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INVESTIGATION OF THE IMPACT ON DIFFERENT TYPE OF TOLL PLAZA CRASH BARRIERS BY NUMERICAL APPROACH

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ABSTRACT

The construction of the highway network in Malaysia is growing rapidly along with the toll plazas facilities and safety constructions such as toll plaza barriers. However, the issue of accidents involving crash barriers at toll plazas turns into horrific nightmare for road users. It have been investigated that accidents at the toll plaza gates due to impacts of the vehicles with concrete crash barriers with results in damage and fatalities. Therefore, the following study is to conduct a simulation test for crash barrier Tensile Wire Fracture toughness (TWFT) system. TWFT system that used hot rolled galvanized steel materials with small displacement rate of 4.0 x 10-4 m which was considered suitable as a replacement for the existing concrete crash barrier. The data analysis were generated by the software Elfen. The graph of displacement, direct shear and effective stress were generated as for the hot-galvanizes steel material model. Elastic energy, kinetic energy and inelastic dissipated energy were compared between these two materials. The results shows that the hot-rolled galvanized steel have the energy to return the material to its original form and the level of damage shows that the concrete material failure are greater than the hot rolled galvanized steel materials. In conclusion, the material for a new alternative crash barrier is likely to reduce the rate of death due to accident and damage with regards to road furnitures and vehicles.

Keywords: accidents, crash barrier, numerical study, crash simulation, fracture toughness.

INTRODUCTION

The automotive industry is one of the positive economic growth at present. Instead of improving the standard of living, somehow it tucked among accidents on the roads which are also disadvantages. Accidents are one of the very serious problems and the number of accidents is increasing day by day (Olegas *et al*, 2009).

There are two aspects that are a priority in the context of traffic safety. The first aspect is to avoid the accident and the second is to reduce the accident when the accident happened. Crash barrier is the safety barriers most frequently used to prevent accidents. Previous studies showed that the presence of rash barrier system design which will reduce the impact of vehicle violations along the barrier.

In recent years the issue of accidents that occur on highways involving violations of vehicles such as motorcycles, cars, and other vehicles with a crash barrier at toll plazas. This is due to several factors, driving exceeding the speed limit, inclement weather such as rain and the vehicle brake system is not functioning. The impact of this accident is negative as damage to crash barriers and vehicles, and trauma to the driver. Loss will occur due to destruction caused by the breach and the loss of a loved one. Previous studies showed that the presence of crash barrier system design which will reduce the impact of vehicle violations along the barrier. Crash barrier is normally to be flexible in order to reduce the damage during an accident (Ali *et al*, 2008).

Accidents involved road users

The involvement of road users in road accidents are the leading cause of death in Malaysia. Accidents are not only involving infringement, even control of the vehicle skidded, but failure is also a major cause. Traffic growth rates increased on average 8.2% per annum equivalent to an increase of 1 million vehicles in a year. Road length of highways increased by about 3.3% in a year. With this rate of increase, road users exposed to the risk of road accidents (Zulkarnain *et al*, 2011).

Table-1. Statistics of road accidents and deaths overall Attitude.

Type of road	Accidents	Fatal accidents	Total death
Expressway	1,350	21	25
Federal Road	3,522	81	90
State Road	2,353	39	41
Municipal Road	5,605	39	42
Other Road	595	10	12
Total	13,425	190	210

Crash barrier tensile wire fracture thoughness (TWFT)

Crash barrier is the traffic management tool known as street furniture for highways in Malaysia. In addition, there are many other street furniture such as signs, road marking, traffic safety, at toll plazas and so on. In this study, the approach to motivate wall roadblocks at the toll plaza. In traffic engineering, crash barrier means barriers of any kind or type of vehicle switched in or out of the actual driving crashed into another vehicle (Saifulnizam, 2010).

Usually the place is often chosen for crash barrier are at the end of the bridge, near the steep slope of the road had, in drains or sewer crossings where steep or vertical dots appear, and near large signs or light poles, at toll plazas or the elements of another roadside which could pose a danger. When the barrier is necessary, careful calculation and will be divided further specify the desired length of the barrier. The calculation takes into account the speed and the amount of traffic using the road, the distance from the edge of the roadway to the danger, and distance or offset from the edge of the roadway to the obstacle (TxDOT Manuals, 2010).

Figure-1. Tensile wire fracture toughness (TWFT).

Characteristic of crash barrier TWFT

TWFT crash barrier system has cartridges that can absorb impact shock during collision made of steel bars and stainless steel wire that can shrink and fold. This system is designed to protect vehicle occupants and ease the way of any possible injuries or collision that occurred between vehicles and road facilities. It provides the capacity to absorb the kinetic energy of a more flexible and softer than other pressure-based products.

Due to the stainless steel wires that are used to absorb the kinetic energy of the vehicle, therefore, it can minimize the reaction between the vehicle and the road barrier wall itself. TWFT system uses two rail track system that will withstand horizontal movement during side collisions occur. While the steel barrier will resist movement in the event of a collision continues. At the front of the wall system of roadblocks has installed thin steel sheet and the reflection tape cartridge that absorbs shock. The system absorbs impact shock TWFT well with the tensile stress of the elastic material. In the event of damage to the crash barrier of the road system, maintenance is not necessary at this overall facilities. Maintenance can be done by replacing some defective parts in an easy way.

Most of the existing crash barrier in the way of road furniture manufacture of various types of materials, system mechanism and the characteristics and advantages of each. Among the characteristics of a barrier wall TWFT are as follows: using this type of collision voltage shock-absorption system which is better than the pressure of conventional products, where it can stop the secondary accidents caused by power parry. Pass the real test crash CC1 (60km / h), CC2 (80km / h), CC3 (100 km / h) grade enforced by the Ministry of Construction and Transportation Security Korea Transportation Driving Aptitude Authority, laboratory testing and Korea Expressway Corporation Expressway and Transport Research Institute. By adopting 2-Rail Systems, TWFT is not only have a high stability and power bounce back when the vehicle collided into a flyer, but this system also displays any softer and more reliable capacity to absorb. It is considered compact design and sophisticated harmony with the surrounding roads (Liang, Yiling, 2010).

Table-2. Fracture toughness of different materials.

Type of material	Material	Kic (Mpa.m1/2)
Metal	Aluminium Alloy (7050)	24
	Steel Alloy (4340)	50
	Aluminium	14-28
Ceramic	Aluminium Oxide	3.0-5.0
	Concrete	0.2-1.4
Polymer	Polymethyl Methacrylate	0.7-1.6
	Polystyrenes	0.7-1.1
Composite	Mullite Composite Fibre	1.8-3.3
	Aerogels Silica	0.0008-0.0048

MATERIALS AND METHODS

The complete model to test the effects were analysed using computerized analysis software Elfen. Elfen is a comprehensive finite element software tools and discrete elements developed by Rockfield Software Ltd. It contains a variety of features to solve a wide range of physics, multi-scale, non-linear problems for both continuum and main discontinuum. Elfen consists of pre and post processor for complete architectural model and the results of the assessment, mesh generator for a variety of elements, modules implicit and explicit solver analysis

and various software interfaces to third-3. There are three phases in any computer aided Pre-engineering of the processing task - to determine the finite element model and environmental factors that are applied.

Further analysis solution is Solver-finite element model to derive the complete software variables, such as reaction forces, stresses the element, and the heat flow. After the decision processes that are used for sorting, printing and design, for further results evaluation, the visualization tools were used.

Crash barriers at the toll plaza is the main focus as the model is Tensile Wire Fracture Toughness (TWFT) which are more resistant to take the strong impact and it would reduce serious injury or death to the user/drivers. The materials used to improve the strength of the crash barrier at the toll plazas are of hot-rolled galvanized steel as well as new materials and technologies that are still under review the level of stiffness.

Table-3. Parameter for car bumper, material of hot-rolled galvanized iron and concrete.

Parameter	Hot-rolled galvanized iron	Concrete	Front car bumper
Young Modolus (E)	200 Gpa	215 Gpa	1.387e-4 Gpa
Yield Stress	400-390 Mpa	20.6 Mpa	27.7 Mpa
Nisbah Poisson	0.33	0.15	0.28
Density	7860 kg/ m^3	967 kg/ m^3	2710 kg/ m^3

RESULTS AND DISCUSSIONS

Apparently the results from data analysis showed that the level of the crash barrier displacement is very small in proportion of $4.0x10^{-4}$ m. Hot-rolled galvanized steel is one of type barriers which is ductile. The material ductility is considered strong when stretched under tensile stress. More ductile materials, the displacement rate will be lower while concrete is a brittle easier to achieve material failure.

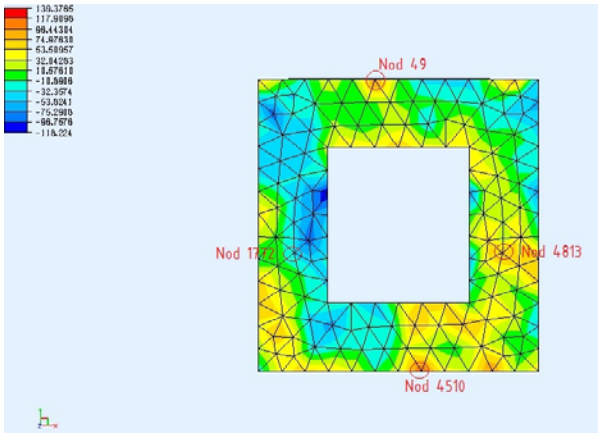

Figure-2. The node selected for plotting the result on the graph generated.

The Figure-2 and Figure-3, shows the extent of the damage model crash barrier using hot-rolled galvanized steel as a whole has a green color while the crash barrier of the road barrier model for concrete materials, the scale of the overall color is red and there is a failure at the end of the model. Therefore, it can be seen that the use of hot-rolled galvanized steel can reduce the damage to the crash barrier.

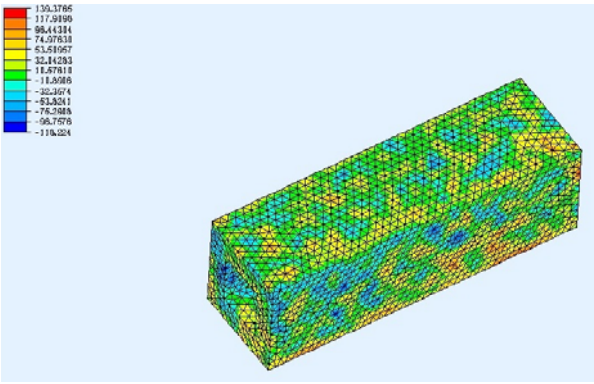

Figure-3. Damage level of hot-rolled galvanized steel material.

In Figure-4, we can see that there is a level of color shown on the left picture. The colour level is to show the extent of damage to the crash barrier. Dark blue is the lowest damage and followed with another color scale green, yellow, orange and ended up in the red color indicates the level of damage critical reading.

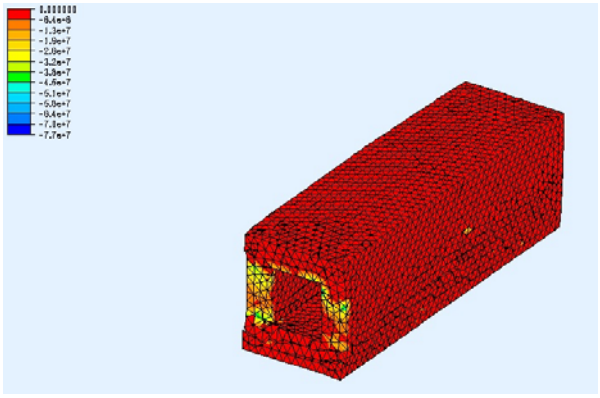

Figure-4. Damage level of concrete material.

Effective stress graph generated from the selected node

Effective stress is present in a breach between the two objects. It results from the force applied when part of the body presses on, pulls on, push against, or tends to compress or twisted elsewhere. In the analysis of this study, some nodal points selected for the prevailing rates effective stress. The graph shows effective stress on the journey of the most critical nodes at the time of 1.0 x 10^{-3} when the nodes 4510 and 1772 followed by a node, the node 49 and node 4813. The effective stress conditions prevailing on all nodes the outlook for the dissemination of the offense are not the same. In addition, changes in effective stresses is dependent on time. In the beginning of time, effective stress acting so high and changed when there is movement to another time.

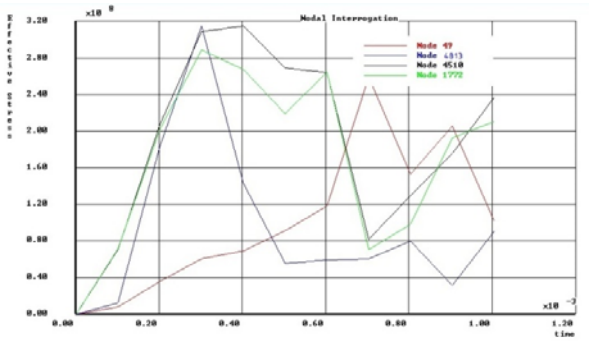

Figure-5. Effective stress graph of hot-rolled galvanize steel material.

Direct shear graph generated from the selected node

Shear stress is the stress state in which stress is parallel to the surface of the material, as opposed to the normal pressure when pressure is vertical to the surface. When there is a clash between the vehicle and the crash barrier, shear stress occurs at the contact surfaces.

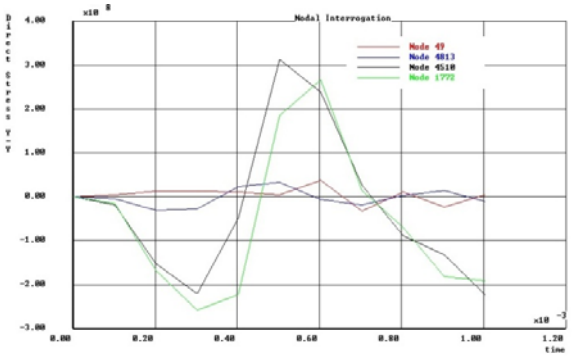

Figure-6. Direct shear stress graph of hot-rolled galvanize steel material.

Displacement graph generated from the selected node

The displacement is measured from a point to another point. Displacement can also occur when an object is moved or knocked down causing the object to change places. In the analysis of this study, the model simulated vehicle bumper crashed into a crash barrier model. The impact of the violation resulted in a shift. Data analysis can be seen from the displacement direction x, and y. Figure 7 shows the displacement in the x direction. The shift is happening is very small in the rate of 4.0x10^{-4} m. Among the most experienced node high rate of displacement is the displacement of the node 1772. Changes occur in ascending and descending due to factors that are elastic crash barrier where it will bounce back and knock objects. Graph shows changing shifts down the rise due to the elastic properties of the material crash barrier and the car itself.

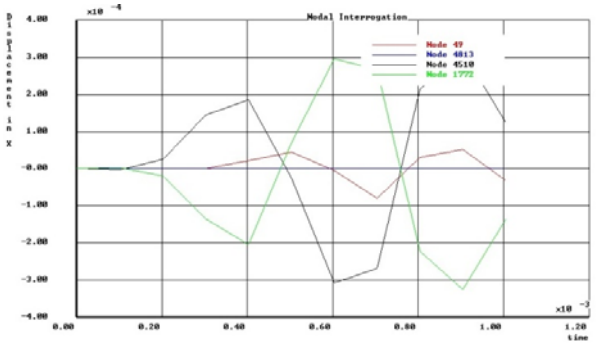

Figure-7. Displacement graph of hot-rolled galvanize steel material.

Comparison between kinetic energy of hot-rolled galvanized steel and concrete material

In addition, the density and weight also play a role. The combination of velocity and density will result in a power and momentum. The more dense material, the higher the rate of energy and momentum that can be generated. In this analysis process, there are some constraints vehicle parameters such as vehicle parameters

of various materials. There are some errors in occurs that also makes a difference in the way of analysis. Graph of kinetic energy, elastic energy and energy dissipated inelastic compared between the two materials. There are differences discussed in the diagram. Finally, the behaviour of materials, density, tensile is very important in the products of high quality wall roadblocks that can withstand the impact of a breach of any objects that knock.

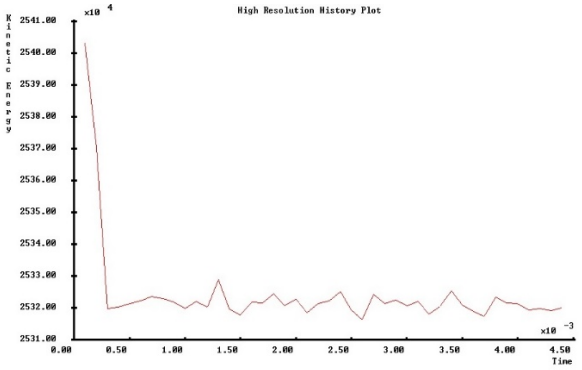

Figure-8. Kinetic energy graph of hot-rolled galvanize steel.

Apparently the results of data analysis shows that the level of the retaining wall displacement is very small in proportion $4.0x10^{-4}$ m. Among the factors that cause the reading to be small is a retaining wall that conduct its wall. One of the materials of the wall is hot-rolled galvanized steel which is ductile material. The material ductility is strong when stretched under tensile stress. More ductile materials, the displacement rate will be lower while concrete material is considered as a brittle and easier to achieve material failure.

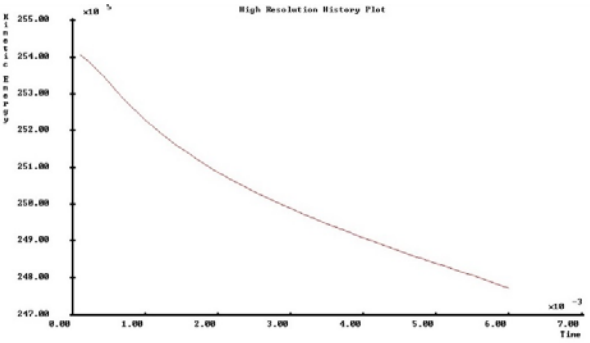

Figure-9. Kinetic energy of concrete material.

Comparison between elastic energy of hot-rolled galvanized steel and concrete material

Elastic energy is the mechanical potential energy stored in the material or physical configuration of the system as work carried out to twist the volume or shape. Elastic energy occurs when the object that is compressed and stretched. Developing a theory of elasticity, it was very complicated system that can be developed with a solid understanding of body mechanics and materials as well as the essence of elasticity which is reversibility.

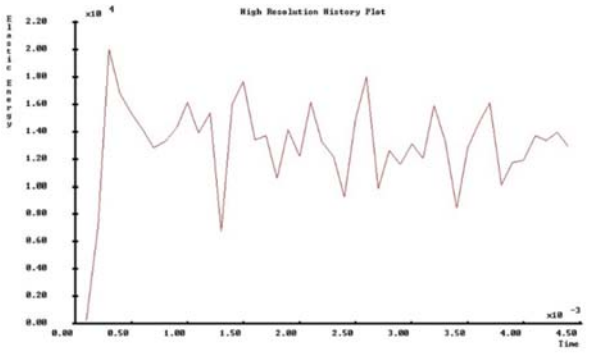

Figure-10. Elastic energy of hot-rolled galvanize steel.

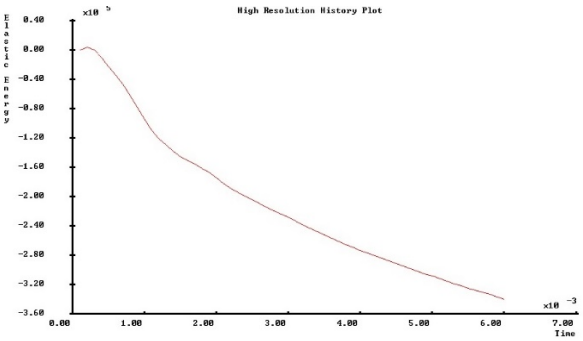

Figure-11. Elastic energy graph of concrete material.

The force exerted on the elastic material transfer energy into the material. When generating energy to its surroundings, it can recover its original shape. However, all materials have limitations on the level of abuse they can withstand without breaking or irreversibly changing the internal structure of the material.

Comparison between dissipated inelastic energy graph for hot-rolled galvanized steel and concrete material

The spread is the result of an irreversible process that occurs in inhomogeneous thermodynamic system. Dissipation process is a process in which energy (internal, bulk flow kinetic, or potential system) changed from the initial design to the final form.

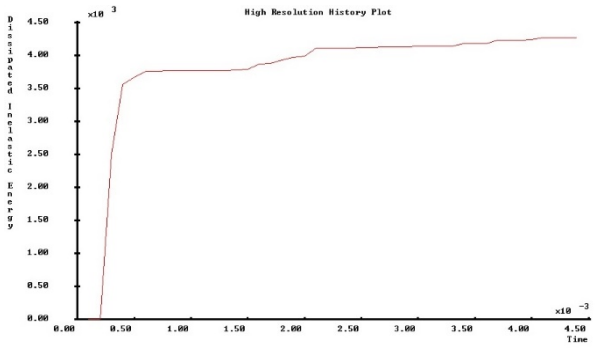

Figure-12. Graph dissipate inelastic energy of hot-rolled galvanize steel material.

The final form of the capacity due to mechanical work are less than the initial form. The difference of inelastic energy dissipation by the two materials are different where dissipation occurs galvanized started late and concrete energy dissipation occurs earlier.

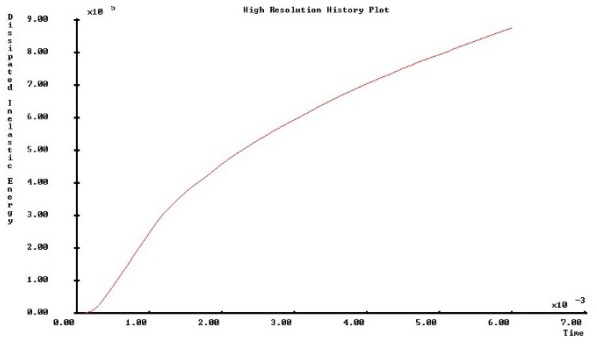

Figure-13. Graph dissipated inelastic energy of concrete material.

In addition, the density and weight also play a role. The combination of velocity and density will result in a power and momentum. The more dense material, the higher the rate of energy and momentum that can be generated. In this analysis process, there were some constraints vehicle parameters such as vehicle parameters of various materials. There are some errors occure which makes a difference in the way of analysis. Graph of kinetic energy, elastic energy and energy dissipated inelastic are compared between the two materials. The differences have been discussed in the previous paragraph. Furthermore, the behavior of materials, density, tensile is very important in the production of high quality wall roadblocks that can withstand the impact of a breach of any objects that knock.

CONCLUSIONS

The following study have identified the types, and designs used in the manufacture of crash barrier at some existing toll plaza gates in Malaysia and most of its crash barrier are made of concrete. Suitability crash barrier system according to materials and design to provide safety and aesthetics of the surrounding streets and highways. Furthermore, software Elfen was used to design the model and analyse the type of crash barriers. Analysis was conducted by performing the model that describes the vehicle and the actual barrier wall with the use of actual parameters of both type of materials.

The analysis have been conducted by using the hot-rolled galvanized steel and concrete barriers. Graph of kinetic energy, elastic energy and inelastic energy dissipated are also developed and investigated. Therefore, it can be concluded from the analysis of following two type materials shows that the kinetic energy, elastic energy and energy dissipated inelastic are well comparable. Through this analysis, it can be seen that the galvanized steel material has a small rate of displacement compare to the concrete material. Therefore, galvanized iron material is seem suitable material for crash barrier at highway toll plaza.

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