

**DEVELOPMENT OF TYRE TREAD COMPOUND USING RIBBED
SMOKED SHEETS (RSS) PREPARED WITH MODIFIED GROUND
RUBBER OF TYRE (GRT) INCORPORATED NATURAL RUBBER
LATEX**

BY

W.M.S.U.BANDARA

04/ AS/073

**A RESEARCH REPORT WAS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENT FOR THE GENERAL DEGREE OF BACHELOR
OF SCIENCE (APPLIED SCIENCES)**

**DEPARTMENT OF PHYSICAL SCIENCES & TECHNOLOGY
FACULTY OF APPLIED SCIENCES
SABARAGAMUWA UNIVERSITY OF SRI LANKA
BELIHULOYA**

MARCH 2009

DECLARATION

The project described in this thesis was carried out at the Rubber Research Institute of Sri Lanka under the supervision of Dr.(Mr.) C.P.Udawatte and Dr.(Mrs.) Dilhara Edirisinghe.

Research Student

W.M.S.U.Bandara

Department of Physical Science & Technology,

Faculty of Applied sciences,

Sabaragamuwa University of Sri Lanka,

Belihuloya.

.....*Suka*.....

Signature

.....2009-05-05.....

Date

Certified by

Internal Supervisor

Dr. C.P.Udawatte,

Head/Department of Physical Science & Technology,

Faculty of Applied sciences,

Sabaragamuwa University of Sri Lanka,

Belihuloya.

.....*C.P. Udawatte*.....

Signature

.....2009-05-05.....

Date

External Supervisor

Dr. Dilhara Edirisinghe,

Head / Rubber Technology & Development Department,

Telawala Rd,

Ratmalana.

.....*Dilhara Edirisinghe*.....

Signature

.....14/05/2009.....

Date

Head of the department

C.P.Udawatte,

Head/Dept.of Physical Sciences & Technology,

Faculty of Applies Sciences,

Sabaragamuwa University of Sri Lanka

Belihuloya

.....*C.P. Udawatte*.....

Signature

.....2009-05-05.....

Date

TO MY DEAREST PARENTS

ACKNOWLEDGEMENT

Fist I would like to express my sincere gratitude to Dr. C.P.Udawatte, Head of the department of Physical sciences and Technology, Sabaragamuwa University of Sri Lanka who was my internal project supervisor for the encouragement, guidance and numerous helpful comments and suggestions given to me through the project.

I would like to express my sincere thank to Dr. Dilhara Edirisingha, Head of the department of rubber technology and development, experimental officer Mr. Ranjith Liyanage and all the staff members of rubber research institute.

ABSTRACT

By considering the tyre manufacturing process, tyre tread is very important because it makes contact with the road. Carbon black is widely used as reinforcing filler in the manufacture of dry rubber based products such as tyres, automobile components etc. However, Carbon black is expensive and it effects badly to the environment. To reduce the effect of carbon black in tyre manufacturing process, carbon black is replaced with GRT (ground rubber of tyre).

GRT is vulcanized material and obtained from tyre waste. So, RSS (Ribbed Smoked Sheets) are prepared with GRT dispersion. Here GRT is added to the latex as a solution because when compounding, it causes to environmental pollution. GRT particles (below 200 sizes) was soaked with KOH (potassium hydroxide). By changing soaking time, four samples were obtained.(By keeping one day, three days, five days and seven days to soak). After preparing RSS with GRT, raw rubber properties were checked. According to tyre tread compound formulation, seventeen samples were compounded by changing the ratio of carbon black to GRT. Physical properties such as tensile strength, tear strength, hardness etc have to be checked.

Physical properties of tyre tread compound prepared with GRT incorporated RSS and conventional RSS, have to be compared.

CONTENTS	page
DECLARATION	i
ABSTRACT	ii
ACKNOWLEDGEMENT	iii
LIST OF ABBREVIATIONS	iv
LIST OF FIGURES	v
LIST OF TABLES	vi
CHAPTER 1	
1. INTRODUCTION & OBJECTIVES	1
1.1 INTRODUCTION	1
1.2 OBJECTIVES	1
CHAPTER 2	
2. REVIEW OF LITERATURE	2
2.1 NATURAL RUBBER	2
2.2 TYPES OF RUBBER	3
2.3 TYRE TREAD	4
2.4 RUBBER COMPOUNDING	5
2.5 RAW RUBBER PROPERTIES	11
CHAPTER 3	
3. MATERIALS AND METHODOLOGY	16
3.1 PREPARATION OF 29% GRT DISPERSION	16
3.2 PREPARATION OF RSS WITH GRT DISPERSION	17
3.3 DETERMINATION OF PLASTICITY RETENTION INDEX (PRI) ISO 2930-1981(E)	18
3.4 DETERMINATION OF VOLATILE MATTER CONTENT ISO 248-1979(E)	19
3.5 DETERMINATION OF MOONEY VISCOSITY ISO/R 289- 1963(E)	20

3.6	ACS(AMERICAN CHEMICAL SOCIETY)	
	1 FORMULATION	20
3.7	DETERMINATION OF TENSILE STRENGTH AND ELONGATION AT BREAK	21
3.8	DETERMINATION OF TEAR STRENGTH ISO 34-1979(E)	22
3.9	DETERMINATION OF REBOUND RESILIENCE	23
3.10	DETERMINATION OF HARDNESS	23
3.11	DETERMINATION OF COMPRESSION SET	23
3.12	DETERMINATION OF ABRASION RESISTANCE	24
3.13	TERMINATION OF DRY RUBBER CONTENT	25
3.14	DETERMINATION OF FLEX CRACKING	25

CHAPTER 4

4	RESULTS AND DISCUSSION	27
4.1	RESULTS	27
4.2	DISCUSSION	37

CHAPTER 5

	CONCLUSION	38
	REFERENCES	39

LIST OF ABBREVIATIONS

NR	-	Natural Rubber
RSS	-	Ribbed Smoked Sheet
GRT	-	Ground Rubber of Tyre
ZnO	-	Zinc Oxide
KOH	-	potassium Hydroxide
DRC	-	Dry Rubber Content
PRI	-	Plasticity Retention Index
VM	-	Volatile Matter
S	-	Sulfur
SBR	-	Styrene butadiene rubber
BR	-	Butadiene Rubber
Pro.oil	-	Processing oil
St.acid	-	Stearic acid
CIR	-	Cuomorone indine resin
T.Q(A.O)-	-	Quinine type (Anti oxidant)
6PPG	-	6 para phenolyne diamine
DPG	-	Diphenyl guandine
PVI	-	Prevulcanizing inhibitor

LIST OF FIGURES

	page
Figure 2.1 Structure of Rubber	02
Figure 2.2 A Ribbed Smoke Sheet	04
Figure 2.3 A Tyre Tread	05
Figure 2.4 Reaction of vulcanization	08
Figure 2.5 Carbon Black	10
Figure 3.1 Coagulation of Rubber	17
Figure 3.2 Punched test pieces	18
Figure 3.3 Test piece after passing two-roll mill	19
Figure 4.1 Variation of hardness	33
Figure 4.2 Variation of rebound resilience	34
Figure 4.3 Variation of tear strength	35
Figure 4.4 Variation of tensile strength	35
Figure 4.5 Variation of Compression set	36
Figure 4.6 Variation of Abrasion resistance	36

LIST OF TABLES

	page
Table 2.1 The composition of latex	02
Table 3.1 Prepared samples	16
Table 3.2 Vulcanizing ingredients	21
Table 4.1 Results of Plasticity Retention Index	27
Table 4.2 Results of volatile matter content	27
Table 4.3 Results of Mooney viscosity	28
Table 4.4 Percentage of GRT	29
Table 4.5 Ratio of carbon black to GRT	30
Table 4.6 Amount of GRT and Raw rubber	31
Table 4.7 Car tyre tread compound	32

CHAPTER 1

1.1 INTRODUCTION

By considering the tyre manufacturing process, tyre tread is very important because it makes contact with the road. Carbon black is the widely used reinforcing filler in the manufacture of dry rubber based products such as tyres, automobile components, etc. However, in order to reduce the cost of these products, manufacturers incorporate ground rubber tyre (GRT) into their rubber compounds as a part replacement for carbon black. GRT is obtained from tyre waste which is already vulcanized and hence use of this low cost material in rubber compounds will minimize the growing environmental problem caused by these waste products all over the world ^[2].

Further, incorporation of carbon black or GRT into raw rubber is carried out using internal mixers or open two-roll mills and hence compounding also causes environmental pollution which leads to health hazards of human beings.

Therefore, manufacture of GRT incorporated (in the latex stage) raw rubber such as ribbed smoked sheet (RSS) would minimize the environmental problem caused by the above mentioned filler, in the rubber products manufacturing industries.

Furthermore, chemical modification of GRT with the aim of devulcanizing the GRT particles would be advantageous as enhancement of the properties of the developed RSS is expected. This will also be investigated in this study.^[8]

1.2 OBJECTIVES

Main objective is to develop a suitable tyre tread compound with RSS, prepared by incorporating modified GRT into natural rubber latex and to minimize environmental pollution caused by the incorporation of GRT and carbon black into RSS during the compounding stage of a tyre tread compound using an internal mixer or a two-roll mill.

CHAPTER 2

2. REVIEW OF LITERATURE

2.1 NATURAL RUBBER

Though, the rubber was introduced to Sri Lanka in 1876, commercial planting was started in 1883. Rubber seeds were first planted at Henerathgoda garden in Colombo district. Rubber can be obtained from latex in various ways and composition of latex is given in table 2.1.

Table 2.1 The composition of latex

Chemical ingredients	Weight %
Solid material	30-38
Proteins and phosphoproteins	1.0-2.0
Resin	2.0
Fatty acids	1.0
Carbohydrates	1.0
Inorganic salts	0.5
Water	60-65

Some natural rubber sources called 'gutta percha' are composed of trans-1-4 polyisoprene, a structural isomer which has similar, but not identical properties. Most rubber in every use is vulcanized. It has properties, i.e. if it is heated and cooled; it is degraded but not destroyed. However, if rubber is vulcanized, it will turn into thermo set.

Natural rubber is an elastomer-an elastic hydrocarbon polymer. Commercially, all natural rubber can be obtained from the species 'Hevea brasiliensis'. The purified form of natural rubber is the chemical polyisoprene which can also be produced synthetically. The structural formula of natural rubber polyisoprene (C_5H_8) is given below.

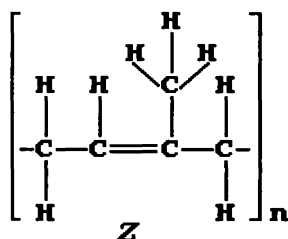


Figure 2.1 Structure of Rubber

Chemically, natural rubber is cis-1-4 polyisoprene. Structure of rubber is shown in figure 2.1. A linear long chain polymer with repeating units (C_5H_8). It has a density of 0.93 at 20 °C. Natural rubber is used extensively in many applications and products. NR is the normal choice for heavy duty applications such as air craft and giant tyres both requiring maximum strength. [5,11]

2.2 TYPES OF RUBBER

There are seven types of natural rubber.

- Ribbed smoked sheet (RSS 60%)
- White and pale crape (2%)
- Crape rubber
- Thin brown rubber
- Technically specified rubber
- Superior processing rubber
- Hevea crumb rubber

Though there are seven types of rubber, RSS was used to make tyre tread compound. [3,13]

2.2.1 RIBBED SMOKED SHEETS(RSS)

Latex is obtained from the field and strained several times to remove all the suspended matter. It is diluted with water and adds 5% formic acid to reduce the p^H . After latex is poured into square shaped plates and keep several hours to coagulate. After coagulation, it is washed suitably. Then it is passed through the two roll mill and diamond mill.

Then it is compressed to 2-3 mm thickness sheets. Finally it is kept several hours in a smoke house to heat. Such a ribbed smoke sheet is shown in figure 2.2. These sheets are then graded into three main grades according to their colour, consistency and observed impurities. The purest is 1RSS S/B, then 2RSS S/B then 3RSS S/B. RSS are used when extra tough rubber is needed. Some applications are tyres, tank liners, and industrial products. [2,3,13]

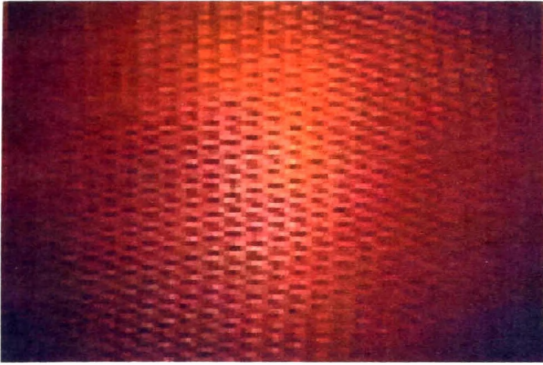


Figure 2.2 a Ribbed Smoke Sheet

2.3 TYRE TREAD

The tread is a thick extruded profile that surrounds the tyre carcass shown in figure 2.3. It makes contact with the road. As tyres are used, the tread is worn down limiting their effectiveness in providing traction. A worn tyre tread can be replaced using a process known as retreading. The word tread is often used incorrectly to refer to the pattern of grooves cut into the rubber. Those grooves are correctly called the tread pattern or simply pattern. Tread compounds include additives to impart wear resistance and traction in addition to environmental resistance.

Design of tire tread has an impact upon noise generated, especially at freeway speeds. Generally there is a tradeoff of tread friction capability; deeper patterns often enhance safety, but simpler designs are less costly to produce and actually may afford some roadway noise mitigation.

Street tires will also include wear limit indicators in the form of small raised bridges within the grooves. When the tread is worn down enough that the limit indicators make contact with the road, the tire is deemed to be at the end of its service life.

Tires without any tread patterns are known as slicks and are generally used for racing only, since they are quite dangerous if the road surface is wet.^[2,7,15]



Figure 2.3 A Tyre Tread

2.4 RUBBER COMPOUNDING

Rubber compounding is essentially the science of selecting and combining ingredients to produce a useful polymer which will have characteristics sufficient to perform satisfactorily under the conditions in which the end product is intended to be used. There are many ingredients in any rubber compound; however, the ingredients can generally be classified into the following generic categories: elastomers (or polymers), cure systems, fillers, processing aids, pigments, and miscellaneous ingredients added to enhance particular properties.

The most important component of a rubber compound is the polymer. Each polymer has its advantages and disadvantages and its own inherent physical properties. For example, natural rubber is generally preferred in applications which require high tensile strength, high elongation, and fatigue resistance at comparatively high elongations. SBR (styrene-butadiene copolymers) is generally preferred in applications which require fatigue resistance at low elongations and in applications where the product will be flexed under compression.^[2,4,5,11]

2.4.1 COMPOUNDING PROCESS

Rubber is a hard material. Chemical ingredients can not be added into rubber. By following compounding process, rubber becomes sticky material. Then, chemical ingredients such as fillers, vulcanizing agents, antioxidants etc can be added. Simply, compounding process is a mixing method.^[4,7]

NR (RSS)



mastication (the process by which the long chain rubber molecules are broken down into small molecules in order to incorporate other compounding ingredients, properly)

Masticated rubber



mixing stage 1

Adding activators (ZnO & st.acid)



mixing stage 2

Incorporating fillers (in this stage processing oil should also be added)



mixing stage 3

Incorporating other chemical ingredients, except the vulcanizing agent (antioxidant, accelerators, resins etc.)



mixing stage 4

Incorporating the vulcanizing agent (in this process, sulfur was used as the vulcanizing agent)

Rubber Compound

- A piece of compounded rubber sample was placed in the mould which gives the required shape of test specimen (tensile sheets, hardness buttons, abrasion buttons, etc.).
- Mould was kept in the hydraulic press for a specified time period in order to give the required temperature and pressure to complete the vulcanization reaction (90% cure).
- After moulding, all the samples were kept for about 16 hrs in a dry and cold place before subjecting to evaluate the properties.

All the samples were evaluated for mechanical and physical properties as shown below.

2.4.2 VULCANIZATION

Uncured NR is sticky. It can deform when warm and go to another state when it cold. Because of this it can not be used to make product with a good level of elasticity. NR is made of long polymer chains. This polymer chain can move independently relative to each other, which results in a change of shape. By the process of vulcanization cross links are formed between the polymer chains. So the chains can not move independently. As a result, when stress is applied the vulcanized rubber will deform, but upon release of the stress, the rubber article will go back to its original shape.

The principal vulcanizing agents continuous to be S, Se and Te are also used but generally with large proportion of S. there are several vulcanization methods.

- Sulfur system
- Peroxides
- Urethane cross linkers
- Metallic oxides

Vulcanization refers to a specific curing process of rubber involving high heat and the addition of S of other equivalent curatives. It is a chemical process in which polymer molecules are linked to other polymer molecules by atomic bridge composed of S atoms or carbon to carbon bonds. The end result is that the springly rubber molecules become cross-linked to greater or lesser extent. This makes the bulk material harder, much more durable and also more resistant to chemical attack and also it makes the surface of the material smoother. This heavily cross-linked polymer has strong covalent bonds with strong forces between the chains and is therefore an insoluble and infusible thermosetting polymer. Vulcanization reaction is shown in figure 2.4. ^[1,10,14]

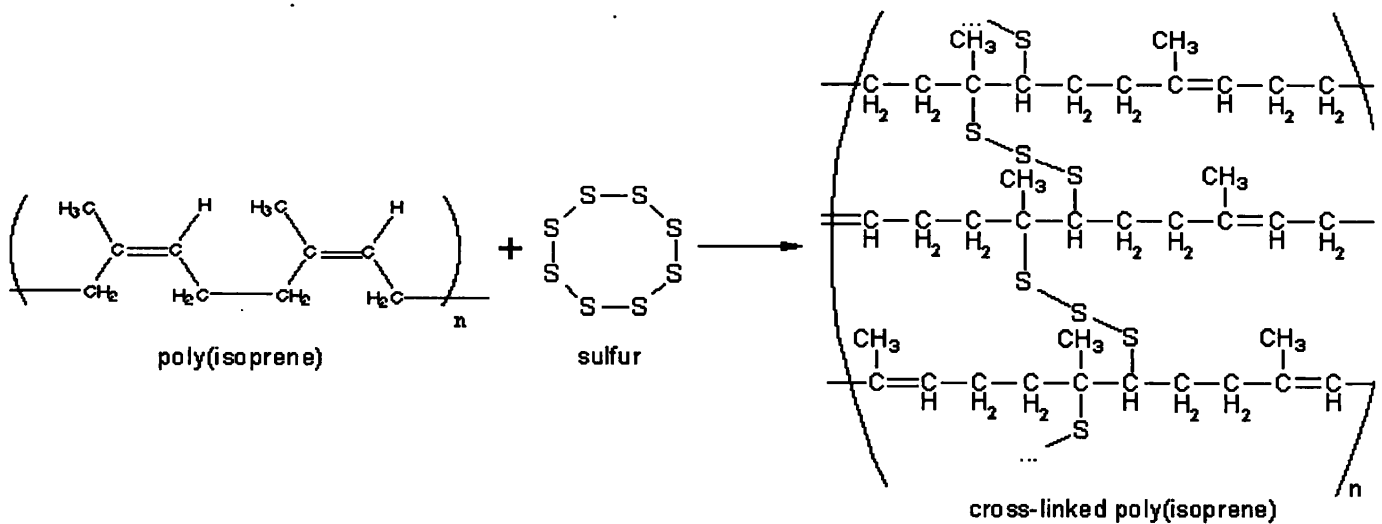


Figure 2.4 Reaction of vulcanization

2.4.3 ACCELERATORS

There are many accelerators available for the vulcanization of rubber. A vulcanization accelerator is typically used in combination with S as the cross-linker and with ZnO and stearic acid as activators. Other additives can be added too. But for the cross linking reaction the above mentioned ones are the most important. The various types of rubber used in the various tyre compounds all have different vulcanization characteristics like speed of cure (cure is the cross linking reaction) and extent of cure (the number of cross links).

For instant in a car tyre alone there can be already up to eight different rubber compounds each with specific properties. For instance the tread in a typical passenger car tyre consist of a mixture of SBR (Styrene-Butadiene Rubber) and BR (Butadiene Rubber). This rubber should have high abrasion resistance and high grip on both dry and wet roads. The side wall of the tyre should have a high flexibility that means that it should resist many flexing during the running of the tyre, without cracking. It consists normally of a mixture of natural rubber and BR. Inside the tyre there is a rubber compound with as major function the adhesion with the steel cord. The basis of the tyre is formed by carcass. Normally a mixture of NR, SBR&BR, it should have a very good adhesion to the polyester cord used as reinforcement. For all these compounds with their different properties different accelerators and mixtures of accelerators have to be used to obtain the required properties.

A typical passenger car tyre is vulcanized for 10 minutes at 170 °C. This means that all the different compounds have to be cured to their optimum state of cure in this same 10 minutes. This is the reason why a lot of different accelerators or mixtures are used in the same tyre.^[4,9]

2.4.4. ACTIVATORS

Activators are substances which increase the effect of accelerators. The most popular activator system is ZnO and stearic acid. The mechanisms by which this pair speed up the cure has not been exhaustively studied and results to date indicate its complexity. ZnO reacts with the stearic acid to form Zinc stearate which is soluble in rubber and it supports the cross linking process. It is essential to have the Zinc ions in soluble form.

Compounding materials which are alkaline have an accelerating effect on vulcanization. ZnO used for activation should be low in lead content and some compounders specify a lead free grade. When the vulcanization is occurred with the presence of ZnO, sulfidic cross links are decreased, while the formation of C-C bond is favored. This is accompanied by an increase of the thermal stability of vulcanization. During the vulcanization is occurred with the presence of ZnO, S is partially converted to zinc sulfide.^[2,7,10]

2.4.5 FILLERS

Fillers are most widely used additives in polymer composition. They are used in all plastics, natural and synthetic rubber. Generally, all properties of rubber are changed by filler. By incorporation of filler the possibility of rubber compound is improved, the cost of the rubber is reduced and its density, modulus, hardness, tensile strength, wear resistance, dynamic properties are changed. Fillers can be classified as many ways. Those are non black fillers, black fillers, reinforcing fillers, non reinforcing fillers, organic fillers and mineral fillers.

Reinforcing fillers that are said to provide excellent performance and processing properties to mechanical and technical rubber goods.

In tyre manufacturing process, carbon black is widely used as reinforcing filler shown in figure 2.5. Carbon black is a material produced by the incomplete combustion of heavy petroleum products such as coal tar, ethylene cracking tar, and a small amount from vegetable oil. Apart from the polymer and the cure system, carbon black is the most important

ingredient which can alter the properties of a rubber compound. It can actually assist in the curing of the compound, reducing the need for curatives and cure time because of its activating effect.

The particle size of the carbon black determines its abrasion resistance. The smaller the particle, the greater the resistance of the polymer to tread wears during moderate service. However, carbon black with smaller particle size is more expensive, and the smaller-size blacks require more work on the rubber batch to achieve adequate dispersion of ingredients than coarser blacks. The smaller blacks also generate more heat during mixing which can lead to scorch (premature vulcanization). Though different elastomers have widely different molecular structures, the incorporation of fillers (specifically carbon black) in appropriate amounts greatly reduces such differences in both cured and uncured stock. This has generally been referred to as the leveling action of carbon black.

The current International Agency for Research on Cancer (IARC) evaluation is that, "Carbon black is possibly carcinogenic to humans ". Short-term exposure to high concentrations of carbon black dust may produce discomfort to the upper respiratory tract, through mechanical irritation.^[2,16]

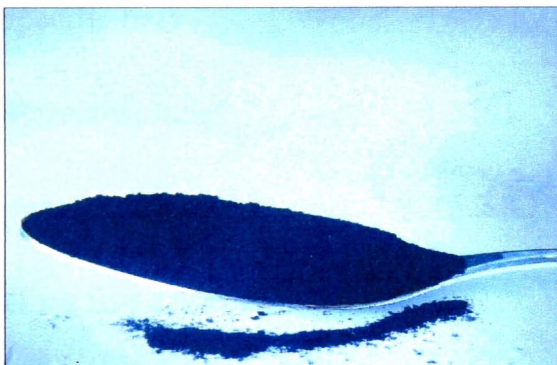


Figure 2.5 Carbon Black

2.4.6 ANTIOXIDANTS AND ANTIOZANANTS

Antioxidants are typically added during rubber compounding to prevent discoloration and loss of physical properties. It is necessary to add antioxidants to natural and synthetic rubber to obtain the best ageing properties. Combinations of various antioxidants are many times used since some of these materials are specific as to the type of protection they impart. For

example, some are particularly efficient for ultra violet light and moisture. Also in many cases a combination of antioxidants give synergistic results.

Oxidation is a chemical reaction that transfers electrons from a substance to an oxidizing agent. Oxidation reaction can produce free radicals, which start chain reaction that damage cells. Antioxidant terminates these chain reactions by removing free radicals intermediate, and inhibits other oxidation reactions by being oxidized themselves. As a result, antioxidants are often reducing agents such as thiols or polyphenols.

Antiozanants are paraphenylenediamine derivatives used to improve resistance of finished rubber products.^[2,4,7]

2.5 RAW RUBBER PROPERTIES

Rubber exhibits unique physical properties and chemical properties.^[2,3,4]

Some physical properties are given below.

Density at 20 °C	-	0.906 – 0.916 g/cm ³
Specific heat	-	1.905 KJ /g k
Refractive index	-	1.5191
Heat of combustion	-	45.2 KJ / Kg

There five system of classifications.

Green book classification

The rubber is graded by visual examination. There are total eight types and thirty five grades of rubber.

Standard Malaysian scheme (SMR)

This classification takes into consideration dirt, ash, calcium, magnesium and nitrogen contents, plasticity retention, Wallace minimum initial value, colour and mooney viscosity.

Bureau of Indian standards (IS)

Standard Indonesian rubber (SIR)

This classification is not widely used now.

Technically specified rubber (TR)

2.5.1 PLASTICITY RETENTION INDEX (PRI)

This test method gives an indication of the oxidation resistance of raw natural rubber at a specified temperature. This resistance is indicated by the plasticity retention index, a ratio expressed as a percentage of the aged plasticity determined by means of a parallel plate plastimeter. A low PRI value indicates a poor resistance to oxidation. A high resistance to oxidation is shown as a high value of the index.

The plasticities being measured on standard samples have been subjected to standard condition (140 °C, 30 min) of oven ageing.^[12]

2.5.2 VOLATILE MATTER (VM)

There are two methods to determine the volatile matter content. Those are hot mill method and oven method. By using above two methods moisture and other volatile matter content in raw rubber can be obtained. But in these causes it is necessary to improve that the change in mass is due solely to loss of original volatile matter and not to rubber degradation. The hot mill method is not applicable to natural and synthetic isoprene rubbers.^[12]

2.5.3 MOONEY VISCOSITY

Mooney viscosity is obtained by measuring the torque that is required to rotate a disc under specified conditions, embedded in the rubber or compounded sample. Viscosity typically measured at 100 c provides a measure of ease with which the material can be processed. It depends on molecular weight distribution. Caution is always required when attempting to establish relationships between Mooney viscosity and molecular weight. It is expressed as ML (1+4). (i.e. Mooney large rotor, with a one minute pause and four minutes test duration.)

Mooney viscosity is directly proportional to the plasticity retention index.^[12]

2.5.4 TENSILE STRENGTH

The tensile strength of an adhesive bond is the maximum tensile load per unit area required to break the bond. This indicates the maximum tensile strength of the elastomer. Tensiometer is used to determine the tensile strength.

Tensile tests are used for controlling product quality and for determining the effect of chemical or thermal exposure on an elastomer.^[12]

2.5.5 MODULUS

Modulus is the force in pounds per square inch (psi) required to produce a certain elongation. This elongation might be 50%, 100% or even 300%, through 100% is the most widely used figure for testing and comparison purposes. Modulus is also known as tensile modulus or tensile stress. Compounds with a higher modulus are more resilient and more resistant to extrusion. Modulus is typically gauged simultaneously with tensile strength on the same dumbbell specimen. As the specimen is being stretched the tester (tensiometer) records the value needed to achieve given elongation.^[12]

2.5.6 ELONGATION

The strain or ultimate elongation is the amount of stretch at the moment of break. It is the percentage increase in original length of rubber specimen as a result of tensile force being applied to the specimen. Elongation is inversely proportional to hardness, tensile strength and modulus. Natural rubber can often stretch up to 700% before breaking. It takes more force to stretch a hard material with high tensile strength and high modulus than to stretch a soft material with low tensile strength and low modulus.^[12]

2.5.7 TEAR RESISTANCE/ STRENGTH

Tensiometer is used to determine the tear strength. It is resistance to the growth of a cut or nick in a vulcanized rubber specimen when force is applied. Tear strength is an important consideration, both as the finished article is being removed from the mold and as it performs in actual service.^[12]

2.5.8 ABRASION RESISTANCE

Abrasion is a measure of the amount of material lost. It measured as a loss percentage based on original weight. It is the resistance of a rubber compound to wearing away by contact with a moving abrasive surface. Because of the many potential variables such as heat fluctuation and surface contamination, abrasion resistance is hard to accurately measure. Testing typically involves the uniform application of an abrasive material such as sand paper to the surface of a sample. Hard compound exhibit less abrasive than soft compound^[12].

2.5.9 REBOUND RESILIENCE

When rubber is deformed, an energy input is involved, part of which is returned when the rubber returns to its original shape. That part of the energy which is not returned as mechanical energy is dissipated as heat in the rubber. The ratio of the energy returned to the energy applied is termed the resilience. When the deformation is an indentation due to a single impact, this ratio is termed the rebound resilience.^[12]

2.5.10 COMPRESSION SET

Compression set is the end result of progressive stress relaxation, which is the steady decline in sealing force that results when an elastomer is compressed over a period of time. In terms of the life of a seal, stress relaxation is like dying, whereas compression set is like death. Though it is very difficult to accurately quantify stress relaxation, compression set is easy to measure. Compression set testing for rubber that will be compressed in air or liquid media.^[12]

2.5.11 HARDNESS

Typically defined as resistance to indentation under specific conditions, the hardness of an elastomer is more accurately thought of as two related properties: inherent hardness and processed hardness. As a result of chemical structure, each elastomer has its own *inherent hardness*. This inherent hardness can be modified (and is typically supplemented) via compounding and vulcanization. Hardness in molded rubber articles (*processed hardness*) is

a factor of cross-link density (and the amount of fillers). The more cross-linking a given material undergoes during vulcanization, the harder the final molded part will be. When judging the potential effectiveness of a molded seal, (processed) hardness is one of the most common criteria in the rubber industry.^[12]

2.5.12 FLEX CRACKING

This test method covers the determination of crack growth of vulcanized rubber when subjected to repeated bending strain or flexing. It is particularly applicable to tests of synthetic rubber compounds which resist the initiation of cracking due to flexing.

Cracking initiated in these materials by small cuts or tears in service, may rapidly increase in size and progress to complete failure even though the material is extremely resistant to the original flexing-fatigue cracking.^[12]

CHAPTER 3

3. MATERIALS AND METHODOLOGY

3.1 PREPARATION OF 29% GRT DISPERSION

3.1.1 MATERIALS

- GRT –Ground Rubber of Tyre
- KOH – potassium hydroxide
- Water
- Dispersal LR
- Sieve
- Beakers
- measuring cylinders

3.1.2 METHODOLOGY

GRT 550g was sifted using 200 μ m sieve. Sieved GRT was mixed with 1.77 M KOH. That mixture was kept one day to soak. Dispersal LR 57.5 g was added as a dispersion agent and it was kept in a ball mill one day.

Likewise, by changing soaking time, four samples were obtained. Those are shown in table 3.1.

Table 3.1 prepared samples

Sample name	Soaking time
1 A	1 day
3 A	3 days
5 A	5 days
7 A	7 days

3.2 PREPARATION OF RSS WITH GRT DISPERSION

3.2.1 MATERIALS

- Latex
- Water
- GRT dispersion
- 5% formic acid
- measuring cylinder

Beakers

- Square shaped plates
- Two roll mill
- Diamond mill



Figure 3.1 Coagulation of Rubber

3.2.2 METHODOLOGY

Latex 1500 ml was filtered to remove all suspended matter and it was poured into square shaped plates. Water 1000 ml was added to those plates. GRT dispersion was stirred well and 1000 ml of GRT was added to above square shaped plates. For coagulation, 700 ml of 5% formic acid was added and it was shown in figure 3.1. Coagulated sheets were washed and passed through the two roll mill and diamond mill to remove the water and non rubber particles. Those sheets were kept in a smoke house about one week to dry. Likewise, RSS were prepared for all samples. (1A, 3A, 5A and 7A)

Latex about 10g was separated to check the DRC (Dry Rubber Content).^[12]

3.3 DETERMINATION OF PLASTICITY RETENTION INDEX (PRI) ISO 2930-1981(E)

3.3.1 MATERIALS

- prepared RSS
- Parallel plate plastimeter
- Two roll mill
- Oven
- Puncher

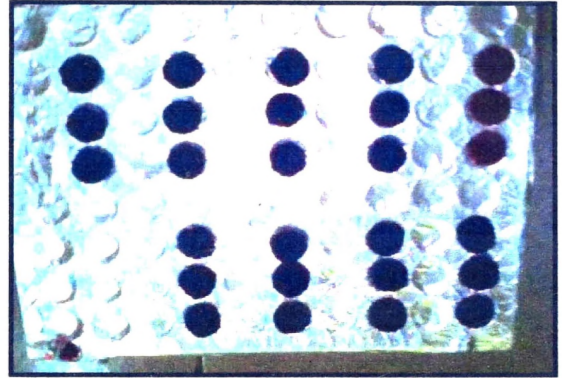


Figure 3.2 Punched test pieces

3.3.2 METHODOLOGY

Raw rubber (prepared RSS), about 30g was homogenized by passing six times through the two roll mill. Homogenized piece was passed two times (doubling the sheet between passes) between the rolls of the mill. Each sheet was punched six times and six test pieces were obtained with thickness between 3.2 mm and 3.6 mm. obtained test pieces are shown in figure 3.2. These were divided into sets of three. One set for test before ageing and other set for test after ageing. Rapid plasticity numbers were obtained using parallel plate plastimeter before ageing. These values are called unaged plasticity numbers. For ageing, temperature of oven was adjusted to 140 °c. The tray with the test pieces was kept in the oven for 30 minutes. The tray was removed from the oven after 30 minutes. It was allowed to cool in laboratory temperature. Rapid plasticity numbers were obtained for aged test pieces. These values are called aged rapid plasticity numbers. PRI was calculated using following equation.

$$\text{PRI} = \frac{\text{Aged rapid plasticity number (P}_{30}\text{)}}{\text{Unaged rapid plasticity number (P}_0\text{)}} * 100\%$$

Unaged rapid plasticity number (P₀)

3.4 DETERMINATION OF VOLATILE MATTER CONTENT ISO 248-1979(E)

3.4.1 MATERIAL

- Raw rubber
- Digital balance
- Two roll mill
- Desiccator
- Oven

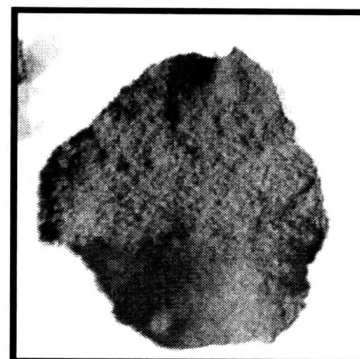


Figure 3.3 Test piece after passing two-roll mill

3.4.2 METHODOLOGY

There are two methods to determine the volatile matter content. Those are hot mill method and oven method. Oven method was used to determine the volatile matter content.

The samples were homogenized by passing through two roll mill six times. A test portion of about 10 g was selected from the homogenized test piece and it was weighed to the nearest 0.0001g (m_1). The test portion was passed twice between the roll again. After passing two roll mill, sheets with a 2 mm thickness were obtained. It is shown in figure 3.3. The test portion was placed for 1 ½ h in the oven controlled at 100 ± 5 °C. Finally, samples were allowed to cool in a desiccator and weighed (m_2). Volatile matter content of all samples was obtained by using following equation.

$$VM = [(m_1 - m_2) / m_1] * 100\%$$

Where,

m_1 = the mass in grams of the test portion as taken from the piece

m_2 = the mass in grams of the test portion after oven drying.

3.5 DETERMINATION OF MOONEY VISCOSITY ISO/R 289-1963(E)

3.5.1 MATERIALS

- Raw rubber
- stop watch
- Viscometer
- Digital balance

3.5.2 METHODOLOGY

Two disks of rubber about 45 mm in diameter and of sufficient thickness to fill completely the die cavity of the viscometer are prepared. The test piece was cut with a die slightly smaller than die cavity, but of a thickness to give an excess volume about 25 cm³. The rubber disks should be free as possible from air and form pocket that may trap air against the rotor and die surfaces. A hole was cut through the center of one disk to permit the insertion of the rotor stem.

The die cavity and rotor were heated to the test temperature 100 °c and allowed to reach a steady state. The die cavity was opened, the rotor stem inserted through the hole in the test disk. The rotor was placed in the viscometer, the solid test disk was placed centrally on the rotor, and die cavity was closed as quickly as possible. The time of closing the die cavity was noted and the rubber was allowed to heat for the specified time, a minimum of one minute was recommended. After one minute, the start button was switched on and noted the Mooney viscosity after five minutes by reading the value of viscometer.

3.6 ACS(AMERICAN CHEMICAL SOCIETY) 1 FORMULATION

3.6.1 MATERIALS

- Hydraulic press
- Two-roll Mill

In these test it is important that the mixing, vulcanization and testing be carried out under standard conditions. It is recommended that a control test with a standard or an already tested rubber is carried out simultaneously. Vulcanizing ingredients and used amounts are shown in table 3.2.

Table 3.2 Vulcanizing ingredients

Ingredients	Amounts (g)
NR	300
ZnO	18
S	10.5
Stearic acid	1.5
MBT	1.5

3.6.2 METHODOLOGY

These compounds were mixed using the two roll mill. Mould was kept in the hydraulic press for a specified time period in order to give the required temperature and pressure to complete the vulcanization reaction (90% cure). The compounded samples were kept in an AC room 16 h.

After, compounded samples were kept it in a hydraulic press under suitable temperature and time to produce test pieces for tensile strength, tear strength, etc.

3.7 DETERMINATION OF TENSILE STRENGTH AND ELONGATION AT BREAK

3.7.1 MATERIALS

- Tensiometer
- Dumbbell shaped teat pieces
- Thickness gauge
- Tensile cutter

3.7.2 METHODOLOGY

For tensile strength, compounded samples were kept in a hydraulic press 27 minutes under 150 °c. Vulcanized rubber sheet was obtained. Dumbbell shaped test pieces were cut from above sheet. Thickness of the test piece was measured at evenly distributed points. The test piece was placed in the grips of the testing machine and the maximum force prior to break, was recorded. Same procedure was done for five pieces.

The average thickness was calculated for each test piece and the average cross sectional area was calculated for each test piece on the basis of the average thickness and fixed width of the central section of the test piece cutter. (13 mm)

The average tensile strength of each test piece expressed in mega Pascal is given by the formula.

F/A

F- Breaking force in N

A- Initial cross sectional area in square millimeters.

3.8 DETERMINATION OF TEAR STRENGTH ISO 34-1979(E)

3.8.1 MATERIALS

- Tensiometer
- Crescent shaped test pieces
- Thickness gauge
- Sharp razor blade

3.8.2 METHODOLOGY

The crescent shaped test pieces were prepared using the same sheet which was used to prepare the tensile test pieces. Thickness of the test piece was measured using thickness guage.(d)

Sharp razor blade or a sharp knife free from ragged edges was used for producing a cut or a nick in the test piece. The test pieces were protected from light as completely as possible during the interval between vulcanization and testing.

The test piece was placed in the grips of the testing machine. A steadily increasing traction force was applied at a rate of separation of grips of 500 ± 50 mm/in for crescent type test pieces until the test piece breaks. The maximum force was recorded (F). Tear strength was obtained by using following formula.

Tear strength = F/d

Where F is the maximum force and d is thickness in mm of the test piece.

3.9 DETERMINATION OF REBOUND RESILIENCE ISO 4662-1978(E)

Test pieces were prepared in accordance with ISO 4661 by moulding. Three impacts were applied at the same velocity to the test piece and three rebound readings were noted.

The average values were calculated for the two test pieces.

3.10 DETERMINATION OF HARDNESS

3.10.1 MATERIAL

- Test pieces
- Durometer

3.10.2 METHODOLOGY

The test piece was placed on a horizontal rigid surface. The force was applied on the surface of the test piece. Direct reading of hardness in international rubber hardness degrees was obtained.

3.11 DETERMINATION OF COMPRESSION SET

3.11.1 MATERIALS

- Thickness gauge
- Test buttons
- Cylindrical disk

3.11.2 METHODOLOGY

Testing generally involves use of cylindrical disk compression set test buttons (0.49" thick by 1.14" diameter) taken from molded slabs. Initial thickness of each sample was measured in three different places. The buttons or plied samples were placed between steel plates. A bolt-tightened device and steel spacers were used. Either way, compression (normally 25% of original thickness) was held for 72 hours at room temperature. After removal from the compression device and a 30-minute cooling period, final thickness was measured in three different places by using the thickness gauge. Compression set was calculated using following equation.

$$[(T_2 - T_1) / (T_2 - 9.47)] * 100\%$$

Where,

T_2 = Initial thickness of the sample

T_1 = Thickness after compressed

3.12 DETERMINATION OF ABRASION RESISTANCE

3.12.1 MATERIALS

- DIN abrader
- Test pieces
- Digital balance

3.12.2 METHODOLOGY

Six test buttons of each sample were obtained and its initial weights were measured. After, each test buttons were fixed in DIN abrader and switched on. After it goes constant distance, the final weight was measured.

3.13 DETERMINATION OF DRY RUBBER CONTENT

3.13.1 MATERIALS

- Natural Rubber Latex
- Petri dishes
- Weighing bottles
- Quick method solution
- Oven

3.13.2 METHODOLOGY

Quick method was used to check the DRC. Two Petri dishes were labeled as A and B. small amount of latex was poured into a weighing bottle and weighed. Latex, less than 0.2 g was poured into dish A from the weighing bottle and again it was weighed. By taking the difference of two weights, initial weight of the sample A was taken. Small amount of latex was poured into dish B and initial weight was taken. Two three drops of quick method solution was added to dish A and B. solution was spread on the latex and let it to coagulate. After, it was washed with water. Two dishes were kept in the oven. After, five minutes weights were measured and again those were kept in the oven. Two samples were dried until get the constant weights. DRC is given by

$$\text{DRC} = (m_1 / m_2) * 100\%$$

Where,

m_1 = Initial weight

m_2 = Dried weight.

3.14 DETERMINATION OF FLEX CRACKING

3.14.1 MATERIALS

- Test pieces
- Flexing Machine

3.14.2 METHODOLOGY

Tester consists of a set of grips to hold test specimens in two tiers with their holding faces lying in the same vertical plane. Test pieces were fixed in to the flexing machine and switched on the machine. The readings were checked until the samples show more than 60000 cycles without any cracks.

CHAPTER 4

4 RESULTS AND DISCUSSION

4.1 RESULTS OF PLASTICITY RETENTION INDEX

Table 4.1 Results of Plasticity Retention Index

Sample	P ₀ value	P ₃₀ value	PRI %
Control	34.3	29.7	86.5
1 A	38.4	19.7	51.3
3 A	43.3	24.5	56.5
5 A	40.8	24.5	60.0
7 A	42.8	21.9	51.1

As shown in table 4.1, PRI value of control sample is higher than other samples. Here, PRI value of 1A, 3A, 5A and 7A samples are between 50 and 60. Though, the PRI values of sample 1A, 3A, 5A and 7A are less than control sample. It is not badly affected for the quality of the RSS because normally PRI value of RSS should be in 50-70.

Table 4.2 Results of volatile matter content

Sample	M ₁	M ₂	VM
Control	10.77	10.63	1.28
1 A	10.30	10.03	2.68
3 A	10.86	10.55	2.80
5 A	10.29	10.13	1.52
7 A	10.19	9.92	2.60

As shown in table 4.2, volatile matter content of control sample is low. Normally, VM content should be between 0.8 and 1.0. 1A, 3A, 5A and 7A samples have high VM content because GRT is contained in these samples. GRT, which are vulcanized particles.

Table 4.3 Results of Mooney viscosity

Sample	Mooney viscosity
Control	58
1 A	70
3 A	64
5 A	65
7 A	57

Results of Mooney viscosity of prepared RSS is shown in table 4.3. Mooney viscosity is proportional to PRI. 1A, 3A, 5A and 7A samples have high Mooney viscosity value than control sample. It is not badly affected to the quality of prepared RSS.

By considering raw rubber properties, incorporation of GRT into NR latex does not badly affect the quality of RSS produced.

RESULTS OF DRY RUBBER CONTENT

Initial weight of sample A	= 0.8275 g
Dried weight of the sample A	= 0.2816 g
DRC of sample A	= $\frac{0.2816 \text{ g}}{0.8275 \text{ g}} * 100\%$
	= 34.03%
Initial weight of sample B	= 0.8075 g
Dried weight of sample B	= 0.2759 g
DRC of sample B	= $\frac{0.2759 \text{ g}}{0.8075 \text{ g}} * 100\%$
	= 34.16%

$$\begin{aligned} \text{Average DRC of used latex} &= (34.03 + 34.16) / 2 = 34.09\% \\ \text{DRC of used latex for one sheet} &= \frac{34.09 * 1500}{100} \\ &= 511.35 \text{ g} \end{aligned}$$

For sample 1 and 5, same latex was used.

DETERMINATION OF GRT PERCENTAGE

$$\begin{aligned} \text{GRT dispersion} &= 29\% \\ \text{Sample A} &= \frac{29 * 1000}{100} \\ &= 290 \text{ g} \\ \text{GRT\%} &= \frac{290 * 100\%}{511.35} \\ &= 56.71\% \end{aligned}$$

Table 4.4 Percentages of GRT

Sample	GRT %
1 A	56.71
3 A	49.00
5 A	56.71
7 A	49.00

FOR CAR TYRE TREAD COMPOUND CARBON BLACK IS REPLACED WITH GRT

Normally, for car tyre tread compound 60 g of carbon black is used as filler. That 60 g of carbon black was replaced with GRT according to following ratio.

Table 4.5 Ratio of Carbon Black to GRT

Carbon black	GRT
50	10
40	20
30	30
20	40

- **GRT 30**

Sample 1A % of GRT is 56.7

$$\begin{aligned}
 &= \frac{100 * 30}{56.7} \\
 &= 52.91 \text{ g} \\
 \text{GRT+NR} &= 52.91 \text{ g} \\
 \text{NR in 30 g of GRT} &= 52.91 - 30 = 22.91 \text{ g} \\
 \text{Total amount of carbon black} &= 180 \text{ g} \\
 \text{Amount of NR take control sample} &= 180 - 22.91 = 157.09 \text{ g} \\
 &= \text{control } 157.09 \text{ g} + \text{GRT } 52.91 \text{ g}
 \end{aligned}$$

- **GRT 60**

$$\begin{aligned}
 &= \frac{100 * 60}{56.7} \\
 &= 105.82 \text{ g} \\
 \text{GRT + NR} &= 105.82 \text{ g} \\
 \text{NR in 60 g of GRT} &= 105.82 - 60 = 45.82 \text{ g} \\
 \text{Amount of NR taken from control sample} &= 180 - 45.82 = 134.18 \text{ g} \\
 &= \text{control } 134.18 \text{ g} + \text{GRT } 105.82 \text{ g}
 \end{aligned}$$

- **GRT 90**

$$\begin{aligned}
 &= \frac{100}{56.7} * 90 \\
 &= 158.73 \text{ g} \\
 \text{GRT+NR} &= 158.73 \text{ g} \\
 \text{NR in 90 g of GRT} &= 158.73 - 90 = 68.73 \text{ g} \\
 \text{Total amount of carbon black} &= 180 \text{ g} \\
 \text{Amount of NR take control sample} &= 180 - 68.73 = 111.27 \text{ g} \\
 &= \text{control } 111.27 \text{ g} + \text{GRT } 158.73 \text{ g}
 \end{aligned}$$

- **GRT 120**

$$\begin{aligned}
 &= \frac{100}{56.7} * 120 \\
 &= 211.64 \text{ g} \\
 \text{GRT + NR} &= 211.64 \text{ g} \\
 \text{NR in 120 g of GRT} &= 211.64 - 120 = 91.64 \text{ g} \\
 \text{Amount of NR taken from control sample} &= 180 - 91.64 = 88.36 \text{ g} \\
 &= \text{control } 88.36 \text{ g} + \text{GRT } 211.64 \text{ g}
 \end{aligned}$$

Likewise, the amount of control RSS and RSS with GRT for samples 3 A, 5 A, 7 A were calculated.

For sample 1 A and 5 A, GRT % is same.

For sample 3 A and 5 A, GRT % is same.

Table 4.6 Amount of GRT and Raw rubber

Sample	Control g	GRT g
1A/ 5A (150/30)	157.09	52.91
1A/5A (120/60)	134.18	105.82
1A/5A (90/90)	111.27	158.73
1A/5A (60/120)	88.36	211.64
3A/7A (150/30)	149.75	60.25
3A/7A (120/60)	119.50	120.50
3A/7A (90/90)	89.25	180.75
3A/7A (60/120)	59.00	241.00

According to the following table 4.7, car tyre tread compounds were prepared.

Table 4.7 Car tyre tread compound

	1 Cont rol	2 1A/G RT 10	3 1A/G RT 20	4 1A/G RT 30	5 1A/G RT 40	6 3A/G RT 10	7 3A/G RT 20	8 3A/G RT 30	9 3A/G RT 40	10 5A/G RT 10	11 5A/G RT 20
NR	150	157.0 9	134.1 8	111.2 7	88.36	149.7 5	119.5 0	89.25	59.00	157.0 9	134.1 8
SBR	120	120	120	120	120	120	120	120	120	120	120
BR	30	30	30	30	30	30	30	30	30	30	30
NR/G RT		52.91	105.8 2	158.7 3	211.6 4	60.25	120.5 0	180.7 5	241.0 0	52.91	105.8 2
C. black	180	150	120	90	60	150	120	90	90	150	120
Pro. Oil	30	30	30	30	30	30	30	30	30	30	30
ZnO	15	15	15	15	15	15	15	15	15	15	15
St. acid	06	06	06	06	06	06	06	06	06	06	06
CIR	09	09	09	09	09	09	09	09	09	09	09
T.Q.(A.O)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
6PPD	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
TBBS	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
DPG	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
PVI	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
S	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6

	12 5A/GRT 30	13 5A/GRT 40	14 7A/GRT 10	15 7A/GRT 20	16 7A/GRT 30	17 7A/GRT 40
NR	111.27	88.36	149.75	119.50	89.25	59.00
SBR	120	120	120	120	120	120
BR	30	30	30	30	30	30
NR/GRT	158.73	211.64	60.25	120.50	180.75	241.00
C. black	90	60	150	120	90	90
Pro. Oil	30	30	30	30	30	30
ZnO	15	15	15	15	15	15
St. acid	06	06	06	06	06	06
CIR	09	09	09	09	09	09
T.Q.(A.O)	3.0	3.0	3.0	3.0	3.0	3.0
6PPD	4.5	4.5	4.5	4.5	4.5	4.5
TBBS	3.0	3.0	3.0	3.0	3.0	3.0
DPG	1.2	1.2	1.2	1.2	1.2	1.2
PVI	0.6	0.6	0.6	0.6	0.6	0.6
S	6.6	6.6	6.6	6.6	6.6	6.6

By varying the percentage of carbon black to GRT, 17 samples were compounded. After compounding, test pieces were prepared to evaluate the tear strength, tensile strength, hardness, etc.

Hardness test was done for above mentioned 17 samples. According to the results of hardness, following graph in figure 4.1 was obtained.

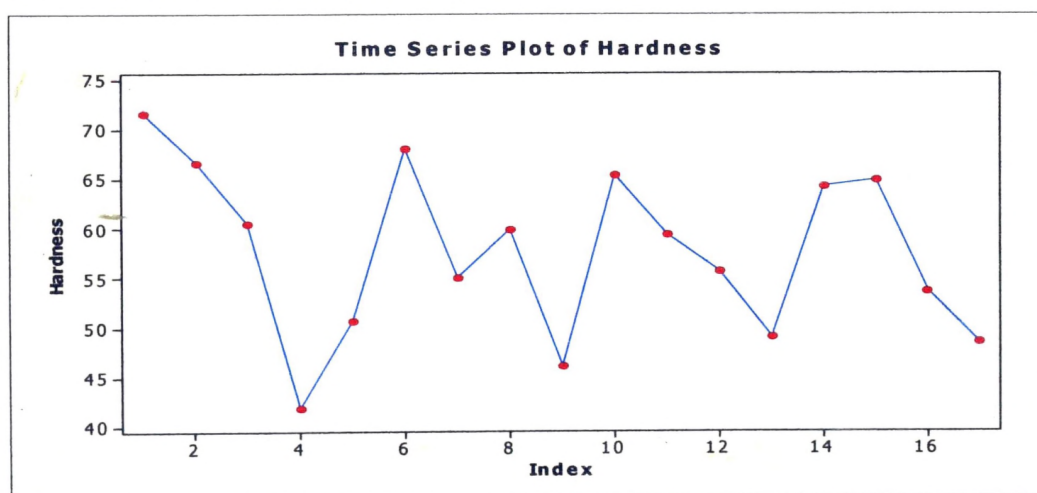


Figure 4.1. Variation of Hardness

Hardness is defined as resistance to indentation and cross-link density also affects hardness. The control sample (containing only carbon black as filler) exhibits a slightly higher value for hardness than the other samples. 10% GRT added samples (1A, 3A, 5A, and 7A) have the next highest values for hardness followed by 20% GRT added samples. The results reveal that an increase in the % of GRT and time of soaking in KOH, reduces the hardness. The latter indicates increased cross-link scission at extended soaking periods. 10% and 20% GRT incorporated samples exhibit acceptable hardness values.



Figure 4.2 Variation of rebound resilience

Results of rebound resilience of 17 samples are shown in figure 4.2 as a graph.

According to the variation of rebound resilience, all the samples have higher values than that of the control sample and hence the developed compounds are better than the Control sample in regard to resilience. Here, sample no.2 is 1A GRT 10% added sample, sample no 3 is 1A GRT 20% added sample, sample no 4 is 1A GRT 30% added sample and sample no 5 is 1A GRT 40% added sample. Likewise, sample no.6 is 3A GRT 10% added sample. With increasing % of GRT, rebound resilience is increased. With soaking time, it slightly decreases.

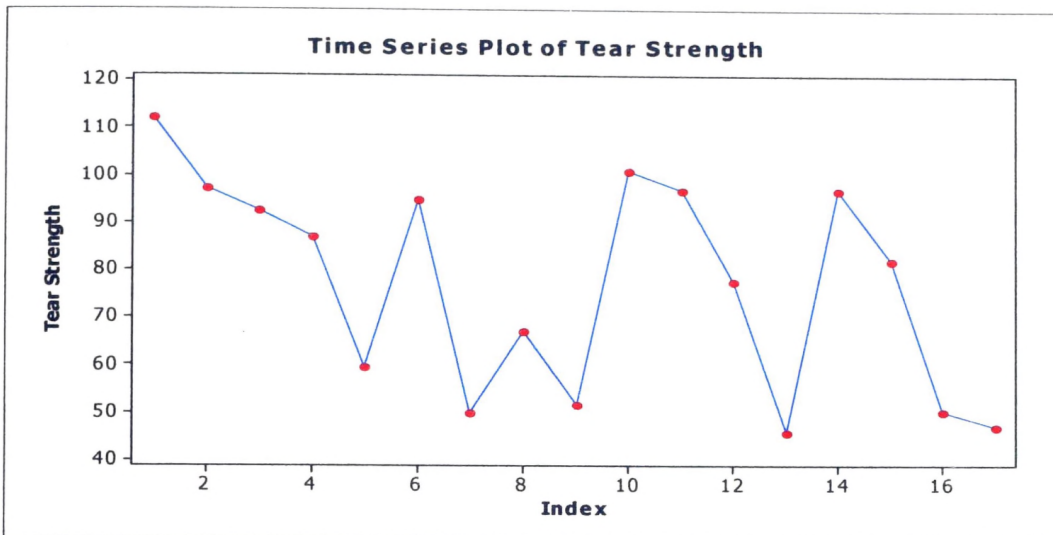


Figure 4.3 Variation of tear strength

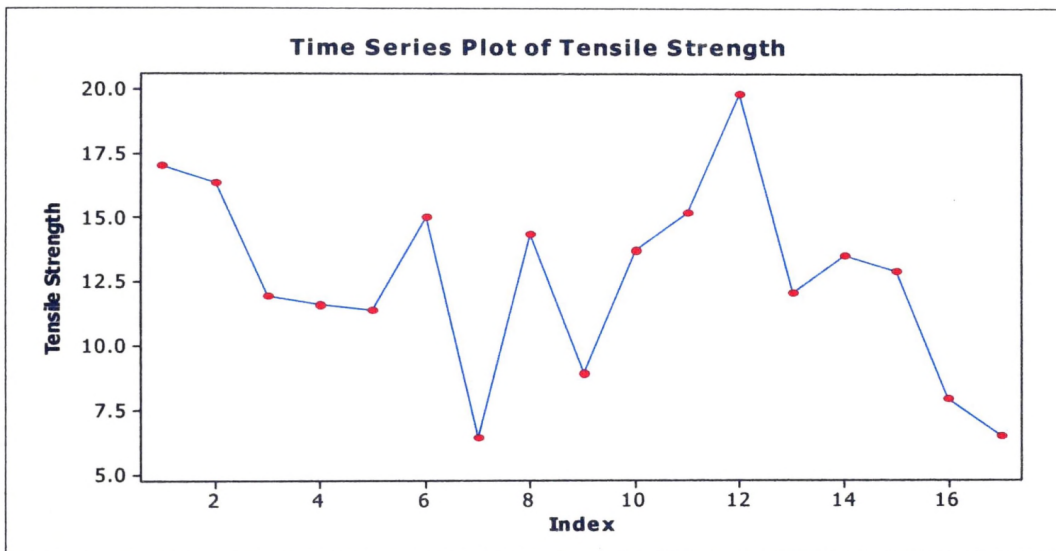


Figure 4.4 Variation of tensile strength

Results of tear strength and tensile strength are shown in figure 4.3 and figure 4.4. In the case of strength properties, the control sample has higher tear and tensile strength than other samples. Variation of strength properties with % of GRT and soaking time is not so clear. Hence compatibility between GRT and NR should be enhanced by carrying out several other modifications as future work of this research for better strength properties.

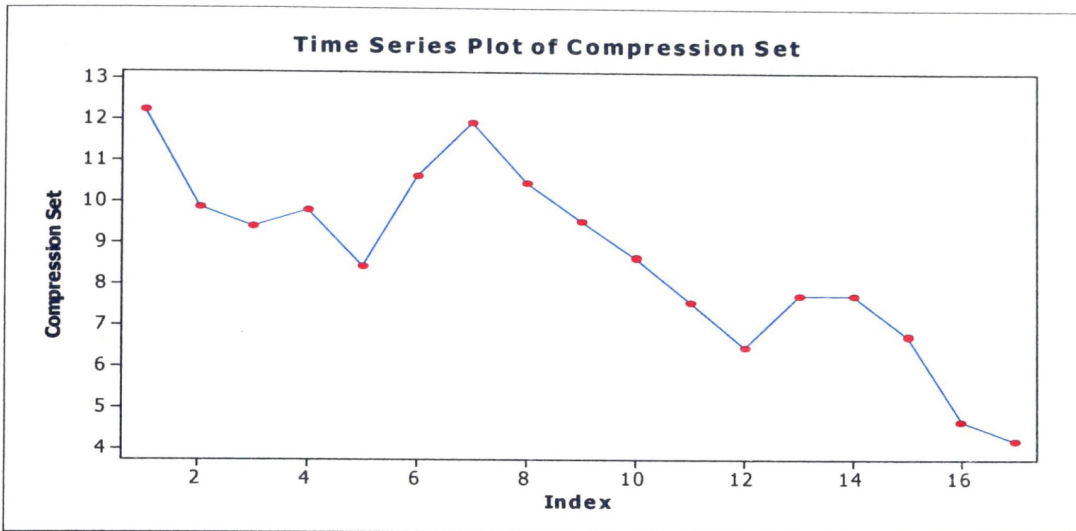


Figure 4.5 Variation of Compression set

However, compression set of the control sample is higher than that of the others according to the figure 4.5. When % of GRT and soaking time increase, values of compression set decrease and this is a favorable observation.



Figure 4.6 Variation of Abrasion resistances

Abrasion resistance was calculated as a weight loss. Graph regarded to abrasion resistance, is shown in figure 4.6. When soaking time and % of GRT is increased, abrasion resistance of GRT incorporated samples decrease. However, the samples prepared with GRT show better abrasion resistance compared to the control sample. This is also a favorable observation in the case of tyre tread compounds.

4.2 DISCUSSION

Ground Rubber Tyre (GRT) is vulcanized rubber in particulate form. Hence, it is less reactive than carbon black. Alkali reclaiming using alkali (NaOH) is reported in literature ⁽¹¹⁾. The hydroxyl anion (OH⁻) was the entity that actually attacked and broke the cross-links. In this research, potassium hydroxide (KOH) was used as the alkali and it was expected to break the sulphur cross-links when GRT was soaked in KOH (modification of GRT). Breakdown of cross-links in GRT would increase its reactivity with virgin natural rubber (NR) in blend compounds such as tyre tread compounds for property enhancement. By mixing the modified GRT dispersion with NR latex, we expect better incorporation of GRT into NR and reduced environmental pollution when compared to mixing GRT with NR in the dry stage during the conventional compounding.

Results of raw rubber properties of GRT incorporated RSS indicate that the Control sample (without GRT) has a higher PRI value compared to the other samples (1A, 3A, 5A and 7A). This indicates that samples 1A, 3A, 5A and 7A have poor resistance to oxidation than the control sample. Also, the Control sample has low volatile matter content than other samples. However, incorporation of GRT into NR latex, does not badly affect the quality of RSS produced.

The results reveal that an increase in the % of GRT and time of soaking in KOH, reduces the hardness.

According to the variation of rebound resilience, the developed compounds are better than the Control sample.

Variation of strength properties with % of GRT and soaking time is not so clear.

When % of GRT and soaking time increase, values of compression set decrease and this is a favorable observation.

The samples prepared with GRT show better abrasion resistance compared to the control sample. This is also a favorable observation. Finally, all the samples show more than 60000 cycles without any crack initiation during the flex cracking test. In overall, some of the compounds prepared by incorporating modified GRT into NR latex have shown good results in the case of most of the tests and the results are comparable to or better than those of the Control sample.

CHAPTER 5

CONCLUSION

Most of the mechanical and physical properties of the developed compounds prepared with GRT incorporated RSS are comparable to those of the compounds prepared with conventional RSS.

It can be concluded that the modified GRT, incorporated to NR in the latex stage can be used as a part replacement for carbon black in a tyre tread compound.

Hence replacement of the latter compound with former compounds will result in a reduction of cost as well as environmental pollution without reducing the physical / mechanical properties.

REFERENCES

1. Akiba M. and Hashim, A. S., Vulcanization and crosslinking in elastomers, (1997), Prog. Polym.Sci, vol 22,475-521pp.
2. Barlow, F.W., Rubber Compounding, (1988),115-130pp, Marcel Dekker, Inc. New York, 325p
3. Bhatnagar M.S., Text book of polymer, processing and application, vol 1, 318.
4. Bhatnagar M.S., Text book of polymer, processing and application, vol 2.
5. Blackly, D.C., High Polymer Latices, (1966), 320-400pp, Vol.1, McLaren & Sons: London, 435p.
6. Blackley, D.C., High Polymer Latices, (1966), 320-400pp, Vol.2, McLaren & Sons: London, 825p
7. Blow, S., Hand book of rubber Technology, (1998), 110-550pp, Galgotiapublishers, 1313p
8. CRRI and IRRDB international rubber conference 2007, natural rubber industry, R And D achievements and challenges 12-13 November 2007.
9. Elliott, D. J. and Tidd, B.K., Developments in Curing Systems for Natural rubber, (1975), 83-124pp, The Malaysian Rubber Producers Research Association., 300p.
10. Hofmann, W., Vulcanization and Vulcanizing Agents, (1967), 73-182 pp, Maclaren And Sons Ltd, London, 225p
11. Nicholas, P.P. The scission of polysulfide cross-links in scrap rubber particles through phase transfer catalyzing, Rubb. Chem. Tech,55,1499,1982

12. ISO 1798-1983 (E), International Standard, vol 1, 2, 3
13. [http:// en.wikipedia.org/wiki/Rubber](http://en.wikipedia.org/wiki/Rubber)
14. [http:// en.wikipedia.org/wiki/Vulcanization](http://en.wikipedia.org/wiki/Vulcanization)
15. [http:// .wikipedia.org/wiki/Tire](http://.wikipedia.org/wiki/Tire)(17 March 2009) (10 March 2009)
16. [http:// en.wikipedia.org/wiki/Carbon_black](http://en.wikipedia.org/wiki/Carbon_black)(20 February 2009)
17. [http:// www.history.com/encyclopedia.do?articleId=221032](http://www.history.com/encyclopedia.do?articleId=221032)(1996-2008)
18. [http:// en.wikipedia.org/wiki/Tensile_strength](http://en.wikipedia.org/wiki/Tensile_strength)(17 March 2009)
19. <http://www.wipo.int/pctdb/en/wo.jsp?IA=WO199004617&DISPLAY=DESC>
20. <http://www.tse-industries.com/abrasion-resistance.asp>
21. <http://www.astm.org/standards/D5963.htm>
22. <http://www.rubbermill.com/durometer.html>
23. <http://www.epa.gov/osw/conserves/materials/tires/ground.htm>
24. <http://pslc.ws/macrog/exp/rubber/menu.htm>
25. <http://www.qualitest-inc.com/resilience.htm>
26. <http://www.ets-test-equipments.com/rubber-testing-equipment.html>

National Digitization Project
National Science Foundation

Institute : Sabaragamuwa University of Sri Lanka


1. Place of Scanning : Sabaragamuwa University of Sri Lanka, Belihuloya

2. Date Scanned : ...2017-09-22.....

3. Name of Digitizing Company : Sanje (Private) Ltd, No 435/16, Kottawa Rd,
Hokandara North, Arangala, Hokandara

4. Scanning Officer

Name :S.A.C. Gandaruman.....

Signature :.....

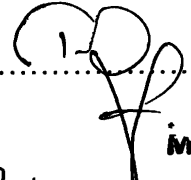
Certification of Scanning

I hereby certify that the scanning of this document was carried out under my supervision, according to the norms and standards of digital scanning accurately, also keeping with the originality of the original document to be accepted in a court of law.

Certifying Officer

Designation : LIBRARIAN.....

Name : T.N. NEIGHSOOREI.....

Signature :.....

Date : ...2017-09-22.....

Mrs. T.N. NEIGHSOOREI
(MSSc, PGD, ASLA, BA)
Librarian
Sabaragamuwa University of Sri Lanka
P.O. Box 02, Belihuloya, Sri Lanka
Tel: 0094 45 2280045
Fax: 0094 45 2280045

"This document/publication was digitized under National Digitization Project of the National Science Foundation, Sri Lanka"