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"A REVIEW ON DESIGN OPTIMIZATION OF SPACER IN GUARDRAIL SYSTEM"

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ABSTRACT

One of the major challenges in road safety is to design a guardrail system that provides an adequate level of safety. To provide an appropriate level of safety for an errant vehicle that hits the guardrail system, the safety barrier should be designed to absorb as much energy as possible through deformation of the soil and the guardrail system while maintaining the integrity of the system. Roadside geometries often call for guardrails to be placed close to rigid obstacles. In such cases, guardrail failure is not forgiving; therefore, this study attempts to use to explicit dynamics to use improve guardrail systems so that they safely and successfully redirect vehicles. Understanding the characteristics of a guardrail system allows better decisions concerning which systems are more effective in different locations to be made. The parametric study conducted in this study clearly reveals the effectiveness of the design factors on the performance of a guardrail system.

Key Words: *Highway guardrail, spacer, channel-section, roadside geometries, explicit dynamics.*

I. INTRODUCTION

Vehicle crashes are one of the leading causes of death worldwide. Annually, more than 1 million people die, and 20e50 million are severely injured in crashes based on the Association for Safe International Road Travel (ASIRT, 2018). According to the U.S. National Highway Traffic Safety Administration (NHTSA, 2016), vehicle crashes ranked 7th overall regarding the years of life lost in 2012e2014. Over 37,000 fatalities and $ 230.6 billion crash cost are recorded annually in the U.S. A considerable proportion of roadside crashes are fatal, and injury crashes. According to Jalayer and Zhou (2016), in 2013, 62% of the U.S. fatal crashes were run-off-the-road (ROTR). Traffic barriers are traditionally known as one of the most popular countermeasures to reduce the crash severity of roadside.
However, in 2008, traffic barriers were identified as the third most common cause of fixed-object fatalities after trees and the utility poles (AASHTO, 2011). This chapter discusses the methods of analysis that are used in this study, including modelling the G4(2W) guardrail system, performing the dynamic tests and validating the FEM model. Computer simulation is the most versatile approach for investigating a wide range of possible impact scenarios (e.g., vehicle type, guardrail type, and impact conditions). Experiments and finite element analysis (FEA) are two methods that were considered for use in this study

II. LITERATURE REVIEW

Olegas Prentkovskis et al,[1] in their work '*A study of the deflections of metal road guardrail elements, 2009'* has discusses Statistical data on traffic accidents in 2008 in Lithuania. Metal guardrails, consisting of Σ-shape metal posts and a protective W-shape horizontal beam, are most popular. The authors examined the deformation processes of the elements of the above mentioned guardrail. They have also taken the account of elastic deformations, as well as the effect of soil on the buried post section of the guardrail. Based on the developed mathematical model of metal road

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guardrail, the deflections of its elements caused by the impact of a vehicle moving at varying speed were determined. The obtained values of deflections of guardrail elements (a protective W-shape horizontal beam and a Σ-shape post) presented in paper do not exceed the admissible values (of beam deflections). The model developed may be modified to use it for the analysis of deformation processes of beam system's structures in transport infrastructure (e.g. light posts, traffic-lights and road signs).

D.A.F. Bayton et al [2] in his work "*Analysis of a safety barrier connection joint post-testing* (Elsevier, 2007)" examine the effect of a full impact vehicle crash test on the joint material and the mechanical fasteners that form part of the safety barrier beam to beam connection joint The results show changes in the safety barrier beam material microstructure in the area of the slotted holes where the mechanical fasteners were subjected to shear loads due to tension forces in the safety barrier beam. Additional information is presented to demonstrate that changes in the material microstructure have not been caused by cold work deformation sustained in the manufacturing process. Further testing using different materials, different slot profiles and different diameter bolts would determine their contribution to joint performance. They may even enhance the barrier performance in terms of reducing joint slip and barrier deflection or indeed they may have little effect on overall system performance.

M. Borovinsek et al **[3]** in their work "*Simulation of crash tests for high containment levels of road safety barriers (Elsevier,2007)*" presents the results of computer simulations of road safety barrier behaviour under vehicle crash conditions for high containment levels as mandated by the European standard EN 1317. A very good agreement of simulation and real crash tests results was observed, which in turn justifies the use of computer simulations in the process of development and certification of road safety barriers. Despite the greater sensitivity of accelerations to not fully constrained experimental parameters, the results of the simulation and of the experiment differ inside acceptable ±10% margin. However, using parametric computer simulations the best barrier design for predicted experiment parameters can be determined with reasonable accuracy.

Omer F. Cansiz, et al **[4]** in their work "*Crash test simulation of a modified thrie-beam high containment level guardrail under NCHRP Report 350 TL 4-12 conditions* (Inderscience,2006)" describes details of a computer simulation study performed on a modified thrie-beam high containment level guardrail designated as SGR09b. A detailed finite element model of the SGR09b guardrail system has been developed and subjected to 8000 kg single unit truck impact under NCHRP Report TL4 conditions. Based on the crash test results, it was determined that the finite element models for both the SGR09b guardrail system and the 8000 kg single unit truck are fairly accurate and can be used with confidence in further computer-simulated virtual roadside safety research. Finally, it is recommended that as a future study, the crashworthiness of the SGR09b guardrail system should be evaluated under EN 1317 H4a or H4b standards which specify impact by a 30 000 kg truck.

Wen Hu, et al [5] in their work '*Median barrier crash severity: Some new insights* (Elsevier, 2010)' they discusses the estimation of a nested logit model of median barrier crash severity using 5 years of data from rural divided highways in North Carolina. Vehicle, driver, roadway, and median cross-section design data were factors considered in the model. A unique aspect of the data used to estimate the model was the availability of median barrier placement and median cross-slope data, two elements not commonly included in roadway inventory data files. The estimation results indicate that collisions with a cable median barrier increase the probability of less-severe crash outcomes relative to collisions with a concrete or guardrail median barrier. Increasing the median barrier offset was associated with a lower probability of severe crash outcomes. The presence of a cable median barrier installed on foreslopes that were between 6H:1V and 10H:1V were associated with an increase in severe crash probabilities when compared to cable median barrier installations on foreslopes that were 10H:1V or flatter.

Gabriel Jiga et al [6] in their article "*Study of Shock Attenuation for Impacted Safety Barriers*.(Elsevier 2014 the authors propose and analyze the impact behavior of two new safety guardrail systems in order to raise the impact energy absorption. The tests were performed using as impact or a 1500 kg Chevrolet C1500 pick-up truck from the NCAC models library. the authors propose and analyse the impact behaviour of two new safety guardrail configurations in order to increase the impact energy absorption. In addition, this system should be designed as an enclosed complex attenuator hat would fit at the interface between guard rail and fixing post. Even that the lamellar and rubber damping elements system is mounted on a U profile with a lower flexural modulus, the structural integrity of the

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guardrail is affected only, the vehicle being safely redirected on the roadway. The new proposed solution is very appropriate one, due to the vehicle yaw displacement rotational angle, avoiding large deformations of the vehicle structure and simultaneously a good redirection on the roadway. In future, new experimental tests will be performed in order to check the availability of the proposed solution.

Jean-Louis Martin et al [7] in their work "*Long-term analysis of the impact of longitudinal barriers on motorway safety* (2013 Elsevier)" assess the influence of longitudinal barriers located on the median strips and hard shoulders of toll motorways on crash severity in vehicles running off the roadway. The study was based on crashes involving injury and property damage only, recorded from 1996 to 2010 on a French toll motorway network of about 2000 km. A specific one-sided W-beam guardrail ("GS4") appeared to be the best solution for cars, and even for LUVs and trucks. This does not affect the advisability of specific guardrails for bridges or of concrete barriers, when narrow working widths are required. In run-off onto median strips, a specific guardrail ("GS2") appeared to be the most efficient, followed by the three other metal guardrails currently installed. Concrete barriers, however, are much more effective in preventing complete crossing of the median, which is uncommon and mainly involves trucks, but often with very serious consequences. certain aspects, such as the influence of vehicle design change (in terms of mass, geometry and passive safety systems), traffic conditions and speeds, were not studied here, and require further research.

Detlef H.-J.F.Neuenhaus et al[8] in their work "*Using multibody-system modeling to make accurate predictions of vehicle impacts on road restraint systems* (2012 Elsevier)" they classify and certify a vehicle restraint systems(VRS) to these levels,EN1317requires carrying out standardized full-scale impact tests ,causing substantial expenses. To reduce such costs, EN1317-part 5 explicitly allows replacing those full-scale impact tests. Due to the high requirements on reproducing the real impact tests by simulations ,the modeling of the VRS as well as of the vehicle demands for great accuracy and high skills. Already minor changes on the model of the VRS or vehicle may cause significant changes in results by computational simulations under certain limitations, in particular if a VRS is only subject to modifications.

Myung-Hyun Noh et al [9] in their article "*Construction tolerance effects of reinforced posts on crash performances of an open-type guardrail system*(2017 Elsevier)" explains about accuracy of the simulation was verified using qualitative and quantitative comparisons with a full-scale crash experiment of trucks and cars. Subsequent simulation results present that the improved model performs much better in containing and redirecting the impacting vehicle in a stable manner. The numerical results for various parameters are verified by comparing different models with dynamic responses and passenger safety evaluations determined in the barrier from the crash simulation. For increased angles in the negative direction. The total stiffness of barrier system is affected very little by the small installation angle variation of the reinforcing plate. The maximum deflection of barriers for the rotation angle of − 15° approaches to the allowed value limit. the usage of the angle tolerance of more than 15° should be avoided for almost all conditions because of its undesirable dynamic response and passenger safety.

John D. Reid et al [10] in their work "*Impact performance of W-beam guardrail installed at various flare rates* (2008 Elsevier)" investigated The potential to increase suggested flare rates for strong post, W-beam guardrail systems and thus reduce guardrail installation lengths. Computer simulation and five full-scale crash tests were completed to evaluate increased flare rates up to, and including, 5:1. Computer simulations indicated that conventional G4(1S) guardrail modified to incorporate a routed wood block could not successfully meet NCHRP Report 350 crash test criteria when installed at any steeper flare rates than the 15:1 recommended in the Roadside Design Guide. All tests conducted up to, and including on, a flare rate of 5:1 passed all NCHRP 350 safety performance evaluation requirements, including occupant risk measures that are not specifically required for Test 3–11 and including not redirecting any vehicles back into the roadway into adjacent traffic. Additionally, all tests had higher impact angles and speeds than those specified in NCHRP 350, resulting in even higher effective flare rates than intended. These tests indicate that the MGS is a very robust system when installed in a flared configuration. Implementing findings from this study should not only improve roadside safety, but also reduce guardrail construction and repair costs.

Z. Ren et al [11] in their article "*Computational and experimental crash analysis of the road safety barrier* (2005 Elsevier)" describes the computational analysis and experimental crash tests of a new road safety barrier. The purpose of this research was to develop and evaluate a full-scale computational model of the road safety barrier for use in crash simulations and to further compare the computational results with real crash test data. The impact severity and stiffness

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of the new design have been evaluated with the dynamic nonlinear elasto-plastic analysis of the three-dimensional road safety barrier within the framework of the finite element method with LS-DYNA code. Comparison of computational and experimental results proved the correctness of the computational model. The tests have also shown that the new safety barrier assures controllable crash energy absorption which in turn increases the safety of vehicle occupants. From comparison of computational (Section 6) and experimental (Section 7) results it can be observed that the results compare very well in relation to the working width of the system (computed 1.2 m; measured 0.95 m) and contact length (computed 10.8 m; measured 12 m). The differences can be attributed to parameters used to describe material dynamic behaviour in computations, which were obviously underestimating the stiffness increase of the material under dynamic impact loading. ASI index for the tested system does not exceed the limiting value in any case. The highest values (computational 0.66; measured 0.63), are observed when the front wheel hits the first post.

Sadok Sassi et al [12] in "*Effect of crushable blockouts on a full-scale guardrail system*(2016 IJC)" discusses about the interaction of the vehicle with the guardrail system by adding more compliance to the guardrail system. A finite-element baseline model of a guardrail system consisting of a light truck (2000 kg) travelling at 100 km/h and striking a guardrail was developed in accordance with the NCHRP Report 350 guidelines for Test Level 3 safety performance. In order for the guardrail system to absorb more energy and offer better stability to the vehicle, a rigid wooden blockout was replaced by a new crushable blockout design that was evaluated at the component level. The new blockout was formed by three crash cans and triggered at the corner, then was implemented in the full-scale model. The results of the analysis indicate that the both models satisfy the requirements of NCHRP Report 350 for the Test 3-11 conditions. In the first simulation, where the guardrail beams used an incompressible blockout, the vehicle was safely redirected after the impact. In the second simulation, a crushable blockout was used to substitute the current rectangular wooden blockout. It consisted of longitudinal tubes sandwiched between two plates and triggered at the four faces. The simulation results clearly indicate that the vehicle was safely redirected, as in the baseline.

Ala Tabiei et al [13] in their work "*Roadmap for crashworthiness "finite element simulation of roadside safety structures* (2000 Elsevier)" investigated to develop an accurate simulation of truck impacting a strong-post W-beam guardrail. Detailed methods for system simulation are proposed and three major issues which involve the use of springs to simulate component crashworthiness behavior is investigated. Rail to blockout bolt connection, soil-post dynamic interaction, and the effect of guardrail ends are modeled and simulated. Soil-post interaction is modeled using both Lagrangian and Eulerian meshes; results using the two methods are presented. The present paper provides a roadmap for simulation of highway safety structures. Three major issues are important when modeling the G4(1S) strong post guardrail for impact simulation. Rail to blockout bolt connection., Soil-post dynamic interaction.,. Effect of guardrail ends Approximating the stiffness of the unmodeled portions of the guardrail by a simple linear spring based on the reported equation is simplification. The model must account for the soil-post interaction. Since position of the bolt in the slotted hole of the guardrail is random, two extreme cases are simulated and both must be used in the full model simulation to determine their effect on the total behavior. Both Lagrangian and Eulerian formulation is employed in the simulation of post-soil dynamic interaction. Theoretically these two methods should lead to the same results. However, there is some difference observed in the results, which is attributed to the mesh instability in the Lagrangian formulation. Eulerian mesh is more stable for soil simulation. All the above findings are incorporated in the full system model for crashworthiness simulation.

Weijia Wu et al [14] in their work "*A study of the interaction between a guardrail post and soil during quasi-static and dynamic loading*(2006 Elsevier)" studies the interaction of gravel with a Sigma-post of a standard Swedish guardrail in experiments and numerical analysis. The aim was to measure the strength of the single post embedded in gravel and use the data to validate a computer model for the investigation of the soil–post interaction. A quasi-static and dynamic test series were designed and carried out. Two corridors were formed by the test data for the quasi-static and dynamic loading conditions, respectively. The interaction of gravel and post was investigated through experiments and computer simulations. In the experiments, the force applied directly to the post was measured to get the strength of the single Sigma-post anchored in gravel. Two corridors were formed from the measured data of the quasi-static and dynamic tests. When a test was repeated using an identical post, the measured resistance force showed some differences probably because the degree of compaction of gravel around the post was not exactly the same. According to the measurement data the dynamic resistance was about twice the quasi-static resistance. Both the passive confinement of

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the soil and the strain rate effect of the steel resulted in this difference. The enhanced strength of the steel material during dynamic loading was the dominant reason that the dynamic resistance force was twice the quasi-static resistance force. In the computer simulations two material models in LS-DYNA were investigated and used to simulate the soil, respectively. The results of this study showed that the soil and concrete material model can effectively capture soil–post interaction under impact loading for approximately 280mm of post deflection, while the FHWA soil behaved overly stiff relative to the soils tested. The soil and concrete model can be used for the impact simulations of a full-scale guardrail system provided that the post deflection is kept within the bound of accuracy determined in this research. The input parameters of the soil and concrete material model were recommended to model roadside gravel.

III. CONCLUSION

In this study by comparing the deflection of post and spacer, we found the max deflection of post with extra cut channel section spacer been more than conventional section. This specifies that the heavy vehicle will over roll the extra cut section, hence not suitable for heavy vehicle. Similarly the light vehicle impact with cut section is within the limit of channel section . The guardrail post with cut c section spacer is more suitable for light vehicle. The guardrail post with c section spacer is more suitable for heavy vehicle. The thrie beam guardrails with cut section spacer can be placed in the city or urban place where few heavy vehicles are observed. The cut section spacer usage will optimize the cost by maintaining the same safety measures as per current guardrail system. The beam guardrail system can be utilize with channel section spacer in highways where heavy vehicles are observed more in numbers.

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