

# The Effect of ASI (Acceleration Severity Index) to Different Crash Velocities

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**Abstract-** Vehicle crash can causes severe injuries to the occupant of the vehicle. These injuries can be measured. The injury measurement is intended to insure minimum safety levels in severe crashes. There are several types of injury measurement such as ASI, HIC, THIV and TTI. This paper presents a numerical simulation of a light vehicle impacted to a curved roadside safety barrier and the ASI (Acceleration Severity Index) analysis of the occupant. The W-beam barrier and road model was developed using CAD software (Solidworks) and simulated using FEA software LS-DYNA.

Three crashes were performed with three types of velocities applied to the light vehicle. Based on the crashed that was performed the ASI value was calculated to evaluate injuries of the occupant. From the simulation it has been found that due the higher velocities the ASI value also increases.

**Keywords-** Safety barrier, Impact, Simulation test, ASI

## I. INTRODUCTION

Many problems are still occurred in road transportation, one of the problems is to make a better road restraint system so it can achieved an adequate safety level for road users. To achieved this goal several research and testing are being performed by many researchers including the American (NCHRP report 350) and European Committee (EN). These committees have been doing research for road restraint system for a long time and have done many improvements. For highway and road, roadside safety barrier have been developed for safety reasons.

To provide appropriate safety levels for impacting vehicle occupants, the safety barriers should be designed to absorb as much impact energy as possible through their deformation and at the same time maintain their integrity [1]. The typical roadside safety are concrete, steel and cable barriers. Each type has different characteristics. For instance, the steel barrier is less stiff than the concrete barrier, this means that it will deflect much more than the concrete barrier and absorbs more energy from the crash.



Fig. 1. Typical steel roadside safety barrier

When a crash condition occurred between a vehicle and a roadside safety barrier it can causes injuries to the occupant and damage to the vehicle. Injuries to the occupant can be measure utilizing ASI (Acceleration Severity Index).

## II. THE ASI (ACCELERATION SEVERITY INDEX)

The index ASI is intended to give a measurement of the severity of the vehicle motion during an impact for a person seated in the proximity of point P [2]. The acceleration severity index (ASI) [3], is a function of time, computed with the following formula:

$$ASI(t) = \left[ \left( \frac{\bar{a}_x}{\hat{a}_x} \right)^2 + \left( \frac{\bar{a}_y}{\hat{a}_y} \right)^2 + \left( \frac{\bar{a}_z}{\hat{a}_z} \right)^2 \right]^{\frac{1}{2}} \quad (1)$$

Where  $\bar{a}_x$ ,  $\bar{a}_y$ , and  $\bar{a}_z$  are the 50-ms average components vehicle accelerations and  $\hat{a}_x$ ,  $\hat{a}_y$ , and  $\hat{a}_z$  are corresponding threshold accelerations for each component direction. The threshold accelerations are 12 g, 9 g, and 10 g for the longitudinal (x), lateral (y) and vertical (z) directions, respectively [2].

$$\begin{aligned}\bar{a}_x &= \frac{1}{\delta} \int_t^{t+\delta} a_x dt; & \bar{a}_y &= \frac{1}{\delta} \int_t^{t+\delta} a_y dt; \\ \bar{a}_z &= \frac{1}{\delta} \int_t^{t+\delta} a_z dt\end{aligned}\quad (2)$$

The ASI only utilizes vehicle accelerations. The ASI assumes that the occupant is continuously contacting the vehicle, which typically achieved through the use of a seat belt [4].

If maximum ASI value exceeds 1.0 in some cases, then it is considered that the consequences of an impact are dangerous or even lethal for the occupants of the impacting vehicle.

### III. ROADSIDE SAFETY BARRIER

The purpose of the road side safety barrier are to prevent the vehicle from veering off the road to restrain it from entering dangerous area to avoid or reduce injuries of the vehicle occupants and other traffic participants and objects [5].

Roadside safety addressed an area outside of the roadway and is an important component of the total roadway design. From the safety perspective, the ideal highway has roadsides and median areas that are flat and unobstructed by hazards [1].

Some elements could make a vehicle leaves the roadway such as slopes, water and other fixed object. These objects can be dangerous to the vehicle and occupants. Sometimes economic and geography factor do not allow an ideal highway conditions at the highway.

There are many types of roadside safety barrier, concrete barrier, steel/beam barrier and cable barrier. Each type has different shape and characterization. For instance steel barrier are less stiff than the concrete barrier so it can absorb much impact energy from the crash.

### IV. MODEL SIMULATION DESCRIPTION

The model from the simulation can be seen in figure 2. Three types of speed velocity applied to the vehicle. They were 40 km/hour, 60 km/hour and 80 km/hour, impact angle at 45° from the x axis. The barrier parts were draw using Solidworks software and some simplification has been used. An oblique impact simulation was performed using the FEA software LS-DYNA [6,7].

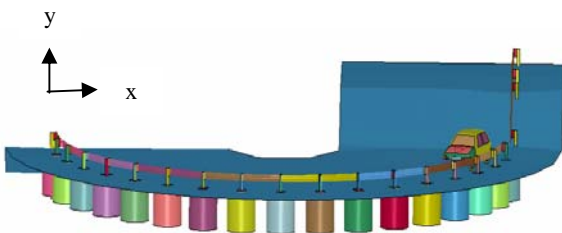


Fig. 2, Full model of the crash simulation

### A. The Vehicle Model

The vehicle model is a small vehicle obtained from the LS-DYNA example library it consists of 25 different parts, 6181 nodes and 4866 elements. The model is using solid (3D) and shell (2D) elements. Solid elements were used for the driver, engine, wheels, radiator, accelerator, hubs and passenger part and shell elements were used for the front cap, car body, glass, windows, floor, hood, bumpers, cradle, mounts and lights.

### B. The Safety Barrier Model

The safety barrier model is shown in figure 3. The safety barrier model that was used for the crash simulation is the W-beam barrier. The safety barrier part consists of guardrail, posts, and distant spacers. The connection between the barrier and the spacer is represented using generalized weld spot constraints. The length of the modeled W-shaped safety barrier is 4446 mm and the thickness is 2.67 mm. The spacer and post is C-shaped steel. The dimension for the spacer is 75 mm x 150 mm. The thickness is 5 mm and 350 mm long. The dimension for the post is 75mm x 150 mm. The thickness is 5 mm and 1820 mm long. The roadside safety barrier models using shell elements. The material properties for the roadside safety barrier is using piecewise linear plastic. For the spacer and post is using plastic kinematic. Material properties for the barrier, spacer and post were obtained from the appropriate material model.

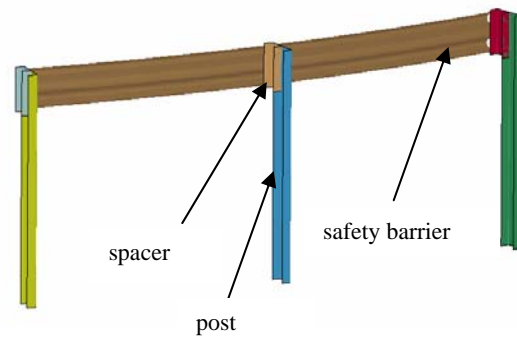


Fig. 3, Roadside safety barrier elements

### C. Boundary Condition and Contact Description

The boundary condition was attached at the concrete part as can be seen in figure 4. The boundary condition was performed in all axis direction (x,y,z) and for rotational (rx,ry,rz). All surfaces of the model were defined as one contact group, thus, effectively accounting for multiple self contacting regimes during simulation. The static and dynamic friction coefficient between all parts was set to 0.1 and 0.1, respectively.

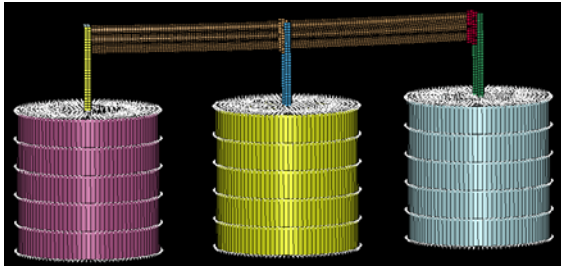


Fig. 4, Boundary condition at concrete foundation

C. Concrete Foundation

The concrete is located at the bottom of the numerical model and it is function as the foundation for the roadside safety barrier model as can be seen in figure 5.

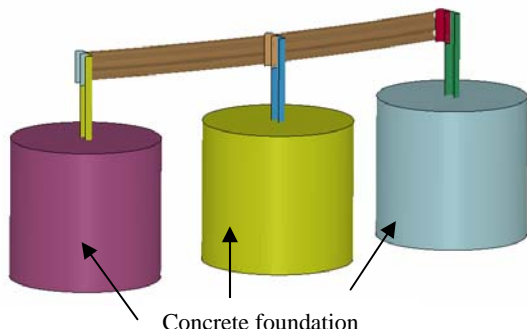


Fig. 5, Concrete foundation

Concrete is a composite material that consists essentially of a binding medium which are embedded particles or fragments of aggregates [8]. The basic components to make a concrete are cement, aggregate, water and mortar.

The concrete diameter is 1500 mm and has a 1500 mm height. The material properties for concrete were using drucker prager. Material properties for the barrier, spacer and post were obtained from the appropriate material model.

V. ANALYSIS of NUMERICAL MODEL

The crash simulation for vehicle velocity applied 40 km/hour, 60 km/hour and 80 km/hour were shown in figure 6, 7, and 8. In part a the vehicle is in a not moving condition. In part b the vehicle is starting to move and crashed the roadside safety barrier and furthermore to part f. In figure 9 the safety barrier parts performed deformation from the impact, part a for vehicle velocity 40 km/hour, b for vehicle velocity 60 km/hour and part c vehicle velocity 80 km/hour. In figure 10 it is been observed that the occupant compartment is still in an appropriate condition after the collision, part a for vehicle velocity 40 km/hour furthermore to part c vehicle velocity 80 km/hour This may reduce injuries and fatal to the passenger

The ASI index is presented in figure 11. It was found that the maximum ASI index from the crash for 40 km/hour velocity was 0.18, at 60 km/hour was 0.32 and at 80 km/hour was 0.51.

It means that the index from the simulation is above the maximum index which is 1.

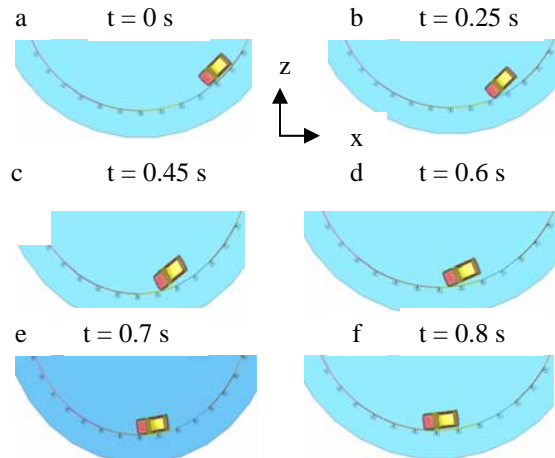


Fig. 6, Impact simulation velocity applied 40 km/hour

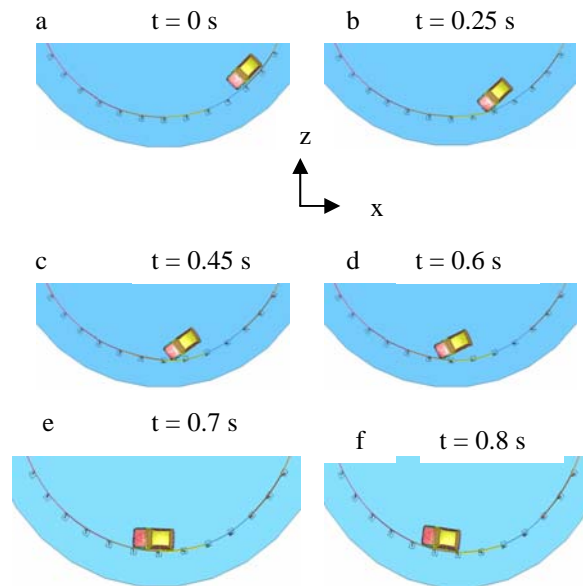


Fig. 7, Impact simulation velocity applied 60 km/hour

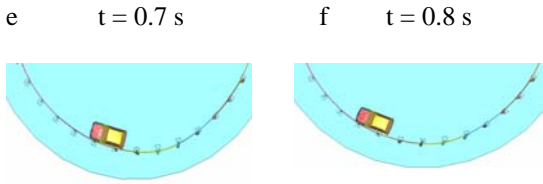


Fig. 8, Impact simulation velocity applied 80 km/hour

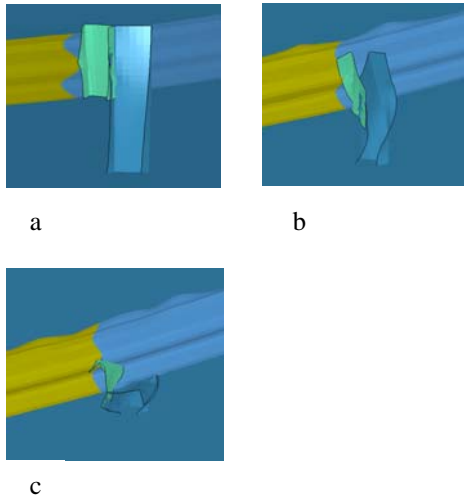


Fig. 9, The post, spacer and barrier deformation

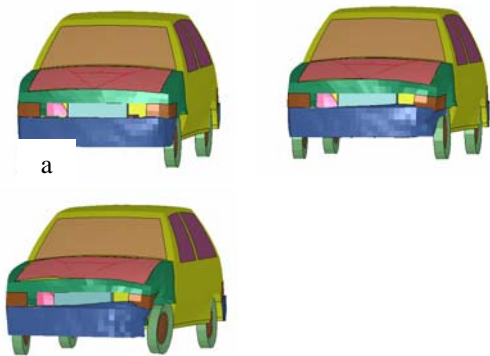


Fig. 10, The vehicle deformation after the impact

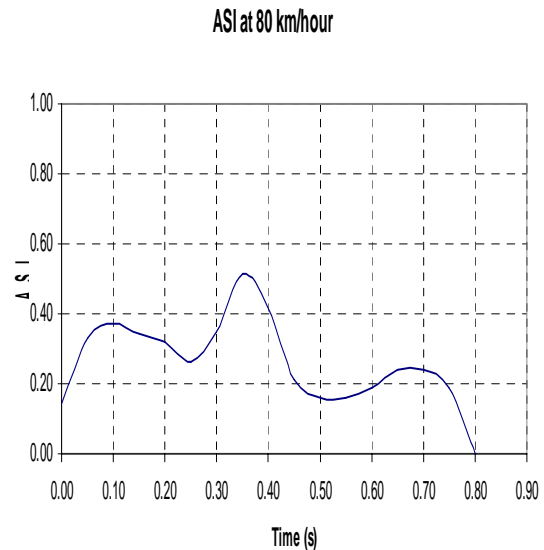
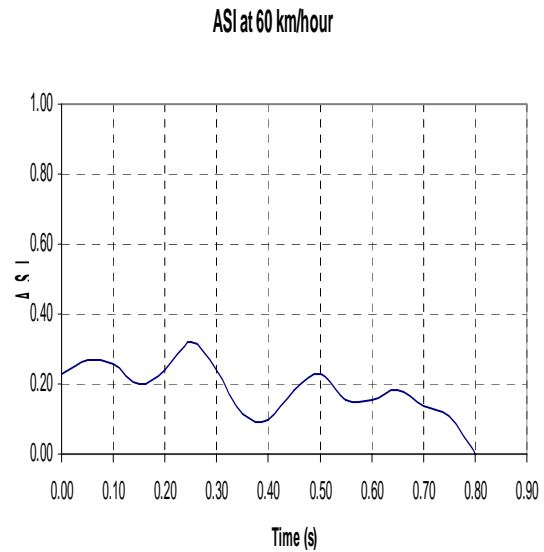
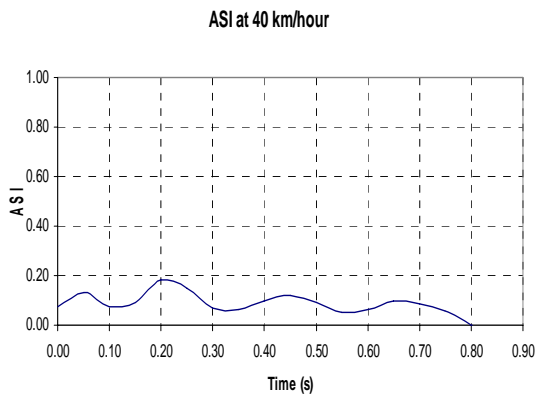


Fig. 11, The computational ASI index

## VI. CONCLUSION

This paper presents the result of a computational simulation of a roadside safety barrier behavior after a crash condition being performed with 3 types of velocity given to the vehicle (40 km/hour, 60 km/hour and 80 km/hour) Simulation was performed using the Finite Element Analysis software LS-DYNA. Adopting from the NCHRP Report 350, the result from the oblique impact simulation has shown that the roadside safety barrier and the vehicle model still performed in appropriate manner. The ASI value was not in the acceptable range, it means that the impact can causes severe injuries to the occupant of the impacting vehicle.

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