DEVELOPMENT OF SYNTHETIC RUBBER AND IT'S COMPARISON WITH URETHANE FOR ROLLING BARRIERS

A Thesis

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Submitted by

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Under the Supervision of

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CERTIFICATE

This is to certify that **Mr. Santosh Kumar** (Enroll. No.-1800100959) has carried out the research work presented in the thesis titled **"DEVELOPMENT OF SYNTHETIC RUBBER AND IT'S COMPARISON WITH URETHANE FOR ROLLING BARRIERS"** submitted for partial fulfillment for the award of the **Degree of Doctor of Philosophy in Production and Industrial Engineering** from **Integral University, Lucknow** under my supervision.

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ABSTRACT

The government is always looking at the latest technology that can ensure safety of road users, as outlined in the construction industry transformation plan. In India total accidents of 2016 are 489400 and in 2017 are 501423. Total number of persons killed in 2016 is 139671 and in 2017 are 146133. Total number of accidents on highways in 2016 is 137903 and in 2017 are 142268. A small Korean manufacturing company invented a new concept Longitudinal barrier, (The Rolling Barrier) which had continuous pipes covered with urethane rings. This study aims to evaluate the effectiveness of the Rolling Barrier and to understand the Rolling Barrier's characteristics of crash cushioning, how to correct the vehicles running direction and the required strength of barriers. The Rolling Barrier satisfied the ministry of construction and transportations, "Guidelines for Installation and management of road safety facilities". The Rolling Barrier can be effectively used in curved roads sections, ramps, medians and entrance or exit ramps in parking garages.

In this work we show that urethane rubbers used in rolling barriers play a vital role in reducing road accidents. In this paper synthetic rubber is developed and its properties are compared with Urethane material. Synthetic rubber is developed by considering the properties of Urethane, like rubbery behaviour, hardness, elongation, tensile strength, impact resistance, compression set and temperature range. Here the Synthetic rubber is developed by using silicone (As a base material) methyl chloride, various fillers and additives. However, Silicone rubber is an elastomer (Rubber like material) composed of silicone itself (A polymer) containing silicon together with carbon, hydrogen and oxygen. The properties as hardness, elongation, tensile strength, impact resistance and temperature range are analysed and make it equivalent to the properties of Urethane. The developed Silicone rubber is further used to manufacture the Rolling Barriers used as a life line, sides to the road. A study says that over 151 thousand fatalities has been reported in India in 2019 due to road accidents. The numbers may be minimized by using the Rolling Barriers made up of Silicone Rubber in future.

Chapter 1
Introduction

1.1 Introduction:

The Road accidents are an outcome of the interplay of various factors, some of which are length of road networks, vehicle population, human population adherence/enforcement of road safety regulations etc. Road accidents cause injuries, fatalities and hospitalization with serve socio economic costs across the country. Consequently, road safety has become an issue of concern both at national and international levels.

	Year-2017	Year-2018	% Increase
Total Accidents	529400	601400	13.6%
Persons Killed	235691	274033	16.26%
Accidents on Highway	237903	280868	18.05%

It is expected to be increased 40% of 2019 to 50% in 2020 and even more in future where the number of vehicles manufacturing is increasing and also the vehicles on road are increasing. India is one of the highest motorization growths in the world accompanied by rapid expansion in road network and urbanization over the years and is facing with serious impacts on road safety levels. The analysis of road accident data 2019 reveals that about 1,374 accidents and 400 deaths takes place every day on Indian roads which further translates into 57 accidents and loss of 17 lives on an average every hour in our country.A small Korean manufacturing company invented a new concept longitudinal barrier (the rolling barrier), a structure equipped with continuous pipes covered with urethane rings. Its general feature resembles an erected abacus. As the rolling barrier activates the rolling friction when vehicles hit the barrier, the rolling barrier reduces severity of traffic accidents. After the rolling barrier was installed at two downgraded and curved roads sections in Busan, the accidents at the sections were reduced by more than 50% in a year. According to Federal Highway Administration, the guardrail can operate to deflect a vehicle back to the roadway, slow the vehicle down to a complete stop or let it proceed past the guardrail. The guardrail can’t completely protect against the situations drivers may find themselves. accidents lead to traffic jams resulting in an overall delayed journey, contradicting the basic purpose of construction of such expressways. Therefore, road safety and management of the expressway has consequently become an issue of national concern.This study aims to evaluate the effectiveness of the rolling barrier and understand rolling barrier's features in crash cushioning, correcting the vehicles running direction and required strength of the barriers.

Fig 1.1: View Of Rolling Barrier

Fig 1.2: View Of Barrier Accident

1.2 Features:

- Made of special chemical compound like hard rubber.
- Easy to maintain due to separated barrels (recyclable).
- Stopper boards installed on the top and the lower part of the barrels to guide objects back to the road.
- Easy to adjust height, noticeable to drivers due to noticeable coloration and self-luminescence.
- Noticeable to drivers due to noticeable coloration and self-luminescence.
- Less costs to install (less post- 1 unit per 2m).
- LED guide lamp (solar energy).
- Two Pieces.
- Material is eco-friendly.
- It reduces the speed of vehicle.
- Reduces costs in repairing & maintenance due to Roller‟s resilience
- Made of special chemical compound like hard rubber.
- Easy to maintain due to separated barrels (recyclable).
- Stopper boards installed on the top and the lower part of the barrels to guide objects back to the road.
- Easy to adjust height, noticeable to drivers due to noticeable coloration and self-luminescence.

1.3 Problem Statement:

The conventional barrier system which includes the likes of concrete barriers as well as the steel guardrails try to absorb as much shock energy from the impact of collision as possible and thus potentially break the momentum of the colliding vehicle. However, as we can see from the number of fatal accidents on the expressway, this prevailing customary system has proven to be substandard. Whereas, the rolling barriers not only absorb the impact energy but also convert it into rotational energy, assisting the vehicle to stay on track and prevent overturning. As we can see from Fig. 1.2 that as soon as an automobile swerves from the actual path and hits the barriers laterally at any angle, the rollers convert the impact energy into rotational energy by rotating with the impact. The rotational energy not only helps to cut down the impact of the collision but also helps to propel the vehicle forward rather than potentially breaking through an immovable barrier. Upper and lower frames adjust tires of large and small vehicles to prevent the steering system from a functional loss. Following Fig.1.3 shows the precise working principle of the rolling barrier system.

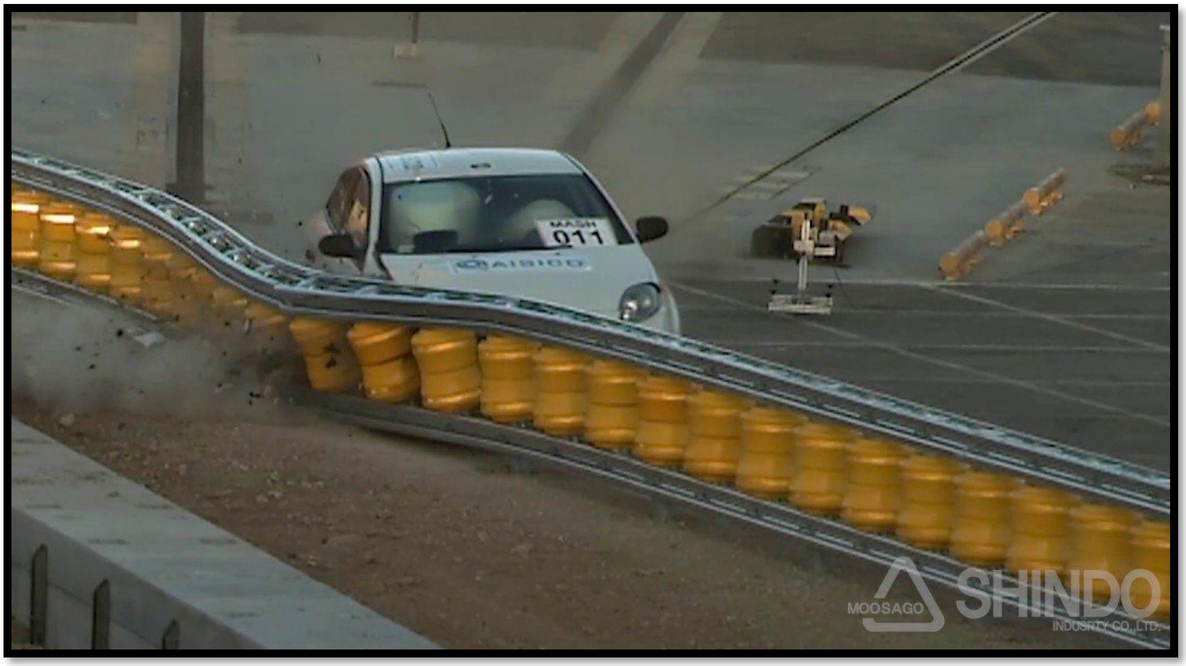


Fig 1.3: Rolling Barrier

Props at an interval of 0.7 m increase bearing power to prevent vehicles from further derailing. As the props used in the system are independent, only damaged parts need to be replaced. This keeps maintenance costs pretty low and the efficiency of the system intact. Fig.3 shows the easy removal of components from the assembly.

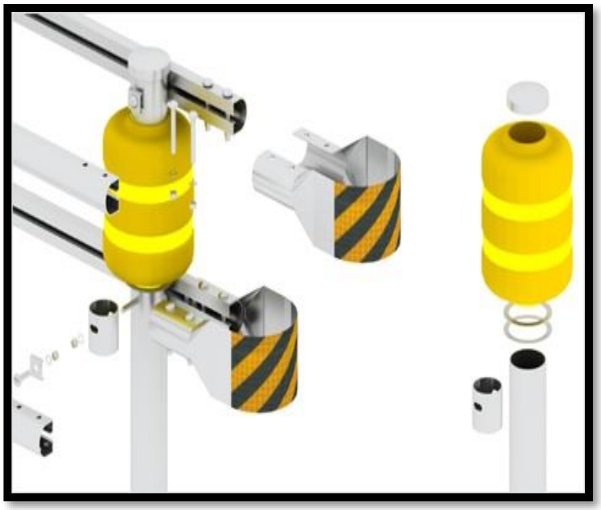


Fig 1.4

1.4 Barrier

Barriers or guard rails or longitudinal barriers or traffic barriers keep vehicles within their road way and prevent vehicles from colliding with dangerous obstacles such as boulders, sign supports, trees, bridge abutments, building walls and large storm drains.

Fig 1.5: Roadside Barrier

1.5 Types of Barrier:

Barriers are categorized in to two ways, by the function they serve and by how much they deflect whena vehicle crashes into them,

Barrier Functions

- Road side barriers are used to protect traffic from roadside obstacles or hazards.

Fig 1.6

Median barriers are used to prevent vehicles from crossing over a median and striking an oncoming vehicle in a head on crash.

Fig 1.7

- Bridge barrier is designed to restrain vehicles from crashing of the side of a bridge and falling onto the roadway.

Fig 1.8

Fig 1.9

- Work zone barriers are used to protect traffic from hazards in work zones.

Barrier Stiffness

Flexible barriers include cable barriers and weak post corrugated guide rail systems. They will deflect 1.6 to 2.6m (5.2 to 8.5 feet) when struck by a typical passenger car or a light truck.

Fig 1.10:

- Semi rigid barriers include box beam guiderail, heavy post blocked out corrugated guide rail and thriebeam rail. They deflect 3-6 feet (0.91 to 1.83m).

Fig 1.11:

Rigid barriers are usually constructed of reinforced concrete. They deflect in negligible distance.

Fig 1.12

Rolling barriers:

This invention lies in the field of safety barriers for highway sand other roadways of the general type which are mounted along the sides of the roadways to intercept errant vehicle and stop them or redirect them in a desired direction. It is directed particularly to such apparatus which suffers little or no damage from impact and which causes minimum damage to the contacting vehicle.

Many types of highway barriers have been proposed over the years and many varieties are presently in use. The conventional type is cable or metal plate, beam, or box beam guardrail mounted on posts parallel to shoulder lines of highways. Other types are heavy stone guardrails adjacent the highway, rustic log guardrails, and concrete barrier walls. These devices are mounted along the marginal limits and in the center medians to contain errant vehicles. Basically they are rigid, relatively non yielding and have little capability for absorbing the energy of the impacting vehicle through elastic or plastic deformation of the barrier. Because of their rigidity and con formation, vehicles impacting them even at low angles of incidence are severely damaged by impact, catapulting, or rich with attendant danger of exploding fuel from ruptured fuel tanks.

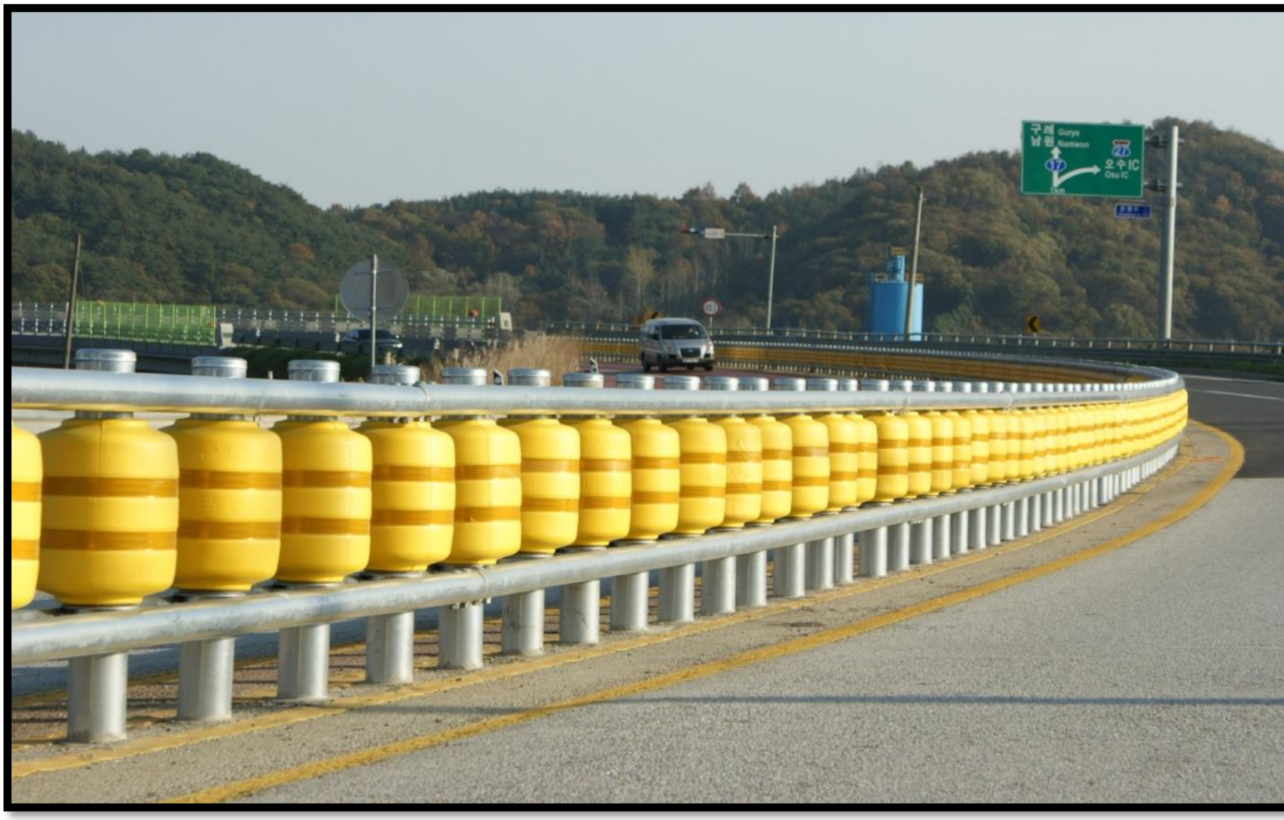


Fig 1.13

Highway Rolling Barrier

Another type, which is widely used in the medians or divider strips of freeways, is chain link or expanded-metal-type fencing mounted on metal posts designed to yield fairly readily and usually reinforced by a pair of vertically spaced horizontal cables. The theory of operation is that the concentrated force of impact of the errant vehicle stretches and distorts the metal, using up the inertia in the way of work. The yielding of the fence is intended to minimize damage to the vehicle. However, it has been found from experience that the vehicle still suffers a great deal of damage from the twisting and tearing action of the fence. In addition, a large section of fence is destroyed and the repair work amounts to several hundred dollars per accident.

To prevent head-on collision with bridge piers, abutments, traffic islands, etc., various protective devices are being used. Included are empty barrels, sand filled containers, water-filled containers, shock-absorbing rails, etc. All are destructive to the impacting vehicle. None pocket and stop the vehicle. Light standards, signposts, power poles, telephone poles, and traffic signal poles in the marginal areas flanking the traffic lanes are potential collision elements for errant vehicles. Both the vehicle and the objects encountered are damaged by impact. Many casualties result. Conventional protection of the objects comprises an enveloping guardrail or mounting them on raised concrete bases which protect the installations but severely damage the impacting vehicles and passengers. Barrier protectors are now being discontinued in favor of breakaway design of post. This design permits impacting vehicle to shear the posts, minimizing vehicle damage, and reducing casualties. Although this device is an improvement over barrier protection, vehicles require costly repairs and the poles must be reinstalled. The proposed pneumatic guard rolls provide a better solution. The poles already in place can be made to serve as the spindle for the buffering elements. This consists of both flexible property and semi rigid property barrier stiffness. They are different in mechanism than other types of barriers also reduces the hazards or accidents. Urethane has become the material of choice in so many of today's performance driven applications because it exhibits extraordinary physical and mechanical properties that other materials simply can't match.

1.6 Purpose of using rolling barriers:

- To reduce the accident numbers.
- To reduce the severity of accidents.
- To reduce the damage to vehicles.
- To reduce the injury to human body.
- To save lives from accidents

1.7 Advantages of rolling barriers are:

- It increases the safety of humans and vehicles.
- It has shock absorbent system, which reduces sudden shocks on vehicles.
- It converts shock energy to rotary rotational energy.
- It is easy to install, and maintenance required is also less than normal barriers.
- It gives good visibility at night also, with help of reflective tape.
- It has more serviceable life than normal barriers.

- It prevents sudden stoppage and overthrowing of vehicles after collision.
- It can be made by recyclable materials, thus it's eco-friendly.
- It may have high initial cost but the final cost is less as maintenance required is less and it has more life.

1.8 Installation of rolling barriers:

Installation of the rolling barriers can be done in main two ways: (i) On existing barriers (ii) By constructing new barriers Rolling barriers can be fixed/attached to existing barriers also. Normally, when the existing barriers are concrete barriers, the rolling barriers can be mounted on the barriers along with all components. The rails are attached to the existing barriers and rollers are attached to the rails. It is difficult to attach roller barriers to existing steel barriers. If the barriers are yet to be construct, then it is easy to directly construct new rolling barriers instead of installing on existing barriers. In new rolling barriers construction, vertical pipes/posts are directly installed on road. And then rails are attached to vertical pipes, to which the rollers are connected.

Fig. 1.14: Installation of barriers on existing barriers & new barrier construction

1.9 Maintenance of rolling barriers:

Every single item needs maintenance to work properly till it's design life. Maintenance is also needed in rolling barriers to work efficiently till its design life. Though rolling barriers needs comparatively less maintenance than ordinary barriers. It needs least amount of maintenance as it absorbs the shocks and converts shock energy into rotational energy. So, maintenance to be done for the damage is least. But after a certain period of time, some maintenance is required. Like the rollers should be replaced at a certain period as it may be damaged after some collisions with vehicles or due to high temperature, the rubber of rollers loses its durability and resistance. The steel rails and pipes in rolling barrier system may be required to be replaced or repaired if it is deformed after collision. The reflective tape and LED lamps also need to be replaced or repaired after some time. For proper maintenance, regular inspection should be carried out to detect the defects and repair it before major problem occurs. Regular inspection should be carried out once in a month to avoid major defects. The initial cost of installing rolling barriers is higher, but maintenance required is least and the cost of maintenance is also low.

Chapter 2

Literature Review

G. Udayakumar et al. In his research paper he suggested idea of flexible median divider with use of polymer material for reducing the risk level of accidents on the median divider on researching on the topic he suggested a new flexible barrier he also used ANsyy engineering simulation software he suggested that the use of PVC barrier instead of Rcc barrier he worked on parameter like flexibility collision input reduction cost effective.

Guido Bonin et al has suggested the use of road safety barrier in his paper he suggested the use of road safety barrier with lightweight concrete elements, by replacing conventional concrete with short elements lightweight concrete in his paper he categorized types of accidents. He suggested that the roller barrier is only the solution to reduce road accidents on the expressway

Nagadarshan Rao B J In his paper suggested the use of roller barrier instead of the conventional barrier system.in the year 2015 there was 2.5% increase in total road accidents and 3.2% accidents on the highway, in this paper he evaluated the property of roller barrier like crash cushioning and correction of the vehicle running direction. The said in his paper that the new idea is replacing the conventional barrier with roller barrier.

Muhammad Farhan In this paper the use of roller barrier with Indian perspective has been discussed he said that in 2016 4, 80,652 accidents took place 1.50,785 deaths caused he suggested that soon the developing countries like India need to not only grow in economy but also focus on the life safety he suggested that RB will safeguard the life of humanity as the implementation other countries like having from their result.

Kim et al In his paper, he stated that the longitudinal barrier help in reduction of accidents by 50% in a year. When the strength performance test was done on 8-ton truck and a passenger protection test on 1.3-ton car the barrier satisfied the guidelines of installation and managing of road safety

Rao. Et al In his paper, he stated that in 2015 1347 accidents took place and 400 deaths took place he said that 57 accident take place every hour he said RB saves lives and prevent damage to the vehicle and said roller barrier are future of road safety and management.

Reddy et al In his paper said that 1.25 million people die due to road accidents he suggested that the installation of the guardrail in the road can minimize large no of accidents.

2.1 History

Rubber is also known by its scientific name “Caoutchouc” or “India rubber”. The indigenous people of the Americas had known and used rubber long before the arrival of European explorers. Rubber makers in ancient Mesoamerica were almost 3,500 years ahead of Charles Goodyear and his vulcanized rubber1,4 . The ancient Mayan people used latex to make rubber balls which were used in an important ritual game. This game was called Tlachtlic, a cross between football and basketball, but had religious significance. This was recorded in the Popul Vuh, a Mayan religious document. In 1525, a person called Padre d’Anghieria reported that he had seen Mexican tribes people playing with elastic balls. An eraser was considered to be the first use for rubber. This was suggested by Magellan, a descendent of the famous Portuguese navigator. It was popularized in England by someone called Priestley and it became known as India Rubber4, 5. The Portuguese meaning of rubber was borracha and this was originated from making jars replacing the leather borrachas that the Portuguese used to shipwine. In 1735, the first scientific study of rubber was undertaken by Charles de la Condamine. According to him, rubber could be used to produce flexible tubes. Since then, there were many craftsmen who become involved with rubber. In 1820, Nadier, a British industrialist produced rubber threads and attempted to use them in clothing accessories. This was the time when America was seized by rubber fever, and there was the waterproof footwear used by the indigenous people which became a success. Snow boots and waterproof fabrics were produced in NewEngland6, 7.

In 1832, the Rosburg factory was set up, and unfortunately did not do well as cold weather affected goods produced from non-vulcanized natural rubber, leaving them brittle and thereby discouraging consumers. Charles Goodyear discovered the process of vulcanization accidentally in 18408. Till 1839, rubber was subject to the change in weather conditions. The rubber was hot and sticky during hot weather. It became cold and brittle during cold weather. Goodyear discovered the process of vulcanization when a mixture of rubber, lead and sulfur were accidentally dropped onto a hot stove. This resulted in a product which wasn't affected by weather, and which came back to its original form if stretched. The process was refined and thereby the uses for rubber materials increased. This new vulcanized rubber was resistant to water and chemical interactions and did not conduct electricity, and hence suitable for a variety of products9.

Today more than 75% of rubber in production is a synthetic product made from crude oil. During World War II, the United States could not supply rubber worldwide, and they stepped up the production of synthetic rubber for use in the war effort. There are about 20 grades of synthetic rubber and ultimately it is the intended end use which determines selection. Natural rubber is just one kind. Because, the rubber plant only thrives in hot, damp regions near the equator. Today, ninety percent of rubber production is by the Southeast Asian countries like Malaysia, Thailand, and Indonesia9, 10. However, Indonesia's production has dropped in recent years and new rubber plantations were started in Africa to take up the slack. Rubber belongs to a class, made up of a number of materials that have the unique property of high elasticity. Natural rubber is an elastic hydrocarbon polymer that naturally occurs as a milky colloidal suspension, or latex, in the sap of some plants. The entropy model of rubber was developed in 1934 by Werner Kuhn. The scientific name for the rubber tree is Hevea brasiliensis. The major commercial source of natural rubber latex is the Para rubber tree (Hevea brasiliensis: Family: Euphorbiaceae). This is largely because it responds to wounding by producing more latex11.

Hypoallergenic rubber can be made from Guayule. Early experiments in the development of synthetic rubber also led to the invention of Silly Putty. Natural rubber is often vulcanized, a process by which the rubber is heated and sulfur, peroxide or bisphenol are added to improve resilience and elasticity, and to prevent it from perishing. It has greatly improved the durability and utility of rubber from 1830. The successful development of vulcanization is most closely associated with Charles Goodyear. Carbon black is often used as an additive in rubber to improve its strength, especially in vehicle tires. Early rubber technologists were found among the Aztecs and Mayas of South America, who used rubber for shoe soles, coated fabrics, and play balls, well over 2000 years ago. An MRPRA (Malaysian Rubber Producers Research Association) article mentions that the Aztec King, Montezuma was paid tribute by the lowland tribes in the form of 16,000 rubber balls, and that ball counts have been excavated in snake town in the south western United States dating back toAD600-9004,10,11.

Subramaniam, in the late Maurice Morton's book rubber technology3 attributes Christopher Columbus as the first European to discover natural rubber, in the early 1940s, when he found natives in Haiti playing ball with an extract from a tree. The book goes on to describe how, by the 18th century, uses for natural rubber were well established in Europe, where the English Chemist J.B.Priestly gave its name since it rubbed out pencil marks. Stern mentions the Scotsman Macintosh who in 1823 used the solvent naphtha to dissolve rubber and applied the resulting solution to textiles in order to produce rainproof clothing4. Rubber at that time was supplied in hard blocks. He notes that Thomas Hancock in London in 1830 used what can be described as the first internal mixing machine, which mechanically worked the rubber, making it softer and therefore more easily processable. He mentions that Hancock moved on to two roll mills and that it took a hundred years before the internal mixer reappeared, becoming a key element in the industry. Buist says that Hancock's internal mixer was invented in 1820, and mentions that Hancock called it as a pickle as Buist puts it to confuse his competitors5 . He also mentions that Hancock's Company, James Lyne Hancock Ltd, in London was the first British Rubber Company, founded in 1820. Rubber products, up to the 19th century, had a major flaw, because, they were sticky on hot days, and very stiff when cold. This problem was solved by a major discovery attributed to Charles Goodyear of Woburn, Massachusetts,USAin 18394,6.

Duerden writes that Goodyear accidentally visited the rubber good store of the Roxbury Company in New York, USA, around 18326 . He comments that, in his search to modify rubber to make it more useful, "Goodyear purchased the claim of combining sulphur with India rubber" from Nanthaniel Hayward. Goodyear was then awarded a contract from the US Government to manufacture mail bags. These bags were made from rubber containing sulphur and white lead. Before long, the mail bags started to decompose. Instead of leading him to riches, Duerden mentions that it brought Goodyear and his large family to poverty. By chance, he heated the raw rubber-sulphur-lead combination, and found that the material charred like leather, and vulcanized leather. The resulting composition was a much stronger material and no longer sticky at higher temperatures. Duerden writes that Goodyear took out a US patent for this momentous discovery in 1841 but that he profited little from it. Later in 1843, Hancock was also combining sulphur with rubber and using heat. Stern states that an artist friend of Hancock coined the term

Vulcanization for this process, after Vulcan, the God of fire in Greek word7 . The words vulcanize, cure, and cross-linking will be used synonymously.At this time went on, the quantity of rubber consuming continuously increased. Suzuki mentions that the native people of theAmazon were ruthlessly exploited, and that a rubber tapper could be killed, simply for not bringing the required quantity of rubber from the surrounding trees8 . White describes how, in 1876, seeds were taken out of Brazil and grown into seedlings at Kew gardens in England9 . They were then slipped to the Far East. In 1889, John Dunlop in England invented the first commercially successful pneumatic tire, which was at that time used for bicycles10 . Dunlop produced his first vehicle pneumatic tire in 1906 11.

An interesting observation by Stern is that in 1904 in England, it was found that a powder called carbon black, blended into rubber, and significantly increased a number of its mechanical properties 12. It seems surprising that this major discovery was then “left on the shelf” for about 8 years. By 1910, the motor car truly arrived and both the use and price of natural rubber exploded. Kuzma notes that the Russians in 1910 prepared such a rubber, known chemically as polybutadiene13. In the 1930s, the German began commercial production of synthetic rubber called Buna-S14, 15. A priest synthesized a chemical building block which led to the discovery of a rubber by DuPont who marketed it as Duprene, in 1931, then changed the name to Neoprene16 . Bryant points out that in 1934 production of an oil resistant rubber called Buna-N was started in Germany, the name later changed in 1937 to Perbunan17. Its given name is nitrile rubber (NBR, Nitrile Butadiene Rubber). It seems to be a fairly straight forward wood. The French call it as Caoutchoue recognizing its historically South American native origin. The wood derives from a South American Indian wood, meaning ‘weeping wood’18, 19. Blow makes comments similar to these, about the word ‘rubbers’ have several meanings20. He suggests that the vulcanized material be called “elastomer”. ASTM Standard D 1566-98 defines “elastomer” as a term often used for rubber and polymers that have the properties similar to those of rubber.

2.2 Synthetic Rubber:

Synthetic rubber is a white, crumbly plastic mass which is processed and vulcanized in the same manner as natural rubber. In other words, synthetic rubber is an artificially produced material having properties similar to natural rubber. Most synthetic rubbers are obtained by polymerization or polycondensation of unsaturated monomers. There are wide varieties of synthetic rubbers, reflecting various applications due to the chemical and mechanical properties they have29. Co-polymerization of different monomers leads to the material properties to be varied across a wide range. Though, WorldWar II became the force for the emergence of synthetic rubber on a largescale basis when governments began building plants to balance natural rubber shortages. Also, there were other reasons as well after the war which led to the development of an alternative or substitute for natural rubber.

2.2.1. Necessity for Synthetic Rubber Production

Synthetic rubbers were first created in the early 1930s and were subsequently developed because of the uncertainty of the supply of natural rubber. This first rubbery synthetic was derived from acetylene gas and was a long chain molecule called polychloroprene, better known as neoprene. Synthetic rubbers in 1980 accounted for about 70 % of the total world's supply of rubber materials. Some of the important synthetic rubbers are styrene-butadiene, nitril e rubbers, and the polychlorprenes. Synthetic rubbers are further developed than natural rubbers. Examples are synthetic natural rubber, butyl, styrene butadiene, polybutadiene, and ethylene propylene. Some of the important factors are listed below.

- Rising prices for natural rubber on the world market in response to the general state of the economy
- Political events which cut customers off from the suppliers of raw materials
- Long transport distances
- Regional constraints with respect to establishing rubber plantations
- The increase in global demand for rubber.

2.2.2. Applications of synthetic rubber

Like natural rubber, synthetic rubbers have a varied range of applications and are mentioned below.

- Applied in the tyre industry to manufacture car, aircraft and bicycle tires
- Used to manufacture drive belts
- To produce hoses.
- To manufacture medical equipments
- To make seals

- To apply as floor coverings
- To process conveyor belts
- To manufacture molded parts.

2.2.3. Properties of Synthetic Rubber

Different varieties of synthetic rubber are available, and each having their unique properties. Some of the common properties of synthetic rubber are as listed below.

- Better abrasion resistance
- Good elasticity
- Better heat and aging resistance
- Used as an electrical insulation material
- Flexible at low temperatures
- Flame retardant
- Resistant to grease and oil

2.3 Natural Rubber:

Natural rubber is produced commercially from the latex of the Hevea brasiliensis tree. The source of natural rubber is a milky liquid known as latex which is a suspension containing very small particles of rubber. The liquid latex is collected from the trees and taken to a processing center where the fluid latex is diluted to 15% rubber content and coagulated with formic acid25. The coagulated material is then compressed through rollers to remove water and to produce a sheet material. The sheets are either dried with currents of hot air or by the heat of a smoke fire. The rolled sheets and other types of raw rubber are usually milled between heavy rolls in which the mechanical shearing action breaks up some of the longer polymer chains and reduces their average molecular weight. Natural rubber production in 1980 accounted for about 30 percent of the total world's rubber market26. Natural rubber is mainly cis-1, 4 polyisoprene mixed with small amounts of proteins, lipids, inorganic salts, and numerous other components. Cis-1, 4 Polyisoprene is a long chain polymer, having an average molecular weight of about 500000 gm/mol. The polymer chains of natural rubber are long, entangled, and coiled at room temperature, which are in a state of continued agitation.

2.3.1. Vulcanization

The tensile strength of natural rubber is increased by a process called as 'vulcanization'. It is a chemical process by which polymer molecules are joined together by cross linking into larger molecules to restrict molecular movement. In 1839, Charles Goodyear discovered this process for rubber by using sulphur and basic lead carbonate. The word Vulcan indicates the roman god of fire. He found that when a mixture of natural rubber, sulphur, and lead carbonate was heated, the rubber changed from a thermoplastic state to an elastomeric material27. Although, even today the reaction of sulphur with rubber is complex and not completely understood. Rubber and sulphur react very slowly even at elevated temperatures. To shorten the curing time at elevated temperatures, accelerator chemicals are usually compounded with rubber along with other additives such as fillers, plasticizers, and antioxidants. Usually, vulcanized soft rubbers contain about 3 weight % sulphur and are heated in the 100 to 200 degree C range for vulcanizing or curing. If the sulphur content is increased, the cross linking that occurs will also increase, producing harder and less flexible material. A fully rigid structure of hard rubber can be produced with about 45% sulphur. The use of fillers can lower the cost of the rubber product also strengthen the material. Carbon black is commonly used as a filler for rubber, the finer the particle size of the carbon black, the higher the tensile strength is. It also increases the tear and abrasion resistance of the rubber. Silica such as calcium silicate and chemically altered clay are used as fillers for reinforcing rubber28. Some of the properties of vulcanized natural rubber: cis-polyisoprene is shown.

Natural rubber compounds are outstanding for their flexibility, good electrical insulation, low internal friction, and resistance to most inorganic acids, salts, and alkalies. However, they have poor resistance to petroleum products, such as oil, gasoline, and Naptha. In addition, they lose their strength at elevated temperatures, so it is advisable that they not to be used at temperatures above 80 degree C. They also deteriorate fairly rapidly in direct sunlight unless specially compounded. It has good resistance to abrasion and fatigue, and it has high frictional properties, but it has low resistance to oil, heat, ozone, and sunlight. Typical applications are tires, seals, shoe heels, couplings, and engine mounts. Natural rubber is a vital agricultural product or commodity which is used in the manufacture of a wide range of products. Rubber plays a major role in the socio-economic fabric of many developing countries. Products made from natural rubber, like tyres, engineering components and latex products are very essential to modern life. It is available in many grades.

2.3.2. Properties of Natural Rubber

Natural rubber combines high strength with outstanding resistance to fatigue. It has an excellent green strength and tack which means that it has the ability to stick to itself and to other materials which makes it easier to fabricate. It has moderate resistance to environmental damage by heat, light and ozone which are one of its drawbacks. The natural rubber has an excellent adhesion to brass-plated steel cord, which is ideal in rubber tyres. It has low hysteresis which leads to low heat generation, and this in turn maintains new tyre service integrity and extends retreadability. The natural rubber has low rolling resistance with enhanced fuel economy. It has high resistance to cutting, chipping and tearing.

2.3.3. Reasons for Natural Rubber Usage

Natural rubber forms an excellent barrier to water. This is possibly the best barrier against pathogens, and so latex is used in surgery as surgical and medical examination gloves. It is an excellent spring material. Natural rubber latex is also used in catheters, balloons, medical tubes, elastic thread, and also in some adhesives. Other than rayon, it is the sole raw material, which is used by the automotive industry. Rubber wood is a bye product of natural rubber. It is a source of charcoal for local cooking.

2.3.4. Natural Rubber as a Tyre Material

The technical strengths of natural rubber matches well and best suitable to be used as an efficient tyre material. These have been succinctly summarized belowbyBaker25 .

- High green strength, tack and cohesive properties: These are essential for maintaining green tyre uniformity and stability during building and shaping operations.
- Excellent adhesion to brass-plated steel cord.
- Low hysteresis which imparts low heat generation, which in turn maintains new tyre service integrity and extends retreadability.
- Low rolling resistance with enhanced fuel economy.
- Excellent snow and ice traction for winter tyres and all season treads.

- High resistance to cutting, chipping and tearing.

2.4 Natural Rubber Vs Synthetic Rubber - A Comparison

Natural rubbers have better resistance to heat, gasoline, chemicals, and can withstand high temperatures. Examples of synthetic rubbers that are resistant to oil are neoprene, nitrile, urethane, and silicones. Synthetic rubbers are applied to process tyres, shock absorbers, seals, and belts 30. Styrene-butadiene rubber (SBR) is an important synthetic rubber and also the most widely used one. Actually, it is a butadiene-styrene copolymer. After polymerization, it contains 20% to 23% styrene. SBR rubber is lower in cost than natural rubber and so utilized in many rubber applications. Nitrile rubbers are copolymers of butadiene and acyrolonitrile with the proportions ranging from 55% to 82% butadiene and 18% to 45% acyrlonitrile. These rubbers are more costly than ordinary rubbers, so these copolymers are limited to special applications such as fuel hoses and gaskets where high resistance to oils and solvents is required.

The polychloroprene or neoprene rubbers are similar to isoprene. They also have fair fuel and oil resistance and increased strength over that of ordinary rubbers. However, they do have poorer low temperature flexibility and are higher in cost. As a result, neoprenes are used in specialty applications such as wire and cable covering, industrial hoses and belts, and automotive seals and diaphragms. Silicone rubbers or Silicones have the highest useful temperature range up to 315 degree C, but such other properties as strength and resistance to wear and oils are generally inferior to those in other elastomers. Typical applications of silicone rubbers are sealants, gaskets, thermal insulation high temperature electrical switches, electrical insulation, auto-ignition cable, spark-plug boots, and electronic apparatus.

Chapter 3
Methodology

Highway safety refers to the methods and measures used to prevent road users from being killed or seriously injured road accident are one of the leading cause of human death. Accident occurs due not following traffic rules improper road construction, clash of vehicles, driving beyond speed limit such accidents cause sudden death or injuries Nowadays transportation sector in India enhancing the services rapidly. Every year approximately 1.5 lakhs peoples dies due to road accidents. Today, India is one of the highest country which growing rapidly by road networks, transportation systems etc. But in road networks, the impact of road accidents on road safety is very major problem nowadays. Road accidents causes major injuries, damage to vehicles, loss of life of people etc. Road safety is very big issue at national level. Road accidents are increased by 10% in 2019 as compared to the 2018. To minimize the road accidents, Rolling Barrier System is newly concept invented with structure consists of urethane rings by Korean company. These rolling barriers are used in hilly areas, curved roads etc. When the vehicles hit the barrier, rolling barrier reduce the speed of vehicles and prevent it from accident. Rollers absorb the shock energy, when vehicle collapse on barrier and shock energy converted into rotational energy.

3.1 Rolling Barrier

The concept of rolling barrier is, a structure equipped with continuous pipes covered with urethane rings. Its general feature resembles an erected abacus. As the rolling barrier activates the rolling friction when vehicles hit the barrier, the rolling barrier reduces severity of traffic accidents. There have a rolling box which is attested with stainless steel. The rolling box can rotate when it will hit by traffic. It’s made of special chemical compound like hard rubber which is capable to absorb the impact of the vehicle. In concrete or steel barriers there target to save the life of the humans but the vehicle situation would be worst and cable barrier try to reduce the impact of the vehicles. Sometime these three types of barrier fail to achieve its target and human lost his life.

Barrier is a type of obstruction that tries to keep vehicles within their road lanes and prevent them from collision with obstacles or other vehicles. They are installed on both side of roads, especially on curves. The main use of barriers is to prevent collision of vehicles with other obstacles or vehicles. The barriers used maybe of steel, concrete or maybe even of cable. These barriers may be used as roadside barriers, median barriers, bridge side barriers or work zone barriers. They are rigid, they do not have much flexibility.

Fig 3.1: Rolling Barriers

There are more chances of accidents on sharp horizontal curves. Barriers are provided on sides of horizontal curve. These barriers can reduce the number of accidents, but when vehicle collides with the barrier, it causes high damage to vehicle, injury to human body or even death. As after the collision the vehicle is not in control, it may be overthrown or suddenly stopped, causing high damage. Due to speed and weight of the vehicle, after collision with barrier, the vehicle driver loses his control and collision occurs. After hitting the barrier, vehicle is not able redirected to its path or it may be even overturned.

Rolling barriers are barriers with rollers installed on it. The concept of rolling barrier is a structure equipped with pipes covered with roller rings. Rolling barrier activates the rolling friction when vehicle collides with it, and with rolling friction activated it reduces the severity of the accident. The roller on the barriers start to roll when it is hit by a vehicle and prevents vehicle from being suddenly stopped or overthrown, and thus reduce the severity of accident. Rolling barriers can be used as roadside barriers, median barriers, barriers on curves, etc. But it's use can be proved more effective on horizontal curves, where there is high chance of accidents.

Fig. 3.2: Rolling barriers at night

3.2. Design Of Rolling Barrier

3.2.1 Components of rolling barrier system:

Top rail: There are two rails in rolling barrier system, which connects and supports the rollers horizontally. The upper rail is known as Top rail. It is like a guard rail, made of steel. Top rail splice is used to connect pipe with rails.

Bottom rail: From the two rails, the lower rail is called Bottom rail. It also connects and supports the rollers horizontally. It is like a guard rail, made of steel. Bottom rail splice is used to connect pipe with rails.

PVC Pipe: The rollers are installed on PVC pipes, which allows the rollers to rotate or roll freely. It is a vertical member connecting both the rails and rollers. It is made up of PVC or steel.
Stopper boards: It is a disc like board, which is installed between rollers and rails, at both upper and lower sides. It is used to guide objects back to road.

Shock absorbing roller: It is the main part of rolling barrier system. The rollers are usually made up of Urethane or recycled hard rubber. It absorbs the shock of vehicles, and convert impact energy into rotational energy.

LED guide lamp: A small LED guide lamp is installed on PVC pipe. It is installed on top of PVC pipe.

Reflective band: A reflective band is attached to the rollers to give better visibility at night. Yellow coloured reflective band/tape is used to increase visibility at night.

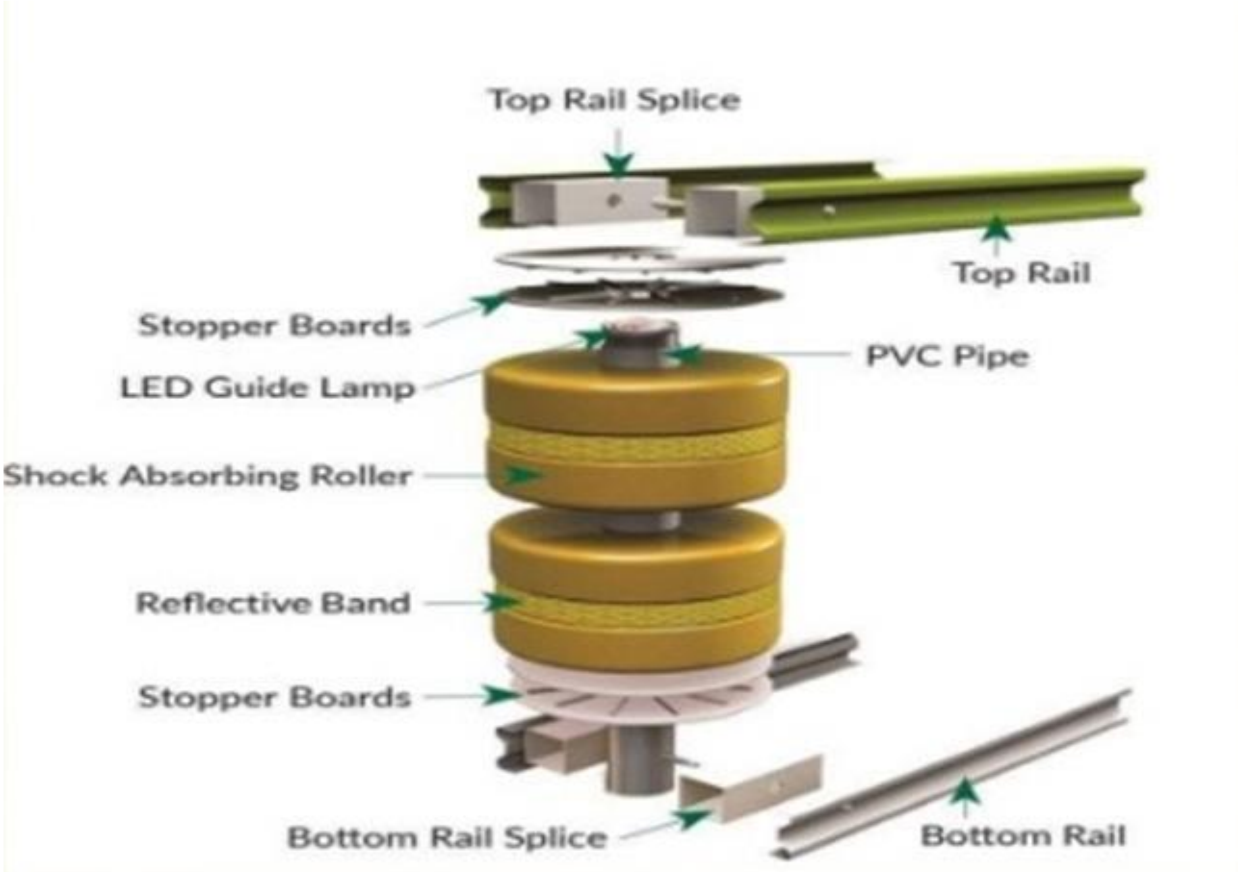


Fig. 3.3: Components of rolling barrier system

3.2.2 Materials used in rolling barrier system:

Urethane has become the material of choice in so many of today's performance driven applications because it exhibits extraordinary physical and mechanical properties that other materials simply can't match. It is a type of an artificial rubber. Urethane is flexible and malleable. It possesses non-brittle property along with elasticity.

Polyurethane is also used for rolling barriers. Polyurethanes are linear polymers that have a molecular backbone containing carbamate groups. They are unique in combining the strength of rigid plastics with the flexibility and elasticity of rubber. It also possesses non-brittle property along with elasticity.

Use of recycled artificial rubber is also possible.

3.2.3 Design specifications of rolling barrier:

Design of the rolling barrier is provided by the South Korean company "KSI". Here, the name of roller is given 'A'. The total diameter of the roller is 370mm and the rounded stainless steel's diameter is 246mm. The distance between one post to another post below the soil is 1400mm. A span's distance is 4200mm. Centre to centre distance between one roller and another roller is 700mm. The vertical distance from ground level to further is 1200mm and the height of upper side is 1000mm. All details are shown in figure.

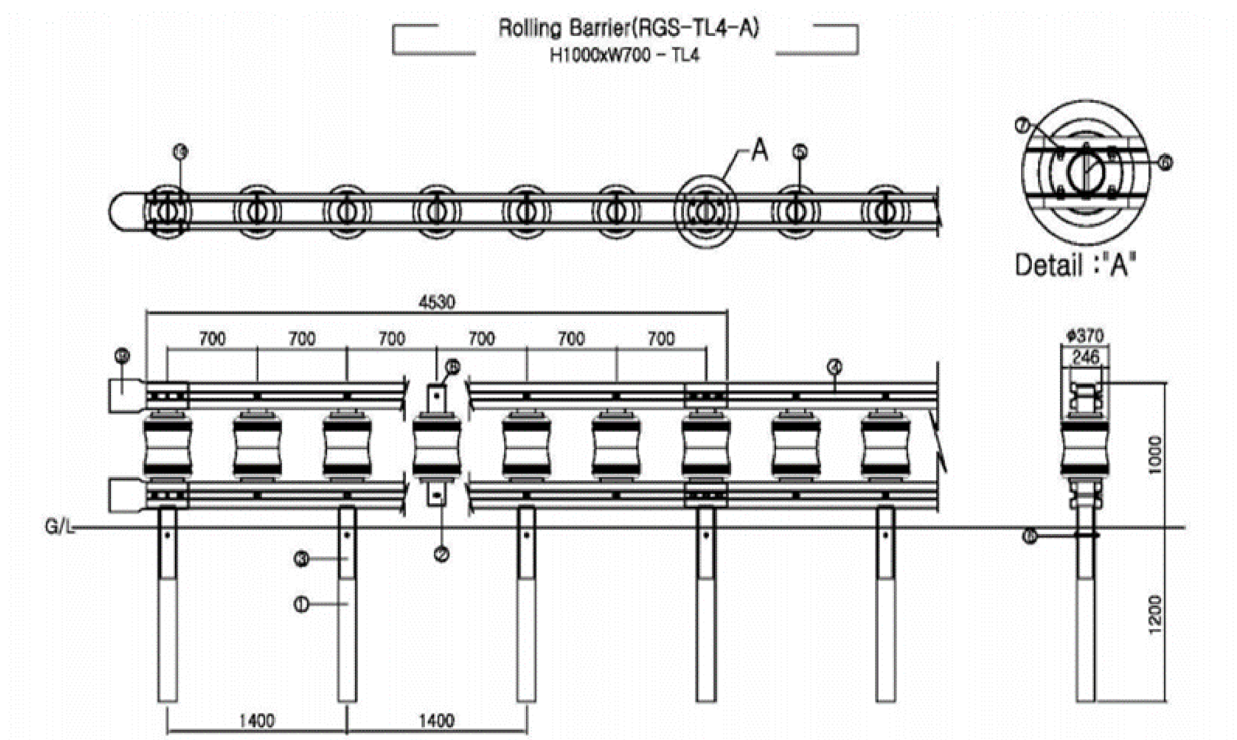


Fig. 3.4 Design specifications of rolling barrier system

3.3 Experimental Method of Rubber Synthesis

The Silicone rubber is manufactured by using silicone gum (Sp. Gr. 0.98 and low shrinkage) or silicone reinforced gum (Sp. Gr. 1.13), reinforcing fillers (Sp. Gr. 1.85, elongation % 200-350 and tensile strength 600-900 psi), extending filler (Sp. Gr. 2.15, elongation % 75-200 and tensile strength 400-800 psi), additives (0.5-2 parts per 100 parts of compound and curing agent generally peroxides.

3.3.1 Materials:

a) Silicone Gum

Pure Silicone rubber polymer differing from one another in polymer type and molecular weight are available in the market. Silicone gum with low shrinkage and having specific gravity 0.98 was obtained from Bhavik Enterprise, D-wing, Mumbai, Maharashtra.

b) Silicone Reinforced Gum

Although pure polymer may be used, it is generally easier and more economical for the rubber compound to develop with Silicone Reinforced Gum. The Silicone Reinforced Gum is the mixture of pure gum and highly reinforcing silica that have been especially processed. In some cases they contain additives for special effects such as improved heat ageing or bonding properties. Silicone Reinforced Gum with specific gravity 1.13 was obtained from Bhavik Enterprise, D-wing, Mumbai, Maharashtra.

c) Reinforcing fillers

The fume process silicas reinforce silicone polymer to a great extent than any other filler. Due to high purity of the silica, the rubbers containing it have excellent electrical insulating properties, especially under wet conditions. Reinforcing filler having specific gravity 1.85, elongation % 200-350 and tensile strength 600-900 psi is used in the developed Silicone rubber compound. Carbon black gives moderate reinforcement. However, the black inhibits cure with the aroyl peroxide vulcanizing agent and this limit their use mainly to the production of electrically conductive or semiconductive rubber.

d) Extending Fillers

The extenders are important for use in compounds containing reinforcing fillers in order to achieve an optimum balance of physical properties, cost and processibility. Extending filler having specific gravity 2.15, elongation % 75-200 and tensile strength 400-800 psi. Siliceous extending filler are used as 25 to 300 parts by weight.

Ground silica and calcined kaolin do not provide significant reinforcement. As a consequence they are added to a reinforced gum or compound in relatively large quantities in order to reduce cost. These extenders are satisfactory in either mechanical or electrical grade rubber.

The reinforcement obtained with calcined silica is greater, though quite modest, than that obtained with any other extender. Therefore, as an extender, it is not as useful as ground silica.

e) Additives

Additives are used as 0.5-2 parts per 100 parts of compound. Organic colours and many inorganic colours have adverse effects on the heat aging of Silicone rubber. However, the inorganic pigments is suitable for use. Red iron oxide is used here as a colour pigment and as a heat aging additives.

f) Curing agents

Curing agent are generally peroxides. Benzoyl peroxide is used as a curing agent. In practice it has been found that there are six (3 Aroyl peroxides and 3 Dialkyl type) commonly used peroxides but none of them is a universal curing agent. The usage of these curing agents is mostly depending on the properties required of a rubber compound. The three aroyl types of peroxides may be considered as general-purpose curing agents as they cure both nonvinyl and vinyl containing polymers. However, benzoyl peroxide is more desirable because of its higher curing temperature. The other three types of peroxides i.e., dialkyl group are vinyl specific since they are giving good cure only to the vinyl containing polymers. All three vinyl specific peroxides are good for thick section moulding.

3.3.2 Compounding and Formulation:

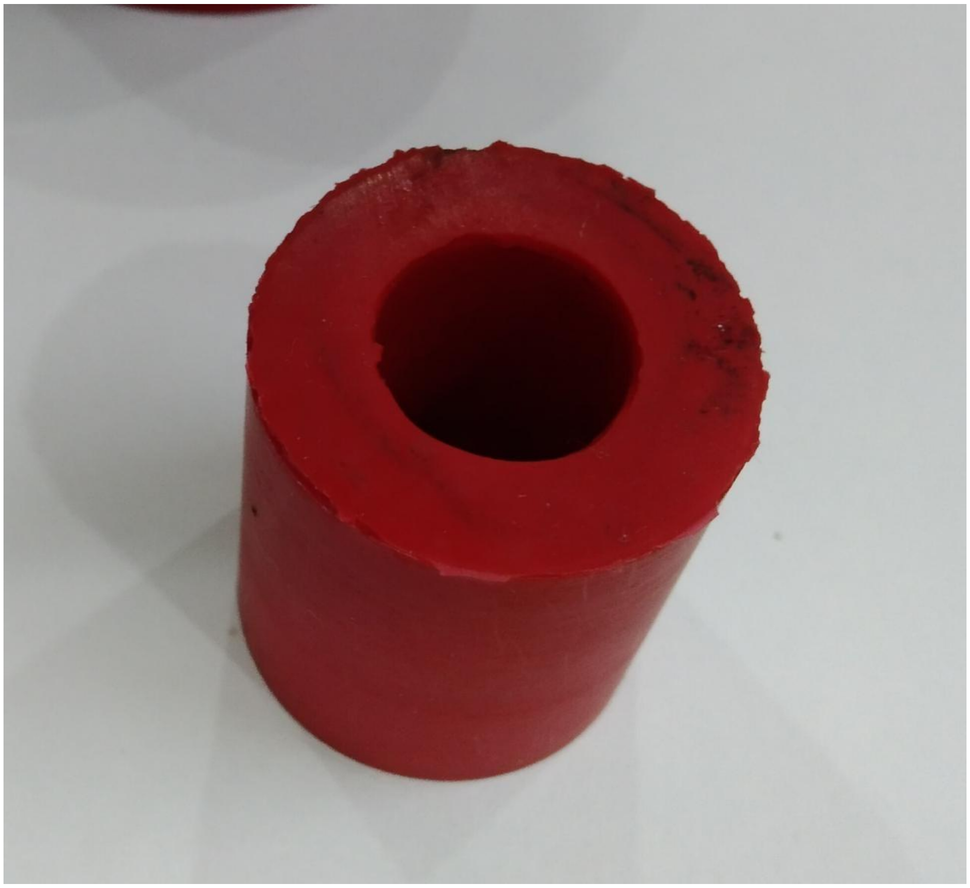
The Silicone rubber samples used for this work here is Silicone Gum Silastic-430, ASTM D-1418, V Si, general purpose, low compression set, specific gravity 0.98, low shrinkage (3% approx.) from Bhavik Enterprise, D-wing, Mumbai, Maharashtra. Silicone reinforced gum SE-517, ASTM D-1418, PV Si, extreme low temperature, high strength, specific gravity 1.13 from Bhavik Enterprise, D-wing, Mumbai, Maharashtra. Reinforcing filler acetylene black, particle size mean diameter 45 mµ, surface area sq. mt. /gm. 75-85, specific gravity 1.85, tensile strength 600-900 psi, elongation % 200-350 and taken from Bhavik Enterprise, D-wing, Mumbai, Maharashtra. Extending Filler as Calcined Diatomaceous Silica, particle size mean diameter 1-5 μ, surface area sq. mt. / gm. <5, specific gravity 2.15, tensile strength 400-800 psi and Elongation range 75-200% and supplied by Bhavik Enterprise, D-wing, Mumbai, Maharashtra. Additive as colour pigment red in colour, RY-2196 and curing agent as Benzoyl Peroxide CADOX BSG-50 in the form of paste from Bhavik Enterprise, D-wing, Mumbai, Maharashtra.

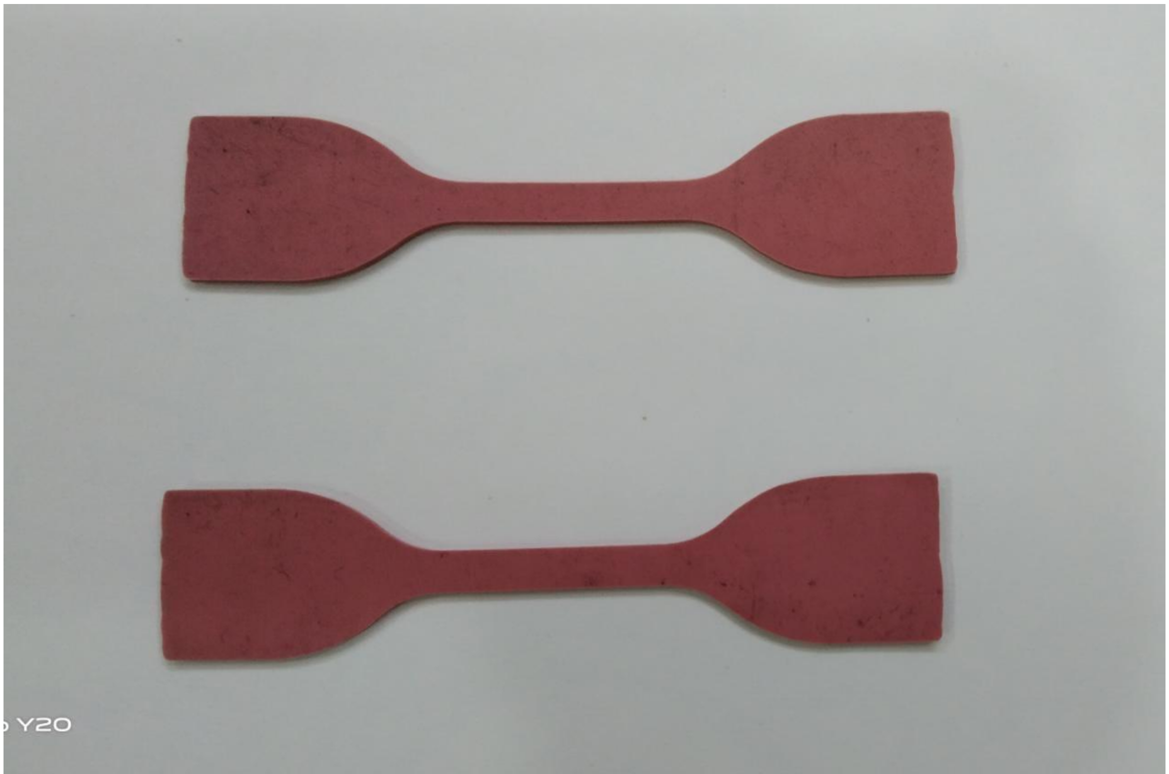
3.3.3 Sample Preparation:

Table 3.:1 Compound formulations of Silicone Rubber Samples

Sample No.	Silastic 430 Wt-%	SF-517 Wt-%	Acetylene Black	Calcined Diatomaceous Silica	RY-2196	CADOX BSG-50
S1	75	25	3	2	2	-
S2	75	25	3	2	5	-
S3	75	25	3	2	10	-
S4	75	25	3	2	-	2
S5	75	25	3	2	-	5
S6	75	25	3	2	-	10

Table 3.1 shows the diffirent formulation of Silicone rubber samples prepared for this work. On the basis of this table the mixing of different components of Silicone Rubber samples were carried out on a two-roll mill with nip gap 2 mm, fast roll peripheral speed as 125 feet/min. and speed ratio of the rolls was 1:1.4. According to ASTM D3182 the mixing time is around 20-25 minutes. Curing time of these samples were carried out as per ASTM D 2084. Post curing of these samples were carried out at 2000C for 4 hours. The main purpose of the post curing was to expel volatile material and improve the properties of the samples.

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Chapter 4

Result and Discussion

4.1 Testing and Comparison of Silicone Rubber with Urethane

4.1.1 Sample Characterisation and Testing

The tensile strength of the samples is determined by using a universal tensile testing machine as per the method ASTM D412. Hardness (Shore A) of the sample was determined according to the standard test method ASTM D2240 on a durometer hardness. Compression set of the sample was determined according to the standard test method ASTM D 395.

Table-4.1 Mechanical Properties of Silicone Rubber Samples

Sample No.	**Tensile Strength psi**	**Elongation at Break %**	**Hardness (Shore A)**	**Tear Resistance kN/m**	**Temperature Range Deg C**
S1	1208.53	520.67	53	56.25	-50 to 200
S2	1166.98	610.38	56	48.28	-48 to 200
S3	1223.45	454.32	51	58.87	-51 to 200
S4	1065.89	540.79	48	53.65	-49 to 200
S5	1103.67	580.36	55	51.23	-49 to 200
S6	1218.76	603.65	52	49.72	-50 to 200

The various properties of the Silicone samples obtained during the experiment are shown in table-2 and the corresponding graph / plot against each property is also mentioned in the further pages.

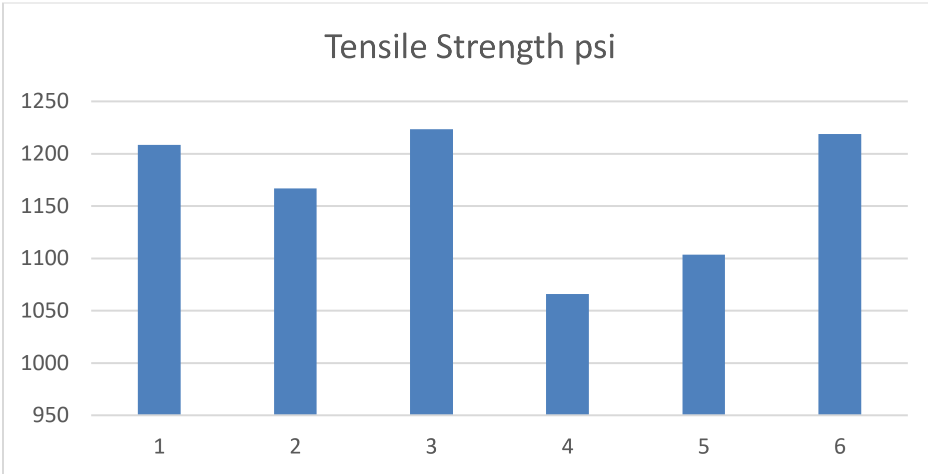

Fig 4.1. Variation in Tensile Strength of Silicone Rubber Samples

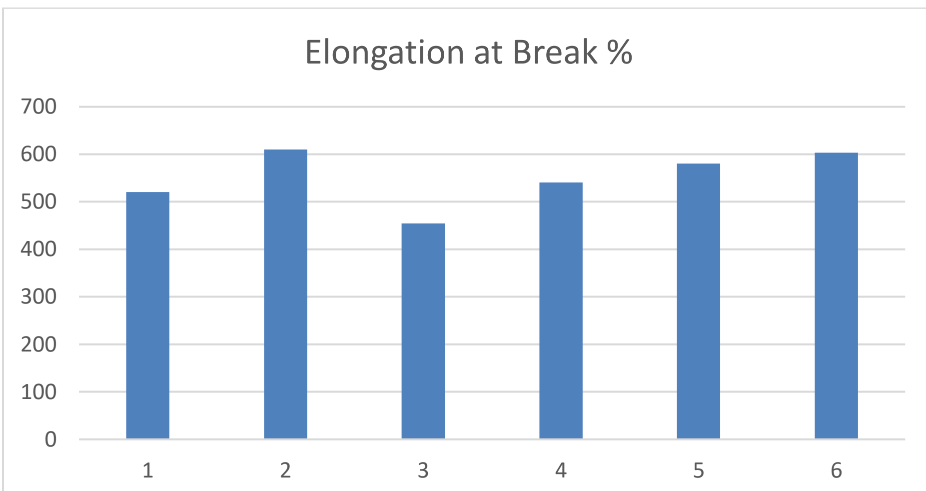

Fig 4.2 Variation in Elongation at Break of Silicone Rubber Samples

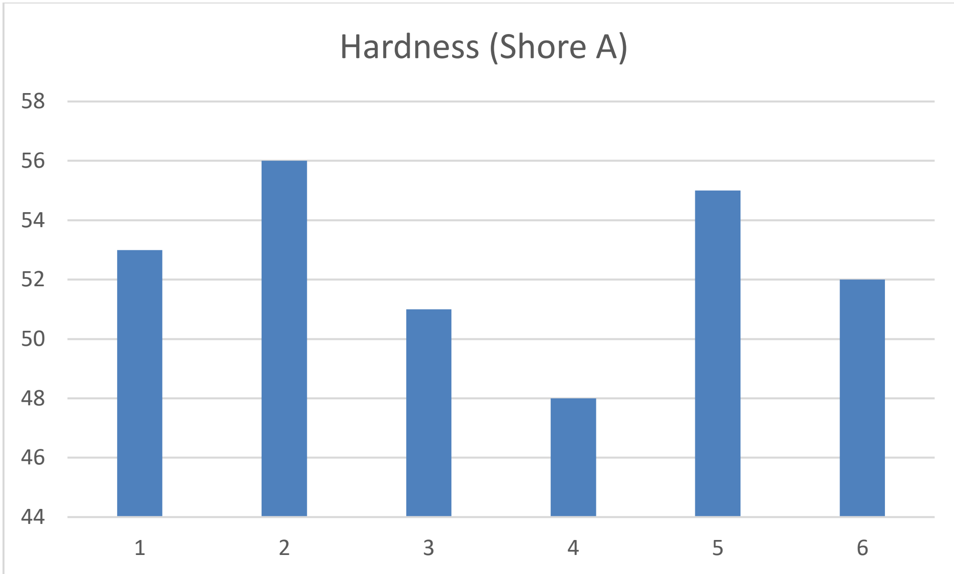

Fig 4.3: Variation in Hardness of Silicone Rubber Samples

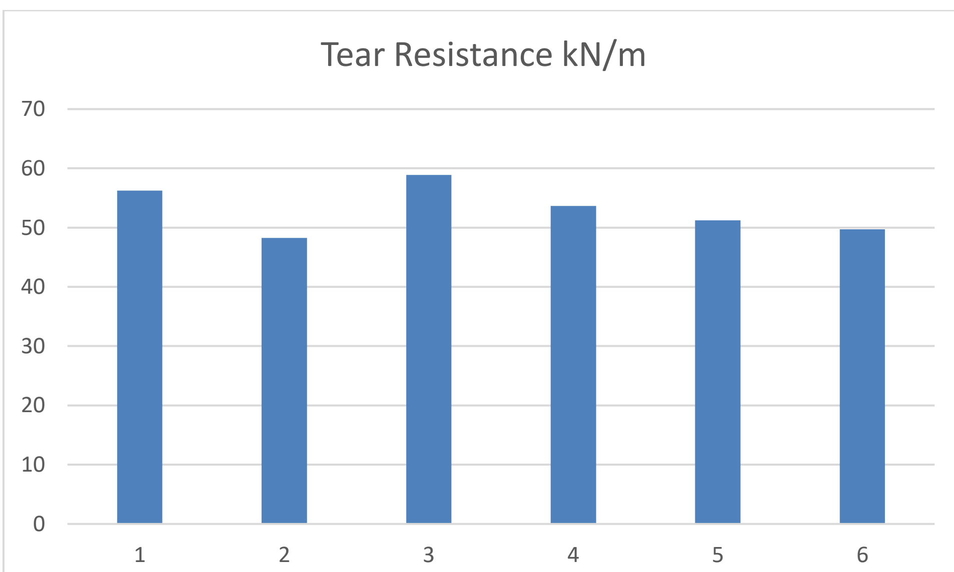

Fig 4.4: Variation in Tear Strength of Silicone Rubber Samples

Chapter 5

Conclusion

It is evident from the table 5.1 that all the properties of Urethane material and the Silicone Rubber is comparable except the tensile strength. However, many alterations are carried out during the formation of sample of silicone rubber but the tensile strength of it is not achieved comparable to the Urethane material. Sample alteration it was observed that if the tensile strength is increased then the other properties like hardness starts decreasing and become incomparable. Also, the Elongation goes on decreasing. In short, it is concluded that the tensile strength of the silicone rubber is not achieved compared to the Urethane material. However, the rolling barriers may be made and used in road sides and may reduce the accidents and ultimately saved the life.

Table 5.1: Comparison of Properties of Urethane and Silicone Rubber

Properties	**Urethane (Avg. Value)**	**Silicone (Avg. Value)**
Hardness (Shore 'A')	62.5	52.5
Sp. Gr.	1.19	1.18
Tensile Strength (psi)	4575.93	1164.54
Elongation (%)	545	551.69
Low Temperature Resistance (Deg C)	-30	-49.5

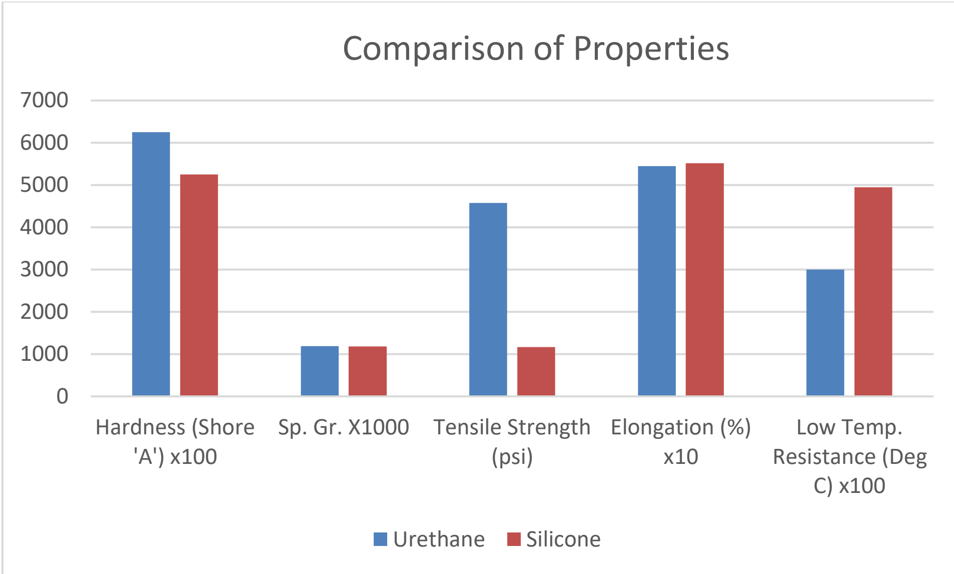

Fig. 5.1 Properties Comparison Urethane Vs Silicone Rubber

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