Hybrid Road Barrier Design As Aesthetic Safety Feature and Urban Furniture

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***Abstract*— There are various types of road barriers such as steel W beam, steel cable, concrete and wooden (timber) that have been used all over the World. They all have some advantages and disadvantages from different kinds of aspects such as construction time, ease of installation, low-cost, proven effectiveness, impact resistance, durability, service life, maintenance, etc. but to attain a more pleasant drive especially in historical and natural urban roads or scenic highways, installing wooden (timber) barriers can be considered as a more aesthetically pleasing alternative. In addition to aesthetic, wooden barriers can be preferred for their impact energy and sound absorption capabilities especially in urban roads. With the design, it is also estimated that light effect of oncoming traffic will be blocked. The main idea is to use hybrid barriers for both aesthetic safety feature in scenic or historical roads and urban furniture. This paper also summarizes comparisons among conventional road barrier systems considering the European standard EN 1317, Road Restraint Systems and provides a discussion of future designs.**

***Index Terms*—road restraint system, timber barrier, hybrid barrier, road barrier, urban furniture**

I. Introduction

Barriers are passive roadside constructions designed and installed to preserve vehicles leading to the road again which are in the tendency of leaving the main road for any kind of reason. On the basis of reported accident data, from 50 to 60% of barrier accidents involve an injury or a fatality [1]. From this point of view, barrier installations may be hazardous if they are not installed properly and if their energy absorption capabilities are not considered. Barriers can be constructed in many different shapes, size and materials such as steel, concrete and wood. Steel and concrete barriers can be used almost in every kind of roads but on the other hand wooden barriers has less utilization areas.

Various kinds of steel guardrails are commonly used in all over the world because of their low cost, high energy absorption capabilities, ease of transportation and installation, lightness, flexibility and durability [3,7,9]. Steel guardrails are placed on roadsides to prevent errant vehicles from hazards such as non-traversable terrain and dangerous obstacles but unfortunately impacting a guardrail itself can be a violent impact and as recent as 2006 such events caused 1,142 crashes with fatalities annually in the United States [2]. Steel guardrails are also a big deal for motorcyclists. In accidents involving W-beam steel guardrails, motorcyclists tend to strike the guardrail at a shallow angle, fall and tumble along the tops of the posts.

If they slide into the guardrail, they tumble along striking the bases of the posts. The post tops and bottoms present edges which tend to concentrate impact forces and increase the severity of injuries as shown in Figure 1. Additionally, the edges of the corrugated metal beam can cause extreme laceration injuries [6]. We can also list many of disadvantages of steel guardrails for example; they need routine maintenance that means maintenance cost, they need professional workmanship, especially terminals may be hazardous as shown in Figure 2, they can't be moved another place, they can be deformed considerably after crashing by a vehicle, they can't be useful for absorbing traffic noise and they can't prevent dazzle caused by the oncoming traffic lights [9].

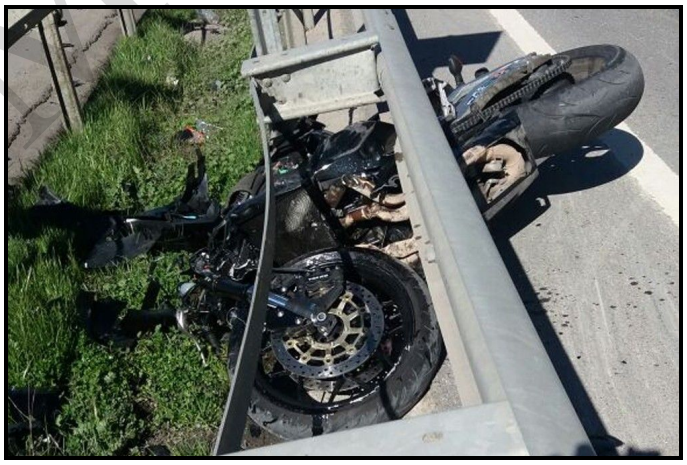


Fig. 1. A motorcycle accident in a steel guardrail



Fig. 2. Steel guardrails terminal hazards [9]

Cable barrier system has gained in popularity and thus has been the focus of research in recent years due to its noticeably good performance demonstrated in containing or redirecting errant vehicles with less imposed impacts. Cable barriers have become an alternative to steel guardrails where clearance to the obstruction behind the barrier [4]. We can summarize the advantages of using cable barriers as follows: lower installation cost, lower impacts on errant vehicles, less visually intrusive, and larger sight distance; while its disadvantages include higher damage cost, greater deflection distance, periodic re-tensioning required and ineffectiveness after impact [5].

Concrete barriers have also been used widely all over the world. They have been used for the first time in early 1950's in the U.S.A and have become a more economical solution compared to steel guardrails. They have been used also in European countries for a long time [9]. The use of concrete barriers, especially median barriers, has been a major advancement in the reduction of head-on collisions and other accidents between approaching vehicles on the roadways. A concrete barrier is primarily used because of its inclined lower surface on each side of the barrier adjacent the roadway for straightening a front vehicle wheel which rides up on the barrier when the vehicle accidentally approaches the barrier at a small angle of incidence. However, when a vehicle impacts the concrete barrier at a high angle of incidence, the high friction hard surface of the concrete barrier and the higher impact force commonly result in significantly greater damage to the vehicle and to the barrier as well as greater injuries to the vehicle driver and passengers in the vehicle. In fact, some impacts will either crack the concrete barrier and/or cause the vehicle to spin out of control, sometimes resulting in accidents with other vehicles moving on the roadway [8].

To name a few advantages of concrete barriers; They are portable and can be replaced where need to arise, their service life regard as 40-50 years and they don't need so much maintenance in the meantime, they can have higher cost of manufacturing but when compared to their service life and maintenance frequency they will have lower cost, they are not heavily deformed after crashing by a vehicle. As for the advantages; energy absorbing capabilities of concrete barriers are not enough so may cause significant vehicle damages or fatalities after crashing, they are very heavy so this increases transportation cost and they have negative psychological effect on drivers [9].

In most timber barriers, the steel serves as a continuous tension member and maintains the structural integrity of the rail during a vehicle impact. Unfortunately, timber barriers are generally expensive due to their use of large solid-sawn timbers. Further, they are relatively heavy and require a large crew or a truck-mounted crane for installation [3]. In the literature, generally, two kinds of wooden barriers have been used; first, main body is wooden but posts are steel, second posts are wooden but main body is steel but there has not yet to be a sufficient wooden guardrail design, evaluating impact energy absorption capability, noise absorbing capability and aesthetic effect of wooden barriers.

II. HYBRID GUARDRAIL DESIGN DETAILS

In this study, a lightweight, cost-effective, aesthetic, impact energy and sound absorbing barrier called "hybrid barrier" that utilizes glued-laminated (glulam) wooden members and sand is designed. A novel feature of the guardrail is its use of sand reinforcing in lieu of steel to carry the tensile forces developed by vehicle impact and the design that provides aesthetic.

Wooden itself has high resilient modulus that can be explained as impact absorption and also with the use of sand depending of its high damping coefficient, it is estimated that impact absorption of the hybrid barrier will be increased significantly and so the damages to vehicle and fatalities after crashing will be diminished. In addition, using sand will lower the cost. On the top of hybrid barrier some vegetal earth will be placed to grow flowers thus blocking the light effect of oncoming traffic and using as an urban furniture. At the bottom, there will be a concrete base to preserve wooden against water and insect effects to which wooden materials are sensitive. All wood used in this design should be treated with preservatives by pressure injection to extend their service life.

The proposed barrier design in this study is a laminated wood-sand new jersey type as shown in Fig. 3.

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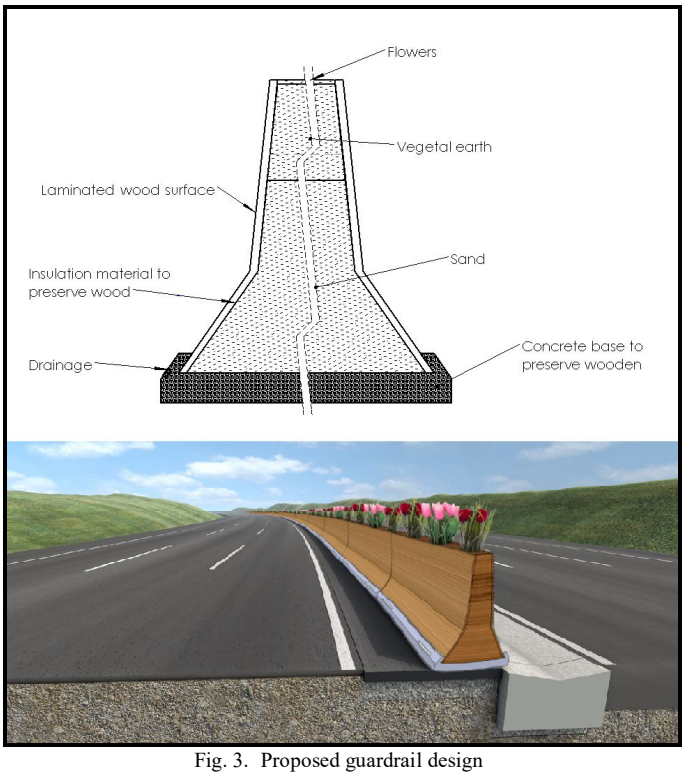


Fig. 3. Proposed guardrail design

ppropriate crash testing is required prior to highway use of the barrier. In order to meet the requirements, it was crucial to analyze the barrier response under vehicle impact, develop a suitable design capable of transferring the large tensile forces caused by vehicle impact, and evaluate the barrier durability for exterior use. In addition, the structural performance of the barrier should be assessed using unique structural tests designed to produce the combined tension and flexure forces produced in a barrier by vehicle impact [3].

The structural performance of road barriers can be best accessed through full-scale crash tests. The standard crash testing procedures for permanent and temporary highway safety features are available in NCHRP Report, "Recommended Procedures for the Safety Performance Evaluation of Highway Features" [10] and the AASHTO Manual for Assessing Safety Hardware (MASH) [11]. In Europe, to be installed on the roadside, the vehicle restraint systems must pass two crash tests, as defined in the European standard EN1317. Although standard crash tests provide a uniform basis upon which researchers, user agencies, and developers can compare safety features and propose installation guidance, the real-world barrier application conditions are so complex that the actual barrier performance should be obtained by in-service evaluation. Unlike the standard tests which measure barrier performance under the practical worst-case scenario, in-service performance evaluation focuses on the observed typical safety performance. Moreover, in-service performance evaluation can lead to reliable cost-benefit analysis with information on installation, maintenance and repair costs [5, 12].

III. CONCLUSIONS

With the design of hybrid barrier, it is estimated that impact absorption of the hybrid barrier will be increased significantly due to energy absorption capabilities of wood and sand so the damages to vehicle and fatalities after crashing will be diminished. In addition, using sand will lower the cost. On the top of hybrid barrier some vegetal earth will be placed to grow flowers so the light effect of oncoming traffic will be blocked and attain a more pleasant drive especially in historical and natural urban roads or scenic highways.

New Jersey type barrier was chosen in our model because to evaluate and compare the effectiveness, a reference model existing and tested previously will be more reasonable but after proving effectiveness, more aesthetic designs can be conceived.

It is obvious that, the design must pass a series of tests considering AASHTO and EN 1317 standards so the next step of this study will be to optimize the above mentioned advantageous features in terms of wood-sand coupling in order to meet the standard criteria and obtain better results. And also the study must be supported by computer simulations such as LS-DYNA and then full-scale crash tests.

After crashing by a vehicle, deformation and translation occurs in the barrier. As a result of the impact if the translation (lateral deformation) is low, passengers in vehicle are highly affected on the other hand if the translation (lateral deformation) is high, the stability and direction angles of vehicles are badly affected. These effects must be optimized for all types of barriers [9]. Thus, when testing our design, these optimizations should be considered to succeed.

In addition to aesthetic, energy absorption, light blockage features of hybrid barrier, sound absorption, vehicle exhaust gas absorption and reflectivity at night features will be researched.

REFERENCES

[1] J.D. Michie, M.E. Bronstad, "Highway Guardrails: Safety Feature or Roadside Hazard," Transportation Research Record, 1468.
[2] J.D. Reid, "Approach Slopes for Midwest Guardrail System," Journal of Transportation Safety & Security, Volume 1, Issue 1, 2009.
[3] G. William, A. Davids, J. K. Botting, M. Peterson, "Development and structural testing of a composite-reinforced timber highway guardrail," Construction and Building Materials 20/ 733–743, 2006.
[4] Y.Zou1, A.P. Tarko, E. Chen, M.A. Romero, "Effectiveness of cable barriers, guardrails, and concrete barrier walls in reducing the risk of injury," Accident Analysis & Prevention, Volume 72, Pages 55–65, 2014.
[5] N. M. Sheikh, C. Alberson, S. Linda, "Chatham State of the practice of cable barrier systems," Journal of the Transportation Research Board, p. 84–91, 2008.
[6] J. V. Ouellet, "Environmental Hazards In Motorcycle Accidents," Traffic Safety Center University of Southern California.
[7] E. Kurtulus, "Development of Next Generation Guardrail Systems using Crash Analysis And Heuristic Optimization Methods," Bursa Technical University, 2015.

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[8] W. E. Arthur, "Energy dissipating system for a concrete barrier" US Patent 6,276,667, 2001.
[9] A. Yeginobali, A. O. Atahan, "Concrete Barriers" Turkish Cement Manufacturers' Association, 2011.
[10] H.E. Ross, D.L Sicking, R.A Zimmer, J.D Michie, "Recommended procedures for the safety performance evaluation of highway features," National Cooperative Highway Research Program 350, Texas Transportation Institute, 1993.
[11] AASHTO, Manual for Assessing Safety Hardware, 2009.
[12] P. Alluri, K. Haleem, A. Gan, "In-service Performance Evaluation for G4 (1S) Type of Strong-Post W-Beam Guardrail System and Median Cable Barrier, 2012.

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