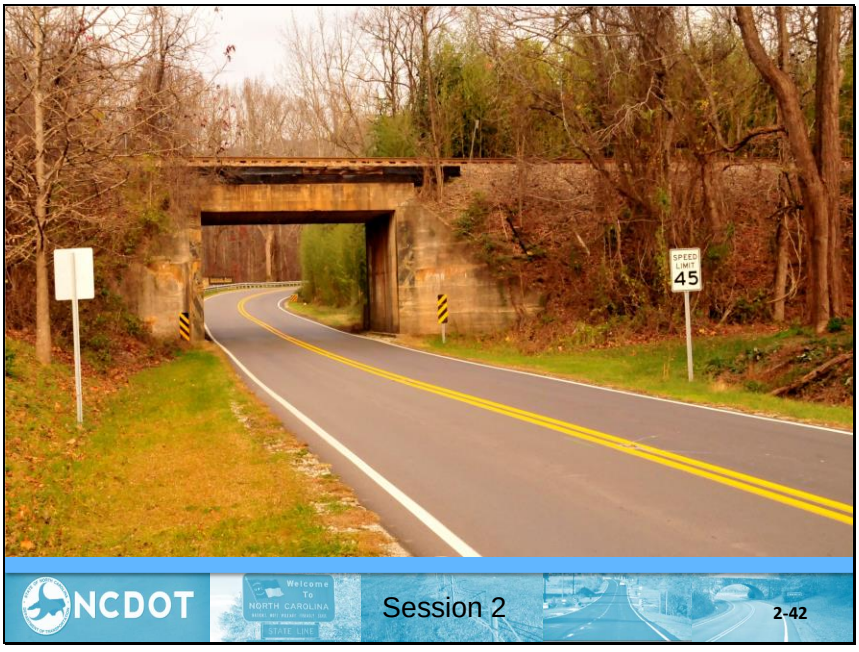
Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 5.1b, Pg. 5-6

NCDOT
Session 2
2-38

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

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


NCDOT
Session 2
2-41

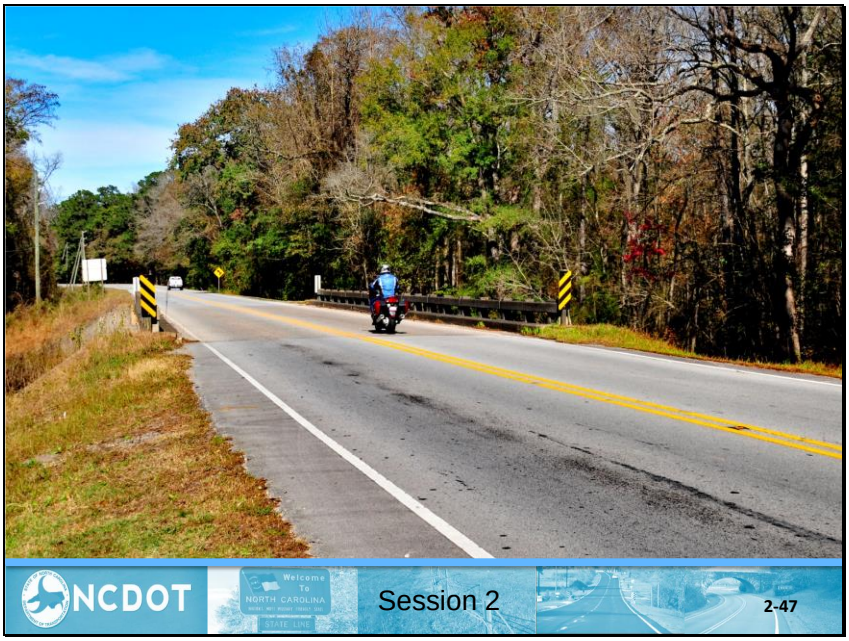

SPEED LIMIT 45
NCDOT
Session 2
2-42

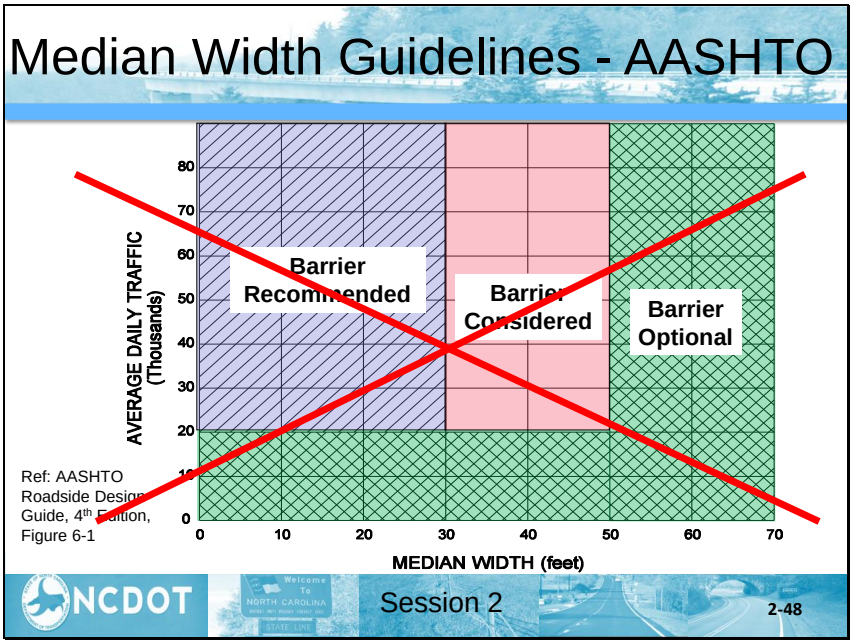

NORTH
EAST
NCDOT
Session 2
2-43


EXIT 14
NCDOT
Session 2
2-44


NCDOT
Session 2
2-45


Laurel Fork
NCDOT
Session 2
2-46


NCDOT
Session 2
2-47


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

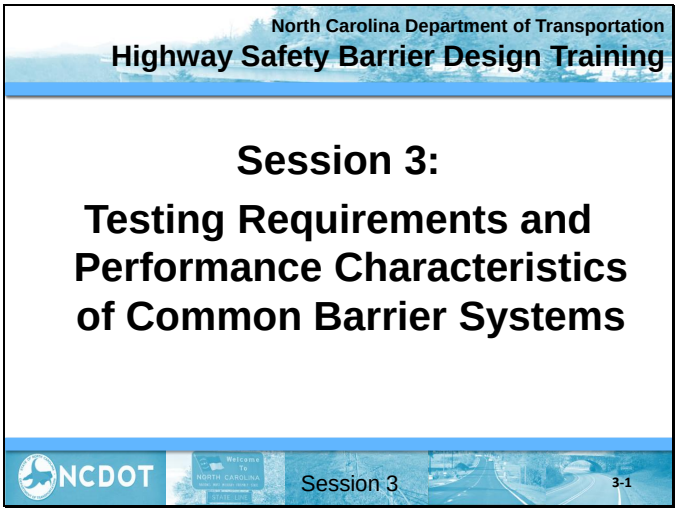
6.8 Median Barrier Selection

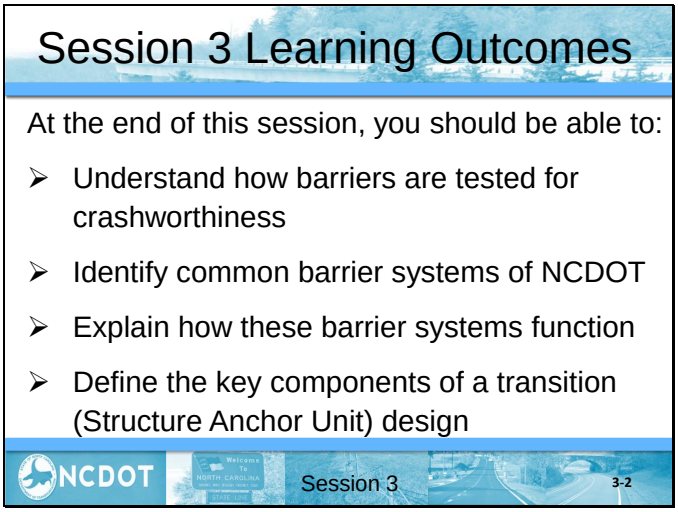
NCDOT requires median guardrail, guiderail, or barrier on all interstate and freeway projects with median widths of 70 feet or less.

Review Learning Outcomes

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

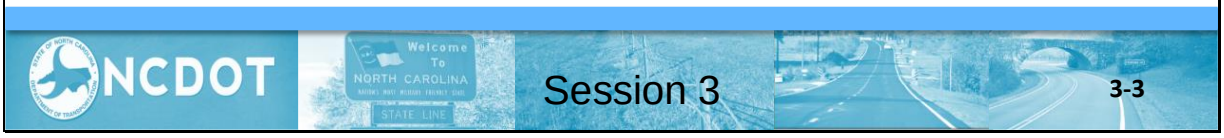
Session 3: Testing Requirements and Performance Characteristics of Common Barrier Systems

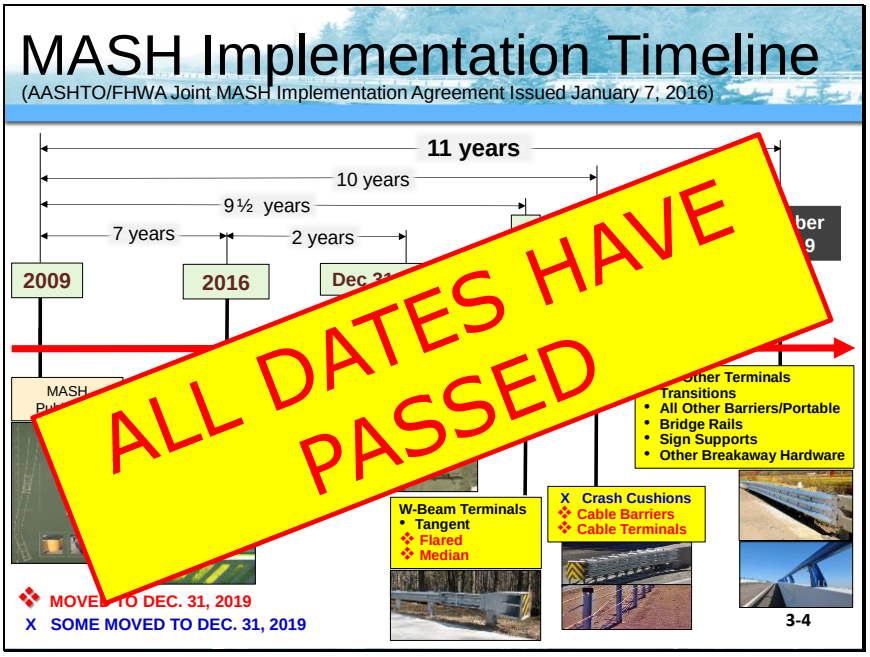

North Carolina Department of Transportation
Highway Safety Barrier Design Training
Session 3:
Testing Requirements and Performance Characteristics of Common Barrier Systems
NCDOT
Session 3
3-1

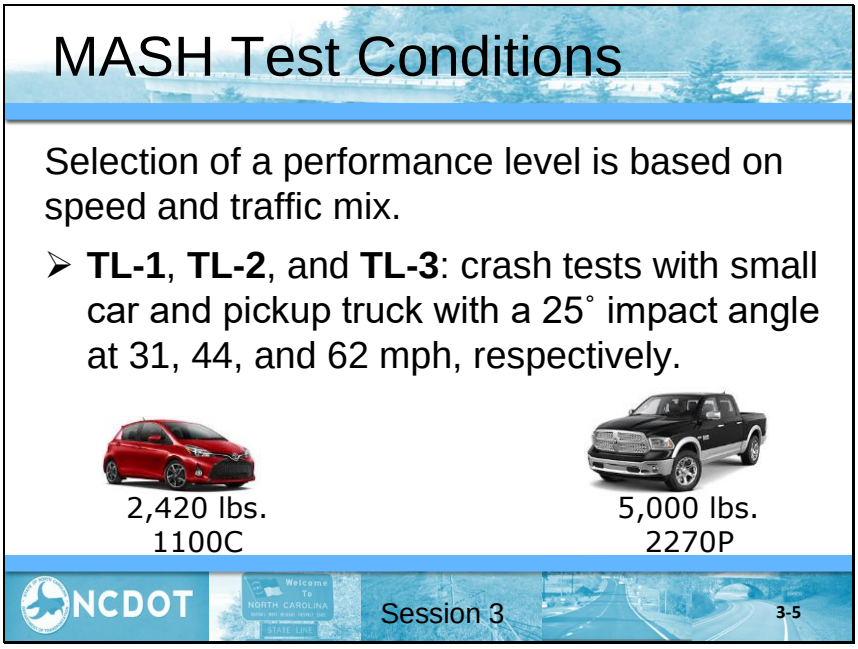

Session 3 Learning Outcomes
At the end of this session, you should be able to:
Understand how barriers are tested for crashworthiness
Identify common barrier systems of NCDOT
Explain how these barrier systems function
Define the key components of a transition (Structure Anchor Unit) design
NCDOT
Session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

Crash Testing Guidelines

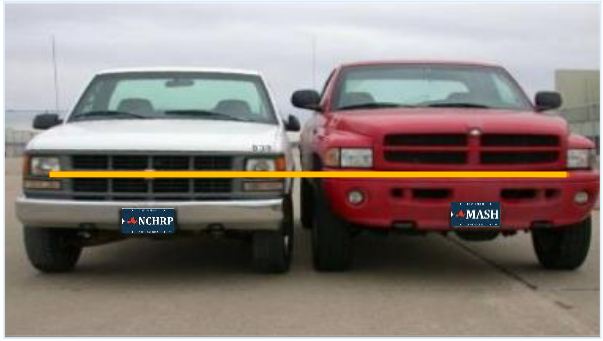
- In 1993, crash testing and evaluation criteria were published as NCHRP Report 350
- In 2009, the Manual for Assessing Safety Hardware (MASH) was published by AASHTO. It was used by FHWA as the testing standard for all new products
- In 2016, an update to MASH was adopted and a timetable for implementation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




MASH Implementation Timeline
(AASHTO/FHWA Joint MASH Implementation Agreement Issued January 7, 2016)
11 years
10 years
9½ years
7 years
2 years
2009
2016
ALL DATES HAVE PASSED
W-Beam Terminals
• Tangent
❖ Flared
❖ Median
X Crash Cushions
❖ Cable Barriers
❖ Cable Terminals
Transitions
• All Other Barriers/Portable
• Bridge Rails
• Sign Supports
• Other Breakaway Hardware
❖ MOVED TO DEC. 31, 2019
X SOME MOVED TO DEC. 31, 2019
3-4


MASH Test Conditions
Selection of a performance level is based on speed and traffic mix.
➢ TL-1, TL-2, and TL-3: crash tests with small car and pickup truck with a 25˚ impact angle at 31, 44, and 62 mph, respectively.
2,420 lbs.
1100C
5,000 lbs.
2270P
NCDOT
Session 3
3-5

NCHRP 350 comparison with MASH Crew Cab Truck



NCDOT Session 3 3-6

MASH Test Conditions (cont'd)

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

22,000 lbs.

80,000 lbs.

80,000 lbs.

NCDOT Session 3 3-7

Functional Requirement of Barrier

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

NCDOT Session 3 3-8

Standard Barrier Systems

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

NCDOT Session 3 3-9

Barrier Systems: Rigid Barriers

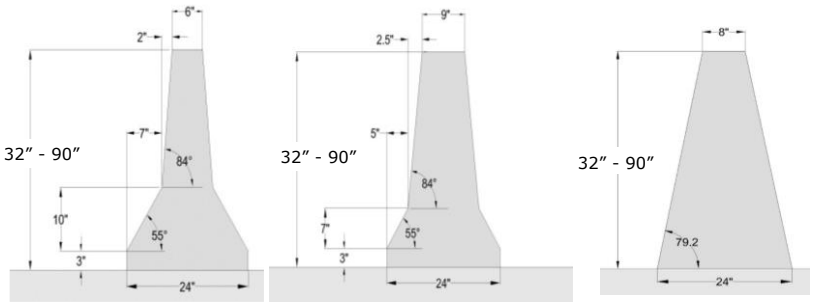
Rigid Barrier Systems have little (between 0 to 1 ft.) deflection under the TL-3 pickup impact. They are generally anchored by some acceptable means.

Examples include:

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

NCDOT Session 3 3-10

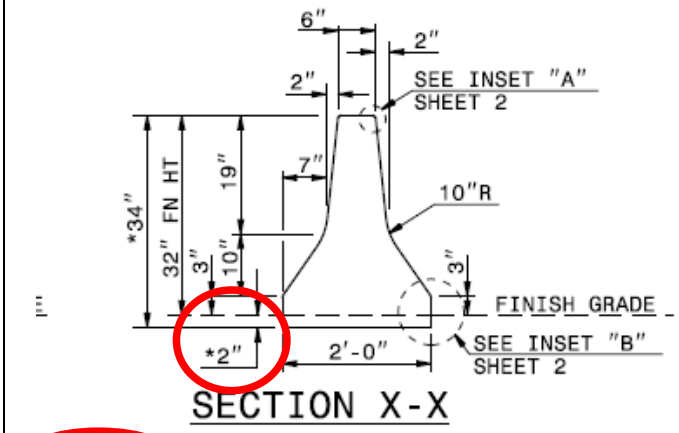
Rigid Barrier



New Jersey Shape F-Shape Single Shape

NCDOT Session 3 3-11

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

1-24 STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

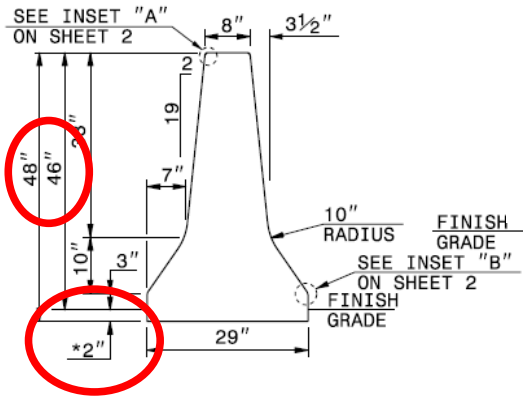
Type IV typically used

Types II & III for bifurcated cross-sections

2" min Embedment minimizes Deflection

When large trucks are not an issue

Rigid Barrier – New Jersey Shape



SECTION X-X

TYPE - T

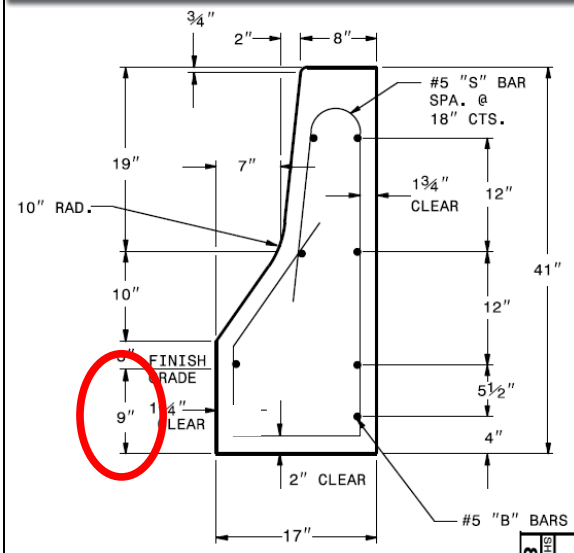
854.02 SHEET 1 OF 4	ROADWAY STANDARD DRAWING FOR **DOUBLE FACED CONCRETE BARRIER** TYPE T, T1 AND T2	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

2" min Embedment minimizes Deflection

Considered TL- 5

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

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

1-24
STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

NCDOT

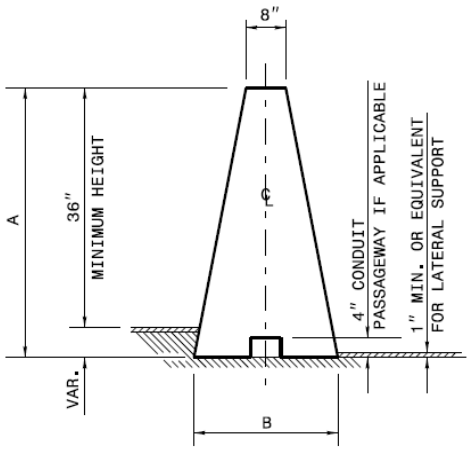
Session 3

3-14

MASH Testing of 32" New Jersey Shaped Concrete Barrier

Video Clip

Rigid Barrier – Single Slope



TYPICAL SECTION

BARRIER HEIGHT (IN.)	A
48"	48
52"	54

ROADWAY STANDARD DRAWING FOR
SINGLE SLOPE CONCRETE BARRIER

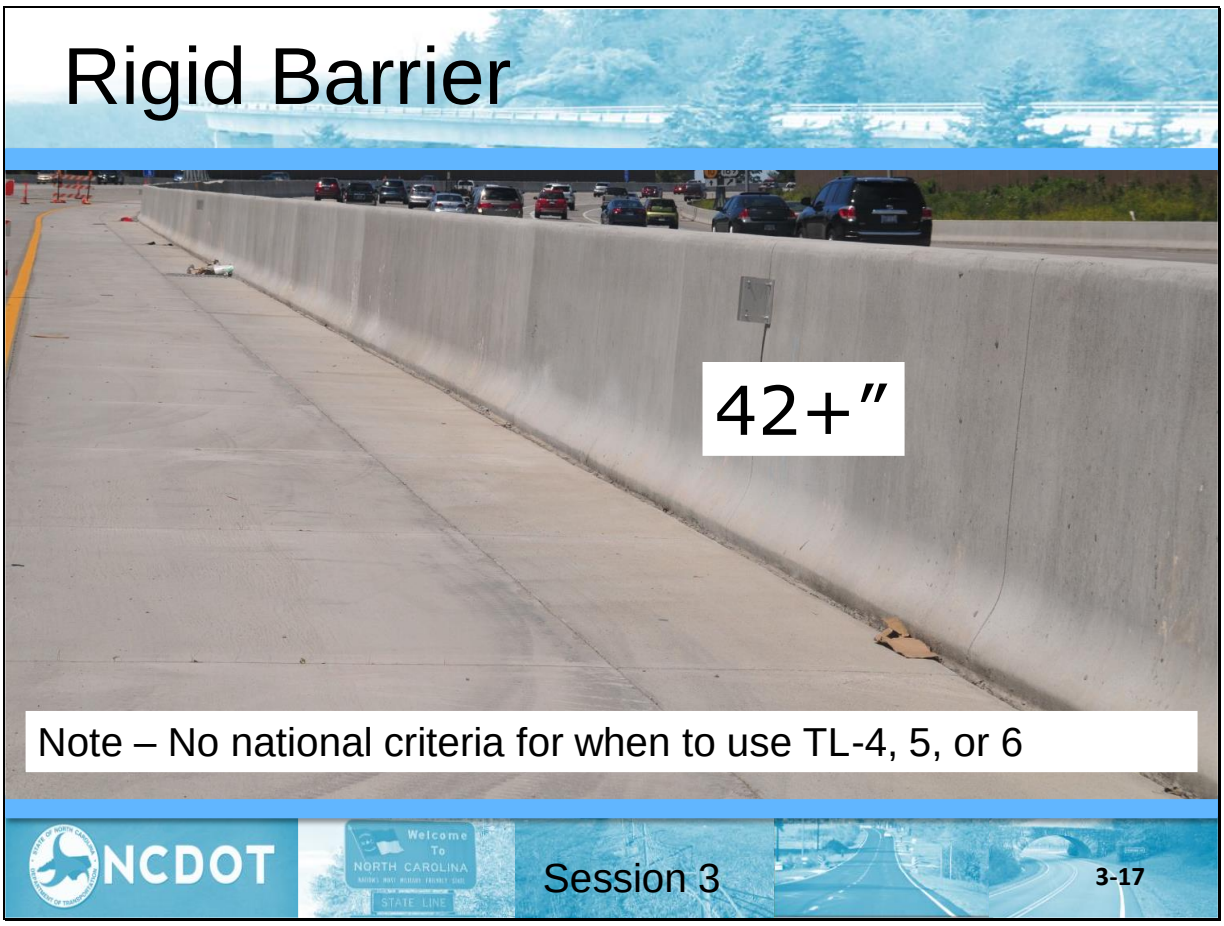
SHEET 1 OF 1
854.07

1-24
STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

NCDOT

Session 3

3-16


Rigid Barrier
42+"
Note – No national criteria for when to use TL-4, 5, or 6
NCDOT
Session 3
3-17


Rigid Barrier: TL-5
Video Clip
NCDOT
Session 3
3-18

Guidance for Selecting Concrete Barrier

Table 6-2 Standard Median Concrete Barrier Types

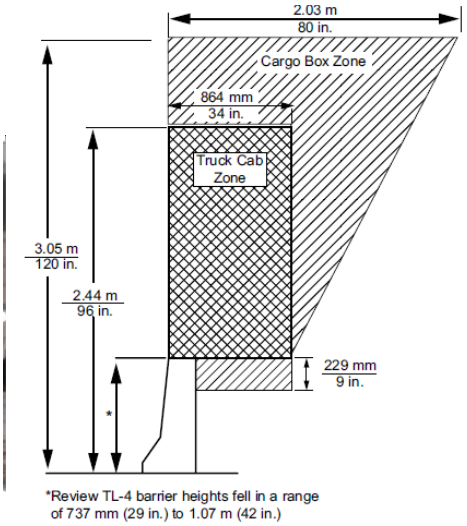
Barrier Type	Standard Drawing	Application
Type I	854.01	Glare screen permitted Freeways with truck traffic less than 250 DHV Arterials, collectors, and local roads
Type II	854.01	Glare screen permitted Grade-separated median Variable height Freeways with truck traffic less than 250 DHV Arterials, collectors, and local roads
Type III	**854.01**	No glare screen permitted Grade-separated median Variable height Freeways with truck traffic less than 250 DHV

6.4 Concrete Barriers

Use “T” Type Double Faced Concrete Barrier (Std. No. 854.02) on all interstates and freeways with truck traffic exceeding 250 DDHV.

Zone of Intrusion

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



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

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

AASHTO LRFD Bridge Specification (9th Edition)

3.6.5—Vehicular Collision Force: *CT*

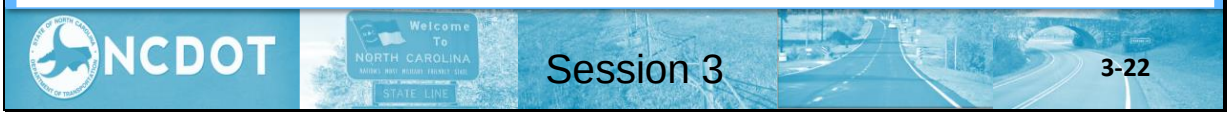
3.6.5.1—Protection of Structures

Unless the Owner determines that site conditions indicate otherwise, abutments and piers located within the clear zone as defined by the *AASHTO Roadside Design Guide* shall be investigated for collision. Collision shall be addressed by either providing structural resistance or by redirecting or absorbing the collision load. The provisions of Article 2.3.2.2.1 shall apply as appropriate.

Where the design choice is to provide structural resistance, the pier or abutment shall be designed for an equivalent static force of 600 kip, which is assumed to act in a direction of zero to 15 degrees with the edge of the pavement in a horizontal plane, at a distance from 2.0 to 5.0 ft above the

Or shield with a TL-5 Barrier

component and the connections to the foundation or pier cap.

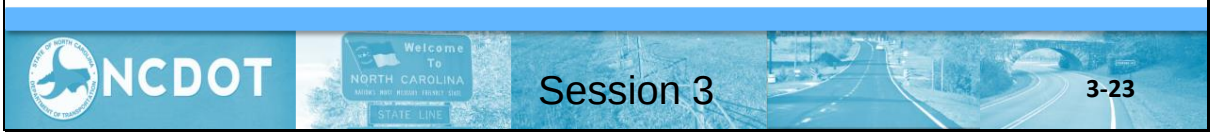


Barrier Systems: Semi-Rigid

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

Typically consist of beam and post elements.

TERMINOLOGY: Call new system 31”



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" – 29"
  - Rail splice at the post.
  - Steel posts: W6 x 8.5/9.0 x 6'-0" long.
  - Offset Block: 6" x 8" recycle plastic or composite.

Although previous practice may have referred to height at mid-rail, all heights used in this training are to top of rail

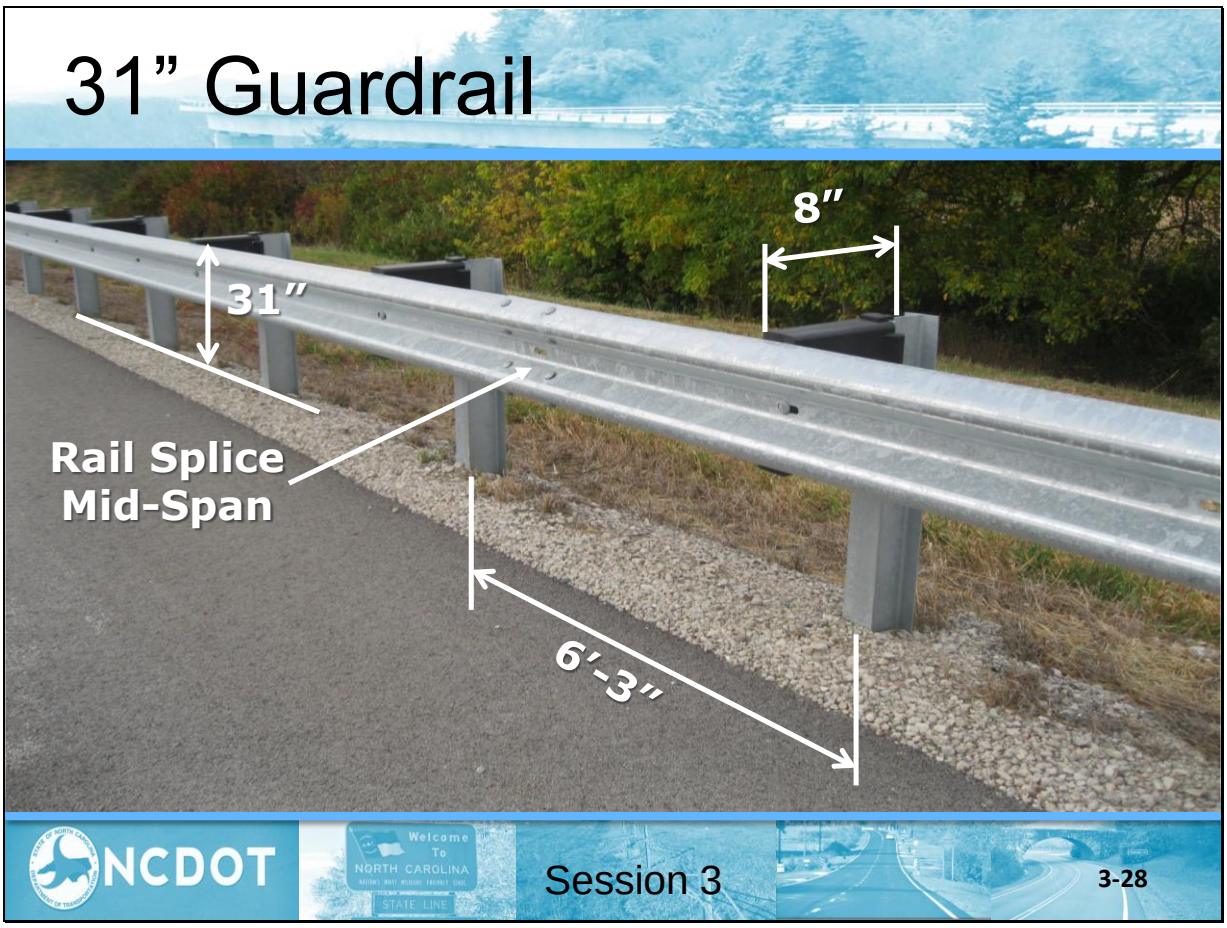
NCDOT Session 3 3-24

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

NCDOT Session 3 3-25

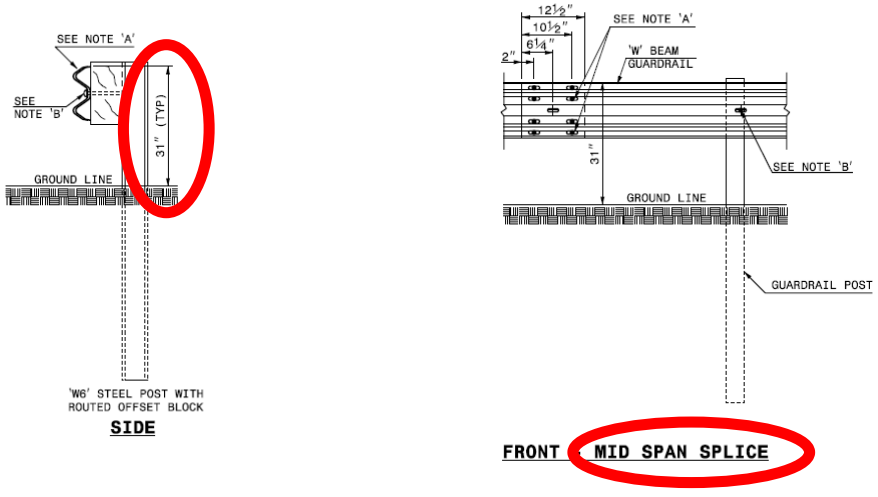
Barrier Systems: Semi-Rigid

- **31" Guardrail**
  - 31" Height to Top of Rail
  - Rail Splice mid-span.
  - Post spacing 6'-3"
  - Steel posts, W6 x 8.5/9.0 x 6'
  - Offset Block: 8" recycled plastic or composite


31” Guardrail
8”
31”
Rail Splice
Mid-Span
6’-3”
NCDOT
Session 3
3-28


31” MASH Test 3-11
Video Clip
NCDOT
Session 3
3-29

NCDOT 31" Guardrail



SHEET 6 OF 9	ROADWAY STANDARD DRAWING FOR	1-24	STATE OF
862.02	**GUARDRAIL INSTALLATION**		NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

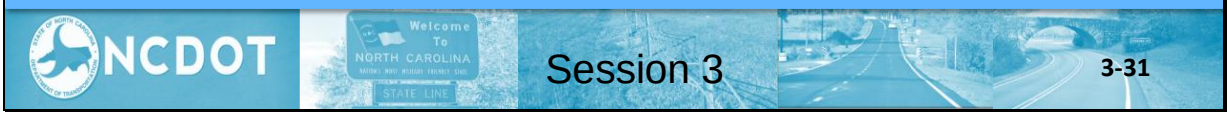
NCDOT Session 3 3-30

Barrier Systems: Flexible Barriers

Flexible Barrier Systems typically have relatively large deflections

Examples of Flexible Barriers include:

- Weak post W-beam No longer in standards
- Low tension cable Guiderail (LTCG)
- High tension cable Guiderail (HTCG)



Barrier Systems: Flexible Barriers

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

NCDOT Session 3 3-32

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Cable Guiderail - LTCG

NCDOT Session 3 3-33

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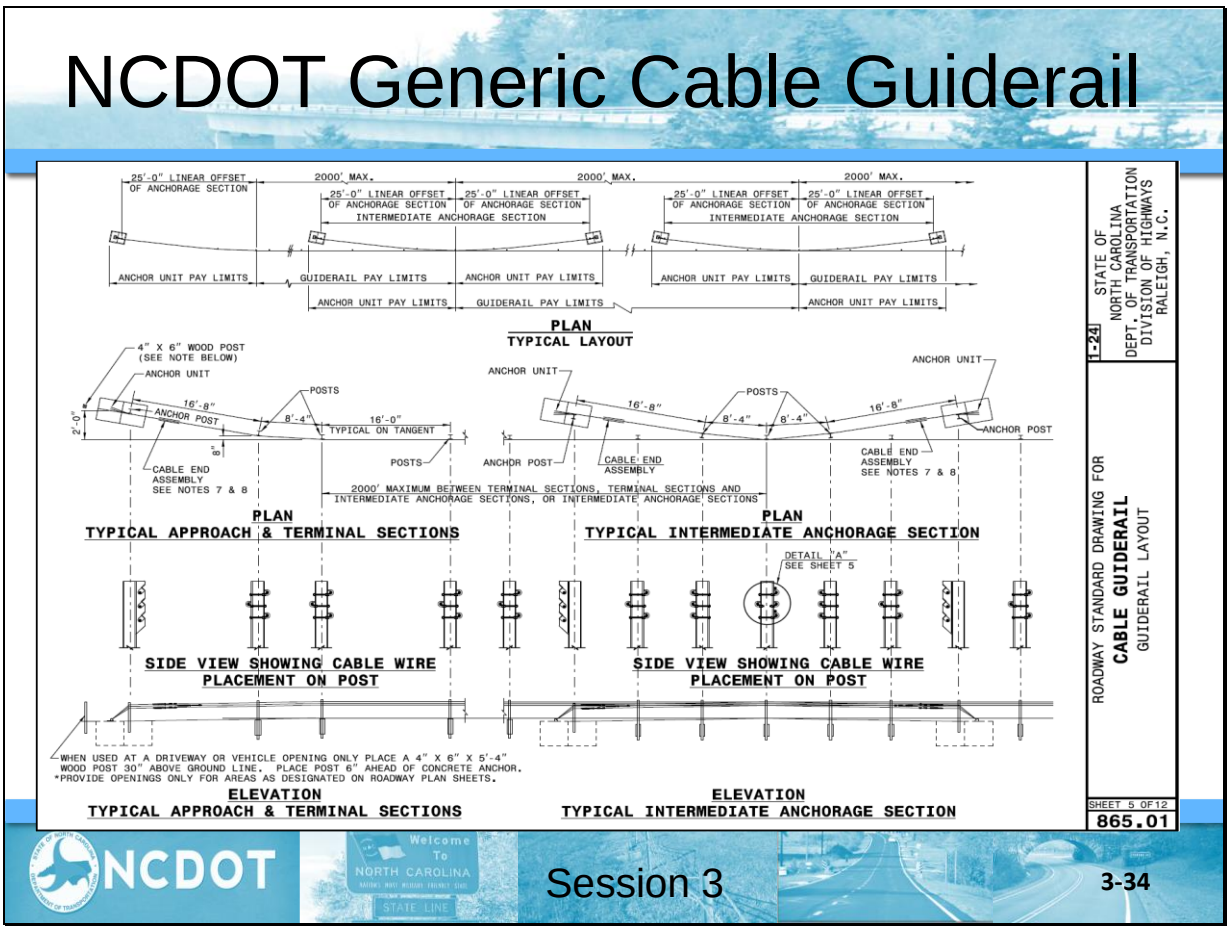

NCDOT Generic Cable Guiderail
PLAN
TYPICAL LAYOUT
PLAN
TYPICAL APPROACH & TERMINAL SECTIONS
PLAN
TYPICAL INTERMEDIATE ANCHORAGE SECTION
SIDE VIEW SHOWING CABLE WIRE PLACEMENT ON POST
SIDE VIEW SHOWING CABLE WIRE PLACEMENT ON POST
ELEVATION
TYPICAL APPROACH & TERMINAL SECTIONS
ELEVATION
TYPICAL INTERMEDIATE ANCHORAGE SECTION
STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.
ROADWAY STANDARD DRAWING FOR
CABLE GUIDERAIL
GUIDERAIL LAYOUT
SHEET 5 OF 12
865.01
NCDOT
Session 3
3-34

Barrier Systems: Flexible Barriers

Advantages of cable systems include:

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

NCDOT Session 3 3-35

Cable Guiderail: Low vs High Tension

6.5 Cable Barriers

Though each system has advantages and disadvantages, in general, a high-tension system has lower long-term maintenance costs but a higher initial cost. Only approved cable barrier systems are allowed on NCDOT projects.

For information on cable guiderail details and placement, see *NCDOT Roadway Standard Drawings* Std. No.865.01 {and RDM} Section 6.8 Median Barrier Selection.

NCDOT Session 3 3-36

Barrier Systems: Flexible Barriers

- High Tension Cable Guiderail (HTCG)
  - Five different proprietary designs developed
  - Each requires a unique proprietary terminal
  - Somewhat reduced deflections
  - Generally easier maintenance
  - Can retain effectiveness after most impacts

High-Tension Cable Guiderail (HTCG)

- Brifen ★ ★
- Safence ★
- CASS (Valtir)
- Nucor
- Gibraltar ★

★ = APL
(Work zone, Type 3)

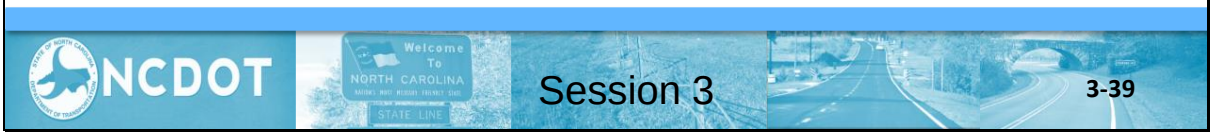
★ = RDM
(6.8.1.1)

As of 8-1-23

High-Tension Cable Guiderail (HTCG)

6.8.1.1 Types of installations to be used

Use HTCG in areas where lower deflections are needed in the median or on the outside shoulder. HTCG systems are proprietary. HTCG systems must be on the NCDOT Approved Products List and may be used at the approval of Division personnel or the State Roadway Design Engineer. Install all HTCG systems per the manufacturer's instructions. Gibraltar, Safence, and Brifen are MASH approved HTCG systems available for use by NCDOT {as of 8-1-23}.



Brifen USA

Brifen "O" Post

- Interweaving cables creates a "mini-anchor" at each post due to friction as the tensioned cables weave past each post.
- MASH 09 approved 4 cable level terrain TL-4 and 4:1 TL-3

http://www.brifenusa.com

Safence Gregory Industries

- Posts have slot located in the upper section of the web.
- 3 or 4 cable TL-3 Level and 4:1 (Also tested TL-3 on 2:1 200mm offset from breakpoint) MASH09

http://www.safence.com

Gibraltar

- Has hairpin type connection to post.
- Posts to cable connection is alternate side-to-side.
- MASH approved 4 cable Level terrain TL-4 and 4:1slope TL-3

https://gibraltarglobal.com

NCDOT Session 3 3-42

Four Cable System

NCDOT Session 3 3-43

Post Foundation and Typical Terminal

NCDOT Session 3 3-44

HTCG On 4:1 Slope

NCDOT Session 3 3-45

Barriers in the Median

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

NCDOT Session 3 3-46

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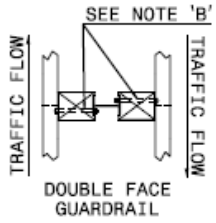
MASH 27” W-Beam Median Barrier Test

NCDOT Session 3 3-47

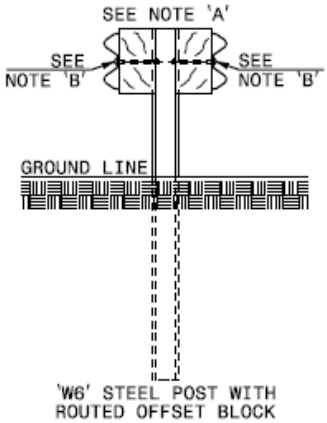
MASH 31" Median Barrier Test

NCDOT Session 3 3-48

MASH 31" Median Barrier



PLAN



SIDE

862.01 SHEET 13 OF 15	ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT** DOUBLE FACED W-BEAM	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

NCDOT Session 3 3-49

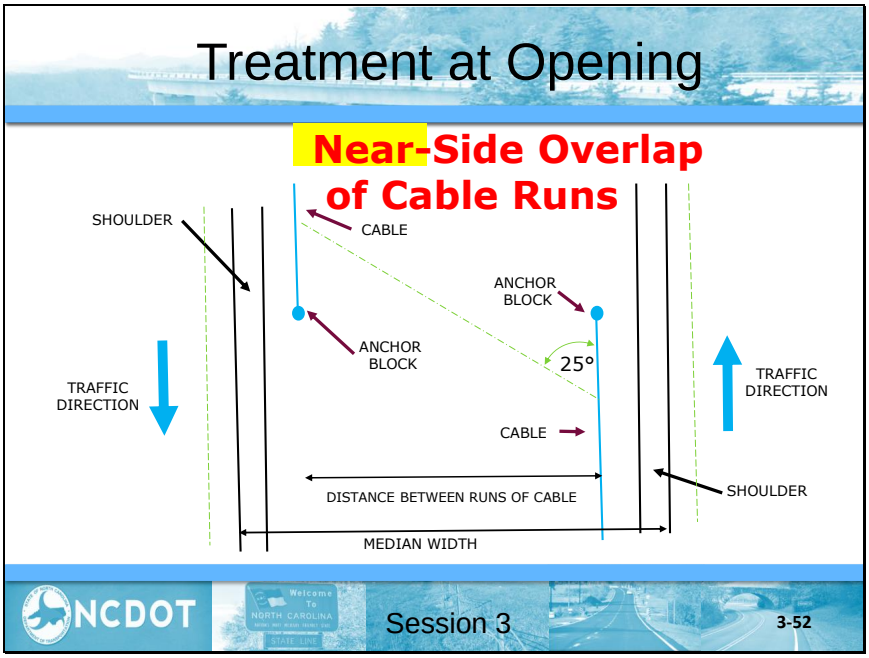
Flexible Median Barriers

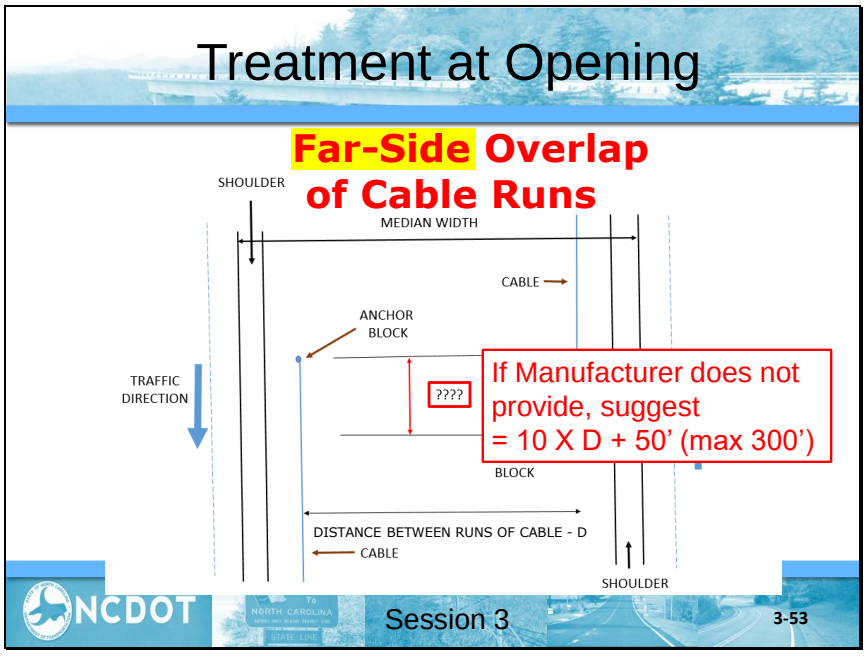
Advantage of high tension cable is it may remain effective after impact.

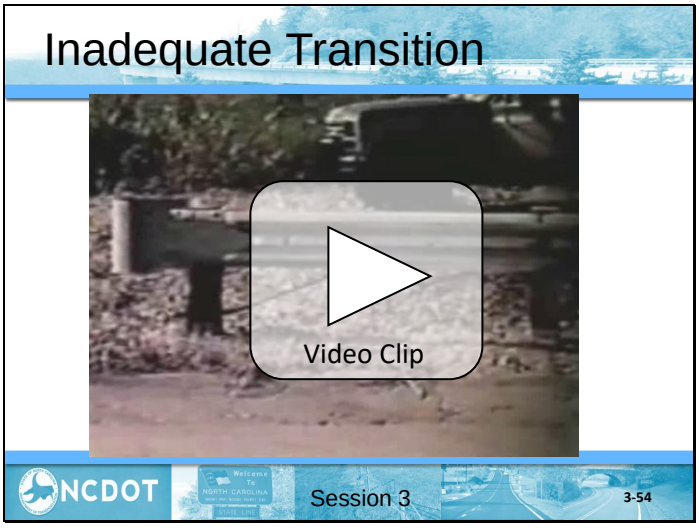
NCDOT Session 3 3-50

Flexible Median Barriers

NCDOT Session 3 3-51


Treatment at Opening
Near-Side Overlap of Cable Runs
SHOULDER
CABLE
ANCHOR BLOCK
ANCHOR BLOCK
25°
TRAFFIC DIRECTION
TRAFFIC DIRECTION
CABLE
SHOULDER
DISTANCE BETWEEN RUNS OF CABLE
MEDIAN WIDTH
NCDOT
Session 3
3-52


Treatment at Opening
Far-Side Overlap of Cable Runs
SHOULDER
MEDIAN WIDTH
CABLE
ANCHOR BLOCK
TRAFFIC DIRECTION
????
If Manufacturer does not provide, suggest
= 10 X D + 50' (max 300')
BLOCK
DISTANCE BETWEEN RUNS OF CABLE - D
CABLE
SHOULDER
NCDOT
Session 3
3-53

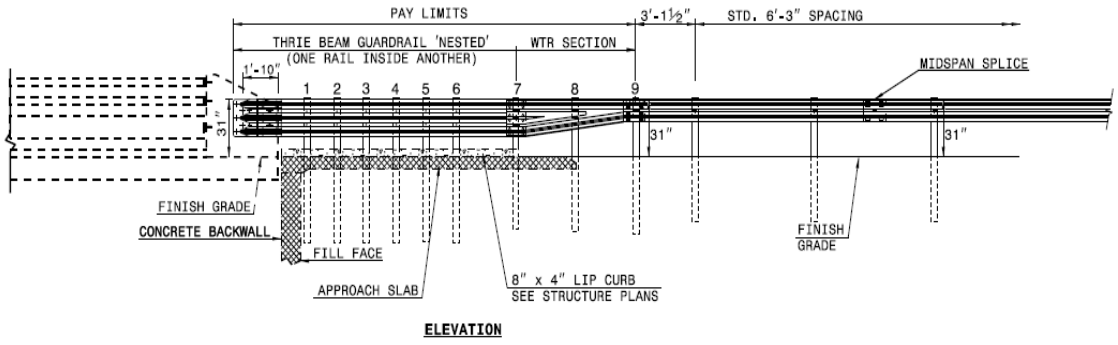


Transition Sections

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



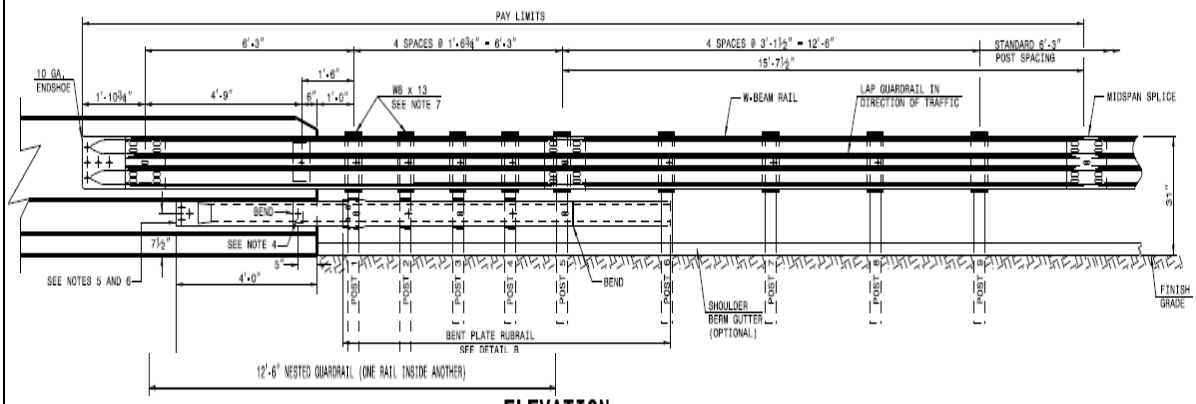
ELEVATION

SHEET 1 OF 9 862.03	ROADWAY STANDARD DRAWING FOR **STRUCTURE ANCHOR UNITS** GUARDRAIL ANCHOR UNIT, TYPE III FOR ATTACHMENT TO RAIL ON BRIDGE	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

NCDOT Session 3 3-56


NCDOT Transition – Previous Standard
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 3
3-57

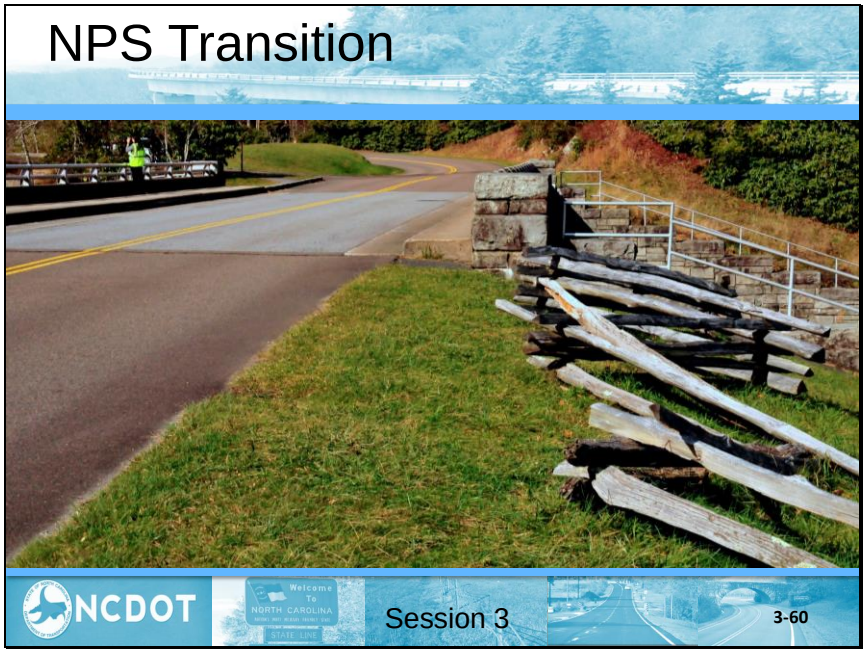
NCDOT Transition – Direct



ELEVATION

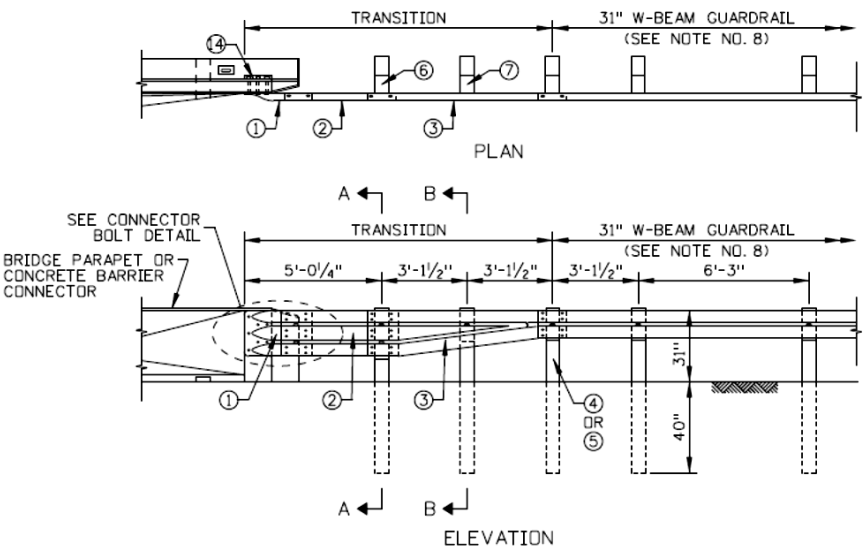
862.03 SHEET 4 OF 9	ROADWAY STANDARD DRAWING FOR **STRUCTURE ANCHOR UNITS** GUARDRAIL ANCHOR UNIT TYPE B-77 FOR F-SHAPE BARRIER	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.


NCDOT Transition – With Curb
NCDOT
Session 3
3-59


NPS Transition
NCDOT
Session 3
3-60

31” Transition - Video

Transition – 31”, TL-2



Tested – NOT a NCDOT standard

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.

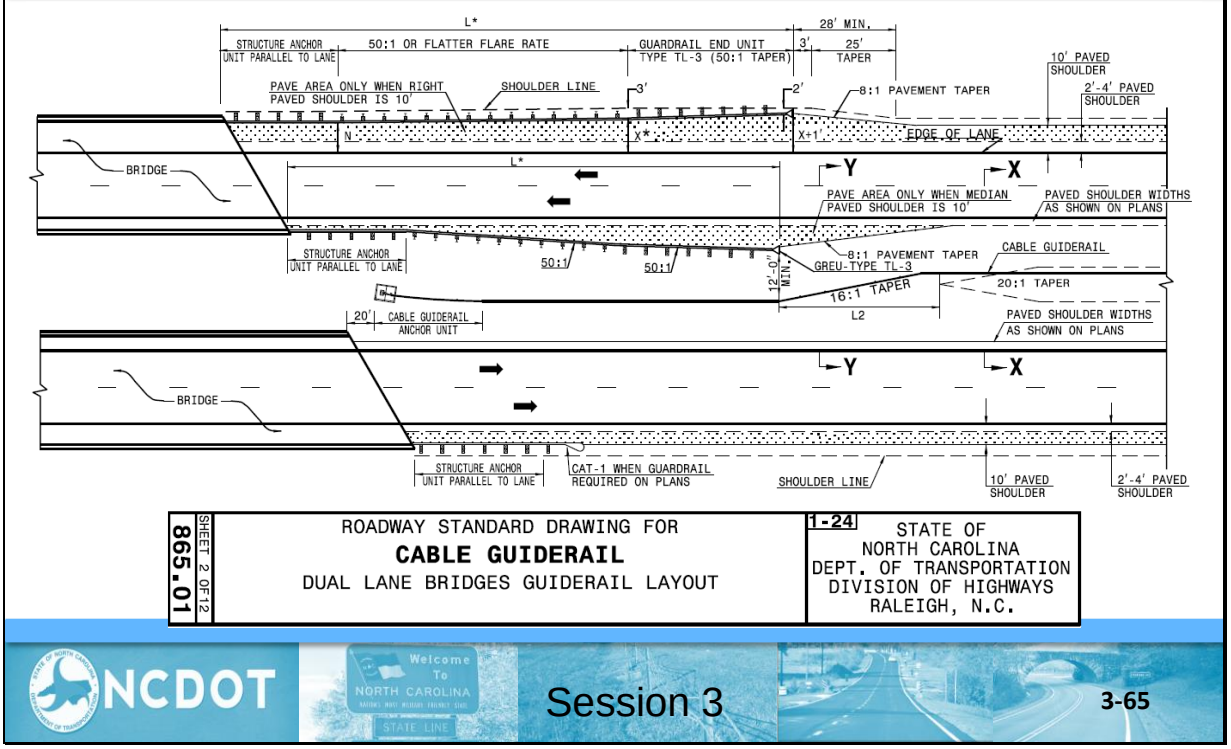
Not Crash Tested

NCDOT Session 3 3-63

Transition: HTCG to Guardrail (Spatial)

NCDOT Session 3 3-64

Transition: HTCG to Guardrail (Spatial)



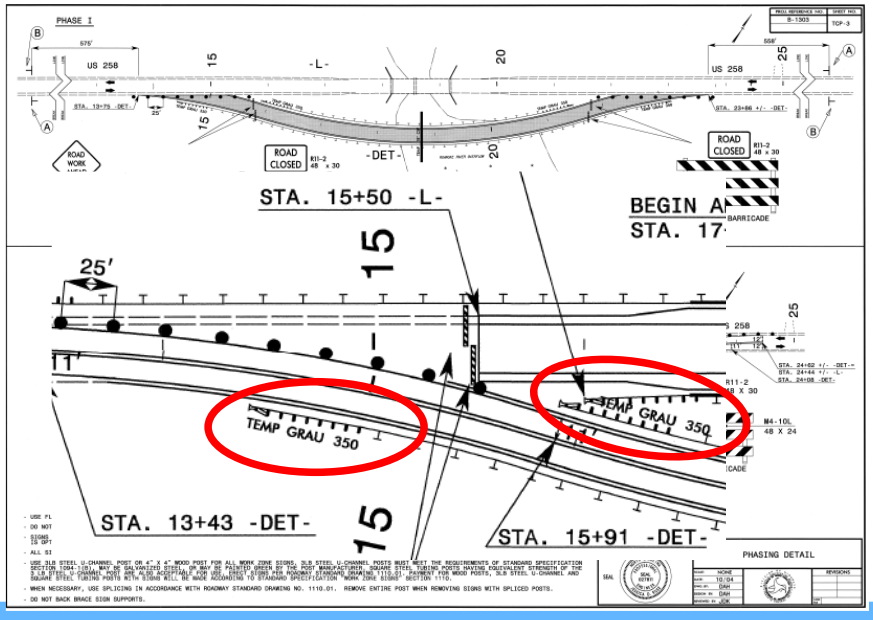
SHEET 2 OF 12 865.01	ROADWAY STANDARD DRAWING FOR **CABLE GUIDERAIL** DUAL LANE BRIDGES GUIDERAIL LAYOUT	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

NCDOT

Session 3

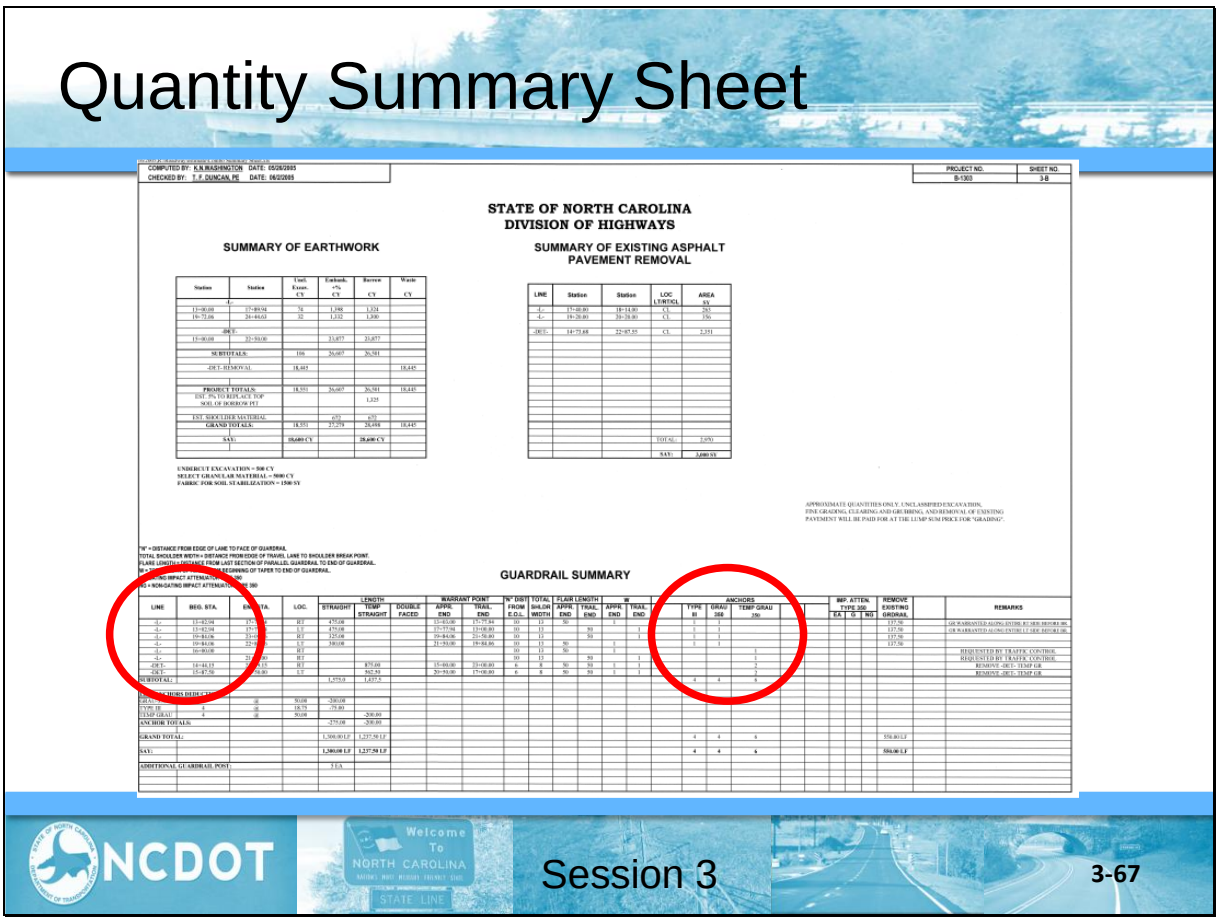
3-65

Temporary Barrier – Need for Tension



Traffic Management Plan

Quantity Summary Sheet



COMPUTED BY: K.N.WASHINGTON DATE: 05/26/2005
CHECKED BY: T. F. DUNCAN, PE DATE: 06/2/2005

PROJECT NO. 8-1303 | SHEET NO. 3-8

STATE OF NORTH CAROLINA
DIVISION OF HIGHWAYS

SUMMARY OF EARTHWORK

Station	Station	Unsl. Excav. CY	Embank. +% CY	Borrow CY	Waste CY
-L-					
13+00.00	17+89.94	74	1,398	1,324	
19+73.06	24+44.63	32	1,332	1,300	
-DET-					
13+00.00	23+50.00		23,077	23,077	
SUBTOTALS:		106	26,005	26,501	
-DET- REMOVAL		18,445			18,445
PROJECT TOTALS:		18,551	26,005	26,501	18,445
EST. 5% TO REPLACE TOP SOIL OF BORROW PIT				1,225	
EST. SHOULDER MATERIAL			470	470	
GRAND TOTALS:		18,551	27,270	28,496	18,445
SAY:		18,600 CY		28,600 CY	

UNDERCUT EXCAVATION = 500 CY
SELECT GRANULAR MATERIAL = 5000 CY
FABRIC FOR SOIL STABILIZATION = 1500 SY

SUMMARY OF EXISTING ASPHALT PAVEMENT REMOVAL

LINE	Station	Station	LOC (LT/RT/CL)	AREA SY
-L-	17+10.00	18+14.00	CL	265
-L-	19+20.00	20+26.00	CL	356
-DET-	14+75.68	22+87.55	CL	2,551
			TOTAL:	3,070
			SAY:	3,000 SY

APPROXIMATE QUANTITIES ONLY. UNCLASSIFIED EXCAVATION, FINE GRADING, CLEARING AND GRUBBING, AND REMOVAL OF EXISTING PAVEMENT WILL BE PAID FOR AT THE LUMP SUM PRICE FOR "GRADING".

"W" = DISTANCE FROM EDGE OF LANE TO FACE OF GUARDRAIL
TOTAL SHOULDER WIDTH = DISTANCE FROM EDGE OF TRAVEL LANE TO SHOULDER BREAK POINT.
FLARE LENGTH = DISTANCE FROM LAST SECTION OF PARALLEL GUARDRAIL TO END OF GUARDRAIL.
W = [illegible] BEGINNING OF TAPER TO END OF GUARDRAIL.
[illegible] NG IMPACT ATTENUATOR = 350
NI = NON-GATING IMPACT ATTENUATOR = 350

GUARDRAIL SUMMARY

LINE	BEG. STA.	END STA.	LOC.	LENGTH STRAIGHT	LENGTH TEMP STRAIGHT	LENGTH DOUBLE FACED	WARRANT POINT APPR. END	WARRANT POINT TRAIL. END	"W" DIST FROM E.O.L.	TOTAL SHLDR WIDTH	FLAIR LENGTH APPR. END	FLAIR LENGTH TRAIL. END	W APPR. END	W TRAIL. END	ANCHORS TYPE 38	ANCHORS GRAU 350	ANCHORS TEMP GRAU 350	IMP. ATTEN. TYPE 350 EA	IMP. ATTEN. TYPE 350 G	IMP. ATTEN. TYPE 350 NG	REMOVE EXISTING GR/GRAIL	REMARKS
-L-	13+02.94	15+	RT	175.00			13+03.00	13+77.94	10	12	50		1		1	1					137.50	GR WARRANTED ALONG ENTIRE RT SIDE BEFORE BR.
-L-	13+02.94	15+	LT	175.00			13+77.94	14+40.80	10	12		50		1	1	1					137.50	GR WARRANTED ALONG ENTIRE LT SIDE BEFORE BR.
-L-	19+84.06	21+	RT	125.00			19+84.06	21+50.80	10	12		50		1	1	1					137.50	
-L-	19+84.06	22+	LT	300.00			21+50.00	19+84.86	10	12	50		1		1	1					137.50	
-L-	16+00.00	15+	RT						10	12	50			1			1					REQUESTED BY TRAFFIC CONTROL
-L-		15+	RT						10	12		50		1			1					REQUESTED BY TRAFFIC CONTROL
-DET-	14+44.13	15+	RT			875.00	15+00.00	15+60.00	6	8	50	50	1	1			2					REMOVE -DET- TEMP GR.
-DET-	15+47.50	16+	LT			562.50	20+50.00	17+00.00	6	8	50	50	1	1			1					REMOVE -DET- TEMP GR.
SUBTOTAL:				1,375.0	1,437.5										4	4	6					
[illegible] NG JOBS DEDUCT																						
GRAU TE		@	50.00	-200.00																		
TYPE 38	4	@	18.75	-75.00																		
TEMP GRAU	4	@	50.00		-200.00																	
ANCHOR TOTALS:				-275.00	-200.00																	
GRAND TOTAL:				1,100.00 LF	1,237.50 LF										4	4	6				550.00 LF	
SAY:				1,200.00 LF	1,237.50 LF										4	4	6				550.00 LF	
ADDITIONAL GUARDRAIL POST:				5 EA																		

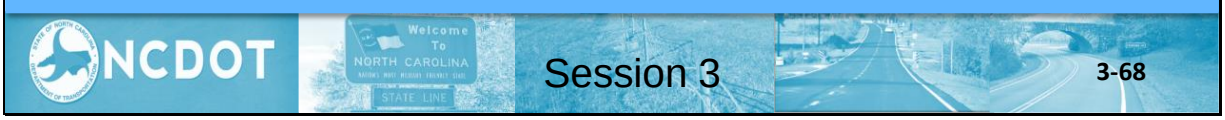
Quantity Summary Sheet – blow-up

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

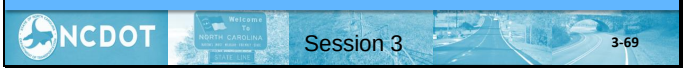
Need to re-establish tension in any altered guardrail – include in plan sheets

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



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

North Carolina Department of Transportation
Highway Safety Barrier Design Training

Session 4:

Testing Requirements and Performance Characteristics of End Treatments and Impact Attenuators

Session 4 Learning Outcomes

At the end of this session, you should 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

Guardrail End Treatments (GREU)

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.

Cable Anchor Terminal – MASH

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

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

Eligibility Letter B-256

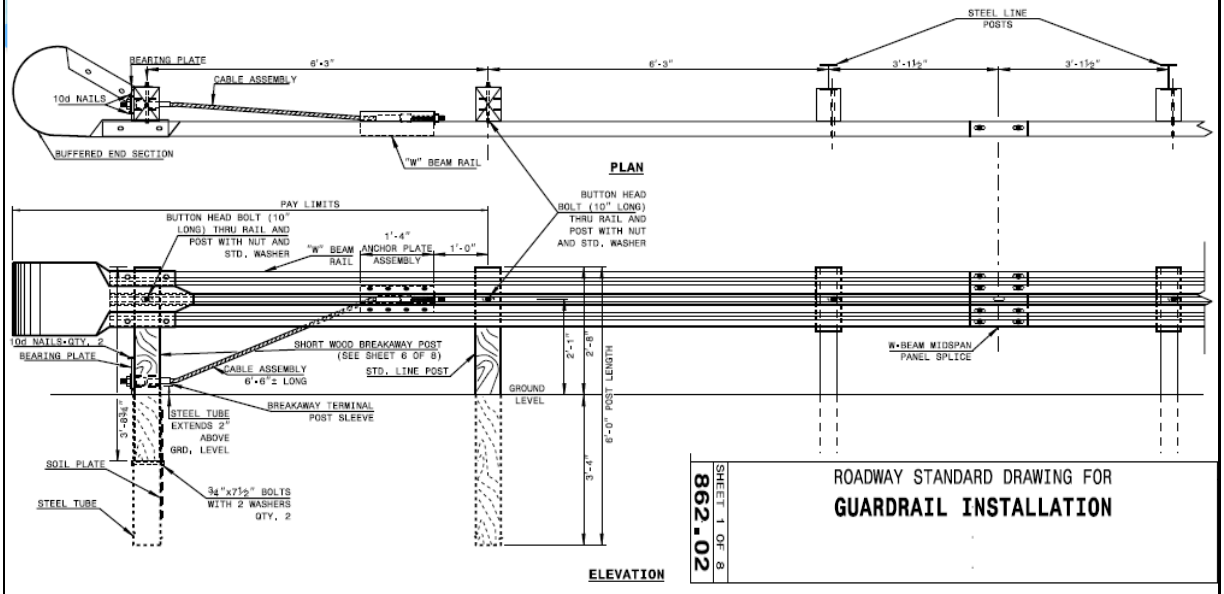
MwRSF Design
12'- 6" rail
Rail extends past last post

NCDOT Session 4 4-4

Cable Anchor Terminal - Tension

NCDOT Session 4 4-5

NC Cable Anchor – Not tested



TRAILING END UNIT ASSEMBLY

C.A.T.-1 SYSTEM

NCDOT Session 4 4-6

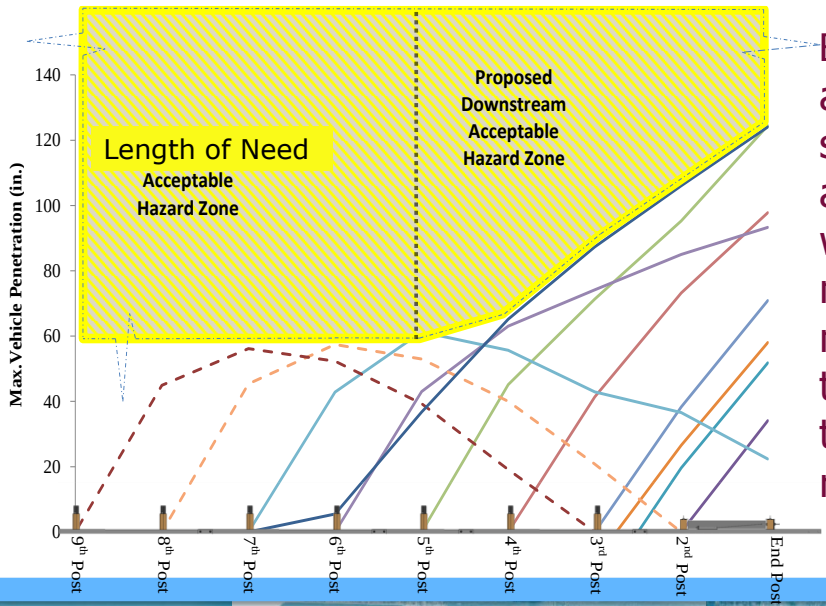
Guardrail Cable Anchor Terminal Test

Impacted at 6th post from the end

Vehicle deflected up to 10' behind the barrier

NCDOT Session 4 4-7

Guardrail Cable Anchor Terminal Test Analysis



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

NCDOT

Session 4

4-8

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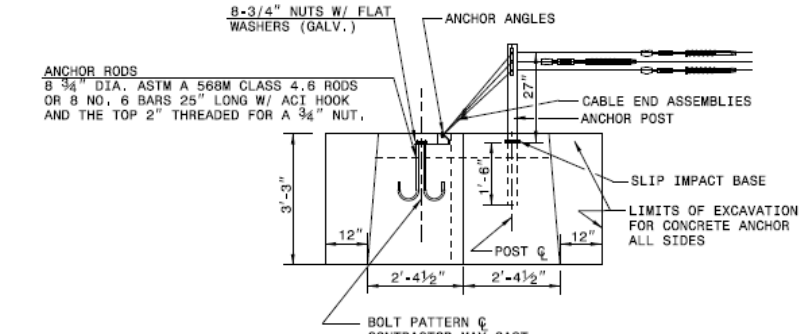
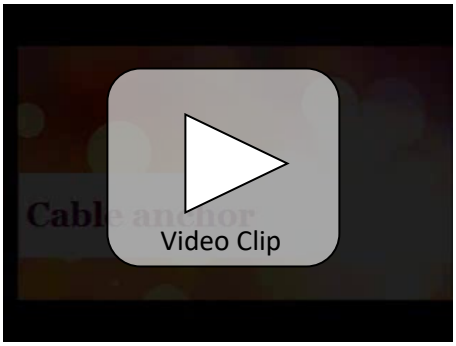
Cable Guiderail Terminal - LTCG



ANCHOR UNIT DETAIL
LEFT HAND
(REINFORCEMENT NOT SHOWN)

865.01 SHEET 10 OF 12	ROADWAY STANDARD DRAWING FOR **CABLE GUIDERAIL** ANCHOR DETAILS	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

Cable Guiderail Terminal – HTCG Video

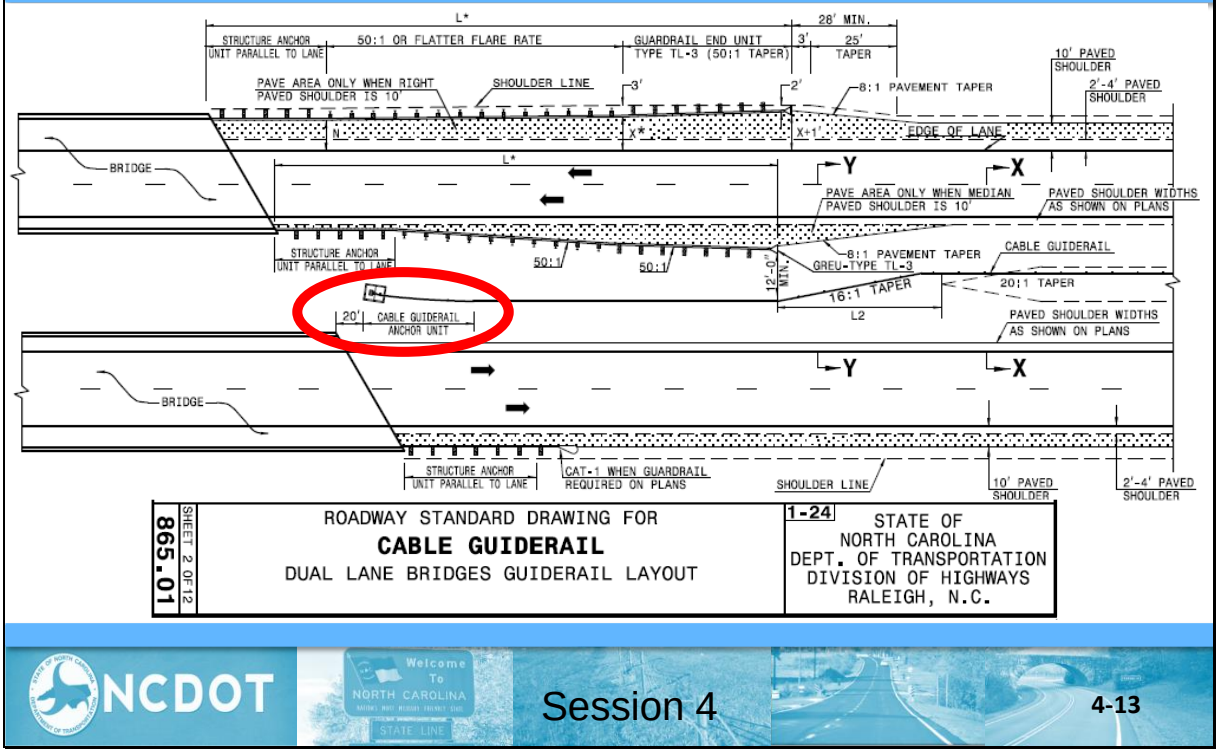


NCDOT Guidance

6.8.1.4 Use of Cable Guiderail with Earth Berm Protection

When using the earth berm, stop the cable guiderail at an approximate distance of 225 feet from the beginning of the concrete slope protection. Note that if the earth berm is not feasible or cost effective, concrete barriers, guardrail, guiderail or impact attenuators should be used.

Cable Guiderail Anchor Unit Placement



NCDOT Session 4 4-13

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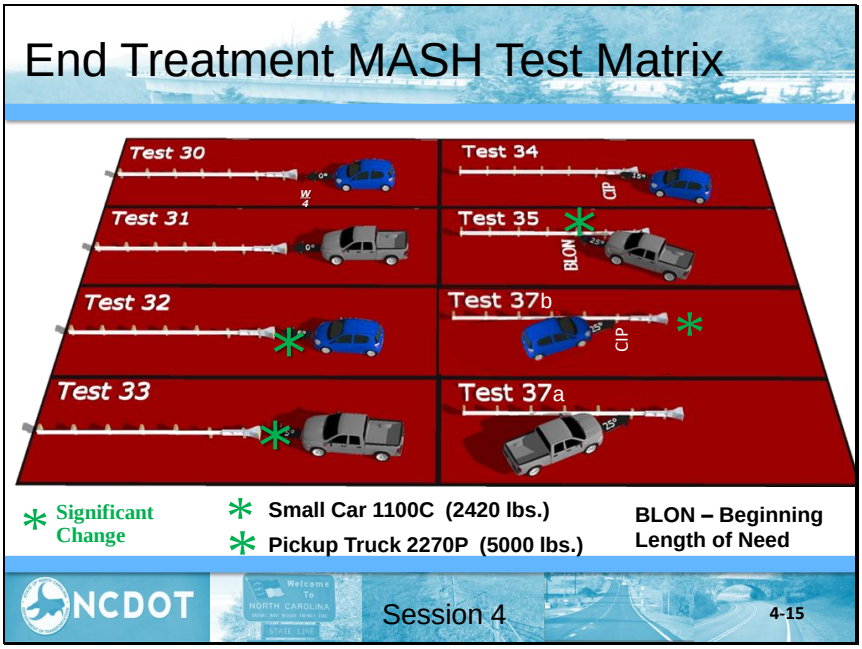
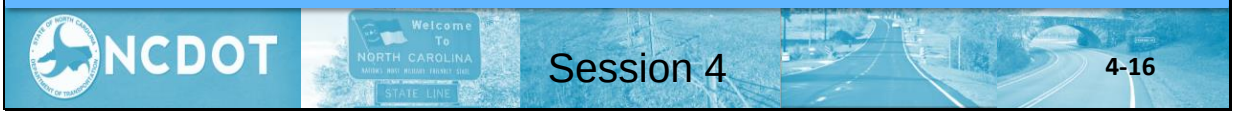
PRE-ASSESSMENT PHOTO
NCDOT
Session 4
4-14


End Treatment MASH Test Matrix
Test 30
Test 34
Test 31
Test 35
Test 32
Test 37b
Test 33
Test 37a
Significant Change
Small Car 1100C (2420 lbs.)
Pickup Truck 2270P (5000 lbs.)
BLON – Beginning Length of Need
NCDOT
Session 4
4-15

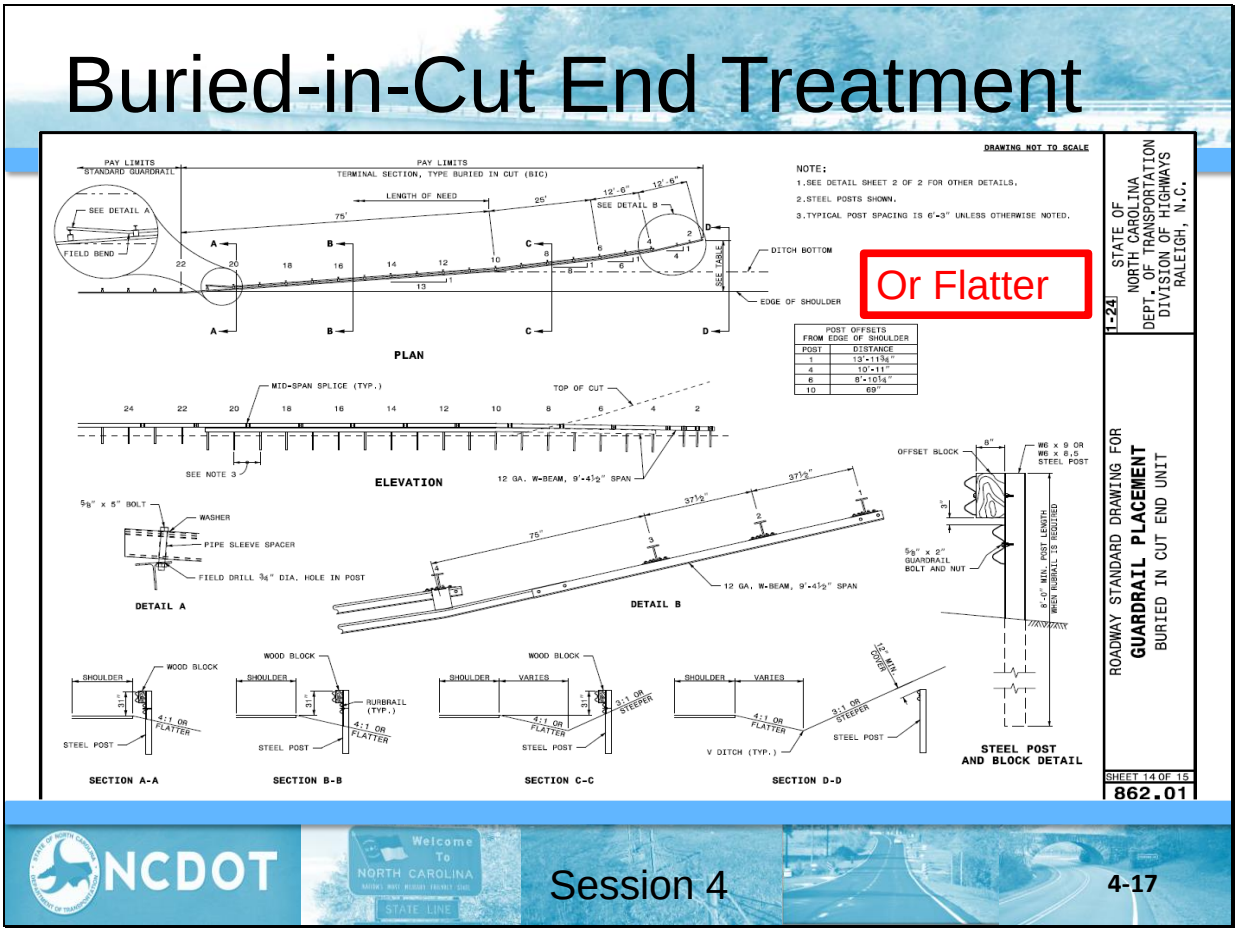
Guardrail End Treatments

Types of End Treatments

- Buried-in-Cut (aka: BIB)
- Tangent terminals – terminal is parallel to the roadway or has a straight flare with a "slight" offset; all are Energy-absorbing
- Flared terminals – terminal is placed on a flare to the roadway typically 3' or 4'; both non-energy- and energy-absorbing



Buried-in-Cut End Treatment



Buried-in-Cut End Treatment

- Key design considerations:
  - 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 of 13:1 or flatter on the foreslope
  - Use an anchor of steel posts capable of developing the full tensile strength of the W-beam rail and buried 1' below ground

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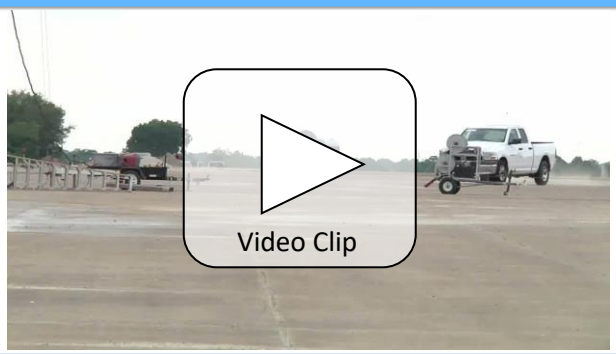
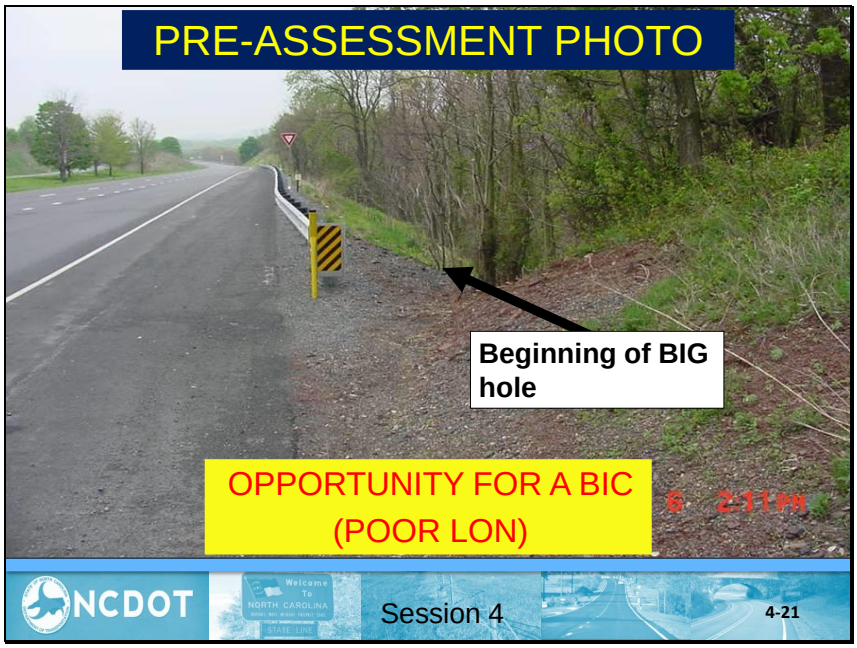
MASH
Buried-in-Cut End Treatment



NCDOT Session 4 4-19


BIC Looking Across Roadway
NCDOT
Session 4
4-20


PRE-ASSESSMENT PHOTO
Beginning of BIG hole
OPPORTUNITY FOR A BIC
(POOR LON)
NCDOT
Session 4
4-21

End Treatments - Terminology

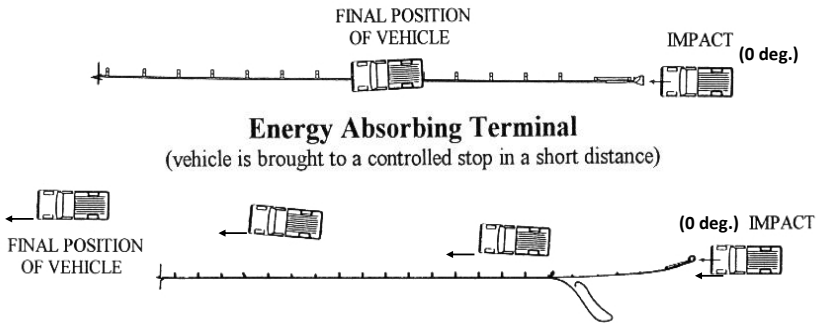
CAT-1 – Cable Anchor Terminal – non-crashworthy device to develop Tension where there is no opportunity for end-on impacts

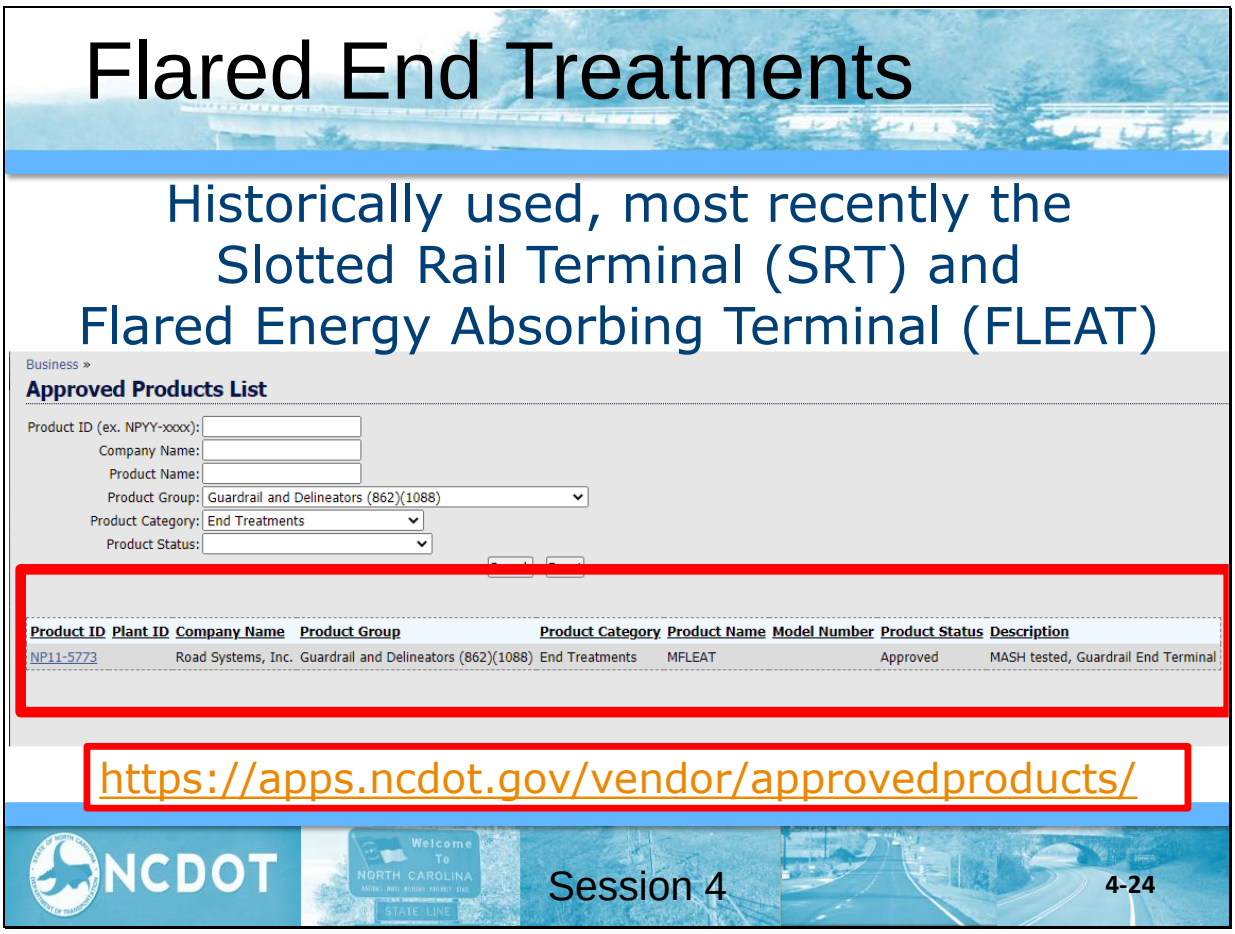
(AT-1 – Anchor Terminal – no cable)

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 Slotted Rail Terminal (SRT) and Flared Energy Absorbing Terminal (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/
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STATE LINE
Session 4
4-24

Flared End Treatment: Energy Absorbing

- **MFLEAT** *MASH Version of FLEAT*
  - 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

_____

_____

MASH
MFLEAT

_____

_____

_____

_____

_____

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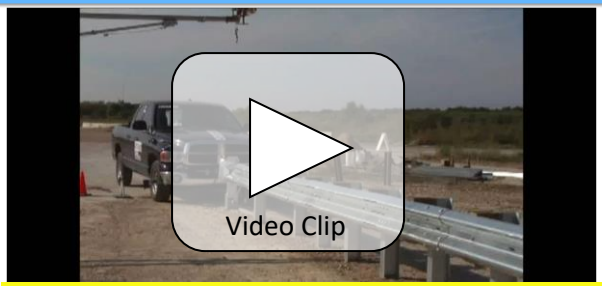
Flared End Treatment: Non-energy-Absorbing

- SRT 350 (Slotted Rail Terminal)
  - W-Beam rails on a parabola or a straight line and horizontal slots in rail
  - Offset - 4’; 31” Height
  - 37’-6” long, BLON at Post 3
  - Cable-anchored system

Correct ONLY if LON and Grading Satisfied

NCDOT Session 4 4-27

Test 3-31: SRT



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

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NOT GOOD!!!!!
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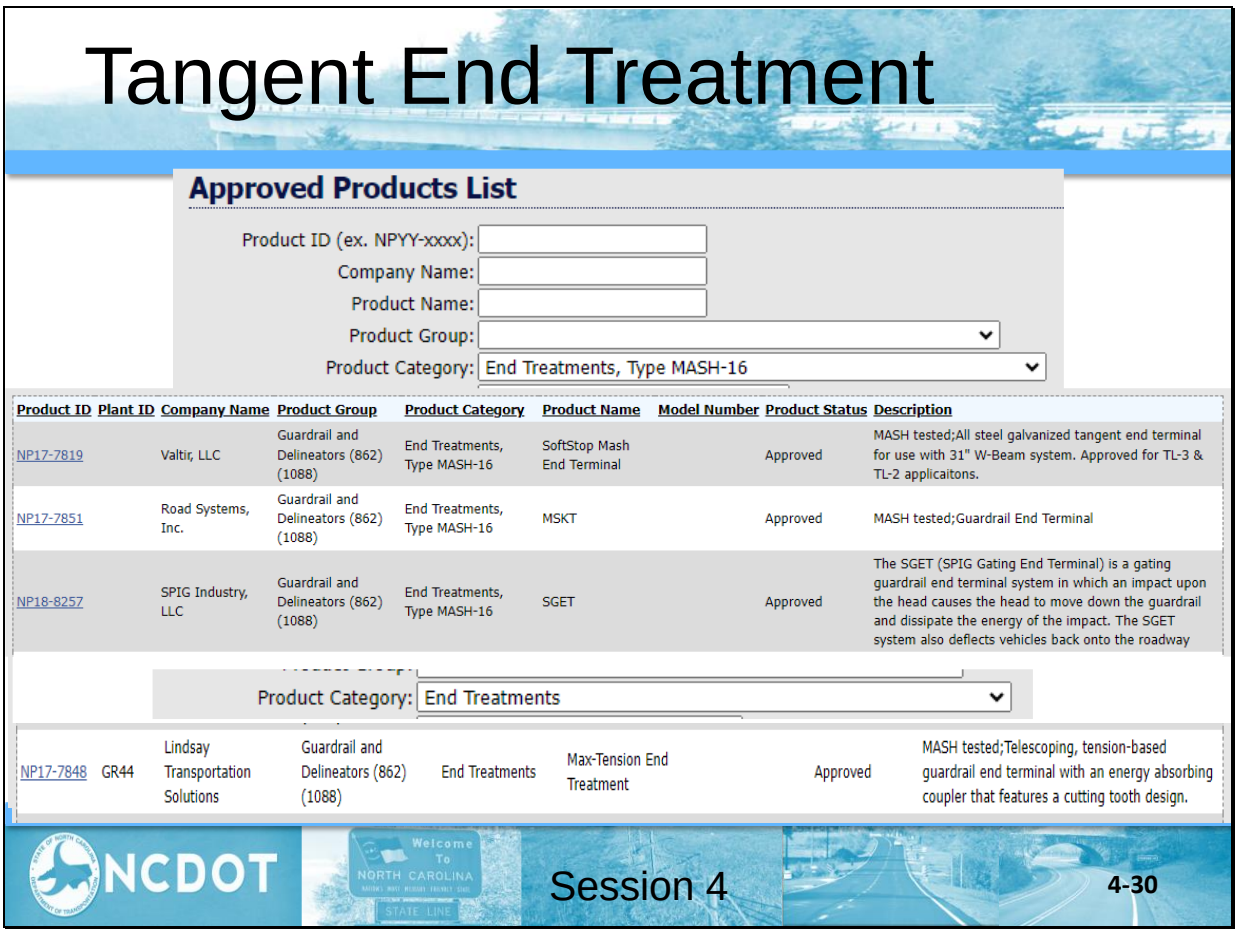
STATE LINE
Session 4
4-29


Tangent End Treatment
Approved Products List
Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: End Treatments, Type MASH-16
Product ID | Plant ID | Company Name | Product Group | Product Category | Product Name | Model Number | Product Status | Description
NP17-7819 | | Valtir, LLC | Guardrail and Delineators (862) (1088) | End Treatments, Type MASH-16 | SoftStop Mash End Terminal | | Approved | MASH tested;All steel galvanized tangent end terminal for use with 31" W-Beam system. Approved for TL-3 & TL-2 applicaitons.
NP17-7851 | | Road Systems, Inc. | Guardrail and Delineators (862) (1088) | End Treatments, Type MASH-16 | MSKT | | Approved | MASH tested;Guardrail End Terminal
NP18-8257 | | SPIG Industry, LLC | Guardrail and Delineators (862) (1088) | End Treatments, Type MASH-16 | SGET | | Approved | The SGET (SPIG Gating End Terminal) is a gating guardrail end terminal system in which an impact upon the head causes the head to move down the guardrail and dissipate the energy of the impact. The SGET system also deflects vehicles back onto the roadway
Product Category: End Treatments
NP17-7848 | GR44 | Lindsay Transportation Solutions | Guardrail and Delineators (862) (1088) | End Treatments | Max-Tension End Treatment | | Approved | MASH tested;Telescoping, tension-based guardrail end terminal with an energy absorbing coupler that features a cutting tooth design.
NCDOT
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Session 4
4-30

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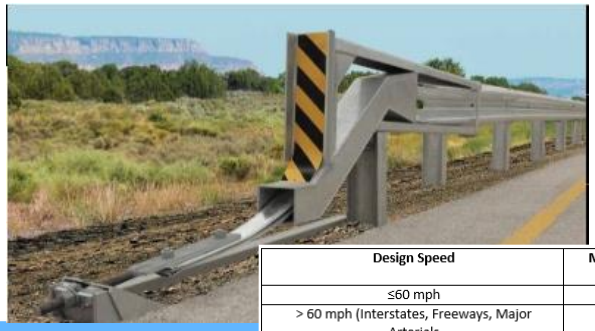
Tangent End Treatment: Energy Absorbing

- Soft Stop (MASH)
  - 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 4 4-31

MASH Soft Stop

NCDOT Session 4 4-32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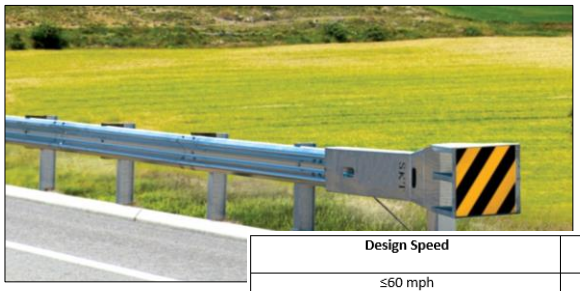
STATE LINE
Session 4
4-33

Tangent End Treatment: Energy Absorbing

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



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

NCDOT Session 4 4-34

MASH MSKT

NCDOT Session 4 4-35

Tangent End Treatment: Energy Absorbing

- SPIG Gating End Terminal (SGET) (MASH)
  - Flattens guardrail when hit head-on or at a shallow angle
  - Steel and wood post system; BLON at 3rd Post
  - TL-3 at 47’ long; attachment to 31” MGS Barrier
  - Cable-anchored system, Compression system

No FHWA Eligibility Letter

MASH SGET – Test 3-31

Tangent End Treatment: Energy Absorbing

- MAX-Tension (MASH)
  - 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

NCDOT Session 4 4-38

MASH MAX-Tension

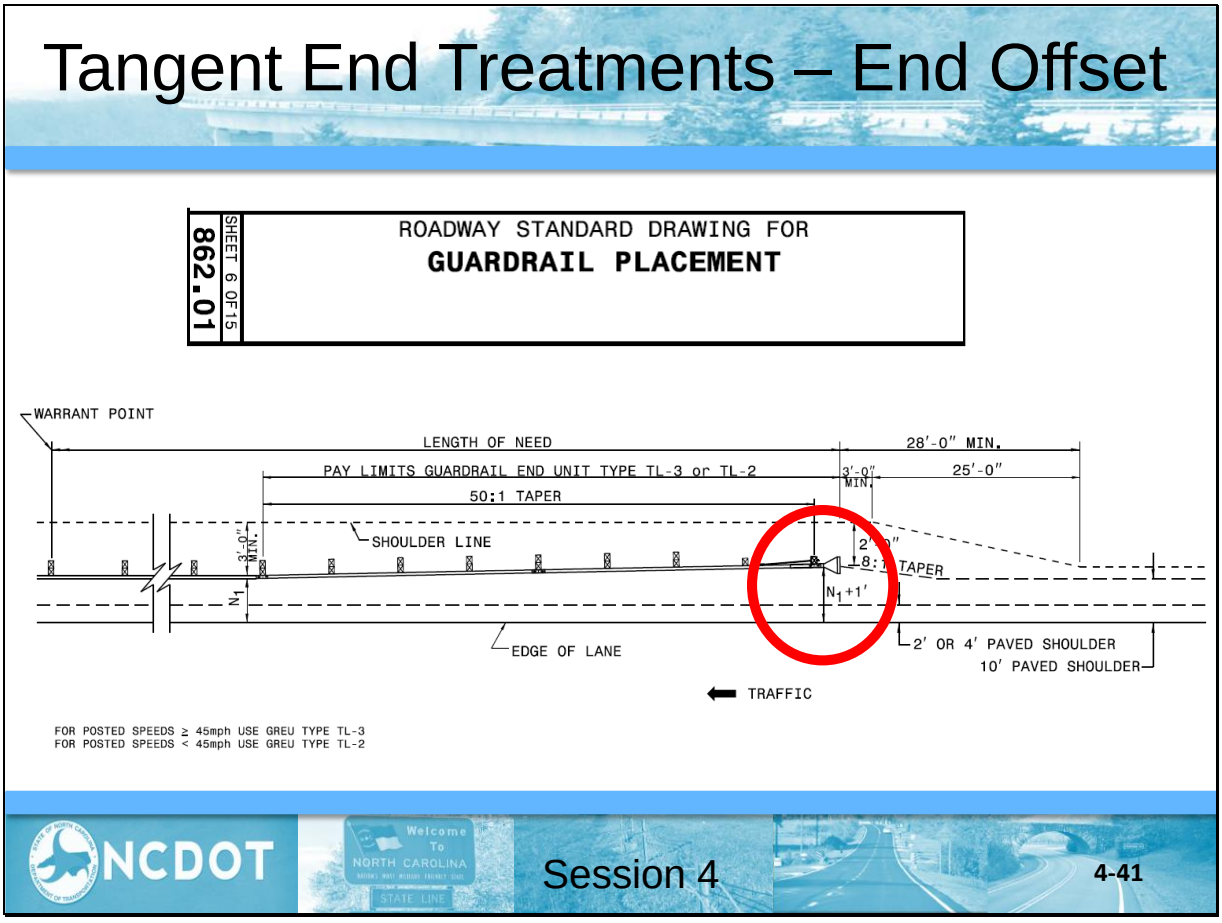
NCDOT Session 4 4-39

Tangent End Treatments – End Offset

6.9 Guardrail End Units

Guardrail End Unit Test Level 2 and Test Level 3 (GREU-TL-2 and TL-3) – The GREU TL-2 and TL-3 are tangential end units used parallel to the travel way. Flare these units over the last 50 feet to provide a 1 -foot offset. GREU-TL-2 (25 feet long) can be used when design speeds are 44 mph or less. GREU TL-3 (50 feet long) can be used when design speeds are 45 mph or greater.

Tangent End Treatments – End Offset

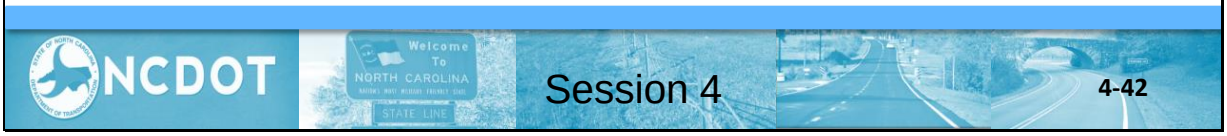


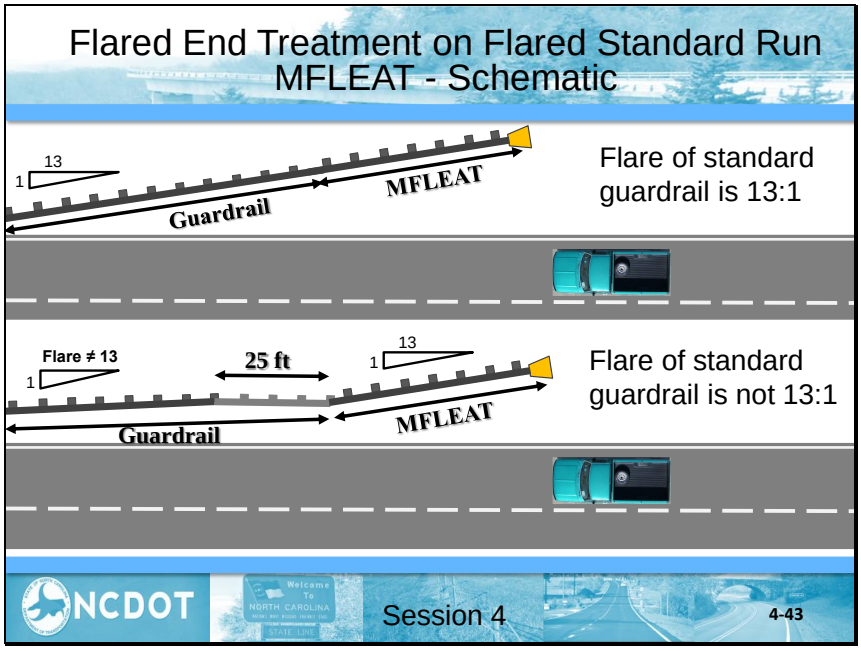
Flared End Treatments on Flared Standard Run

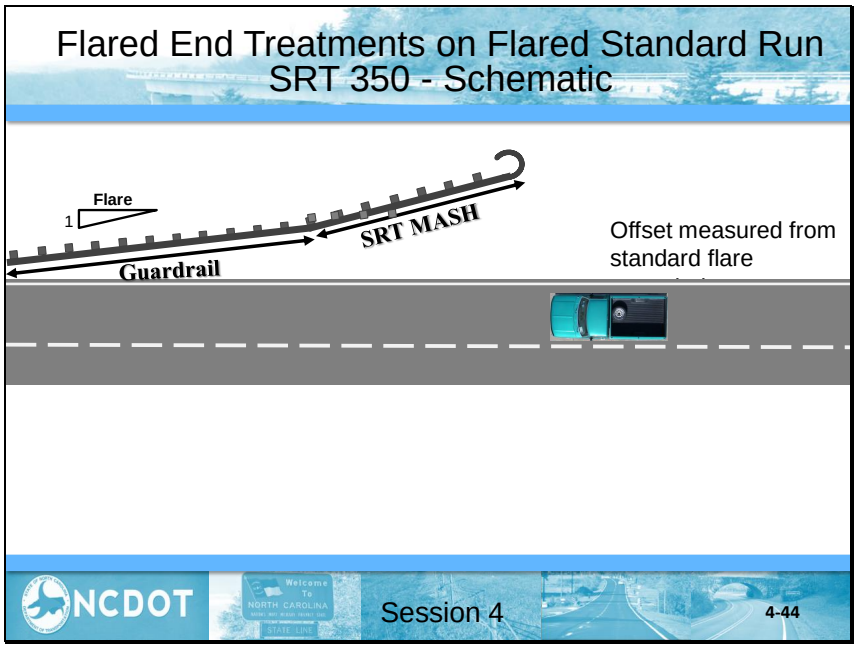
The flare of the end treatment is measured from a line parallel to the ROADWAY:

- 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 350, the offsets historically were measured from the standard flare extended

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




Flared End Treatment on Flared Standard Run
MFLEAT - Schematic
13
1
Guardrail
MFLEAT
Flare of standard guardrail is 13:1
Flare ≠ 13
1
25 ft
13
1
Guardrail
MFLEAT
Flare of standard guardrail is not 13:1
NCDOT
Session 4
4-43


Flared End Treatments on Flared Standard Run
SRT 350 - Schematic
Flare
1
Guardrail
SRT MASH
Offset measured from standard flare
NCDOT
Session 4
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Tangent End Treatments on Flared Standard Run

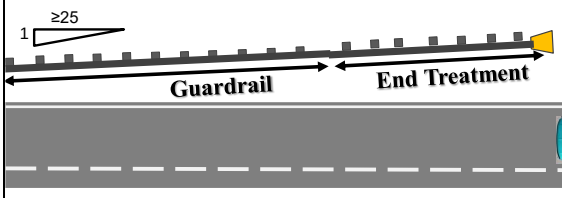
The offset of the end treatment is measured from a line parallel to the ROADWAY:

- 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

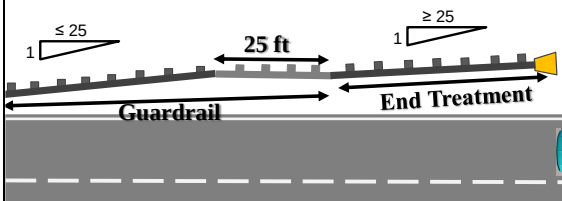
NCDOT guidance is to provide 25' of parallel guardrail in advance of any end treatment requiring a kink.

NCDOT Session 4 4-45

Tangent End Treatments on Flared Standard Run Schematic



Standard Run Flare of 25:1 or flatter



Standard Run Flare is sharper than 25:1

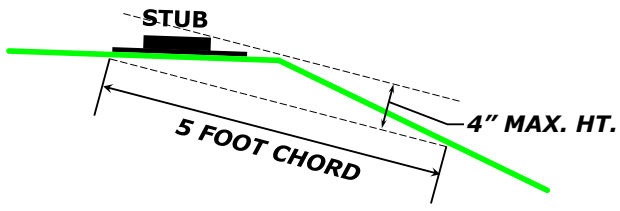
NCDOT Session 4 4-46

End Treatment Grading

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

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

Stub Height Criteria

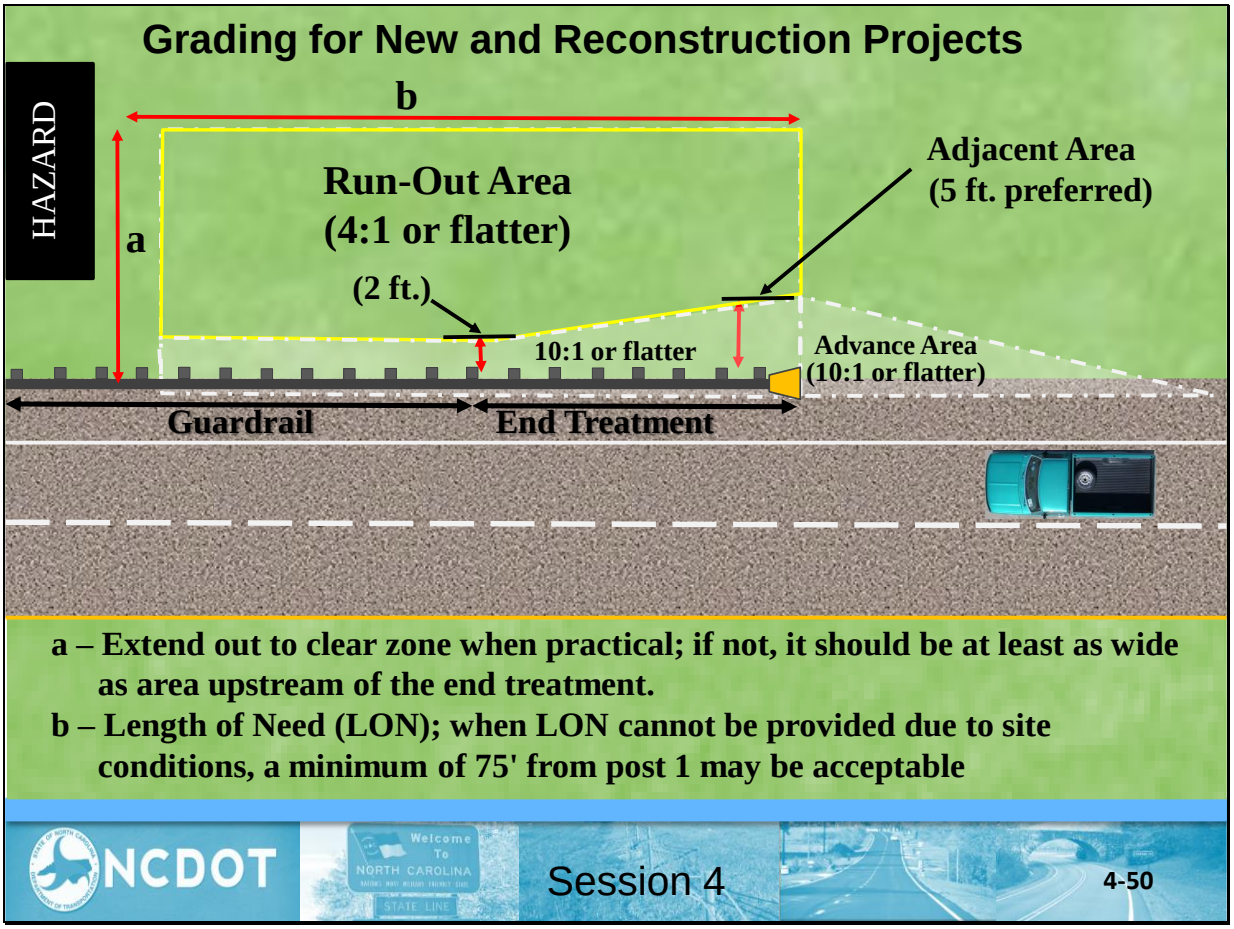


Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 4.1

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 longitudinal 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.


Grading for New and Reconstruction Projects
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 – Length of Need (LON); when LON cannot be provided due to site conditions, a minimum of 75' from post 1 may be acceptable
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Session 4
4-50

Flared End Treatment Grading - AASHTO

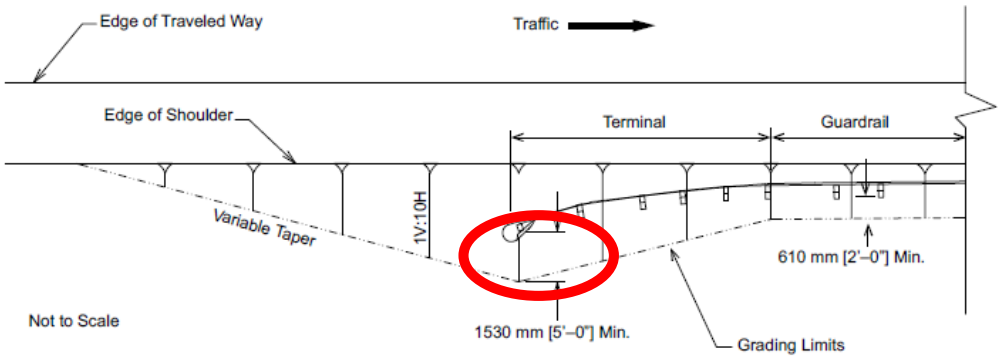

Figure 8-2. Grading for Flared Guardrail Terminal

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

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


PRE-ASSESSMENT PHOTO
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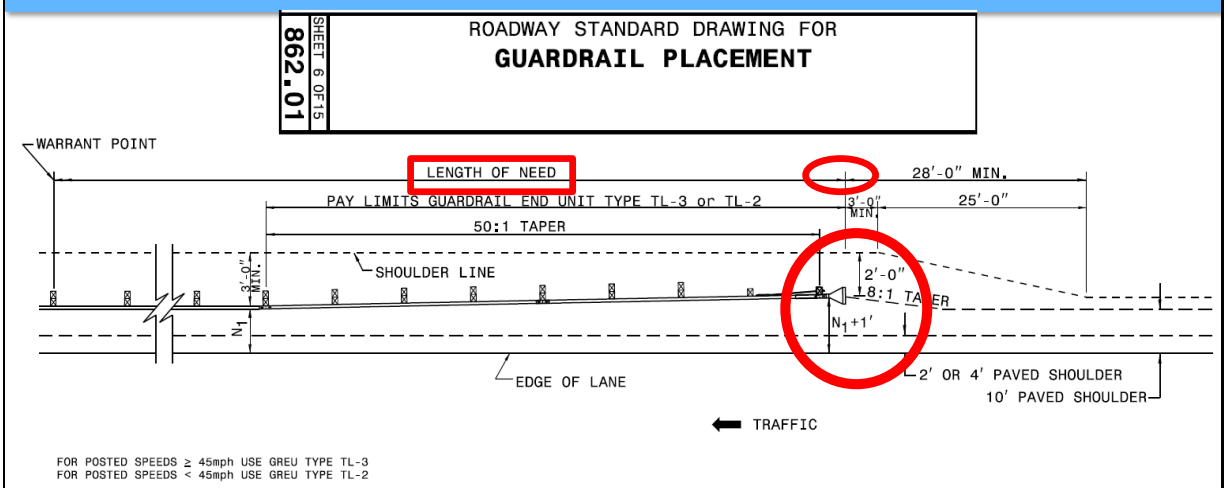
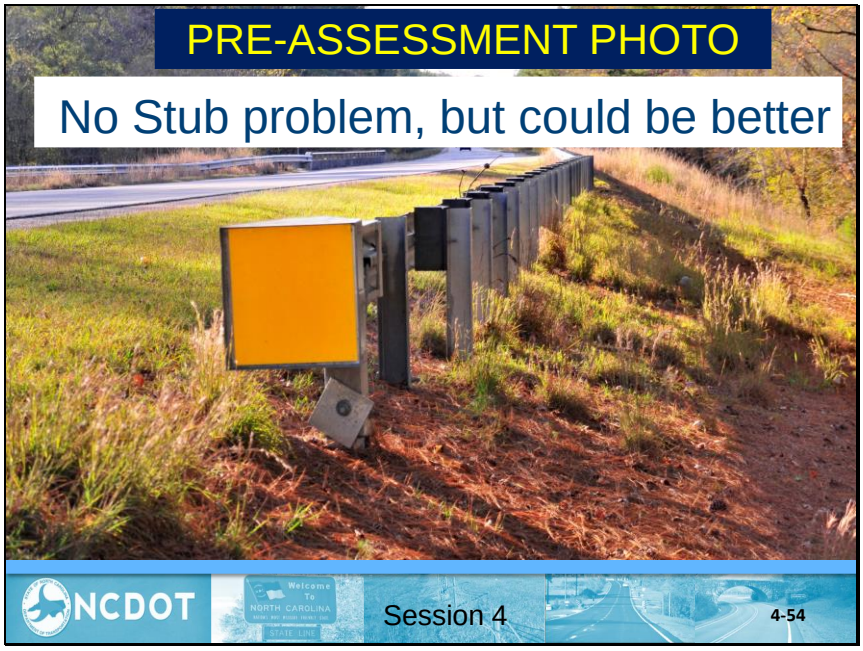
STATE LINE
Session 4
4-52

Tangent End Treatment Grading - NCDOT



Need special Borrow bid item for 3R projects

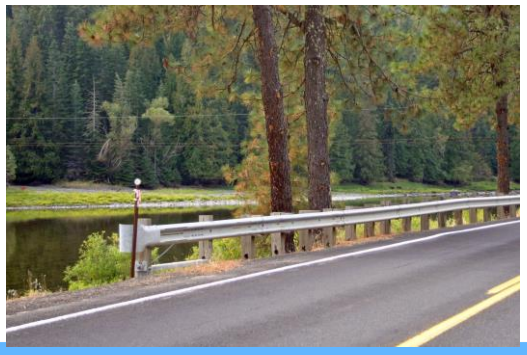
Need Special Provision for Density


PRE-ASSESSMENT PHOTO
No Stub problem, but could be better
NCDOT
Session 4
4-54


Substandard Grading – DOCUMENT
NCDOT
Session 4
4-55

Thing to Remember about End Treatments

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

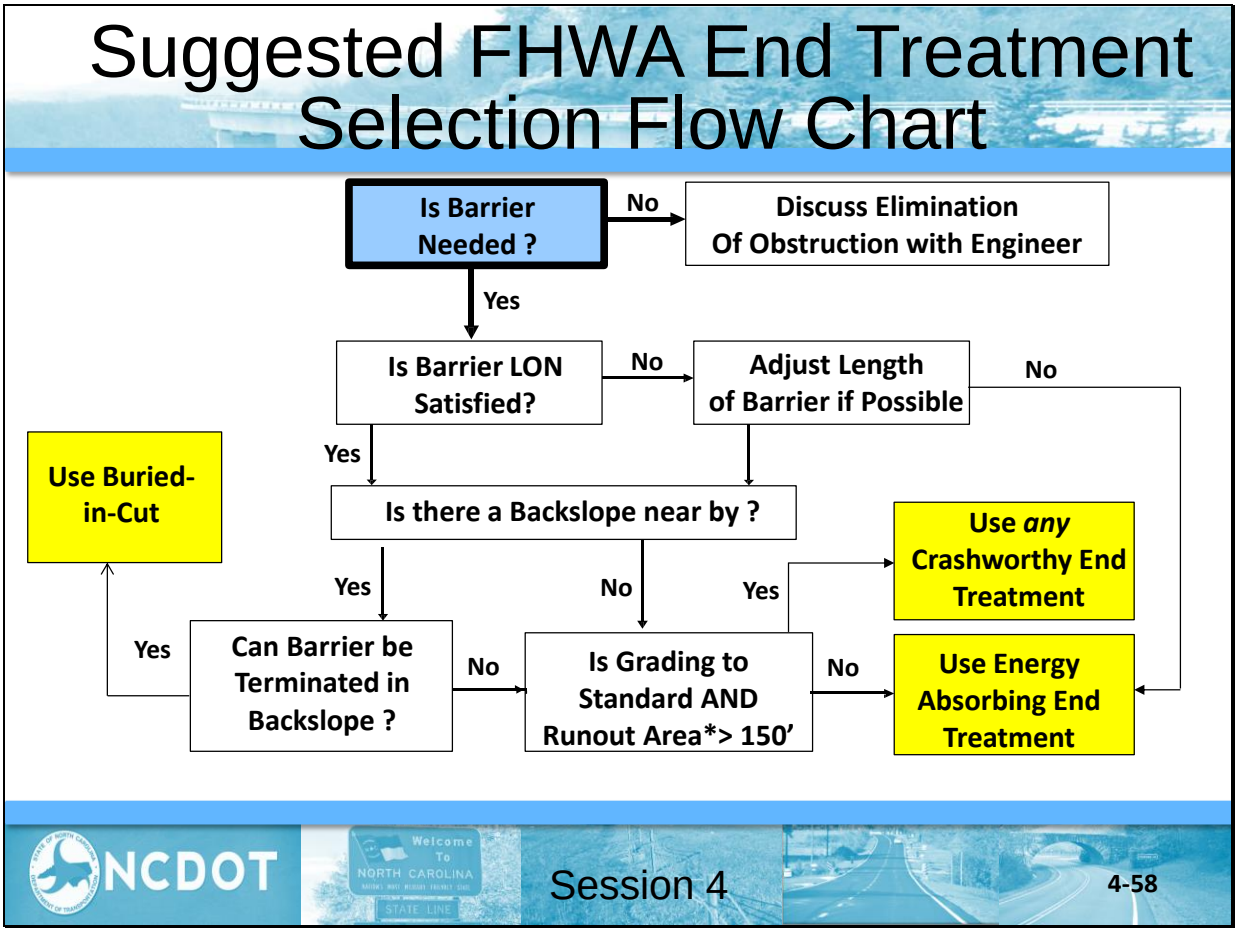


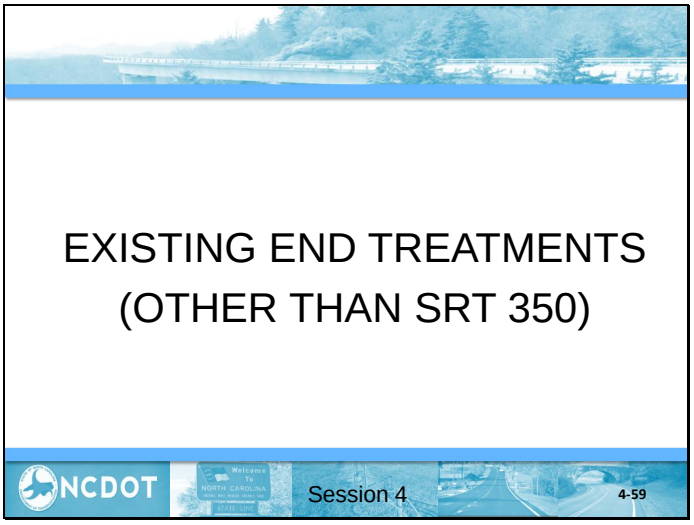
NCDOT Session 4 4-56

Thing to Remember about End Treatments

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

NCDOT Session 4 4-57


Suggested FHWA End Treatment Selection Flow Chart
Is Barrier Needed ?
No
Discuss Elimination Of Obstruction with Engineer
Yes
Is Barrier LON Satisfied?
No
Adjust Length of Barrier if Possible
No
Yes
Use Buried-in-Cut
Is there a Backslope near by ?
Use any Crashworthy End Treatment
Yes
No
Yes
Yes
Can Barrier be Terminated in Backslope ?
No
Is Grading to Standard AND Runout Area*> 150'
No
Use Energy Absorbing End Treatment
NCDOT
Session 4
4-58


EXISTING END TREATMENTS
(OTHER THAN SRT 350)
NCDOT
Session 4
4-59

Tangent Guardrail End Treatment
Energy Absorbing

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

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

NCDOT Session 4 4-60

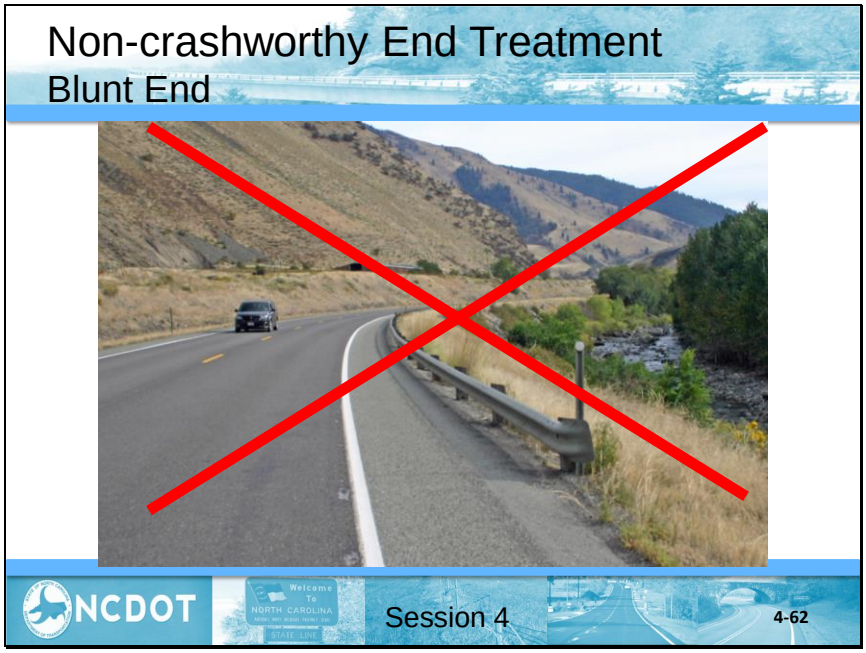
Tangent Guardrail End Treatment
Energy Absorbing

- ET Plus (Guardrail Extruder Terminal)(NCHRP 350)
  - Flattens the rail element when hit head-on
  - Weakened wood or [illegible] (several option[illegible])
  - 50' long[illegible] either height
  - [illegible]at 3rd Post
  - Cable-anchored, compression system

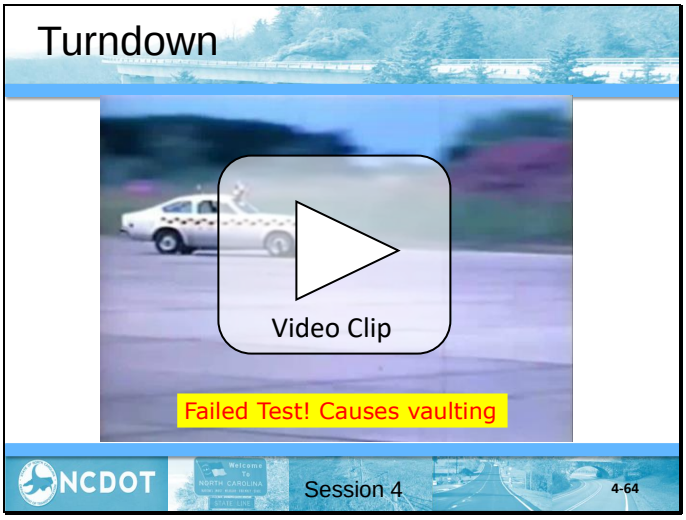
PARTS NO LONGER AVAILABLE

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

NCDOT Session 4 4-61


Non-crashworthy End Treatment
Blunt End
NCDOT
Session 4
4-62


Non-crashworthy End Treatment
Turndown
NCDOT
Session 4
4-63



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.

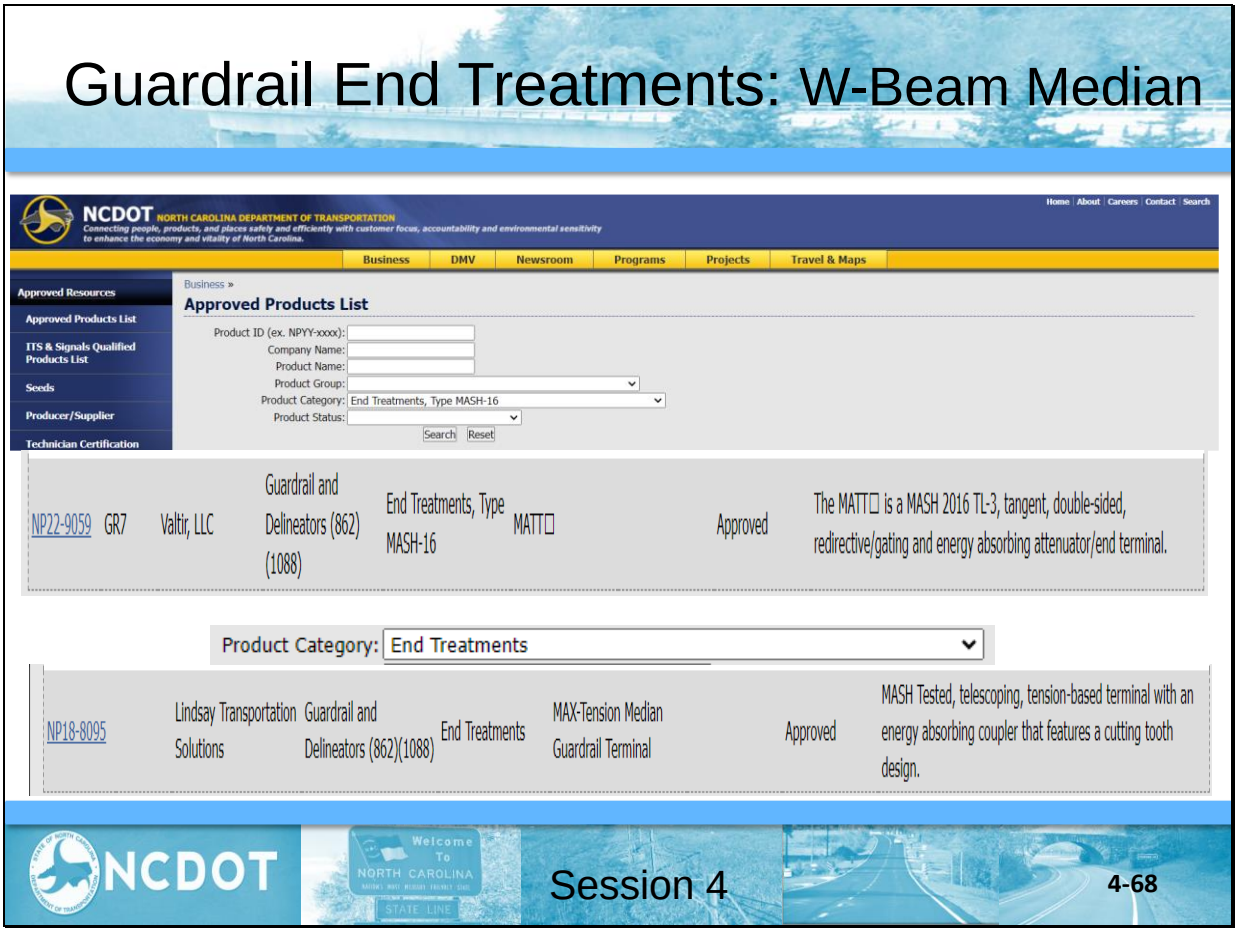
For Identification Only

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

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

For Identification Only

(NCHRP 350 TL-2)


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.
Home | About | Careers | Contact | Search
Business
DMV
Newsroom
Programs
Projects
Travel & Maps
Approved Resources
Approved Products List
ITS & Signals Qualified Products List
Seeds
Producer/Supplier
Technician Certification
Business »
Approved Products List
Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: End Treatments, Type MASH-16
Product Status:
Search
Reset
NP22-9059 GR7 Valtir, LLC Guardrail and Delineators (862) (1088) End Treatments, Type MASH-16 MATT Approved The MATT is a MASH 2016 TL-3, tangent, double-sided, redirective/gating and energy absorbing attenuator/end terminal.
Product Category: End Treatments
NP18-8095 Lindsay Transportation Solutions Guardrail and Delineators (862)(1088) End Treatments MAX-Tension Median Guardrail Terminal Approved MASH Tested, telescoping, tension-based terminal with an energy absorbing coupler that features a cutting tooth design.
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STATE LINE
Session 4
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MASH Terminals: W-Beam Median

- MATT (Median Attenuating TREND Terminal) (MASH)
  - The MATT is similar to the CAT, utilizing special HS bolts to tear tabs between multiple slots in 6”-3” rail panels upon head-on impact
  - Cable-anchored, compression system; BLON at Post 3

NCDOT Session 4 4-69

MATT Terminal Video

NCDOT Session 4 4-70

MASH Terminals: W-Beam Median

- MAX-Tension Median (MASH) – TL-3
  - The MAX system utilizes cables, telescoping panels, and a cutting tooth to absorb the kinetic energy
  - TL-3 at 50’ long; BLON at 9’-4 ½” from post 1; 31” only
  - Has rail elements on both sides

Ref: FHWA Eligibility Letter CC-141 dated 01/10/2018

NCDOT Session 4 4-71

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Impact Attenuator

Crash test with blunt end – Video:

NCDOT Session 4 4-72

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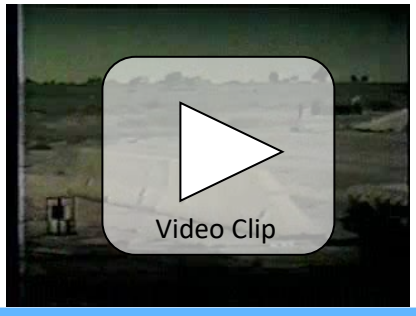
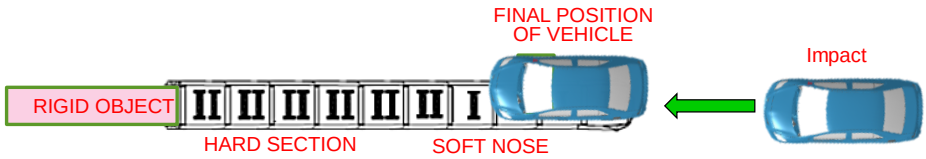
Impact Attenuator

Crash test with ramped end – Video:

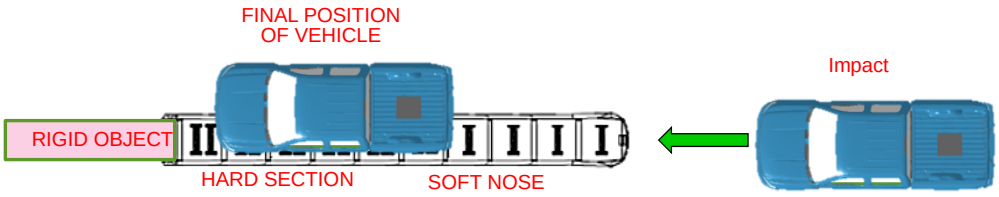


NCDOT Session 4 4-73

Impact Attenuator Theory



Soft nose to bring a small car to a controlled stop



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

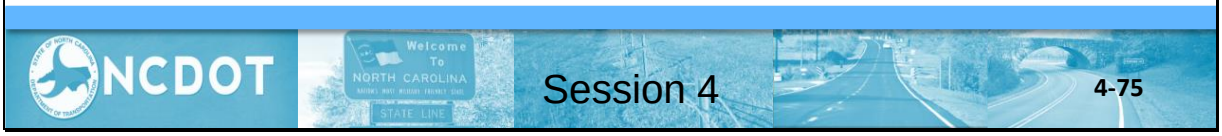
NCDOT Session 4 4-74

Impact Attenuator, Sacrificial - Water Filled

- Water-filled Barriers

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

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



Impact Attenuator, Sacrificial - Water Filled

Approved Products List

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

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

NCDOT Session 4 4-76

Impact Attenuator, Sacrificial - Water Filled

Absorb M (MASH)

ACZ-350

Sled (MASH)

TRITON barrier CET

NCDOT Session 4 4-77

Water Filled

NCDOT Session 4 4-78

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:

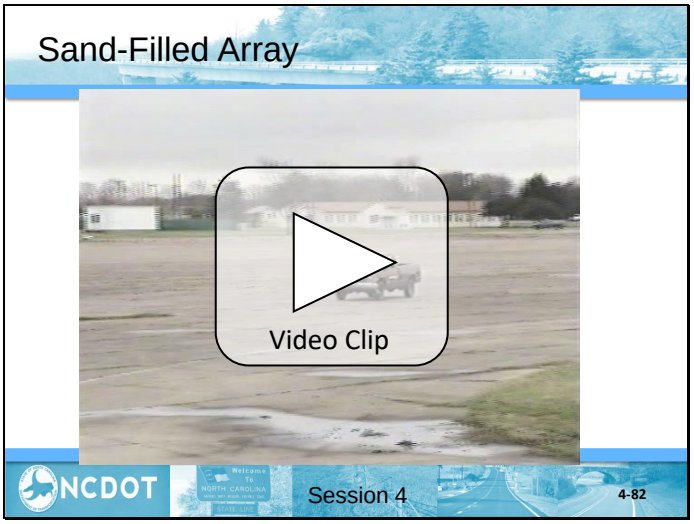
Energite

TrafFix Big Sandy (MASH)

Not Normally Used

CrashGard (MASH)

Sand Barrels – Good Application



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.

Use MASH passed Systems if Available

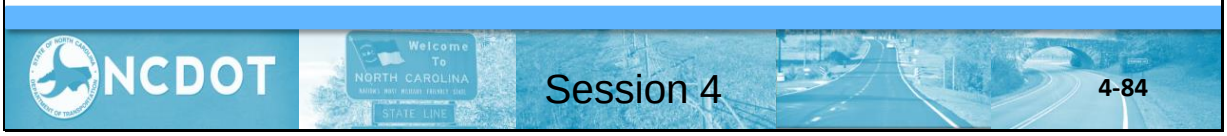
Impact Attenuators, Non-Gating

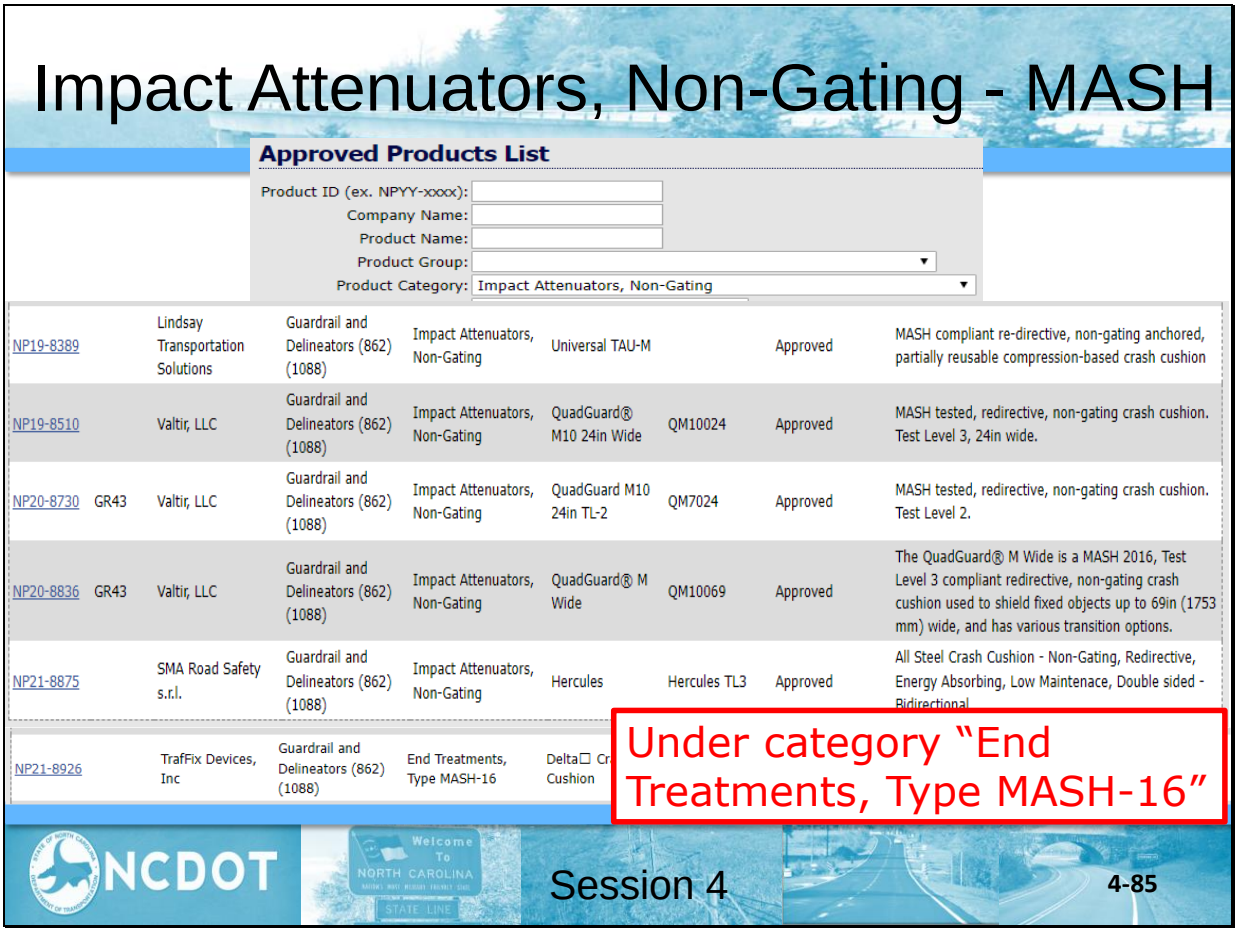
Approved Products List

Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: Impact Attenuators, Non-Gating

NCHRP 350 - Allowed if Conditions Mandate

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.




Impact Attenuators, Non-Gating - MASH
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
NP19-8510 Valtir, LLC Guardrail and Delineators (862) (1088) Impact Attenuators, Non-Gating QuadGuard® M10 24in Wide QM10024 Approved MASH tested, redirective, non-gating crash cushion. Test Level 3, 24in wide.
NP20-8730 GR43 Valtir, LLC Guardrail and Delineators (862) (1088) Impact Attenuators, Non-Gating QuadGuard M10 24in TL-2 QM7024 Approved MASH tested, redirective, non-gating crash cushion. Test Level 2.
NP20-8836 GR43 Valtir, LLC Guardrail and Delineators (862) (1088) Impact Attenuators, Non-Gating QuadGuard® M Wide QM10069 Approved The QuadGuard® M Wide is a MASH 2016, Test Level 3 compliant redirective, non-gating crash cushion used to shield fixed objects up to 69in (1753 mm) wide, and has various transition options.
NP21-8875 SMA Road Safety s.r.l. Guardrail and Delineators (862) (1088) Impact Attenuators, Non-Gating Hercules Hercules TL3 Approved All Steel Crash Cushion - Non-Gating, Redirective, Energy Absorbing, Low Maintenace, Double sided - Bidirectional
NP21-8926 TrafFix Devices, Inc Guardrail and Delineators (862) (1088) End Treatments, Type MASH-16
Under category "End Treatments, Type MASH-16"
NCDOT
Welcome To NORTH CAROLINA STATE LINE
Session 4
4-85

Impact Attenuators, Non-Gating

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


NCDOT Session 4 4-86

Impact Attenuators, Non-Gating

- QuardGuard M10 (MASH)
  - Can be attached directly to a W-beam or Thrie-beam median barrier as well as to a concrete safety shape.

  - Slides back on a single track when struck head-on and uses specially fabricated side panels having four corrugations.
  - Energy-absorbing cartridges in each bay need to be replaced if damaged
  - M10 has metal nose, available at 24” & 69” widths
  - (350 available in widths from 24 to 36 inches with parallel sides and 69 or 96 inches with flared sides)

REF: FHWA Eligibility Letters CC-35M dated 3/29/16 350 CC-121 dated 7/30/12 MASH

NCDOT Session 4 4-87

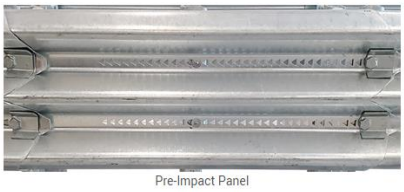
Crash Cushions– Reusable

- HERCULES (MASH)
  - 23” width, 19’-5” long
  - Comes pre-assembled

FHWA Letter CC-156

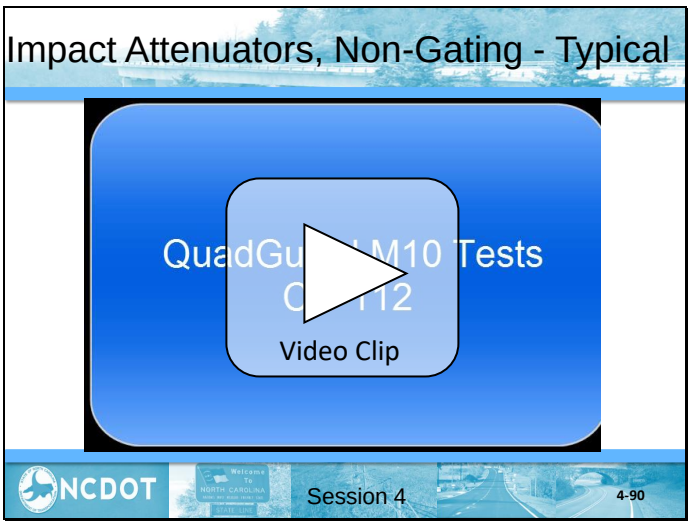
Crash Cushions– Reusable

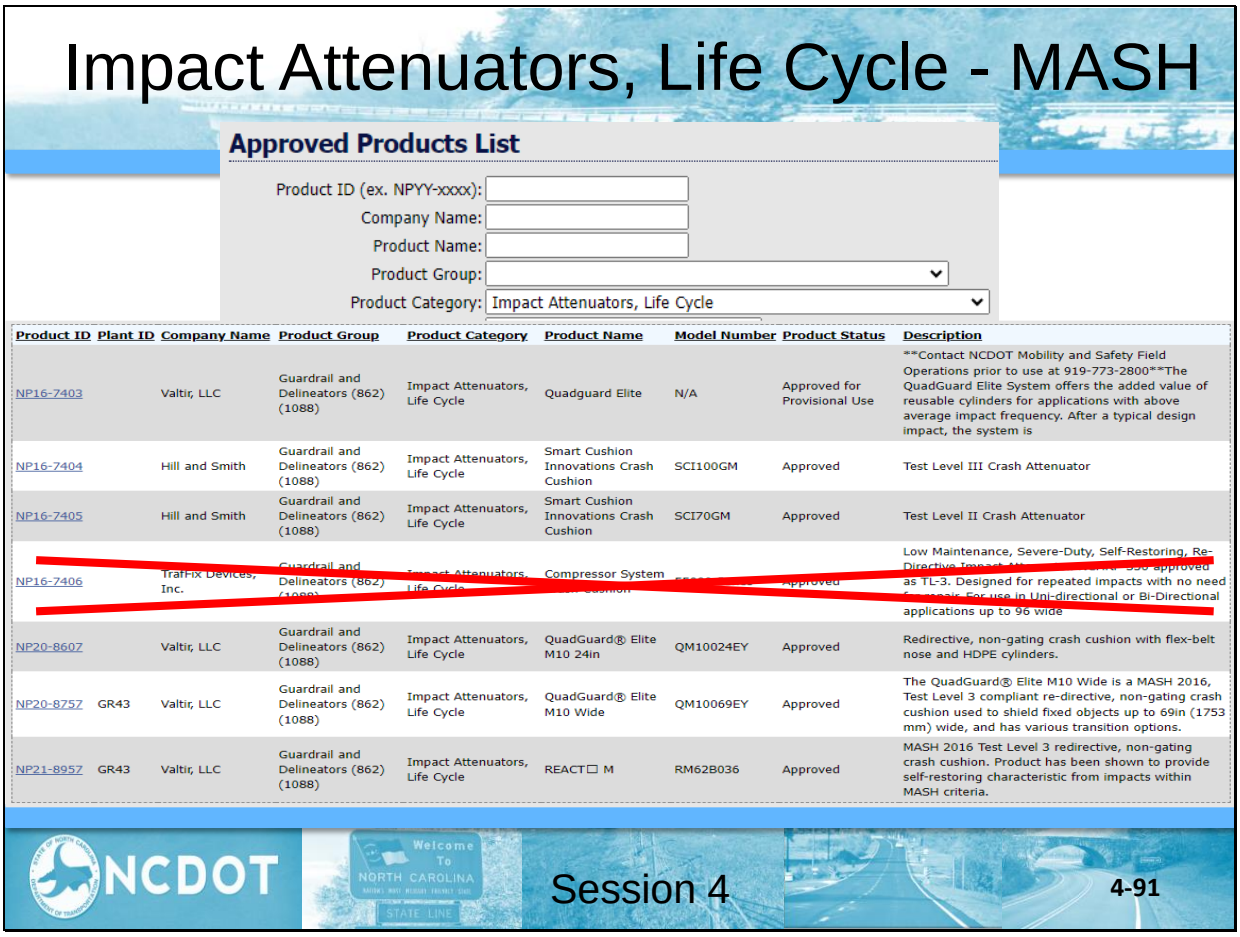
- DELTA (MASH)
  - DELTA is 30” width, 21’ long
  - Attenuates energy evenly for all vehicle types with shear bolts tearing through cut-outs of various sizes and shapes



Pre-Impact Panel

Post-Impact Panel


Impact Attenuators, Non-Gating - Typical
Video Clip
NCDOT
Session 4
4-90


Impact Attenuators, Life Cycle - MASH
Approved Products List
Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: Impact Attenuators, Life Cycle
Product ID | Plant ID | Company Name | Product Group | Product Category | Product Name | Model Number | Product Status | Description
NP16-7403 | | Valtir, LLC | 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 | | Approved | Low Maintenance, Severe-Duty, Self-Restoring, Re-Directive Impact At... ...as TL-3. Designed for repeated impacts with no need ...For use in Uni-directional or Bi-Directional applications up to 96 wide
NP20-8607 | | Valtir, LLC | Guardrail and Delineators (862) (1088) | Impact Attenuators, Life Cycle | QuadGuard® Elite M10 24in | QM10024EY | Approved | Redirective, non-gating crash cushion with flex-belt nose and HDPE cylinders.
NP20-8757 | GR43 | Valtir, LLC | Guardrail and Delineators (862) (1088) | Impact Attenuators, Life Cycle | QuadGuard® Elite M10 Wide | QM10069EY | Approved | The QuadGuard® Elite M10 Wide is a MASH 2016, Test Level 3 compliant re-directive, non-gating crash cushion used to shield fixed objects up to 69in (1753 mm) wide, and has various transition options.
NP21-8957 | GR43 | Valtir, LLC | Guardrail and Delineators (862) (1088) | Impact Attenuators, Life Cycle | REACT☐ M | RM62B036 | Approved | MASH 2016 Test Level 3 redirective, non-gating crash cushion. Product has been shown to provide self-restoring characteristic from impacts within MASH criteria.
NCDOT
Session 4
4-91

Impact Attenuators, Life Cycle

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

Example – Low Cost

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
  - 24” Standard and 69” Wide

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

Crash Cushions (Essentially)Self Restoring

- REACT M (MASH)
  - High density Polyethylene cylinders HMW/HDPE
  - "Self-restoring" after design impact
  - Self-contained back-up
  - Side redirection by side cables anchored to foundation
  - Single cylinder width 36 inches

REF: FHWA Eligibility Letter CC-169 dated 6/23/2021

NCDOT Session 4 4-95

Example - Self Restoring

NCDOT Session 4 4-96

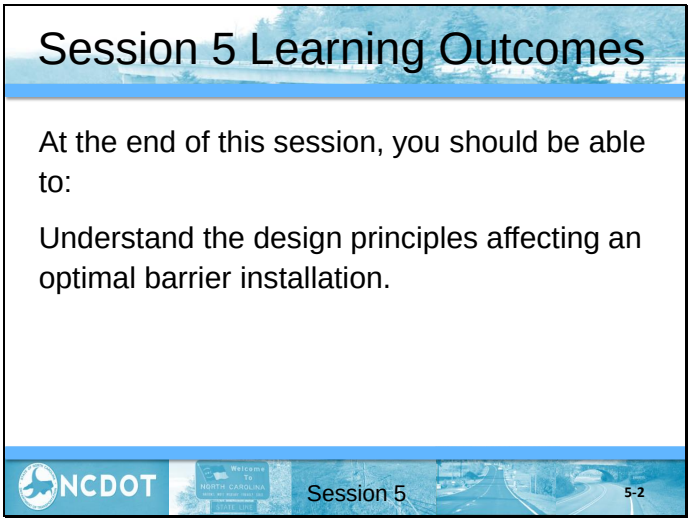
Review Learning Outcomes

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

NCDOT Session 4 4-98

Session 5: Design Principles


North Carolina Department of Transportation
Highway Safety Barrier Design Training
Session 5:
Design Principles
NCDOT
Session 5
5-1


Session 5 Learning Outcomes
At the end of this session, you should be able to:
Understand the design principles affecting an optimal barrier installation.
NCDOT
Session 5
5-2

Order of Preference

4.6 Roadside Design

6.1 General Considerations

- Remove obstacle
- Redesign obstacle to be safely traversed
- Relocate obstacle
- Reduce impact severity with a breakaway device
- Shield obstacle with barrier that will redirect vehicle or use crash cushion
- Delineate obstacle if other options are not appropriate

NCDOT Session 5 5-3

Guardrail Placement

Place AS FAR AWAY as Possible

without affecting function

NCDOT Typical Guidance

6.3 Guardrail Placement

6.3.1 Placement on Approach End of Rigid Obstacle Warrant

- N_1 = The distance from the edge of the adjacent travel lane to the face of the guardrail.
  - N_1 = Normal shoulder width for locals and collectors (minimum 4 feet).
  - N_1 = Normal shoulder width plus 2 feet for arterials, interstates and freeways.

Barrier Design Principles

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

NCDOT Session 5 5-7

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 5 5-8

Deflection Distance

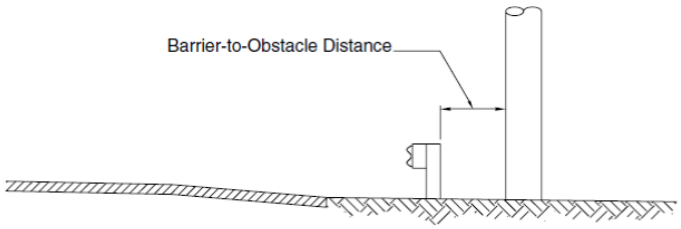


Figure 5-33. Recommended Barrier Placement for Optimum Performance

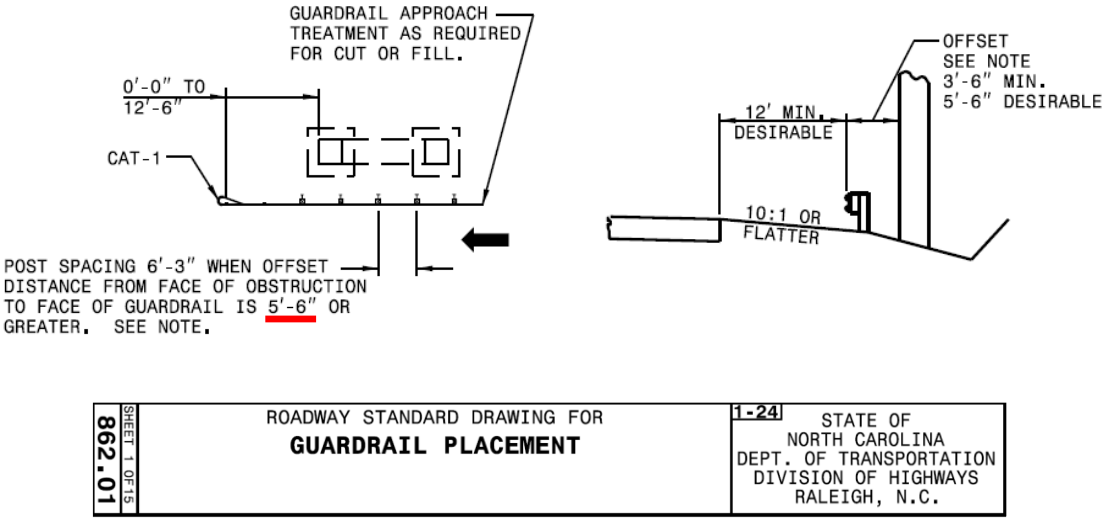
Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – Figure 5-33

NCDOT Session 5 5-9

Deflection

NCDOT Session 5 5-10

Deflection Distance - NCDOT



NCDOT Session 5 5-11

Half Post Spacing

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.

862.01 SHEET 1 OF 15	ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT**	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

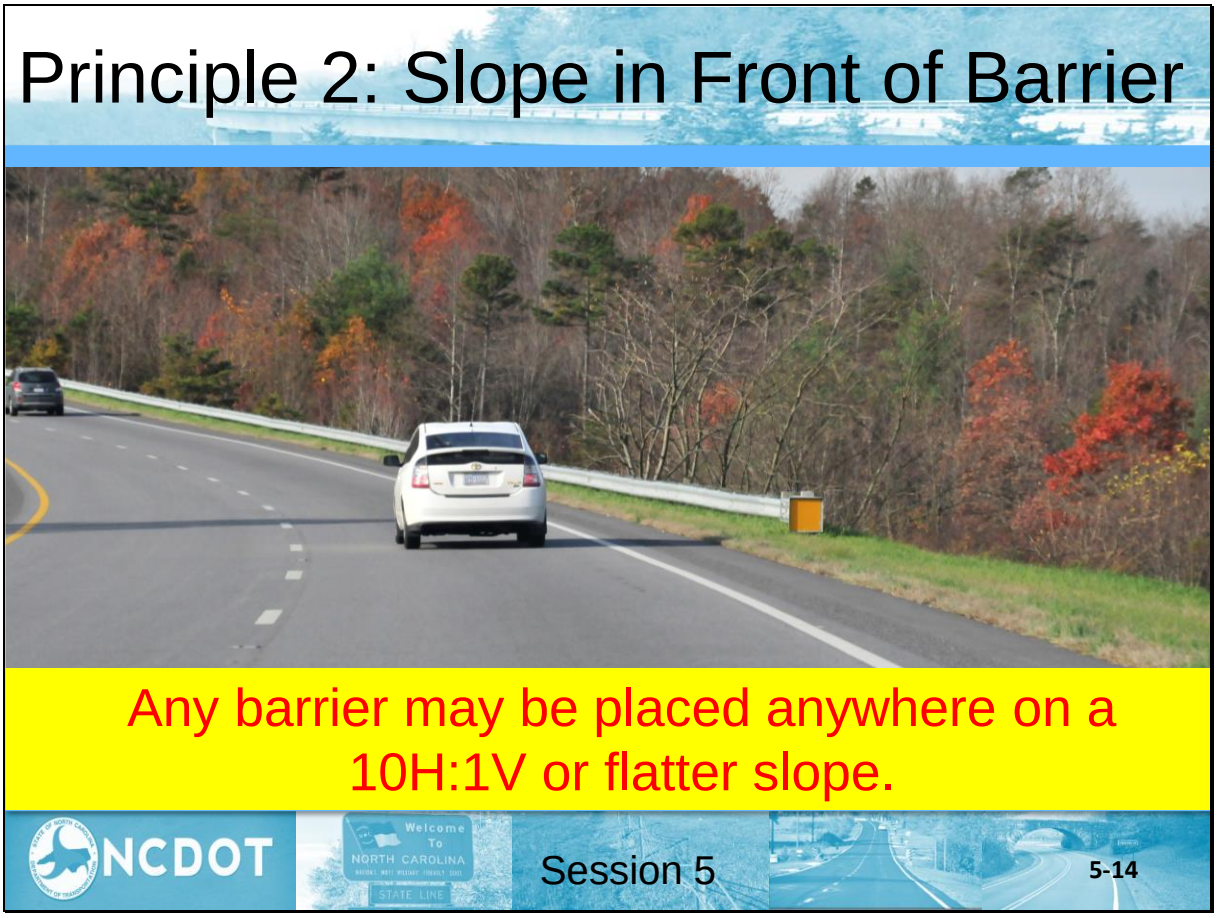
NCDOT Session 5 5-12

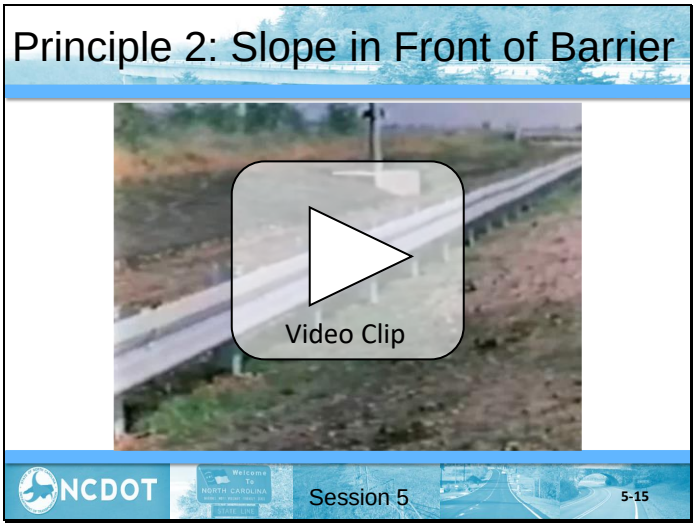
Offset to Piers

6.3.9 Placement Under Bridges

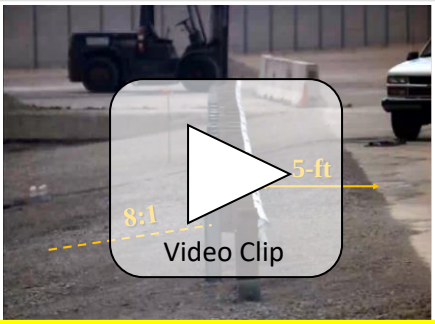
1. With Outside Bridge Piers
   a. With a Concrete Barrier
      i. If the outside pier is 15 feet 6 inches or less from the edge of the main travel lane, use a concrete barrier and guardrail *NCDOT Roadway Standard Drawings* Std. No. 857.01.

NCDOT Session 5 5-13


Principle 2: Slope in Front of Barrier
Any barrier may be placed anywhere on a 10H:1V or flatter slope.
NCDOT
Welcome To NORTH CAROLINA STATE LINE
Session 5
5-14


Principle 2: Slope in Front of Barrier
Video Clip
NCDOT
Session 5
5-15

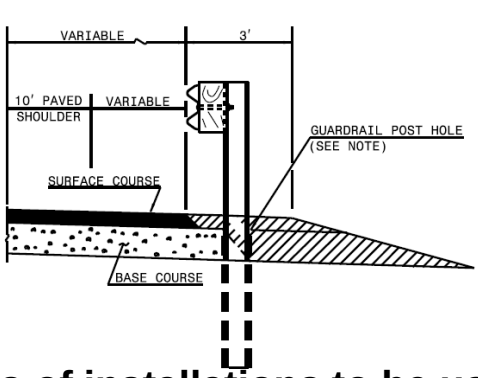
NCHRP 350 TL-3 31” on 8:1 Slope

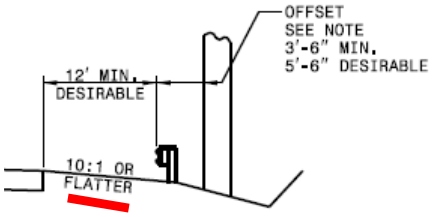


Vehicle is contained and redirected but shows instability

Slope in Front of Barrier

IMPLIED – FLAT





6.8.1.1 Types of installations to be used

Steel beam guardrail must be placed on 10:1 or flatter slopes

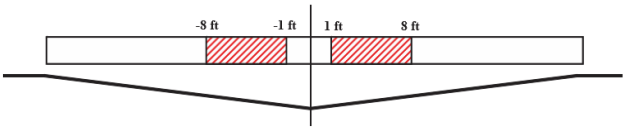
FLEXIBLE PAVED SHOULDER

862.01 SHEET 11 OF 15	ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT**	1-24 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

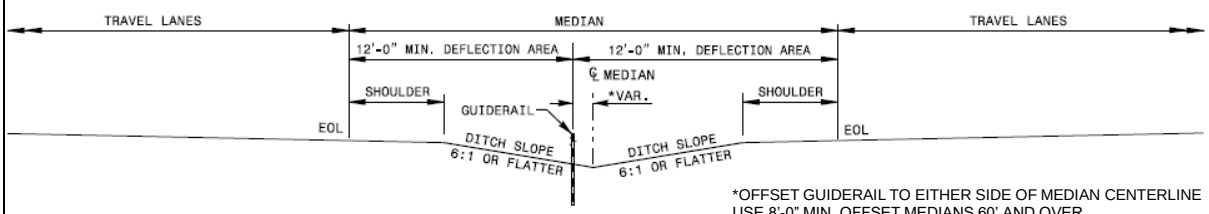
- Cable barrier may be placed anywhere on a 10:1 or flatter slope.
- Cable barrier may be placed on slopes of 6:1, but not in the area from 1 ft. to 8 ft. from the ditch bottom.



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

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

NCDOT Slope/Swale Guidance - LTCG



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

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

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

Caution

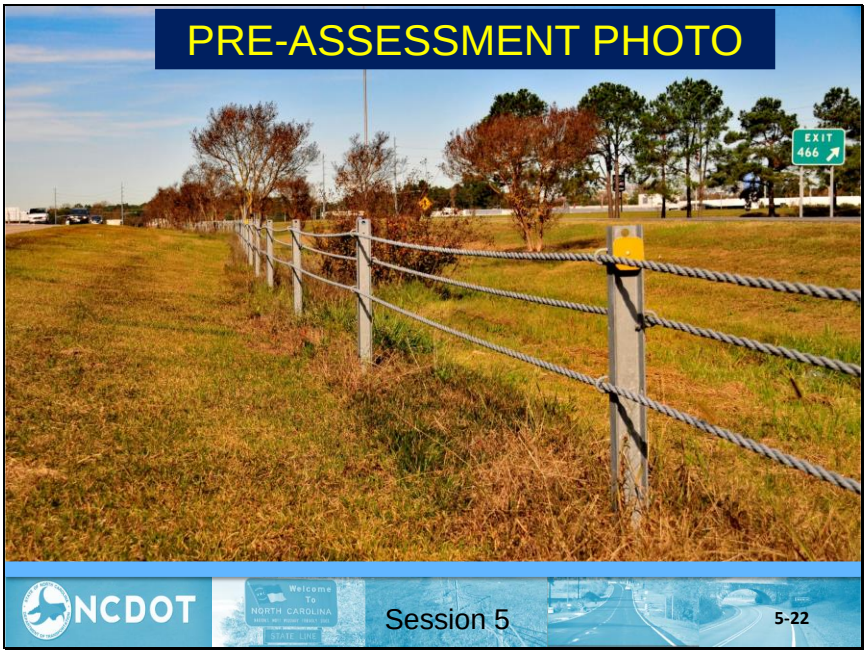
SHEET 4 OF 12 **865.01**
ROADWAY STANDARD DRAWING FOR
CABLE GUIDERAIL
DESIGN AND PLACEMENT

Location of Cable in Swales

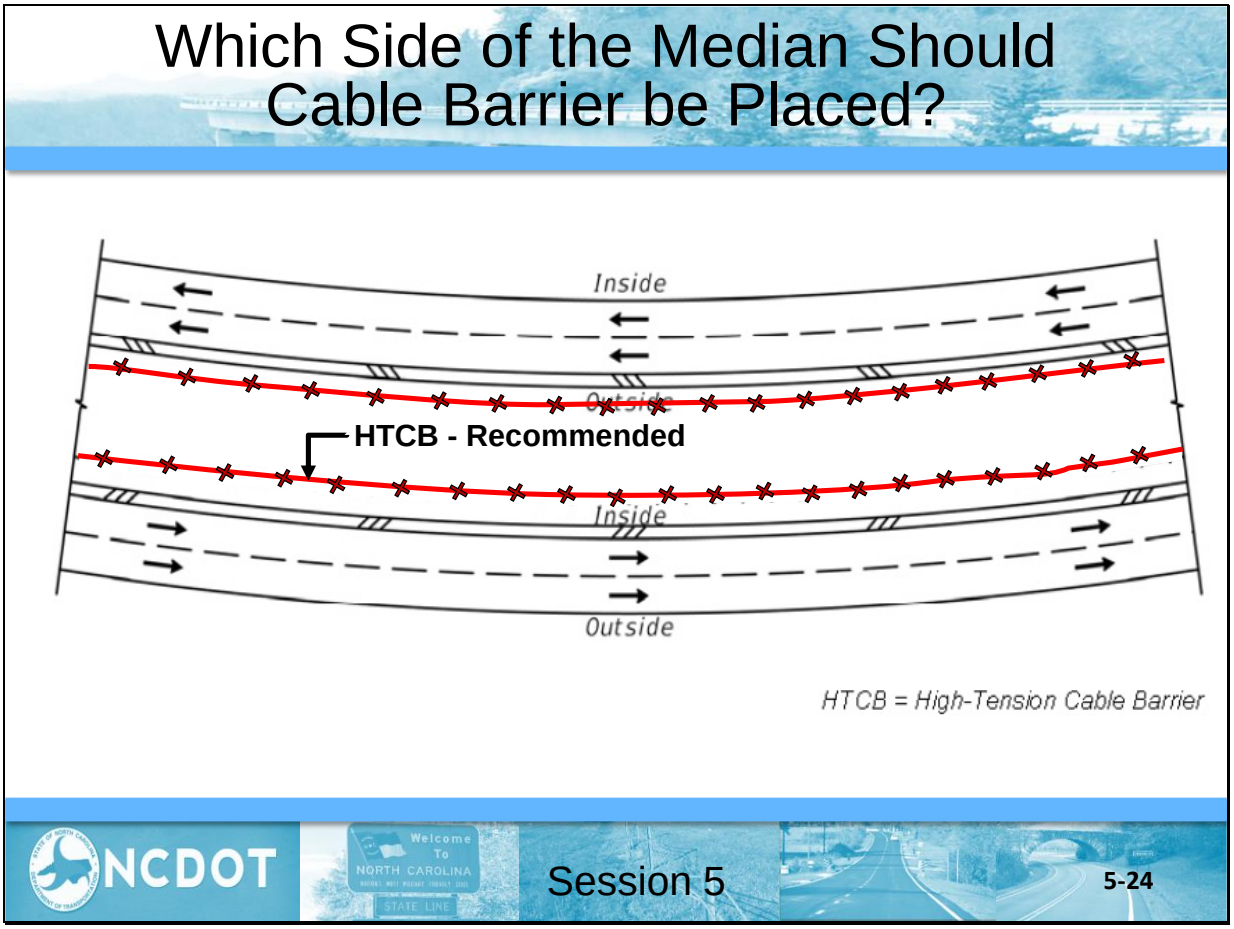
MASH 2016 includes testing with a mid-sized vehicle because of this problem (NC experience)

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

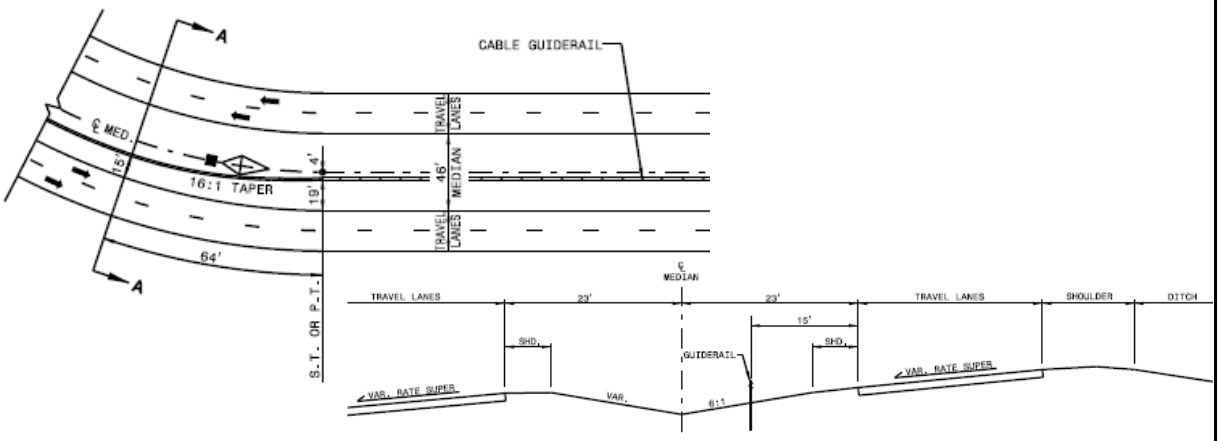
Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – 6.6.1.1, Pg. 6-18


PRE-ASSESSMENT PHOTO
EXIT 466
NCDOT
Session 5
5-22


Barrier in Sloped Median
NCDOT
Session 5
5-23


Which Side of the Median Should Cable Barrier be Placed?
Inside
Outside
HTCB - Recommended
Inside
Outside
HTCB = High-Tension Cable Barrier
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 5
5-24

Barrier in a Curved Median



SECTION A-A

865.01 SHEET 3 OF 12

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

NCDOT

Session 5

5-25


Principle 3: Guardrail and Curbs
NCDOT
Session 5
5-26


PRE-ASSESSMENT PHOTO
6” Curb not acceptable for old 29” System on HS
NCDOT
Session 5
5-27

Guardrail and Curbs

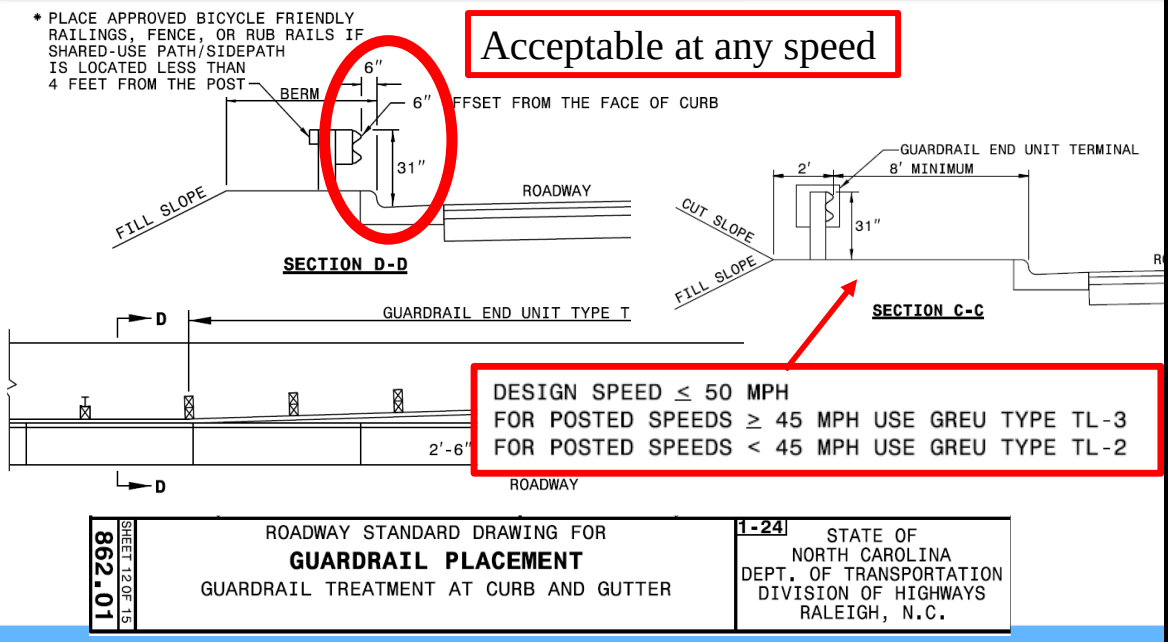
- Curbs may function to channelize traffic, to control drainage, improve delineation, control access, and reduce erosion.
- Curbs are not adequate to prevent a vehicle from leaving the roadway; they are not a barrier.
- Use of any guardrail/curb combination where high-speed, high-angle impacts are likely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

NCDOT Session 5 5-28

Guardrail and Curbs – 29”

NCDOT Session 5 5-29

NCDOT Guardrail and Curbs

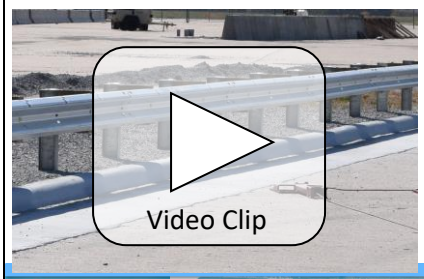


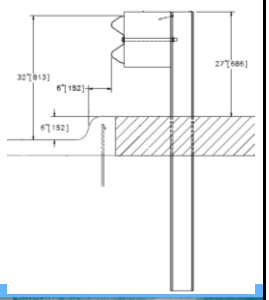
Acceptable at any speed

NCDOT Session 5 5-30

31" and Curbs

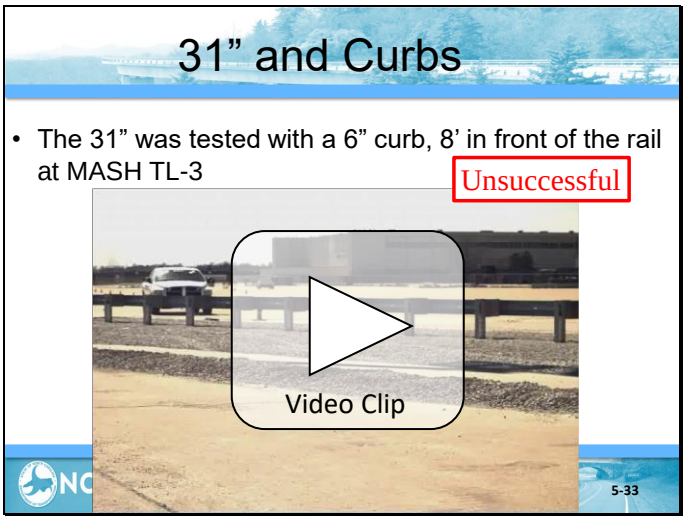
Successfully tested to MASH placed 6" behind a 6" high curb at TL-3

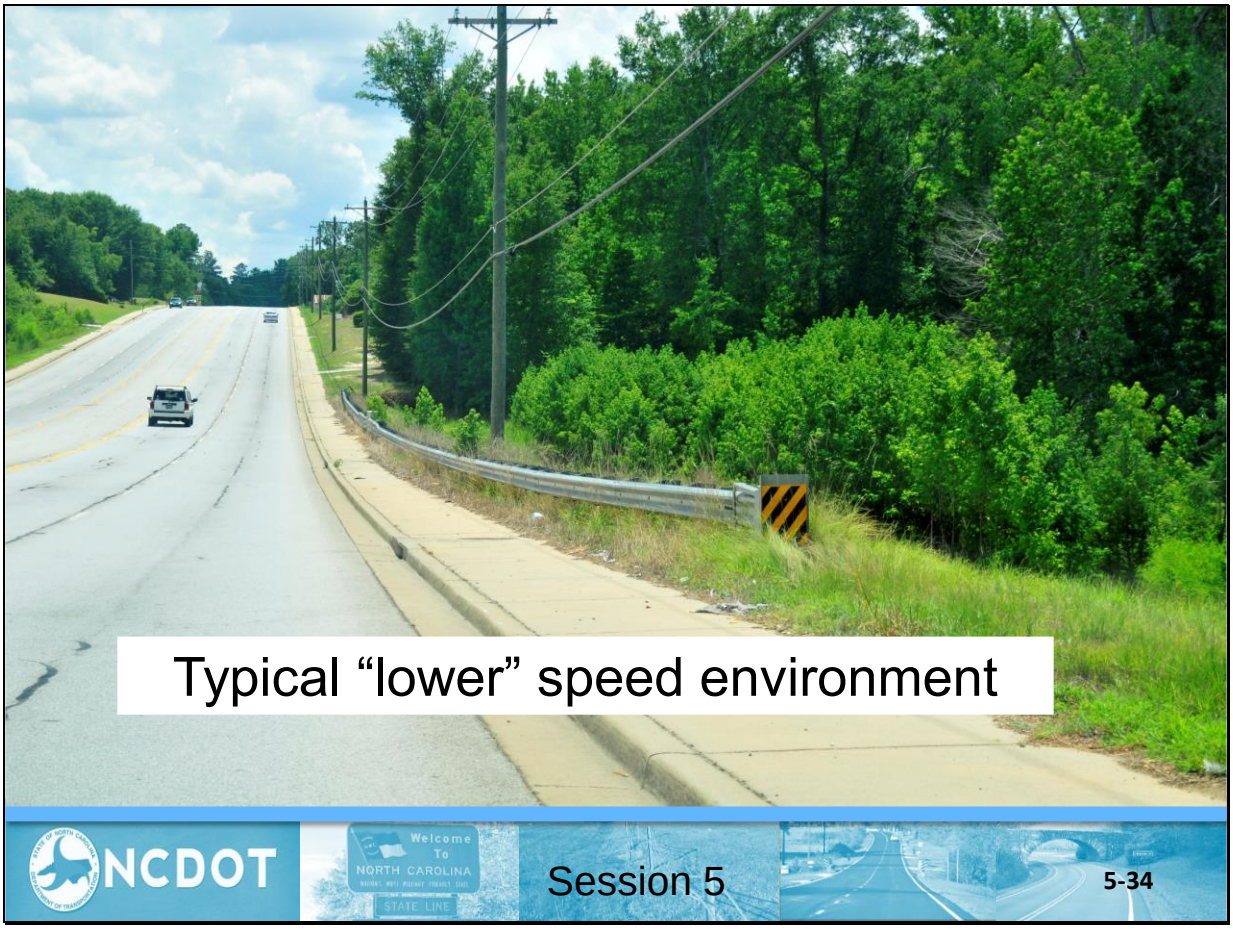




NCDOT Session 5 5-31


MASH TL-3 31”
Placed 6” behind 6” high Curb
Video Clip
NCDOT
Session 5
5-32


31” and Curbs
• The 31” was tested with a 6” curb, 8’ in front of the rail at MASH TL-3
Unsuccessful
Video Clip
5-33


Typical “lower” speed environment
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 5
5-34


MASH TL-2 31” 6 ft. behind curb
Video Clip
NCDOT
Session 5
5-35

End Treatments and Curbs

Although Standard 862.01, sheet 12 of 15, provides guidance for placing end treatments in combination with 6” curb, unfortunately there is no crash tested design for this common situation.

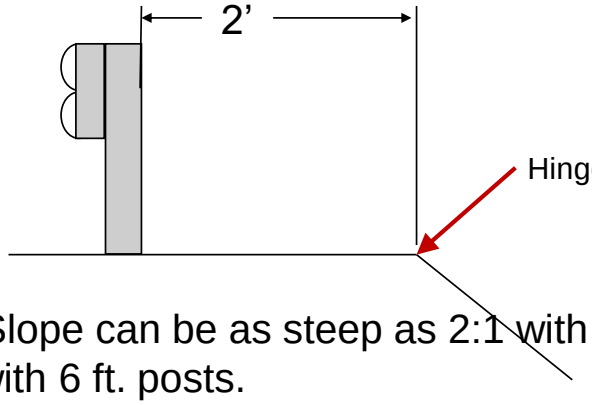
Especially careful with BCA Terminal Anchor – Don’t let Bearing Plate be buried

End Treatments and Curbs

Principle 4: Soil Backing For Fill Locations

NCDOT Session 5 5-38

Soil Backing Recommendation



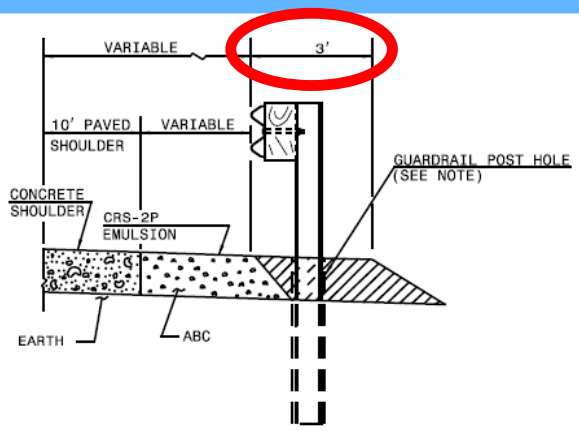
Historical Guidance

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

NCDOT Session 5 5-39

Soil Backing – NCDOT



862.01 SHEET 11 OF 15

ROADWAY STANDARD DRAWING FOR
GUARDRAIL PLACEMENT

1-24

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

NCDOT

Session 5

5-40

31” with Posts on a 2:1 Slope

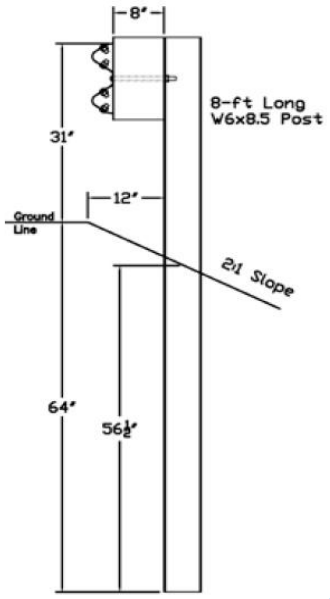
31” with face of rail at slope break point of 2:1 slope

Posts

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

Offset Blocks

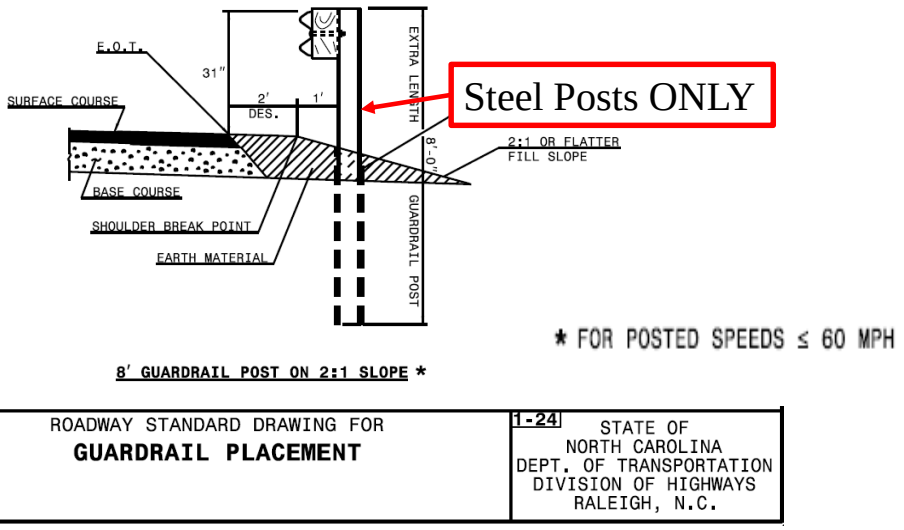
- 8” Offset block tested
- Not recommended without offset block at this time



31” with Posts on a 2:1 Slope

Working Width – 55.2”
Eligibility Letter B-261

31” with Posts on a 2:1 Slope

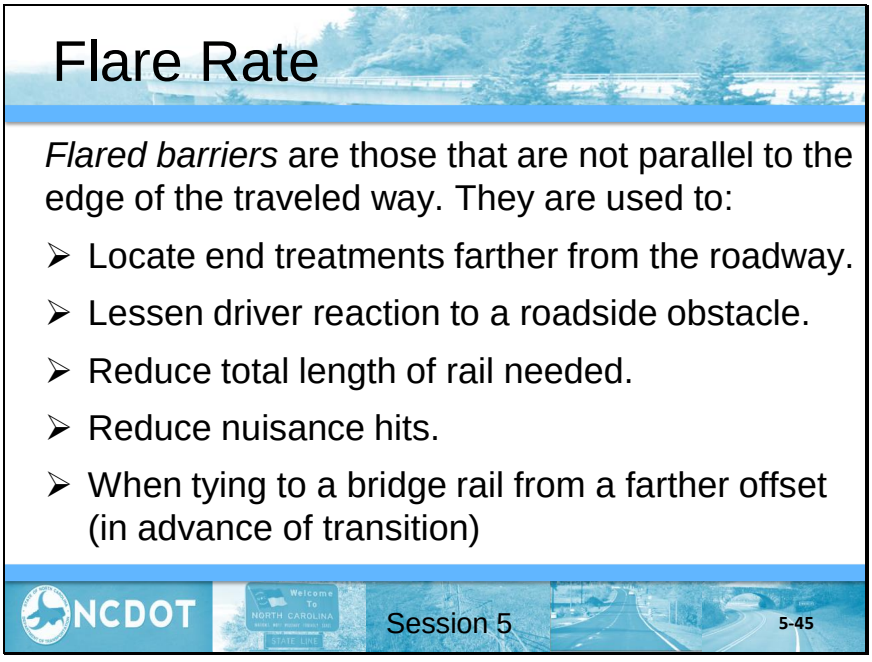


8′ GUARDRAIL POST ON 2:1 SLOPE *

862.01 SHEET 11 OF 15	ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT**	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

NCDOT Session 5 5-43


Principle 5: Flare Rate
NCDOT
Session 5
5-44


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)
NCDOT
Session 5
5-45

Flare Rate

Trade offs and restrictions of flared barriers:

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

NCDOT Session 5 5-46

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.

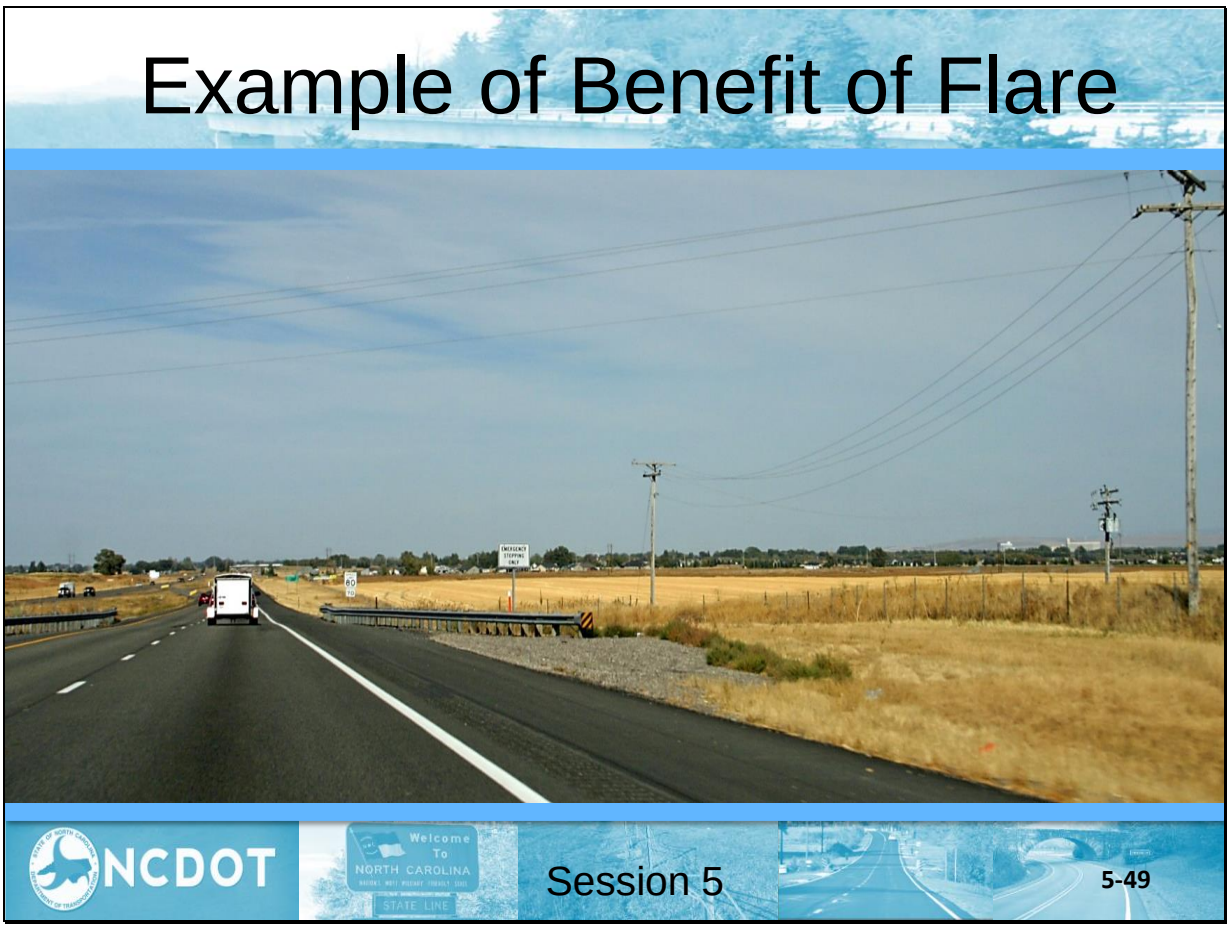
NCDOT Session 5 5-47

Suggested Flare Rates - RDG

Table 5-9. Suggested Flare Rates for Barrier Design

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

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


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

Review Learning Outcomes

Understand the design principles affecting an optimal barrier installation.

Session 6: Length of Need and Special Considerations

North Carolina Department of Transportation
Highway Safety Barrier Design Training

Session 6: Length of Need and Special Considerations

NCDOT Session 6 6-1

Session 6 Learning Outcomes

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

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

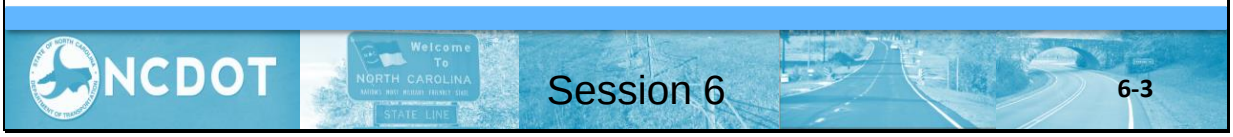
NCDOT Session 6 6-2

Order of Preference

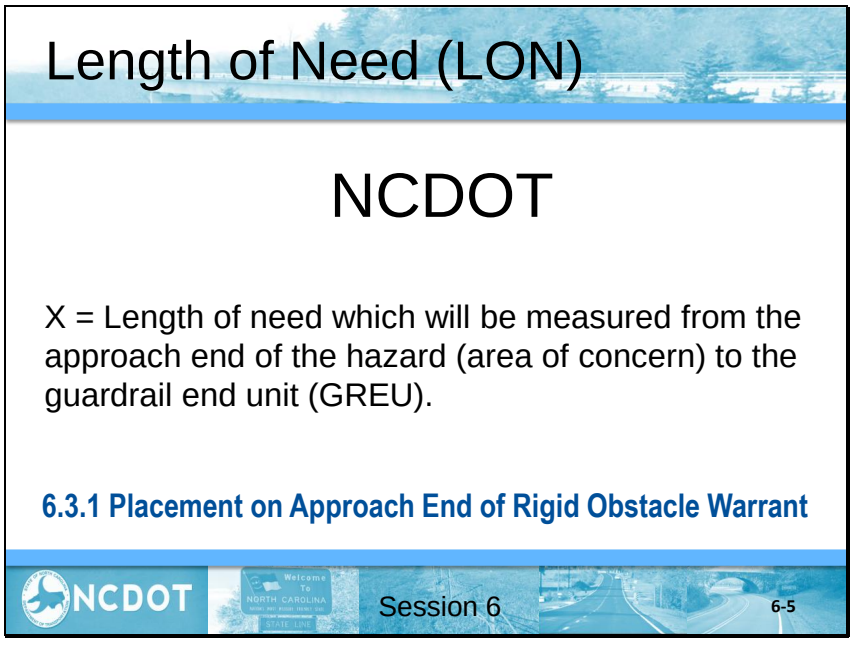
4.6 Roadside Design

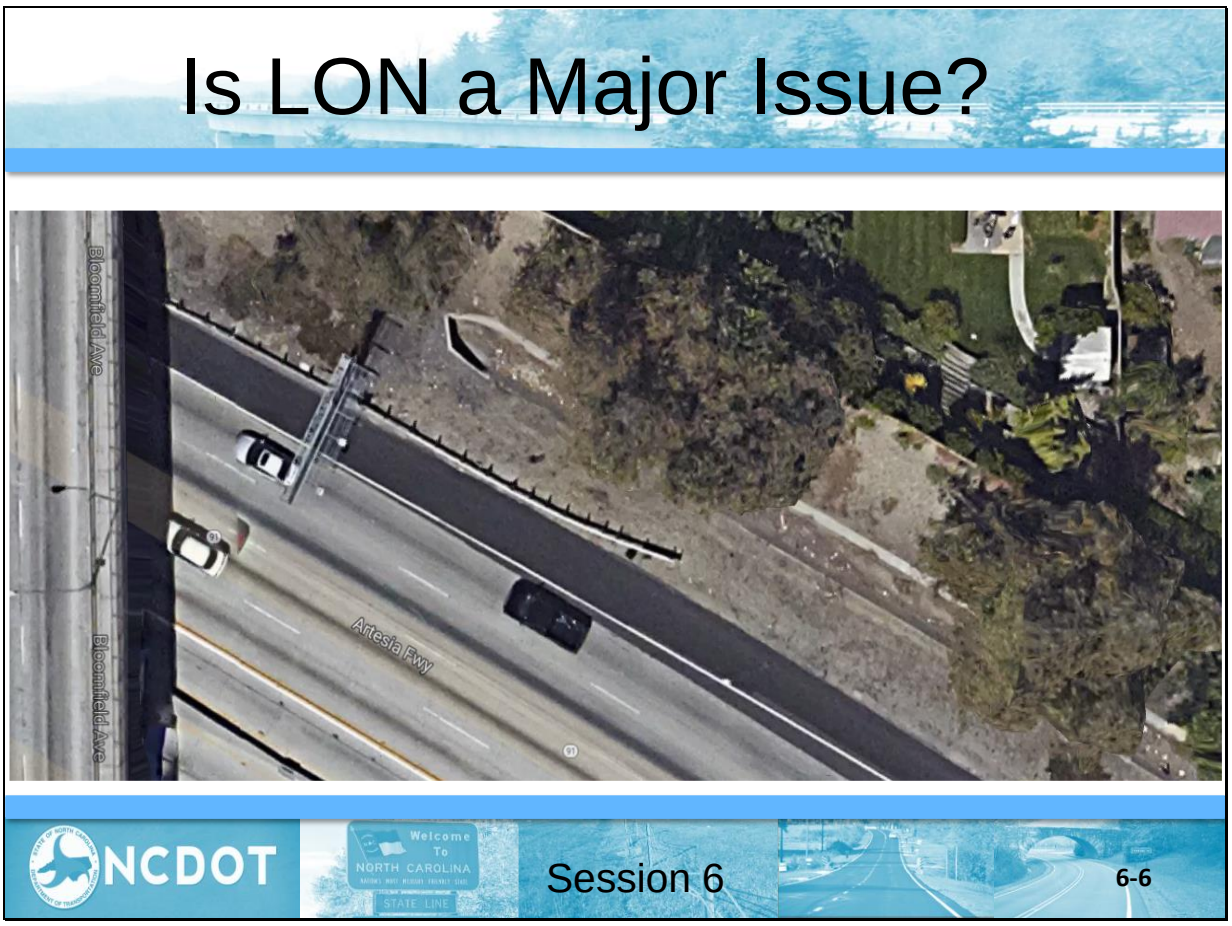
6.1 General Considerations

- Remove obstacle
- Redesign obstacle to be safely traversed
- Relocate obstacle
- Reduce impact severity with a breakaway device
- Shield obstacle with barrier that will redirect vehicle or use crash cushion
- Delineate obstacle if other options are not appropriate




Length of Need (LON) Definition
AASHTO
The length of effective barrier needed IN ADVANCE OF the hazard to intercept and redirect an encroaching vehicle.
NCDOT
Session 6
6-4


Length of Need (LON)
NCDOT
X = Length of need which will be measured from the approach end of the hazard (area of concern) to the guardrail end unit (GREU).
6.3.1 Placement on Approach End of Rigid Obstacle Warrant
NCDOT
Session 6
6-5


Is LON a Major Issue?
Bloomfield Ave
Artesia Fwy
Bloomfield Ave
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
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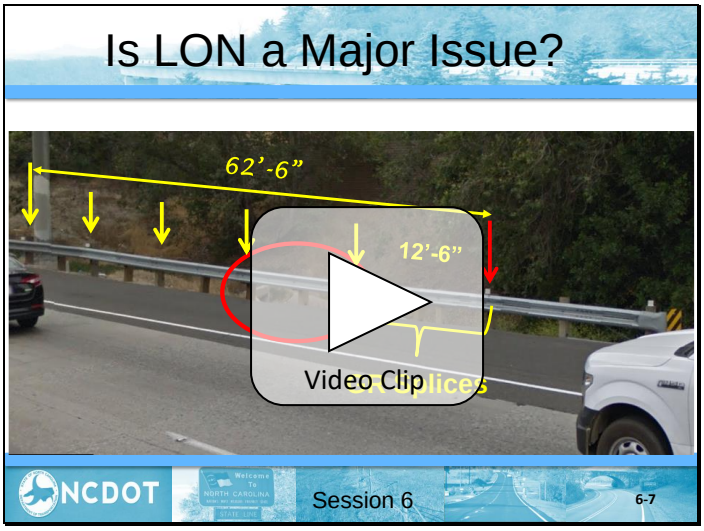
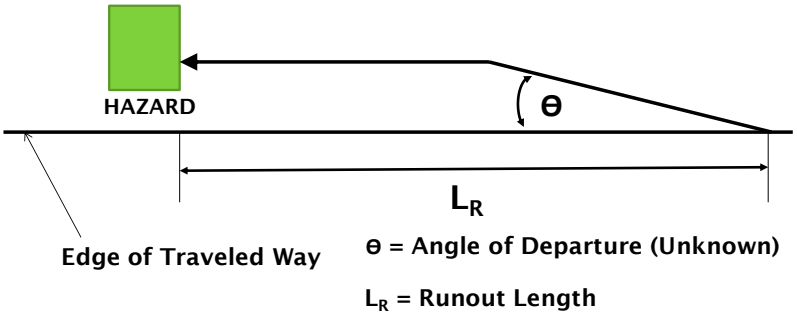
6-6


Is LON a Major Issue?
62'-6"
12'-6"
Video Clip
NCDOT
Session 6
6-7

Length of Need (LON) Theory

AASHTO



Runout Lengths - NCDOT

6.3 Guardrail Placement

6.3.1 Placement on Approach End of Rigid Obstacle Warrant

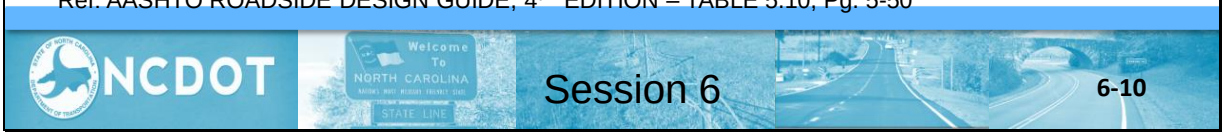
L_R = Runout length or theoretical distance needed for a vehicle which has left the roadway to come to a complete stop. Refer to RDG Chapter 5 Section 5.6.4 Table 5-10b.

Runout Lengths - AASHTO

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

Design Speed (mph)	Runout Length (L_R) Given Traffic Volume (ADT) (ft)			
	Over 10,000	5,000 to 10,000	1,000 to 5,000	Under 1,000
80	470	430	380	330
70	360	330	290	250
60	300	250	210	200
50	230	190	160	150
40	160	130	110	100
30	110	90	80	70

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



Length of Need – AASHTO

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

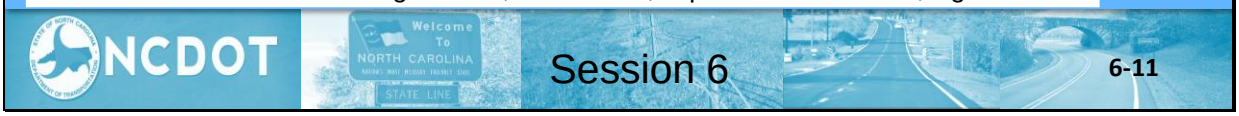
$$X = \frac{L_A + (b/a)\,(L_1) - L_2}{(b/a) + (L_A/L_R)}$$

b/a = flare rate per Slides 5-46+

  - For parallel guardrail installations:

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

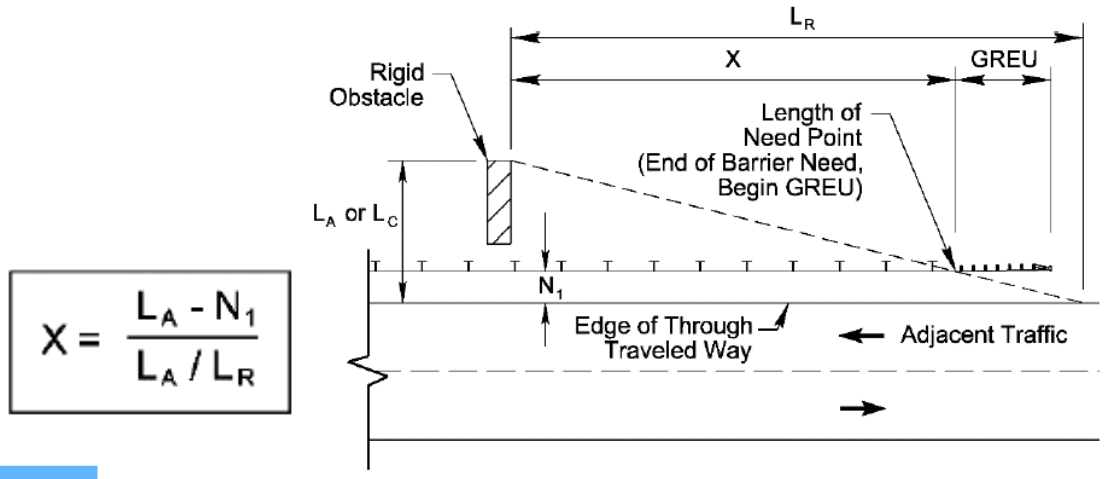
Ref: AASHTO Roadside Design Guide, 4th Edition, Equation 5-1 and 5-2, Pg 5-51



LON Design Procedure for Approach Barrier Layout - NCDOT

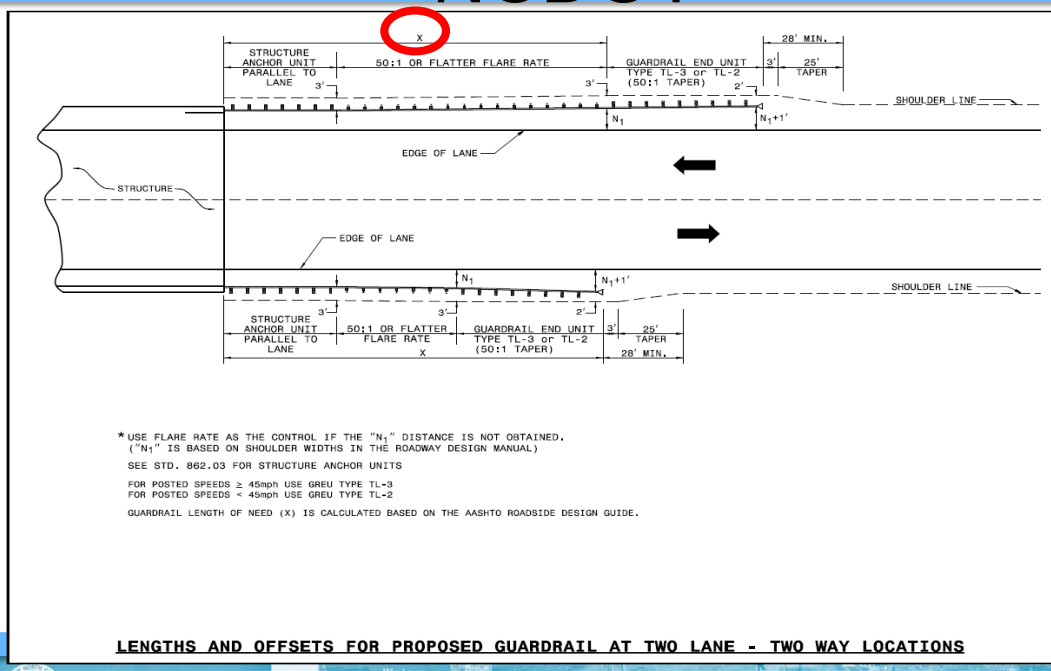
6.2.2 Length of Need

Figure 6-1 Detail of Guardrail Placement on Approach End of Rigid Obstacle Warrant



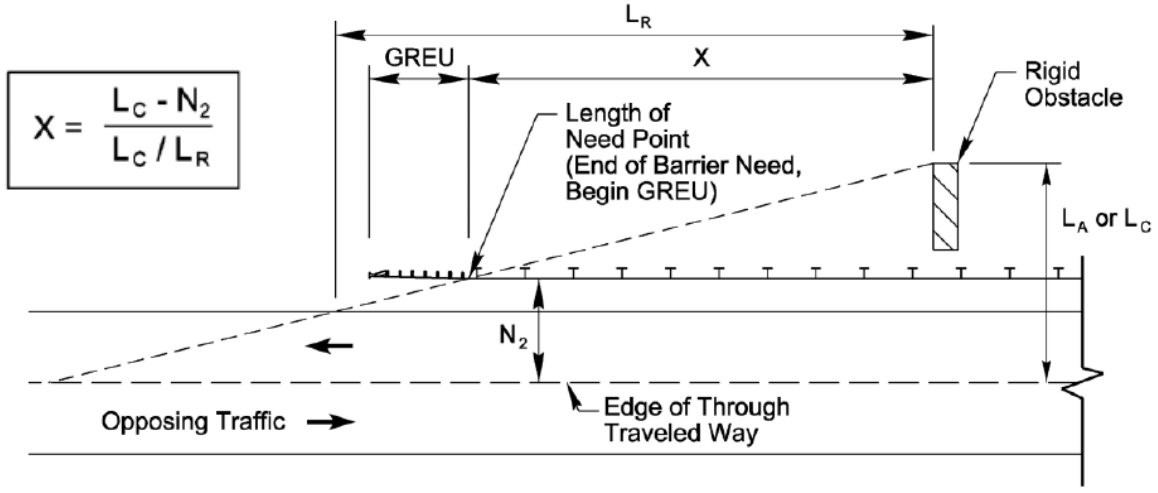
$$X = \frac{L_A - N_1}{L_A / L_R}$$

Length of Need for Bridge Approach NCDOT



LON Design for Opposing Traffic

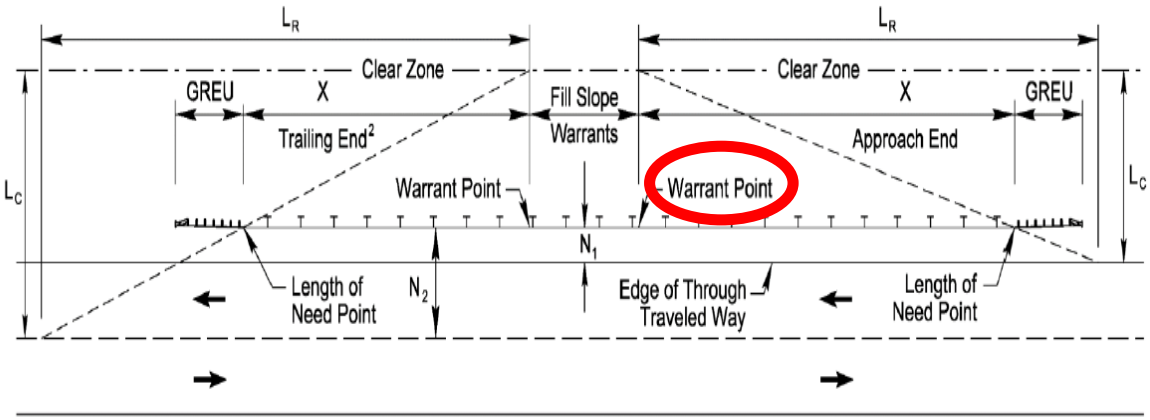
Figure 6-2 Detail of Guardrail Placement on Trailing End of Rigid Obstacle Warrant



NCDOT Session 6 6-14

Fill Slope Length of Need

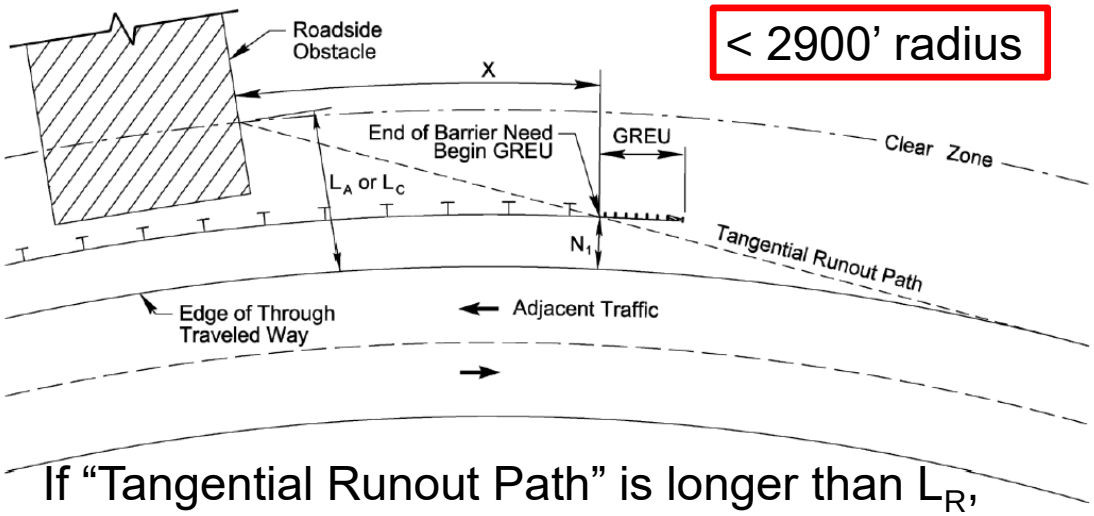
Figure 6-3 Detail of Guardrail Placement on Approach and Trailing End of Fill Slope Warrant



Typically, the fill slope warrant point is at the location where the fill slope becomes steeper than 3:1 (or 4:1 if a hazard is present at the bottom of the slope). Refer to RDG Chapter 5 Section 5.2.1 Figure 5-1b for further detail.

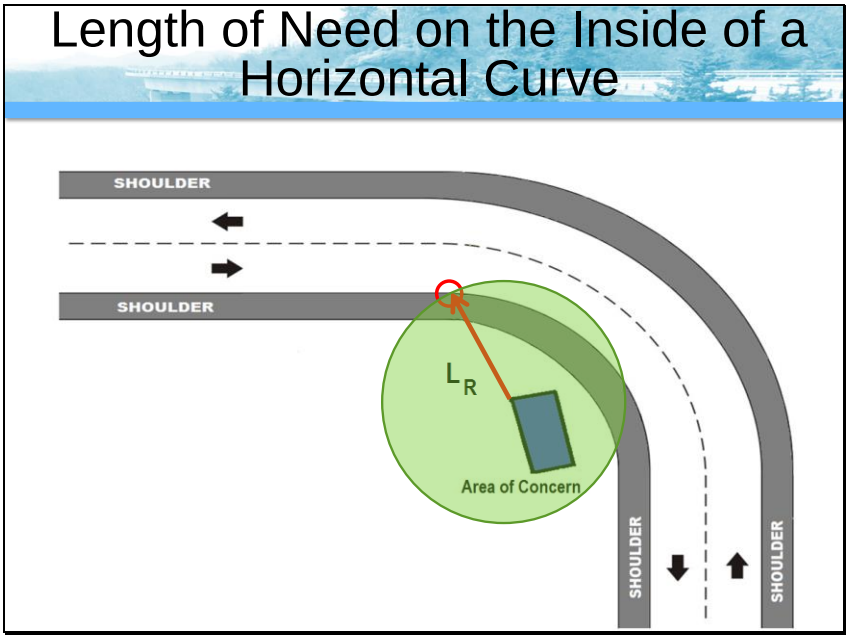
Length of Need on the Outside of a Horizontal Curve

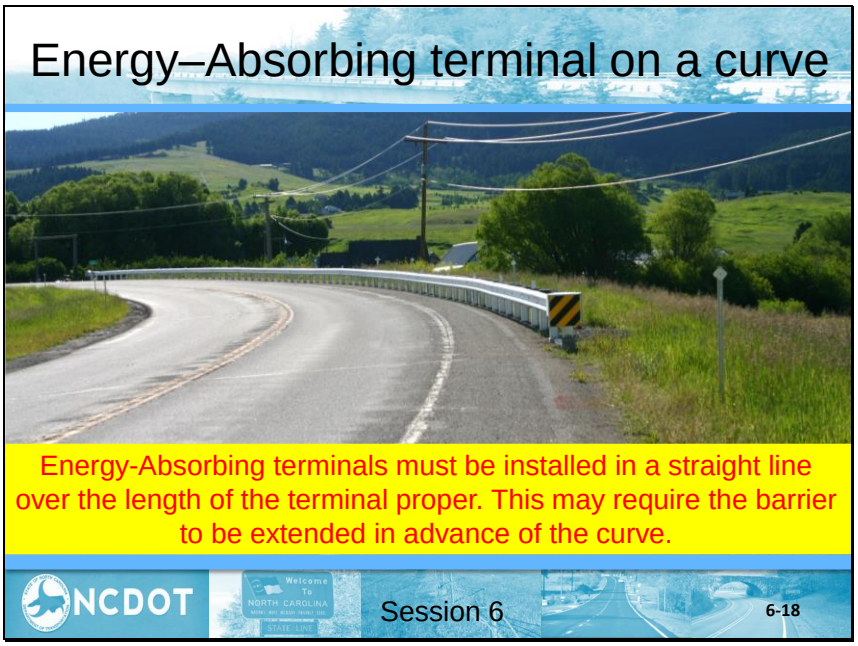
Figure 6-4 Detail of Guardrail Placement on Approach End of Hazard Located on Horizontal Curve

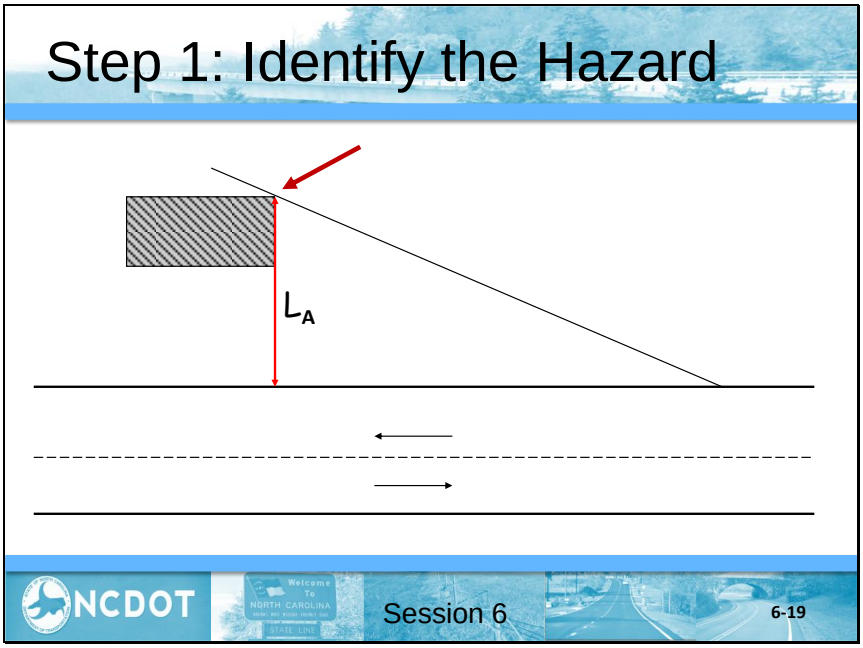


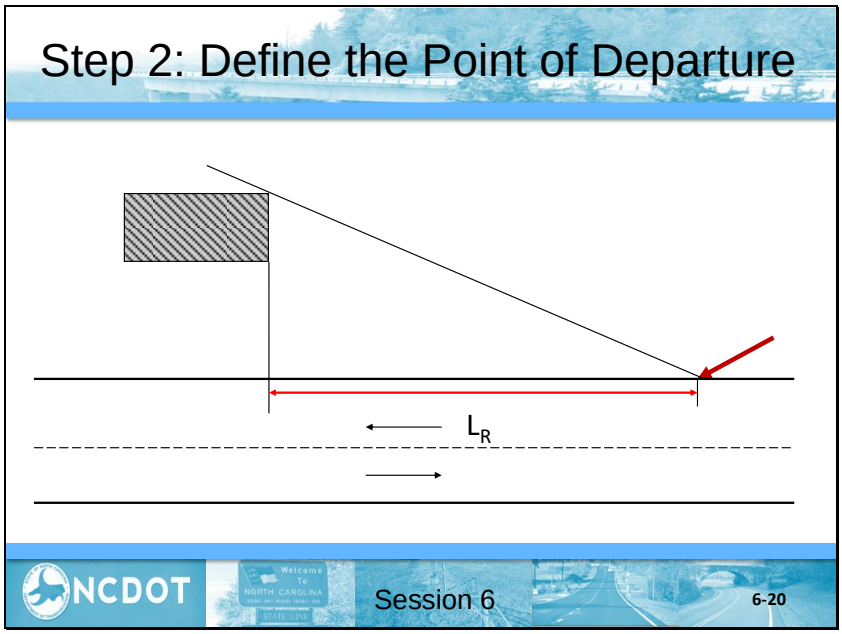
< 2900' radius

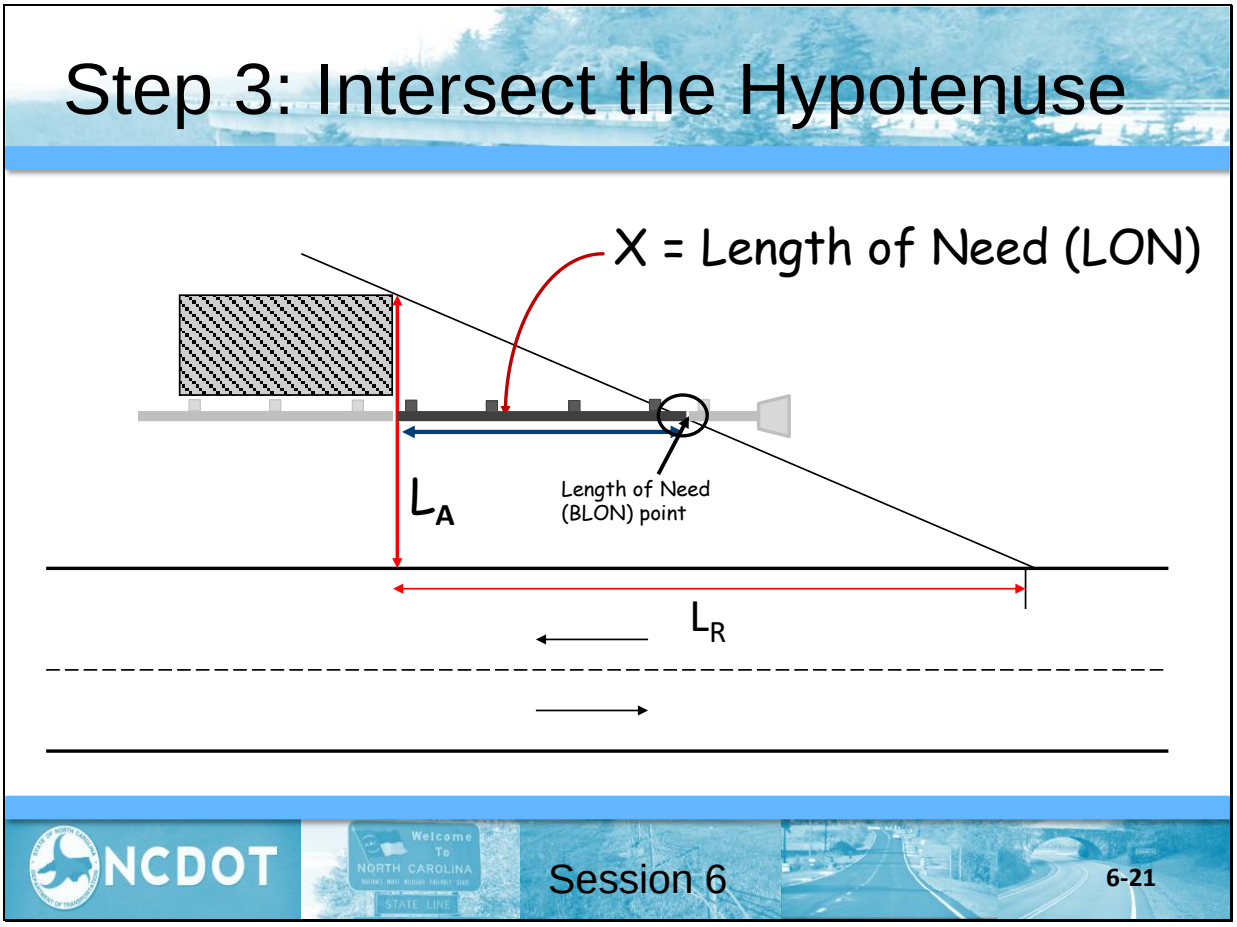
If "Tangential Runout Path" is longer than L_R, draw line to L_R


Length of Need on the Inside of a Horizontal Curve
SHOULDER
SHOULDER
L_R
Area of Concern
SHOULDER
SHOULDER


Energy–Absorbing terminal on a curve
Energy-Absorbing terminals must be installed in a straight line over the length of the terminal proper. This may require the barrier to be extended in advance of the curve.
NCDOT
Session 6
6-18


Step 1: Identify the Hazard
L_A
NCDOT
Session 6
6-19


Step 2: Define the Point of Departure
L_R
NCDOT
Session 6
6-20


Step 3: Intersect the Hypotenuse
X = Length of Need (LON)
L_A
Length of Need
(BLON) point
L_R
NCDOT
Session 6
6-21


Length of Need – Adequate?
NCDOT
Welcome To NORTH CAROLINA
STATE LINE
Session 6
6-22


Length of Need – Adequate?
NCDOT
Session 6
6-23


Length of Need – Adequate?
NCDOT
Session 6
6-24

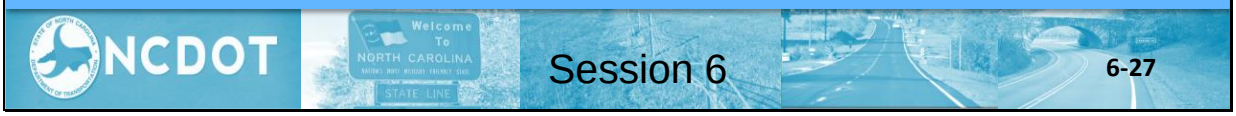

Length of Need – Adequate?
NCDOT
Session 6
6-25


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

NCDOT Guidance for Transverse Slope

6.3.9 Placement Under Bridges

2. Without Outside Bridge Piers
   a. Approach with a Natural or False Cut
      i. No guardrail is needed if the 6-foot vertical curve is used with *NCDOT Roadway Standard Drawings* Std. Nos. 225.07 and 610.03.
   b. Approach in a Fill without a False Cut
      i. Guardrail is normally placed 6 feet to 12 feet from the edge of a local, collector, or auxiliary lane, and 12 feet to 20 feet from the edge of a main travel lane. Guardrail spacing at the end bent slope will typically be 6 feet 3 inches. Extend the guardrail based on the length of need requirements as outlined in Section 6.2.2 above.

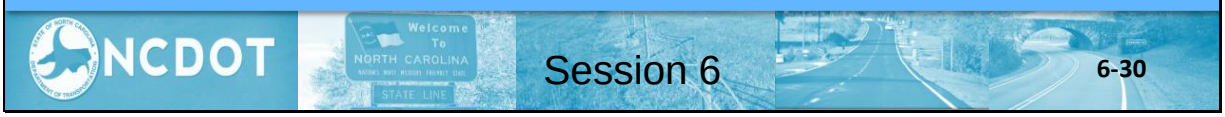



EXIT
265 B
PRE-ASSESSMENT PHOTO
NCDOT
Session 6
6-28

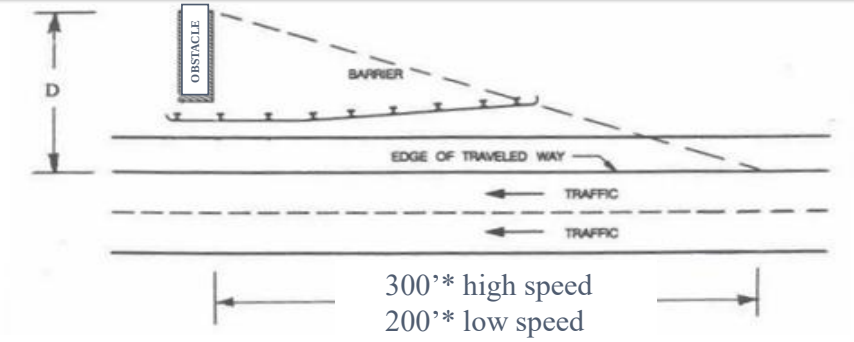

Length of Need – Adequate?
NCDOT
Session 6
6-29

Quick Field Check of LON

1. Stand on roadway edgeline opposite the upstream edge of the hazard.
2. Pace upstream along edgeline appropriate runout length (based on speed of roadway and traffic volume) – use 300'/200' as default value.
3. Turn and look at far lateral edge of hazard.
4. If planned (or existing) guardrail run intercepts this line of sight, it satisfies basic design length of need.
5. Check for ALL hazards that should be shielded in this area
6. Check for better terminal location by extending barrier a short distance (especially on curves!!!)

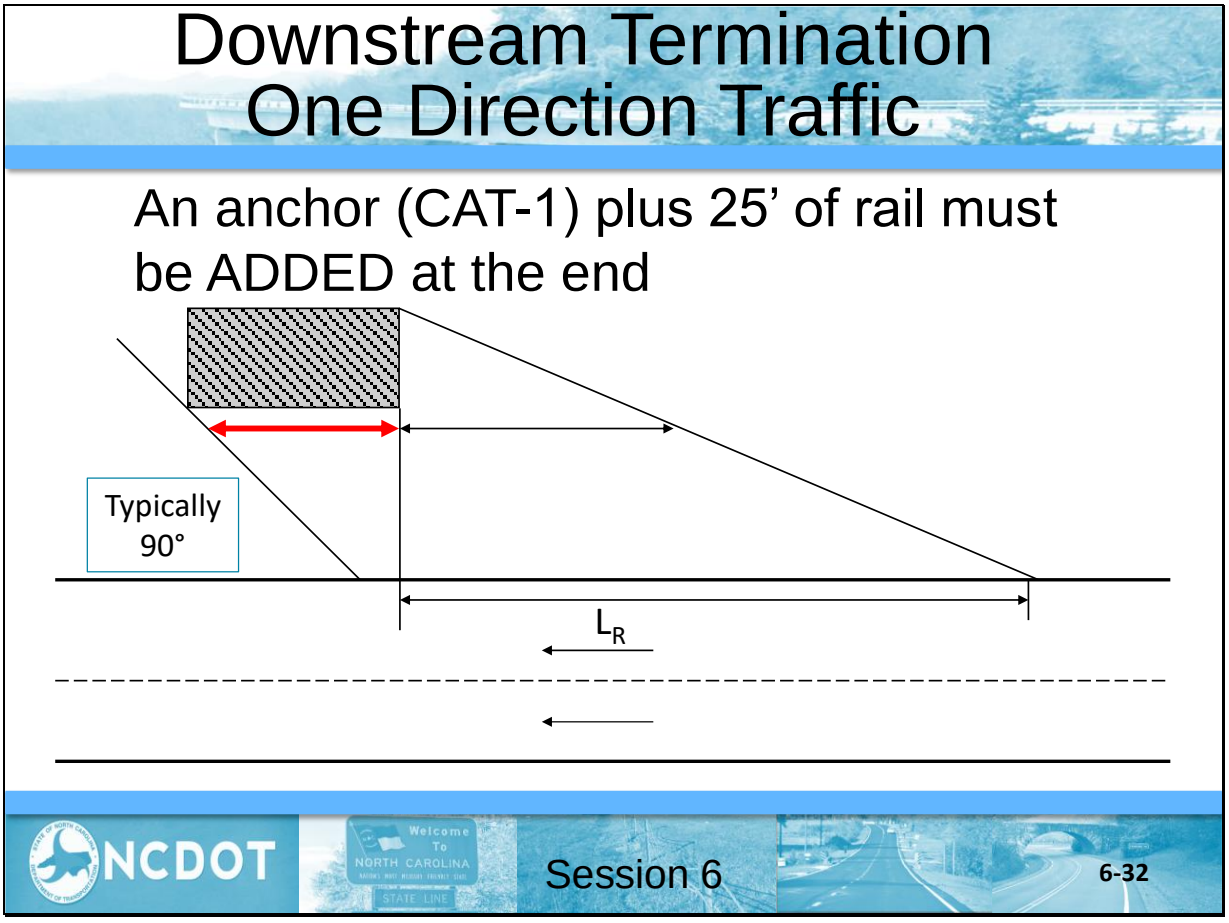


Length of Need Field Check



Procedure

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

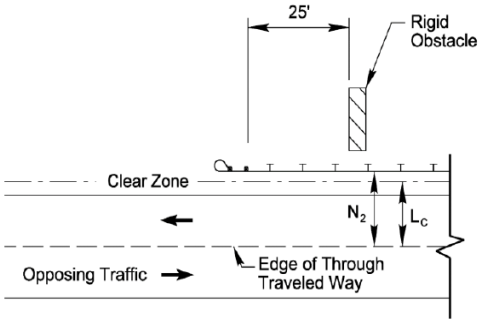

Downstream Termination
One Direction Traffic
An anchor (CAT-1) plus 25’ of rail must be ADDED at the end
Typically 90°
L_R
NCDOT
Welcome To NORTH CAROLINA STATE LINE
Session 6
6-32

Downstream Termination One Direction Traffic

6.3.2 Placement on Trailing End of Rigid Obstacle

On roadways where the distance from the edge of the opposing travel lane to the face of guardrail is equal to or greater than the clear zone distance, use a CAT-1 Anchor Unit placed 25 feet beyond the end of the guardrail warrant point (refer to Figure 6-2).

Figure 6-2 Detail of Guardrail Placement on Trailing End of Rigid Obstacle Warrant



NCDOT Session 6 6-33

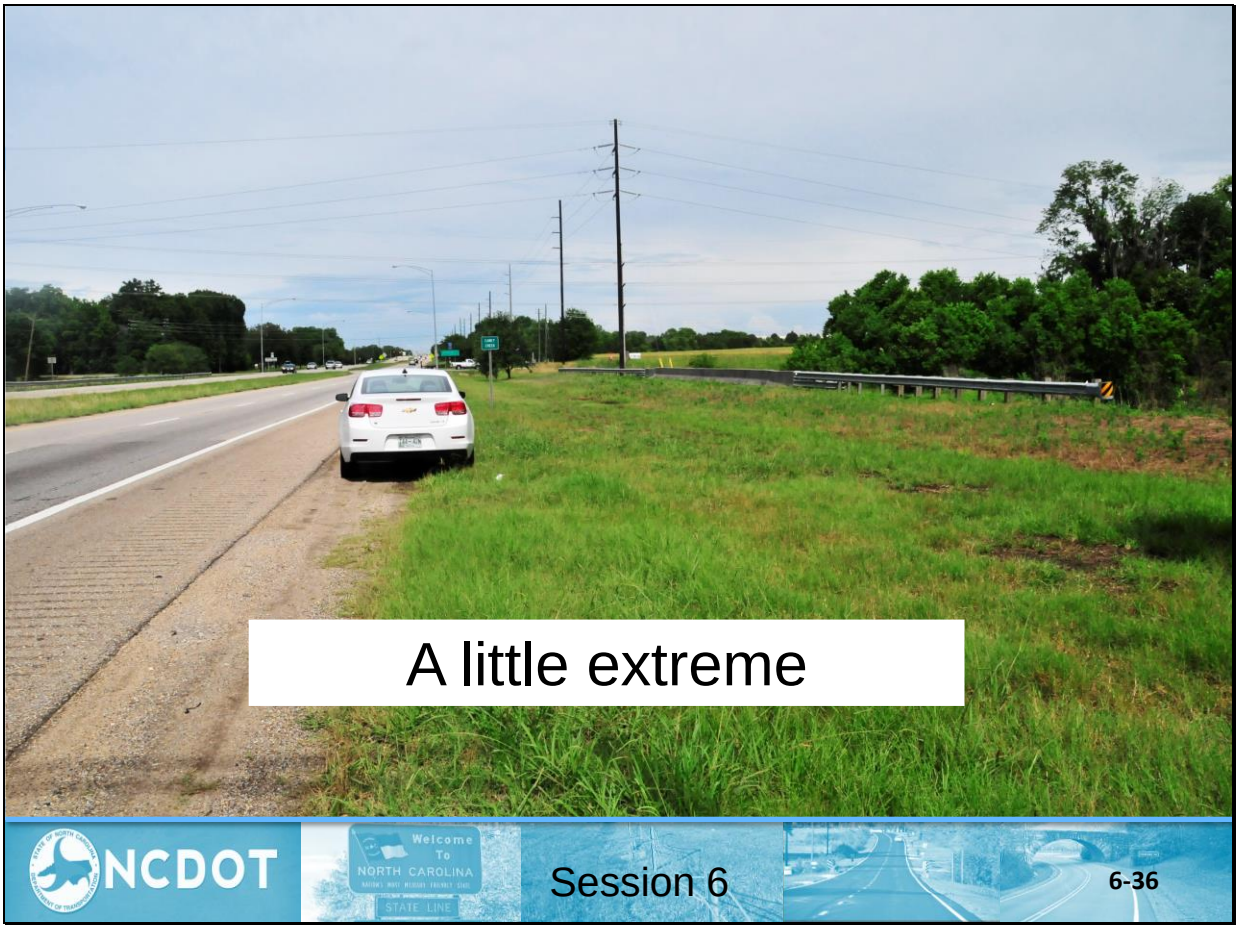
Minimum Lengths of Guardrail

6.2.2 Length of Need

The minimum length of guardrail between end units is 12.5 feet when the design speed is 45 mph or less and 25 feet when the design speed is greater than 45 mph. Guardrail end units and structural anchor units are not designed to connect to each other warranting a section of guardrail between them.

Guardrail Placement

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



Guardrail Placement in Special Situations

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


Guardrail Placement at Intersections
NCDOT
Session 6
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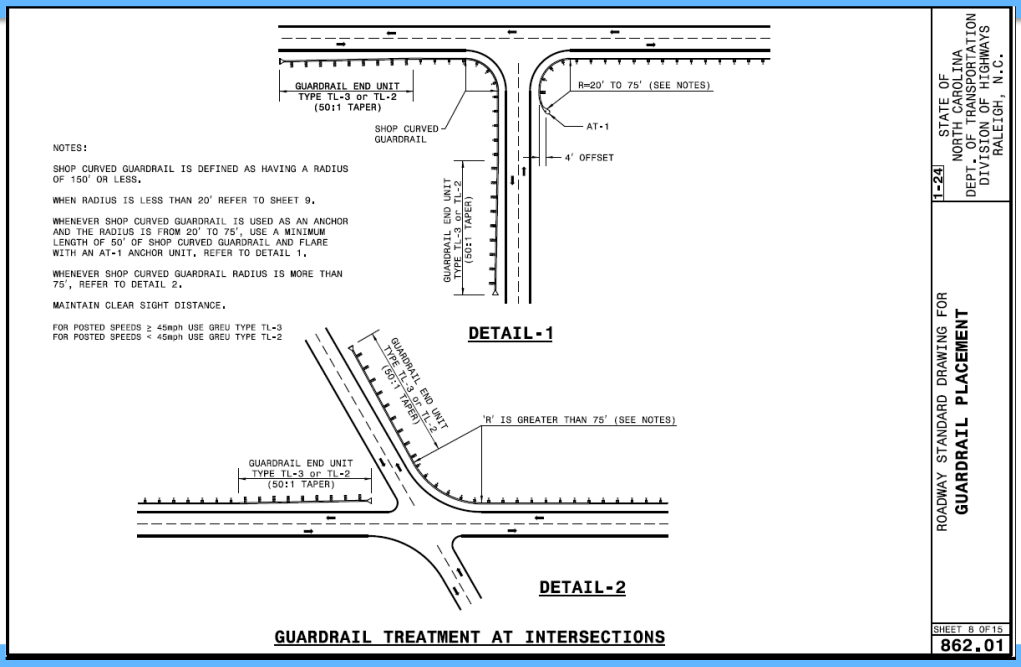
PRE-ASSESSMENT PHOTO
NCDOT
Session 6
6-39

Guardrail Placement at Intersections

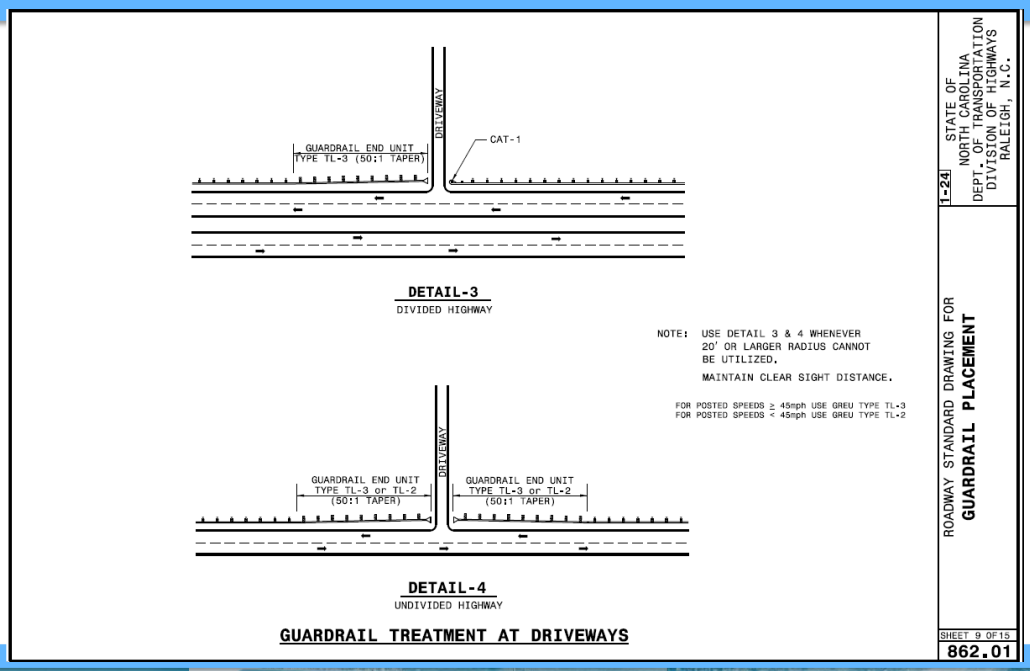


NCDOT Session 6 6-40

_____

_____

Guardrail Placement at Driveways

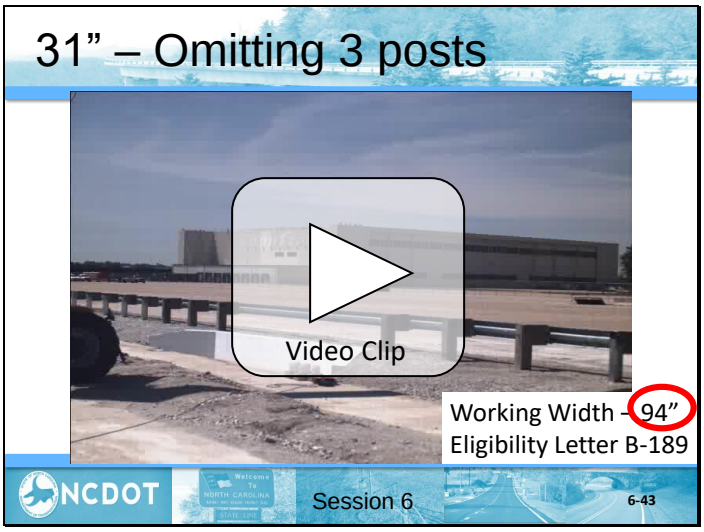


NCDOT Session 6 6-41

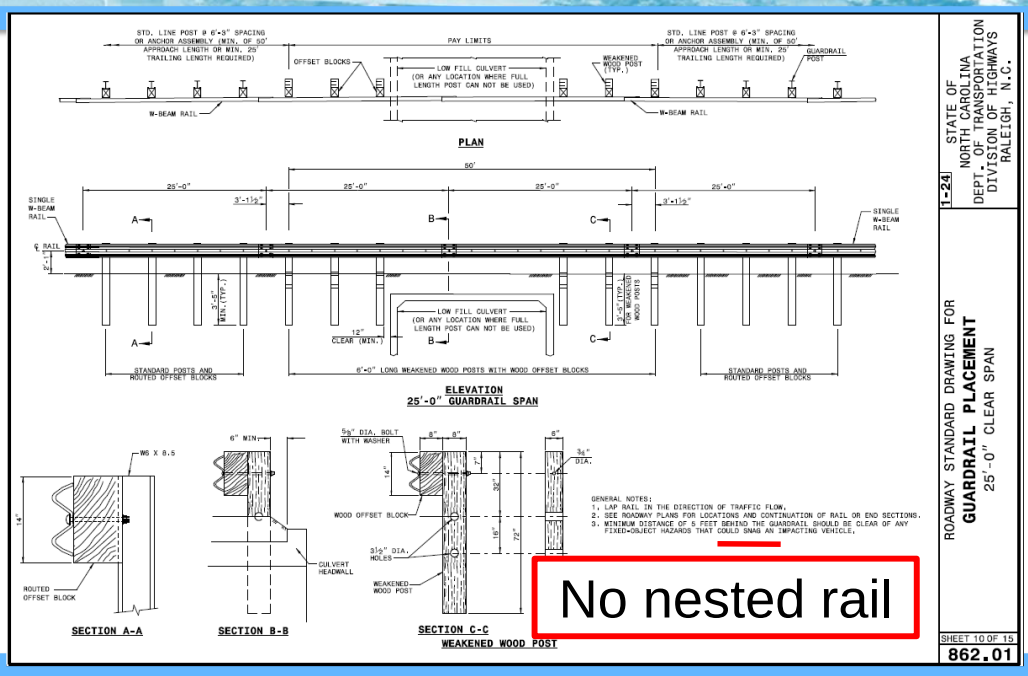
_____

_____


Omitting posts – old 29” guardrail
Required nested rail
NCDOT
Session 6
6-42


31” – Omitting 3 posts
Video Clip
Working Width – 94”
Eligibility Letter B-189
NCDOT
Session 6
6-43

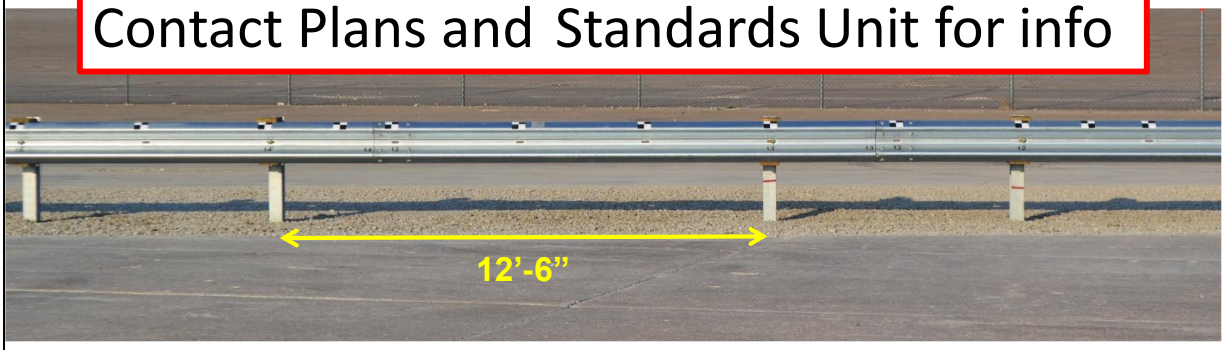
31” – Omitting 3 posts



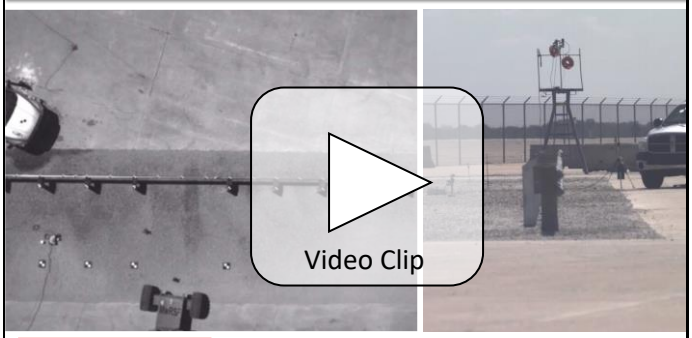
MGS - Omitting 1 post – Future??

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

Contact Plans and Standards Unit for info

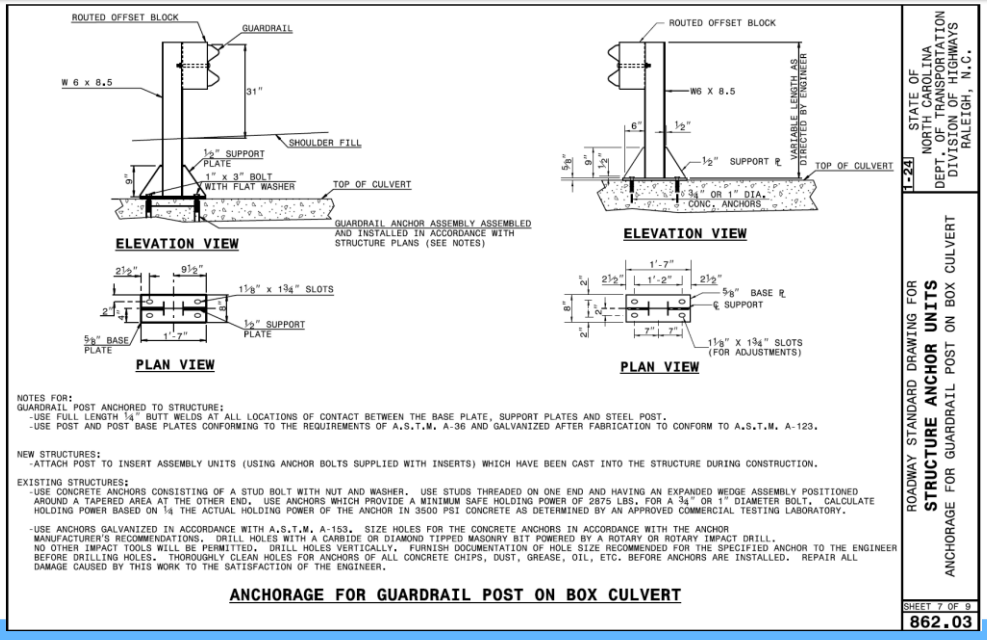


MGS - Omitting 1 post – NCDOT Looking into Developing Guidance



Working Width 50.1”
Limit 1 per 50’

Structure Mounted Guardrail



Participant Notebook

Openings in Barriers

Check with maintenance, ROW, etc

NCDOT Session 6 6-48

Openings in Barriers - NCDOT

6.2.2 Length of Need

Note: Do not leave a space of less than 300 feet between guardrail installations. Extend the guardrail through the area if less than 300 feet exists between installations.

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

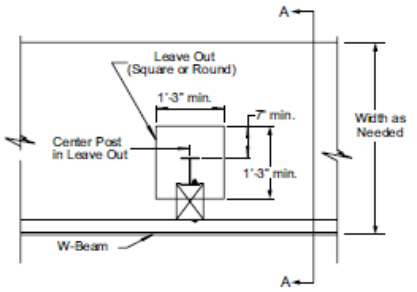
NCDOT Session 6 6-49

Extra Offset Blocks – National Guidance

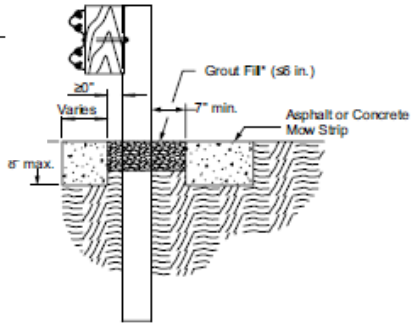
- Two Offset blocks (up to 16” deep) may be used at any time, for any number of posts.
- Three Offset blocks may be used at one or two posts in a section of guardrail.

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

Leaveouts in Structural Pavement



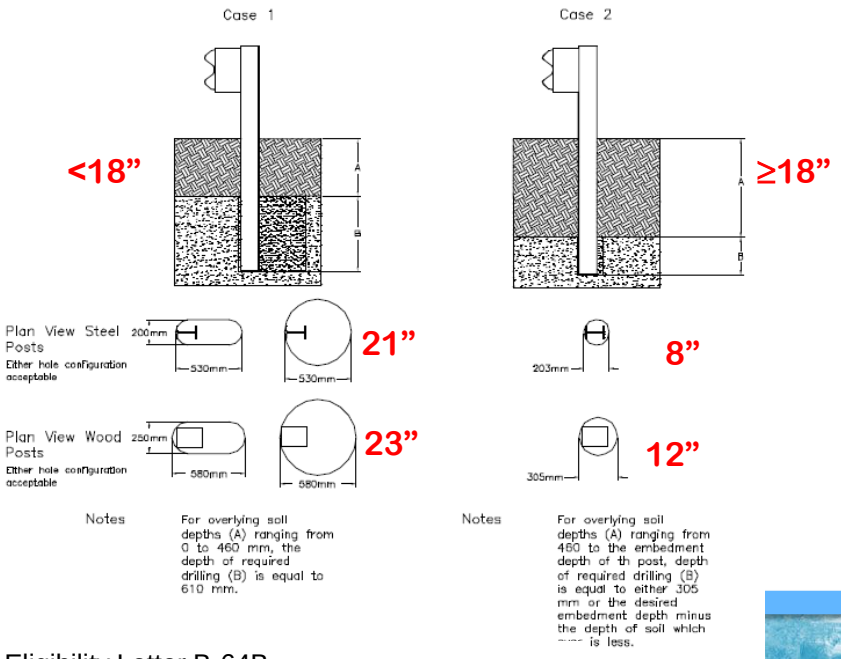
Steel Post Detail



Section A-A

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

Guardrail Posts in Rock AASHTO



Eligibility Letter B-64B

6-52

Guardrail Posts in Rock - NCDOT

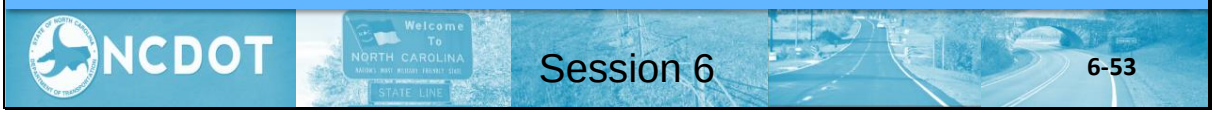
SECTION 862

GUARDRAIL

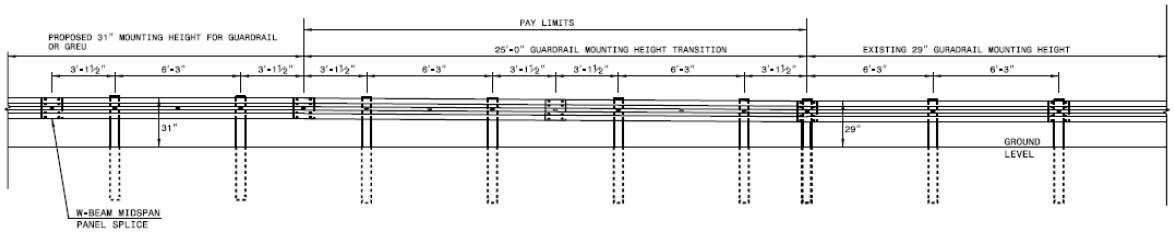
862-3 CONSTRUCTION METHODS

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.

Provide bid item if aware of rock



Height Transition – 31” to/from Old Guardrail



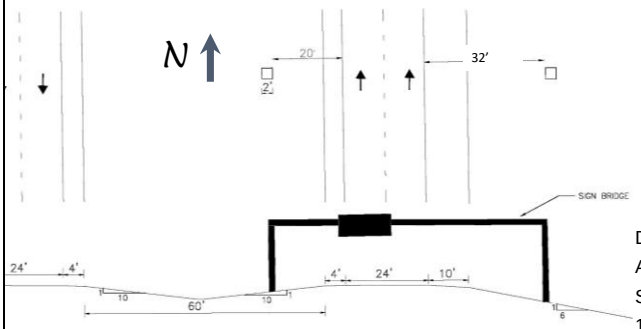
ELEVATION VIEW

TRANSITION FROM 29" TO 31" W-BEAM GUARDRAIL MOUNTING HEIGHT

862.02 SHEET 5 OF 6	ROADWAY STANDARD DRAWING FOR **GUARDRAIL INSTALLATION**	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

NCDOT Session 6 6-54

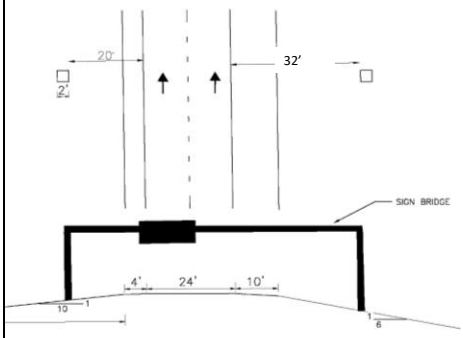
Example - LON



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

DETERMINE TREATMENTS FOR NB TRAFFIC

Example - LON



Determine Design Clear Zone

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

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

Design Clear Zone Distance – Fill

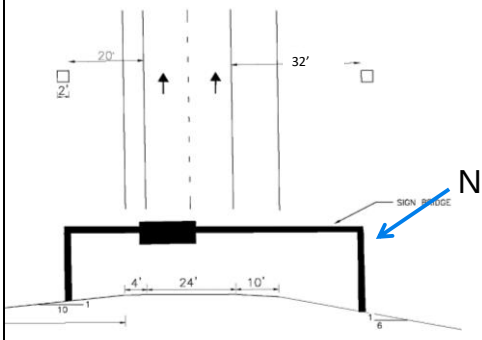
Design Speed (mph)	Design ADT	Foreslopes 1V:6H or flatter	Foreslopes 1V:5H to 1V:4H	Foreslopes 1V:3H
40 mph	UNDER 750	7-10	7-10	b
	750-1500	10-12	12-14	b
	1500-6000	12-14	14-16	b
	OVER 6000	14-16	16-18	b
45-50 mph	UNDER 750	10-12	12-14	b
	750-1500	14-16	16-20	b
	1500-6000	16-18	20-26	b
	OVER 6000	20-22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

Design Speed 70 mph
AADT = 53,000

L_C = 32 ft.

NCDOT Session 6 6-57

Example – LON



Identify ALL the hazards

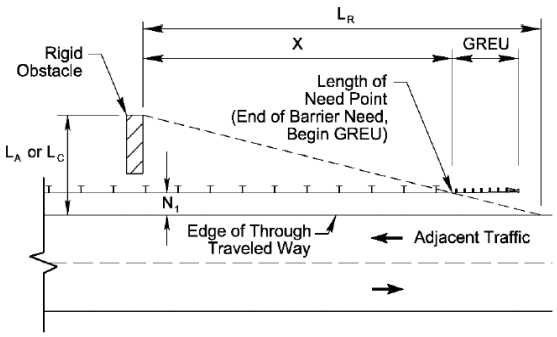
NOT SHIELDED

Sign supports – both sides

NCDOT Session 6 6-58

Calculating the Length of Need (X)

Figure 6-1 Detail of Guardrail Placement on Approach End of Rigid Obstacle Warrant



$$X = \frac{L_A - N_1}{L_A / L_R}$$

Look up L_R:

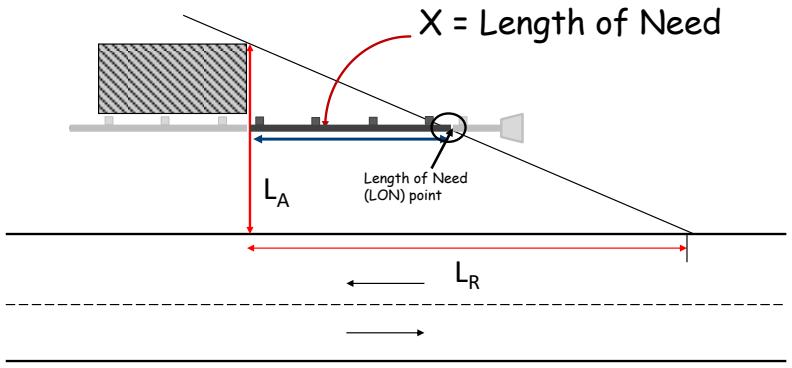
Design Speed 70 mph
AADT = 53,000

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

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

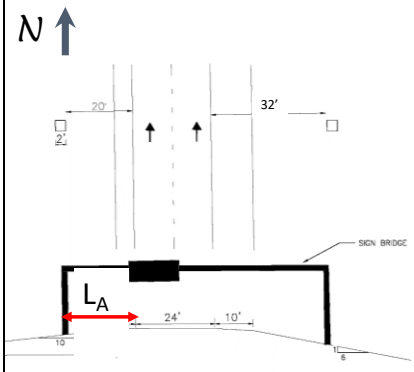
L_R = 360 ft.

Step 3: Intersect the Hypotenuse



NCDOT Session 6 6-61

Example – LON



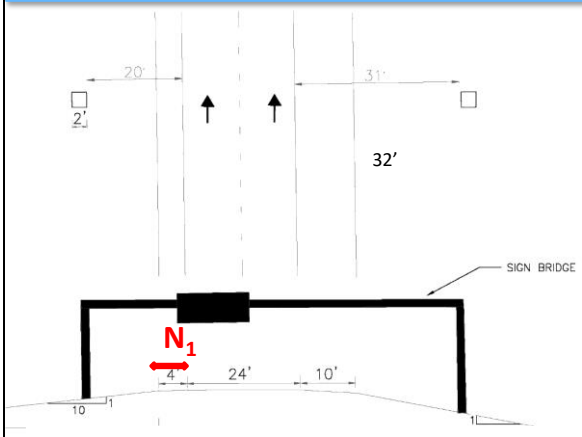
Determine L_A – distance to the backside of hazard

For the back of the sign support:

L_A = 20 + 2 = 22'

NCDOT Session 6 6-62

Find N_1



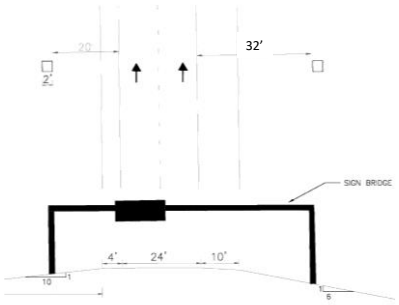
N_1 – Guardrail offset from edge of travel lane.

N_1 = 6 ft.

- N_1 = The distance from the edge of the adjacent travel lane to the face of the guardrail.
  - N_1 = Normal shoulder width for locals and collectors (minimum 4 feet).
  - N_1 = Normal shoulder width plus 2 feet for arterials, interstates and freeways.

NCDOT Session 6 6-63

Calculate LON – Determine Bid Item



L_A = 22 ft N_1 = 6 ft L_R = 360

Using the formula L =

$$L = \frac{L_A - N_1}{L_A / L_R}$$

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

= 262 ft.

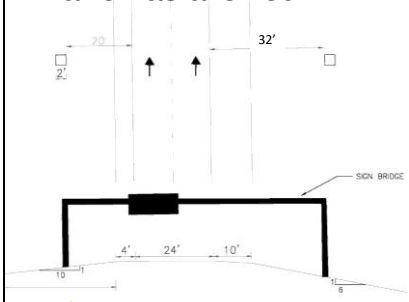
Does **NOT** include Terminal: GREU (50±')

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

A CAT-1 must be added

Calculate LON – Additional Offset

If guardrail is placed as far off as allowed:



L_A = 22 ft N_1 = (20'-5.5') =14.5' L_R = 360'

Using the formula L =

$$L = \frac{L_A - N_1}{L_A / L_R}$$

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

= 123 ft.

A CAT-1 must be added

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

Example – LON

TALKING POINTS

What if the situation were a dual bridge? Normal design sets L_A to L_C, in this case 32'; but if the designer chose to shield the ENTIRE opening, L_A would be 64'(to the opposite bridge rail) (assuming a 68' median).

How much more barrier would that require?

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

For L_A = 32' (and N_1 = 6'), L = 293'

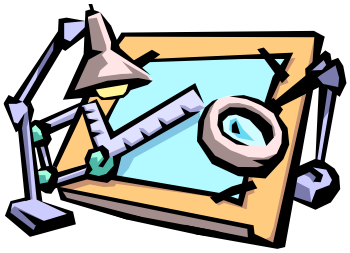
For L_A = 64' (and N_1 = 6'), L = 326'

Review Learning Outcomes

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

Session 7: Design Workshop

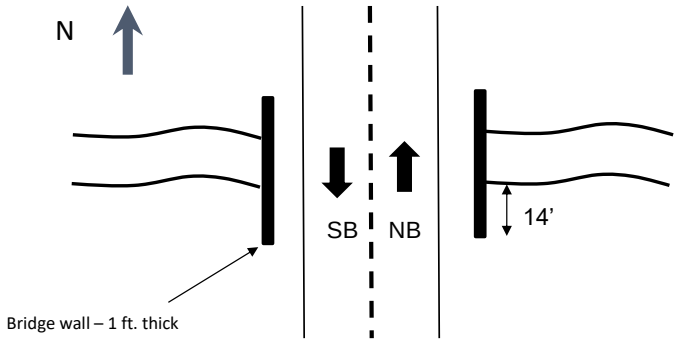
North Carolina Department of Transportation
Highway Safety Barrier Design Training

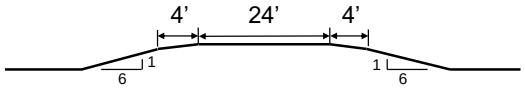


Designer Workshop

NCDOT Session 7 7-1

Workshop #1: Bridge on Rural Road with Two-Way Traffic





Design Speed 55 mph
AADT 1,800 vph

Lane width: 12 ft.
Shoulder width: 4 ft.
Side slope: 1V:6H

Design for both sides of road, NB

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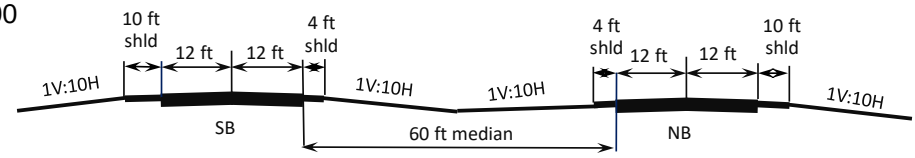
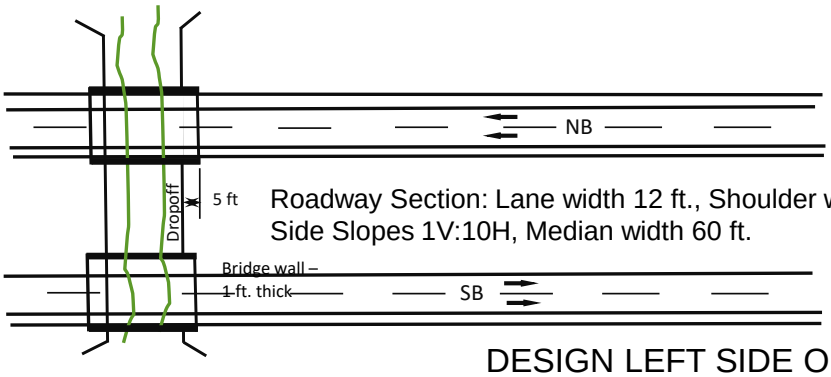
Workshop #2 – Median Drop Off (Elephant Trap)

Design speed: 70 mph

ADT: 23,000

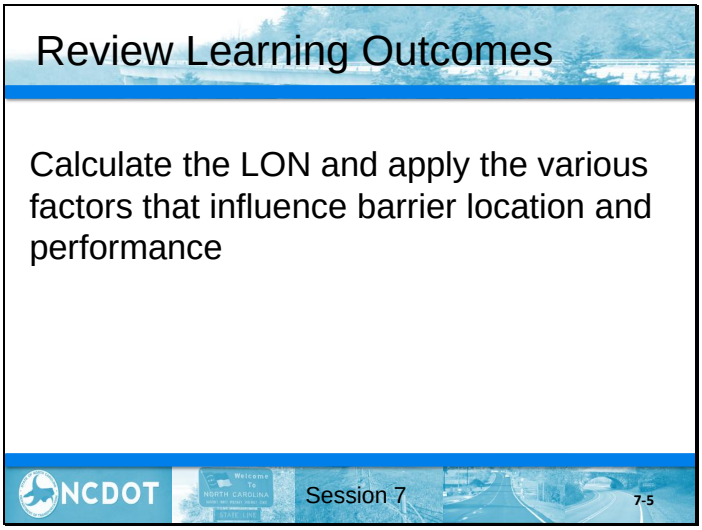




Roadway Section: Lane width 12 ft., Shoulder width 10 ft. Rt. 4 ft. LT. Side Slopes 1V:10H, Median width 60 ft.

DESIGN LEFT SIDE OF THE ROAD, NB

Workshop #2 – Median Drop Off (Elephant Trap)


Review Learning Outcomes
Calculate the LON and apply the various factors that influence barrier location and performance
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