



**Engineering Support Services and Recommendations for Roadside Safety Issues or Problems  
for Member States**

Pooled Fund Program TPF-5(501)

Task Order T1969-C5, TTI Project 623631

**Engineering Opinion No. 623631-02**

**ASSESSMENT OF FENCE MOUNTED ON VARIOUS CAST-IN-PLACE CONCRETE  
BARRIERS FOR MASH TEST LEVEL 3**

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## **DISCLAIMER**

Opinions and conclusions provided in this report are based on review of information currently known to the author(s). If new relevant research or crash testing information becomes available, opinions or conclusions presented in this report should be re-evaluated considering the new information. Author(s) bears no responsibility to provide a revised report or opinion based on the new information. Users of this report are expected to stay informed of future research and periodically review their practices based on more current information. Opinions and conclusions provided in this report are for the specific safety hardware and/or application(s) described herein. They are not intended for other similar hardware and/or application(s).

## Objectives

This report provides an assessment of Pennsylvania Department of Transportation's (PennDOT) barrier mounted fence (BMF) designs to determine their compliance with American Association of State Highway Transportation Officials' (AASHTO) Manual for Assessing Safety Hardware (MASH) for Test Level 3 (TL-3).

## System Overview and Scope Limitations

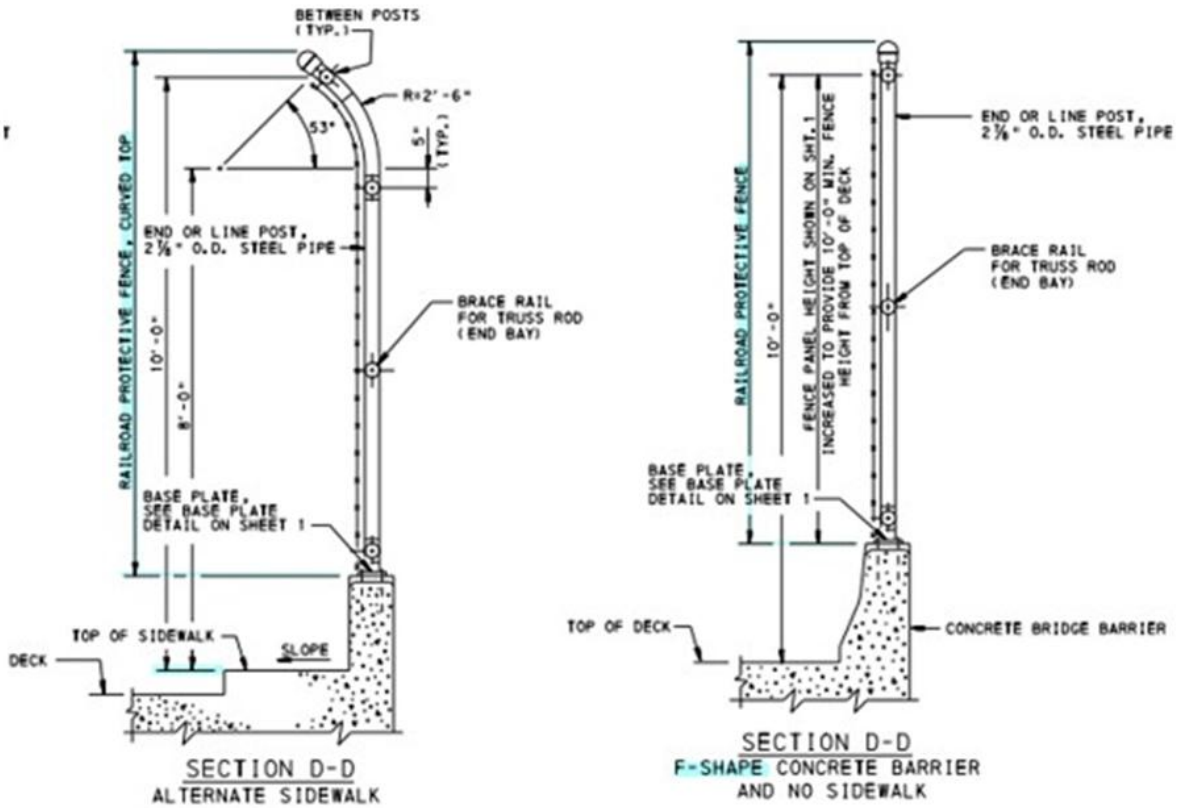
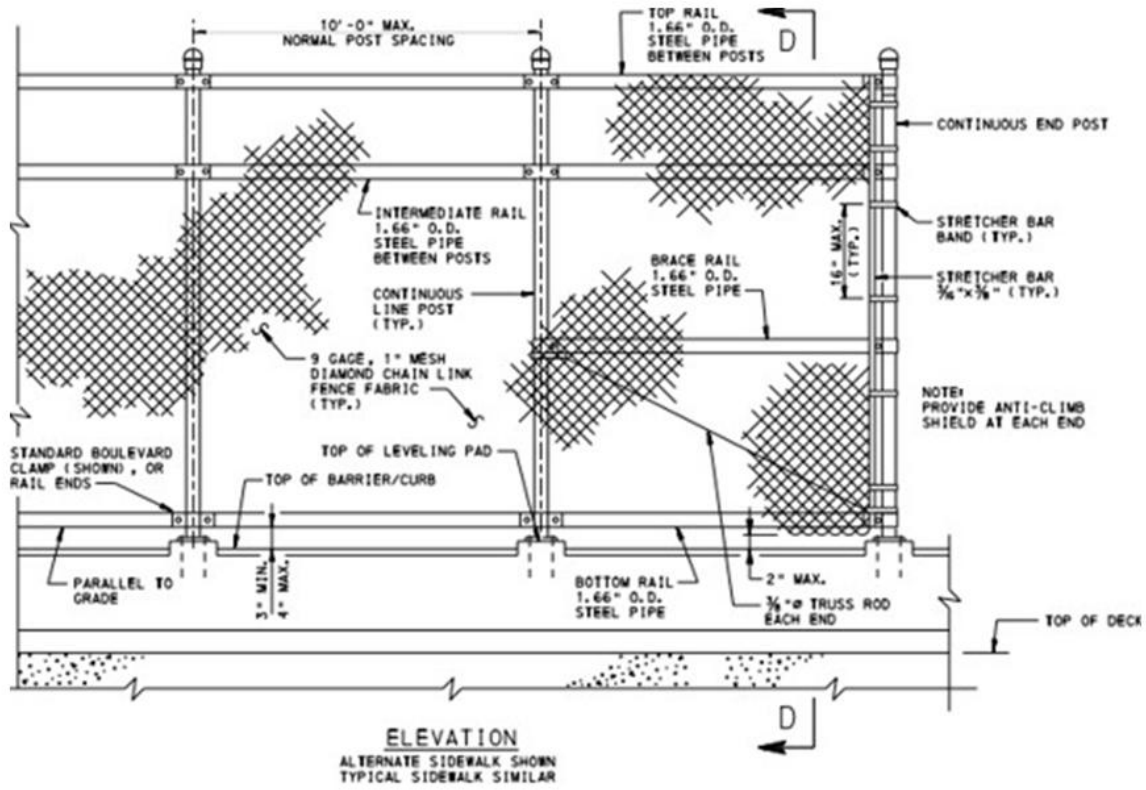
The PennDOT BMF designs are included in PennDOT standard BC-701M. Key details of these barriers are shown in Figure 1. The system features a cast-in-place concrete barrier or bridge rail mounted with a chain-link fence system, where fence posts with baseplates are bolted to the top of the barrier using threaded anchor rods. The fence system has two main variations: one comprises an entirely vertical fence with a minimum height of 10 feet above the concrete deck or sidewalk, and the other consists of a 10-foot vertical fence with the top 2 feet curved toward the traffic side of the barrier. The concrete barrier is available in several height variations, ranging from 32 inches to 45 inches, and two profile types: F-shape and vertical wall. In some configurations, the barrier is constructed above a 5-foot wide and up to 8-inch tall sidewalk.

The following list provides the five specific BMF variations included in the scope of this assessment:

- 42-inch tall F-shape without sidewalk – assessed for TL-3
- 45-inch tall F-shape without sidewalk – assessed for TL-3
- 32-inch tall F-shape without sidewalk – assessed for TL-3
- 42-inch tall vertical wall without sidewalk – assessed for TL-3
- 42-inch tall vertical wall with a 5-foot wide and up to 8-inch tall sidewalk – assessed for Test Level 2 (TL-2)

The evaluation of MASH compliance for these BMF systems was based on previously conducted crash testing. No new testing was performed as part of this assessment.

The steel reinforcement of the concrete barrier and deck is similar to that used in other previously tested designs, but the structural adequacy of the barrier and deck to withstand MASH impact loading under TL-3 conditions was not included within the scope of this assessment.



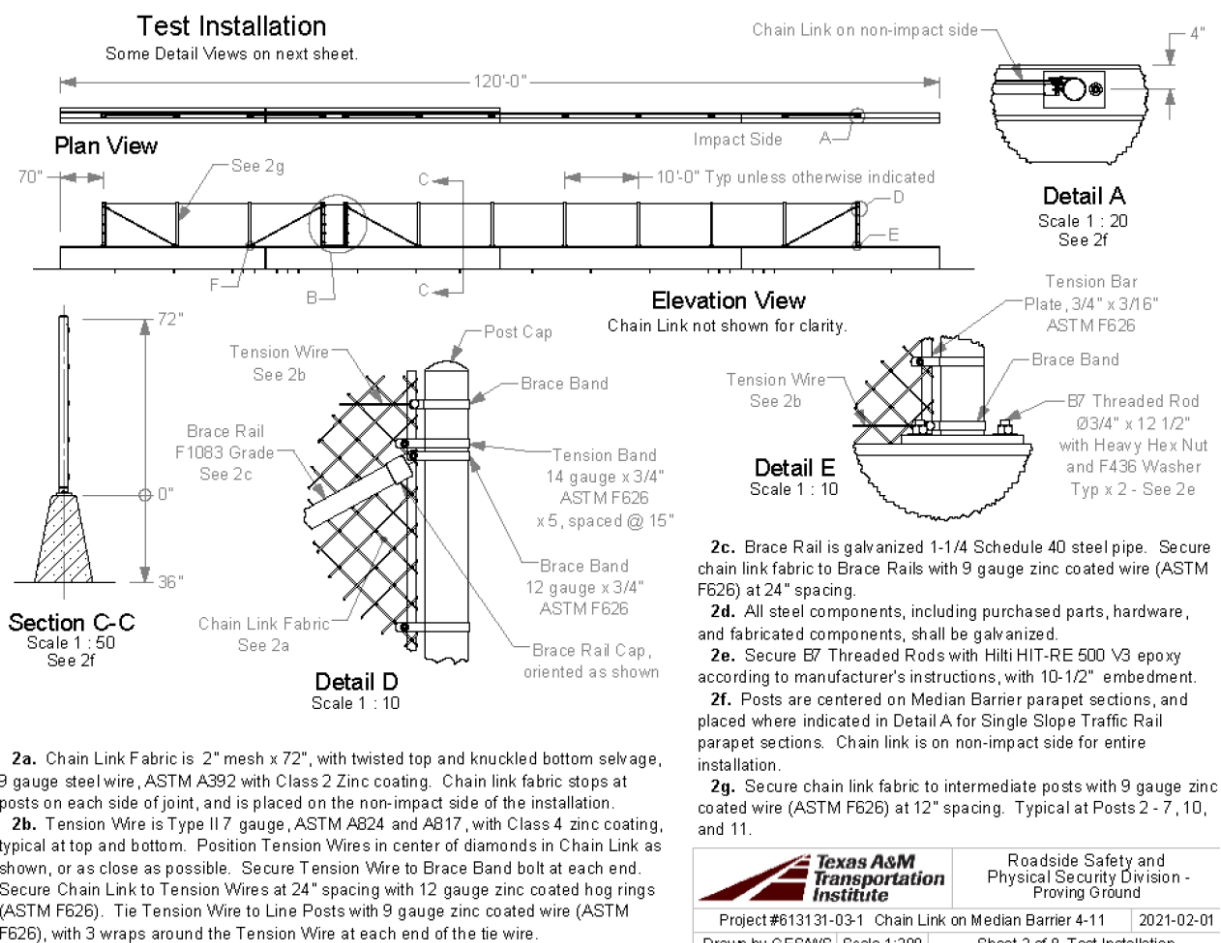
**BARRIER MOUNTED DETAILS**

Figure 1. Key details of PennDOT BMF design (PennDOT standard BC-701M).

## Prior MASH Crash Testing

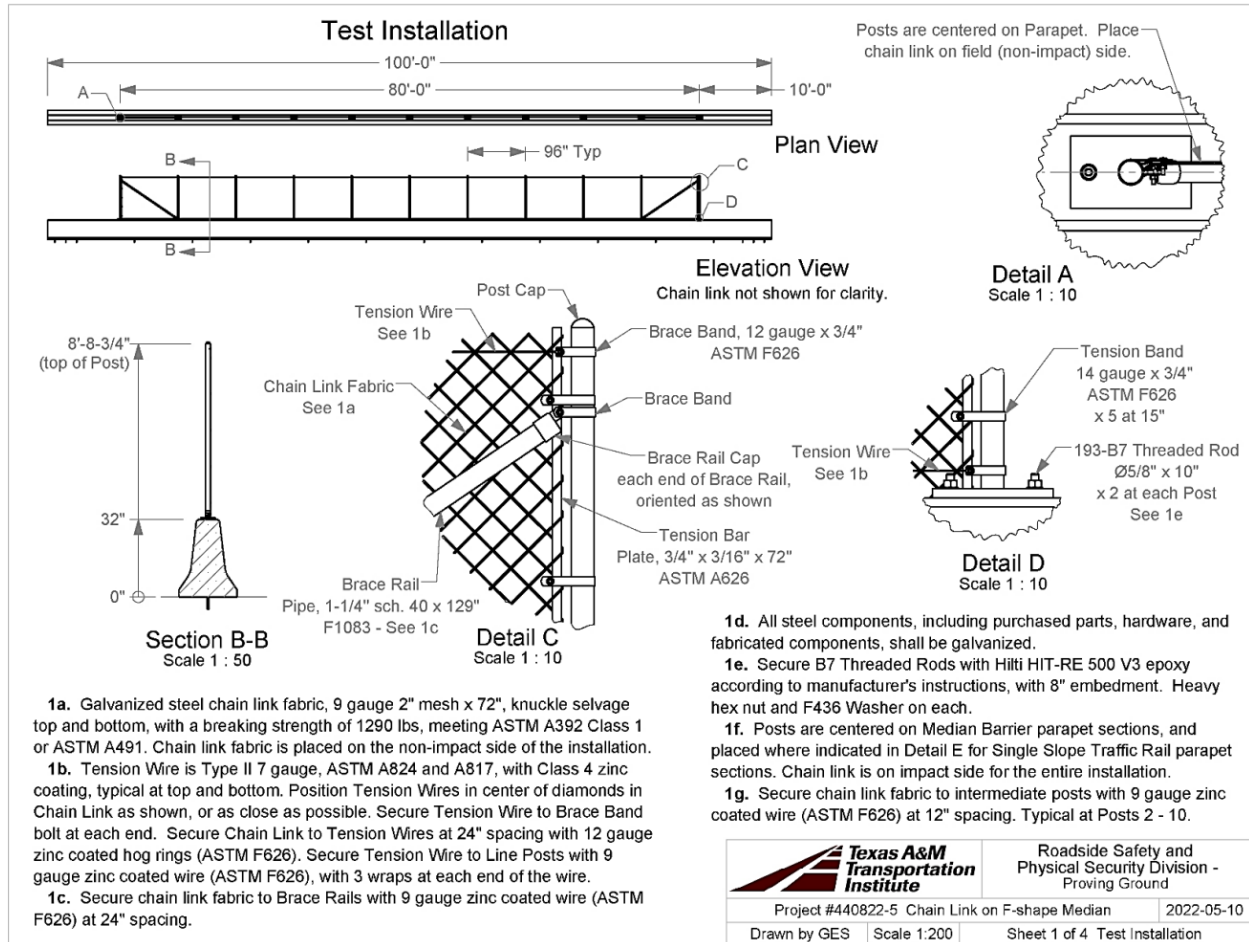
In 2022, TTI conducted MASH Test 4-11 on a 36-inch tall single slope barrier with a 6-foot tall, 2-inch mesh chain-link fence mounted on top (Test 613131-03-1).<sup>i</sup> MASH Test 4-11 is an equivalent test designation to Test 3-11. The single slope concrete barrier was a cast-in-place rigid barrier with a 10.8-degree slope on the impact face (see Figure 2). The chain-link fence was supported by fence posts spaced 10 feet apart, which were attached to the top of the barrier using baseplates bolted to anchored threaded rods cast into the barrier. Figure 2 presents key details of the crash-tested system.

This single slope BMF system tested by TTI successfully passed the MASH Test 3-11/4-11 evaluation criteria. Test 4-10 (the equivalent of 3-10) was not performed, as the small car test vehicle is not expected to have significant interaction with the fence system installed on a 36-inch tall concrete barrier.



**Figure 2. Key Details of 36-inch-tall Single Slope BMF in TTI Test 613131-03-1.**

In 2023, TTI performed MASH Test 3-11 on a 32-inch tall cast-in-place F-shape concrete barrier with an approximately 6-foot tall, 2-inch mesh chain-link fence mounted on top (Test 440822-01-5).<sup>ii</sup> In this design, the fence posts were spaced 8 feet apart (see Figure 3). The F-shape BMF system successfully passed MASH Test 3-11. Test 3-10 was not conducted, as it was considered non-critical for the reasons previously stated.



**Figure 3. Key Details of 32-inch-tall F-shape BMF in TTI Test 440822-01-5.**

Although a MASH Test 3-10 has not been performed with a BMF system, a previously conducted test (690900-ITG1-3) has adequately assessed vehicle stability and occupant risk for an 1100C small car impacting an F-shape concrete barrier.<sup>iii</sup> Test 690900-ITG1-3 was a MASH Test 3-10 performed by TTI to evaluate the performance of the rigid F-shape concrete barrier. In this test, the small car was successfully contained and redirected in a stable manner, and all occupant risk factors remained within MASH limits. The results demonstrate that the F-shape concrete barrier provides acceptable performance in terms of vehicle stability and occupant risk under MASH Test 3-10 conditions.

## MASH Compliance Assessment of F-shape BMF

Test 3-11 of the 32-inch tall F-shape BMF system (TTI Test 440822-01-5), together with the previously established acceptable performance in Test 3-10 of the F-shape profile (Test 690900 ITG1 3), supports the conclusion that PennDOT's 32-inch tall F-shape BMF design is MASH TL-3 compliant. Although the PennDOT system uses a taller fence, which may be entirely vertical or curved toward the impact side near the top, this increased height is not expected to result in greater interaction with the test vehicle compared to the TTI test, which featured approximately 6-foot-tall, entirely vertical fence posts.

For taller barrier heights of 42 inches and 45 inches, the interaction between the vehicle and the fence system is expected to decrease compared to the 32-inch barrier. The increased height of the concrete

barrier raises both the fence posts and the chain link mesh, reducing the interaction between the impacting vehicle and the fence system. As a result, these taller barrier configurations are also expected to perform acceptably.

Based on previous testing and the discussion above, the following F-shape BMF systems are assessed to perform acceptably for MASH TL-3:

- 32-inch tall F-shape BMF without sidewalk
- 42-inch tall F-shape BMF without sidewalk
- 45-inch tall F-shape BMF without sidewalk

## **MASH Compliance Assessment of Vertical Wall BMF**

### **42-inch Vertical Wall for TL-3**

A 32-inch tall vertical wall concrete barrier without a fence has been tested under MASH Test 3-11 evaluation criteria.<sup>iv</sup> In general, taller barrier heights are considered acceptable if a shorter barrier has demonstrated satisfactory performance. For BMF systems, however, there are additional considerations regarding the potential interaction between the pickup truck and the fence system due to differences in the profiles of the tested and assessed barriers.

Since a vertical wall BMF has not been directly tested, its performance can only be inferred from the results of the single slope or F-shape BMF tests referenced previously. While the 42-inch height of the vertical wall BMF provides additional barrier protection compared to the 36-inch tall BMF tested by TTI, the vertical profile also allows the vehicle to be closer to the fence system. Increased barrier height is generally expected to reduce the degree of interaction between the vehicle and the fence; however, the proximity to the fence posts due to the vertical profile could potentially worsen vehicle-to-fence interaction. Because of these conflicting factors, it is difficult to reliably assess the level of interaction between the vehicle and the fence system.

For this reason, it is recommended that the MASH TL-3 performance of the following BMF system be evaluated through new crash testing and/or simulation analysis:

- 42-inch tall vertical wall BMF without sidewalk

If only simulation analysis is used, it is recommended that the simulation models be first validated using data from existing crash tests, and then applied to simulate the effects of barrier profile changes to assess the MASH compliance of the vertical wall BMF systems.

### **42-inch Vertical Wall with Sidewalk for TL-2**

In 2016, Whitesel et al. evaluated a vertical wall bridge rail with an 8-foot wide sidewalk, known as the California Department of Transportation (Caltrans) Type 713SW bridge rail, in accordance with MASH TL-2 evaluation criteria.<sup>v</sup> The bridge rail consisted of a 32-inch tall concrete vertical wall cast on top of an 8-inch tall and approximately 8-foot wide sidewalk. A 16-inch tall tubular rail was attached to the top of the vertical wall, featuring two longitudinal tube rails and vertical pipe posts spaced 9 feet 1.5 inches apart.

MASH Test 3-11 was conducted on this system, and it passed the relevant evaluation criteria. MASH Test 3-10 was also performed but did not pass due to exceeding the MASH threshold for occupant ride-down acceleration. Subsequently, MASH Test 2-10 was conducted and the system passed the MASH criteria (Test No. 110MASH2C14-01). As a result, the bridge rail was determined to be MASH TL-2 compliant.

The PennDOT 42-inch tall vertical wall BMF system with a sidewalk is taller than the Caltrans 32-inch tall Type 713SW design. Additionally, the PennDOT sidewalk is 5 feet wide compared to the 8-foot wide sidewalk used in Caltrans testing. Review of Caltrans Test 110MASH2C14-01 shows that the leading front corner of the small car was at approximately the same height at the 5-foot width of the sidewalk as it was at the 8-foot width at the time of impact with the vertical wall bridge rail. Therefore, it can be concluded that PennDOT's 42-inch tall vertical wall BMF on a 5-foot wide and 8-inch tall sidewalk will not result in diminished crash performance regarding the interaction of the small car with the BMF system.

In some design variations, PennDOT uses sidewalks that are less than 8 inches tall. The reduced height of the sidewalk is not expected to worsen vehicle interaction with the BMF system, as a shorter sidewalk height is likely to result in less upward climb of the vehicle. Therefore, sidewalks less than 8 inches high are also expected to perform acceptably for MASH TL-2.

Based on the previous testing and the discussion above, the following vertical wall BMF system is assessed to perform acceptably for MASH TL-2:

- 42-inch tall vertical wall BMF with a 5-foot wide and up to 8-inch tall sidewalk

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<sup>i</sup> Dobrovolny, S. C., R. P. Bligh, J. C. Kovar, W. L. Menges, W. Schroeder, B. L. Griffith, and D. L. Kuhn. MASH TL-4 Evaluation of Concrete Median Barrier with Fence Mounted on Top. Test Report No. 613131-03-1&2, Texas A&M Transportation Institute, College Station, Texas. 2022.

<sup>ii</sup> Dobrovolny, S. C., R. P. Bligh, M. Kiani, A. Zalani, W. J. L. Schroeder, and D. L. Kuhn. Evaluation of Attachments to Concrete Barrier Systems to Deter Pedestrians – Volume 2: Crash Report. Report No. 0-7082-R1-Vol2, Texas A&M Transportation Institute, College Station, Texas. 2023.

<sup>iii</sup> FHWA Eligibility Letter HSST-1/B-39, F-shape Barrier on Cantilevered Bridge Deck with Noise Wall Panels, May 27, 2020.

<sup>iv</sup> Bligh, R. P., J. L. Briaud, K. M. Kim, and A. Abu-Odeh. Design of Roadside Barrier Systems Placed on MSE Retaining Walls. National Cooperative Highway Research Program Report 663, Transportation Research Board, National Research Council, Washington, D.C., 2010.

<sup>v</sup> Whitesel, D., J. Jewell, and R. Meline. Compliance Crash Testing of the Type 732SW Bridge Rail. Test Report No. FHWA/CA15-2181, California Department of Transportation, Sacramento, California. 2016.