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# Engineering Opinion No. 202309A

# REDUCED-LENGTH ANCHORING PINS FOR F-SHAPE PCB PINNED ON ASPHALT

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## Introduction and Objective

This document provides assessment of a 32-inch tall F-shape portable concrete barrier (PCB) system anchored on asphalt pavement with shortened inclined anchor pins. In the previously crash tested design of this barrier, the anchor pins were 48 inches long (*1*). There is a desire to use shorter 36 inches long anchor pins due to occasional field restrictions that prevent the use of the 48-inch anchor pins. This report presents an assessment of the design with the 36-inch anchor pins with regards to its compliance with American Association of State Highway Transportation Officials' (AASHTO) Manual for Assessing Safety Hardware (MASH) for Test Level 3 (TL-3). This assessment was made based on past testing and additional finite element (FE) simulation analysis.

## System Overview and Scope

The previously crash tested anchored PCB system was comprised of 12.5 ft long and 32 inches tall barrier segments with the F-shape profile. The PCB segments were anchored by passing 48 inches long steel pins through inclined holes cast in the toe of the barrier and driving down into minimum 4-inch thick asphalt pavement. Three anchor pins per segment were used to restrain the barrier. The barrier was placed at a 12-inch offset from the edge of a 1V:1.5H slope. This system passed MASH Test 3-11 and Figure 1 presents the key details of the system (*1*).

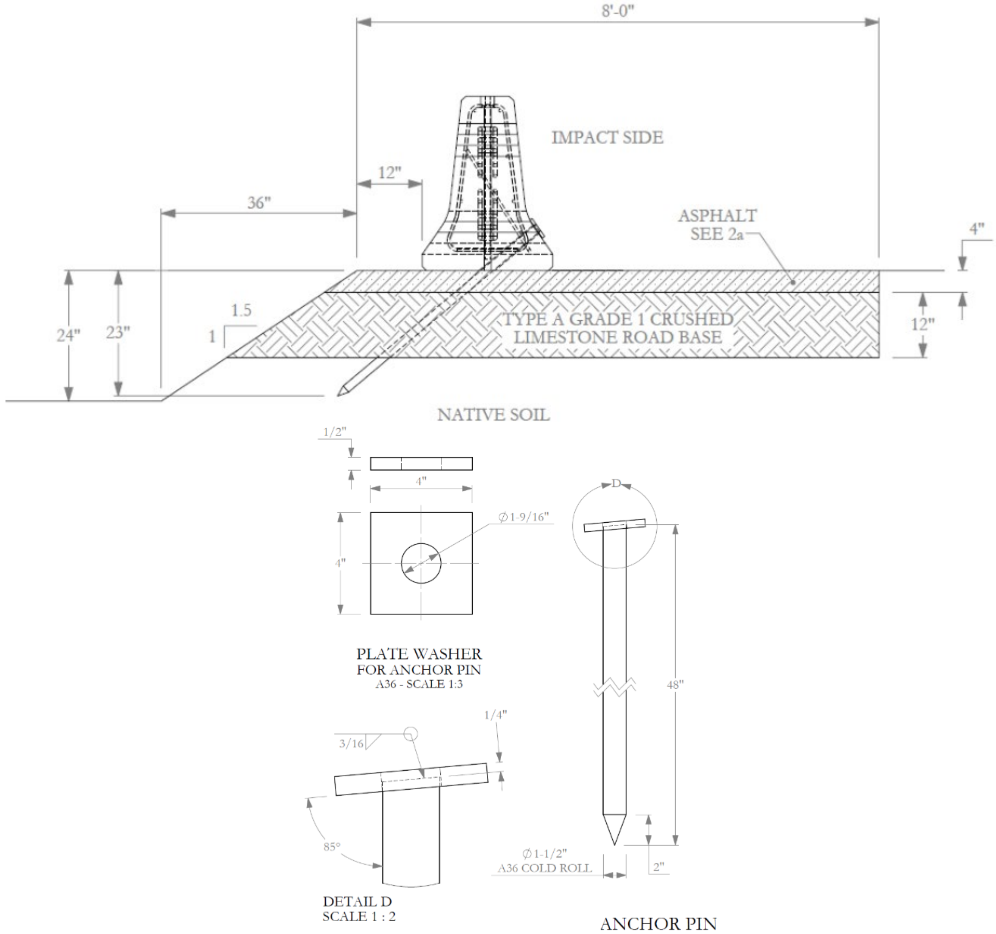


Figure 1. Previously crash tested anchored PCB system with 48-inch long anchor pins (*1*).

MASH TL-3 compliance assessment of the above-mentioned anchored PCB system with the 36-inch anchor pins instead of the 48-inch anchor pins is presented next.

## MASH Compliance Assessment

The research team assessed the MASH compliance of the anchored barrier with the shorter 36-inch anchor pins by reviewing the past crash testing results and by performing an impact simulation using the previously existing FE model of the barrier system.

The FE model was previously developed and used as a predictive design tool to arrive at the final design of the anchored barrier system with the 48-inch anchor pins (*1*). To evaluate the performance of the barrier system with the 36-inch anchor pins, the research team reduced the pin length in the previously used model and performed an impact simulation with MASH Test 3-11 impact conditions, i.e., a 5,000-lb pickup truck impacting the barrier at an impact speed and angle of 62 mi/h and 25 degrees, respectively. It should be noted that the scope of this assessment did not include making extensive changes to the model to improve model validation with the crash test. Differences between the results of the simulations of the 48-inch and the 36-inch anchor pins, along with the crash testing results were evaluated in a comparative manner for the purposes of this assessment.

In the simulation with the 36-inch anchor pins, the pickup truck was contained and redirected. Figure 2 shows the maximum vertical climb of the vehicle as it redirected in the test and the two simulations. The vehicle had slightly higher vertical climb in both simulations compared to the crash test, indicating the simulation models were more conservative in this aspect. Vehicle climb was nearly the same in the simulation with the 48-inch and 36-inch anchor pins, indicating that vehicle climb is not significantly affected by the reduction in the pin length.

| Test with 48-inch anchor pins | Simulation with 48-inch pins | Simulation with 36-inch pins |
|---|---|---|

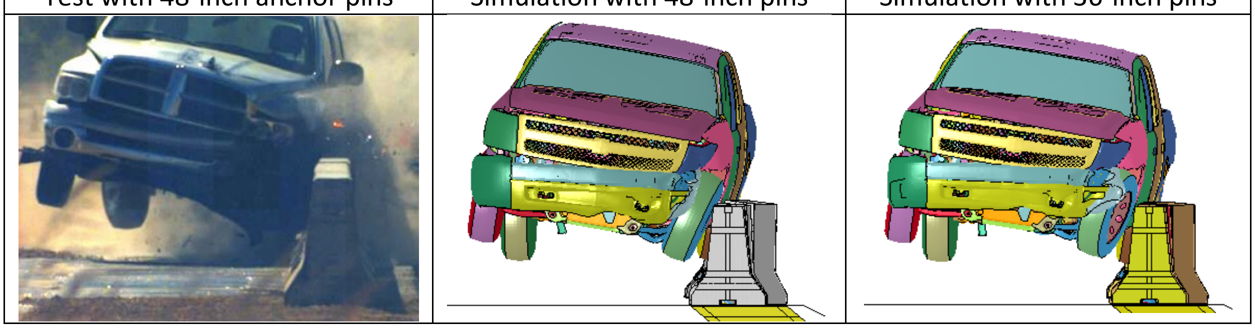

**Figure 2. Comparison of the maximum vertical climb of the vehicle.**

Figure 3 shows comparison of the barrier deflection at the joint of impact in the test and the two simulations. The concrete around the anchor pins was damaged at the joint of impact in the test whereas the simulation model did not incorporate concrete material damage. This resulted in higher maximum dynamic barrier deflection in the test (17.8 inches) compared to the simulations with the 48-inch and 36-inch pins (13.5 inches and 13 inches, respectively).

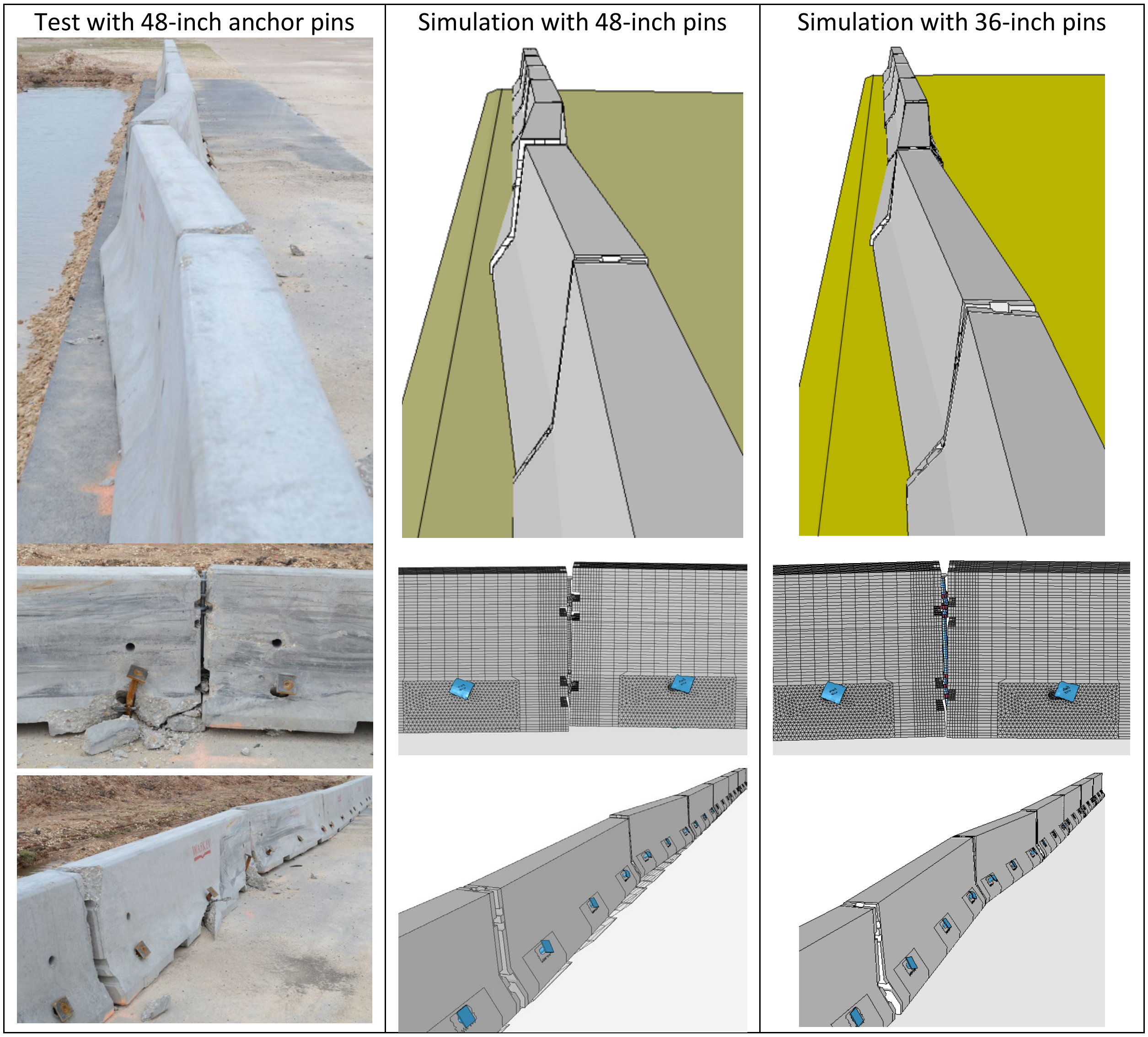


**Figure 3. Comparison of barrier deflection after vehicle impact.**

While the simulation model of the barrier segments lacked concrete damage and was not able to capture the full extent of the barrier deflection, it can be observed from Figure 3 that the barrier deflection was nearly the same for simulations with the 48-inch and the 36-inch anchor pins. This implies that the reduced 36-inch pin depth is not likely to increase the barrier deflection significantly more than what was observed in the test with the 48-inch anchor pins.

The research team also compared the overall anchor pin pullout in the test and the two simulations. It can be observed from Figure 3 that the pin pullouts in the test and the simulation were not significantly different. The length of the undeformed pin that remains below grade after the impact can be assumed to serve as a reserve anchorage capacity for the barrier. Figure 4 shows a comparison of the deformed state of the anchor pins in the impact region for the simulations with the 48-inch and 36-inch anchor pins. For clarity, only the end and the middle anchor pins of adjacent barrier segments at the joint of impact are shown in Figure 4. The 48-inch anchor pins had plenty of undeformed length below grade, indicating that the tested design is more conservative, with reserve capacity in the design to allow shorter anchor pins. Results of the simulation showed that the 36-inch anchor pins also had sufficient undeformed anchor pin length below grade, which provides an extra factor of safety in the anchorage design (Figure 4).


48-inch Anchor Pins 36-inch Anchor Pins

**Figure 4. Comparison of anchor pins below grade after pickup truck impact.**

Based on these observations, the research team concluded that reduction of the anchor pin length to 36 inches is likely to result in adequate anchorage for the PCB system in Test 3-11. The overall barrier deflection and vehicle kinematics are expected to be similar to what was observed in the previously performed crash test with the 48-inch anchor pins.

For longitudinal barriers, MASH requires Test 3-10 with the 2,420-lb small passenger car, impacting the barrier at an impact speed and angle of 62 mi/h and 25 degrees, respectively. This is not a critical test for the anchored barrier system and was not performed previously with the 48-inch anchor pins. It is also not needed for the 36-inch anchor pins. Impact of the lighter small car of Test 3-10 is not likely to impart greater load into the barrier anchorage or cause other instability to the barrier in comparison to the pickup truck impact of Test 3-11. Furthermore, the F-shape profile PCB system has previously passed MASH Test 3-10 in free standing, anchored, and rigid configurations – which demonstrates that the F-shape barrier profile and the PCB design are MASH Test 3-10 compliant (*2,3,4*).

## Conclusion

Based on the discussion of the crash testing and simulation results presented herein, it is the assessment of the research team that the F-shape PCB system of Figure 1 with the reduced anchor pin length of 36 inches is expected to be MASH TL-3 compliant.

## Implementation

In some field situations, the anchored PCB system needs to be installed on asphalt that this thicker than 4 inches. Since asphalt is expected to be stiffer than the underlying road base or soil, anchoring the PCB system on asphalt that is thicker than 4 inches is not expected to negatively affect the MASH performance of the barrier. Thus, asphalt thickness of 4 inches or greater would be acceptable for the anchored barrier design (Figure 5).

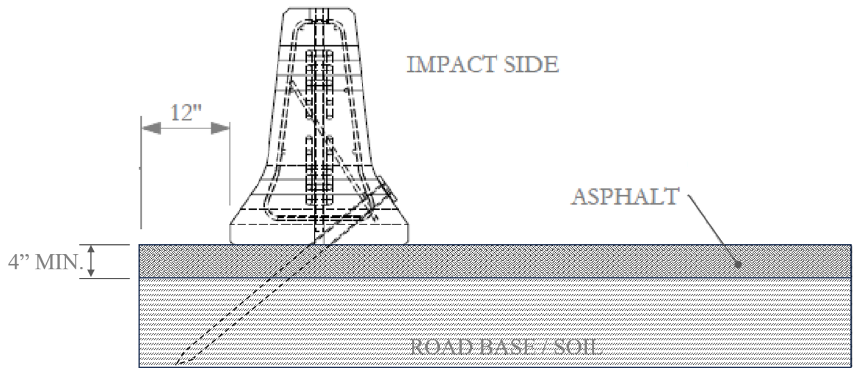


**Figure 5. Anchored PCB placement adjacent to vertical cut with 36-inch anchor pins.**

In some field situations, the anchored PCB system needs to be installed adjacent to a vertical cut instead of a slope. The anchored PCB system requires a minimum 12-inch offset from the back of the barrier to the top of an adjacent slope. With the reduction of the anchor pin length to 36 inches, the anchor pin does not extend beyond the 12-inch-offset. This allows the barrier to be installed adjacent to the vertical cut with the minimum 12-inch offset (Figure 5). While this setup results in small reduction in the amount of soil behind the pin (toward the bottom length of the pin) it is not expected to significantly deteriorate the anchorage performance. Pin deformation pattern in previous pullout testing of the anchor pins has shown that near the bottom half of the anchor pin, the pin bears against the soil infront of the pin (traffic side), thus making the small reduction of soil behind the pin non-significant (*1*).

Based on the discussion above, it is the assessment of the research team that the PCB system anchored with the 36-inch anchor pins in the configuration depicted in Figure 5 is expected to be MASH compliant.

## References

[1] N.M. Sheikh and W.L. Menges. Development and Testing of Anchored Temporary Concrete Barrier for use on Asphalt. Texas A&M Transportation Institute, Report 405160-25-1, College Station, Texas, 2012.

[2] N.M. Sheikh, W.L. Menges, and D.L. Kuhn. MASH TL-3 Testing and Evaluation of Free-Standing Portable Concrete Barrier. Texas A&M Transportation Institute, Report 607911-1&2, College Station, Texas, 2017.

[3] Federal Highway Administration, Safety Eligibility Letter B-339, J-J Hooks® MASH Free-Standing Barrier, Dated February 09, 2024, Washington, D.C.

[3] Federal Highway Administration, Safety Eligibility Letter B-300, F-Shape Barrier on Cantilevered Bridge Deck with Noise Wall Panels, Dated May 27, 2020, Washington, D.C.