

**Delaware Department of Transportation
Design Guidance Memorandum**

Memorandum Number: 1-31

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|-----------------|------------------|---------------------|
| 1. Road Design | 2. Bridge Design | 3. Utilities Design |
| 4. Right of Way | 5. Other | |

Title: <u>MASH Compliant 31" Curved Guardrail</u>	Effective Date: 08/12/2026
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I. Purpose

To provide design guidance and a summary of associated considerations when prescribing a MASH compliant 31" curved guardrail roadside safety hardware application during the design phase.

II. Background

In 2016, the American Association of State Highway and Transportation Officials (AASHTO) published the second edition of the *Manual for Assessing Safety Hardware* (MASH) as well as agreed to a joint implementation agreement with the Federal Highway Administration (FHWA) which outlined implementation dates for MASH 2016 compliant roadside safety hardware for work performed on the National Highway System (NHS). The implementation agreement required that all "cable barriers, cable barrier terminals, and crash cushions" be MASH 2016 compliant for contracts let after December 31, 2018.

Transportation agencies have continued to prescribe non-MASH compliant hardware after the MASH implementation date for certain applications due to a lack of effective and MASH compliant treatments. There has been a nationwide deficiency of MASH compliant hardware meeting the needs of a curved guardrail roadside safety hardware system designed to provide a gradual and controlled containment of an impacting vehicle. NCHRP Report 1013 *Roadside Barrier Designs near Bridge Rail Ends with Restricted Rights-of-Way: A Guide* was released in 2022 and serves to document the development of a MASH compliant 31" curved guardrail roadside safety hardware system.

III. Applicability

The curved guardrail system described within this Design Guidance Memorandum may be prescribed on new construction applications when warranted and as site conditions permit on DelDOT Capital projects (these include highway projects, bridge projects, TAP projects, ADA/PAR projects, Pave & Rehab projects, Maintenance projects, and Traffic projects). The MASH compliant 31" curved guardrail should only be installed where other acceptable roadside safety hardware applications cannot be utilized because of the future maintenance considerations associated with the application.

IV. Design Guidance

As with all roadside safety hardware, proper design and construction is paramount to ensure a system's effective and intended in-field performance. It is encouraged that each component of the MASH compliant 31" curved guardrail be laid out to scale during the design phase to verify its suitability to the unique features of a given site. The design guidance provided herein has been further divided into several unique location specific considerations:

A. Test Level Performance and Associated Grading Requirements

Roadside safety hardware is typically categorized by its “test level”. This “test level” is based on standardized crash testing criteria with which the system was tested, evaluated, and ultimately assigned. It indicates to a user the conditions which the hardware is expected to adequately perform. The MASH compliant 31” curved guardrail application could either be considered as a test level 2 (TL-2) or TL-3 MASH compliant device depending upon the terrain grading behind the slope break. For both test levels, the system requires a grading area consisting of a 2’-0” minimum width with a 10:1 maximum slope measured from the back of the guardrail post to the beginning of the slope break as shown in Figure 1.

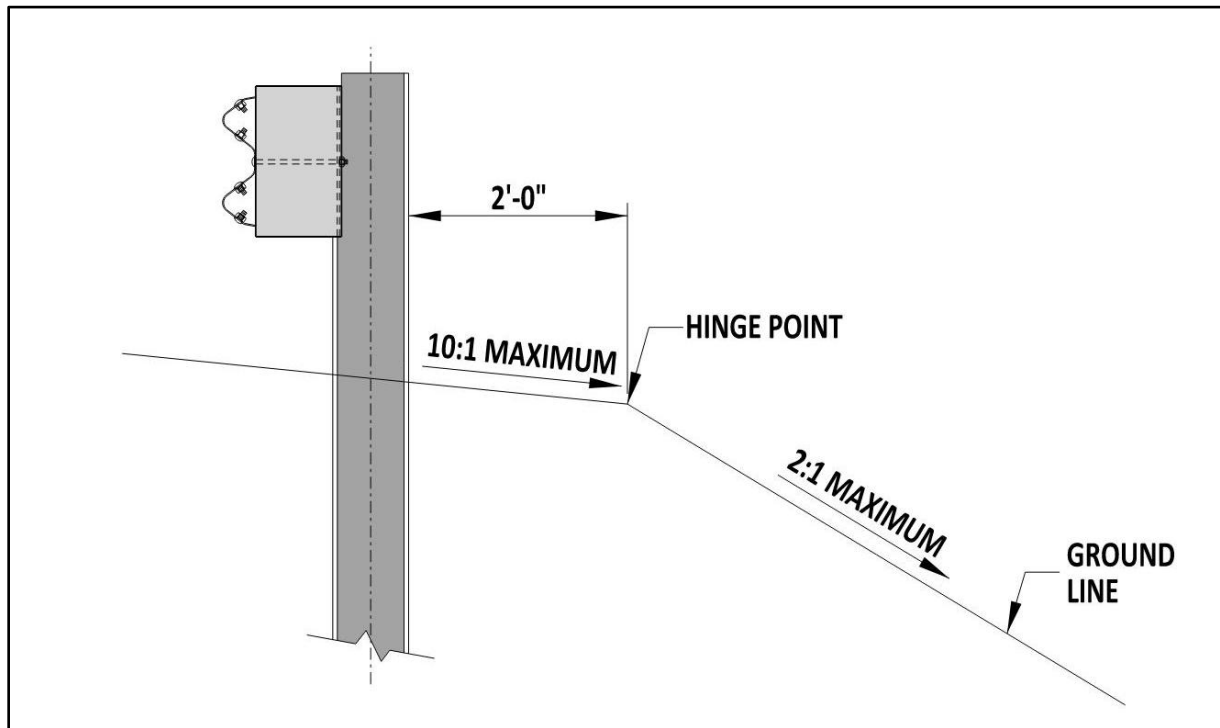


Figure 1

Table 1 below provides the TL that the curved guardrail system can be expected to perform depending upon the slope provided behind the 2’-0” grading area.

Table 1

Grading	Test Level Application
6:1 or flatter	TL-3
Steeper than 6:1 to 2:1	TL-2 (Tested at 50mph)
Steeper than 2:1	Not evaluated and therefore not recommended

B. Adjacent Roadside Safety Hardware Connections

Curved guardrail systems are required to connect to adjacent roadside safety hardware applications to maintain tension throughout the system. Connecting to adjacent roadside safety hardware also provides continuity and protection from adjacent roadside obstacles. The MASH compliant 31” curved guardrail application may be connected to various adjacent roadside safety hardware systems which provides significant site flexibility. Listed below are the adjacent roadside safety hardware applications which may be attached to the MASH compliant curved guardrail system:

- **Rigid Barrier Attachment** – The MASH compliant application may attach directly to an adjacent bridge rail or other rigid barrier application through use of a stiffness transition. NCHRP Report 1013 developed both an 18’-9” Thrie-beam transition and an 18’-9” W-beam transition which may be used for this purpose. The stiffness transition cannot be

shortened but can be lengthened to meet field conditions. In these cases, consideration must be given to ensure that no new snag point is created.

- **Adjacent W-Beam Guardrail** – The historically most common adjacent roadside hardware connection for a curved guardrail system is to an adjacent W-beam system. The MASH compliant application allows for the main road or for the sideroad to tie directly into an adjacent W-beam system at the end of the 10-gauge W-beam section.
- **Crashworthy Guardrail End Treatment** – The application may tie the sideroad or main road into a crashworthy guardrail end treatment when additional shielding is required. In these installations, a full 12'-6" section of 12-gauge W-beam rail must be placed between the last section of 10-gauge W-beam rail and the crashworthy end treatment.
- **Sideroad End Anchorage** – A non-crashworthy sideroad end anchorage may be placed at the end of the 10-gauge W-beam section to tension the system.

C. Available Radii Applications

The MASH compliant application was crash tested with an 8'-0" radius, however, the application is also acceptable for use with a 16'-0" and 24'-0" radius. Radius sizes outside of these have not been evaluated and are therefore not recommended. Usage of the 8'-0" radius application should be prioritized due to the physical crash testing data available to confirm its effectiveness and limitations.

D. Clear Area Behind Curved Guardrail Application

Curved guardrail systems are designed to provide a controlled release that contains an impacting vehicle and slowly brings it to rest. Therefore, to achieve intended results, curved guardrail applications require an area clear of fixed objects such as non-breakaway signs, luminaire, traffic signal supports, or trees behind the barrier. Additional information regarding features that constitute a fixed object is included in the *AASHTO Roadside Design Guide*. Crash testing and finite element analysis of the application resulted in recommendations to provide a clear area that extends 30'-0" laterally along the sideroad and 15'-0" laterally along the main road as shown in Figure 2. The clear area is recommended to be as large as practical to account for variations between the analyzed applications and for various in-service conditions that the application will encounter like varying radii size, adjacent roadside safety hardware connections, approach slopes, backslope grading, and curb condition.

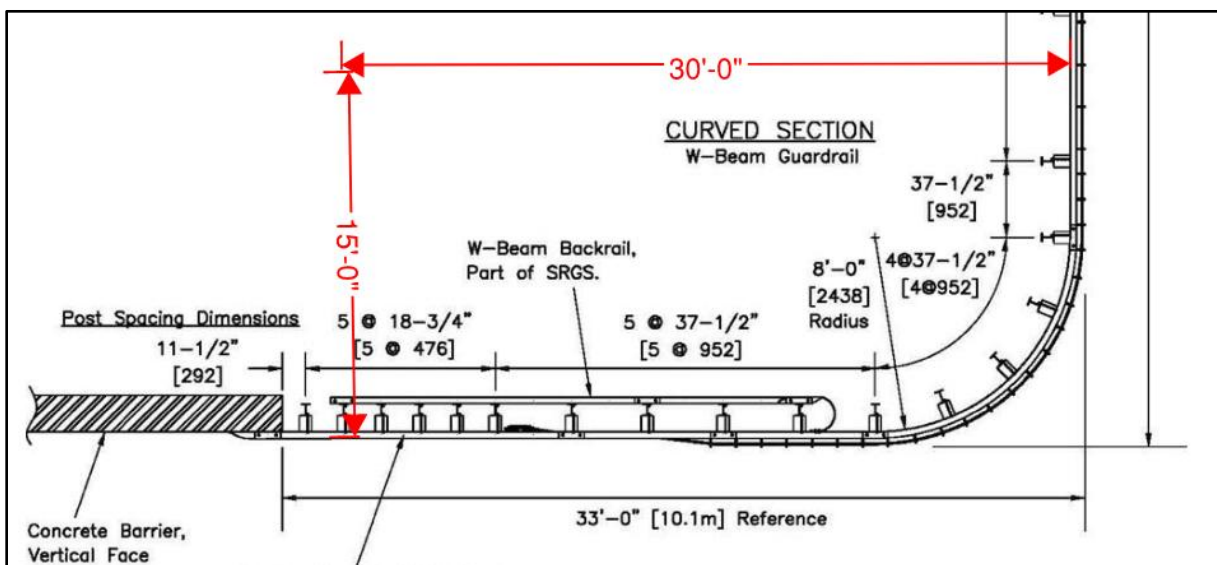


Figure 2

E. Side Road and Main Road Angle

The angle in which the side road and main road intersect will rarely be at the 90-degree angle that was crash tested. However, no research has been performed on how different intersection angles will affect the system at this point. Therefore, it is recommended that all locations in which the application is prescribed use the 90-degree intersection angle that was crash tested and then offset from the adjacent road as required. Modifications to this configuration can be considered on a case-by-case basis at locations which are highly constrained.

F. Usage with Curb

When a vehicle strikes a curb, the front bumper moves upwards which affects how the vehicle impacts adjacent roadside safety hardware. This curved guardrail application was not tested with curb and its use with curb is therefore discouraged. However, if curb is required at the location, a laydown curb in accordance with C-1 sheet 4 of the Standard Construction Details can be provided but only along the tangent portions of the application outside of the stiffness transition.

G. Approach Slopes

Steep approach slopes will also affect how an impacting vehicle will interact with a roadside safety hardware application. Curved guardrail systems are designed and evaluated as crash cushion devices which means they are intended to absorb a 90-degree collision. Steep approach slopes with this impact angle will greatly exacerbate the effect of an approach slope; therefore, approach slopes perpendicular to the hardware should be made as flat as practical and limited to 10:1 maximum.

H. Hardware

Though typically viewed more as an aspect of construction, the hardware that is used to assemble the curved guardrail system is also an important design level consideration. The most notable feature of the application is its use of 10-gauge W-beam as most common roadside safety hardware installations use 12-gauge guardrail. Special attention to this feature should be made during installation to ensure proper in-field performance. 8" blocks must be used within the transition section to create a connection between the W-beam end section in the backrail and the traffic side rail. The blocks outside of the transition section may be either 8" or 12" and may be either wood or composite material.. The system uses standard W6x9, 6'-0" long posts.

I. Delineation

Installed applications should be properly delineated to reduce nuisance strikes. No ground mounted delineation should be placed within the clear area described in Section D. Instead, a durable composite delineator that is mounted to the back of the post should be utilized. Coordination should occur with the Maintenance district that the application will be installed to verify the delineator type and placement.

V. Justification

To ensure consistent Department usage and subsequent design of MASH compliant 31" curved guardrail applications throughout the state given the application's complexities and site-specific considerations.

Prepared by: Engineering Support

Date: 3/3/2026



Recommended by: Chief of Environmental & Administrative Support

07/28/2026

Date



Attest to Form and Process: Support Engineer

07/29/2026

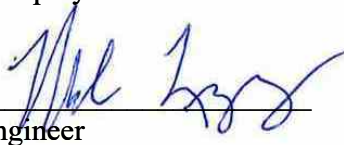
Date



Recommended by: Deputy/Division Director

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Date



Approved: Chief Engineer

08/12/2026

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