PERFORMANCE ASSESSMENT OF CRASH BARRIERS USED IN ROAD SAFETY: A CASE STUDY OF MALEKHU KURINTAR SECTION OF THE PRITHVI HIGHWAY

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Abstract

Hill roads in Nepal are comprised of critical geometry and limited roadway clearances. It causes high number of runoff roadway type of accidents with single vehicle. These accidents often carry huge number of fatalities and severe injuries. Installation of crash barriers is the most effective way of preventing such accidents along hill roads. However, the existing practice of construction of crash barriers does not show the satisfactory results. Therefore, this research aimed at the evaluation of typical crash barriers constructed along the valley side of highway. Analysis of the road accident of Malekhu-Kurintar section of Prithvi Highway record shows that this section has relatively higher accident rate and most of the accidents are runoff roadway type. Further, these accidents are mainly caused due to either the absence or the failure of the crash barriers along the valley side of the highway. On the basis of field records, kinetic energy absorbed by the crash barriers and their deflections was investigated by application of computer based analysis tool ABAQUS V6.10. It has given satisfactory results on the deflection of W-beam and plum concrete barriers due to the impact of vehicle moving in various range of speed.

Keywords: Crash barriers, Runoff roadway, W-Beam, Plum concrete.

1. Introduction

Nearly 1.3 million people die globally from Road Traffic Accidents (RTA) annually or more than 3000 on a daily basis. In addition, 20-50 million people are injured causing disabilities. About 90 percent of fatalities from road traffic accident occur in low and middle-income countries that have less than half of the world’s registered vehicle. Road traffic injuries are one of the main causes of death for people between the age of 15 to 44 years and results in a huge economic loss to countries worldwide (MoPIT, 2013). Studies show that the global loss to be over US$ 500 billion and between 1% to 3% of the gross national product of the respective countries. It is estimated that the number of deaths from road accidents in Asia is about 700,000 per year, accounting for more than half of the world's road fatalities. By 2020 it is estimated that two thirds of the world's road fatalities will occur in Asia. In addition, with increasing motorization worldwide, road traffic injuries are predicted to be the fifth leading cause of death around the world unless immediate, middle and long term interventions are not taken (WHO, 2012).

Road accidents are increasing in Nepal due to increased vehicle fleet and speed. As per the Traffic Directorate of Nepal Police Headquarter, the total number of accidents during the fiscal year 2012/013 A.D. are 13,582. Out of which 1,816 fatalities, 3,986 serious injuries and 8,000 slight injuries occurred. The fatality ratio of passengers and pedestrians per 10,000 vehicles is 11.57 (Thapa, 2013). That means road traffic accident is a serious problem in Nepal.

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2. Methodology

2.1. Introduction

This research is to carry out the performance assessment of crash barrier under vehicle impact. Road traffic accident data of the Malekhu-Kurintar section of the Prithvi highway were collected from the District Traffic Police Office at Gajuri. The data of the year from 2007 to 2014 A.D. were compiled and the most accident occurring locations are identified. Speed measurement of the vehicles was carried out by using radar gun as speed is the major factor affecting the accident rate. The major causes of road accident, different types of accident were also identified. The different types of crash barriers were studied and its dimensions and photographs were taken. The parameters of vehicle were collected from different secondary sources. Finally the performance of the crash barriers was assessed by using finite element analysis software ABAQUS V6.10. This is very useful tool for problem with complicated geometries, loading, and material properties. Some other general finite element software available in the market includes: ALGOR, ANSYS, MADMO, NASTRAN, LS-DYNA and more.

2.2. Study Area

The study area is the Malekhu-Kurintar section of the Prithvi Highway (33 km from Malekhu to Kurintar).

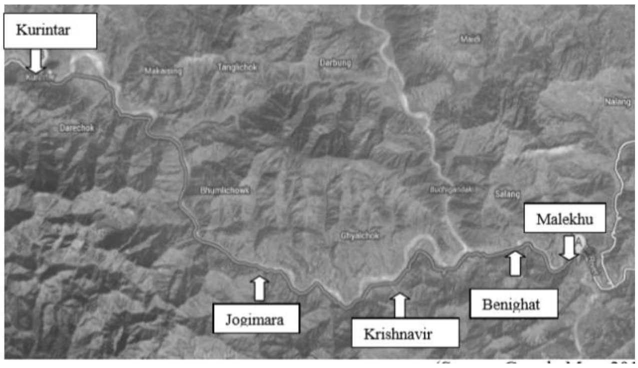


Fig.1 Study Area *(Source: Google map, 2014)*

2.3. Method of Data Collection

The traffic accident data of the year 2007 to 2014 is collected from DTPO at Gajuri. Different types of the crash barriers are also studied by field observation. The dimensions of the barriers and speed of the vehicles are measured in the field for simulation. The speed of different types of the vehicles is measured by radar gun.

2.4. Data Analysis

The analysis of the data is done by FEM analysis software ABAQUS V6.10 using computer simulation. The parameters required for the modeling in ABAQUS V6.10 are shown in Table 1, Table 2 and Table 3.

Table 1: Dimension of Vehicle

Parameters	Truck
Height (m)	4.65
Width (m)	2.50
Length (m)	12

(Source: MoPIT, 2013)

Table 2: Variables for Analysis in ABAQUS V6.10

<table>
<tr><td rowspan="2">Variables parameter</td><td>Speed of vehicle (kmph)</td><td>Angle of impact (°)</td></tr>
<tr><td>Speed range from 40 to 80</td><td>1 to 30</td></tr>
<tr><td rowspan="2">Fixed parameter</td><td>W-beam barrier</td><td rowspan="2">Material thickness, length, width, height</td></tr>
<tr><td>plum concrete barrier</td></tr>
</table>

Table 3: Material Description

Parts	Material	Density (kg/m³)	Poisson Ratio	Young Modulus(Pa)
W-beam Barrier	Galvanized Steel	7860	0.3	200x109
Plum Concrete Barrier	stone with plum concrete	2700	0.3	600x105

(Source: Material Properties, 2014)

2.5. Computer Simulation

Finite element crash worthiness simulations were performed for truck as it is most frequent vehicle involved in accident. The gross weight of the truck is 8000kg and dimension of the vehicle is given in Table 3.Two types of crash barriers (W-beam barrier and plum concrete barrier) and vehicle are modeled in the ABAQUS V6.10. The crash barriers are modeled as deformable type and solid feature while the vehicle is modeled as discrete rigid and shell feature. The material properties are assigned and different parts are assembled. The analysis step is assigned, the interaction properties are defined with contact behavior and contact parts. Loads and simulation time for analysis are assigned. The models are divided into finite elements by assigning mesh properties and analysis is done. The result is based on the energy absorption of the barrier and deflection upon impact. The energies are kinetic energy and internal energy. Kinetic energy is dependent on the mass and velocity of the vehicle whereas the internal energy is dependent on the material properties of the crash barriers such as density, Young's modulus of elasticity, Poisson's ratio, coefficient of friction, etc. For the simulation of the model, the velocities of the vehicle and impact angle are two parameters. The random numbers for the velocity are taken from 40kmph to 80kmph and the impact angles are taken from 1° to 30°. The different combinations of the velocities and impact angles are shown in the following scatter diagram of Fig.2. The diagram shows fifty combinations of speed and angle of impact.

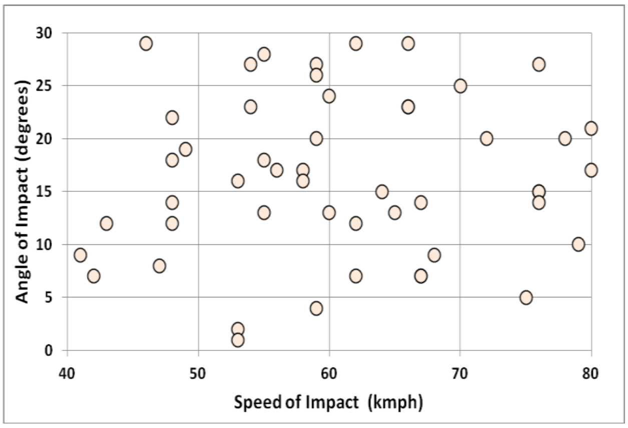


Fig.2 Scatter Diagram of Speed and Angle of Impact

3. Result and Discussion

3.1. Accident Data of the Study Area

The accident data of the year 2007 to 2014 A.D. was collected from the District Traffic Police Office, Gajuri. Fig.3 and Fig.4 show total accident and runoff roadway accident data from 2007 to 2014.

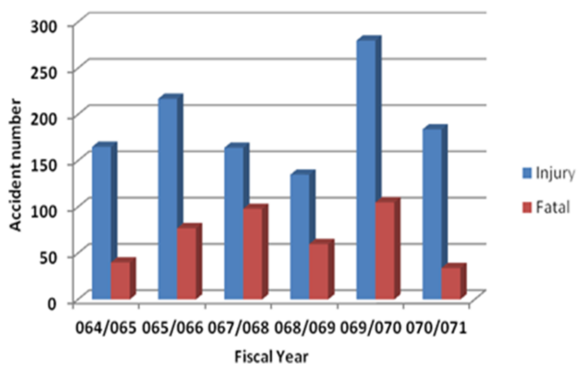


Fig.3 Total Accident of the Study Area
(Source: DTPO, 2014)

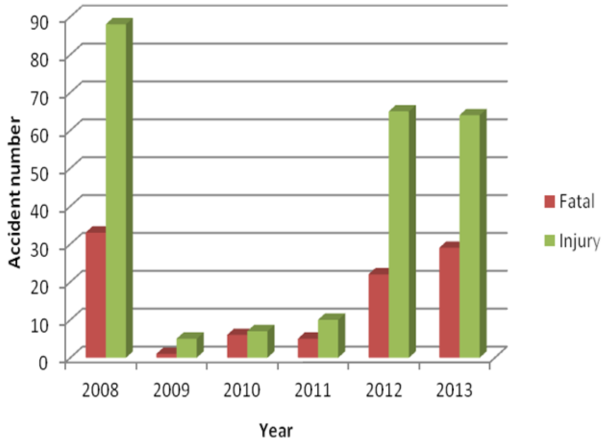


Fig.4 Total Runoff Roadway Accident

3.2. Accident Based on Vehicle Type

The major accident locations as per the data collected from year 2007 A.D. to 2014 A.D. are Benighat, Krishnavir and Jogimara. The accident percentage of these locations are shown in Fig. 5.

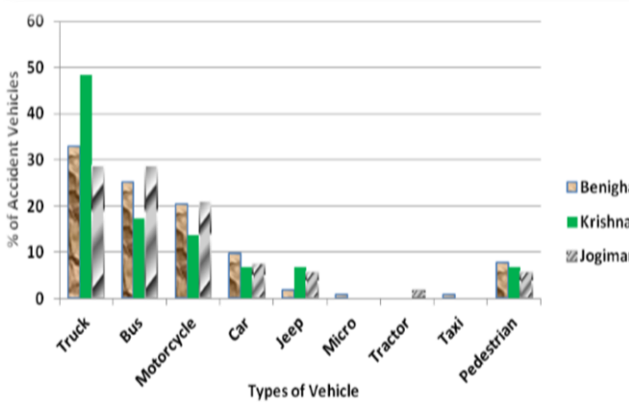


Fig.5 Accident Based on Vehicle Type
(Source: DTPO, 2014)

3.3. Types of Accident

The percentage of different types of accident of Malekhu-Kurintar section of the Prithvi highway is shown in Fig. 6. From this figure, it can be said that the most common type of accident is runover roadway accident.

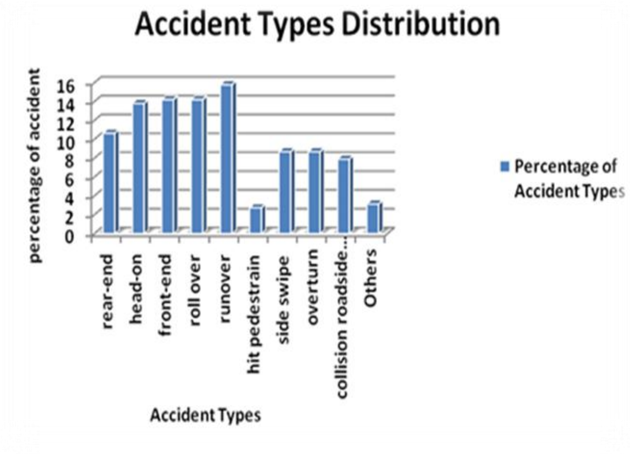


Fig.6 Types of Accident *(Source: DTPO, 2014)*

3.4. Main Causes of Accident

The total numbers of accident based on different causes are shown in Fig.7.

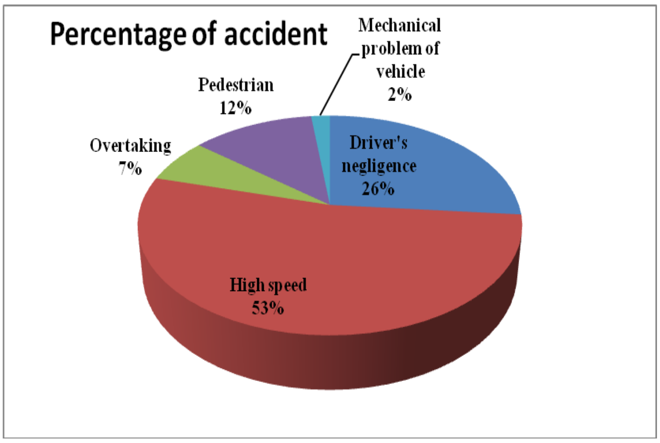


Fig.7 Causes of Accident *(Source: DTPO, 2014)*

The various causes of the accident in the highway are high speed (53%), driver's negligence (26%), pedestrian fault (12%), overtaking (7%) and mechanical problem of vehicle (2%). The result showed that the major cause of accident along Malekhu-Kurintar section of the Prithvi Highway is high speed (53%). As the road is open in the highway, driver tends to drive higher than the speed limit. The speed limit of the highway is 60kmph but by speed measurement, the speed is found to be above 80kmph. So, most of the accident occur due to high speed.

3.5. Comparison of Efficiency of Crash Barriers

The comparison of efficiency of crash barriers is shown in Table 4.

Table 4: Comparison of Efficiency of Crash Barriers

Type of crash barrier	Kinetic Energy (KJ)	Internal Energy (KJ)	Deflection (m)	Efficiency	Remark
W-beam barrier	1937.99	1210	0.341	62.40%	at 21° and 80kmph
Plum concrete barrier	1936.39	890	0.229	45.96%	at 21° and 80kmph

So, efficiency of the W-beam barrier is more than the plum concrete barrier in terms of internal energy and deflection.

3.6. Comparison of Deflections of Crash Barriers

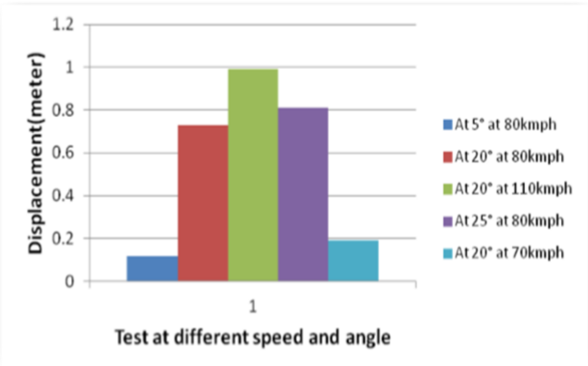
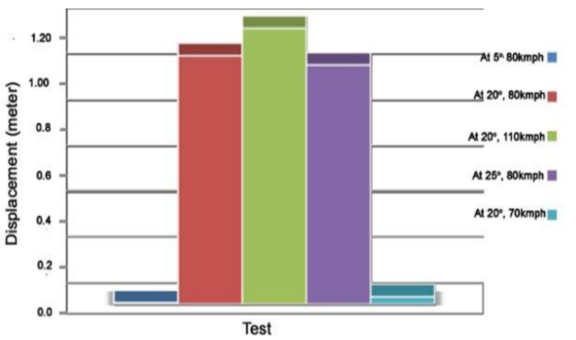


Fig.8 Maximum Deflection of W-Beam Barrier



(Source Shaedi, 2012)

Fig.9 Maximum Deflection of W-Beam Barrier by Shaedi

The above Fig. 8 and Fig. 9 show the deflection of W-Beam Barrier at different angles and speed by using Finite Element Analysis (FEM) software ABAQUS V6.10. The maximum deflection by Shaedi, 2012 is 1.1m and by experiment is 0.91m. The standard deflection is approximately 1.2m. This shows the validation of the result.

4. Conclusion

The research work deal with the study of different types of accidents, causes of accident, various types of crash barrier and performance of the barriers in terms of energy absorption and deflection. The analysis is done by using finite element software ABAQUS V6.10. and the result is based on the amount of energy that can be absorbed by the crash barriers under impact crash. Hence, improvement can be applied in the future to the present crash barriers and will reduce the severity of injury to vehicle occupants upon impact in road accidents involving crash barriers.

The computer simulation of crash barriers was done by using FEA software, ABAQUS V6.10. The efficiency of the crash barrier is given in terms of energy absorption behavior. The efficiency of the barrier is maximum at high velocity and high impact angle and minimum at low velocity and low impact angle. The efficiency of Plum concrete barrier is 45.95% and W-beam barrier is 62.40%. This shows that the efficiency of the W-beam barrier is more than plum concrete barrier in terms of energy absorption. Similarly, comparing the deflection of the crash barriers, the maximum deflection of the plum concrete barrier is 0.229m and W-beam barrier is 0.341m. So, the deflection criteria of W-beam barrier are more than plum concrete barrier. So, considering all criteria, the performance of W-beam barrier is better than plum concrete barrier.

For the calibration of the model, the data used by the previous researcher Shaedi ,2012 is used in this research work and the validation of the test shows the deviation is only 22.75% in terms of energy and 0.91m in terms of deflection. So, it concludes that the test done in ABAQUS V6.0 is similar to the test in ABAQUS V6.10.

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