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Analysis of Crash Barriers in Terms of Impact Strength

by

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled **"Analysis of Crash Barriers in Terms of Impact Strength"**, submitted by Srijana Lekhak (072/MST/268) in partial fulfillment of the requirements for the degree of Master of Science in Transportation Engineering.

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ABSTRACT

Run-off road vehicle crashes are a major cause of loss and causality on roads, with errant vehicle incidents often leading to potentially serious injury or death for both the vehicle user and other road users. A road safety barrier is designed to safely control and redirect errant vehicles, absorbing the energy from the collision event and minimizing injury to vehicle occupants or other road users. This study aimed to show the impact performance of semi-rigid and flexible crash barriers in terms of energy absorption of barrier, ASI value and deflection.

Finite Element Software Abaqus was used to develop models of three types of barriers, i.e. w-beam steel crash barrier, modified thrie beam steel crash barrier and cable barrier. The barriers were impacted upon by simplified vehicle model with an impact velocity at an impact angle to carry out the computer simulation using Abaqus. Crash simulation were carried out under different conditions of impact varying the impact velocity as 80 kmph, 60 kmph, 40 kmph and 30 kmph and impact angle as 15º, 20º and 25º. The impactor of 2000 kg and 8000 kg were used. The simulation results of the models showed that the optimal result was registered by the cable barrier, which demonstrated higher crash energy absorption and a lower ASI value than the other barriers did. Overall, it was found that both the barriers, modified thrie beam and cable barrier could be preferred for use over w-beam barrier, also considering the lateral space availability at installation site. The space required for deflection was found to be 1.28 m, 0.83 m and 2.35 m for w-beam, modified thrie beam and cable barrier respectively. The modified thrie beam and cable barrier would be more effective for restraining heavy vehicles as found from the results and their use along the hazardous locations would result in more energy absorption of the crash and less risk of injury to the vehicle occupants lowering the severity of crash and eventually improving the road safety aspect.

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LIST OF ACRONYMS AND ABBREVIATIONS

AASTHO- American Association of State Highway and Transportation Officials

ASI-Acceleration Severity Index

DoR-Department of Roads

FEA-Finite Element Analysis

FEM-Finite Element Method

GoN-Government of Nepal

IE-Internal Energy

IS-Indian Standard

IRC-Indian Road Congress

KE-Kinetic Energy

KJ-Kilo Joule

KN-Kilo Newton

Mpa-Mega Pascal

MASH-Manual for Assessing Safety Hardware

NCHRP-National Cooperative Highway Research Program

RTA-Road Traffic Accident

RTI-Road Traffic Injury

TE-Total Energy

UN-United Nations

US-United States

WB-World Bank

WHO-World Health Organization

WRSB-Wire Rope Safety Barrier

CHAPTER I

INTRODUCTION

1.1 Background

Road Traffic Crashes prove to be the primary cause for the tragic end of more than 1.35 million lives and the leading cause of death for children and young adults aged 5–29 years, each year (WHO, 2018). In South-East Asia Region, Road Traffic Injuries (RTI) cause approximately 20.7 deaths per 100,000 population where the majority of deaths are among riders of motorized two and three-wheelers, who represent 43% and 36% of all deaths respectively. The Table 1.1 shows the national statistical trend of road traffic crashes.

Table 1.1 National Statistical Trend of Road Traffic Crashes

Year	Crashes	Fatalities	Serious Injuries	Slight Injuries
2009/10	7,438	1,734	4,130	7,383
2010/11	8,803	1,689	4,701	8,503
2011/12	8,892	1,837	4,018	7,811
2012/13	8,484	1,816	3,986	8,000
2013/14	8,406	1,787	3,516	7,877
2014/15	9,145	2,004	4,053	8,127
2015/16	10,013	2,006	4,182	8,213
2016/17	10,178	2,384	4,250	8,290
2017/18	10,965	2,541	4,144	8,247
2018/19	13,366	2,789	4,376	10,360
Total	95,690	20,587	41,357	82,824

Source: (Traffic Directorate, Nepal Police, 2019)

In the context of Nepal, as per the facts of 2015/16, more than 2,000 lives are lost, and 12,400 people either get injured by RTA, and its' rate is observed to be increased by almost 9.5% every year and per day average of five deaths; 11 seriously injured; 22 minor injured in about 25 road crashes (Nepal Traffic Police, 2017). Likewise, data from 2001-2013 has shown that 14512 lives were lost and 100499 people injured due to RTA (Karki, 2016). Similarly, review report has shown that there were 68,808 numbers of vehicles and 76071 people involved in handling the RTAs from the period of 2007-2013. Also, the total registered buses are 46346 out of 2783428 vehicles of all categories (website: www.dotm.gov.np; data source from 2046-2074 B.S.). In a report of the world bank, bus crashes on the long-distance routes accounted for about 13 percent of all fatalities and 31 percent of serious injuries suffered because of road traffic collisions in Nepal. These studies refer that RTA is recognized to be a severe public health issue for Nepal.

1.2 Road Safety Barrier

A road safety barrier, traffic barrier or crash barrier may be defined as “a physical barrier installed alongside a road in order to contain errant vehicles, to shield them from striking fixed objects or from rolling over undrivable slopes, to redirect them along the road and to thus minimize injury to the vehicle occupants”(RSI). The primary purpose of a longitudinal barrier is to protect motorists from a collision with a fixed roadside object that is likely to be more severe than a collision with the barrier itself.

Crash barrier is a feature on a road which is primarily designed to avoid errant vehicle or motorist from leaving the road and protecting them from hazardous features. These features should be installed where run-off crashes are recorded to be high at each location which would result in the reduction of crash severity. One of the basic pre-requisites for crash barriers is that it should withstand high force. This is because when a collision takes place of car/truck at full speed, the barrier should be able to withstand all that momentum. Crash barriers should be able to withstand the impact of vehicles of certain weights at a certain angle while travelling at the specified speed by absorbing the impact energy during the collision. It is the role of the road safety barrier to slow the errant vehicle at a safe rate, while ensuring that it is redirected safely, as per the requirements of the relevant standards.

Also, safety would be increased if the barrier with high absorption material properties is used for better energy dissipation during impact of collision.
Safety barriers are used to stop ‘out of control' vehicles from:

• leaving the road and hitting roadside hazards, including slopes (roadside barriers)
• crossing into the path of on-coming vehicles (median barriers).

They are designed to redirect the vehicle and have a lower severity than the roadside hazard they protect. There are three main types of safety barrier (but within these types there are different systems which have their own specific performance characteristics).

1.3 Road Safety Barrier Types

Barriers are divided into three types, based on the amount they deflect when struck by a vehicle and the mechanism the barrier uses to resist the impact forces. The use of these three different types of barriers is correlated with the different safety requirements of each particular road which varies in terms of their deflection and energy absorption properties as well as their suitability for different road characteristics.

Rigid Barrier

Rigid safety barriers are characterized by limited dynamic deflection during an impact. The deformation and management of kinetic energy is contained within the impacting vehicle. Therefore, rigid barriers have the highest values associated with occupant forces and they are the least forgiving of all barriers. When reliable breakthrough prevention is required at narrow space conditions, the rigid safety barrier is the first choice. They are primarily used at locations where little or no movement of the barrier can be tolerated (for example as median barriers on divided high-speed arterials or on bridges). Some temporary concrete barriers are used at construction sites and these may deflect by a small amount because they are unrestrained at their base. Impact energy is dissipated through redirection and deformation of the vehicle itself. Currently (depending on their height and other details) these provide the highest level of containment of heavy vehicles. In most cases following impact these barriers require little or no maintenance. Reinforced Cement Concrete, Plum Concrete, Random Rubble Masonry barriers are some of the types of rigid barrier. The more widely used concrete rigid barriers include the Vertical face barrier, the Constant (single) slope barrier, the New Jersey barrier, and the F shape barrier.

Semi-Rigid Barrier

Semi-rigid barriers are the most widely used type in the world. They deflect 3 to 6 feet (0.91 to 1.83 m): more than rigid barriers, but less than flexible barriers (AASTHO). These deflect less than flexible barriers and so they can be located closer to the hazard when space is limited. Depending on the impact these barriers may be able to redirect secondary impacts. Steel beam barrier is the most commonly used guardrail in the world. It is a W section galvanized steel barrier set on spacing blocks that are set on steel or hardwood posts. These barriers work through restraining and redirecting errant vehicles through a combination of beam bending and tensioning.

Lateral restraint is provided by the posts. Semi-rigid barriers include box beam guide rail, heavy post blocked out corrugated guide rail and thrie-beam guide rail.

Flexible Barrier

Flexible barriers have the greatest deflection and energy absorption properties of the three types of barriers, providing significant lateral deflection and thus resulting in the lowest deceleration forces on vehicles and their occupants. These are referred to as flexible barriers because they will deflect 1.6 to 2.6 m (5.2 to 8.5 ft) when struck by a typical passenger car or light truck. These barriers consist of a number (generally three or four) of wire ropes (cables) held in place by steel posts at fixed spacings. The ropes deflect when struck by an errant vehicle, guiding the vehicle along the barrier while the posts progressive collapse. The posts, anchors and pre-tensioned wire ropes absorb the kinetic energy of the vehicle, slowing it down. In addition, it guides the collided vehicle forward away with minimal impact through the barrier rather than redirect the vehicle back to the flow of traffic thus keeping the vehicle to a minimum damage and reducing the risk of injury. Flexible barriers include cable barriers and weak post corrugated guide rail systems.

1.4 Road Safety Barrier Efficiency

Crash barrier has proven its dispensability at the most unfortunate times of vehicles. The survey and statistics have shown that these barriers have minimized the gravity of run-off-road crashes. Most of the times, especially on highways, vehicles seldom get off-balance or out of control due to various reasons. During such events, this vital infrastructural feature protects the vehicles by lowering the uncontrollable tendency.

(a) In the Tallodungeswor-Jumla Road, local people reported that after the installation of crash barriers at Km 70+770 (Darbari Bhir), there had been three road crashes. However, due to the steel crash barrier, the lives of passengers travelling in the vehicles were saved (WB Report).

(b) In a report of world bank, simplified impact evaluation experiment was conducted to develop a rough measure of vehicle falls avoided after the installation of the crash barriers at five vulnerable locations along the 700 km of RSDP roads. The result of the evaluation shows that at least seven vehicle hits were recorded and vehicles with a total occupancy of 270 passengers were protected from departing the roadway and potentially falling into the valley.

Road safety barriers normally installed along the highways of Nepal are:

- Random Rubble Masonry barrier
- Plum Concrete barrier
- Reinforced Cement Concrete barrier
- W-beam Guardrail
- Gabion barrier

To provide appropriate safety levels for impacting vehicle occupants, the safety barriers should be designed in order to fascinate as much high kinetic energy as possible during the crash as well as maintain the reliability.

1.5 Problem Statement

Transport systems and infrastructure have expanded rapidly in developing countries, while little has been achieved in preventing crashes or lessening their severity. In the context of Nepal, the data records show a constant increase in road crashes with the increase in traffic volume. Along with the increasing road traffic intensity, the issue of road traffic safety is becoming more important requiring further attention from all the institutions. Road Traffic Crashes are generally caused by vehicle diversion from the intended direction. One of the ways to improve road safety is the use of road restraint systems. Road safety barriers allow not only reducing the number of road traffic crashes, but also lowering their severity.

W-beam guardrails have commonly been in use in the recent years along the roads of Nepal, especially in the hill roads. As most of the hill roads in Nepal are along the river routes and are characterized by steep vertical alignment and sharp curves, installation of steel beam barriers become necessary and suitable compared to other types of barriers because of the narrow width section or space restriction in most of the hilly roads. However, w-beam barrier which is mostly in use does not always meet the requirements of safety barrier in some cases, especially for heavy vehicles and may fail to serve the purpose as a barrier. There is clearly a need to assess other road safety barriers which could possibly facilitate in reducing the severity of crashes. As the rigid barriers cause high injury risk upon impact, semi-rigid and flexible barriers can be considered to minimize the severity of crash. The literature review in the next chapter shows that cable barrier and modified thrie beam barrier can be considered for improved performance over w-beam barrier.

Modified thrie beam barrier, which is a type of semi-rigid barrier, and cable barrier, a type of flexible barrier needs to be investigated for their performance so that the barriers can be considered for improvement of safety along the roads. Therefore, this research study is carried out to predict the behavior of two types of steel beam barriers, w-beam and modified thrie beam barrier as well as cable barrier under impact condition in terms of impact energy absorption, occupant risk severity (ASI value) and deflection of the barrier.

1.6 Objective of the study

The broad objective of the study is to analyze the impact performance of three different crash barriers. The specific objectives of this research study are:

1. To observe the impact behavior of w-beam steel crash barrier, modified thrie beam steel crash barrier and cable barrier under different conditions of impact velocity, impact angle and impact load.
2. To determine the absorption energy, occupant risk indicator ASI and deflection of the barriers.
3. To find if the other two barriers can be preferred over w-beam barrier to be used for the improvement of road safety and determine the lateral space required behind the barriers for deflection.

1.7 Thesis Layout

The thesis is broadly divided into five chapters. The titles of the five chapters are: (1) Introduction, (2) Literature Review, (3) Methodology, (4) Results, and (5) Discussion. Chapter one briefly describes the background of the study including traffic crash situation of Nepal, road safety barriers and establishes the statement of the problem. The objectives of the study are also stated in this section. Chapter two provides an overview of the relevant literature associated to this research. Previous studies reflecting efficacy of crash barriers, researches involving computer simulation of crash scenarios of crash barriers that have been undertaken, acceleration severity index are mentioned in this chapter. Chapter three explains in detail the methodology adopted and elaborates the detail design and specifications of crash barriers used, finite element software used for simulation, parameters selected for simulation study, construction of crash barrier models and crash simulation. Chapter four presents the results from the computer simulation carried out on crash barriers along with the graphical comparison and analysis of the results. Chapter five discusses the results, limitations and recommendations for future research.

CHAPTER II
LITERATURE REVIEW

2.1 Introduction

More focus was in developing road length by constructing new roads and very low consideration was given for maintenance and road safety till 80s. Most of the roads were under traffic to their design capacity. Road construction followed standard geometries with least concern for road safety. As the traffic increased in these roads, crashes are also increasing in alarming rate. Constantly increasing intensity of road traffic and the allowed speed limits seem to impose stronger requirements on road infrastructure and use of road safety systems.

2.2 Study on Efficacy of Crash Barriers

A numerous study has been conducted in the past to assess the safety performance of road safety barriers.

In a study by Russo et al. (2015), the results showed that cable barriers were 96.9 percent effective in preventing penetration in the event of a cable barrier strike. The same study statistical analyses which accounted for regression-to the-mean effects showed that fatal and incapacitating injury crashes were reduced by 33 percent after cable barrier installation.

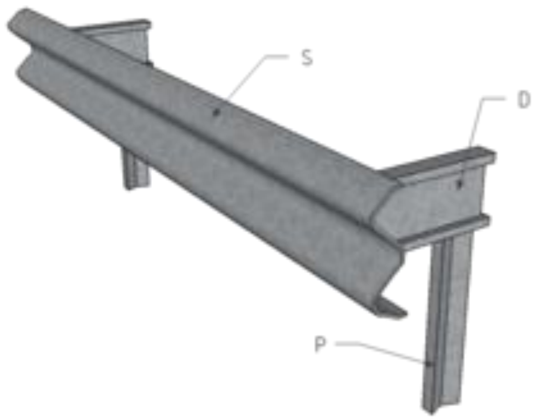
In a research undertaken by Zou et al. (2014), the safety performance of road barriers in Indiana in reducing the risk of injury was assessed, with hazardous events such as rolling over, striking three types of barriers (guardrails, concrete barrier walls, and cable barriers) with different barrier offsets to the edge of the travelled way, and striking various roadside objects being studied. A total of 2124 single-vehicle crashes (3257 occupants) that occurred between 2008 and 2012 on 517 pair-matched homogeneous barrier and non-barrier segments were analyzed. The study found that the odds of injury are reduced by 39% for median concrete barrier walls offset 15–18 ft from the travelled way, reduced by 65% for a guardrail face offset 5–55 ft, reduced by 85% for near-side median cable barriers (offset between 10 ft and 29 ft), and reduced by 78% with far-side median cable barriers (offset at least 30 ft).

An evaluation of 293 miles of cable median barrier in Washington found fatal collision rates were reduced by half and an estimated 53 fatal collisions were prevented after the installation of cable median barrier (Olson, D., et al., 2013).

The modifications improved the performance of the crash barrier by way of keeping the deflection lower and keeping the vehicle upright even after the impact. Due to improvements in Modified Thrie beam type crash barrier, it is considered most appropriate for the hilly areas where space is constrained and lesser space is available for deflection and is recommended for installation [16].

2.3 W-beam Guardrail

A W-beam guardrail type is the most appropriate of longitudinal safety barrier along the road in every country. This is a semi-rigid barrier system which can be used for the least to moderate deflection. It consists of w-beam corrugated rail attached to post through spacer as shown in Figure 2.1 below. The distance between posts can be equal to 1, 2 or 4 m depending upon the required containment level on the roads. The function is to provide the guardrail stiffness so that it is capable to restraint the heavy vehicle and limit deflection impact. The W-beam guardrail can be used on single shoulder as well as a median barrier to separate the opposite flow of traffic where high strength is required but inappropriate for rigid barrier due to limited adequate space. Metal beam crash barrier is widely used for highway safety on the roads. Highway guardrail barrier can provide railing protection to motor vehicles at dangerous road areas such as steep slope, high embankments, obscure curves, sharp corners to absorb sudden impact during a collision, thus minimizing damage to the vehicle and injury to the passenger.



S: W-beam

D: Spacer

P: Post

Figure 2.1 W-beam barrier

2.3.1 Specification for W-beam Barrier as per DoR

As per DoR specifications, IRC-5 1998, the standard design for this barrier is about

312 mm wide W-shaped profile with length of 4318 mm supported using C-channel section 150*75*5 mm steel posts. These posts are 1800 mm length with 1100 mm rammed into the soil which is nearly two-third of its length. Packer or C-channel spacer with section 150*75*5 mm and length 330 mm is placed in between the post and the steel-beam rail. The rail consists of 23*29 slotted holes for splice bolts and 19*64 slotted holes for post bolts. The steel beam is designed to 3 mm thickness. The rail shall be 70 cm above the ground level and post shall be spaced 2 m centre-to-centre. The “W” beam, the posts, spacers and fasteners for steel barriers shall be galvanized by hot dip process (zinc coated 0.55 kg per square metre; minimum single spot) unless otherwise specified. The Galvanizing on all other steel parts shall confirm to the relevant NS/IS specifications. All fittings (bolts, nuts, washers) shall confirm to the IS: 1367 and IS: 1364. All galvanizing shall be done after fabrication. The specification for w-beam barrier is given in Table 2.1.

Table 2.1 Technical Specification of W-beam Barrier

SN	Item	Requirement
1	W-beam guard rail:	Base Metal: The beam, end sections shall consist of sheet made of open hearth, electric furnace, or basic oxygen steel and shall meet the mechanical properties specified below. Length of rail -- 4.318 m/ 2.318 m Yield stress, minimum, 310 MPa; and Elongation, in gauge length (5.65X (sqrt of cross-sectional area)) minimum, 15 percent.
2	C- Channel Post	Length of Post – 1800 mm. Yield stress, minimum 410 MPa;
3	C-Channel spacer	Length of Spacer– 330 mm. Yield stress, minimum 410 MPa
4	All fittings (Bolt , Nuts, washer)	Confirm to IS 1364 and IS 1367

(Source: DoR, GoN, 2073)

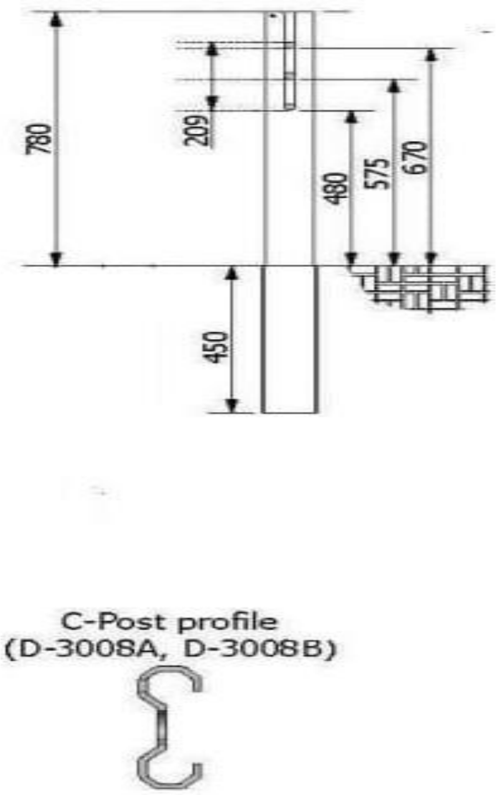
2.4 Cable Barrier

A cable barrier, sometimes referred to as guard cable or wire rope safety barrier (WRSB), is a type of roadside or median safety traffic barrier/guard rail. It consists of steel wire ropes mounted on weak posts. As is the case with any roadside barrier, its primary purpose is to prevent a vehicle from leaving the traveled way and striking a fixed object or terrain feature that is less forgiving than itself (AASTHO). Also similar to most roadside barriers, cable barriers function by capturing and/or redirecting the errant vehicle.

The system is more forgiving than traditional concrete (Jersey) barriers or steel barriers used today and remains effective when installed on sloping terrain. The flexibility of the system absorbs impact energy and dissipates it laterally, which reduces the forces transmitted to the vehicle occupants. The small space taken up makes it possible to install the systems on highways where road space is limited and where other types of barriers that take up too much space cannot be used. It consists of a system of steel wire ropes attached to weak posts. The main function of this type of highway barrier is to prevent a vehicle from straying into a fixed and unforgiving object or into a hazard such as oncoming traffic, down a steep embankment or mountain slope, over the side of a bridge, or into a body of water. These types of highway barriers are more cost-effective to install than concrete types. They are lighter and can be installed without cranes to lift the barriers from the trucks. There are two types of wire-rope barriers. The first is the low-tension type, which has just enough tension between posts to prevent sagging of the cable. The system has springs on the ends of the cable to attain the required tension. Upon impact, the wire-rope cable moves considerably from its original position. The high-tension type is now widely used. The cable is tensioned to ensure optimal strength. It has good energy absorption and deflection capacity.

2.4.1 Specification for Cable Barrier

The wire rope safety barrier model used is in accordance with IRC 119:2015 complying to standards of EN 1317 as well as NCHRP Report 350. The 3-strand cable guardrail consists of three 19 mm round post-tensioned wire cables (7 wires per strand) having a tensile strength of 16.7 KN. The cables are connected to steel posts, which are placed at a spacing of 3m. The top edge of the post is at a height of 780 mm above the ground level while the top and the bottom cable being at a height of 670mm and 480mm respectively. The details and tensioning table of cable barrier is shown in Figure 2.2.



Tensioning table T2 for SAFENCE wire rope safety fence

Temp [°C]	Temp [F]	Force [kp]	Force [kN]	Pressure [bar]*
-20	-4	3 200	31.4	350
-10	14	2 900	28.4	320
0	32	2 600	25.5	290
+10	50	2 300	22.5	250
+20	68	2 000	19.6	220
+30	86	1 700	16.7	190
+40	104	1 400	13.7	150
+50	122	1 100	10.8	120

b. Tensioning table of cable barrier

a. Details of cable barrier (Source: Safence WRSB)

Figure 2.2 Details and tensioning table of cable barrier

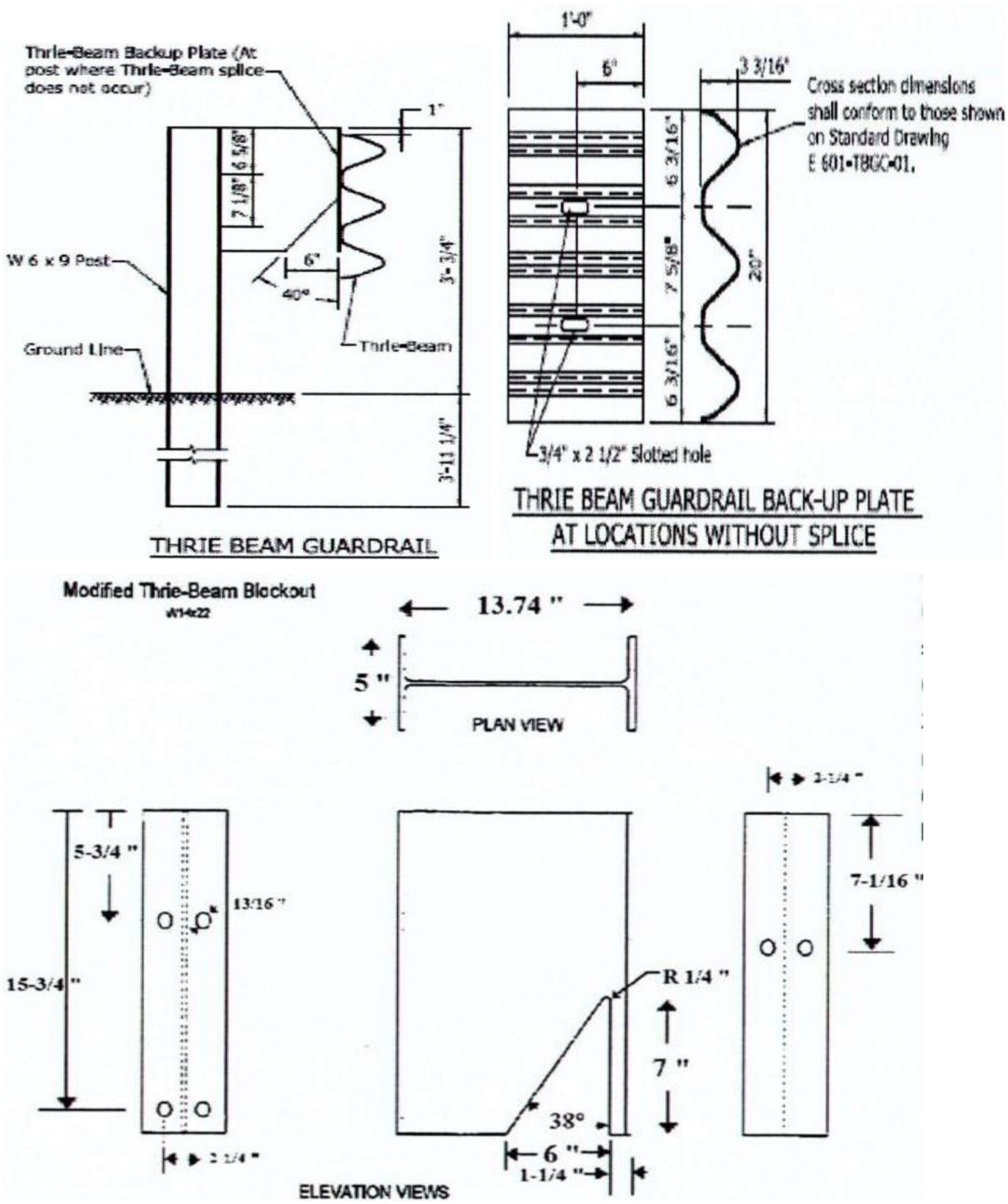
2.5 Modified Thrie Beam Barrier

Thrie-beam barrier is a type of semi-rigid barrier and is similar to w-beam corrugated rail, but it has three ridges instead of two. An important attribute of thrie beam guardrail is their high level of performance especially for large vehicles. Due to the greater height of the rail face, thrie beam guardrail provide reduced deflection and improved resistance to vehicle vaulting or under running. In modified thrie beam crash barrier, a few modifications have been made compared to normal thrie beam type barriers by increasing the spacer channel size compared to the post size leaving the lower edge of the thrie bream unconnected to the spacer channel and providing large notch cut to the web of the spacer channel at the lower end. These modifications improved the performance of the crash barrier by way of keeping the deflection lower and keeping the vehicle upright even after the impact.

2.5.1 Specification for Modified Thrie Beam Barrier

The details of modified thrie beam crash barriers which are slightly improvised version of the thrie beam type are elaborated in "Road Side Design Guide" of AASHTO. Testing of this crash barrier is as per European Standard for safety testing of crash barriers i.e., EN 1317 or NCHRP Report 350/ Manual for Assessing Safety Hardware (MASH).

The modified thrie beam guardrail system consists of 2.1-m-long steel posts spaced 1.9 m apart with block-outs. The post should be taken below ground level up to sufficient depth (not less than 1.15m). Posts of I-section of minimum 150mm x l00mm x 4.3mm and spacers of I-section of minimum 350mm x 127mm x 5.9mm are used. Thrie beam steel section shall be of specified dimensions of minimum 3 mm thickness. Steel to be used shall have minimum ultimate tensile strength of 490 Mpa. All the bolts, fasteners shall develop requisite strength in the intended working conditions and all the components of crash barrier shall be galvanized through hot dip process. The details of modified thrie beam barrier is shown in Figure 2.3.



(Source: Road Side Design Guide, AASHTO)

Figure 2.3 Details of Modified Thrie-beam barrier

2.6 Finite Element Method and Abaqus

Finite Element Method, FEM, is a numerical calculation method which solves various differential equations with the aid of a computer. FEM divide a continuum into a finite number of elements. Some finite element software available in the market includes: ABAQUS, ALGOR, ANSYS, COSMOS, NASTRAN, LS-DYNA, SimScale and more. Abaqus is a finite element program originally developed by

Dassault Syst`emes. Abaqus is a suite of engineering simulation programs that can solve problems ranging from simple linear analysis to highly complex nonlinear dynamic simulations. It consists of wide range of elements which make it possible to model any type of geometry. It has a broad list of material models that can be used to simulate material behavior of interest such as steel, concrete, aluminum, geotechnical materials such as soils and rock and other materials.

2.7 Crash Performance of Crash Barriers using FEM

The Finite Element Method has been previously used to construct models of road safety devices to simulate the performance of the devices in certain impact scenarios.

Ogmaia et al. (2015) investigated if Abaqus/Explicit could be used as the finite element software for simulation of crashes. A full-scale test was conducted and the parapet installation and vehicle used was modeled. Same conditions as in the full-scale were used in the simulation. The results indicated that it is possible to simulate the full-scale crash using Abaqus/-Explicit provided a proper vehicle model and a detailed model of the test installation.

Aziz et al. (2018) conducted a simulation study using CAE software, Abaqus to predict the mechanics behavior of the barrier under impact condition. The impact velocity of 100 kmph was assigned at the rigid impactor of 900 kg with an angle of 20º from the reference plane. The computed value from simulation was compared to the experimental test values and the results were found to be acceptable.

In a research by Neves, R.R. et al. (2018), flexible and rigid road restraint system subjected to a 900 kg car impact is studied in detail via a finite element simulation, with the model being validated against experimental results. According to test TB11 from EN 1317 standard, the impact simulation results show that the flexible guardrail is safer than any of the analyzed concrete barriers.

Jayakkanavar, R. et al. (2016) conducted a experiment on a baseline model (steel material) and a new modified model (thermo plastic material with block out) as guard rail designs that were implemented in full scale finite element model of a Ford Taurus sedan car impacting the guard rails. The new design consisted of replacing the incompressible block out by a crushable one. The result of simulation showed that the car was redirected safely with more reduced speed, less strain, less displacement for modified model than for the baseline model.

Kaplan, E.M. (2013) studied the crash of a medium heavy vehicle onto a designed vehicle barrier numerically. Structural integrity of the vehicle barrier was studied by nonlinear dynamic methods under the loading conditions which is defined in the standards. Nastran and Ls-Dyna which are commercial software were used to solve the problem.

In a study by Teng T.L. et. al (2015), the finite element code LS-DYNA was applied for evaluating the safety performance of an AG04-2.0 A-type barrier, which was designed using three post spacings and various rail heights, when impacted by a 900-kg small passenger car. Eight crash test simulations were conducted for evaluating the crashworthiness of the AG04-2.0 barrier according to the European Standard EN 1317. A baseline model was developed and validated against the existing crash test models. The results showed that the various post spacings (1.33, 2, and 4 m) and rail heights (600, 650, 700, 750 and 800 mm) enabled the AG04-2.0 barrier to withstand the impact of the 900-kg car, satisfying the EN 1317 criteria (i.e. TB11 test). The 2000-mm post spacing and 700-mm rail height were considered the optimal dimensions for AG04-2.0 road safety barriers.

Borovinsek, et al. (2007) presented the results of computer simulation on European standard En 1317 road safety barrier behavior under impact crash for high containment level. The studies were running on a multiprocessor computer platform in order to conduct a simulation using explicit finite element code LS-DYNA. Two different studies were conducted to satisfy the capability of computer simulation under high containment level. Initial study was to determine the most suitable reinforcement evaluated with different reinforcements of a chosen safety barrier. Next, the results from the simulation were compared to the large-scale experiment of the same road safety barrier design to illustrate the correlation with. Comparing the results showed a good relation between the computer simulation and the experimental of the same road safety design. Indeed, the use of computational simulation provided good benefits on reducing the cost of expensive full-scale crash test.

Shen, et al (2008) estimated the crashworthiness and optimized the design of the guardrail system in terms of relative vertical distance from the vehicle centroid to the mounting height of W-beam. This study used ABAQUS/Explicit v6.5 software to simulate the dynamic response of the safety barrier under impacts. The simulation was carried out with various heights of centroid of vehicle and the results obtained that the design with 600 mm vertical distance between the centroid of vehicle and mounting height of W-beam showed the most effective in absorbing energy during the crash process. From the present study, it is clear that the computer simulation of the road barrier impact crash can be performed by using ABAQUS/Explicit tools.

2.8 Acceleration Severity Index (ASI)

Acceleration Severity Index (ASI) is a vehicle occupant severity indicator measured during homologation of road safety barriers. For evaluation of road restraint systems, certain test methods and impact test acceptance criteria for safety barriers are defined in European standard EN 1317 (parts 1 and 2). In this standard, among others, different indices are carefully set out which should be taken into account for evaluation of impact severity and injury risk for occupants. In most of the cases, the ASI (Acceleration Severity Index) describes the impact severity well (Shojaati, 2003). ASI may vary with impact configuration (impacting vehicle mass, speed and angle) and barrier flexibility (Burbridge et al., 2016). ASI may be a vector to occupant injury outcomes. ASI is calculated according to the expression in Equation 2.1:

$$\text{ASI}=\max\left[\left(\frac{a_x}{\hat{a}_x}\right)^2+\left(\frac{a_y}{\hat{a}_y}\right)^2+\left(\frac{a_z}{\hat{a}_z}\right)^2\right]^{\frac{1}{2}} \qquad \text{Equation 2.1}$$

where $a_{x,y,z}$ are average component vehicle accelerations respectively in the longitudinal, lateral and vertical direction measured over a prescribed time interval (50 milliseconds), and $\hat{a}_{x,y,z}$ are corresponding threshold values for the respective component accelerations (Gabauer & Gabler, 2005). The denominator values for the component threshold accelerations $\hat{a}_{x,y,z}$ as adopted in both the US and European test protocols are respectively $\hat{a}_x$=12g, $\hat{a}_y$=9g and $\hat{a}_z$=10g (and g = acceleration due to gravity). The threshold accelerations are interpreted as the values below which passenger risk is very small (light injures if any). 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 vehicle. ASI is a dimensionless quantity and is a scalar function of time; it has only positive values. The ASI is used for characterizing the impact intensity, which is considered the most critical indicator of the impact rate on vehicle occupants. In general, a higher ASI index indicates a more severe collision and thus, a higher injury risk. The more ASI exceeds unity, the more the risk to the occupant. Therefore, the maximum value attained by ASI in a collision is assumed as a single measure of its severity.

CHAPTER III
METHODOLOGY

3.1 Introduction

This chapter describes the methodology used in this study to predict the impact behavior of crash barriers under impact in terms of absorption energy, occupant severity indicator ASI and deflection. The analysis utilizes finite element software which is widely used in many engineering courses. This is very useful for problem with complicated geometries, loading and material properties, where analytical solutions are not available. The computational simulation test for road safety barrier impact crash consists of the vehicle and the barrier models. The simulation would be done using the models that meet the standard specifications by referring several guidelines for steel beam crash barriers, W-beam barrier and Modified Thrie beam barrier as well as cable barrier.

3.2 Finite Element Modelling

The study uses Finite Element Method software ABAQUS v.6.14 to analyze the impact crash test. Modelling and analysis of the impact were carried out in Abaqus/CAE and Abaqus/Explicit. The modeling was performed in the CAE while the analysis was performed using the Explicit solver. The analysis process for any simulation task consists of

- Pre-processing – defining the finite element model and environmental factor to be applied to it such as geometric property, element types, constraints and loading to the model.
- Analysis Solver – solution of finite element model which the software solves for deriving variables, such as reaction forces, element stresses, energy, and heat flow.
- Post-processing of results – used for sorting, printing and plotting in evaluating the results using visualization tools.

3.3 Computer Simulation in ABAQUS

The first step to carry out the simulation process was to construct the models of the crash barriers and simplified vehicle model. The components of crash barriers were modelled carefully by following to the exact specification in order to represent as the actual model. The modeling was performed in CAE. When satisfactory models were developed, the final model was used to carry out the simulation. A simplified vehicle model was used as the impactor and an impact velocity and impact angle was assigned to the reference point of the vehicle. Simulation of vehicle impact on three different crash barriers was conducted. In order to simulate the dynamic response behavior of the crash barrier, analysis is conducted by using Dynamic/Explicit for crashworthiness simulations. The models are simulated to carry out finite element analysis (FEA) by following steps as shown in Figure 3.1 below.

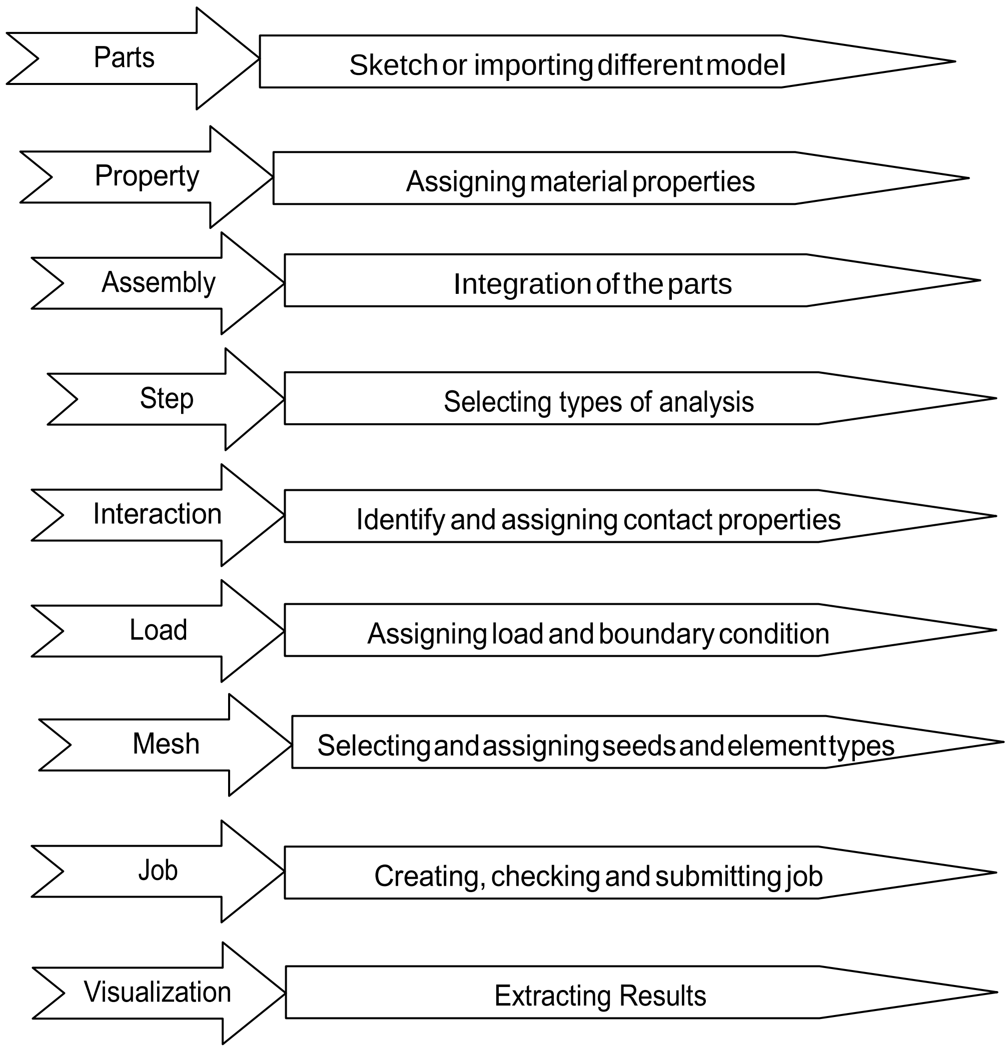


Figure 3.1 Simulation Steps

3.3.1 Part

All the parts of the crash barriers were firstly modelled by using ABAQUS/CAE tool. The model is created carefully based on the specifications and dimensions specified as given in section 2.3.1, 2.4.1 and 2.5.1. The cross section of the parts was created in the sketch feature of Abaqus/CAE. The length of the sketched part was obtained by extruding the cross section. The parts of the barriers were modelled as homogeneous shell element and the vehicle was modelled as discrete rigid. The w-beam part of w-beam barrier model is shown in Figure 3.2 and thrie beam part of modified thrie beam barrier model is shown in Figure 3.3.

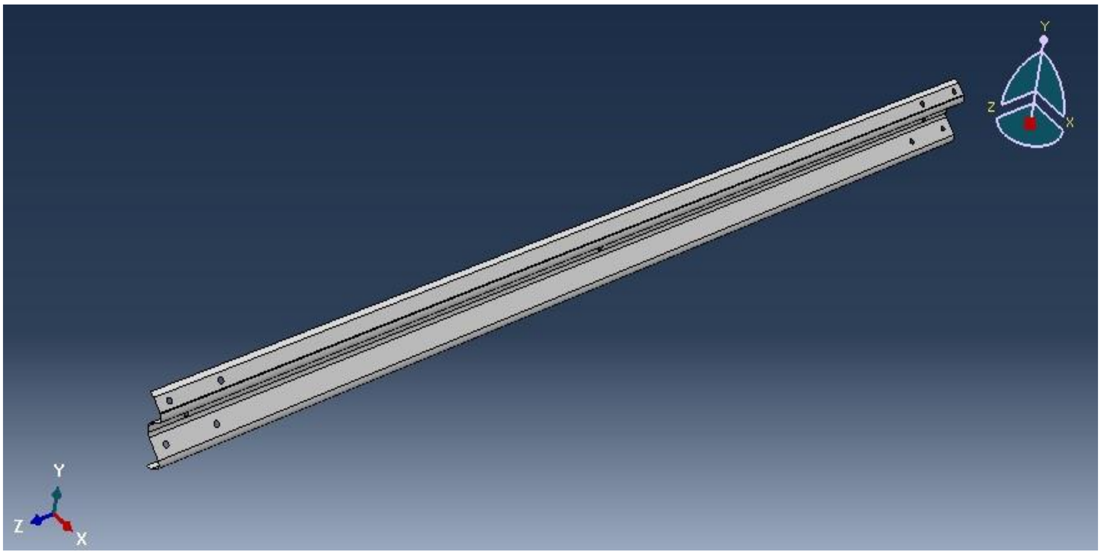


Figure 3.2 W-beam part

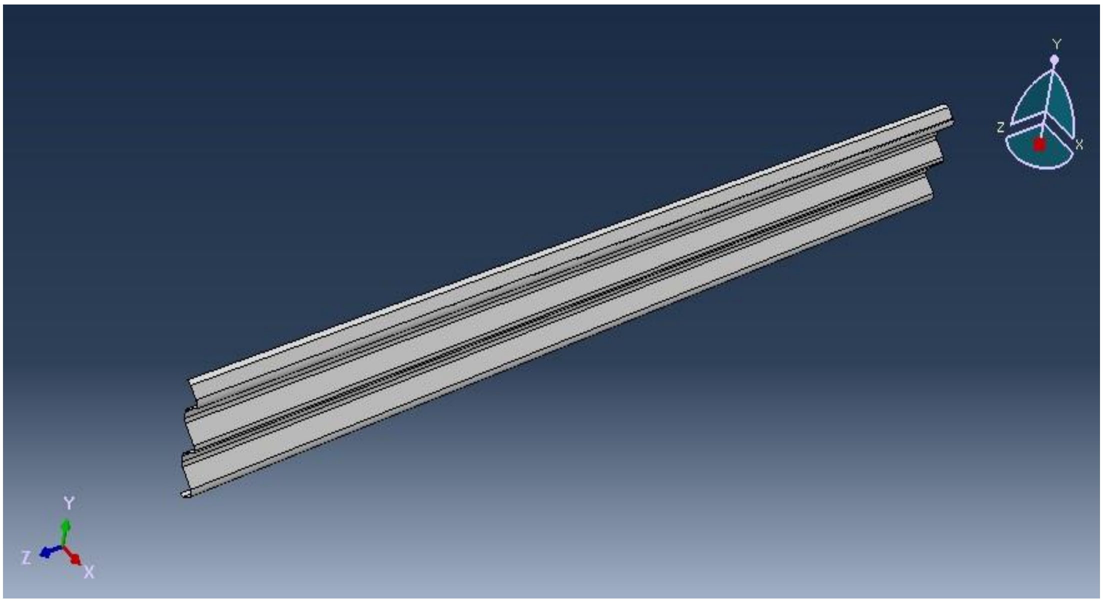
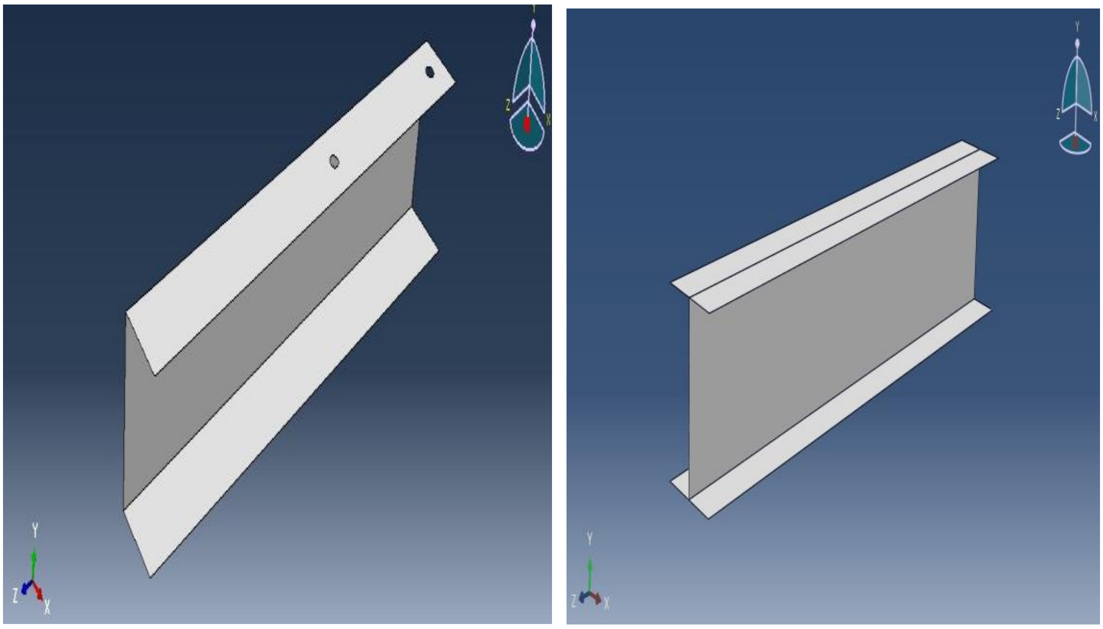


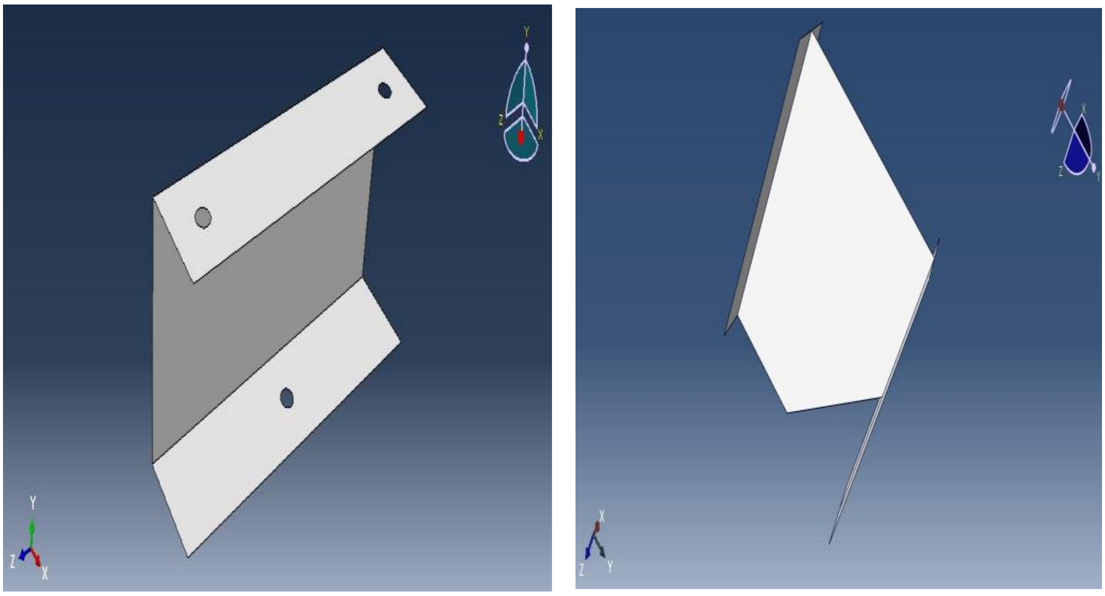
Figure 3.3 Thrie beam part

Similarly, Figure 3.4 shows post part of w-beam model and modified thrie beam model. Also, spacer part of w-beam and modified thrie beam model is shown in Figure 3.5. Post and rope part of cable barrier model is shown in Figure 3.6.



a) Post part for w-beam model b) Post part for modified thrie beam model

Figure 3.4 Post Part of w-beam and modified thrie beam model



a) Spacer part for w-beam model b) Spacer part for modified thrie beam model

Figure 3.5 Spacer Part of w-beam and modified thrie beam model

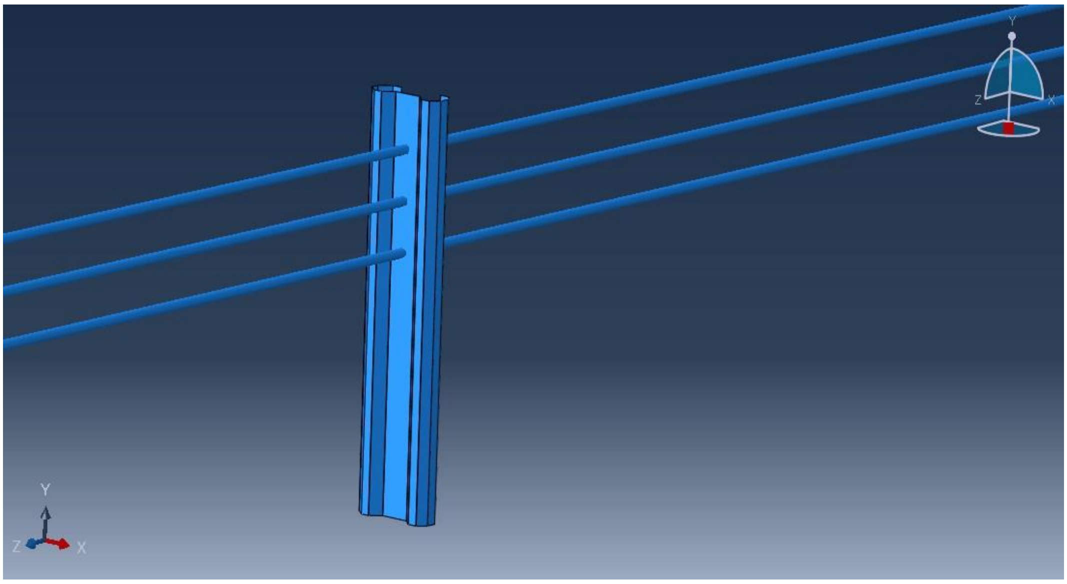


Figure 3.6 Post and rope part of cable barrier model

3.3.2 Property

After all the parts of the models have been generated, the material was defined and all the parts were assigned the material properties except the parts that have been created as discrete rigid. The density, elasticity and plasticity of the material steel was defined. The material properties for the steel used is as tabulated in Table 3.1. For the rigid part, vehicle, a point mass of 8000 kg and 2000 kg was created as inertia and was assigned to the reference point of the vehicle to represent as the impact load.

Table 3.1: Material Properties of Steel

Material Properties	**Value**
Density, ρ (kg/m^3)	7850
Young’s Modulus, *E* (Gpa)	200
Poisson’s Ratio, υ	0.3
Yield Stress, σ_y (Mpa)	310
Tensile Strength of rope (kN)	16.7

3.3.3 Assembly

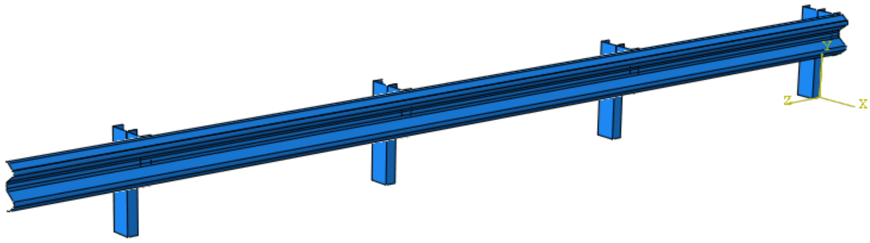
When all the necessary parts required for the simulation were created, a complete model could be assembled. The parts of the models after being assigned the material properties were imported into the assembly module for the assembly of the parts to create a model. Two commands Translate and Rotate were used to assemble the parts. The beam parts were connected to the posts through the spacer in the w-beam and modified thrie beam model while the 3-strands of ropes were assembled to the posts in cable barrier model. The posts in all the models were fixed to the ground. The top of the guardrail was located 700 mm and 930 mm above the ground level for w-beam and modified thrie beam respectively with 2m spacing between the posts along the rail. For the cable barrier, the top edge of the post was at a height of 780 mm above the ground level while the top and the bottom cable being at a height of 670mm and 480mm respectively. The posts in cable barrier model were placed at a distance of 3m center-to-center. The longitudinal rail system of 8m length was used for each model. The simplified vehicle model was also positioned to complete the model for crash. The models of barriers as well as the assembled barrier-vehicle model are shown in Figure 3.7.

3.3.4 Step and Output Definitions

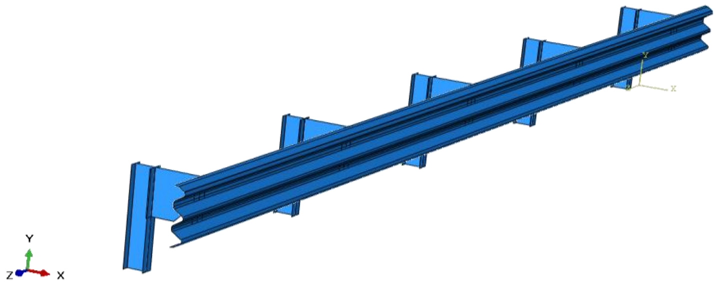
To perform crash simulation of vehicle to barrier, a Dynamic/Explicit step was created. The step was assigned time period of 0.03 second. Stresses, strains, displacement, velocity, acceleration, force and contact were requested in the field output while the energy was requested for the results in history output. The output for the whole model at every 0.001 units of time was requested. Field output basically used the Visualization module to view field output data using deformed shape, contour or symbol plots while the history output used the Visualization module to display history output using X-Y plot.

3.3.5 Interaction

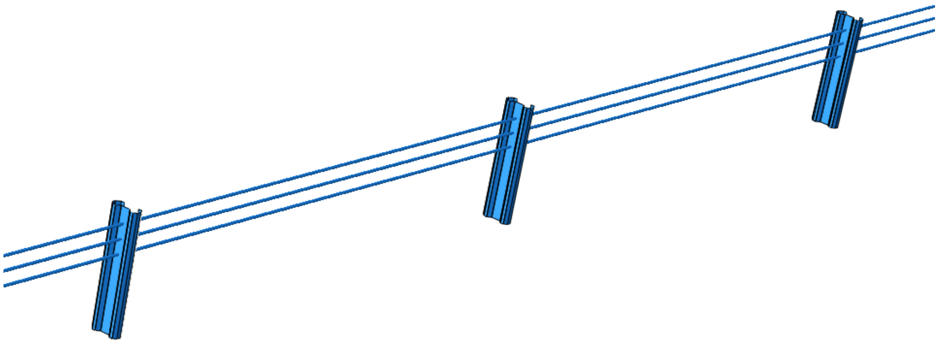
The contact definition was made in the contact property tool for the whole model which applied for all exterior surfaces of the parts. The contact definition normal behavior with hard surface contact and also mechanical tangential behavior penalty with friction coefficient 0.1 was set in the contact property. Tie surface interactions were created between beams, posts and spacers to represent bolt connections between the parts for w-beam and modified thrie beam barrier model and were assumed to be connected throughout the simulation. Tie surfaces were also created to connect the ropes to the posts in the cable barrier model.



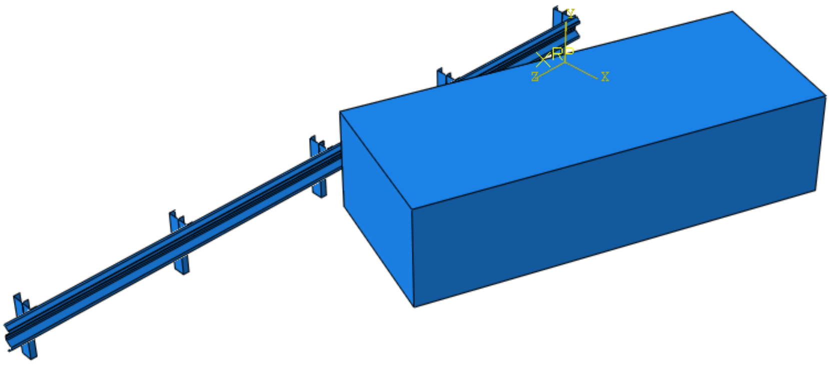
a) W-beam barrier model



b) Modified thrie beam barrier model



c) Cable barrier model



d) Assembled barrier-vehicle model

Figure 3.7: Barrier models and assembled barrier-vehicle model

3.3.6 Load and Boundary Conditions

The initial step which is predefined and created is a gravitational load for the whole model and is assumed to be 9.81 m/s^2 to represent as a gravitational force from the ground. In the load module, vehicle's initial velocity and impact angle were defined in the predefined field tool in order to simulate the crash. Fixed boundary conditions were imposed at the bottom of the posts of all barriers. In the predefined field of load module, tension force of 16.7kN was created in the initial step to represent tension in the ropes for cable barrier.

3.3.7 Meshing

The mesh characteristics of the parts such as mesh density, element shape and the element type were firstly defined in the mesh control tool. A final global mesh size of 5 mm was assigned according to the appropriate number of nodes and elements and the mesh was generated.

3.3.8 Job Analysis

The job was created and data check was performed to determine any possible error. Then the job was submitted for analysis to monitor the progress. The input file was written and a full analysis was run. The results of the completed analysis were obtained by using the Abaqus/CAE under visualization module.

3.4 Crash Configuration

The mass of 8000 kg and 2000 kg was used to represent heavy and light vehicles as per the nominal mass used in standard crash tests of NCHRP Report 350.

The impact angles of 15º, 20º and 25º were used as per the recommendation of the NCHRP Report 350 for crash testing of the road safety barriers.

The speeds of 80 kmph, 60 kmph, 40 kmph and 30 kmph were used as per the design speeds for mountainous terrain in NRS 2070 to represent varying impact conditions of speed.

CHAPTER IV
RESULTS

4.1 Introduction

This chapter presents the results of the study based on computational simulation of the crash barriers using finite element software. The simulation was done by impacting the three types of barriers under different crash conditions. Vehicle loads of 8000 kg and 2000 kg at impact velocities of 80 kmph, 60 kmph, 40 kmph and 30 kmph as well as impact angles of 15º, 20º and 25º were used for simulation of crashes. A total of 24 simulations were carried out for each barrier. The results of simulation test are evaluated based on the amount of absorbed energy in terms of kinetic energy and internal energy, occupant risk indicator ASI and deflection of the barriers.

4.2 Energy absorption behavior of barriers

The results of simulation test are evaluated based on the amount of absorbed energy in terms of kinetic energy and internal energy. Kinetic energy is dependent on the velocity and mass of the vehicle. Internal energy is dependent on the material properties of the crash barriers. The absorbed energy by the w-beam, modified thrie beam and cable barriers in terms of internal energy under various crash conditions are presented in Figures 4.1, 4.2 and 4.3 respectively.

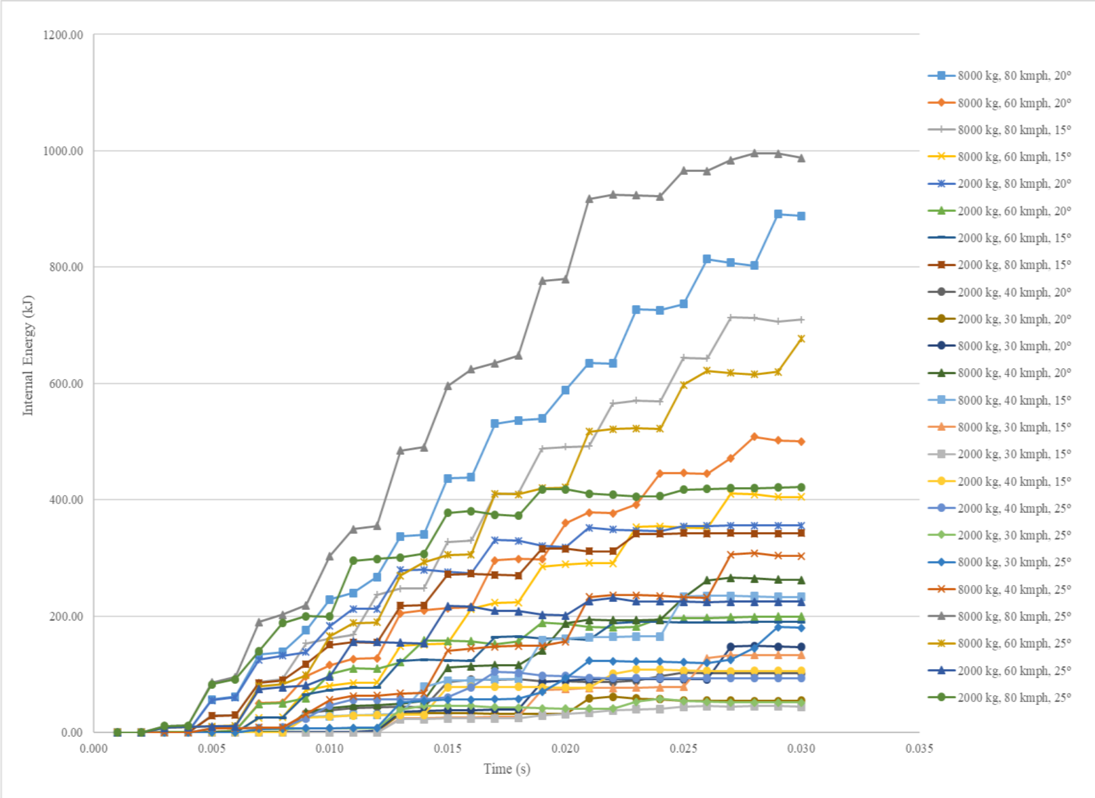


Figure 4.1 Internal Energy of w-beam barrier under different crash conditions

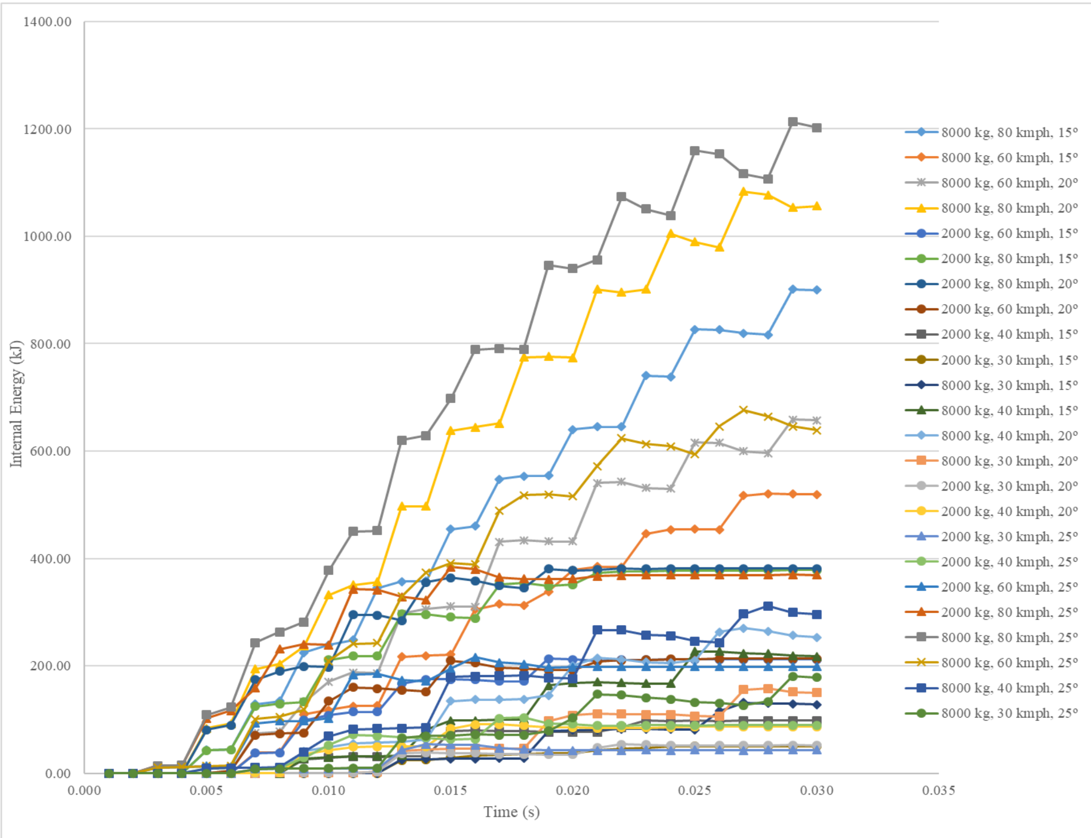


Figure 4.2 Internal Energy of modified thrie beam barrier under different crash conditions

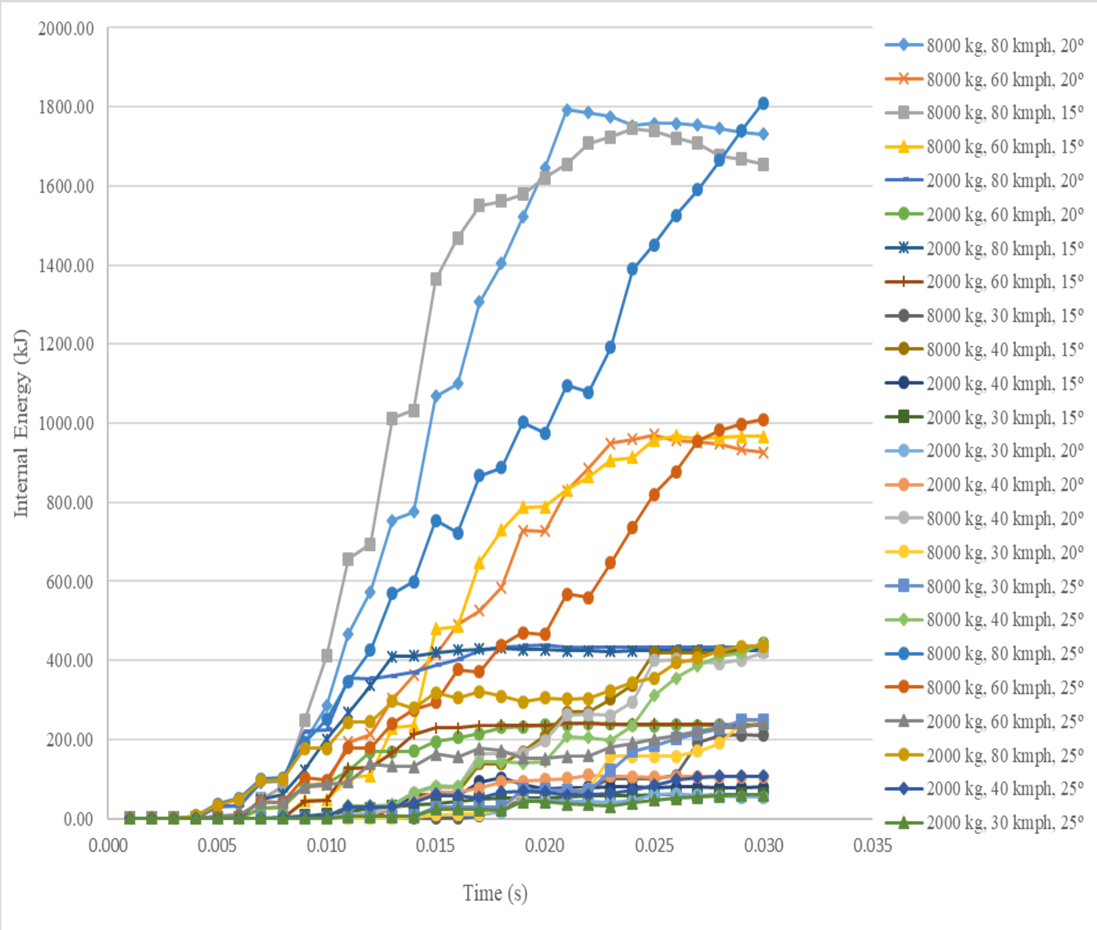


Figure 4.3 Internal Energy of cable barrier under different crash conditions

From the Figures 4.1, 4.2 and 4.3, it can be seen that the maximum internal energy for all the barriers is under the impact condition of 8000 kg, 80 kmph and 25º. It implies that the absorption energy of the barrier is higher at higher mass, higher impact speed and higher impact angle of the vehicle as observed from the graph. The comparison of the internal energy of three barriers at maximum energy absorption condition, i.e. for 8000 kg, 80 kmph and 25º is shown in Figure 4.4 below.

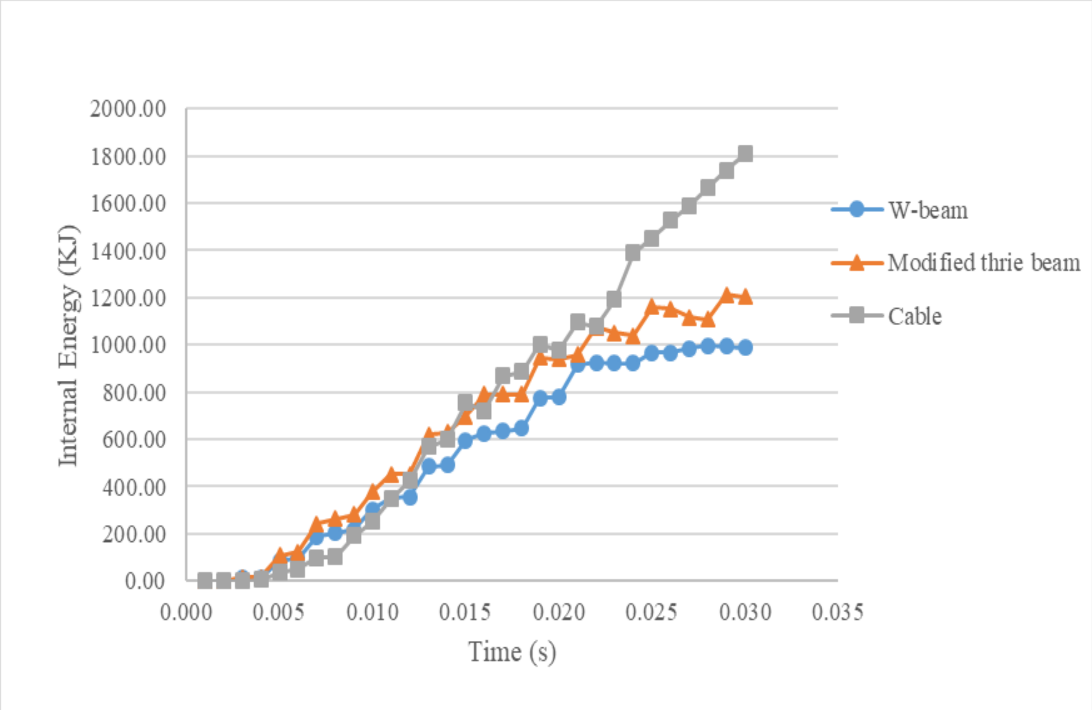


Figure 4.4 Internal Energy of different barriers at mass 8000 kg, speed 80 kmph and impact angle 25º

As observed from the Figure 4.4, the cable barrier has the highest internal energy while the w-beam barrier has the lowest value. The maximum values of internal energy for the w-beam, modified thrie beam and cable barrier are obtained as 995.96 KJ, 1213.15 KJ and 1809.12 KJ respectively (refer Annex A, B and C). This indicates that modified thrie beam barrier absorbs 21.80% more energy and cable barrier absorbs 81.65 % more energy than w-beam barrier. Also, cable barrier absorbs 49.12 % more energy than modified thrie beam barrier.

Similarly, the internal energy of three barriers at impact condition of minimum energy absorption, i.e. at 2000 kg, 30 kmph and 15º is as shown in Figure 4.5.

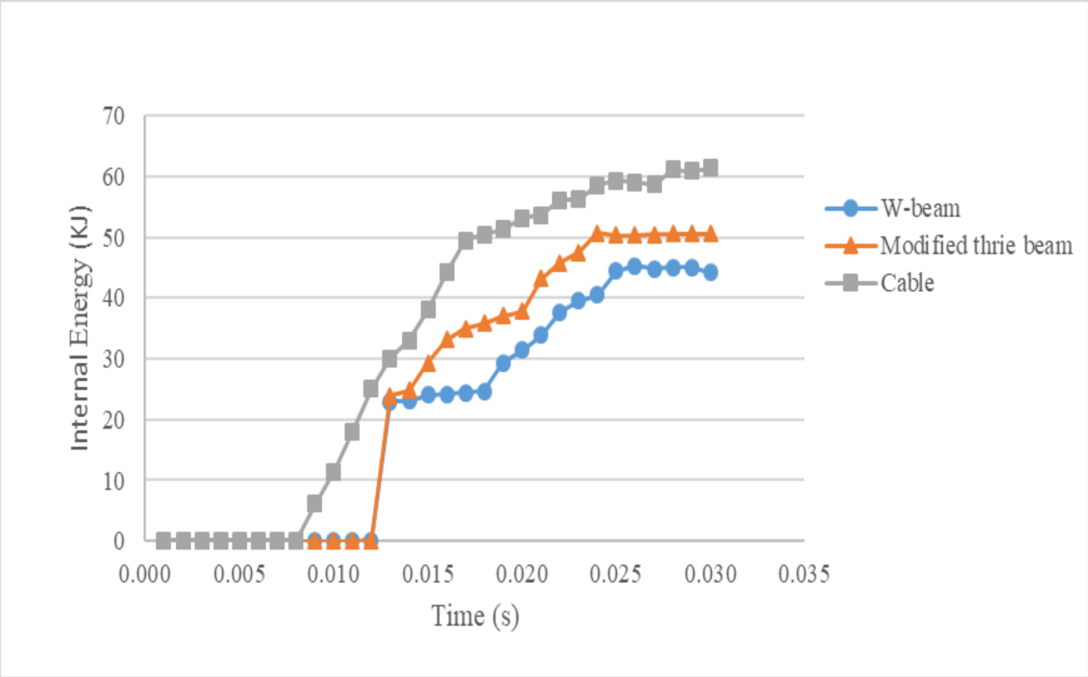


Figure 4.5 Internal Energy of different barriers at mass 2000 kg, speed 30 kmph and impact angle 15º

The Figure 4.5 also shows that maximum energy is absorbed by cable barrier followed by modified thrie beam and w-beam respectively. The maximum internal energy at impact condition of 2000 kg, 30 kmph and 15º for w-beam, modified thrie beam and cable barrier is 45.30 KJ, 50.66 KJ and 61.32 KJ respectively (refer Annex A, B and C). This indicates that modified thrie beam absorbs 11.83% more energy than w-beam whereas cable absorbs 35.36% more energy than w-beam barrier. This shows that energy absorption by cable barrier and modified thrie barrier is more significant at higher values of impact conditions than for lower values.

4.3 ASI value of barriers

The Acceleration Severity Index value (ASI) of different barriers were calculated at impact condition of impact load 8000 kg, impact speed 80 kmph and impact angle 15º. ASI was calculated using the equation as given in Section 2.8 as:

$$\text{ASI}=\max\left[\left(\frac{a_x}{\hat{a}_x}\right)^2+\left(\frac{a_y}{\hat{a}_y}\right)^2+\left(\frac{a_z}{\hat{a}_z}\right)^2\right]^{\frac{1}{2}}$$

Equation 2.1

where $a_{x,y,z}$ are average component vehicle accelerations respectively in the longitudinal, lateral and vertical direction measured over a prescribed time interval (50 milliseconds), and $\hat{a}_{x,y,z}$ are corresponding threshold values for the respective component accelerations.

For w-beam barrier, in the longitudinal direction, the maximum 0.050-s average acceleration was obtained from the acceleration values on centre of gravity of vehicle from simulation process as 2.5g's. In the lateral direction, the maximum 0.050-s average was 3.1g's.

So, $a_x = 2.5g$ and $a_y = 3.1g$

Also, from Section 2.8, $\hat{a}_x$=12g, $\hat{a}_y$=9g and $\hat{a}_z$=10g. Putting these values in Equation 2.1, we get ASI value 0.40.

Similarly, for modified thrie beam barrier, $a_x = 1.6g$ and $a_y = 2.5g$

$\hat{a}_x$=12g, $\hat{a}_y$=9g and $\hat{a}_z$=10g

From the equation 2.1, ASI is calculated as 0.30.

Likewise, for cable barrier, $a_x = 0.8g$ and $a_y = 2.1g$

Also, $\hat{a}_x$=12g, $\hat{a}_y$=9g and $\hat{a}_z$=10g

Putting these values in Equation 2.1, we get ASI value 0.24.

From the calculations, the cable barrier shows minimum ASI value which means least vehicle occupant risk and w-beam shows highest value of occupant risk indicator.

4.4 Deflection of barriers

The deflection of different barriers was calculated at impact condition with maximum internal energy, i.e. at impact load 8000 kg, impact speed 80 kmph and impact angle 25º. The values of deflection for w-beam, modified thrie beam and cable barrier were obtained from simulation as 1.28 m, 0.83 m and 2.35 m respectively.

4.5 Validation

For the validation purpose, the result of the crash simulation tests in this study is compared to the previously conducted standard tests. In the NCHRP Report 350 Test 4-12 of the Modified Thrie Beam Guardrail, crash test was conducted on modified thrie beam guardrail with vehicle load of 8000 kg, impact speed 78.8 kmph and impact angle of 15.7º. The ASI value from the standard test is found to be 0.2. While the ASI value of modified thrie beam barrier from the simulation was found to be 0.3.

Similarly, Burbridge et al. (2016) presents the nominal crash test data for test 4-12 of

NCHRP Report 350 in which crash test on wire rope barrier with vehicle mass 8050 kg, impact speed 79.7 kmph and impact angle 15.8º gives an ASI value of 0.18. The value from this study was found to be 0.24. The difference in values may be due conditions that were unaccounted for from the actual full-scale test and because of the simplifications and assumptions made during modelling.

CHAPTER V
DISCUSSIONS

5.1 Findings of the study

The study applied the finite element code Abaqus to evaluate the safety performance of w-beam guardrail, modified thrie beam guardrail and cable barrier when impacted upon by vehicle at different impact conditions of mass, speed and angle. The findings of the study can be summarized in the following points:

1. Based on the simulation results, clearly the modified thrie beam barrier and cable barrier absorb more kinetic energy of the vehicle than the w-beam barrier.
2. The severity level for the vehicle was also found to be less for other two barriers than the w-beam barrier as indicated by the occupant risk indicator acceleration severity index (ASI).
3. The values of deflection for w-beam, modified thrie beam and cable barrier were obtained from simulation as 1.28 m, 0.83 m and 2.35 m respectively.
4. The energy absorption of modified thrie beam barrier and cable barrier in comparison to w-beam barrier was more significant for heavy vehicle than for light vehicle which shows that the barriers can be more effective in conditions of impact with heavy vehicle.
5. Overall, the impact performance of modified thrie beam barrier and cable barrier was found better than w-beam guardrail. The optimal result was registered by the cable barrier, which demonstrated higher crash energy absorption and a lower ASI value than the other barriers did.

5.2 Limitations of the Study

The assumptions and simplifications used in this study are as presented below:

1. The vehicle was not modelled, instead a simplified vehicle model was used and it was assumed as discrete rigid.
2. The boundary conditions were assumed to be fixed and the post-ground interaction was not accounted for.
3. The study uses FEM software Abaqus based on the results of previous researches that Abaqus can be used for preparing impact scenario models and simulation that represents full-scale crash tests.

4. Simplifications were made in the modelling.

5.3 Suggestions for Future Work

Based on the limitations of this study and future scope, the following suggestions can be made for further works:

1. Detailed modelling can be done and actual vehicle model be used that would represent more accurate and real crash scenario.
2. Study can be carried out for other conditions of impact load, speed and angle.
3. The crash simulation can be conducted using other finite element software.
4. The study can be extended to other types of rigid, semi-rigid and flexible barrier to understand their behavior.

5.4 Conclusion and Recommendations

Road crashes and safety issue are a serious global problem. The problem is severe in Nepalese roads as well especially because of the increase in road crashes along with increasing traffic flow and critical road geometry along hill roads. Crash barriers are one of the ways to address this issue. Different types of crash barriers are in use in context of Nepal, which seem not to be sufficient with high traffic intensity and adverse road conditions leading to high rate of crashes. This study reviews the various types of barrier along with the conventional w-beam steel barrier that is mostly in use to explore the possibility of use of these barriers to improve road safety.

From the study, it was found that the modified thrie beam barrier and cable barrier absorb more impact energy than w-beam barrier and the occupant risk injury was also found to be less for these barriers than w-beam barrier. The best performance was demonstrated by the cable barrier with maximum impact energy absorption and lowest ASI value. Overall, it was found that both the barriers, modified thrie beam and cable barrier could be preferred for use over w-beam barrier, also considering the lateral space availability at installation site. The modified thrie beam and cable barrier would be more effective for restraining heavy vehicles as found from the results and their use along the hazardous locations or high crash areas would result in more energy absorption of the crash and less risk of injury to the vehicle occupants lowering the severity of crash and eventually improving the road safety aspect.

Hence, modified thrie beam barriers and cable barriers can be used at locations having high crash rates to reduce the crash severity and occupant risk, where the traffic and road conditions allow. Furthermore, the roadside safety can be improved by opting to these barriers which is also evident from the previous studies on safety performance of barriers that indicate the reduction in the severity of crashes as well as overall crash rates. In order to mitigate and lower the severity of road crashes, these unconventional safety barriers can play an important role which needs to be recognized by the concerned institutions. The potential of using simulation method to explore the behavior of different road safety devices also needs to be assessed to make improvements on existing design of barriers as well as design a new type of barrier for road safety.

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APPENDIX A: KE, TE and IE of W-beam barrier

	At 8000 kg, 80 kmph, 20º			At 8000 kg, 80 kmph, 15º			At 8000 kg, 60 kmph, 20º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	1974.94	1974.94	0.00	1974.38	1974.38	0.00	1110.91	1110.91	0.00
0.002	1974.94	1974.94	0.00	1974.40	1974.40	0.00	1110.91	1110.91	0.00
0.003	1974.51	1974.91	0.40	1974.40	1974.40	0.00	1110.64	1110.92	0.28
0.004	1974.37	1974.86	0.49	1974.40	1974.40	0.00	1110.59	1110.90	0.31
0.005	1918.34	1974.82	56.48	1945.43	1974.45	29.02	1110.33	1110.84	0.51
0.006	1913.38	1974.83	61.45	1944.84	1974.54	29.70	1107.46	1110.85	3.39
0.007	1841.13	1974.79	133.66	1887.10	1973.80	86.70	1060.28	1110.86	50.58
0.008	1836.63	1974.79	138.16	1882.03	1973.80	91.77	1059.07	1110.85	51.78
0.009	1799.43	1975.00	175.57	1820.32	1973.67	153.35	1014.30	1110.94	96.64
0.010	1746.32	1974.83	228.51	1812.32	1973.64	161.32	995.16	1110.83	115.67
0.011	1735.35	1974.88	239.53	1805.12	1973.46	168.34	984.75	1110.80	126.05
0.012	1708.24	1975.19	266.95	1737.01	1973.44	236.43	983.27	1110.80	127.53
0.013	1638.98	1975.73	336.75	1726.45	1973.43	246.98	906.17	1110.79	204.62
0.014	1635.91	1976.08	340.17	1725.51	1973.36	247.85	901.05	1110.79	209.74
0.015	1540.10	1976.58	436.48	1645.78	1973.27	327.49	897.29	1110.78	213.49
0.016	1538.21	1976.84	438.63	1643.15	1973.13	329.98	895.37	1110.80	215.43
0.017	1446.67	1977.52	530.85	1563.31	1972.65	409.34	814.84	1110.77	295.93
0.018	1441.03	1977.62	536.59	1561.98	1972.47	410.49	812.24	1110.77	298.53
0.019	1438.33	1977.89	539.56	1484.25	1972.14	487.89	812.88	1110.79	297.91
0.020	1389.52	1978.46	588.94	1480.97	1972.01	491.04	750.98	1110.93	359.95
0.021	1343.12	1978.33	635.21	1479.53	1971.68	492.15	732.54	1110.78	378.24
0.022	1343.94	1978.40	634.46	1406.23	1971.69	565.46	733.72	1110.78	377.06
0.023	1251.94	1978.80	726.86	1400.83	1971.30	570.47	718.94	1110.84	391.91
0.024	1252.93	1978.83	725.90	1402.18	1971.29	569.11	665.11	1110.77	445.66
0.025	1242.72	1979.24	736.52	1326.95	1971.35	644.40	664.60	1110.77	446.18
0.026	1165.69	1979.26	813.57	1328.45	1971.33	642.88	665.92	1110.75	444.83
0.027	1171.56	1979.31	807.75	1257.84	1971.39	713.55	639.03	1110.85	471.82
0.028	1176.56	1979.34	802.78	1258.78	1971.39	712.61	602.55	1110.74	508.19
0.029	1088.29	1979.67	891.38	1265.01	1971.48	706.47	608.34	1110.74	502.40
0.030	1091.55	1979.75	888.20	1261.78	1971.55	709.77	610.36	1110.73	500.37

	At 8000 kg, 60 kmph, 15º			At 2000 kg, 80 kmph, 20º			At 2000 kg, 80 kmph, 15º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	1111.14	1111.14	0.00	493.74	493.74	0.00	493.60	493.60	0.00
0.002	1111.14	1111.14	0.00	493.74	493.74	0.00	493.60	493.60	0.00
0.003	1111.14	1111.14	0.00	493.33	493.73	0.40	493.60	493.60	0.00
0.004	1111.14	1111.14	0.00	493.25	493.74	0.48	493.60	493.60	0.00
0.005	1111.14	1111.14	0.00	438.38	493.73	55.35	464.79	493.60	28.81
0.006	1111.14	1111.14	0.00	433.48	493.73	60.25	464.12	493.62	29.50
0.007	1085.36	1110.92	25.56	368.37	493.71	125.34	408.76	493.69	84.93
0.008	1085.09	1110.83	25.74	361.93	493.73	131.79	404.30	493.73	89.43
0.009	1037.80	1110.56	72.76	355.53	493.72	138.19	376.56	493.94	117.38
0.010	1030.08	1110.45	80.37	310.67	493.86	183.19	343.19	493.85	150.66
0.011	1025.13	1110.24	85.11	281.48	493.73	212.25	338.81	493.95	155.14
0.012	1024.26	1110.15	85.89	281.33	493.73	212.40	339.53	493.97	154.44
0.013	961.27	1109.97	148.71	214.91	493.73	278.82	276.33	494.01	217.68
0.014	958.93	1109.95	151.02	214.00	493.73	279.74	275.13	494.03	218.90
0.015	956.66	1109.75	153.09	217.73	493.73	276.00	222.68	494.08	271.40
0.016	897.53	1109.70	212.17	219.52	493.73	274.21	221.26	494.07	272.81
0.017	886.65	1109.58	222.94	163.22	493.72	330.50	223.26	494.13	270.87
0.018	886.33	1109.60	223.27	164.14	493.72	329.58	224.66	494.14	269.49
0.019	824.27	1109.60	285.33	173.05	493.72	320.67	178.60	494.17	315.57
0.020	820.53	1109.61	289.08	175.54	493.72	318.17	178.18	494.19	316.00
0.021	818.32	1109.62	291.31	141.46	493.71	352.26	182.62	494.23	311.61
0.022	818.53	1109.64	291.11	144.80	493.72	348.92	182.61	494.24	311.63
0.023	756.34	1109.66	353.32	146.87	493.71	346.84	152.64	494.25	341.62
0.024	754.93	1109.67	354.75	147.33	493.71	346.38	152.86	494.26	341.40
0.025	757.31	1109.69	352.38	139.11	493.71	354.60	151.80	494.27	342.47
0.026	758.29	1109.70	351.41	138.79	493.71	354.92	152.12	494.27	342.15
0.027	698.97	1109.71	410.74	138.21	493.71	355.50	151.85	494.27	342.42
0.028	700.13	1109.71	409.58	138.14	493.71	355.57	152.17	494.27	342.10
0.029	704.65	1109.74	405.09	138.21	493.71	355.50	152.10	494.27	342.17
0.030	705.09	1109.74	404.65	138.00	493.71	355.71	151.73	494.27	342.54

At 2000 kg, 60 kmph, 20º				At 2000 kg, 60 kmph, 15º			At 2000 kg, 80 kmph, 25º		
Step Time (s)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	277.73	277.73	0.00	277.79	277.79	0.00	493.79	493.79	0.00
0.002	277.73	277.73	0.00	277.79	277.79	0.00	493.79	493.79	0.00
0.003	277.46	277.73	0.27	277.79	277.79	0.00	482.78	493.74	10.96
0.004	277.42	277.73	0.31	277.79	277.79	0.00	482.23	493.70	11.47
0.005	277.26	277.74	0.47	277.79	277.79	0.00	411.23	493.68	82.45
0.006	274.38	277.74	3.37	277.79	277.79	0.00	402.18	493.68	91.50
0.007	228.75	277.74	48.99	252.35	277.74	25.39	353.94	493.77	139.83
0.008	227.72	277.74	50.02	252.20	277.73	25.53	305.84	493.68	187.84
0.009	218.99	277.77	58.78	212.22	277.67	65.45	293.65	493.68	200.03
0.010	177.45	277.75	100.30	204.60	277.65	73.05	294.67	493.67	199.01
0.011	167.87	277.75	109.88	200.65	277.61	76.96	198.51	493.69	295.18
0.012	168.09	277.75	109.67	200.28	277.60	77.32	195.10	493.67	298.57
0.013	157.09	277.79	120.70	154.21	277.55	123.34	192.76	493.66	300.90
0.014	119.46	277.75	158.29	152.44	277.54	125.10	186.88	493.70	306.82
0.015	120.17	277.76	157.59	153.71	277.50	123.79	115.96	493.68	377.72
0.016	121.01	277.76	156.75	154.25	277.49	123.24	112.89	493.67	380.78
0.017	126.05	277.75	151.70	113.72	277.46	163.74	119.25	493.68	374.43
0.018	120.69	277.77	157.08	112.25	277.45	165.20	120.96	493.68	372.72
0.019	89.11	277.75	188.64	115.59	277.43	161.84	75.80	493.69	417.89
0.020	90.72	277.75	187.04	116.09	277.42	161.34	75.50	493.68	418.18
0.021	95.92	277.75	181.83	117.87	277.40	159.53	83.21	493.68	410.47
0.022	97.30	277.75	180.44	89.61	277.39	187.78	84.82	493.69	408.86
0.023	96.01	277.75	181.73	87.70	277.37	189.67	87.92	493.68	405.76
0.024	81.30	277.75	196.45	87.74	277.37	189.62	87.62	493.69	406.07
0.025	81.54	277.74	196.20	87.91	277.35	189.44	76.40	493.70	417.30
0.026	81.16	277.74	196.58	87.83	277.35	189.52	74.90	493.70	418.80
0.027	79.70	277.74	198.04	87.89	277.35	189.46	73.80	493.70	419.90
0.028	78.82	277.74	198.93	87.54	277.35	189.81	73.86	493.70	419.85
0.029	78.52	277.74	199.22	87.60	277.35	189.75	72.28	493.70	421.42
0.030	78.40	277.74	199.35	87.52	277.35	189.83	72.03	493.70	421.67

	At 2000 kg, 40 kmph, 20º			At 2000 kg, 40 kmph, 15º			At 2000 kg, 30 kmph, 20º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	123.43	123.43	0.00	123.43	123.43	0.00	69.43	69.43	0.00
0.002	123.43	123.43	0.00	123.43	123.43	0.00	69.43	69.43	0.00
0.003	123.44	123.44	0.00	123.43	123.43	0.00	69.43	69.43	0.00
0.004	123.44	123.44	0.00	123.43	123.43	0.00	69.43	69.43	0.00
0.005	123.16	123.44	0.28	123.43	123.43	0.00	69.43	69.43	0.00
0.006	123.16	123.44	0.28	123.43	123.43	0.00	69.43	69.43	0.00
0.007	122.98	123.44	0.47	123.43	123.43	0.00	69.22	69.43	0.21
0.008	122.85	123.44	0.59	123.43	123.43	0.00	69.14	69.43	0.29
0.009	90.69	123.44	32.75	97.63	123.43	25.80	68.98	69.43	0.45
0.010	85.25	123.44	38.18	96.00	123.43	27.43	68.94	69.43	0.49
0.011	81.16	123.43	42.27	94.52	123.47	28.95	68.86	69.42	0.56
0.012	80.25	123.44	43.19	93.98	123.48	29.50	66.80	69.42	2.62
0.013	79.48	123.43	43.95	93.31	123.51	30.19	37.93	69.42	31.49
0.014	79.69	123.43	43.74	93.22	123.52	30.30	36.84	69.43	32.59
0.015	36.53	123.44	86.91	45.79	123.54	77.75	36.16	69.43	33.27
0.016	32.39	123.43	91.05	45.10	123.55	78.45	36.74	69.43	32.69
0.017	32.38	123.43	91.05	45.03	123.56	78.53	37.03	69.44	32.41
0.018	32.29	123.43	91.14	45.41	123.56	78.15	36.91	69.44	32.53
0.019	34.91	123.43	88.52	45.95	123.58	77.63	37.63	69.45	31.82
0.020	35.78	123.43	87.65	46.20	123.58	77.39	37.62	69.45	31.83
0.021	37.08	123.42	86.34	46.48	123.60	77.12	10.87	69.45	58.59
0.022	37.18	123.42	86.24	22.81	123.61	100.79	8.21	69.45	61.24
0.023	34.26	123.42	89.17	15.26	123.61	108.34	10.87	69.46	58.59
0.024	27.21	123.42	96.21	15.46	123.61	108.15	12.49	69.46	56.97
0.025	19.94	123.42	103.48	17.09	123.61	106.52	14.84	69.45	54.62
0.026	21.51	123.42	101.92	17.68	123.61	105.93	14.84	69.45	54.62
0.027	22.27	123.42	101.15	18.19	123.60	105.41	15.05	69.45	54.40
0.028	21.89	123.42	101.53	17.94	123.60	105.67	15.15	69.45	54.30
0.029	22.05	123.42	101.37	17.92	123.60	105.68	15.09	69.45	54.37
0.030	21.76	123.42	101.66	17.81	123.60	105.79	15.07	69.45	54.38

Step Time	At 8000 kg, 30 kmph, 20º Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	At 8000 kg, 30 kmph, 15º Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	At 2000 kg, 30 kmph, 15º Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	277.72	277.72	0.00	277.87	277.87	0.00	69.47	69.47	0.00
0.002	277.72	277.72	0.00	277.87	277.87	0.00	69.47	69.47	0.00
0.003	277.71	277.71	0.00	277.87	277.87	0.00	69.47	69.47	0.00
0.004	277.71	277.71	0.00	277.87	277.87	0.00	69.47	69.47	0.00
0.005	277.72	277.72	0.00	277.87	277.87	0.00	69.47	69.47	0.00
0.006	277.72	277.72	0.00	277.87	277.87	0.00	69.47	69.47	0.00
0.007	277.49	277.70	0.22	277.87	277.87	0.00	69.47	69.47	0.00
0.008	277.38	277.68	0.30	277.87	277.87	0.00	69.47	69.47	0.00
0.009	277.15	277.64	0.49	277.87	277.87	0.00	69.47	69.47	0.00
0.010	277.11	277.64	0.53	277.87	277.87	0.00	69.47	69.47	0.00
0.011	276.99	277.66	0.67	277.87	277.87	0.00	69.47	69.47	0.00
0.012	274.29	277.67	3.38	277.75	277.87	0.12	69.34	69.47	0.12
0.013	242.43	277.73	35.30	253.87	277.88	24.01	46.48	69.47	22.98
0.014	241.15	277.75	36.60	253.77	277.87	24.10	46.40	69.47	23.07
0.015	239.58	277.82	38.25	252.53	277.88	25.35	45.42	69.47	24.05
0.016	239.51	277.84	38.33	252.23	277.88	25.65	45.25	69.47	24.22
0.017	238.45	277.90	39.45	251.55	277.87	26.33	45.06	69.47	24.41
0.018	237.95	277.92	39.97	251.06	277.88	26.81	44.76	69.47	24.70
0.019	191.44	277.98	86.55	204.35	277.89	73.53	40.15	69.47	29.32
0.020	188.30	277.99	89.70	202.98	277.89	74.91	38.01	69.47	31.46
0.021	186.50	278.05	91.55	201.47	277.92	76.45	35.59	69.47	33.88
0.022	185.89	278.08	92.19	201.47	277.93	76.45	31.81	69.47	37.66
0.023	186.07	278.12	92.05	200.54	277.95	77.40	29.92	69.47	39.55
0.024	186.32	278.13	91.80	200.52	277.96	77.44	28.96	69.47	40.50
0.025	186.71	278.17	91.46	199.40	277.98	78.58	25.09	69.47	44.38
0.026	186.66	278.18	91.53	150.55	278.01	127.47	24.17	69.47	45.30
0.027	130.84	278.23	147.39	144.84	278.01	133.17	24.63	69.47	44.83
0.028	129.23	278.24	149.01	144.51	278.02	133.52	24.36	69.47	45.10
0.029	130.70	278.29	147.58	144.55	278.05	133.50	24.38	69.46	45.08
0.030	131.60	278.29	146.69	144.75	278.06	133.31	25.30	69.46	44.17

	At 8000 kg, 40 kmph, 20º			At 8000 kg, 40 kmph, 15º			At 2000 kg, 40 kmph, 25º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	493.74	493.74	0.00	493.71	493.71	0.00	123.50	123.50	0.00
0.002	493.74	493.74	0.00	493.71	493.71	0.00	123.50	123.50	0.00
0.003	493.74	493.74	0.00	493.71	493.71	0.00	123.50	123.50	0.00
0.004	493.74	493.74	0.00	493.71	493.71	0.00	123.50	123.50	0.00
0.005	493.47	493.76	0.29	493.70	493.70	0.00	116.29	123.49	7.20
0.006	493.47	493.76	0.29	493.70	493.70	0.00	116.09	123.49	7.40
0.007	493.24	493.74	0.50	493.70	493.70	0.00	115.29	123.49	8.20
0.008	493.11	493.74	0.63	493.70	493.70	0.00	115.09	123.49	8.40
0.009	458.12	493.74	35.62	467.23	493.74	26.50	99.32	123.50	24.19
0.010	452.44	493.73	41.29	465.62	493.74	28.12	76.63	123.51	46.88
0.011	447.64	493.72	46.09	464.12	493.86	29.75	66.71	123.50	56.79
0.012	446.38	493.73	47.35	463.52	493.90	30.38	66.95	123.50	56.55
0.013	444.38	493.72	49.34	462.56	494.04	31.47	66.32	123.50	57.18
0.014	439.10	493.73	54.62	415.78	494.08	78.30	66.05	123.50	57.45
0.015	382.47	493.73	111.26	405.29	494.12	88.84	63.43	123.50	60.07
0.016	380.03	493.73	113.70	404.98	494.15	89.16	45.57	123.51	77.94
0.017	378.12	493.75	115.64	402.84	494.24	91.40	18.97	123.50	104.53
0.018	378.22	493.75	115.52	402.40	494.26	91.87	20.76	123.50	102.75
0.019	352.84	493.81	140.97	335.66	494.34	158.68	25.84	123.50	97.65
0.020	306.15	493.79	187.64	333.16	494.37	161.21	26.65	123.50	96.85
0.021	300.20	493.77	193.58	330.84	494.44	163.60	29.78	123.49	93.72
0.022	300.51	493.79	193.27	330.20	494.48	164.28	30.25	123.49	93.24
0.023	300.51	493.78	193.27	329.59	494.54	164.96	30.44	123.49	93.06
0.024	300.22	493.79	193.57	329.48	494.55	165.07	30.45	123.49	93.04
0.025	262.71	493.85	231.14	261.13	494.64	233.50	30.37	123.49	93.12
0.026	232.09	493.81	261.72	259.98	494.65	234.67	30.42	123.49	93.07
0.027	228.11	493.79	265.69	260.23	494.72	234.50	30.38	123.49	93.11
0.028	228.97	493.79	264.82	260.52	494.73	234.21	30.39	123.49	93.11
0.029	230.96	493.78	262.82	261.61	494.80	233.19	30.37	123.49	93.12
0.030	231.78	493.78	262.00	262.09	494.82	232.73	30.37	123.49	93.12

	At 8000 kg, 30 kmph, 25º			At 8000 kg, 40 kmph, 25º			At 2000 kg, 30 kmph, 25º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	277.57	277.57	0.00	493.98	493.98	0.00	69.39	69.39	0.00
0.002	277.57	277.57	0.00	493.98	493.98	0.00	69.39	69.39	0.00
0.003	277.57	277.57	0.00	493.98	493.98	0.00	69.39	69.39	0.00
0.004	277.57	277.57	0.00	493.98	493.98	0.00	69.39	69.39	0.00
0.005	277.57	277.57	0.00	486.72	493.98	7.25	69.39	69.39	0.00
0.006	277.57	277.57	0.00	486.51	493.97	7.46	69.39	69.39	0.00
0.007	271.39	277.53	6.14	485.63	493.98	8.35	63.30	69.38	6.08
0.008	271.11	277.51	6.40	485.38	493.98	8.60	63.06	69.38	6.32
0.009	270.39	277.44	7.06	462.40	493.99	31.60	62.50	69.37	6.86
0.010	270.07	277.42	7.35	438.12	493.99	55.86	62.27	69.36	7.10
0.011	269.69	277.36	7.67	431.08	493.98	62.89	62.15	69.35	7.20
0.012	269.27	277.36	8.08	430.55	493.97	63.42	62.07	69.35	7.28
0.013	225.89	277.36	51.48	426.91	493.96	67.05	29.35	69.36	40.01
0.014	223.46	277.36	53.90	425.94	493.96	68.02	23.56	69.35	45.80
0.015	221.02	277.36	56.34	353.58	493.98	140.40	23.24	69.36	46.12
0.016	221.09	277.37	56.28	349.66	493.97	144.31	23.47	69.35	45.88
0.017	220.07	277.36	57.30	346.13	493.95	147.82	25.90	69.35	43.45
0.018	219.49	277.37	57.88	344.92	493.95	149.03	26.36	69.35	42.99
0.019	207.43	277.38	69.95	344.88	493.93	149.05	27.88	69.34	41.47
0.020	184.18	277.39	93.21	337.83	493.95	156.12	28.32	69.34	41.03
0.021	154.05	277.38	123.33	261.19	494.01	232.82	28.61	69.34	40.73
0.022	154.49	277.37	122.89	257.91	494.03	236.13	28.62	69.34	40.72
0.023	155.24	277.37	122.13	258.37	494.12	235.75	16.29	69.34	53.05
0.024	155.18	277.36	122.18	259.14	494.14	235.00	11.57	69.34	57.78
0.025	156.89	277.36	120.47	261.63	494.22	232.60	15.18	69.34	54.16
0.026	157.63	277.36	119.73	262.28	494.24	231.96	16.41	69.34	52.93
0.027	152.07	277.37	125.30	188.58	494.33	305.75	18.00	69.34	51.34
0.028	132.18	277.40	145.22	186.22	494.34	308.13	17.85	69.34	51.49
0.029	96.12	277.41	181.29	190.58	494.39	303.81	17.81	69.34	51.53
0.030	97.70	277.42	179.72	191.34	494.41	303.07	17.60	69.34	51.74

	At 8000 kg, 80 kmph, 25º			At 8000 kg, 60 kmph, 25º			At 2000 kg, 60 kmph, 25º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	1975.17	1975.17	0.00	1111.50	1111.50	0.00	277.88	277.88	0.00
0.002	1975.17	1975.17	0.00	1111.50	1111.50	0.00	277.88	277.88	0.00
0.003	1963.87	1974.86	10.99	1103.22	1111.48	8.26	269.64	277.87	8.24
0.004	1962.95	1974.47	11.52	1102.31	1111.48	9.17	268.73	277.87	9.15
0.005	1888.66	1974.50	85.84	1101.11	1111.45	10.34	267.63	277.86	10.23
0.006	1879.47	1974.50	95.03	1099.93	1111.43	11.50	267.29	277.86	10.57
0.007	1784.75	1974.57	189.82	1032.08	1111.42	79.34	203.35	277.87	74.52
0.008	1772.21	1974.49	202.28	1028.64	1111.42	82.78	199.99	277.87	77.88
0.009	1755.85	1974.48	218.63	1012.94	1111.45	98.51	197.17	277.87	80.71
0.010	1671.02	1974.67	303.65	945.92	1111.49	165.57	181.22	277.92	96.69
0.011	1625.24	1974.43	349.19	923.17	1111.41	188.24	121.62	277.88	156.27
0.012	1619.52	1974.43	354.91	922.25	1111.41	189.16	122.22	277.88	155.66
0.013	1489.60	1974.42	484.82	841.82	1111.51	269.69	123.17	277.88	154.71
0.014	1483.91	1974.40	490.49	818.69	1111.42	292.73	124.64	277.88	153.24
0.015	1378.96	1974.62	595.66	806.42	1111.43	305.01	60.57	277.90	217.33
0.016	1350.20	1974.42	624.22	805.52	1111.43	305.91	61.98	277.90	215.91
0.017	1339.62	1974.41	634.79	700.89	1111.49	410.60	68.50	277.89	209.39
0.018	1326.75	1974.50	647.75	702.09	1111.44	409.35	69.06	277.89	208.83
0.019	1198.16	1974.46	776.30	691.44	1111.39	419.95	75.32	277.88	202.57
0.020	1194.90	1974.48	779.58	690.49	1111.39	420.90	76.66	277.88	201.22
0.021	1057.46	1974.75	917.29	594.47	1111.47	517.00	52.01	277.89	225.88
0.022	1049.95	1974.48	924.53	590.07	1111.43	521.36	45.90	277.88	231.98
0.023	1051.21	1974.42	923.21	588.82	1111.41	522.59	52.55	277.88	225.33
0.024	1052.91	1974.48	921.57	589.51	1111.40	521.89	52.62	277.88	225.27
0.025	1008.53	1974.49	965.96	514.17	1111.52	597.35	52.91	277.88	224.97
0.026	1009.17	1974.47	965.30	489.33	1111.40	622.07	53.45	277.88	224.43
0.027	990.37	1974.57	984.20	493.05	1111.40	618.35	52.81	277.88	225.07
0.028	978.87	1974.83	995.96	495.74	1111.39	615.65	53.20	277.88	224.68
0.029	979.64	1974.48	994.85	491.57	1111.40	619.84	52.91	277.88	224.97
0.030	986.78	1974.46	987.68	433.95	1111.50	677.55	52.99	277.88	224.89

APPENDIX B: KE, TE and IE of Modified thrie beam barrier

	At 8000 kg, 80 kmph, 20º			At 8000 kg, 80 kmph, 15º			At 8000 kg, 30 kmph, 25º		
Step Time (s)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	1974.94	1974.94	0.00	1974.38	1974.38	0.00	277.57	277.57	0.00
0.002	1974.94	1974.94	0.00	1974.38	1974.38	0.00	277.57	277.57	0.00
0.003	1974.33	1974.96	0.63	1974.38	1974.38	0.00	277.57	277.57	0.00
0.004	1974.30	1974.96	0.66	1974.38	1974.38	0.00	277.57	277.57	0.00
0.005	1891.04	1974.87	83.83	1931.07	1974.34	43.27	277.57	277.57	0.00
0.006	1882.73	1974.86	92.13	1930.28	1974.39	44.11	277.57	277.57	0.00
0.007	1780.34	1974.84	194.50	1845.68	1974.40	128.72	269.56	277.58	8.03
0.008	1771.62	1974.86	203.24	1839.95	1974.38	134.43	269.12	277.59	8.47
0.009	1738.28	1974.97	236.69	1749.29	1974.33	225.04	268.40	277.60	9.19
0.010	1642.34	1974.85	332.51	1735.60	1974.29	238.69	268.65	277.60	8.95
0.011	1624.29	1974.81	350.52	1725.92	1974.26	248.34	268.01	277.61	9.60
0.012	1618.66	1974.88	356.22	1629.53	1974.23	344.70	267.91	277.60	9.69
0.013	1477.83	1974.80	496.97	1617.18	1974.20	357.02	212.50	277.61	65.12
0.014	1477.25	1974.79	497.54	1616.67	1974.22	357.55	208.14	277.61	69.48
0.015	1336.43	1974.73	638.30	1519.55	1974.12	454.57	206.93	277.62	70.69
0.016	1330.10	1974.72	644.62	1514.10	1974.13	460.03	205.30	277.63	72.33
0.017	1322.84	1974.78	651.94	1426.61	1974.04	547.43	206.24	277.62	71.39
0.018	1199.87	1974.66	774.79	1420.93	1974.04	553.11	206.59	277.62	71.04
0.019	1198.29	1974.61	776.32	1419.85	1974.05	554.20	198.96	277.65	78.68
0.020	1200.54	1974.60	774.06	1333.48	1973.97	640.49	174.42	277.66	103.24
0.021	1073.20	1974.48	901.28	1328.87	1973.94	645.07	130.32	277.65	147.33
0.022	1078.84	1974.48	895.64	1328.56	1973.89	645.33	131.67	277.65	145.98
0.023	1073.38	1974.57	901.19	1233.31	1973.80	740.49	136.75	277.66	140.91
0.024	968.93	1974.45	1005.53	1235.44	1973.83	738.39	139.77	277.65	137.87
0.025	984.66	1974.42	989.76	1146.79	1973.77	826.98	145.16	277.64	132.48
0.026	994.43	1974.38	979.95	1147.93	1973.75	825.82	146.79	277.64	130.85
0.027	891.11	1974.30	1083.19	1154.08	1973.71	819.63	151.36	277.63	126.27
0.028	897.33	1974.28	1076.95	1157.01	1973.69	816.68	144.24	277.64	133.40
0.029	920.90	1974.25	1053.35	1072.40	1973.66	901.26	97.04	277.65	180.61
0.030	918.00	1974.33	1056.33	1073.39	1973.61	900.22	98.95	277.65	178.70

	At 8000 kg, 60 kmph, 20º			At 8000 kg, 60 kmph, 15º			At 2000 kg, 60 kmph, 15º		
Step Time (s)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	1110.88	1110.88	0.00	1111.15	1111.15	0.00	277.79	277.79	0.00
0.002	1110.88	1110.88	0.00	1111.15	1111.15	0.00	277.79	277.79	0.00
0.003	1110.41	1110.81	0.40	1111.15	1111.15	0.00	277.79	277.79	0.00
0.004	1110.32	1110.78	0.46	1111.14	1111.14	0.00	277.79	277.79	0.00
0.005	1110.04	1110.75	0.71	1111.14	1111.14	0.00	277.79	277.79	0.00
0.006	1106.35	1110.76	4.41	1111.14	1111.14	0.00	277.79	277.79	0.00
0.007	1036.06	1110.74	74.68	1073.06	1111.16	38.10	240.11	277.77	37.67
0.008	1033.03	1110.76	77.73	1071.97	1111.16	39.19	239.13	277.77	38.64
0.009	978.05	1110.95	132.90	1001.96	1111.14	109.18	178.66	277.87	99.21
0.010	940.00	1110.80	170.80	993.36	1111.14	117.78	169.94	277.77	107.83
0.011	922.88	1110.85	187.97	985.96	1111.15	125.19	162.91	277.76	114.86
0.012	924.22	1110.86	186.65	985.20	1111.14	125.94	163.05	277.76	114.71
0.013	813.77	1110.88	297.11	894.54	1111.17	216.63	110.85	277.82	166.97
0.014	805.20	1110.87	305.67	892.33	1111.18	218.85	102.55	277.76	175.20
0.015	800.33	1110.92	310.59	889.78	1111.22	221.44	102.69	277.75	175.07
0.016	800.63	1110.95	310.32	806.34	1111.51	305.17	103.39	277.75	174.37
0.017	679.54	1110.92	431.38	795.71	1111.19	315.48	105.99	277.75	171.77
0.018	676.85	1110.93	434.08	798.54	1111.19	312.65	106.21	277.75	171.54
0.019	679.14	1110.98	431.84	772.36	1111.22	338.86	64.52	277.75	213.22
0.020	679.25	1111.02	431.77	732.97	1111.13	378.16	65.65	277.75	212.09
0.021	570.19	1110.95	540.76	726.34	1111.13	384.79	67.69	277.75	210.06
0.022	567.85	1110.97	543.12	726.64	1111.13	384.50	66.33	277.75	211.42
0.023	579.71	1111.05	531.35	664.92	1111.12	446.21	66.25	277.75	211.50
0.024	581.39	1111.06	529.67	656.96	1111.10	454.14	65.98	277.75	211.77
0.025	494.96	1111.00	616.04	656.67	1111.09	454.42	65.75	277.75	212.00
0.026	495.45	1110.99	615.54	657.38	1111.09	453.71	66.09	277.75	211.66
0.027	511.23	1111.03	599.80	594.13	1111.04	516.92	65.75	277.75	212.00
0.028	514.72	1111.02	596.30	590.06	1111.04	520.98	65.83	277.75	211.92
0.029	452.00	1110.97	658.97	590.92	1111.04	520.12	65.76	277.75	211.99
0.030	453.79	1110.92	657.13	591.67	1111.04	519.37	65.71	277.75	212.04

	At 2000 kg, 80 kmph, 20º			At 2000 kg, 80 kmph, 15º			At 2000 kg, 60 kmph, 20º		
Step Time (s)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	493.74	493.74	0.00	493.59	493.59	0.00	277.72	277.72	0.00
0.002	493.74	493.74	0.00	493.59	493.59	0.00	277.72	277.72	0.00
0.003	493.12	493.75	0.62	493.59	493.59	0.00	277.30	277.70	0.40
0.004	493.11	493.75	0.64	493.59	493.59	0.00	277.25	277.69	0.45
0.005	412.48	493.74	81.26	450.61	493.57	42.96	277.02	277.70	0.68
0.006	404.48	493.74	89.26	449.85	493.58	43.73	273.43	277.71	4.28
0.007	319.28	493.75	174.47	368.95	493.55	124.60	206.45	277.69	71.25
0.008	304.00	493.71	189.71	364.37	493.56	129.18	203.68	277.70	74.02
0.009	294.76	493.73	198.97	360.53	493.56	133.03	202.51	277.71	75.20
0.010	296.30	493.73	197.43	282.19	493.53	211.35	143.66	277.79	134.13
0.011	198.66	493.72	295.06	274.93	493.54	218.61	117.75	277.70	159.95
0.012	199.39	493.72	294.33	274.83	493.54	218.71	120.12	277.71	157.59
0.013	209.19	493.75	284.56	196.81	493.52	296.71	122.67	277.73	155.06
0.014	138.06	493.91	355.84	197.91	493.52	295.61	125.63	277.72	152.09
0.015	129.37	493.73	364.35	202.77	493.51	290.74	68.14	277.70	209.56
0.016	135.50	493.75	358.25	204.37	493.51	289.13	72.13	277.70	205.57
0.017	144.46	493.76	349.29	141.29	493.49	352.21	81.55	277.73	196.17
0.018	148.55	493.75	345.20	139.31	493.49	354.18	82.45	277.73	195.27
0.019	113.51	493.74	380.23	144.59	493.49	348.90	85.68	277.72	192.04
0.020	115.89	493.75	377.85	142.25	493.49	351.24	85.45	277.72	192.28
0.021	114.32	493.75	379.42	120.25	493.48	373.23	69.53	277.72	208.19
0.022	112.44	493.75	381.30	117.51	493.48	375.97	67.20	277.72	210.52
0.023	113.07	493.75	380.68	117.42	493.48	376.06	66.69	277.72	211.03
0.024	112.30	493.75	381.45	116.11	493.48	377.37	64.84	277.72	212.88
0.025	112.52	493.75	381.23	116.21	493.48	377.27	65.16	277.72	212.57
0.026	112.32	493.75	381.43	115.80	493.48	377.68	64.09	277.72	213.63
0.027	112.25	493.75	381.50	115.76	493.48	377.72	64.49	277.72	213.24
0.028	112.57	493.75	381.17	115.52	493.48	377.96	64.26	277.72	213.46
0.029	112.20	493.75	381.55	115.33	493.48	378.15	64.28	277.72	213.44
0.030	112.56	493.75	381.19	115.18	493.48	378.30	64.58	277.72	213.14

Step Time	At 2000 kg, 40 kmph, 15º Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	At 2000 kg, 30 kmph, 15º Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	At 8000 kg, 30 kmph, 15º Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	123.43	123.43	0.00	69.47	69.47	0.00	277.87	277.87	0.00
0.002	123.43	123.43	0.00	69.47	69.47	0.00	277.87	277.87	0.00
0.003	123.43	123.43	0.00	69.47	69.47	0.00	277.87	277.87	0.00
0.004	123.43	123.43	0.00	69.47	69.47	0.00	277.87	277.87	0.00
0.005	123.43	123.43	0.00	69.47	69.47	0.00	277.87	277.87	0.00
0.006	123.43	123.43	0.00	69.47	69.47	0.00	277.87	277.87	0.00
0.007	123.43	123.43	0.00	69.47	69.47	0.00	277.87	277.87	0.00
0.008	123.43	123.43	0.00	69.47	69.47	0.00	277.87	277.87	0.00
0.009	96.77	123.42	26.65	69.47	69.47	0.00	277.87	277.87	0.00
0.010	94.40	123.42	29.02	69.47	69.47	0.00	277.87	277.87	0.00
0.011	92.27	123.41	31.14	69.47	69.47	0.00	277.86	277.86	0.00
0.012	92.84	123.41	30.57	69.30	69.47	0.17	277.69	277.86	0.17
0.013	92.21	123.41	31.20	45.48	69.46	23.98	252.62	277.85	25.23
0.014	91.84	123.41	31.57	44.68	69.46	24.78	251.73	277.85	26.12
0.015	45.00	123.41	78.41	40.09	69.46	29.38	250.64	277.85	27.21
0.016	43.48	123.41	79.93	36.37	69.46	33.10	250.67	277.85	27.18
0.017	44.93	123.41	78.48	34.50	69.46	34.96	250.05	277.85	27.80
0.018	45.04	123.41	78.37	33.57	69.46	35.89	250.09	277.85	27.76
0.019	46.63	123.41	76.77	32.39	69.46	37.07	198.99	277.85	78.86
0.020	46.90	123.41	76.50	31.66	69.47	37.81	197.46	277.85	80.39
0.021	46.44	123.41	76.96	26.29	69.47	43.18	196.93	277.86	80.93
0.022	38.33	123.41	85.08	23.63	69.46	45.84	195.35	277.86	82.51
0.023	25.34	123.40	98.07	21.90	69.46	47.56	195.61	277.86	82.26
0.024	26.27	123.40	97.13	18.80	69.46	50.66	196.41	277.86	81.45
0.025	25.27	123.40	98.13	19.13	69.46	50.34	196.65	277.86	81.22
0.026	26.20	123.40	97.21	19.18	69.46	50.29	161.74	277.90	116.15
0.027	25.45	123.40	97.95	19.03	69.46	50.44	146.64	277.87	131.23
0.028	25.46	123.40	97.94	18.89	69.46	50.58	147.69	277.87	130.18
0.029	25.55	123.40	97.85	18.88	69.46	50.59	148.78	277.87	129.10
0.030	25.33	123.40	98.07	18.89	69.46	50.57	149.84	277.87	128.03

	At 8000 kg, 40 kmph, 20º			At 8000 kg, 30 kmph, 20º			At 8000 kg, 40 kmph, 15º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	493.74	493.74	0.00	277.72	277.72	0.00	493.71	493.71	0.00
0.002	493.74	493.74	0.00	277.72	277.72	0.00	493.71	493.71	0.00
0.003	493.74	493.74	0.00	277.72	277.72	0.00	493.71	493.71	0.00
0.004	493.74	493.74	0.00	277.72	277.72	0.00	493.71	493.71	0.00
0.005	493.36	493.73	0.36	277.73	277.73	0.00	493.71	493.71	0.00
0.006	493.40	493.73	0.33	277.73	277.73	0.00	493.71	493.71	0.00
0.007	493.21	493.72	0.51	277.46	277.74	0.28	493.71	493.71	0.00
0.008	493.05	493.72	0.67	277.40	277.74	0.34	493.71	493.71	0.00
0.009	452.68	493.73	41.05	277.26	277.75	0.49	466.21	493.68	27.47
0.010	445.39	493.71	48.32	277.21	277.75	0.54	463.85	493.68	29.83
0.011	437.97	493.72	55.75	277.10	277.76	0.66	461.43	493.65	32.22
0.012	437.09	493.72	56.63	274.66	277.77	3.11	461.82	493.64	31.82
0.013	435.01	493.72	58.70	235.69	277.77	42.08	460.40	493.65	33.25
0.014	431.41	493.72	62.31	233.59	277.77	44.19	412.27	493.70	81.43
0.015	359.33	493.69	134.36	232.44	277.79	45.35	395.70	493.65	97.95
0.016	356.61	493.70	137.09	231.90	277.79	45.88	395.24	493.65	98.41
0.017	356.16	493.72	137.56	231.57	277.79	46.22	393.56	493.67	100.10
0.018	356.03	493.72	137.69	231.34	277.79	46.45	393.39	493.67	100.28
0.019	348.31	493.75	145.44	180.58	277.82	97.24	329.95	493.67	163.73
0.020	293.17	493.76	200.59	169.66	277.76	108.10	325.04	493.68	168.64
0.021	278.85	493.72	214.87	166.60	277.80	111.20	323.78	493.68	169.90
0.022	281.54	493.71	212.17	167.60	277.81	110.20	325.36	493.69	168.33
0.023	286.48	493.73	207.25	168.08	277.80	109.72	326.38	493.68	167.30
0.024	288.20	493.72	205.52	168.06	277.81	109.75	326.53	493.69	167.16
0.025	283.21	493.75	210.54	171.41	277.82	106.41	267.05	493.69	226.65
0.026	230.73	493.79	263.06	171.77	277.83	106.06	266.68	493.69	227.01
0.027	223.55	493.71	270.16	122.27	277.82	155.55	270.50	493.69	223.19
0.028	228.93	493.72	264.79	119.80	277.80	158.01	270.99	493.69	222.70
0.029	236.82	493.74	256.93	126.11	277.83	151.72	274.91	493.68	218.77
0.030	240.17	493.73	253.55	128.04	277.85	149.81	276.24	493.68	217.43

	At 2000 kg, 30 kmph, 20º			At 2000 kg, 40 kmph, 20º			At 2000 kg, 30 kmph, 25º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Interna l Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Interna l Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Interna l Energy (KJ)
0.001	69.43	69.43	0.00	123.43	123.43	0.00	69.39	69.39	0.00
0.002	69.43	69.43	0.00	123.43	123.43	0.00	69.39	69.39	0.00
0.003	69.43	69.43	0.00	123.43	123.43	0.00	69.39	69.39	0.00
0.004	69.43	69.43	0.00	123.43	123.43	0.00	69.39	69.39	0.00
0.005	69.43	69.43	0.00	123.07	123.43	0.36	69.39	69.39	0.00
0.006	69.43	69.43	0.00	123.11	123.43	0.32	69.39	69.39	0.00
0.007	69.16	69.43	0.28	122.95	123.43	0.49	61.46	69.39	7.94
0.008	69.10	69.43	0.33	122.84	123.43	0.60	61.06	69.39	8.33
0.009	69.00	69.44	0.43	86.93	123.45	36.51	60.64	69.40	8.76
0.010	68.96	69.44	0.47	80.04	123.42	43.39	60.82	69.40	8.57
0.011	68.91	69.44	0.53	74.13	123.43	49.30	60.47	69.40	8.92
0.012	66.31	69.44	3.13	73.87	123.43	49.56	60.36	69.40	9.04
0.013	32.58	69.43	36.85	73.93	123.43	49.50	26.21	69.41	43.20
0.014	31.18	69.44	38.25	73.88	123.43	49.55	15.12	69.40	54.29
0.015	31.70	69.45	37.75	40.26	123.45	83.19	15.82	69.41	53.59
0.016	31.79	69.44	37.65	32.11	123.43	91.31	16.97	69.41	52.44
0.017	33.60	69.44	35.84	32.56	123.43	90.87	22.29	69.40	47.11
0.018	34.02	69.44	35.43	34.19	123.43	89.24	24.39	69.40	45.01
0.019	34.90	69.44	34.55	38.10	123.43	85.33	26.42	69.40	42.98
0.020	34.82	69.44	34.63	38.21	123.43	85.22	26.42	69.40	42.98
0.021	21.88	69.45	47.56	39.29	123.43	84.14	26.41	69.40	42.98
0.022	15.64	69.44	53.81	38.87	123.43	84.56	26.45	69.40	42.95
0.023	15.86	69.44	53.58	38.58	123.43	84.86	26.32	69.40	43.08
0.024	17.72	69.45	51.73	38.19	123.43	85.24	26.45	69.40	42.95
0.025	18.54	69.45	50.90	36.96	123.43	86.47	26.37	69.40	43.03
0.026	17.46	69.45	51.99	36.62	123.43	86.81	26.38	69.40	43.02
0.027	17.57	69.45	51.88	36.68	123.43	86.76	26.45	69.40	42.95
0.028	17.70	69.45	51.74	36.61	123.43	86.82	26.33	69.40	43.07
0.029	17.10	69.45	52.35	36.53	123.43	86.90	26.39	69.40	43.01
0.030	17.64	69.45	51.81	36.54	123.43	86.89	26.35	69.40	43.05

	At 2000 kg, 60 kmph, 25º			At 2000 kg, 80 kmph, 25º			At 2000 kg, 40 kmph, 25º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	277.87	277.87	0.00	493.79	493.79	0.00	123.50	123.50	0.00
0.002	277.88	277.88	0.00	493.79	493.79	0.00	123.50	123.50	0.00
0.003	267.37	277.87	10.51	479.39	493.79	14.39	123.50	123.50	0.00
0.004	265.97	277.88	11.91	478.96	493.78	14.82	123.49	123.49	0.00
0.005	264.64	277.88	13.24	391.09	493.79	102.69	114.23	123.50	9.27
0.006	264.90	277.88	12.98	377.44	493.78	116.34	113.85	123.50	9.65
0.007	184.56	277.87	93.31	335.46	493.92	158.46	113.30	123.50	10.20
0.008	180.74	277.88	97.14	262.74	493.80	231.06	112.70	123.50	10.80
0.009	180.55	277.88	97.33	253.48	493.81	240.33	94.65	123.51	28.86
0.010	175.30	277.90	102.60	254.95	493.81	238.86	70.93	123.51	52.58
0.011	94.27	277.90	183.63	151.19	493.84	342.65	51.40	123.50	72.10
0.012	92.34	277.90	185.57	152.05	493.83	341.78	53.60	123.50	69.90
0.013	104.29	277.91	173.62	164.86	493.81	328.94	56.68	123.50	66.82
0.014	106.52	277.90	171.39	170.94	493.80	322.86	57.16	123.49	66.34
0.015	83.14	277.91	194.77	109.68	493.80	384.12	60.48	123.49	63.01
0.016	61.80	277.91	216.11	114.17	493.79	379.62	59.21	123.49	64.29
0.017	71.84	277.89	206.05	129.18	493.78	364.60	20.73	123.50	102.76
0.018	74.32	277.89	203.57	131.51	493.77	362.27	19.95	123.50	103.55
0.019	80.81	277.88	197.07	132.06	493.77	361.70	30.89	123.50	92.61
0.020	80.12	277.88	197.76	131.78	493.77	361.99	31.86	123.49	91.63
0.021	79.20	277.88	198.67	126.42	493.76	367.34	34.72	123.49	88.77
0.022	79.70	277.88	198.18	125.17	493.76	368.59	34.91	123.49	88.58
0.023	79.25	277.88	198.62	124.53	493.76	369.23	34.14	123.49	89.35
0.024	79.14	277.88	198.73	124.71	493.76	369.05	34.22	123.49	89.27
0.025	79.32	277.88	198.56	124.89	493.76	368.88	34.33	123.49	89.16
0.026	79.16	277.88	198.72	124.41	493.76	369.35	33.88	123.49	89.61
0.027	79.16	277.88	198.72	124.56	493.76	369.20	34.13	123.49	89.36
0.028	79.27	277.88	198.61	124.55	493.76	369.21	33.97	123.49	89.52
0.029	79.12	277.88	198.76	124.18	493.76	369.58	33.88	123.49	89.61
0.030	79.19	277.88	198.69	124.41	493.77	369.36	34.16	123.49	89.33

	At 8000 kg, 80 kmph, 25º			At 8000 kg, 60 kmph, 25º			At 8000 kg, 40 kmph, 25º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	1975.17	1975.17	0.00	1111.50	1111.50	0.00	493.98	493.98	0.00
0.002	1975.17	1975.17	0.00	1111.51	1111.51	0.00	493.98	493.98	0.00
0.003	1960.73	1975.18	14.45	1100.95	1111.51	10.56	493.98	493.98	0.00
0.004	1960.26	1975.19	14.93	1099.53	1111.51	11.98	493.98	493.98	0.00
0.005	1866.52	1975.19	108.67	1098.02	1111.51	13.49	484.61	493.98	9.38
0.006	1852.40	1975.20	122.80	1097.64	1111.50	13.86	484.22	493.98	9.76
0.007	1732.42	1975.43	243.01	1010.73	1111.49	100.76	483.53	493.98	10.45
0.008	1712.15	1975.28	263.13	1006.08	1111.50	105.42	482.91	493.98	11.07
0.009	1693.42	1975.30	281.88	993.04	1111.52	118.48	453.97	493.99	40.02
0.010	1598.14	1975.67	377.53	902.42	1111.63	209.21	424.94	493.98	69.04
0.011	1524.74	1975.36	450.62	870.15	1111.50	241.35	411.86	493.97	82.11
0.012	1523.42	1975.38	451.96	869.28	1111.50	242.22	410.97	493.97	83.01
0.013	1354.79	1975.42	620.63	782.21	1111.74	329.53	409.90	493.97	84.07
0.014	1346.75	1975.41	628.66	737.18	1111.53	374.35	408.46	493.96	85.51
0.015	1277.99	1975.76	697.77	720.37	1111.52	391.15	314.46	493.99	179.53
0.016	1186.36	1975.42	789.06	722.45	1111.51	389.06	313.37	493.99	180.62
0.017	1184.26	1975.41	791.15	622.14	1111.73	489.59	312.67	493.99	181.32
0.018	1185.38	1975.36	789.98	593.28	1111.52	518.24	312.26	494.00	181.74
0.019	1028.91	1975.37	946.46	592.08	1111.52	519.44	316.09	493.98	177.89
0.020	1035.67	1975.35	939.68	595.86	1111.51	515.65	317.26	493.97	176.71
0.021	1019.15	1975.49	956.34	539.72	1111.64	571.92	227.41	494.03	266.62
0.022	902.28	1975.48	1073.20	487.42	1111.53	624.12	227.43	494.01	266.58
0.023	924.55	1975.35	1050.80	498.02	1111.51	613.49	236.20	493.99	257.79
0.024	936.85	1975.34	1038.49	502.78	1111.51	608.73	237.81	494.00	256.19
0.025	815.46	1975.36	1159.90	517.78	1111.47	593.69	247.57	493.97	246.41
0.026	821.86	1975.32	1153.46	465.84	1111.55	645.71	251.04	493.97	242.92
0.027	859.20	1975.28	1116.08	434.97	1111.48	676.52	197.52	494.01	296.50
0.028	868.51	1975.25	1106.74	447.00	1111.49	664.49	182.52	493.98	311.46
0.029	762.08	1975.23	1213.15	465.49	1111.47	645.98	194.14	493.97	299.83
0.030	772.69	1975.26	1202.57	472.56	1111.45	638.89	198.27	493.97	295.70

APPENDIX C: KE, TE and IE of Cable barrier

	At 8000 kg, 80 kmph, 20º			At 8000 kg, 80 kmph, 15º			At 2000 kg, 30 kmph, 25º		
Step Time (s)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	1974.94	1975.01	0.07	1974.38	1974.44	0.06	69.39	69.46	0.07
0.002	1974.94	1975.01	0.07	1974.37	1974.44	0.07	69.39	69.46	0.07
0.003	1974.94	1975.01	0.07	1974.36	1974.43	0.07	69.39	69.46	0.07
0.004	1974.94	1975.01	0.07	1974.36	1974.43	0.07	69.39	69.46	0.07
0.005	1945.09	1975.02	29.93	1974.36	1974.43	0.07	69.39	69.46	0.07
0.006	1942.58	1975.01	32.43	1974.36	1974.43	0.07	69.39	69.46	0.07
0.007	1884.41	1974.99	90.58	1925.06	1974.43	49.37	69.39	69.46	0.07
0.008	1881.59	1974.99	93.40	1894.03	1974.43	80.40	69.39	69.46	0.07
0.009	1782.67	1974.98	192.31	1726.21	1974.37	248.16	69.39	69.46	0.07
0.010	1690.83	1975.04	284.21	1564.00	1974.33	410.33	69.39	69.46	0.07
0.011	1507.66	1975.20	467.54	1317.95	1974.00	656.05	64.31	69.46	5.15
0.012	1402.23	1975.03	572.80	1279.62	1973.86	694.24	64.77	69.46	4.69
0.013	1221.95	1975.58	753.63	962.04	1973.54	1011.50	64.14	69.46	5.31
0.014	1200.73	1975.57	774.84	940.73	1973.37	1032.65	64.29	69.46	5.17
0.015	907.29	1975.92	1068.63	609.11	1973.01	1363.90	45.08	69.46	24.37
0.016	876.52	1975.93	1099.41	505.25	1972.84	1467.60	45.16	69.46	24.30
0.017	671.10	1977.26	1306.17	422.94	1972.44	1549.50	47.36	69.46	22.10
0.018	573.66	1977.22	1403.56	410.51	1972.61	1562.10	48.11	69.46	21.35
0.019	455.44	1977.14	1521.70	395.76	1974.44	1578.68	27.58	69.45	41.87
0.020	335.90	1979.85	1643.95	354.28	1974.31	1620.03	26.92	69.45	42.53
0.021	191.67	1983.85	1792.18	319.64	1974.01	1654.38	33.14	69.45	36.32
0.022	198.39	1983.83	1785.44	266.19	1973.93	1707.74	34.81	69.45	34.64
0.023	209.39	1983.79	1774.40	250.80	1973.68	1722.88	38.65	69.45	30.80
0.024	231.14	1983.75	1752.61	228.22	1973.64	1745.42	29.40	69.45	40.05
0.025	237.23	1995.33	1758.10	234.92	1973.68	1738.76	22.63	69.45	46.82
0.026	242.88	2000.48	1757.60	253.20	1973.61	1720.41	18.27	69.45	51.17
0.027	257.66	2010.96	1753.30	266.35	1973.40	1707.05	15.48	69.45	53.97
0.028	265.45	2010.94	1745.49	297.38	1973.34	1675.96	12.33	69.45	57.12
0.029	274.94	2010.89	1735.95	305.41	1973.16	1667.75	10.31	69.45	59.14
0.030	280.16	2010.88	1730.72	318.67	1973.10	1654.43	9.82	69.45	59.62

	At 8000 kg, 60 kmph, 20º			At 8000 kg, 60 kmph, 15º			At 2000 kg, 60 kmph, 15º		
Step Time (s)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	1110.89	1110.96	0.07	1111.17	1111.24	0.07	277.79	277.86	0.07
0.002	1110.89	1110.96	0.07	1111.18	1111.25	0.07	277.80	277.86	0.07
0.003	1110.89	1110.96	0.07	1111.19	1111.26	0.07	277.80	277.86	0.07
0.004	1110.89	1110.95	0.06	1111.19	1111.26	0.07	277.80	277.87	0.07
0.005	1110.89	1110.95	0.06	1111.19	1111.26	0.07	277.80	277.87	0.07
0.006	1110.89	1110.95	0.06	1111.19	1111.26	0.07	277.80	277.87	0.07
0.007	1084.00	1110.96	26.96	1111.20	1111.26	0.06	277.80	277.87	0.07
0.008	1081.18	1110.96	29.78	1111.20	1111.26	0.06	277.80	277.87	0.07
0.009	1031.35	1110.97	79.62	1066.21	1111.27	45.06	233.94	277.88	43.94
0.010	1027.59	1110.96	83.37	1065.01	1111.27	46.26	232.77	277.87	45.11
0.011	918.13	1110.96	192.84	1006.78	1111.27	104.49	150.26	277.88	127.62
0.012	897.45	1110.96	213.51	1003.25	1111.27	108.02	147.54	277.87	130.33
0.013	809.33	1110.95	301.62	881.77	1111.29	229.52	110.74	277.88	167.14
0.014	748.51	1110.94	362.43	877.26	1111.28	234.02	64.71	277.87	213.16
0.015	697.50	1110.93	413.43	631.20	1111.25	480.05	49.69	277.86	228.16
0.016	621.29	1111.35	490.06	625.60	1111.19	485.59	49.06	277.85	228.79
0.017	585.11	1111.33	526.22	463.36	1111.21	647.86	43.85	277.84	233.98
0.018	526.53	1111.37	584.84	381.57	1111.30	729.73	42.15	277.83	235.69
0.019	385.17	1112.76	727.59	323.77	1111.17	787.40	43.28	278.01	234.72
0.020	385.81	1112.75	726.94	323.07	1111.14	788.07	44.20	278.08	233.89
0.021	284.44	1113.47	829.03	280.79	1111.43	830.64	38.02	278.12	240.11
0.022	227.92	1114.20	886.28	246.82	1111.69	864.87	38.39	278.12	239.73
0.023	165.92	1114.16	948.24	205.07	1111.53	906.46	39.63	278.11	238.49
0.024	155.19	1114.16	958.97	198.29	1111.49	913.20	39.51	278.11	238.60
0.025	143.71	1114.15	970.44	154.21	1111.50	957.29	39.39	278.10	238.71
0.026	158.88	1114.44	955.56	144.52	1111.61	967.10	40.46	278.10	237.63
0.027	169.47	1120.58	951.11	149.58	1111.53	961.95	40.29	278.09	237.81
0.028	172.93	1120.56	947.63	148.22	1111.50	963.28	41.31	278.09	236.78
0.029	187.98	1120.52	932.54	145.45	1111.42	965.97	41.36	278.08	236.72
0.030	193.85	1120.52	926.67	145.70	1111.40	965.71	41.07	278.08	237.01

	At 2000 kg, 80 kmph, 20º			At 2000 kg, 80 kmph, 15º			At 2000 kg, 60 kmph, 20º		
Step Time (s)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	493.74	493.80	0.07	493.59	493.66	0.07	277.72	277.79	0.07
0.002	493.74	493.80	0.07	493.59	493.66	0.07	277.72	277.79	0.07
0.003	493.74	493.80	0.07	493.59	493.66	0.07	277.72	277.79	0.07
0.004	493.74	493.80	0.07	493.59	493.66	0.07	277.72	277.79	0.07
0.005	463.43	493.82	30.39	493.59	493.66	0.07	277.72	277.79	0.07
0.006	460.93	493.81	32.88	493.59	493.66	0.07	277.72	277.79	0.07
0.007	399.47	493.81	94.33	445.15	493.66	48.51	251.38	277.80	26.42
0.008	396.27	493.80	97.53	433.06	493.66	60.60	248.59	277.80	29.20
0.009	274.14	493.83	219.69	370.28	493.65	123.37	195.30	277.80	82.50
0.010	269.89	493.82	223.93	293.81	493.66	199.84	189.32	277.79	88.47
0.011	137.80	493.86	356.07	226.45	493.63	267.18	157.54	277.82	120.29
0.012	140.46	493.86	353.40	157.07	493.67	336.60	109.14	277.83	168.70
0.013	132.91	494.09	361.18	84.12	493.64	409.52	109.43	277.82	168.40
0.014	124.75	494.08	369.34	83.14	493.63	410.49	107.63	277.82	170.19
0.015	106.37	494.07	387.70	73.70	493.84	420.15	83.21	277.95	194.74
0.016	91.58	494.07	402.49	68.37	493.82	425.45	73.85	277.94	204.10
0.017	68.50	494.06	425.55	65.99	493.83	427.83	64.00	277.93	213.93
0.018	59.95	494.05	434.11	63.15	493.82	430.66	47.80	277.93	230.13
0.019	57.33	494.13	436.80	66.41	493.80	427.39	46.50	277.93	231.42
0.020	56.46	494.13	437.67	66.76	493.80	427.04	41.59	277.92	236.33
0.021	61.39	494.12	432.74	69.71	493.78	424.07	41.04	277.93	236.89
0.022	61.48	494.12	432.64	70.13	493.78	423.65	38.11	277.93	239.82
0.023	61.24	494.12	432.88	70.67	493.76	423.09	39.03	277.93	238.89
0.024	60.92	494.12	433.20	70.50	493.76	423.25	41.29	277.92	236.63
0.025	60.94	494.11	433.17	70.30	493.74	423.44	42.63	277.92	235.29
0.026	60.74	494.11	433.37	70.42	493.74	423.32	42.35	277.92	235.57
0.027	60.53	494.10	433.58	70.39	493.73	423.34	42.82	277.91	235.10
0.028	60.60	494.10	433.51	70.27	493.72	423.45	42.17	277.91	235.74
0.029	60.02	494.10	434.08	70.32	493.71	423.39	42.32	277.91	235.58
0.030	60.50	494.10	433.59	70.23	493.71	423.47	42.56	277.91	235.35

	At 8000 kg, 30 kmph, 15º			At 8000 kg, 40 kmph, 15º			At 2000 kg, 40 kmph, 15º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	277.88	277.94	0.07	493.71	493.78	0.07	123.43	123.49	0.07
0.002	277.88	277.95	0.07	493.71	493.77	0.07	123.43	123.49	0.07
0.003	277.88	277.95	0.07	493.71	493.77	0.07	123.43	123.49	0.07
0.004	277.88	277.95	0.07	493.71	493.77	0.07	123.43	123.49	0.07
0.005	277.88	277.95	0.07	493.71	493.77	0.07	123.43	123.49	0.07
0.006	277.88	277.95	0.07	493.71	493.77	0.07	123.43	123.49	0.07
0.007	277.88	277.95	0.07	493.70	493.77	0.07	123.43	123.49	0.07
0.008	277.88	277.95	0.07	493.70	493.77	0.07	123.43	123.49	0.07
0.009	277.88	277.95	0.07	493.70	493.77	0.07	123.43	123.49	0.07
0.010	277.88	277.95	0.07	493.70	493.77	0.07	123.43	123.49	0.07
0.011	277.88	277.95	0.07	493.70	493.77	0.07	123.43	123.49	0.07
0.012	277.88	277.95	0.07	493.70	493.77	0.07	123.43	123.49	0.07
0.013	277.88	277.95	0.07	463.64	493.77	30.13	95.85	123.49	27.64
0.014	277.88	277.95	0.07	433.78	493.78	60.00	67.57	123.50	55.93
0.015	277.88	277.95	0.07	432.71	493.77	61.07	66.49	123.49	57.00
0.016	277.88	277.95	0.07	426.45	493.77	67.32	65.58	123.49	57.91
0.017	271.56	277.95	6.39	355.32	493.78	138.45	30.37	123.50	93.13
0.018	248.55	277.95	29.40	355.78	493.77	138.00	20.42	123.49	103.07
0.019	232.77	277.95	45.19	325.68	493.80	168.12	37.85	123.49	85.64
0.020	232.51	277.95	45.45	285.65	493.80	208.15	47.86	123.49	75.63
0.021	219.99	277.95	57.96	225.30	493.79	268.48	46.73	123.49	76.76
0.022	200.34	277.95	77.61	224.57	493.78	269.21	45.32	123.49	78.17
0.023	178.45	277.95	99.50	191.20	493.80	302.61	43.95	123.48	79.54
0.024	178.52	277.95	99.43	156.63	494.06	337.43	43.56	123.48	79.92
0.025	177.08	277.95	100.86	74.34	494.08	419.73	46.03	123.48	77.45
0.026	169.31	277.94	108.64	74.45	494.07	419.62	43.74	123.48	79.74
0.027	86.86	278.00	191.15	74.13	494.06	419.93	44.13	123.48	79.35
0.028	69.64	278.01	208.37	75.19	494.06	418.87	44.55	123.48	78.92
0.029	66.97	277.99	211.02	71.66	494.05	422.38	44.71	123.48	78.76
0.030	68.49	277.99	209.50	49.76	494.05	444.29	43.67	123.48	79.81

	At 2000 kg, 30 kmph, 20º			At 2000 kg, 40 kmph, 20º			At 2000 kg, 30 kmph, 15º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	69.43	69.50	0.07	123.43	123.50	0.07	69.47	69.54	0.07
0.002	69.43	69.50	0.07	123.43	123.50	0.07	69.47	69.54	0.07
0.003	69.43	69.50	0.07	123.43	123.50	0.07	69.47	69.54	0.07
0.004	69.43	69.50	0.07	123.43	123.50	0.07	69.47	69.54	0.07
0.005	69.43	69.50	0.07	123.43	123.50	0.07	69.47	69.54	0.07
0.006	69.43	69.50	0.07	123.43	123.50	0.07	69.47	69.54	0.07
0.007	69.43	69.50	0.07	123.43	123.50	0.07	69.47	69.54	0.07
0.008	69.43	69.50	0.07	123.43	123.50	0.07	69.47	69.54	0.07
0.009	69.43	69.50	0.07	123.43	123.50	0.07	63.35	69.54	6.19
0.010	69.43	69.50	0.07	123.43	123.50	0.07	58.09	69.54	11.45
0.011	69.43	69.50	0.07	111.30	123.50	12.20	51.47	69.54	18.07
0.012	69.43	69.50	0.07	112.12	123.50	11.38	44.47	69.54	25.07
0.013	69.43	69.50	0.07	101.35	123.50	22.15	39.47	69.54	30.07
0.014	65.78	69.50	3.71	76.74	123.50	46.76	36.47	69.54	33.07
0.015	60.30	69.50	9.20	57.34	123.50	66.17	31.47	69.54	38.07
0.016	59.86	69.50	9.64	57.69	123.50	65.81	25.35	69.54	44.19
0.017	59.96	69.50	9.54	47.31	123.50	76.18	20.09	69.54	49.45
0.018	53.06	69.50	16.44	31.49	123.51	92.02	19.09	69.54	50.45
0.019	23.39	69.50	46.11	28.79	123.51	94.72	18.23	69.54	51.31
0.020	22.99	69.50	46.51	25.50	123.51	98.01	16.43	69.54	53.11
0.021	25.06	69.49	44.44	21.88	123.50	101.62	15.92	69.54	53.62
0.022	25.63	69.49	43.86	13.32	123.50	110.18	13.45	69.54	56.09
0.023	27.86	69.49	41.63	17.01	123.50	106.49	13.30	69.54	56.24
0.024	23.72	69.49	45.77	18.23	123.50	105.27	10.96	69.53	58.57
0.025	8.95	69.50	60.55	19.06	123.50	104.44	10.19	69.53	59.34
0.026	7.20	69.50	62.30	18.30	123.50	105.19	10.45	69.53	59.08
0.027	11.64	69.50	57.86	18.29	123.50	105.21	10.86	69.52	58.66
0.028	13.30	69.50	56.20	18.49	123.50	105.01	8.43	69.52	61.09
0.029	15.84	69.50	53.66	18.40	123.49	105.09	8.61	69.52	60.91
0.030	15.95	69.50	53.54	18.41	123.49	105.08	8.19	69.52	61.32

	At 8000 kg, 40 kmph, 20º			At 8000 kg, 30 kmph, 20º			At 8000 kg, 30 kmph, 25º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	493.73	493.80	0.07	277.72	277.79	0.07	277.57	277.64	0.07
0.002	493.73	493.80	0.07	277.72	277.79	0.07	277.57	277.64	0.07
0.003	493.73	493.80	0.07	277.72	277.79	0.07	277.57	277.64	0.07
0.004	493.73	493.80	0.07	277.72	277.79	0.07	277.57	277.64	0.07
0.005	493.73	493.80	0.07	277.72	277.79	0.07	277.57	277.64	0.07
0.006	493.73	493.80	0.07	277.72	277.79	0.07	277.57	277.64	0.07
0.007	493.73	493.80	0.07	277.72	277.79	0.07	277.57	277.64	0.07
0.008	493.73	493.80	0.07	277.72	277.79	0.07	277.57	277.64	0.07
0.009	493.73	493.80	0.07	277.72	277.79	0.07	277.57	277.64	0.07
0.010	493.73	493.80	0.07	277.72	277.79	0.07	277.57	277.64	0.07
0.011	481.37	493.80	12.43	277.72	277.79	0.07	272.41	277.64	5.23
0.012	482.14	493.80	11.67	277.72	277.79	0.07	272.84	277.64	4.80
0.013	462.66	493.80	31.14	277.72	277.79	0.07	271.92	277.63	5.72
0.014	428.73	493.80	65.07	273.98	277.79	3.81	271.60	277.63	6.03
0.015	415.42	493.79	78.37	268.30	277.79	9.49	249.54	277.63	28.09
0.016	415.73	493.79	78.06	267.68	277.79	10.11	249.08	277.63	28.56
0.017	331.04	493.80	162.75	267.19	277.79	10.60	248.57	277.63	29.06
0.018	331.09	493.79	162.71	251.97	277.79	25.82	248.10	277.63	29.53
0.019	328.66	493.79	165.13	210.59	277.79	67.20	205.28	277.63	72.35
0.020	297.81	493.79	195.98	211.63	277.79	66.16	205.26	277.62	72.36
0.021	231.30	493.79	262.49	209.25	277.78	68.53	207.10	277.62	70.52
0.022	230.48	493.79	263.31	203.74	277.78	74.05	207.54	277.62	70.08
0.023	233.15	493.78	260.63	120.67	277.87	157.20	156.81	277.61	120.80
0.024	199.52	493.77	294.25	120.64	277.86	157.23	107.62	277.61	169.99
0.025	95.70	494.82	399.12	120.32	277.86	157.54	93.55	277.60	184.05
0.026	92.96	494.82	401.85	120.94	277.86	156.92	75.72	277.60	201.88
0.027	99.91	494.80	394.89	108.40	277.85	169.45	62.38	277.59	215.21
0.028	102.07	494.80	392.73	88.26	277.85	189.59	50.34	277.59	227.25
0.029	93.69	494.79	401.10	32.96	278.08	245.11	29.17	277.58	248.41
0.030	75.35	494.79	419.44	29.16	278.07	248.92	28.21	277.58	249.37

	At 8000 kg, 80 kmph, 25º			At 8000 kg, 60 kmph, 25º			At 8000 kg, 40 kmph, 25º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	1975.17	1975.23	0.06	1111.49	1111.55	0.06	493.98	494.05	0.07
0.002	1975.16	1975.23	0.07	1111.48	1111.55	0.07	493.98	494.05	0.07
0.003	1975.17	1975.23	0.06	1111.48	1111.55	0.07	493.98	494.05	0.07
0.004	1968.30	1975.23	6.93	1111.48	1111.55	0.07	493.98	494.05	0.07
0.005	1938.85	1975.22	36.37	1105.19	1111.55	6.36	493.98	494.05	0.07
0.006	1924.22	1975.22	51.00	1103.55	1111.55	8.00	493.98	494.05	0.07
0.007	1875.37	1975.22	99.85	1069.00	1111.55	42.55	493.98	494.05	0.07
0.008	1872.67	1975.21	102.54	1069.98	1111.55	41.57	489.87	494.05	4.18
0.009	1784.26	1975.19	190.93	1008.29	1111.54	103.25	487.02	494.04	7.03
0.010	1724.70	1975.19	250.49	1014.27	1111.53	97.26	487.56	494.04	6.48
0.011	1628.17	1975.17	347.00	933.33	1111.52	178.19	461.71	494.05	32.34
0.012	1549.23	1975.15	425.92	933.08	1111.50	178.42	461.78	494.04	32.27
0.013	1406.00	1975.11	569.11	871.16	1111.49	240.33	459.18	494.04	34.86
0.014	1376.77	1975.00	598.23	836.25	1111.46	275.21	428.23	494.04	65.81
0.015	1221.34	1974.90	753.56	818.42	1111.45	293.03	412.12	494.03	81.91
0.016	1252.41	1975.01	722.60	734.41	1111.43	377.02	412.97	494.03	81.07
0.017	1107.55	1974.89	867.34	740.20	1111.41	371.21	351.33	494.02	142.69
0.018	1087.98	1974.96	886.98	673.77	1111.39	437.62	351.01	494.02	143.01
0.019	973.14	1974.88	1001.74	640.82	1111.35	470.53	353.50	494.01	140.50
0.020	999.74	1974.80	975.06	645.80	1111.35	465.55	349.47	494.00	144.54
0.021	879.24	1974.77	1095.53	543.90	1111.29	567.39	286.63	493.99	207.36
0.022	896.27	1974.69	1078.43	552.53	1111.30	558.77	289.85	493.99	204.14
0.023	783.41	1974.66	1191.25	465.35	1111.25	645.90	297.22	493.98	196.76
0.024	585.38	1974.71	1389.33	374.83	1111.24	736.42	258.70	493.97	235.27
0.025	523.19	1974.68	1451.49	291.48	1111.23	819.75	183.38	493.95	310.57
0.026	449.16	1974.67	1525.51	233.39	1111.22	877.83	139.14	493.95	354.81
0.027	385.02	1974.63	1589.61	156.62	1111.19	954.58	107.83	493.94	386.11
0.028	309.37	1974.60	1665.23	129.78	1111.18	981.40	84.32	493.94	409.62
0.029	234.42	1974.61	1740.19	114.12	1111.15	997.03	76.11	493.92	417.81
0.030	165.49	1974.61	1809.12	101.78	1111.15	1009.37	49.67	493.92	444.25

	At 2000 kg, 60 kmph, 25º			At 2000 kg, 80 kmph, 25º			At 2000 kg, 40 kmph, 25º		
Step Time	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)	Kinetic Energy (KJ)	Total Energy (KJ)	Internal Energy (KJ)
0.001	277.87	277.94	0.07	493.79	493.86	0.07	123.50	123.56	0.07
0.002	277.87	277.94	0.07	493.79	493.86	0.07	123.50	123.56	0.07
0.003	277.87	277.94	0.07	493.79	493.86	0.07	123.50	123.56	0.07
0.004	277.87	277.94	0.07	486.97	493.86	6.89	123.50	123.56	0.07
0.005	271.60	277.94	6.34	459.93	493.86	33.93	123.50	123.56	0.07
0.006	269.97	277.94	7.97	445.05	493.86	48.81	123.50	123.56	0.07
0.007	237.60	277.94	40.34	398.17	493.85	95.69	123.50	123.56	0.07
0.008	237.65	277.94	40.29	395.19	493.85	98.66	119.45	123.56	4.11
0.009	198.52	277.93	79.42	316.82	493.82	177.00	116.67	123.56	6.89
0.010	190.92	277.93	87.01	316.48	493.82	177.35	117.28	123.56	6.29
0.011	185.70	277.92	92.22	251.09	493.80	242.71	93.49	123.56	30.08
0.012	138.96	277.91	138.95	249.29	493.80	244.51	93.86	123.56	29.70
0.013	145.58	277.90	132.32	197.49	493.78	296.29	94.51	123.56	29.05
0.014	147.22	277.90	130.68	214.53	493.77	279.25	84.66	123.56	38.89
0.015	114.91	277.89	162.98	176.36	493.76	317.40	61.84	123.55	61.71
0.016	122.42	277.89	155.47	189.41	493.75	304.35	64.99	123.55	58.56
0.017	101.07	277.89	176.82	172.88	493.75	320.87	71.22	123.55	52.33
0.018	106.42	277.88	171.46	184.28	493.74	309.47	56.54	123.55	67.01
0.019	124.38	277.88	153.49	198.73	493.74	295.01	53.34	123.55	70.21
0.020	126.63	277.88	151.25	189.13	493.74	304.61	56.26	123.54	67.28
0.021	120.59	277.88	157.29	191.83	493.74	301.90	63.35	123.54	60.19
0.022	119.76	277.87	158.12	189.94	493.73	303.80	64.10	123.54	59.44
0.023	98.09	277.87	179.78	170.68	493.73	323.06	58.99	123.54	64.55
0.024	88.28	277.87	189.59	150.33	493.73	343.40	50.56	123.54	72.99
0.025	78.33	277.87	199.54	139.27	493.73	354.46	39.98	123.54	83.56
0.026	67.87	277.87	210.00	100.45	493.73	393.28	25.13	123.54	98.41
0.027	57.83	277.86	220.03	88.87	493.72	404.86	19.99	123.54	103.55
0.028	48.12	277.86	229.74	69.59	493.72	424.13	16.04	123.54	107.50
0.029	47.91	277.86	229.95	58.19	493.72	435.53	15.93	123.54	107.61
0.030	37.77	277.86	240.09	58.47	493.72	435.25	16.76	123.54	106.77