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Bolster Barrier (BOLER): A New Device to Improve Safety of Accidents

Bibie Sara Salleh [1] , Iskandar Zulkarnain Adamulhasza[2] , Nur'Izzah Sahirah Samat[3] , Nur Qasrina Amiruddin [4] , Awangku Nazrul Haziq[5].

[1,2,3,4,5] Faculty of Civil Engineering
Polytechnic Sultan Salahuddin Abdul Aziz Shah, 40150 Shah Alam, Selangor, Malaysia.

*Corresponding Email : bibiesalleh@gmail.com

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Abstract

Guardrail is the most important road furniture to prevent vehicles from crashing to the shoulder of the road or into the opposite lane. It also protect the objects at the roadside and prevent vehicles from entering into dangerous areas such a ravine or river. Performance of guardrail is not only influenced its design, but also the design of the vehicle. Fundamental design of guardrails is aimed to reduce serious effects to vehicles and users in the event of an accident. One of the guardrail impact devices is Bolster Barrier (BOLER) that enhances the existing W-shape guardrails. It is intended to reduce the accident impact between road users and the guardrails themselves. Usually, the application of BOLER is focused at critical areas where it will reduce the numbers of serious injuries and fatalities in an accident. To test the performance of the BOLER, it was placed through an impact test known as dolly test at MIROS Lab, Provisional Crase Crash Centre (PC3) of Ayer Molek, Melaka. The test measured the dolly's velocity, w-beam guardrail bar's deformation and the overall force overtime trace. Results for Standard W-beam guardrail with BOLER recorded a lower peak force (47.6kN versus 51.5kN) and a delayed time to reach peak force by 11.4 milliseconds as compared to guardrail without BOLER. The delay of 11.4 milliseconds creates a safe zone for an airbag to fully inflate before the full impact between road users and the guardrails occurs.

Keywords: *Bolster Barrier, guardrails, accident impact, impact test*

1.0 Introduction

Comparatively, Malaysia is having one of the best highway networks as compared with other developed countries. Highways in Malaysia are equipped with modern road network infrastructure and the motorway networks. Nevertheless, there are many news of accidents involving various types of vehicles, be it private or commercial. These accidents are caused by various factors, namely human, environment, road structure and the vehicle itself [4, 5]. In general, the number of accidents involving commercial vehicles, especially buses and tracks is increasing every year. According to the statistics, the number of road accidents in Malaysia has increased in 2015 after it dropped in 2014. In 2015, a total of 489,606 accidents were recorded, which it is about 2.8% increase as compared to 476,196 in 2014 [10].

Statistics also indicate that the number of road accidents would reach its peak during the arrival of the festive season and school holidays [1]. The volume of vehicles using the route contributes to road congestions and this in turn escalates the frequency and risk of accident occurrences. Thus, road furniture such as guardrails, plays an important role in road safety particularly in terms of the impact of the accidents in reducing the numbers of fatalities and serious injuries on highways or state roads [6]. However, some of the serious injury or fatal cases were caused by the guardrails themselves. The effectiveness of the guardrail in protecting road users in terms of reducing the impact of collisions and minimizing injuries are at an unsatisfactory level. This situation raises the question on how exactly guardrails work in protecting road users.

The application of BOLER is concentrated at areas with existing w-beam guardrail particularly at the critical areas such as sharp bends and T-junctions. In addition to that, an impact test was conducted at the Malaysian Institute of Road Safety Research, MIROS and a comparative analysis was carried out with reference to the existing impact test data records from Public Works Department, PWD and MIROS. This research has 2 objectives: 1) to design an impact device that can be applied on existing guardrails, namely at the w-beam guardrails according to the specifications underlined by the Public Works Department of Malaysia, and 2) to analyse the workability of Bolster Barrier using an impact test, known as Dolly Test at MIROS Lab, Provisional Crase Crash Centre (PC3) [11].

2.0 Materials for BOLER

Material used in the making of road furniture should be carefully investigated, tested and approved by the relevant professional engineers. Primary material used to develop the BOLER consisted of course sand, U-clip, loose-rubber and HDPE. Sand is placed inside the BOLER and it is covered by HDPE as a high impact absorber. Sand is widely used as an impact absorber in most of the sharp corners in a high speed track circuit as a high impact absorption measure. According to geologists, sand particles range from 0.0625mm (or 1⁄16mm) to 2mm in diameter [2]. The composition of mineral in sand highly varies.

The secondary material is U-clip with high level of oxidation resistance in air at the ambient temperature is normally achieved with the addition of a minimum of 13% (by weight) chromium, where up to 26% is used for harsh environments [8]. U-clip is used to attach the BOLER to the w-beam guardrail as a strong holder when the impact between a vehicle and the w-beam guardrail occurs. Four holes are drilled through the guardrail and they are tightened by bolt. Each one-meter BOLER consists of two U-clip and four bolt. The U-clip is made of stainless steel that is highly recommended by some experts because of it durability in any type of weather and high impact conditions as well as for its long lasting feature and its 100mm size in accordance to the size of HDPE.

Loose-rubber is pure rubber that has been grinded and bound with the binder. The space between the grinded rubber acts as an impact absorber which reduces the risk for vehicles to bounce back to the road when a collision occurs. The use of loose-rubber can also protect the shape of the w-beam guardrail as the energy from a high impact is absorbed, leading to a reduction in the maintenance of the w-beam guardrail. The loose-rubber, which is located between the BOLER and w-beam guardrail, is moulded according to the shape of the w-beam guardrail. Eight holes are drilled through the w-beam guardrail and the loose-rubber is fitted using bolts and nuts.

HDPE is known for its large strength-to-density ratio. The density of HDPE can range from 0.93 to 0.97 g/cm3 or 970 kg/m3. HDPE, high density polyethylene is one of the most important materials in BOLER and it is highly recommended by some of the experts because HDPE is already widely used in the industry of road furniture, especially in Spain. In fact, the w-beam guardrail in Spain is made of HDPE; moreover, HDPE is used in the underground oil transportation pipe in the current oil rigs. It is round and has a diameter of 100mm. The properties of these materials are as shown in Table 1:

Table 1 : Material Properties

Materials	Materials Properties	
Course Sand		Loose and dry sand with 95 lb/ft3 and 1,520 kg/m3 To absorb the high impact energy when accidents occur [2]
U-Clip		Stainless steel U-clip with bolt. SAE grade 440F, UNS S44020 BOLER holder to the w-beam guardrail [8]
Loose-rubber		A type of rubber known as Loose-rubber Pure rubber that is grinded and bound with the binder to create a space between each rubber to act as an impact absorber [15]
High Density Polyethylene (HDPE)		HDPE, high density polyethylene with density from 0.93 to 0.97 g/cm3 or 970 kg/m3 [9]

3.0 BOLER Design

The existing guardrails have many advantages and disadvantages. Therefore, improvements to the existing guardrails to make them a more efficient safety device should be done in order to reduce the impact of a collision between the vehicle and the guardrails. The concept of BOLER was obtained from the race circuits in Spain where the guardrails are made from high-density polyethylene (HDPE) which makes them very flexible and elastic and at the same time impact resistant and almost unbreakable as shown in figure 1.

Figure 1: Barrier made of HDPE from Spain

BOLER is a product that prioritizes on safety features because generally it will be placed at the corners of highways and areas with a great potential for accidents to happen with existing guardrails. BOLER has a simple and dynamic design that is focused on rounded shape in order to comply with the requirements of road safety specification. In line with its objectives, BOLER will be able to reduce the impact of accident and at the same time lower the risk of serious injuries or fatal accidents.

The existing guardrails are made according to the guardrails specifications in Malaysia. BOLER can be placed in front of the existing W-beam using the U-clip. The U-clip helps BOLER to stay fixed at its position without any movement. Every road furniture must be fixed using bolts and nuts. The length of a BOLER is one meter and its thickness is seven inches to fit exactly into the W-beam. The HDPE is painted in yellow colour. Reflective sheet is placed in front of the BOLER to help reflect the light to vehicles so they are aware of the existence of accident risk-prone areas. The layout application of BOLER to the guardrails are illustrated as in Figures 2 to 6.

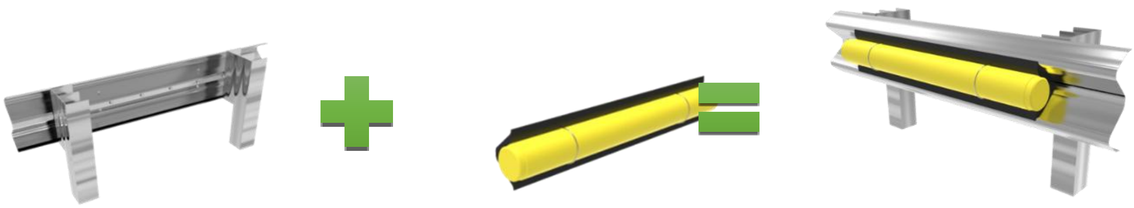


Figure 2: Application of Bolster Barrier at Existing W-beam Guardrails.

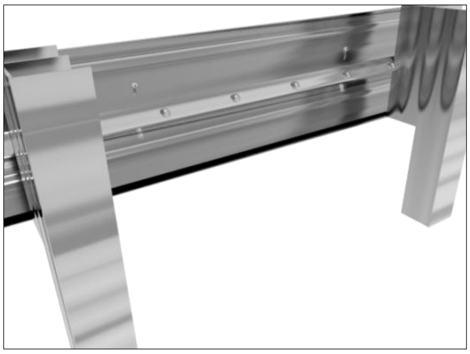


Figure 3: Back View.

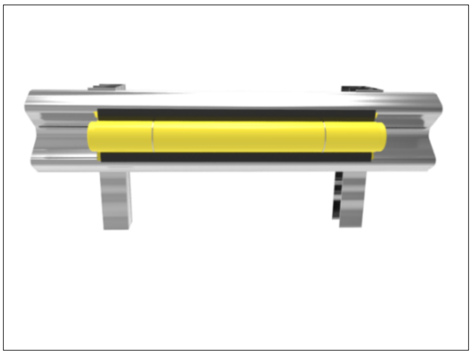


Figure 4: Front View.

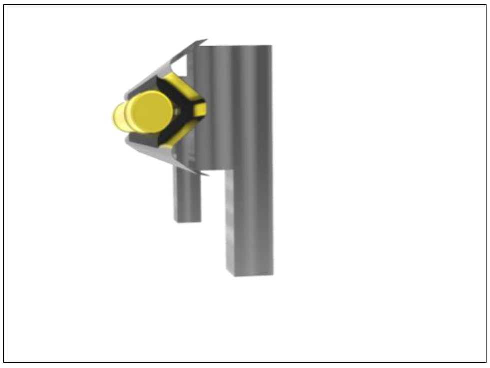


Figure 5: Side View.

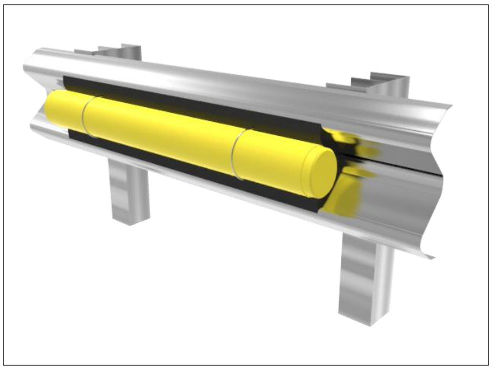


Figure 6: Isometric View.

4.0 Data Analysis

Usability testing is helpful because it focuses on actual behavioral patterns and design solutions as opposed to solely relying on the assumptions and prescribed solutions by clients or designers [3]. Usability test is one of the important phases in the commercialization or patenting of a product. It is a phase which proves that the product is reliable to use and follows the objective through a concept idea. The Usability test for BOLER was conducted by the Malaysian Institute of Road Safety Research (MIROS) to replicate the frontal dolly impact test scenario in a smaller scale and condition. The test utilized the equipment and the service available at the laboratory facilities to suit the test method requirements on 23rd and 24th November 2016 at the Malaysian Institute of Road Safety Research Provisional CRASE Crash Centre Laboratory (MIROS PC3) Ayer Molek, Melaka (Service Provider).

The test was conducted by using a movable dolly which travelled on a straight path and impacted a test specimen at a designated speed at 90º angle. The specimen was mounted in a horizontal position on an offset rigid barrier block (Figure 6). All the equipment and tools for the tests were calibrated.

- Striker: Movable dolly with mass of 1212kg
- Speed detection: Laser speed meter, recorded at 1350mm before impact point
- Specimens:
  - 2 units Standard W-beam guardrail
  - 2 units BOLER
- Impact force measurement: Load cells embedded in a rigid offset barrier block (Make: Kyowa)

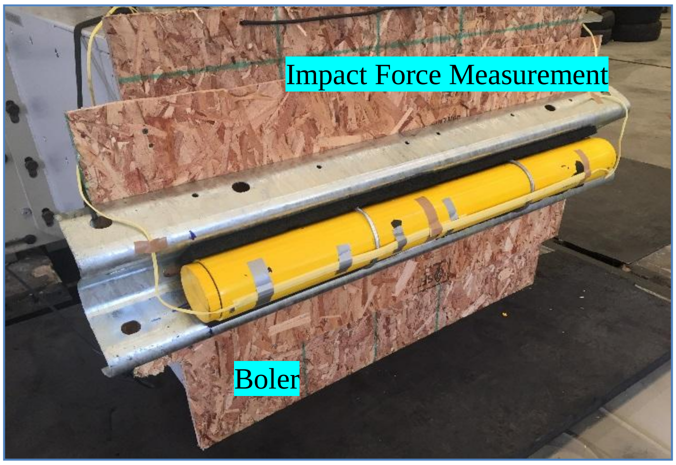


Figure 6 : The specimen was mounted on the rigid offset barrier block

The test specimen was mounted on the rigid offset barrier block (Figure 6). The block was embedded with load cells to measure the impact force experience by the W-beam guardrail. A movable dolly with mass of 1212kg (Figure 7), travelled in 23km/h were propelled towards the block.

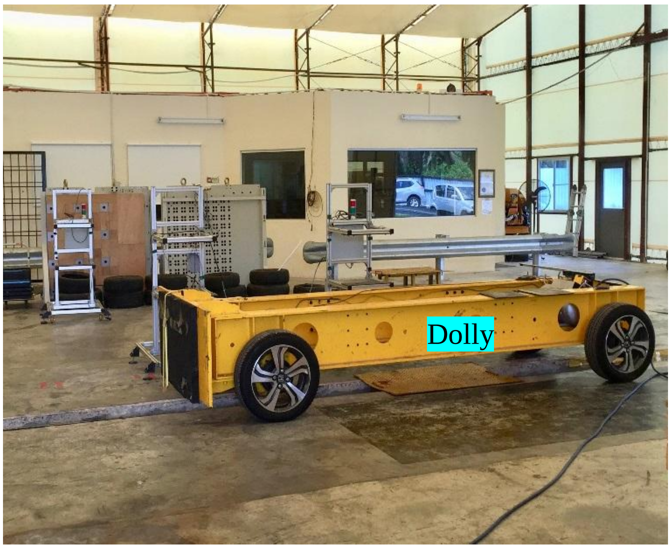


Figure 7 : Movable Dolly with mass of 1212 Kg

A sample of test specimen mounted offset on a barrier block was impacted by the movable dolly (Figure 7) (with pre-determined load) at a designated speed. First, the impact test was carried out on a one-unit Standard W-beam guardrail and the next on a one-unit BOLER (Figure 6) with the same speed and distance length travelled by the movable dolly with the same mass. Two specimens were tested for comparison and the results are summarized as follows:

Table 2: Peak force and time at peak

Specimen Number	Name Of Specimen	Specimen mass (kg)	Peak Force, (kN)	Time at Peak (millisecond)
1	Standard W-beam guardrail	12.5	51.5	21.4
2	BOLER *Product	29.5	47.6	32.8

The table clearly provides two important data that need to be evaluated which are Peak Force and time at peak. Peak force is the maximum force obtained from the whole impact taken for a full crash to completely occur. The time at peak is the differences in the time taken for the maximum peak force to occur on each of the specimen. The data showed the difference in the performance for the both specimens when they received the impact. The time unit used by the test is millisecond because the total time taken for the whole impact to fully occur was 0.06 second only. Thus, what happened in that specific time needs to be evaluated using the millisecond unit.

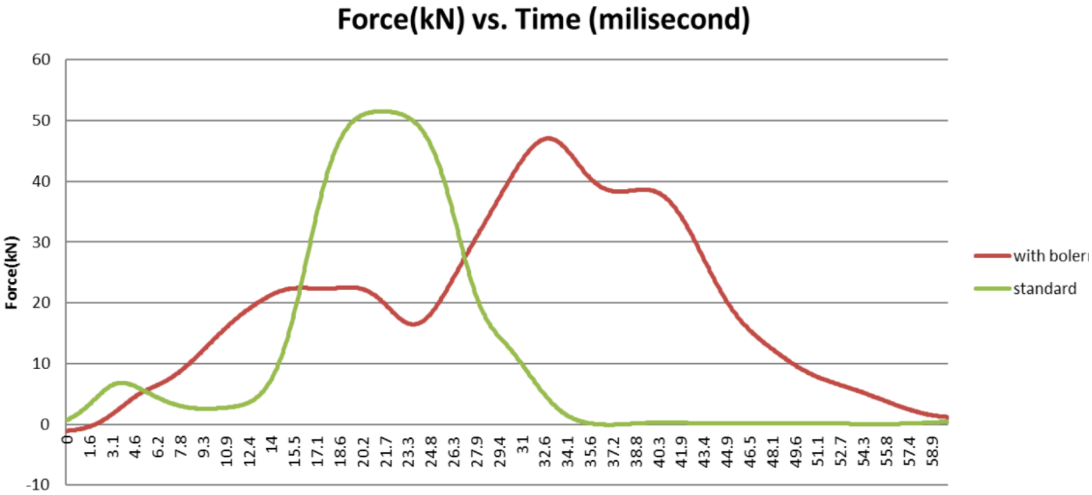
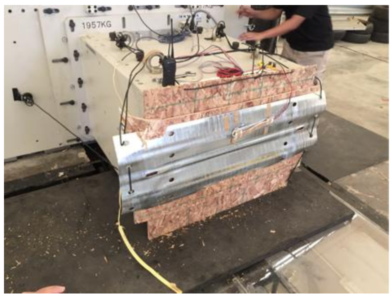


Figure 8 : Test result plot

Figure 8 indicates that maximum peak force time which occurred for the Standard W-beam guardrail is 21.4 milliseconds and for the BOLER is 32.8 milliseconds. This indicated the delayed time at peak force between the two specimens by 11.4 milliseconds. It can be concluded hence that the BOLER can delay the impact time of a crash by 34.76%. The maximum impact force for the Standard W-beam guardrail was 51.52 kN and for the BOLER, it was 47.06 kN. This showed a reduction of force by 4.46 kN. This proves the improved force absorption capability of the BOLER as compared to the Standard W-beam guardrail. Inflation deployment of airbag is an important element in saving lives. The full inflation of airbag will occur within 30 milliseconds [13]. Thus, the BOLER's delayed peak force which was 11.4 milliseconds can help to add to airbag's full inflation time before the maximum peak force by 62%. The condition of specimens before and after impact as shown in Table 3

Table 3: Condition of specimens before and after mmpact

Name Of Specimen	Pre-Test	Post-Test (After Impact)
Standard W-beam guardrail		
BOLER		

5.0 Conclusion

In conclusion, BOLER-Bolster Barrier is an innovation product that can enhance the safety of transportation system for highway and road users. From this investigation, it can be concluded that the existence of BOLER can help to boost the safety of road users by reducing the risk of severe accidents or fatalities. The descriptions of the product in this research in terms of the material used, its shape and the results of the usability test clearly revealed the significant advantage of this new innovative product. This indicates that the BOLER will provide a positive contribution to the society in terms of the safety aspect of the daily users in the transportation system.

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