

# Crash Investigation on Automobile vs. Crash Barrier: Assessment of W-Beam Guardrail with respect to REAM Standard

I. Abdul Hamid<sup>\*1</sup>, S. T. M. Syed Tajul Arif<sup>2</sup>, N. S. Mohd Zulkiffli<sup>2</sup>, R. Sarani<sup>2</sup>,  
M. S. Solah<sup>1</sup> and M. R. Osman<sup>1</sup>

<sup>1</sup>Vehicle Safety and Biomechanics Research Centre, Malaysian Institute of Road Safety  
Research (MIROS), 43000 Kajang Selangor, Malaysia

<sup>2</sup>Road Safety Engineering & Environment Research Centre, Malaysian Institute of Road  
Safety Research (MIROS), 43000 Kajang Selangor, Malaysia

*\*Corresponding author: iskandar@miros.gov.my*

## ORIGINAL ARTICLE

Open Access

### Article History:

Received  
1 Mar 2017

Received in  
revised form  
10 Apr 2017

Accepted  
19 Apr 2017

Available online  
1 May 2017

**Abstract** – Road traffic crashes involving longitudinal traffic safety barriers, especially W-beam guardrails, are not uncommon. This shows the importance of the guardrails in performing its functions. In Malaysia, installation of the guardrails are according to a guideline published by REAM in 2006. However, the compliance of the barriers installation to the standards can be further verified to ensure its quality and integrity. Site survey on the barriers shows that compliance to the standards are high if it is installed and maintained under the concession, e.g. by PLUS Expressways Berhad. However, there are some issues concerning installation of barriers if it is under custodian of local authorities. The parameters used to measure the compliance, among others, are installation ground condition, overlapping, post height, post spacing, clear zone, guardrail conditions and sub-standards installation. It is suggested to the local authorities to give more emphasis on the inspection of existing barriers, as well as maintenance and replacement of barriers. This is because the barriers will not perform according to its function as it is intended under non-reliable conditions. The outcomes of this study will provide the road transport related agencies on the real conditions of W-beam guardrails installed on roads in Malaysia.

**Keywords:** Automotive crash investigation, traffic safety barrier, W-beam guardrail, barrier installation, REAM

Copyright © 2017 Society of Automotive Engineers Malaysia - All rights reserved.  
Journal homepage: [www.journal.saemalaysia.org.my](http://www.journal.saemalaysia.org.my)

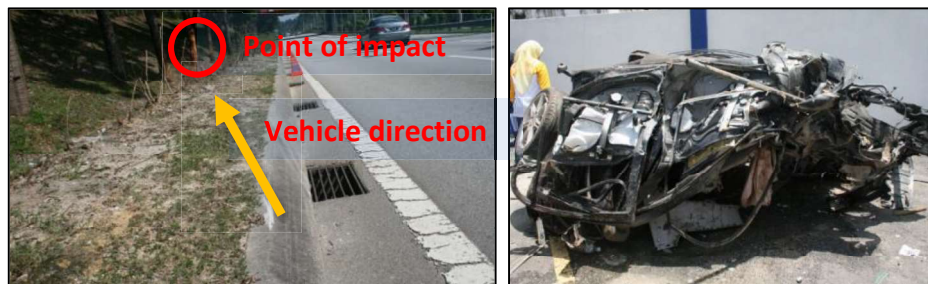
## 1.0 INTRODUCTION

Road traffic crash investigations on single-vehicle accidents or crashes (SVA) involving vehicles collided with road side objects, have long been conducted and discussed (Zainal Abidin et al., 2009). Among the typical findings highlighted on this type of crash are

unavailability of crash barriers (e.g. W-beam guardrail), barriers that were built or installed not according to the standard, or inappropriate barriers were installed at unsuitable locations. Case studies briefly discussed in the following sections show the importance of these issues to be handled carefully by relevant parties (Mohd Huzaifah et al., 2010). Review on some literatures were also made on W-beam guardrails, focusing on its installation and its suitability to play its role if being hit by various vehicles, e.g. passenger cars, buses and motorcycles. To assess the installation of the W-beam guardrail, a survey was made at various locations so the real installed W-beam can be compared with the available standard used.

### 1.1 Case Studies

Installation of longitudinal traffic safety barriers along the road sides and medians are very crucial. Unavailability of safety barriers expose the out-of-control vehicles to cross the road sides or median and hit the fixed objects or in coming vehicles from the opposite direction. Figure 1 shows photos from real crash investigation on a SVA involving a passenger car hitting the trees planted along the side of the road. This type of crashes may be prevented if the safety barriers were installed on the road sides.



**Figure 1:** Case study 1 – A passenger car experienced severe damage after hitting a tree

However, the availability of safety barriers may not serve its purpose if it is wrongly installed. Figure 2 shows a SVA involving a bus hitting a semi-rigid guardrail. The poor end-treatment caused the guardrail to pierce inside the lower deck of the bus, killing several people and injured many others.



**Figure 2:** Case study 2 – Semi-rigid guardrail piercing into a bus

In Figure 3, it shows the W-beam guardrail collapsed after being hit by a bus. Besides compatibility issue, other concerns like the barrier selection, installation procedure and the integrity of the guardrail can also be put into questions.



**Figure 3:** Case study 3 – A guardrail collapsed and failed to redirect the bus

The above crashes show the importance of safety barriers, and at the same time, it must be installed correctly according to standard requirement. The aim of this paper is to assess the condition of safety barriers installed at Malaysian roads and how much does they comply with the available safety standard and specifications. As the most common longitudinal barrier used along the road side in Malaysia is W-beam guardrail, this study is limited only to this type of barrier.

## 1.2 Literature Review

The review discussed the standard used for W-beam installation, previous assessments made on few aspects of W-beam potential hazards if wrongly installed, and the ability of W-beam guardrails to withstand impact by vehicles like buses and motorcycles.

There are various types of guardrail available globally. In Malaysia, W-beam guardrail is mostly used as roadside and median barriers. The guardrail installation criteria are highlighted in the guideline published by REAM (Guidelines on Design and Selection of Longitudinal Traffic Barrier, REAM-GL 9/2006). Guardrail system need to be installed correctly at site according to the standard, so it can function as intended, e.g. absorbing the energy from the crashing vehicle. W-beam guardrail is a semi-rigid barrier because it deflects substantially but not excessively under U.S. standard structural adequacy crash test (REAM, 2006). The guideline provides details on various type of barrier including concrete barrier, W-beam guardrail and wire rope safety fence. As this study focuses only on W-beam guardrail, several installation requirements of this guardrail will be highlighted according to the guideline.

Mohd Huzaifah et al. (2010) determine the frequency and probability of encountering hazards at curves specifically focusing on guardrail posts installation and road pavement height difference between both travelling directions. It also assesses and analyses the end treatments of roadside crash barrier, median barrier and bridge barrier. The result shows that the probability for a road user to encounter a hazard curve for urban and major expressways are about one, while rural area is about three times for every 10 km travelled, respectively. It also shows that the probability for a road user to encounter end treatment hazards for roadside barrier and bridges are 1.47 km travelled for major expressways, followed by rural expressways (1.09 km) and urban expressways (0.7 km).

A crash investigation using finite element method in a study by Marzougui et al. (2007) on the effect of rail height on the safety performance of G4(1S) W-beam guardrail systems show that by reducing the height of the guardrail for as little as 40 mm could hinder the ability of the barrier to redirect pickup trucks and large SUVs.

For a vehicle with higher centre of gravity (CoG), Aqbal Hafeez et al. (2012) revealed that for areas which are known to have a history of bus-rollover accidents, concrete barriers which can withstand a crash energy of TL-4 (Test Level 4) and up to TL-6 should be considered for installation, as rigid barriers perform better than semi-rigid barriers in preventing rollover of high-deck buses during collisions with traffic barriers. This is supported by Cortese & Gazzaniga (2015), where the safety barrier systems were tested in finite element environment. The results show that the semi rigid barrier seems able to restrain the errant bus, but the barrier deflection is so high that the vehicle invades the opposite traffic lane. The aged bus with deteriorated strength can further worsen the bus rollover results (Iskandar et al., 2013).

Study by Ibitoye et al. (2004) concluded that the W-beam guardrails are not adequately designed to prevent run off crash involving motorcycles since it was not considered as a test vehicle during the design of guardrail.

From the above literature reviews, it can be concluded that the standard semi-rigid guardrail like W-beam is not suitable for vehicles like buses and motorcycles. It may not function properly if wrongly installed or poorly maintained. Therefore, it is important to relook into its installation conditions and compare it to the available standards. Some aspects of comparison used in the study is explained in the following section.

## 2.0 METHODOLOGY

All data collected about guardrails were based on observations at site. W-beam guardrails are commonly installed on Malaysian road, therefore cluster sampling based on the area where the guardrails were installed was used. There were six types of area identified expressway/highway, highlands, city/urban area, seaside, rural area, and industrial area

Observations were carried out on each of the area above. For each area type, several sites were sampled and the distance between each site was at least 5 km. The locations selected by area type is tabulated in Table 1 below.

**Table 1:** Survey locations

Area	Locations
Expressway/highway	PLUS
Highland	Cameron Highlands
City/urban area	Kajang city
Seaside	Pantai Puteri, Melaka
Rural area	Kampung Duyong, Melaka
Industrial area	Sunpower Factory, Alor Gajah

During data collection, the team observed the selected sites and record the findings. At the same time, the team members measured the geometry of the guardrail, observed the installed guardrail conditions and took pictures of the guardrail. Several variables were noted during data collection. In general, there are six variables surveyed at sites which are:

- a) Installation ground condition
- b) Guardrail overlapping



- c) Post height of guardrail
- d) Post spacing of guardrail
- e) Clearance behind the guardrail
- f) Substandard issues

Each of the variable above will be further discussed in the next section.

### 3.0 RESULTS AND DISCUSSION

This section summarizes the W-beam guardrail installation conditions in terms of post ground condition, overlapping issues, guardrail post height, post spacing, rear guardrail clear zone and guardrail substandard issues.

#### 3.1 Post Ground Condition

At survey locations, many posts were found installed according to the standard as mentioned earlier. Figure 4(a) indicates the post was installed in the soil to allow it to bend and deflect, whereas Figure 4(b) shows the stiffened W-beam post by concrete. This is because there was a rigid object located less than 1.0m behind the guardrail.



**Figure 4:** (a) Post installed in the soil; (b) Post was stiffened by concreting it

However, survey carried out at rural area found several posts without being concreted even though the rigid objects, e.g. gantry signs, were placed less than 1.0 m behind it (Figure 5). If the vehicle hit the guardrail, it would deflect more and may hit the gantry signs.



**Figure 5:** Fixed object is placed less than 1.0m behind pole without concrete

#### 3.2 Guardrail Overlap

Guardrail panels will be overlapped to join two or more panels. The overlap direction is critical for a safe function of the guardrail. Guardrail could pierce into vehicle compartment if improperly overlapped. Guardrails were found correctly overlapped for all sites except one location at seaside area, where guardrails were found wrongly overlapped (Figure 6). According to the standard, the rails of the incoming direction must be at the front of the next rail. This practise is to avoid ‘spearing’ condition if the overlapping is wrongly installed. This is when the vehicle hitting the first rail while the second rail, be at the front lap, intrude into the vehicle.



**Figure 6:** Wrong overlapping

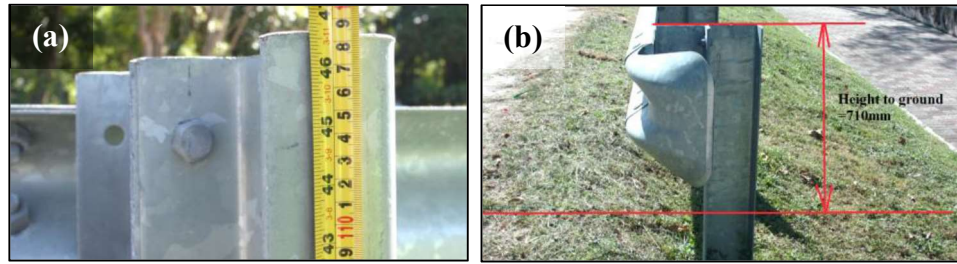
### 3.3 Guardrail Post Height

Based on REAM (2006), the standard guardrail height is 710 mm (plus minus 20 mm). So the tolerance is in between 690 mm to 730 mm. From the results as in Table 2, it can be said that part of the guardrails installed in five locations are not in the specified heights as per standard, except for industrial area where its minimum height is within the tolerance.

**Table 2:** Guardrail heights at the surveyed locations

Location	Minimum height (mm)	Difference from standard (mm)	Percentage difference from the standard (%)	Maximum height (mm)	Difference from standard (mm)	Percentage difference from the standard (%)
Expressway/highway	642	-48	-7.0	795	65	8.9
Highland	642	-48	-7.0	795	65	8.9
City/urban area	685	-5	-0.7	762	32	4.4
Seaside	483	-207	-30.0	1185	455	62.3
Rural area	610	-80	-11.6	885	155	21.2
Industrial area	700	10	1.4	800	70	9.6

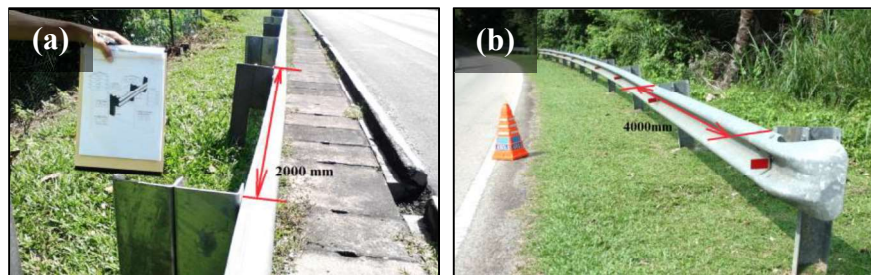
However, if height to ground is considered, many of these guardrails can be considered installed within the tolerance because the ground height (road surface) is usually higher than the post ground. Figure 7(a) shows the post height at the seaside is 1850 mm, but its ground height as shown in Figure 7(b) is 710 mm.



**Figure 7:** (a) Post height is 1850 mm; (b) Height to ground is 710 mm

### 3.4 Post Spacing

Post spacing depends on the design speed of the road. For expressway, the allowable maximum speed is 110 km/h. Referring to the REAM (2006), for design speed of more than 90 km/h, it is recommended to use TL-3 containment level. For the design speed of less than 90 km/h, the recommended containment level is TL-2. For TL-2, the spacing is 4000 mm while for TL-3, the spacing is 2000 mm. From the survey, it was found that all of the post spacing is in accordance with the standard (Figure 8(a) and (b)).



**Figure 8:** (a) TL-3 with 2000 mm spacing; (b) TL-2 with 4000 mm spacing

### 3.5 Guardrail Clear Zone

Based on REAM (2006), about 0.6 to 1.0 m clearance is required at the back of the guardrail. Adequate clear zone is vital to ensure that an impacting vehicle will not crash into the hazard with the consequence of injury to the occupants. At the highway, most of the areas provide sufficient clear zone (Figure 9(a)). Only some of the locations where the gantry signs are placed less than the minimum clearance (Figure 9(b)).



**Figure 9:** (a) Clear zone > 1000 mm; (b) Clear zone < 1000 mm

At the highlands, it was found that many guardrails are installed with adequate clear zone. A few cases, like in Figure 10(a), the clear zone is inadequate for drainage, however the posts



have been concreted, hence comply to the standard. In Figure 10(b), pipelines were laid behind the non-standard guardrail and this is not following the clear zone requirement. At seashores, sufficient clear zone is provided as shown in Figure 11.



**Figure 10:** (a) Posts are concreted as  $< 1000$  mm; (b) Pipeline behind the drainage clear zone guardrail with clear zone  $< 1000$  mm



**Figure 11:** Good clear zone at seaside

At rural areas, clear zone was narrow because of space limitations. Figure 12 shows the trees behind the guardrails. Clear zone is critical, especially in rural areas where the space is limited and occupied by trees. Other typical obstacles are poles, gantry signage, street lights, etc. Under such conditions, the posts are recommended to be made stiffer (concreted) as stated in REAM (2006).



**Figure 12:** Rural areas have inadequate clear zone

### 3.6 Guardrail Substandard Issues

This subsection discusses four substandard guardrail issues found at survey locations represented by timber posts, non-standard posts and objects placed at the front of guardrail. In



REAM (2006), it was stated that spacers and posts are generally constructed from steel. Concrete posts and timber posts are not favoured because of poor impact performance. However, timber posts were found at city area as depicted in Figure 13. The use of timber posts as in this case may refer to other standards, but as far as the authors are concerned, it is not applicable in Malaysia.



**Figure 13:** Timber posts were installed and used at the city

Figure 14 shows non-standard posts used to hold the rail. This square-shaped posts may be used to accommodate the limited space between the post and the blue pipeline stretched behind the guardrail, as the standard post is wider in size. It is unknown whether this practice is tested and acceptable, and it requires further research to verify the practice.



**Figure 14:** Non-standard posts were used to hold the rail

The third issue is objects located in front of the guardrail. The examples are concrete drain and signage. REAM (2006) states that concrete drains need to be a minimum of 600 mm of earth behind the post, as the guardrail requires lateral earth pressure to allow it to bend and deflect. However, it was found at rural area that the concrete drain is at the front of the guardrail (Figure 15). With this substandard installation, the run-off-road vehicles may fall in the drain before it hit the guardrail. This will make the height of the vehicle, especially passenger cars, to be incompatible to the height of the rail. Hence, this creates a greater risk for the rail to hit the passenger's head instead of the door.

It was found in the survey that some fixed object, e.g. signage was placed at the front of the guardrail (Figure 16). The space at the front of the guardrail should be left clear to allow smooth vehicle deflection in case a crash happened. According to REAM (2006), this is considered as an obstacle and it should be removed or relocate, or be made a breakaway (having

a slip-base), or should be shielded. In this case, it seems none of the recommendations applied. In the case of accident, the vehicle will hit the signage and guardrail will not function properly.



**Figure 15:** Concrete drain at the front of guardrail installed at rural area



**Figure 16:** Signage is placed in front of guardrail

### 3.7 Overall Discussion

The study is more towards qualitative assessment rather than quantitative, as quantitative study requires much more data to be collected at survey locations. All of the discussed issues are examples that were found during the survey. These issues show several possibilities: (i) monitoring of newly installed objects, e.g. pipeline, signage, gantry signs, etc. were not being properly made; (ii) how guardrails are functioning are not well understood; and (iii) guidelines for installing guardrails are not strictly being followed. Wrong installations, substandard issues, non-compliance with standards, etc. are the issues related to insufficient knowledge and understanding of the purpose and function of guardrail. Authorities, contractors, subcontractors and repair crews may not fully have trained and informed of the basic guardrail design, guidelines and procedures. It is not only the matter of level of working knowledge of the system, but understanding the environment and surrounding areas are also critical factor requires close attention.

With regard to the maintenance aspect, it was found that the guardrails installed along expressways or highways under concession are having less issues compare to guardrails installed at other locations. This is because concessionaires are obliged to the contract requirements or else they may face penalties by the client (government). Furthermore, with high revenues, they are capable to do excellent guardrail maintenance and inspection jobs by a dedicated professional team. Guardrails installed at locations other than expressways or

highways are maintained by the government bodies or agencies, or local authorities. The number of guardrails under these authorities are huge and managed by multi-layers of management and technical teams. The budget is also crucial as other priorities are also being considered. Therefore, it is expected that the level of maintenance and inspection jobs on the existing guardrails by the authorities are not the same as the one under concessionaires.

#### **4.0 CONCLUSION**

The study attempts to compare the standards and guidelines used to install and maintain the W-beam semi rigid guardrail with the actual guardrail along the Malaysian roads. The installations and maintenance of guardrails at sites show some discrepancies when compared to the standard, i.e. REAM – GL 9/2006. Little issues were found with guardrails installed along the road under responsibilities of the concessionaires. However, much more issues were found with the guardrails along the road under local or federal authorities. Critical issues like sub-standards, post height and clear zone require immediate attention by respected parties as this issues directly reduce the ability and functions of the guardrail.

#### **5.0 RECOMMENDATIONS**

Several recommendations are highlighted to improve the installation, inspection and maintenance of guardrails, as follows:

- (i) It is recommended that crash testing facilities and standards like Manual for Assessing Safety Hardware (MASH) (Sicking, 2009) or NCHRP report 350, “Recommended Procedures for the Safety Performance Evaluation of Highway Features” are made available in Malaysia. The availability of facilities like this will enhance the knowledge and understanding of safety barriers purpose, design, functions, installation, etc. This is especially for designers, engineers, contractors and to the general public. Consequently, this will reduce issues, e.g. sub-standard, wrong installation, non-compliance to the standards, etc.
- (ii) A dedicated and sufficient maintenance and inspection teams are created to ensure the installed guardrails always comply with the standard and guideline requirements. All inspection and maintenance works, e.g. routine maintenance, collision maintenance and material and storage requirements as stated in the standard must be properly scheduled, executed and monitored regularly to ensure the guardrails are at its required conditions.
- (iii) Any defect or damaged guardrail should be reported immediately by the public to the authority so that replacement of the guardrails can be conducted quickly.

#### **REFERENCES**

- Aqbal Hafeez A., Mohd Khairudin R., Mohd Syazwan S., Khairil Anwar A.K., & Wong S.V. (2012). *Stability of high-deck buses in a rollover and contact-impact with traffic barriers* (MRR 01/2012). Kuala Lumpur: Malaysian Institute of Road Safety Research.
- Cortese, M., & Gazzaniga, M. (2015). *Numerical approach to assess critical installation of vehicle restrain systems* (Master’s thesis). Polytechnic University of Milan, Italy.

- Ibitoye, A.B., Radin Umar R.S., Wong S.V., & Hamouda, A.M.S. (2004). *Safety performance evaluation of W-beam guardrail along exclusive motorcycle lane*. Paper presented at Malaysian Universities Transport Research Forum Conference (MUTRFC), Shah Alam, Malaysia.
- Iskandar A.H., & Li, Q.M. (2013). *Ageing Effect on crashworthiness of bus rollover*. Paper presented at 9<sup>th</sup> European LS-DYNA Conference, Manchester, UK.
- Marzougui, D., Mohan, P., Kan, C.D., & Opiela, K.S. (2007). *Evaluation of rail height effects of the safety performance of W-beam barriers*. Virginia: National Crash Analysis Center, The George Washington University.
- Mohd Huzaifah M., Muhammad Marizwan A.M., Alvin Poi W.H., Ahmad Noor Syukri Z.A., Mohd. Hafzi M.I., Sharifah Allyana S.A.R., Iskandar A.H., & Wong S.V. (2010). *Assessment of crash barriers and roadsides hazards along Malaysian Expressways*. Kuala Lumpur: Malaysian Institute of Road Safety Research.
- REAM (2006). *Guidelines on design and selection of longitudinal traffic safety barrier*. Shah Alam: Road Engineering Association of Malaysia.
- Sicking, D.L., Mak, K.K., Rohde, J.R., & Reid, J.D. (2009). *Manual for assessing safety hardware*. Washington, DC: American Association of State Highway Transportation Officials.
- Zainal Abidin, A.N.S., Abdul Rahim, M.M., Wong S.V., & Radin Sohadi, R.U. (2009). *Single-vehicle accidents involving trees in Malaysia – A preliminary study* (MRR 12/2009). Kuala Lumpur: Malaysian Institute of Road Safety Research.