Agenda

• Morning Session
  • Standard Specifications Update – Guardrail and Barrier

• Afternoon Session
  • Crash Testing and MASH
  • DelDOT’s MASH Compliance
  • Standard Construction Details – Guardrail
  • Standard Construction Details – Concrete Barrier
Crash Testing and MASH
Crash Testing

• FHWA policy requires that all roadside appurtenances used on the NHS meet the performance criteria contained in the AASHTO Manual for Assessing Safety Hardware (MASH)

  • Applies to:
    • Traffic barriers
    • Barrier terminals
    • Crash cushions
    • Bridge railings
    • Sign and light pole supports
    • Work zone hardware

• Some form of crash testing has been occurring since the 1930s
Crash Testing History

1962

1974

1980

1993

2009

2016

DelDOT
• What is MASH?
  • AASHTO Manual for Assessing Safety Hardware
  • 1st Edition published in 2009 to replace NCHRP Report 350
  • National guidelines for crash testing of roadside safety hardware
  • Developed under NCHRP Project 22-14(02)
  • 2nd Edition published in 2016
    • Errata issued in June and July 2020

• Purpose of MASH
  • Uniform testing guidelines
  • Recommended testing criteria for evaluation of crash tests
MASH vs. NCHRP 350

• Differences under MASH
  • Updated test vehicles to reflect current vehicle fleet
    • Heavier small cars
    • Heavier pick-up trucks
    • Higher bumper heights
    • Changes in centers of gravity
  • Updated inconsistencies in test matrices
    • Account for real-world conditions
  • Updated evaluation criteria to reduce subjectivity
    • Deformation of passenger compartment thresholds
# MASH Test Levels

<table>
<thead>
<tr>
<th>TEST LEVEL</th>
<th>Test VEHICLE Type – (weight Lb.)</th>
<th>SPEED mph</th>
<th>ANGLE OF IMPACT</th>
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<tr>
<td>1</td>
<td>PASSENGER CAR – (1809 to 2,420) → PICKUP TRUCK – (4409 to 5,000) ←</td>
<td>31</td>
<td>25 (20) ←</td>
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<td>31</td>
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<td>2</td>
<td>PASSENGER CAR – (2,420)</td>
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<td>PICKUP TRUCK – (5,000)</td>
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<td>PASSENGER CAR – 2420</td>
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<td>PICKUP TRUCK – 5000</td>
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<td>PASSENGER CAR – (2,420)</td>
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<td>PICKUP TRUCK – (5,000)</td>
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<tr>
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<td>SINGLE UNIT TRUCK – (17636 to 22,000) ←</td>
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<td>5</td>
<td>PASSENGER CAR – (2,420)</td>
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<td>25</td>
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<td></td>
<td>PICKUP TRUCK – (5,000)</td>
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<td>TRACTOR VAN TRAILER – (79,300)</td>
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<td>6</td>
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<td>PICKUP TRUCK – (5,000)</td>
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<tr>
<td></td>
<td>TRACTOR TANK TRAILER – (79,300)</td>
<td>50</td>
<td>15</td>
</tr>
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Graphic Source: PENNDOT
MASH 2009 vs. MASH 2016

• Major update:
  • Crash testing criteria for cable barriers on slopes

• Minor updates:
  • Soil strength testing
  • Improved documentation of vehicle damage
  • Longer tractor-trailer lengths
MASH Implementation

• 2009 MASH
  • Anticipated manufacturers would develop MASH-compliant devices
  • No sunset requirements of NCHRP 350 devices
  • Safety benefits not realized

• 2016 MASH
  • FHWA/AASHTO Joint Implementation Agreement
  • Sunset dates of NCHRP-350 roadside hardware
    • 12/31/2017: W-beam barriers and cast-in-place concrete barriers
    • 6/30/2018: W-beam terminals
    • 12/31/2018: Cable barriers, cable barrier terminals and crash cushions
    • 12/31/2019: Bridge rails, transitions, all other longitudinal barriers, all other terminals, sign supports and all other breakaway hardware
  • Specific requirements for work zone devices dependent on normal service life
MASH Compliance

- MASH Compliance is determined by the **User Agency**.

- Excerpts from an April 9, 2018 FHWA memo to Division Administrators, Federal Lands Division Engineers and Directors of Field Services:
  - The FHWA’s longstanding policy is that all roadside safety hardware installed on the NHS be crashworthy.
  - Roadside safety hardware is eligible for Federal funding if it has been determined to be crashworthy by the user agency (i.e. **State DOT**).
  - It is each **State’s responsibility** to determine crashworthiness and to approve new or modified roadside safety hardware meeting the State’s specific needs.
  - The determination of crashworthiness of roadside safety hardware, acceptance for use on highway projects, and installation and maintenance are responsibilities handled at the **State and local level**.
MASH Compliance at DelDOT
MASH Compliance at DelDOT

Status of DelDOT meeting the FHWA/AASHTO Sunset Dates

✓ W-Beam Barrier
✓ W-Beam Terminals
✓ Cast-in-Place Concrete Barrier
✓ Cable Barrier and Cable Barrier Terminals
✓ Crash Cushions (Permanent Impact Attenuators)
✓ Bridge Railing
✓ Transitions
✓ All other longitudinal barriers
✓ All other terminals
✓ Sign supports
✓ Other Breakaway Hardware
✓ Work Zone Devices

Approved Products List

2020 Standard Specifications require MASH compliant devices
Approved Products List

2020 Standard Specifications require MASH compliant devices

NCHRP 350 Devices in use until suitable MASH compliant devices are available

See Approved Products List for Delaware specific sunset dates
MASH Compliance at DelDOT

• MASH Committee
  • Policy Implement forthcoming
  • Purpose of committee
    • Primary technical group regarding roadside safety hardware
    • Development of standard details regarding roadside safety hardware
    • Recommendations of roadside safety hardware for the Approved Products Lists
    • Review of crash testing paperwork
    • Establishment of Delaware specific sunset dates
    • Review/recommendation for approval of self-certification documents
    • Review/recommendations for approval of devices that are exempt from MASH certification
MASH Compliance at DelDOT

- MASH Committee
  - Roadside safety hardware approval
    - If hardware has approved crash testing from a recognized national crash testing facility, device may be approved without self certification.
  - Hardware requiring self certification
    - Document why crash tested hardware cannot be used
    - Justification with appropriate engineering calculations regarding why the proposed hardware is acceptable
    - Prepared by the DelDOT group that is the appropriate subject matter expert
    - Reviewed and voted on by the MASH Committee
    - If approved, signed by the DelDOT SME, Committee Chair and forwarded to Chief Engineer for review and approval.
Standard Construction Details: Guardrail
Guardrail Details

• Update Summary
  • Overall MASH compliance review
    • Updated existing details as needed
    • Eliminated non-compliant details
    • Maintained some NCHRP 350 compliant details as needed
  • Remove metric dimensions
  • New details
    • Type 1-31 Guardrail with Omitted Post
      • With and without curb
    • Type 1-31 Guardrail on Steep Slope
    • Type 3-31 Guardrail-to-Barrier Connection
      • Includes Concrete Buttresses
    • End Anchorage, Type 31
    • Buried-in-Backslope, Type 31
Guardrail Details

2020 Standard Construction Details: Guardrail

- B-1: Guardrail Applications
  - Type 1-31, 2-31, 3-31; Plan, Elevation and Section Views
  - Type 1-31 Guardrail with Omitted Post
  - Type 1-31 Guardrail on Steep Slope
- B-2: Grading for Guardrail End Treatments (Types 1, 2 and 3)
- B-3: Guardrail over Culverts (Types 1-31, 2-31 and 3-31)
- B-4: End Anchorage, Type 1-31
- B-7: W-Beam, Type 1-27 to Type 1-31 Transition Section
- B-8: Guardrail to Barrier Connection – Approach and Exit Type 31
- B-10: Guardrail to Barrier Connection – Type 3-31
- B-13: Hardware
- B-15: Guardrail Applications (Types 1-27, 2-27 and 3-27)
- B-17: Guardrail End Treatment, Type 4-27
- B-18: Curved Guardrail Section, Type 1-27
- B-20: Buried in Back Slope End Terminal, Type 1-31
Guardrail Applications

• Detail B-1: Guardrail Applications
  • Type 1-31
    • Also known as Midwest Guardrail System (MGS)
    • Standard guardrail application, basis for all other guardrail details
    • Guardrail height = 31”
    • Post spacing = 6’-3” or 75”
    • 12” Offset Blocks
    • Minimum clearance to obstruction = 4’-0”
    • Guardrail splices midspan
    • MASH Compliant system
  • Type 2-31
    • Half post spacing, 3’-1 ½” or 37.5”
    • Minimum clearance to obstruction = 3’-0”
    • Not compliant with MASH; testing still underway
  • Type 3-31
    • Median guardrail (double sided)
    • 8” Offset Blocks
    • Standard post spacing
    • MASH compliant system

Source: Midwest Roadside Safety Facility
Guardrail Applications

- Detail B-1: Guardrail Applications
Guardrail Applications

- Detail B-1: Guardrail Applications
Guardrail Applications

- Detail B-1: Guardrail Applications
Guardrail Applications

- Detail B-1: Guardrail Applications

- Revised curb placement allowances:
  - Posted speed $\leq$ 50 MPH: Curb height $\leq$ 6"
  - Posted speed $>$ 50 MPH: Curb height $\leq$ 4"
  - Face of guardrail $\leq$ 6” behind face of curb (flush is preferred)
Guardrail Applications

- Detail B-1: Guardrail Applications

Type 1-2 Curb (when required)
Detail C-1, sheet 4

8” Offset Blocks, only
Guardrail Applications

- Detail B-1: Guardrail Applications

Guardrail height to ground at face of guardrail = 34” MAX.

Guardrail height at top of curb = 31” – 32”

This application ONLY for low speed conditions <45 MPH

Source: Midwest Roadside Safety Facility
Guardrail Applications

• Detail B-1, Sheet 4: Type 1-31 Guardrail with Omitted Post

Source: Midwest Roadside Safety Facility
Guardrail Applications

- Detail B-1, Sheet 4: Type 1-31
  Guardrail with Omitted Post

- Nested guardrail within limit of payment when curb is present
- Guardrail is not nested when there is no curb
Guardrail Applications

• Detail B-1, Sheet 4: Type 1-31 Guardrail with Omitted Post

**Location of omitted post within proximity of an end terminal is critical**
Guardrail Applications

- Detail B-1, Sheet 5: Type 1-31 on a Steep Slope

Source: Texas Transportation Institute
Grading for Guardrail End Treatments

- Detail B-2: Grading for Guardrail End Treatment, Type 1
- See Approved Products List for allowable systems

Grading for Guardrail End Treatments

• Detail B-2: Grading for Guardrail End Treatment, Type 2
  • See Approved Products List for allowable systems


Curb height 2” MAX

No guardrail reflectors within limits of end treatment

All dimensions from face of guardrail
Grading for Guardrail End Treatments

- Detail B-2: Grading for Guardrail End Treatment, Type 3
- See Approved Products List for allowable systems


Curb height 2” MAX

No guardrail reflectors within limits of end treatment

50’ MIN. Transition Grading
Guardrail over Culverts

- Detail B-3: Guardrail over Culverts, Type 1-31

**MASH Compliant System**

- Min. 12” offset from wingwall to back of post
- MAX 2” height curb, if curb is used
Guardrail over Culverts

• Detail B-3: Guardrail over Culverts, Type 2-31

- Min. 12" offset from wingwall to back of post
- Posts 2-7, Type 31 Long Wood Breakaway Posts
- MAX 2" height curb, if curb is used

MASH Compliant System

DelDOT

GUARDRAIL OVER CULVERTS, TYPE 2-31

RECOMMENDED: B-3 (DD90)

SHT.: 2 OF 3

APPROVED
Guardrail over Culverts

- Detail B-3: Guardrail over Culverts, Type 3-31

**MASH Compliant System**

- Min. 12" offset from wingwall to back of post
- Max. 2" height curb, if curb is used
Design Considerations

• Guardrail with Omitted Post
  • Use only where one post needs to be omitted
    • Curb openings
    • Span an underground utility conflict

• Guardrail over Culvert
  • Use to span pipe or box culverts
  • Unsupported span lengths between 12’-6” and 25’-0”
  • Max span length 25’-0”
End Anchorage

• Detail B-4: End Anchorage

New Detail

END ANCHORAGE, TYPE 31

NOTES:
1. ADDITIONAL BOLTS FOR ANCHOR PLATE SHALL BE ORDERED PRIOR TO E4443 FABRICATION.
   SEE STANDARD HARDWARE SHEET FOR HOLE DRILLING INFORMATION.
2. PLACE A 6" WIDE ENAXTED CONCRETE TO CAP MOUNTING Holes (SEE TYPE 31)
   MASH HARDWARE FOR INSTANCING THE PROPER DRILLING OF THE HOLE TO CAP MOUNTING Holes.

NO CURB!!!

MASH Compliant System
Guardrail Transitions

- Detail B-7: Transition from 1-31 to 1-27

Revised Detail (based on guidance from MwRSF)

Transition height and rail splice locations

![Diagram showing the transition detail](image-url)
**Approach Guardrail Transitions**

- **Detail B-8:** Guardrail-to-Barrier Connection, Type 1-31

No Changes

Consistent with early MASH testing
Approach Guardrail Transitions

- Detail B-8: Guardrail-to-Barrier Connection, Exit
- Crash testing not required for this system
- Standard Exit connection used where opposing traffic cannot strike end of concrete barrier.

No Changes
Formerly Detail B-5, sheet 6 of 6
Approach Guardrail Transitions

- **Detail B-10:**
  - Guardrail-to-Barrier Connection, Type 3-31

*Source: Midwest Roadside Safety Facility*
Approach Guardrail Transitions

• Detail B-10: Guardrail-to-Barrier Connection, Type 3-31
Approach Guardrail Transitions

• Design Considerations
  • Use Type 1-31 AGT for retrofit applications at existing F-shape barrier wall attachments
  • Use Type 3-31 AGT for new construction or where it is desirable to construct the concrete buttress
  • Consult MASH Committee and/or Bridge Design for retrofit situations where the Type 3-31 AGT may be beneficial
Concrete Buttress

• Detail B-11: Thrie-Beam Approach Guardrail Transition (AGT) to Concrete Buttress
  • Concrete buttress to be used with Type 3-31 Guardrail to Barrier Connection
  • Four options provided in details:
    • Vertical face (sheets 1-2)
    • Transition from vertical face to 36” F-Shape (sheets 3-4)
    • Transition from vertical face to 42” F-Shape (sheets 5-6)
    • Transition from vertical face to 42” Single Slope (sheets 7-8)
  • No MASH compliant options available for transitions to median barrier
    • Use applicable NCHRP 350 guardrail transitions for the time being
    • National research to be monitored
Barrier Hardware

- Detail B-13: Barrier Hardware (12 sheets)
  - All Sheets
    - Removed metric dimensions
    - Updated dimensions where applicable to be consistent with AASHTO Task Force 13 standardized dimensions
    - Updated sheet titles where appropriate
Barrier Hardware

• Detail B-13, Sheet 7: Short & Long Wood Breakaway Posts

Ground line adjusted to be consistent with MASH crash testing

Added labels for clarification
Barrier Hardware

• Detail B-13, Sheet 9: Guardrail Reflector

Added reflector color and placement requirements (based on DE MUTCD, Section 3F.04)

NOTES:
1. Guardrail reflectors on type 1 and 3 guardrail shall be installed in the center slot holes where posts are not located. Guardrail reflectors on type 2 guardrail are to be installed in the center slot holes located on the splice only. Guardrail reflectors on type 3 guardrail are to be located on the upper most center slot hole located on the splice only.
2. Guardrail reflectors shall not be installed within the limits of guardrail end terminals.
3. Guardrail reflector spacing shall be no less than 50 feet.
4. Guardrail reflectors placed on the right side of a two way two lane roadway shall display white retroreflective sheeting to both directions of travel.
5. Guardrail reflectors placed on the left side of a divided highway or ramp shall display yellow retroreflective sheeting to the approaching direction of travel and red retroreflective sheeting to the wrong direction of travel.
6. Guardrail reflectors placed on the right side of a divided highway or ramp shall display white retroreflective sheeting to the approaching direction of travel and red retroreflective sheeting to the wrong direction of travel.

NOTE:
1. Guardrail reflectors on type 1 and 3 guardrail shall be installed in the center slot holes where posts are not located. Guardrail reflectors on type 2 guardrail are to be installed in the center slot holes located on the splice only. Guardrail reflectors on type 3 guardrail are to be located on the upper most center slot hole located on the splice only.
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6. Guardrail reflectors placed on the right side of a divided highway or ramp shall display white retroreflective sheeting to the approaching direction of travel and red retroreflective sheeting to the wrong direction of travel.
Barrier Hardware

• Detail B-13, NEW sheets 11 & 12
Guardrail Applications, 27”

- Detail B-15: Guardrail Applications, 27”

*Only for use in maintenance of existing 27” high guardrail or minor retrofit applications*

*NCHRP 350 Compliant System*
Guardrail Applications, 27”

• Detail B-17: Guardrail End Treatment, Type 4-27

**Only for use at entrance locations on roadways with a posted speed limit ≤ 40 MPH**

**Use only where a standard end treatment will not fit**

**NCHRP 350 Compliant System**
Guardrail Applications, 27”

• Detail B-18: Curved Guardrail Section

Use only where absolutely necessary

Detail B-7 required to transition from 27” to 31” approaching curved guardrail section

NCHRP 350 Compliant System
Buried End Section

- Detail B-20: Buried End Section
• Detail B-20: Buried End Section
Standard Construction Details: Concrete Barrier
Concrete Barrier Details

• Update Summary
  • Overall MASH compliance review
    • Resulted in elimination of existing concrete barrier details
  • Added new concrete barrier details
  • Address common Department uses
  • Minimizes need for project specific details
  • Roadside Concrete Barrier
    • 36” F-Shape, Single Face (Test Level 4)
    • 42” F-Shape, Single Face (Test Level 4)
  • Median Concrete Barrier
    • 32” F-Shape (Test Level 3)
    • 36” F-Shape (Test Level 4)
    • 42” F-Shape (Test Level 4)
    • 42” Single Slope (Test Level 5)

• Designs based on available MASH crash testing and appropriate structural analyses
Concrete Roadside Barriers

- Detail B-25: 36” Concrete Roadside Barrier (F-Shape)
- Test Level 4
- 3 application options
- Cast-in-place or slip form
- Reinforcement shown on Sheet 2

**Typical Barrier Application - Type 1**

**723010: Concrete Roadside Barrier, 36” Type 1**

**Typical Barrier Application - Type 2**

**723011: Concrete Roadside Barrier, 36” Type 2**
Concrete Roadside Barriers

- Detail B-25: 36” Concrete Roadside Barrier (F-Shape)
- Test Level 4
- 3 application options
- Cast-in-place or slip form
- Reinforcement shown on Sheet 2
Concrete Roadside Barriers

- Detail B-26: 42” Concrete Roadside Barrier (F-Shape)
  - Test Level 4
  - 3 application options
  - Cast-in-place or slip form
  - Reinforcement shown on Sheet 2

**Typical Barrier Application - Type 1**
723012: Concrete Roadside Barrier, 42” Type 1

**Typical Barrier Application - Type 2**
723013: Concrete Roadside Barrier, 42” Type 2

**Typical Barrier Application - Type 3**

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DeIDOT

42” CONCRETE ROADSIDE BARRIER (F-SHAPE)

RECOMMENDED

STANDARD NO. B-26 (2023)

QHT. 1 OF 2

APPROVED
Concrete Roadside Barriers

- **Detail B-26: 42” Concrete Roadside Barrier (F-Shape)**
  - Test Level 4
  - 3 application options
  - Cast-in-place or slip form
  - Reinforcement shown on Sheet 2
Concrete Median Barriers

- Detail B-27: 32” Concrete Median Barrier (F-Shape)
  - Test Level 3
  - Cast-in-place or slip form
Concrete Median Barriers

- Detail B-28: 36” Concrete Median Barrier (F-Shape)
- Test Level 4
- Cast-in-place or slip form
Concrete Median Barriers

- Detail B-28: 42” Concrete Median Barrier (F-Shape)
  - Test Level 4
  - Cast-in-place or slip form

723015: Concrete Median Barrier, 42” F-Shape

**NOTE:**

1. **Concrete Slab Edges for Reinforcement Bars shall be 2” minimum, unless otherwise noted.**
2. **Barber Construction joints over existing pavement construction joints shall be restrained by expansion joint strip.**
3. **Barrer construction joints shall be at 42” increments.**
4. **All cast-in-place or slip form construction sections shall be restrained by expansion joint strip.**
5. **All expansion joints shall be placed within the barrier at structural and other expansion joints in existing concrete.**
6. **The expansion joint strip shall be placed in the barrier at structural and other expansion joints in existing concrete.**
7. **The expansion joint strip shall be placed in the barrier at structural and other expansion joints in existing concrete.**
8. **The expansion joint strip shall be placed in the barrier at structural and other expansion joints in existing concrete.**
9. **The expansion joint strip shall be placed in the barrier at structural and other expansion joints in existing concrete.**
Concrete Median Barriers

• Detail B-28: 42” Concrete Median Barrier (Single Slope)
  • Test Level 5
  • Cast-in-place or slip form
  • Footing requires reinforcement
  • Only for Interstates, freeways and expressways
Topics Covered

• Morning Session
  • Standard Specifications Update – Guardrail and Barrier

• Afternoon Session
  • Crash Testing and MASH
  • DelDOT’s MASH Compliance
  • Roadside Design Considerations
  • Standard Construction Details – Guardrail
  • Standard Construction Details – Concrete Barrier
Thank you!

Adam Weiser, PE, PTOE, RSP
Whitman, Requardt & Associates, LLP
aweiser@wrallp.com
(302) 485-0863 (direct line)