

# Advances in Simulating Corrugated Beam Barriers under Vehicular Impact

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## Abstract

*W-beam guardrail systems are the most common roadside railing systems used by many road authorities worldwide. They have been used for decades as roadside barrier to protect errant vehicles from intruding into hazardous areas. This paper gives a description of this rail system and recent methods to simulate its performance under roadside impacts. The availability of simulation technologies such as LS-DYNA<sup>®</sup> makes it possible to evaluate the performance of guardrail systems under given impact condition. A predictive simulation example and a subsequent crash test are presented as how simulation can be integrated into roadside safety hardware design process.*

## INTRODUCTION

W-beam rail element is a corrugated steel section that has a cross section resembling that of the letter W. Figure 1 shows a W-beam rail cross section and its end (splice) bolt holes. These eight bolt holes are used to connect to other W-beam while the middle slotted hole is used to connect to the post.



**Figure 1 W-beam rail element showing the end (splice) section**

There are several W-beam guardrail systems used throughout the globe. However, the common systems used are wood post and weak post W-beam rail systems shown in Figure 2 and the strong steel post G4(1S) shown in Figure 3.

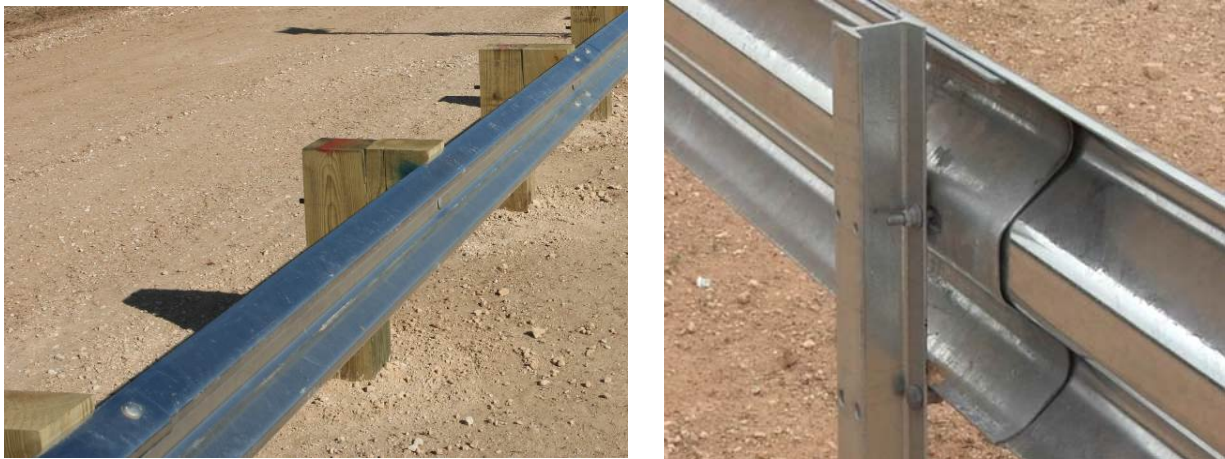


Figure 2 W-beam rail systems. Wood post (left) and Weak steel post (right)

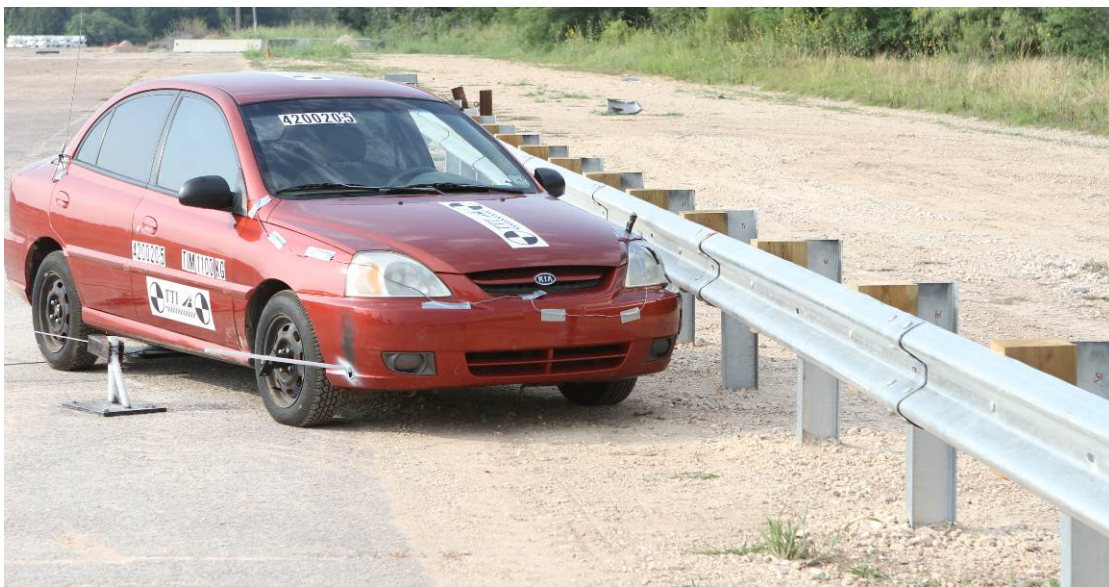


Figure 3 Strong Post G4(1S) W-beam guardrail system

The standard dimensions of a W-beam railing element come from AASHTO specifications for barrier hardware develop by Task Force 13 (TF13) and are presented in Figure 4 .

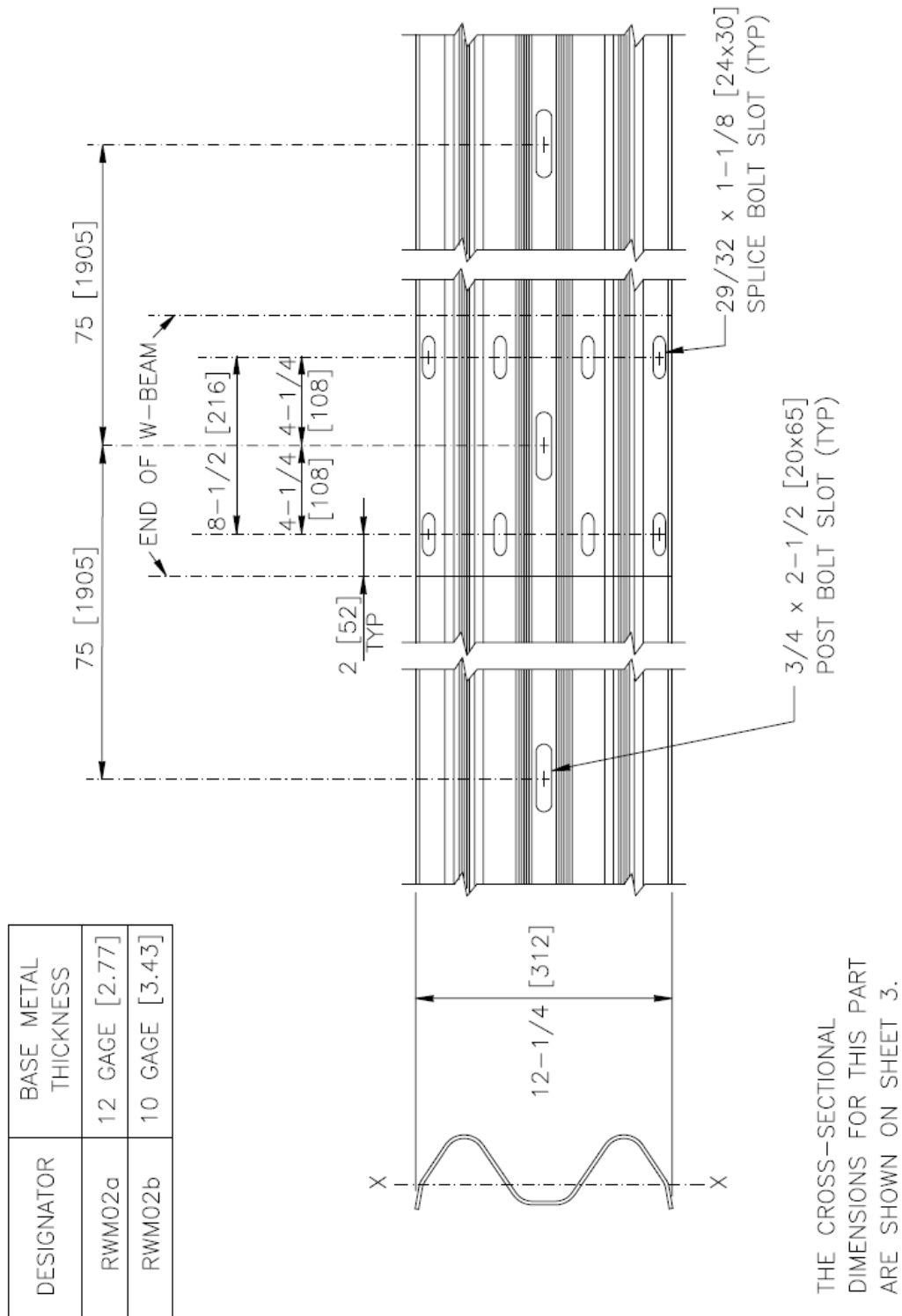


Figure 4 W-Beam dimensions (Barrier Guide, AASHTO TF13)

Finite element model of a typical W-beam rail is shown in Figure 5 for a strong steel post W-beam system. This model has key components of a guardrail systems defined including the W-beam segments, splice bolts, post bolts, steel posts and the timber offset blockout.

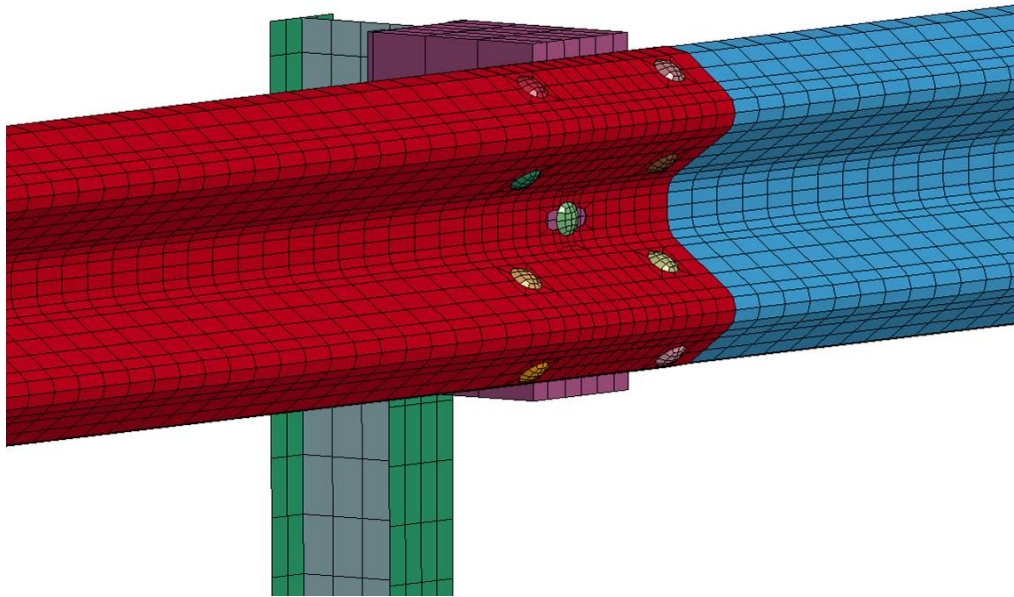


Figure 5 A model of a W-beam rail system (NCAC)

### Improving the Performance of the W-beam Median Barrier

The W-Beam median barrier system a variation of the strong steel post W-beam system for use in median areas of highways. This presents a unique performance challenge due to the additional constraint of the posts imposed by the double-sided G4(1S) W-beam median barrier.

The G4(1S) W-beam median barrier (American Association of State Highway and Transportation Officials (AASHTO) Designation SGM04a with non-steel blocks) is a 27-inch

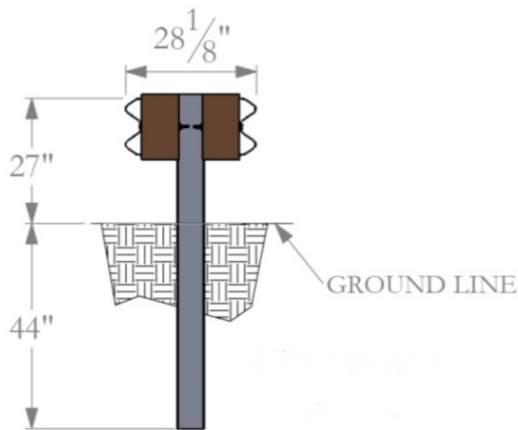


Figure 6 Cross-section of a 27 in W-beam median barrier

tall, strong steel post, W-beam median barrier. The median barrier was constructed using 12

gauge W-beam guardrail elements attached to 6 ft long W6×8.5 steel posts spaced 6 ft 3 inch on center. The W-beam guardrail elements were offset from the posts using non-steel blockouts nominally 6 inch × 8 inch × 14 inch long. Two tests were performed under NCHRP Project 14(03), MASH test 3-10 and MASH test 3-11. MASH test 3-10 involves a 1100C vehicle with test inertial mass of 2420 lb impacting the median barrier at an impact speed of 62.2 mi/h at an angle of 25 degrees. MASH test 3-11 involves a 2270P vehicle weighing 5000 lb and impacting the median barrier at an impact speed of 62.2 mi/h and an angle of 25 degrees. The W-beam median barrier was able to contain and redirect the 1100C vehicle in MASH test 3-10. However, it did not contain or redirect the 2270P vehicle in MASH test 3-11. During TTI test 476460-1-9, the left front tire and wheel of the 2270P vehicle rode up on post 14 and the bumper of the vehicle contacted post 14. The front of the vehicle became airborne above the median barrier, and the vehicle lost contact with the barrier as it was airborne over the median barrier. This is shown in Figure 7 below.

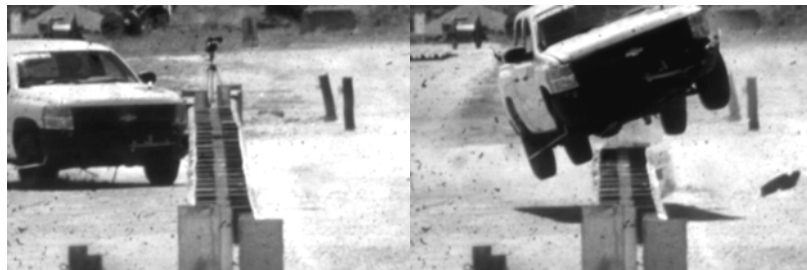


Figure 7 MASH test 3-11 of the 27-inch W-beam median barrier

### Modeling the Failed Crash Test and the Design Change

A detailed model of the W-beam median barrier was constructed with the purpose of simulating the failed crash test. First a much finer mesh of the W-beam segment was built from IGES surface generated by the 3D CAD program SolidWorks® as shown in Figure 8. The mesh of the W-beam is shown in Figure 9



Figure 8 W-beam CAD model as built in SolidWorks®

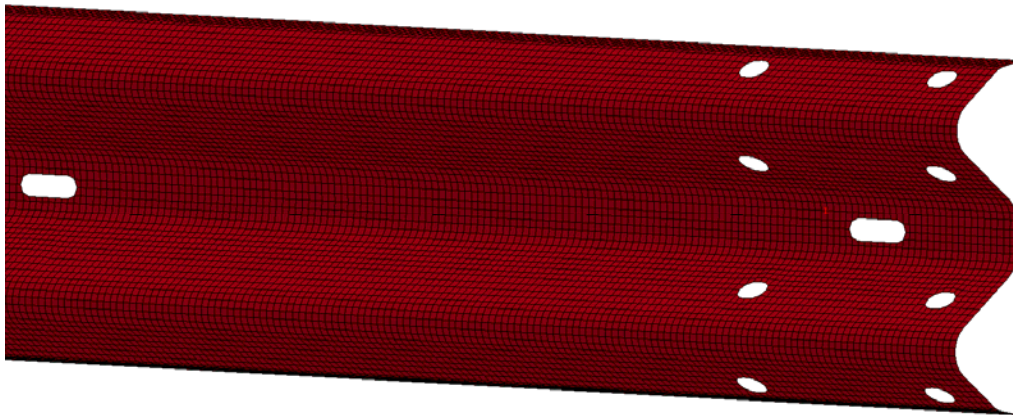


Figure 9 A finely mesh W-beam rail segment

Explicit modeling of the posts, offset blockouts, splice and post bolts were incorporated into the W-beam median barrier model as shown in Figure 10. It should be noted that splice were placed at post location as it was constructed in the test.

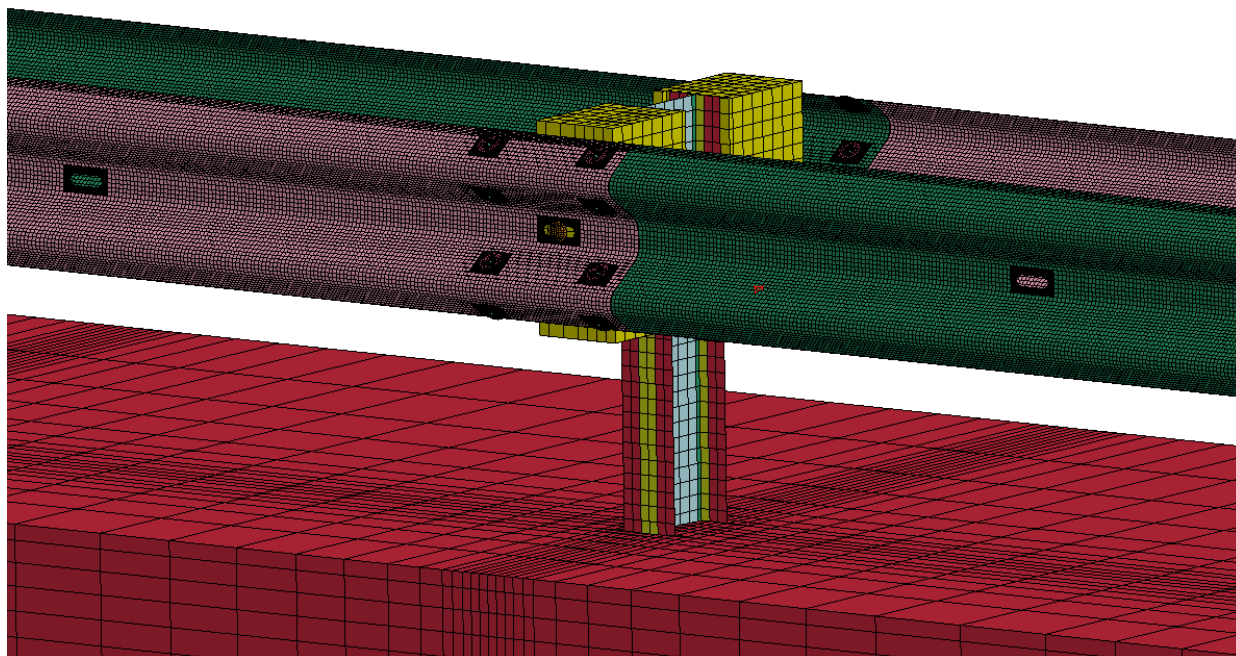


Figure 10 Model of the W-beam median guardrail with typical splice location (27 in high)

The post model was comprised of different thicknesses to accurately represent the shape of a W6×9 steel post. A total of 18,240 shell elements were used for modeling the posts. Additionally, the W-beam model contains a more refined element mesh than previously used W-

beam models so it can capture deformation more realistically. A total of 182,304 shell elements were used for modeling the W-beam segments.

The vehicle model used for simulation was the Chevrolet Silverado model, which was developed by NCAC. This vehicle model represents the *MASH 2270P* test vehicle. The setup for the vehicle and the barrier models and the replicated outcome of this test are shown in Figure 12.

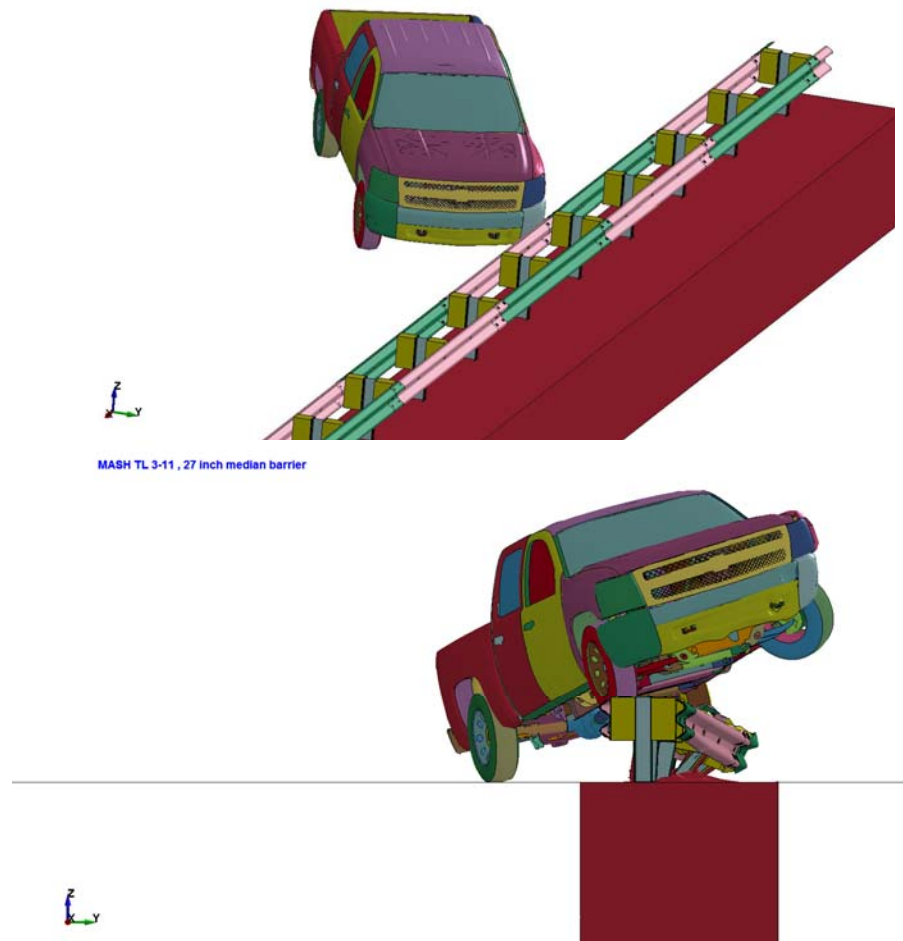


Figure 12 Failed test model and override outcome

### Designs Changes and Simulation

Design changes included increasing the rail height from 27 inches to 31 inches high and moving the splice location from at post to mid-span. The cross-section views of the new system design and the model are shown in Figure 13. Two simulations were conducted using the 2270P vehicle model. One was conducted with vehicular impact at a post and the other with vehicular impact at mid-span. Both simulations give very close results and thus, for brevity, only the results of one case are presented herein.

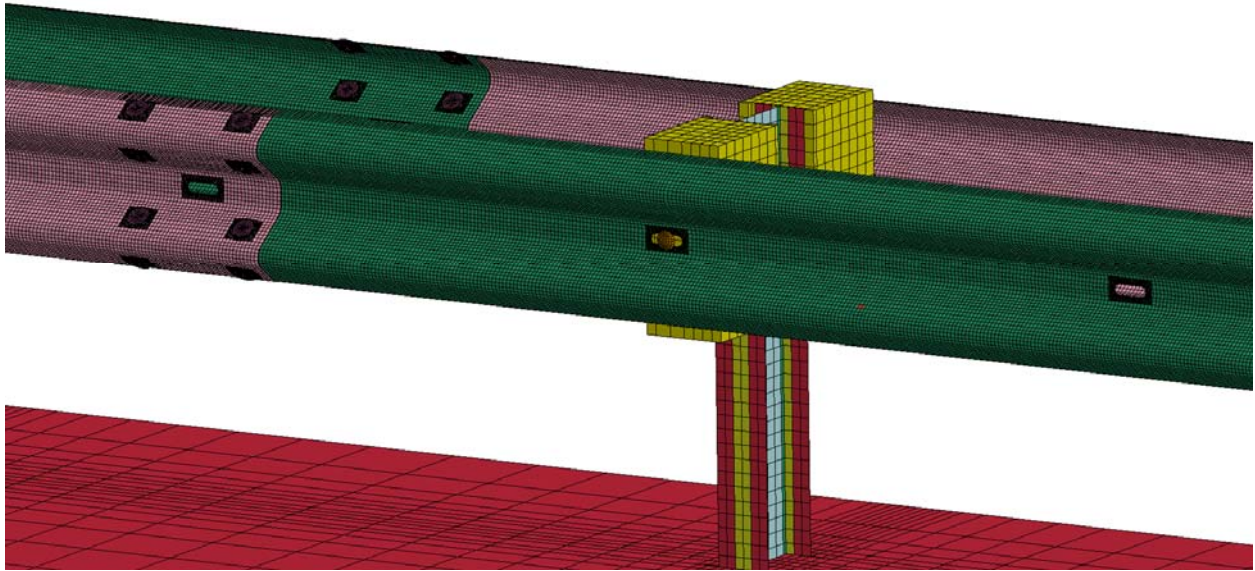


Figure 13 Model of the modified W-beam median barrier

The simulation represented an impact by a Chevy Silverado truck traveling at 62.2 mph and an angle of 25 degrees.

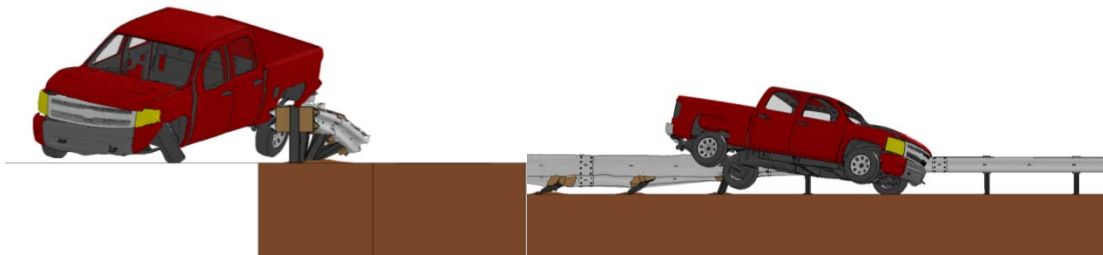


Figure 14 Views of vehicle behavior in the mid-span impact simulation case

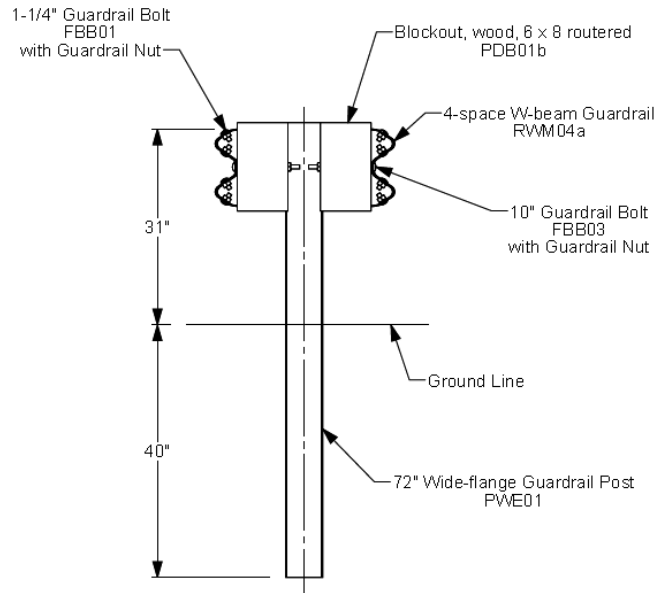
Both simulation cases indicated that the 31-inch W-beam median barrier is able to contain and redirect the test vehicle and pass *MASH* evaluation criteria hence, the new design was recommended for further evaluation using full-scale crash test.

### Full Scale Crash Test

The TxDOT W-Beam Median Barrier is a 31-inch tall, strong steel post, W-beam median barrier. The median barrier was constructed using 12-gauge W-beam guardrails attached to 6 ft long W6×8.5 steel posts spaced 6 ft-3 inch on center. The W-beam guardrails are offset from the posts using wood blockouts nominally 6 inch × 8 inch × 14 inch long. For this installation, the W-beam rail element joints were moved off the posts and centered mid-span between posts.



Figure 15 depicts the cross-section of the TxDOT 31-inch W-Beam Median Barrier. Photographs of the completed installation are shown in Figure 16.



**Figure 15 Cross section of the TxDOT 31-inch W-beam median barrier**



**Figure 16 TxDOT 31-inch W-beam median barrier installation**

*MASH* test 3-11 involves a 2270P vehicle weighing 5000 lb  $\pm$ 110 lb and impacting the TxDOT 31-inch W-Beam Median Barrier at an impact speed of 62.2 mi/h  $\pm$ 2.5 mi/h and an angle of 25 degrees  $\pm$ 1.5 degrees. The target impact point was 10.5 ft upstream of post 13. The 2007 Dodge Ram 1500 pickup truck used in the test weighed 5017 lb, and the actual impact speed and angle were 63.0 mi/h and 25.4 degrees, respectively. The actual impact point was 10.8 ft upstream of post 13. The rail was able to redirect the vehicle without override and no occupant compartment deformation occurred. Damage to the guardrail and the vehicle is shown in Figure 18.



Figure 18 Vehicle and guardrail damage after MASH test 3-11



Figure 17 Front view comparison of the predicted simulation and the MASH TL3-11 test

### Conclusion

A new *MASH* compliant W-beam median barrier system was developed and tested successfully per *MASH* TL-3 tests conditions. Finite element simulation using LS-DYNA was utilized to assess the system performance prior to testing. The simulation results compared favorably with the subsequent crash test as presented in Figure 17 and Figure 19 This median barrier system passed the evaluation criteria for both *MASH* tests 3-10 and 3-11. This system utilizes standard

blockouts and standard post spacing. The system is 31 inches tall and has splices positioned off post locations.

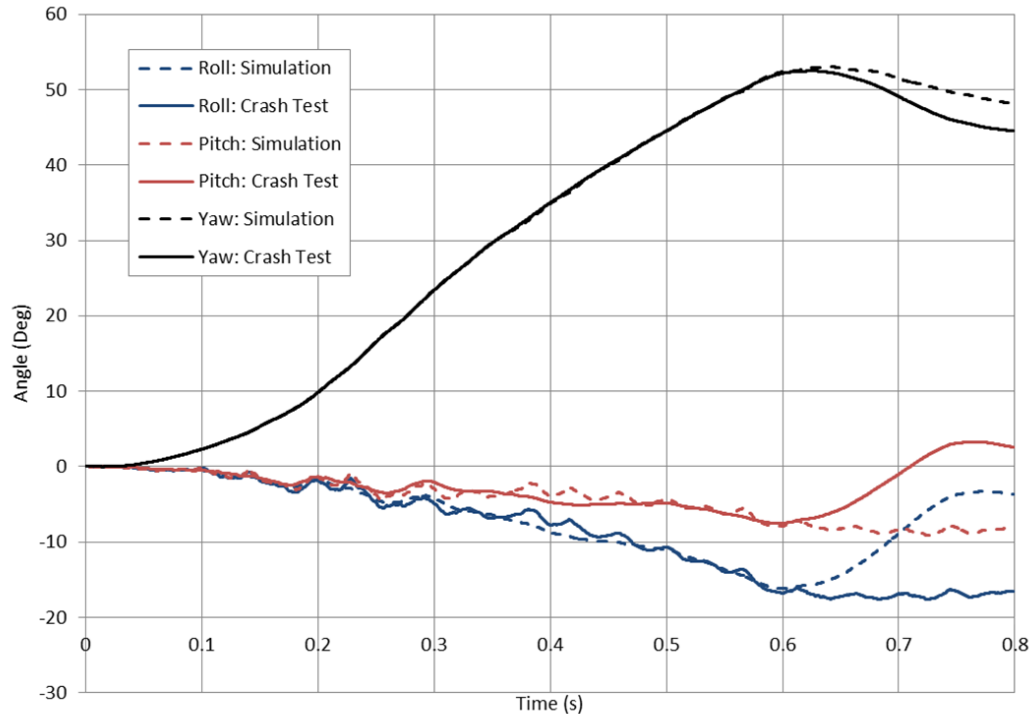


Figure 19 Angular displacement comparison between simulation and test

## Acknowledgment

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