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Executive Summary Report

Development of a TL-3 Deep Beam Tubular Backup Bridge Rail

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Project Background

Ohio Department of Transportation (ODOT)'s Office of Structural Engineering has a need to evaluate and, if necessary, improve an existing bridge rail design with a simple retrofitting procedure to meet current or proposed crash testing standards. This bridge rail is the ODOT deep beam bridge guardrail that has been accepted to National Corporate Highway Research Program (NCHRP) Report 350 Test Level 2 (TL-2). A TL-2 condition involves an 1808 lb (820 kg) passenger car and a 4400 lb (2000 kg) pickup truck impacting the bridge rail at a speed of 43.5 mph (70 km/h). The impact angles for the passenger car (test designation 2-10) and pickup truck (test designation 2-11) are 20 and 25 degrees respectively. However, this bridge rail cannot be constructed (or more importantly, cannot remain) in locations where a TL-3 bridge rail is required. The TL-3 conditions involve an 1808 lb (820 kg) passenger car and a 4400 lb (2000 kg) pickup truck impacting the bridge rail at a speed of 62 mph (100 km/h). The impact angles for the passenger car (test designation 3-10) and pickup truck (test designation 3-11) are 20 degrees and 25 degrees, respectively.

The current policy for bridge railing requires upgrading non-conforming railing systems to the TL-3 acceptance level during certain types of structural rehabilitations. The costs associated with such railing upgrades will often exceed the allotted budget for the project resulting in rehabilitations that are not performed and non-conforming railing systems left in service. Hence, there is a need for a cost effective retrofit upgrade to such railing system.

Study Objectives

The objective of this study is to investigate the performance of the ODOT Deep Beam bridge guardrail system per the *NCHRP Report 350* TL-3 criteria and identify needed design changes. The final expected product is a design of the ODOT Deep Beam Bridge railing system with any needed retrofit that will bring the system into compliance with the *NCHRP Report 350* performance criteria per TL-3. This design should utilize existing rail components with simple retrofit and minimal construction effort.

Description of Work

A literature search was performed to gain knowledge related the ODOT deep beam tubular backup design (Figure 1). Similar side-mounted railings were reviewed to identify performance limits and issues with this type of bridge railing.

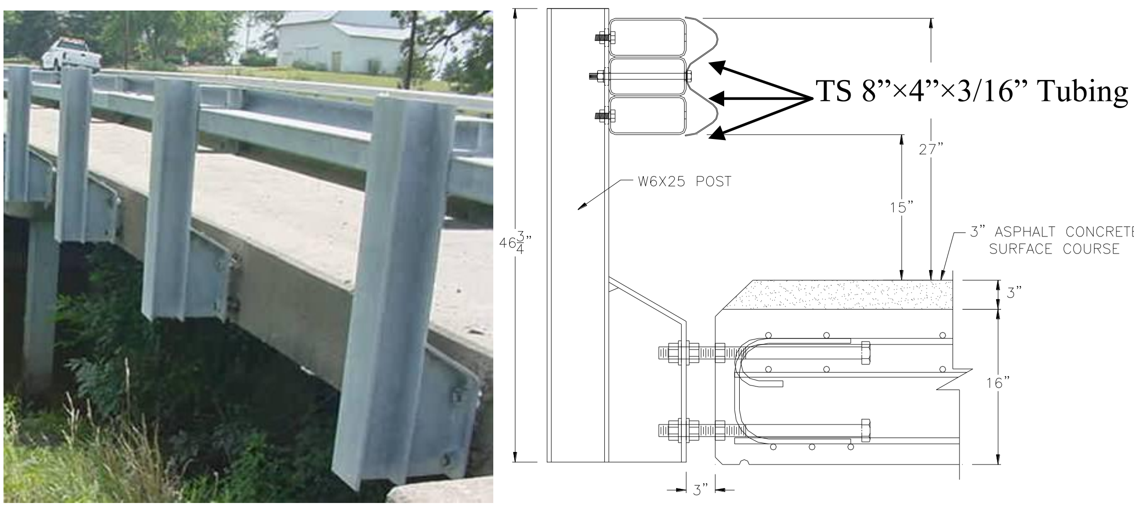
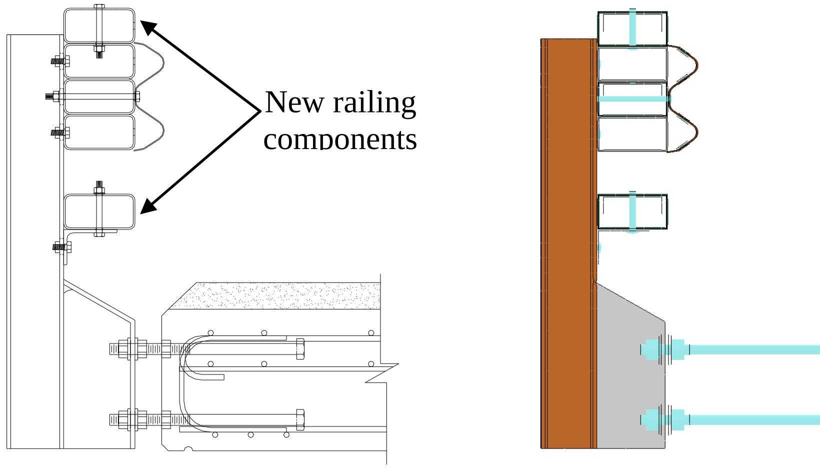


Figure 1 Original ODOT Deep Beam bridge rail.

Subsequently, strength and capacity analyses were performed to identify performance limits of the railing system. This included evaluation of the strength capacity of the individual components as well as checking for potential pocketing of the small car impact per the *AASHTO LRFD Bridge Design Specifications*.

Then, a retrofit design was developed to improve the system performance under *NCHRP Report 350* TL-3 test condition. The retrofit comprises of two additional railing components to the system as shown in Figure 2 (a). The lower rail will reduce the potential of small car tire snagging with the post while the upper rail will reduce the potential of pickup truck rolling.

Nonlinear finite element simulation of the retrofitted bridge rail design was performed to evaluate performance of the retrofitted rail under *NCHRP Report 350* TL-3 test condition. The finite element model consists of detailed representation of all structural elements of the rail. A cross sectional view of the model is shown in Figure 2 (b). LS-DYNA, a commercial nonlinear finite element code, was used to evaluate the performance of this retrofitted bridge rail. First simulation was for a pickup truck impacting the bridge rail at 62 mph (100 km/h) and 25 degrees impact angle as shown in Figure 3. Two more simulations were conducted with small passenger vehicle impacting the bridge rail at 62 mph (100 km/h) and 25 degrees impact angle as shown Figures 4 and 5. Two simulations were conducted to account for the presence and the absence of pavement overlay.



(a) CAD representation (b) Model (deck is masked)

Figure 2 Retrofit design of the ODOT Deep Beam bridge rail.

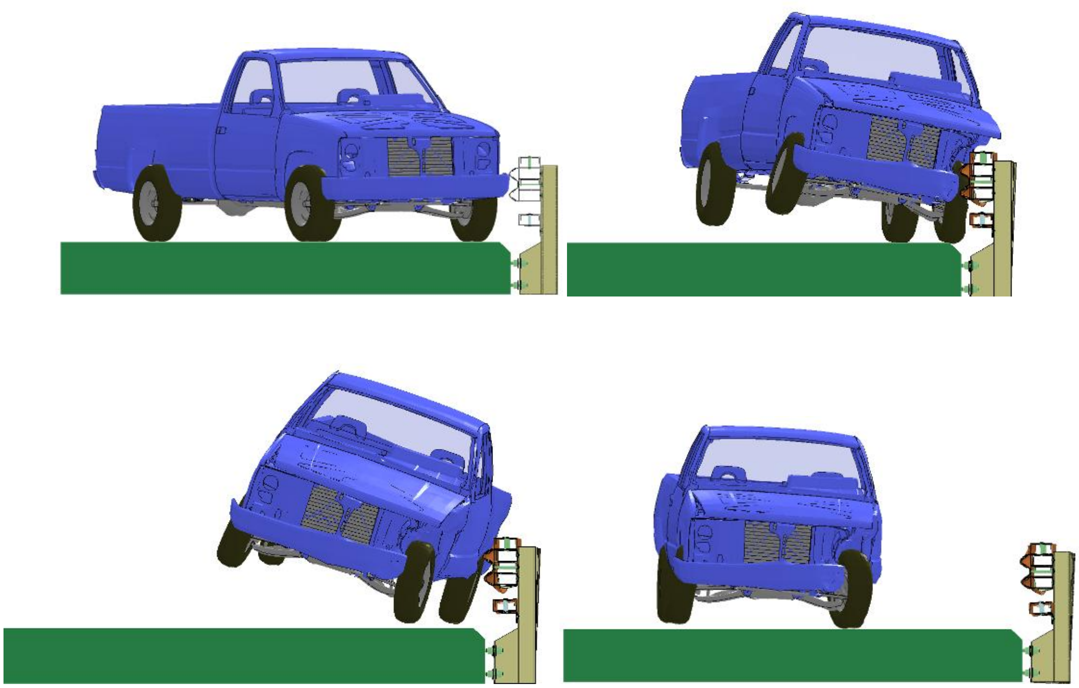
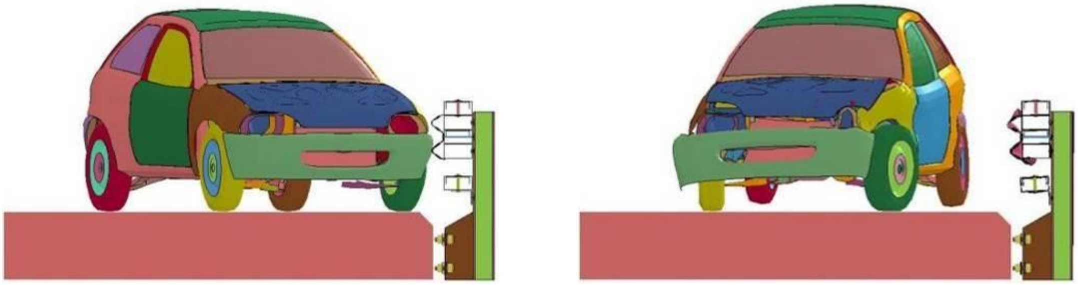
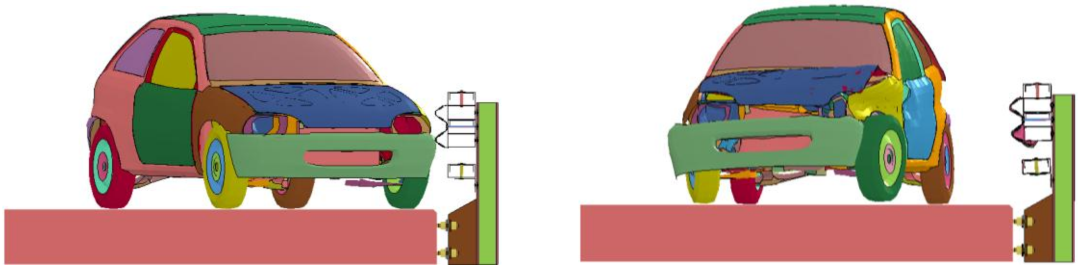


Figure 3 Sequential images of impact simulation of the retrofitted bridge rail with pickup truck.



(a) Set-up **(b) After impact**

Figure 4 Sequential images of impact simulation of the retrofitted bridge rail (pavement overlay) by the small car.



(a) Set-up **(b) After impact**

Figure 5 Sequential images of impact simulation of the retrofitted bridge rail (without pavement overlay) by the small car

Research Findings & Conclusions

The retrofitted ODOT Deep Beam bridge rail design is shown to be successfully able to pass NCHRP Report 350 test level 3 assessment criteria as shown. This conclusion is based on engineering strength analysis and nonlinear finite element simulation. The added rail on the top of the bridge rail helped reduced potential vehicular dynamics instability that may occur if only the original rail (less height) was used. Also, the additional lower rail (rub rail) provided protection against tire snagging in the opening between the main rail and the deck. This snagging mode could be detrimental for small vehicle impacts due to the subsequent excessive deformation of the vehicle and increased occupant risk factors.

Implementation Recommendations

This design is ready to be implemented in the field since the FHWA Office of Safety accepted the research results (FHWA letter HSSI/B-207 dated November 10, 2010). The modified design presented herein represents a retrofit that can be installed by a qualified construction crew. Implementing this retrofit will result in significant saving to the ODOT in upgrade cost.