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Tensile Set Properties for Ternary Rubbery Blends (NR\SBR\BR) Reinforced with Cement Waste as Filler Material

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By

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

﴿ يَرْفَعِ اللَّهُ الَّذِينَ ءَامَنُوا۟ مِنْكُمْ وَ الَّذِينَ
أُوتُوا۟ العِلْمَ دَرَجَٰتٍ وَ اللَّهُ بِمَا تَعْمَلُونَ
خَبِيرٌ ۞ ﴾

صَدَقَ اللَّهُ العَلِيُّ العَظِيمُ

(سورة المجادلة)

(من الآية 11)

Dedication

For my parents,

The reason of what I become today,

Thanks for your great support and continuous care.

Acknowledgements

Praise is to *Allah*, Mercy and peace are to the Prophet Mohammed and his relatives and companions.

Firstly, I would like to express my sincere gratitude to my supervisor **Prof. Dr. Sameer Hassan Hadi**, for the continuous support in my higher diploma study and related research, for his patience, motivation, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my master study. Besides my advisor, I would like to thank the rest of my thesis committee for their time and efforts reading this thesis.

A word of thanks is due to the staff members of the Physics Department in the College of Education for Pure Sciences and to the dean of the college of education for pure sciences at University of Babylon for their help and kind assistance.

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Last but not the least, I would like to thank my family: my parents, my brother and sisters for supporting me spiritually throughout writing this thesis and my life in general.

Zahraa

Supervisor certificate

I certify that this thesis entitled **"Tensile Set Properties for Ternary Rubbery Blend (NR\SBR\BR) Reinforced with Cement Waste as Filler Material"** was prepared by the student **(Zahraa Abbas Hameed Omran)** under my supervision at the Department of Physics, College of Education for Pure Sciences,University of Babylon as partial fulfillment of the requirement the degree of Higher Diploma Education / Physics of Materials and its Applications .

Signature:
Name: Dr. Sameer H. Hadi
Title: Professor
(Supervisor)
Date: / / 2021

Head of the Department Certificate

In view of the available recommendations, I forward this thesis for debate by the examining committee.

Signature:
Name: Dr. Khalid H. Abbas
Title: Professor
(Head of Physics Department)
Date: / / 2021

Scientific Supervisor's Certification

This is to certify that I have read this thesis, entitled **“Tensile Set Properties for Ternary Rubbery Blend (NR\SBR\BR) Reinforced with Cement Waste as Filler Material”** and I found that this research is qualified for debate.

Signature:
Name:
Title:
Address:
Date: / / 2021

Linguistic Supervisor's Certification

This is to certify that I have read this thesis, entitled **“Tensile Set Properties for Ternary Rubbery Blend (NR\SBR\BR) Reinforced with Cement Waste as Filler Material”** and I found that this research is qualified for debate.

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Summary

The research included the preparation of the triple mixtures ($NR40/SBR60/Br_{cis}0$), ($NR30/SBR60/Br_{cis}10$) and ($NR60/SBR30/Br_{cis}10$) reinforced with a fixed percentage of carbon black (50 pphr), and then reinforced by different percentages of (Cement waste) and these ratios are

(0, 10, 20).

The mechanical properties or tensile properties such as Tensile strength, Elongation, Elastic modulus, and Tear resistance were studied as they were measured by Universa \ Fensometer according to the international specifications (American Society for Testing and material) ASTM (D624) as well as the Hardness property was carried out by Share A(2240) Hardness device according to the specification and all of these properties were carried out before and after aging, as it was noticed the hardness increased with the increase loading percentage of (Cement waste). While the other properties such as tensile strength, elongation, modulus of elasticity and tear resistance, decreased with increase loading ratio before and after aging.

Contents

List of Abbreviations

Abbreviations	Physical meaning
ASTM	American Society for Testing and Materials
PPhr	Parts Per Hundred Rubber
Tg	Glass Transition Tempetature
Tm	Melting Temperature
OSP	Oyster shell bowder
IRHD	International Rubber Hardness Degrees
CW	Cement waste

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Chapter One

General Introduction

1.1 Introduction

Rubbers play a very important role in modern technology. They are presently used in wide areas of application such as cables, tires, adhesives, domestic appliances, coatings, packaging materials, textile and sporting goods transportations, building infrastructures, medical and optical devices, etc., due to their lightweight, elastic and other properties. There are many types of rubber such as Natural Rubber (NR), Synthetic Rubber (SBR), nitrile rubber, etc. The properties of a particular rubber are determined by the compound composition. A mix of raw rubbers with additives and the vulcanization process is important to the adjustment of rubber with requirement application [1].

Vulcanization is one of the key factors in the technology of rubbers. It involves the conversion of raw rubber into a network through the formation of a cross link between chains of rubber. This network is not sticky like raw rubber does not harden with cold weather or soften much except at very high temperatures, is elastic is highly resistant to abrasion and becomes tighter and the forces necessary to achieve a given deformation increase [2,3].

Most commonly used for its high mechanical properties due to its density and ease of manufacture. In addition to being lightweight, high durability and low manufacturing cost. The polymeric basis was divided into materials, thermoplastics and thermosetting materials [4].

The term was used as an alternative to rubber where previously the term rubber was a rubber band is used to refer to synthetic rubber. Flexible materials differ from other polymers with special specifications where they can deform when shedding stress on them and then regain their dimensions, quickly after removing these stresses . The mechanical properties can be significantly improved such as elasticity resistance to melting and bloating in the presence of temperature and appropriate vulcanization conditions [5].

The rubber material is not only flexible but also energy-dispersing materials because of the flexible viscous nature, yet plasticization reduces plasticity [6].

1.2 Types of Rubber

Rubbers can be divided broadly into two types: thermosets and thermoplastics. thermosets are three dimensional molecular networks, with the long molecules held together by chemical bonds. They absorb the solvent and swell, but do not dissolve; furthermore, they cannot be reprocessed simply by heating. On the other hand the molecules of thermoplastic rubbers, , are not connected by primary chemical bonds. Instead, they are joined by the physical aggregation of parts of the molecules into hard domains [7].

Hence, thermoplastic rubbers dissolve in unsuitable solvents and soften on heating, so that they can be processed repeatedly. In many cases, thermoplastic and thermoset rubbers may be used interchangeably. However, in demanding uses, such as tires, engine mounts, and springs, thermoset elastomers are used exclusively because of their better elasticity, resistance to set, and durability. The addition of various chemical materials to raw rubber to impart desirable properties is termed rubber compounding or formulation [8].

1.2.1 Natural Rubber (NR)

NR is only a natural product. It is a cis-polyisoprene but contains a variety of impurities such as proteins and resins. It crystallizes much more readily upon stretching compared to synthetic cis-polyisoprene, which does not contain impurities. NR has a very high molecular weight and contains long branches [9].

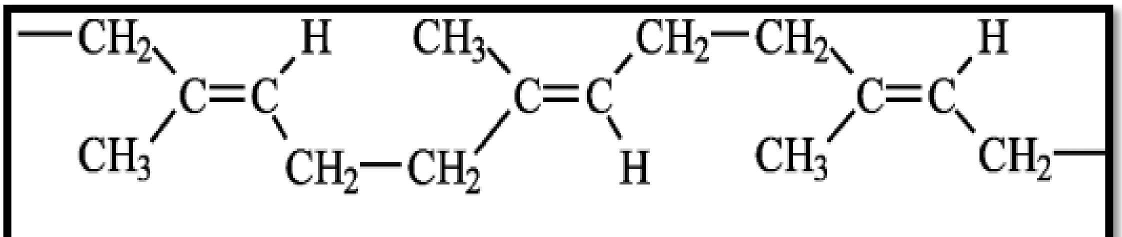
Natural rubber is collected in the form of latex that exudes from the bark of the tree when it is cut. The tree Havea Braziliensis is the largest produced of this latex. The average rubber content of latex may range between 30 – 45%. Latex concentrates are differentiated by the method of concentration and type of preservative used. Concentration is achieved by Centrifugation (most common), creaming, or by evaporation [10].

The elastomer used alone or with reinforcing filler, possesses first class mechanical properties with excellent process ability. It crystallizes easily at low temperatures and, so in subzero temperatures, it is necessary to thaw it by storing it a hot room at 40 – 50 °C before the winter season. Both these operations are unnecessary with synthetic elastomers. NR requires lower curing temperatures and therefore longer vulcanization time. At mixing, NR has a sufficiently high viscosity to allow optimum dispersion of reinforcing fillers and other ingredients [11].

Chemical Structure: Natural rubber is high molecular polymer isoprene, C_5H_8. The repeating unit is (– CH_2 – C (CH_3) = CH– $CH_2{}^{-}$).

The Hevea rubber is the major naturally occurring form of cis 1.4–poly isoprene. This rubber contains more than 98% of its double bonds in the cis – configuration that is essential for elasticity in poly isoprene. Over 90% of all cis 1.4– polyisoprene used industrially is natural Hevea rubber [12].

The double bond in each repeating unit in the polymer chain is a site of steric isomerism since it can have either a cis or a trans configuration. The polymer chain segment on each carbon atom of the double is located on the same side of the double bond in the cis configuration and on the opposite sides in the trans configuration, see figure (1.1) [13].



trans-Polyisoprene (repeat units, n = 100: M_w = 7000)

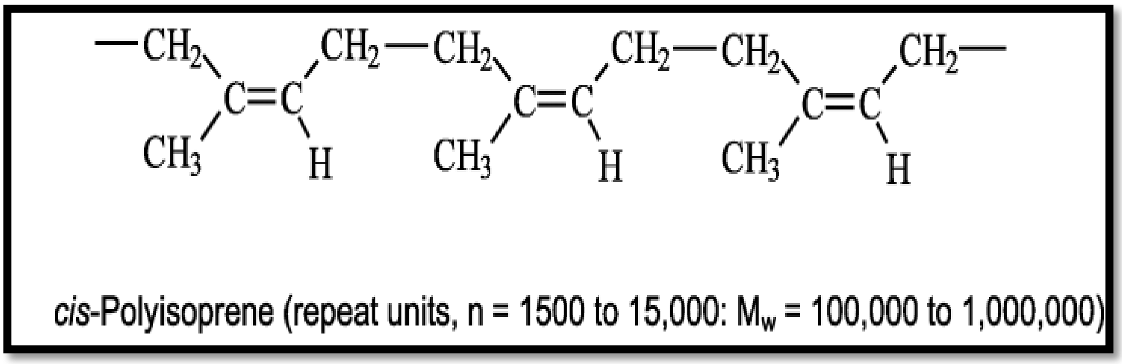


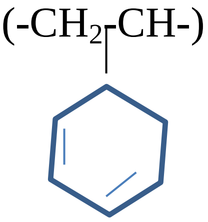
Figure (1.1) : cis and trans isomers of natural rubber [13].

The trans isomer which has a higher molecular symmetry crystallizes to a greater extent and therefore has higher T_m and T_g Values and significant crystallinity. It is less an elastomer and more like a thermoplastic. The T_g of NR is about 200 K its T_m equal to 298 K and its structure is thought to be completely cis 1.4– poly isoprene, except for the chain ends , 1.4– poly isoprene is found in both the cis and transform [11].

1.2.2 Styrene – Butadiene Rubber (SBR)

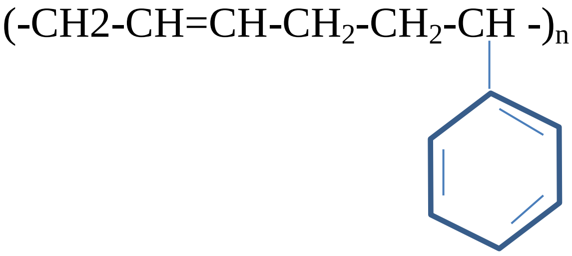
SBR is derived from petroleum oil, this applies to most elastomers, with the obvious exception of NR. SBR represents half of all synthetic rubber production, and is much consumed in tires, where it competes with and complements NR. There are many subgroups of the raw gum elastomer, depending on the method of synthesis of the polymer ,whether it is solution or emulsion polymerized, and the ratio of the two major chemical building blocks styrene and butadiene. The raw gum elastomer must have reinforcing fillers , such as carbon black, in order to obtain good mechanical strength and the filler increases hardness, at the same time. The properties of SBR are broadly similar to NR, for chemical, solvent, and weather resistance [14]. The upper temperature heat aging resistance limit is a little higher. The cost of the raw gum elastomer is low on the relative scale for elastomers in general and is comparable with NR [10].

Chemical Structure :SBR is a synthetic copolymer, chemically SBR is a copolymer of styrene and butadiene typically containing about 23% styrene and 77% polybutadiene with a T_g is about -55 ^{o}C, see Figure (1.2) [15,16].



Styrene; $(-CH_2-CH-)$ polybutadiene: $(-CH_2-CH=CH-CH_2-)$

Then the repeating unit (monomer) is:



$$(-CH2-CH=CH-CH_2-CH_2-CH\ -)_n$$

Figure (1.2) : SBR structure.[11]

SBR is generally marketed at lower viscosity than NR ,owing to its irregular structure and does not crystallize. Reinforcing filler is needed to achieve good physical properties with SBR, the best reinforcing agent is carbon black. Abrasion resistance and resistance to degradation under heat are better for SBR than those of NR. SBR is less active chemically than NR and is thus slower curing, requiring more accelerators than NR [11, 17].

1.2.3 Poly-Butadiene Rubber (BR)

Although this is a significant elastomer, it is most commonly used as a blend with other rubbers. BR is traditionally difficult to process on rubber machinery; this difficulty is not apparent when BR is blended with other nonpolar elastomers such as NR .

BR vulcanizates confer high resilience and T_g is about -100 ^oC. therefore low heat buildup, and good abrasion resistance to blends with other rubbers In view of the above properties, its major application area is in tires . Other applications are golf ball centers, modification of polystyrene to make high impact polystyrene and miscellaneous products needing improvements in abrasion, low temperature and resilience [10].

BR is made with similar polymerisation systems as SBR. The molecular architecture of the BR is essentially the same as that described for the anionic SBR. The microstructure is also the same and some high vinyl BR is made. This system gives well-defined polymers. BR made by emulsion polymerisation with a free radical initiator is used as the rubber component of a high polystyrene and acrylonitrile-butadienestyrene (ABS) resins [18]. The structure (1.4) is an approximately equal mix of cis and trans .Because it consists of mixed isomers, anionically prepared BR does not crystallize. Emulsion BR has mostly trans microstructure and also does not crystallize [19].

Chemical Structure of BR: The Chemical Structure of Polybutadiene rubber BR has existed at three configurations see Figure (1.3) [20];

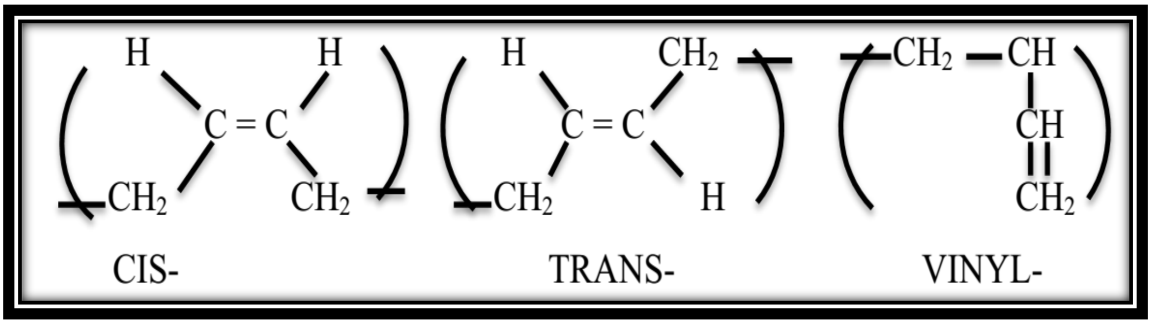


Figure (1.3) : Polybutadiene rubber configuration[20]

1.3 Carbon Black

Carbon black is the most widely used material for reinforcement. The mechanism of the reinforcement is believed to be both chemical and physical. Its primary properties are surface area and structure. Smaller particle-size blacks having a higher surface area gives a greater reinforcing effect. The increased surface area gives increased tensile, modulus, hardness, abrasion resistance, tear strength, and electrical conductivity and decreased resilience and flex-fatigue life. The same effects are also found with increased levels (parts per hundred rubber) of carbon black, but peak values occur at different levels. Structure refers to the high temperature fusing together of particles into grape-like aggregates during manufacture. The increased structure will increase modulus, hardness, and electrical conductivity but will have little effect on tensile, abrasion resistance, or tear strength [21,22].

The most commonly used filler is CB, because it is easily processed and reinforcing effect on the material is produced .However, the addition of CB into a rubber matrix does always give huge enhancements to the mechanical properties. This is due to the good dispersion of CB in the rubber matrix. It is also caused by the sufficiency of affinity between the CB and the organic polymers. Different carbon black grades were produced by the chemical decomposition of hydrocarbons at elevated temperatures. It is still the most desirable reinforcing filler where resistance to abrasion, cutting, and ageing must be at a maximum. The four main processes of the formation of four types of carbon blacks are [24].

1. Lampblack:
2. Channel black:
3. Furnace black (e.g N110 to N762)
4. Thermal black (e.g N990, N991): Table (1.1) gives the various properties associated with the four types of processes.

Table (1.1) : Properties of different carbon black [25].

Characteristic	Channel	Furnace	Lampblack	Thermal
Average particle size (nm)	1 – 3	14 – 80	100 – 150	240 – 320
Surface area (N_2) (m^2/g)	100–1125	27 – 145	20 – 95	7 – 11
Oil absorption (ml/g)	1.0 – 6.0	0.67 – 1.55	1.05 – 1.65	0.32 – 0.47
Volatile matter (%)	3.5 – 16.0	0.3 – 2.8	0.4 – 0.9	0.1 – 1.0
Ash %	0 – 0.1	0.1 – 1.0	0 – 0.16	0.2 – 0.5
Sulfur	0 – 0.1	0.5 – 1.5	----	10 ppm
pH	5.0 – 9.5	5.0 – 9.5	3 - 7	7 – 9

High structure blacks exhibit a high number of primary particles per aggregate, which is called strong aggregation, whereas low structure blacks show only weak aggregation. These aggregates may form loose agglomerates linked by Van der Waals interactions [26]. The empty space within the aggregates and agglomerates, expressed as the volume of Di-Butyl Phathalate (DBP) in cubic centimeters absorbed by a given amount (100 gm) of carbon black, is described by the term (structure) of carbon black, the larger is the DBP value , the higher is the carbon black structure (Figure (1.4)) [27].

The important damping property is rebound resilience. This property is one of the outstanding features of rubber. It shows the ability of rubber vulcanized to return the energy used to deform it. Resilience is important mainly because it affects the operating temperature of a rubber product, thus influencing its strength and aging behavior. Rebound resilience increases with temperature [28].

Resilience is the ratio of the energy returned upon recovery from deformation to the energy required to produce the deformation. The study of impact strength of the material is considered as the first key to study the properties of the material, and it is defined for the un notched sample as the absorbed energy during the impact to the cross section area of the sample at the fracture of polymer of high toughness has high crack energy, and it is possible to calculate the impact strength from the following relation.

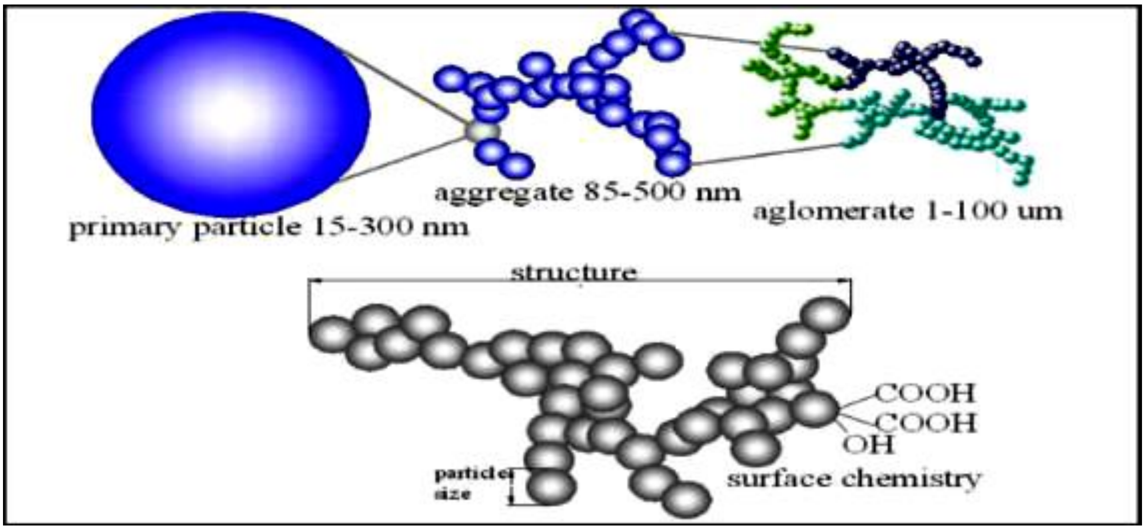


Figure (1.4) : Carbon Black structures [29].

Impact strength = Energy required for crack/sample cross sectional area. It depends on various variables including type of the materials, temperature, stress system, strain rate, manufacture, and geometry of particle, fabrication and environment conditions. In the case of rubber, the case is different, when rubber is deformed, the energy, which is not returned as mechanical energy,but is dissipated as heat in the rubber. The ratio of the energy returned to the energy applied is termed resilience [30].

1.4 Literature Review

In 2016, S. H. Hadi et. al. [31] studied the effect of fillers such as mix of carbon black and cement waste on rheological characteristics are studied in styrene butadiene rubber (SBR). The study carried out through four recipes according to the loading level of mixed of industrial scraps (cement waste) and carbon black (N375) (C.B) that it used as reinforcement materials in the compounds.

In 2016, S. H. Hadi et. al. [31] studied the possibility of using a mix of some industrial scraps such as cement waste and lamp black as reinforcement in natural rubber/styrene–butadiene rubber (NR70/SBR30), was explored as an alternative filler to prepare batches that it used in fender ship application. Mix of reclaim or cement waste and lamp black used in this paper as additives or fillers to study some of the mechanical properties of NR70/SBR30 blends.

In 2017, S. H. Hadi et. al. [31] studied the effect of the molecular size of the black carbon (N326, N375, N660) on the damping properties such as (Rebound Resilience, damping time) and Mechanical properties (hardness, specific gravity).

In 2019, M. H. Naeem and S. H. Hadi [32] studied includes preparation (NR50/SBR50/Oyster Shell Powder OSP) composites while the loading ratio of OSP were 0, 5, 10, 15, 20, 25, 30, 40, 60, 80, 100 pphr. The examination of FTIR (Fourier Transform Infrared analysis) of some specimen composites were carried out and study the effect of calcium carbonate (Oyster Shell Powder OSP) grain size <225 μ on the rheological properties of (NR50/SBR50/OSP) composites with different loading ratio of (OSP).

In 2019, A. A. Abd el salam et. al. [33] studied investigated the effect of carbon black (CB) filler loading on mechanical and rheological properties of natural rubber (NR)/styrene-butadiene rubber (SBR)/nitrile butadiene rubber (NBR) ternary rubber nanocomposites. The nanocomposites were prepared using a melt mixing method. Four different samples with different filler loadings namely S2 (15 phr), S3 (30 phr), S4 (45 phr), and S5 (60 phr) were prepared. The mechanical properties of these samples were investigated. The higher value of tensile strength for these samples was S4 (loading with 45-phr CB). Therefore, had higher stiffness compared to the other content ratio.

In 2019,Muhammad Juma̕a et.al.(31**)** studied the rheological properties (density and specific weight) as well as mechanical properties such as (ultrasound velocity ,relaxation time relaxation capacity ,vocal impedance ,compression and elastic modulus) of rubber compounds containing (NR/ SBR/OSP) where he prohibited without carbon black (CB) once and by using carbon black again with loading rations (CB) .The results showed that there is a significant effect of the substance (OSP) as well (CB) where it was found that some of these properties increase with an increase in the percentage of loading (OSP) and (CB) .

In 2020, S. H. Hadi et. al. [34] studied the rubber batches composites were prepared using Natural rubber (NR) and synthetic rubber (SBR) as model materials. The composites were reinforced using oyster shell powder (OSP) with particle size less than (225µm). Two groups of samples were prepared with (0, 5, 10, 15, 20, 25, 30, 40 and 60 pphr) with loading ratio of OSP and (CB-10pphr) of CB, whereas other composites were without CB. Density, viscosity and multi ultrasound velocity wave devices were applied to characterize the density according to the specification (ASTM-D1817-66) (Densitron), rheological properties with specification (ASTM-D2084-89) standard and mechanical properties, respectively. The result showed significant influence of the reinforcements (OSP) material and (CB) on some of these properties that exhibited an increasing with the increasing of loading ratio of (OSP) and (CB), such as density, relaxation amplitude and compressibility, but the other properties were decreasing like viscosity, relaxation time, velocity waves, bulk modulus and specific acoustic impedance.

In 2020 Bustan Fadel Abud (18)studied the mechanical properties such as hardness, as well as the damping properties like rebound resilience and damping time of overlapping rubber composite batches consisting of (NR 50 / SBR 50) as a matrix material was added oyster shell powder (OSP) with granular size less than (225µm) and loading ratios (0, 5, 10, 15, 20, 25, 30, 40, 60) pphr to. Also, carbon black material (CB) with a loading ratio (10 pphr) as support material is used. The results show that there is an increase in hardness values as the loading ratio is increased. Also, the results clarify that both rebound resilience and damping time were decreased clearly as the loading ratio increased. Finally, for swelling with salt water, the results proves that these overlays have a slight increase as it immersion in saline water.

1.5 The aim of this Research

1. Preparation the rubber composites (NR40\SBR60\CB50), (NR30\SBR60\BR$_{cis}$10\CB50) and (NR60\SBR30\BR$_{cis}$10\CB50) at different ratio of cement waste.
2. Study the tensile properties such as tensile strange, elongation, elastic modulus tear resistance and hardness.
3. Study the effect of aging on the mechanical properties before and after aging.

4.Use this Manufctured composites in finder ship applications.

Chapter Two

Theoretical Part

2.1 Introduction

The history of the discovery of Natural rubber date back to the eleventh century. Man used to paint pis clothes to prevent them from getting wet. I made Rubber balls from him to play, but the name rubber was launched by the scientist (priestley) in the year (1770 AD) , as he noticed that it aus able to . he erased the traces of writing the pencil and noticed that the trees are able to form this rubber material [34] NR is only natural product .

It is a cis-polyisoprene but contains a variety of impurities such as proteins and resins. It crystallizes much more readily upon stretching compared to synthetic cis-polyisoprene, IR, which dos not contains long branches [38] Natural rubber is collected in the form of latex that exudes form the bark of the tree when it is cut . The tree Havea Braziliensis is the largest produced of this latex . The average rubber content of latex may range between 30-45 %. Latex concentrates are differentiated by the method of concentration and type of preservative used. Concentration is achieved by centrifugation (most common), by creaming, or by evaporation [35].

The elastomer , used alone or with reinforcing filler ,possesses first class mechanical properties with excellent process ability . It crystallizes easily at low temperatures and , so in subzero temperatures , it is necessary to it by storing in a hot room at (40–50 ℃) before winter season bot these operations are unnecessary with synthetic elastomers. NR reuires lower curing temperatures and therefore longer vulcanization time.

At mixing, NR has a sufficiently high viscosity to allow optimum dispersion of reinforcing fillers and other ingredients [11].

2.2 Blends

polymer blends has been one of the primary areas in polymer science and technology over the past several decades. Polymer blends offer versatile industrial applications through enhancement of properties and economic benefits. The blending of two or more polymers of similar or dissimilar natures has been practiced for many years [36, 37]

The blending of two or more types of polymer is a useful technique for preparing and developing materials with properties superior to those of individual constituents. It is important especially from an industrial point of view to control the state of mixing of polymer blends [38].

There are many reasons why polymer blending is considered one of the most important areas in polymer research and development. Among these reasons, that polymer blends offer a fast and cheap way to obtain new polymeric materials. These materials generally exhibit a range of features that depend upon the properties of their components [39].

The idea of blending synthetic rubbers with natural rubber is certainly not a new one, but now it can be applied positively, by using new techniques developed over the last 5 years. These compounds are capable of forming a chemical link between these dissimilar rubbers to produce a technologically compatible blend. The blend vulcanizates produced exhibit enhanced physical properties by judicious selection of the SBR: NR ratio [40].

The blending of Styrene Butadiene Rubber(SBR) and other types of rubber and its perforamance have been studied earlier , it was demonstrated that the physical and mechanical properties of such blends can be significantly improved by adding a suitable compatibiliser. The effect of carbon black loading and cement waste on the tensile set, compression set and fatigue of SBR and Butadiene rubber (BR_{cis}) rubber compounds need to be understood deeply [40].

2.3 Composites

A composite material is a material system composed of a mixture or combination of two or more macro constituents differing in form material composition and that are essentially insoluble in each other [41, 42]. The two constituents are normally the reinforcements (fibers, particulates, whisker's, or laminate, or flakes, or fillers) .

The term "reinforcement" refers to an improvement in the end – use performance of the rubber compound associated with an increase in modulus and the so – called ultimate properties including tensile strength, tear resistance and abrasion resistance. A reinforcement filler is a particulate material that is able to increase: (1) the tensile strength; (2) the tear strength; and (3) the abrasion resistant of rubber. A semi – reinforcing filler is a particulate material that is able to increase: (1) the tensile strength; and (2) the tear strength, but does not improve abrasion resistance. A non-reinforcing filler is unable to provide any increase on these properties and functions [43]. These are structural constituent that determine the internal structure of the composite, and the matrix is the body constituent serving to enclose the composite and give it its bulk form, maybe metal, polymer and ceramics . There are modern classification of composite used instead of various materials in the fields in different applications in medicine ,civil engineering and military due to their specific properties such as strength and stiffness [41] .

2.4 Rubber composite

Goodyear and Hancock first developed rubber compound, it continues to develop as new materials , and new variations on old ones appear in the marketplace. The compound we see every day as rubber, such as in a tire or pencil eraser, is a mixture of a number of different ingredients. It starts with the raw gum elastomer, supplied by the plantation owner as NR, or by the petrochemical complex converting petroleum products such as ethylene, propylene and butadiene into ‘raw’ bales or chips of rubbery polymers such as EPDM, BR, SBR, NBR or CR. It is shipped to the rubber processor who blends it with various ingredients. The raw gum elastomer itself has very limited use, although adhesives provide one example. Most are mechanically weak and subject to significant swelling in liquids, and will not retain their shape after molding [10].

The growing use of rubber in engineering applications results from its unique properties that include high extensibility, high strength, high-energy absorption, and high resistance to fatigue. Other attributes are good environmental resistance and high resilience. Engineered rubber products consist of all rubber, or rubber combined with other materials. Product complexity ranges from that of a simple rubber band to complex composites such as radial tires or rubber-metal bearings for use in aerospace applications [50]. Materials such as steel, aluminum, plastics, fabric, and cords are often combined with rubber to form composites. The purpose of these materials is generally to increase strength, minimize distortion [44].

Rubber compounds exhibit several phenomena like the ability to retain elastic properties during prolonged action of compressive stresses compression set behavior, and loss of resiliency. The lower the percentage of compression set , the better the material resists permanent deformation under a given deflection and temperature also, the selection of rubber compounds for use in engineering industry [45].

High elastic polymer composites are very important in the applications of rubber industries, such as tires transportation belts, pipes for fluids and oils transmission, damping and support parts in the mobiles as well as diaphragm. Rubber composite materials with different types of rubber are used in dampers and support applications. Therefore: it is occupied wide field studies, because rubber has good characterization in the high elastic strain damping which is obtained from the suddenly impact loading because of different acceleration of the system. Therefore a different modification of a new type of rubber composite for loading resistance in addition to the interference of the usages conditions with the mechanical loads such as environmental effects at high temperatures in the presence of oils and friction result in the creation of blended polymers such as (NBR, SBR , NR , CR , … etc) [46,47].

2.5 Vulcanization

Most useful rubber articles, such as tires and mechanical goods, cannot be made without vulcanization. Unvulcanized rubber is generally not very strong, The first commercial method for vulcanization has been attributed to Charles Goodyear .His process (heating natural rubber with sulfur) is first used in 1841. Thomas Hancock used essentially the same process about a year later in England. Since those early days, there has been continued progress toward the improvement of the process and in the resulting vulcanized rubber articles. In addition to natural rubber, over the years, many synthetic rubbers have been introduced .Also, in addition to sulfur. many other substances have been introduced as components of curing (vulcanization) systems(e.g., natural rubber [NR], styrene-butadiene rubber [SBR], and butadiene rubber [BR]) by sulfur in the presence of organic accelerators [48].

Vulcanization is a process generally applied to rubbery or elastomeric materials. These materials forcibly retract to their approximately original shape after a rather large mechanically imposed deformation. Vulcanization can be defined as a process that increases the retractile force and reduces the amount of permanent deformation remaining after removal of the deforming force. Thus vulcanization increases elasticity while it decreases plasticity. It is generally accomplished by the formation of a cross-linked molecular network as shown in figure (2.1). In vulcanization the randomly oriented chains of raw rubber become cross-linked as indicated diagrammatically at the right [48].

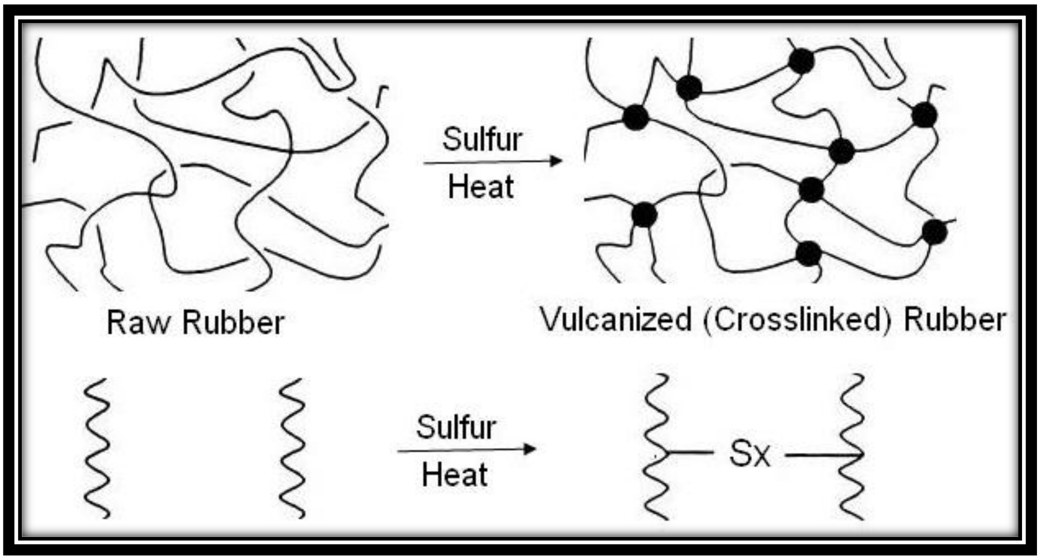


Figure (2.1) : Network vulcanization [13].

Vulcanization, thus, is a process of chemically producing network junctures by the insertion of crosslinks between polymer chains, a crosslink may be a group of sulfur atoms in a short chain, a single sulfur atom, carbon to carbon bond, a polyvalent organic radical, an ionic cluster, or a polyvalent metal ion. The process is usually carried out by heating the rubber, mixed with vulcanizing agents, in a mold under pressure [48]

The most important cross-linking agent is sulfur, which is relatively inexpensive and plentiful, and yet vital to the rubber industry. Sulfur links one chain to another through these double bonds. Elastomers such as NR and SBR need only a small percentage of these double bonds to be utilized to produce a useful product; however this leaves the larger percentage unused and therefore vulnerable to attack by oxygen, ozone and heat [10].

An elastomer, as synthesized, is basically a high molecular weight liquid with low elasticity and strength. Although the molecules are entangled, they can readily dissent angle upon stressing leading to viscous flow .Vulcanization or curing is the process in which the chains are chemically linked together to form a network, there by transforming the material from a viscous liquid to a tough elastic solid. Strength and modulus of elasticity increase [19] .

There are four principle changes which are brought about by vulcanization [49].

1- Rubber is converted from essentially a plastic substance of very low strength to an elastic of considerable strength and resilience.

2- The physical properties, such as tensile, modulus, hardness, abrasion resistance, break elongation and stress relaxation undergo profound changes as vulcanization progresses, as shown in figure (2.2)[13].

3- The physical properties of vulcanizates are maintained over a much wider temperature range than in the case of unvulcanized rubber.

4- The cross linked polymer (vulcanizate) only swells in liquids which normally dissolve the uncross linked polymer.

There are many vulcanization systems for various elastomers , the conventional systems , sulfur vulcanization , peroxide crosslinke , resin vulcanization , electron beam vulcanization and metal oxides vulcanization .

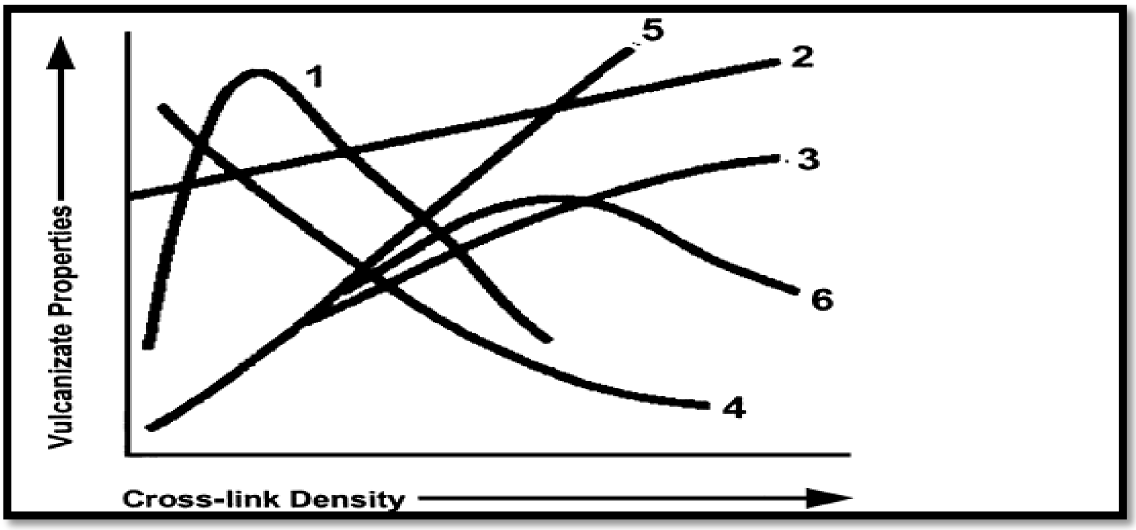


Figure (2.2) : Effects of vulcanization on physical properties. 1. Tear strength; 2.dynamic modulus; 3. hardness; 4. hysteresis, permanent set; 5. static modulus; tensile 6.strength [13].

2.6 Mechanical properties

2.6.1 Tear Resistance

Tear resistance in rubber may be described as the specimen resistance to the growth of a nick or cut when tension was applied to the tear specimen. A tearing strain was apply to a test specimen by means of a tensile testing machine operated without interruption at a constant rate until the specimen is completely torn. This test method measures the force per unit thickness required to rupture, initiate, or propagate a tear through a sheet of rubber in the form of one of several test piece geometries. The calculation of the tear strength is through the formula [50]:

$$\text{Tear Resistance} = \frac{F*t1}{t2} \qquad \ldots\ldots\ldots\ldots\ldots (2.1)$$

Where F=maximum force, t_1=thickness of standard piece, t_2= width of the specimen tested (nick region).

2.6.2 Hardness

Perhaps the most widely used test in the rubber industry is the measurement of hardness. Hardness is defined by ASTM as the resistance of material surface to indentation as measured under specified conditions. Rubber technologists use hardness as a convenient means of classifying rubber materials. There are many different hardness tests that claim nearly universal acceptance: the durometer and the International Rubber Hardness tester. Different durometers were shown in figure (2.3) which are designed to cover the wide range of hardness encountered in rubbers[10]. The shore A scale is the most appropriate for rubber compounds commonly used in engineering. The shore D scale is appropriate for harder rubber compounds such as ebonite, plastics. The Rockwell scale is also used for hard urethane [51].

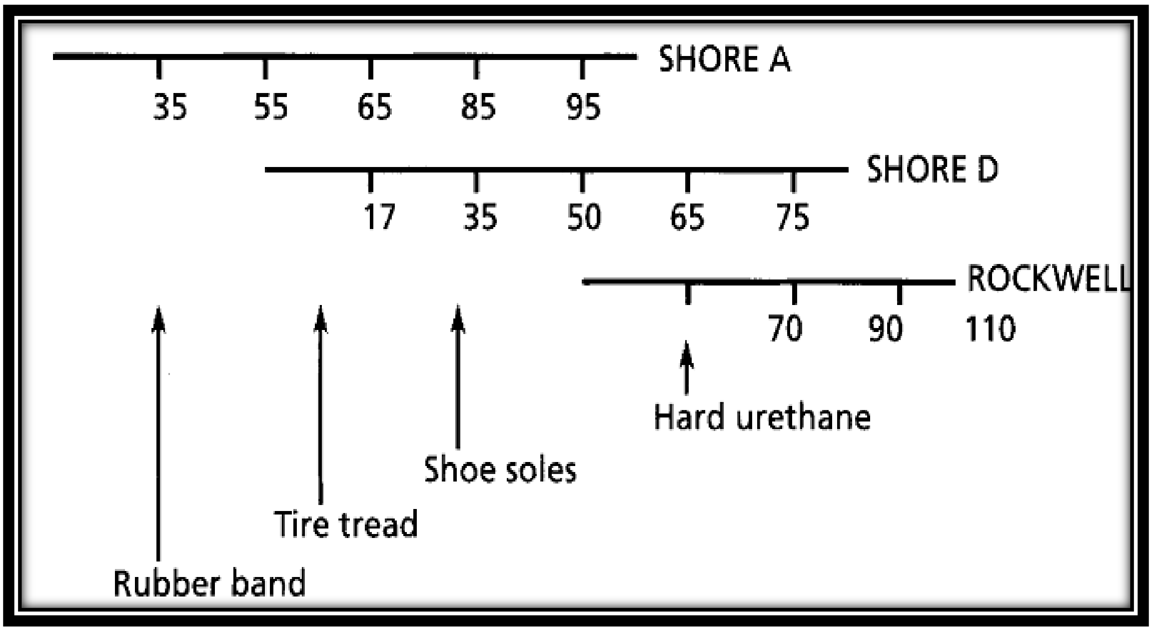


Figure (2.3) : Approximate equivalence of hardness scales [10].

The International Rubber Hardness tester differs from the durometer in several important aspects. It is a small bench top instrument that uses dead weights to apply defined loads to a spherical indenter, while the penetration is measured with a dial gauge. The dial gauge is commonly calibrated directly in International Rubber Hardness Degrees (IRHD). The IRHD scale was chosen to have readings numerically equivalent to the popular A scale over the range normally encountered in practical engineering compounds. While the approximate equivalence of the IRHD and the A scales is valid for highly elastic materials, significant differences may be expected for materials that show marked time-dependent behavior [10,52]

According to the ASTM standard the penetration of the indenter bears a known relation to the Young's modulus of the rubber .This relation is an empirical relation obtained by Scott 1948 [53].

$$\frac{F}{E} = 1.9\ P^{1.35}\ r^{0.65} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2.2)$$

Where F is the indenting force (N) ,k is Young's modulus (MPa) ,P is the depth of Penetration (mm) ,and r is the radius of the indenter (mm) [58] showed that a theoretical relation may be derived from the classical theory of elasticity in the form:

$$\frac{F}{E} = 1.78\ P^{1.5}\ r^{0.5} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2.3)$$

If we taken Young's modulus to be equal to three times The shear modulus G is given by :

$$\frac{F}{G} = 5.33\ P^{1.5}\ r^{0.5} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2.4)$$

These relations between hardness and Young's or shear modulus , whether empirical or theoretical , should be regarded as only approximate . Significant discrepancies may occur simply from the way Young's modulus is defined and measured hardness. Discrepancies are also expected when the material deviates markedly from perfectly elastic behavior [54].

2.6.3 Tensile, Elongation and Modulus

The tensile test consists of stretching rubber samples at a uniform speed in a tensile tester and recording the values of stress on the samples and the resulting elongation at more or less regular time intervals. The curve drawn with the elongation on the abscissa and the stresses on the ordinate axis is called the tensile curve. The tensile stress is the ratio of the total force acting on the sample to the initial cross section of the sample. The tensile stress at the breaking point of the rubber sample is called tensile strength. It is defined as the force per unit area of the original cross section, which is applied when the specimen is ruptured [55].

The tensile strength is calculated by the equation;

$$\text{Tensile Strength} = \frac{F}{A} \qquad \text{……….. (2.5)}$$

Where F = observed force required to break the specimen of the cross section area A.

Young's modulus is defined as the ratio between the applied stress and the strain resulting from it in the elastic region in the stress- elongation. In the elastic deformation of solid material the elongation relates to the stress by a quantity called elastic modulus (E) which is the straight region in the stress - elongation curve the stress and strain are described by the following expressions;

$$\text{Stress } \sigma = \frac{\text{Force or load F}}{\text{Cross sectional area A}} \qquad \text{…………..(2.6)}$$

$$\text{Strain } \varepsilon = \frac{(\text{L} - \text{Lo})}{\text{Lo}} \qquad \text{…………(2.7)}$$

Thus, Young's modulus in a tensile test is given by ;

$$E = \frac{\Delta\sigma}{\Delta\varepsilon} \qquad \ldots\ldots\ldots\ldots\ldots(2.8)$$

The maximum elongation is called "elongation at break" or "ultimate elongation" Therefore; the mathematically relation to calculate the ultimate elongation is;

$$\text{Ultimate elongation} = [\frac{\mathrm{L-Lo}}{\mathrm{Lo}}]*100\% \qquad \ldots\ldots\ldots\ldots..(2.9)$$

Where Lo=initial length and L=final length.

Chapter Three

Experimental Part

3.1 Introduction

The development or finding an alternative of a new rubber composite material for application in shock absorbers such as fenders in the berth requires many mechanical tests which simulate conditions that these parts are subjected to such as tensile strength, rebound resilience, compression, hardness ,tear resistance, etc. .In addition, these tests are necessary under the effect of seawater ,temperature, and aging.

The testing of the various kinds of recipes for study under the effect of addition of the suggested materials required preparation of some reinforcement materials, one of these materials is the cement waste (cement factory scrap and dust) and the other is reclaimed tire. So the mixing of these materials with carbon black N375 and then prepared blends such as NR /SBR,SBR/BRcis and NR/SBR/BRcis carried out then preparation of samples for mechanical tests by using the standard molds according to the ASTM which will be mentioned later.

3.2 Materials

NR used in this study is SMR 20 which has a specific gravity 0.92 gm/cm^3, supplied by the Perlis, Malaysia. The compositions of NR listed in Table (3.1) these Tables (3.1)-(3.5) were supplied by chemical laboratory in Babylon factory.

Table (3.1) : Compositions of NR .

Composition	Percentage %
Rubber (SMR–20)	**94.3%**
Protein	**1%**
Organic matter	**2%**
Nitrogen content	**0.6%**
Volatile matter	**0.8%**
Ash	**1%**
Slag or dirt	**0.2%**
Water	**0.8%**

- SBR used in these experiments is SBR 1502 (contain 23.5% styrene content and butadiene), with specific gravity (o.95 gm/cm^3), supplied by the Kumho CO. Koria. The composition of SBR is listed in Table (3.2). Therefore, BR$_{cis}$ (specific gravity 0.90 gm/cm^3) composition is listed in Table (3.3)

Table (3.2) : Composition of SBR 1502.

Composition	**Percentage %**
Bound styrene	**23.5 ±1 % max.**
Volatile matter	**0.75% max.**
Ash	**1.0% max.**
Soap	**0.5% max.**
Organic acid	**4.7 – 7.2%**
ETA extract	**4.75-7.75%**

Table (3.3) : Composition of BR$_{cis}$.

Composition	**Percentage %**
Polybutadeine	**97%**
ETA extract	**1.00 % max.**
Volatile matter	**0.75% max.**
Ash	**0.20% max.**
ETA extract	**1,00 %max**

Carbon black N375 supplied by Doudah, Iran. It is examined in accordance with DBP absorption (ASTM D136) and Iodine absorption (ASTM D135). The properties of N375 are listed in Table (3.4).

in table (3.5) Cement waste (Kiln dust**)** supplied by Karbala factory, with the properties of cement waste powder shown in Table (3.6) this Table supplied by chemical laboratory in Karbala cement factory .

Zinc oxide (97%) and stearic acid (99.4%) were supplied by Acidchem-International CO. Malaysia. 6PPD N- (1, 3 – Dimethyl butyl) – N – Phenyl – Para – Phenylenediamine (98%) was supplied by Shenyang Sunnyjoint Chemicals CO. China. MBS N- oxy diethylene benzothiazole 2- sulfonamide (98.2%) supplied by ITT, India. The South Patrol Company supplied Paraphenic wax, processing oil. Sulfur was supplied by Al-Meshrak CO. Iraq.

Table (3.4) : Properties of Carbon black N375.

PROPERTIES	N375
Density (g/cm^3)	**1.8**
Specific surface areas(Iodine number) m^2/g	**92±5**
DBP absorption number ml/100g	**114±5**
Particle size (nm)	**32**
Loss at 105 °C	**1%**
Ash content	**0.75%**

Table (3.5) : Analysis of cement waste powder.

MATERIALS	%
SiO_2	**11.11**
Al_2O_3	**2.38**
Fe_2O_2	**2.55**
CaO	**46.29**
MgO	**1.12**
SO_3	**0.59**
Cl	**0.12**

3.3 Equipment and Instruments

3.3.1 Laboratory mill

A two -roll mill was used as shown in Figure. (3.1), it consists of two hollow cast iron rolls of cylindrical shape of 150mm in diameter and 300mm in length, having provision for passing cold water or steam through the rolls. The mixing of powder takes place at the compressive zone of the roll nip, where the mixing take place along the circumferential direction of the rubber bank on the mill. In mill mixing temperature control is very important so, chilled water is passed through the rolls at a regulated flow rate to remove excessive heat developed during mixing, and prevents scorching of compound, and heat is also necessary in some processes to warm up the rolls instead of cooling them. [56]

Figure (3.1) Laboratory mill

3.3.2 Hydraulic press

The vulcanization processes are a function of pressure, heat, and time according to the specification test. The preparation processes of samples were carried out by the hydraulic press has maximum pressure equal to 700bar, the hydraulic press is equipped with a thermocouple and the maximum temperature is equal to 300°C,see figure (3.2).

Figure (3.2) Hydraulic press

3.3.3Equipment of Tensile

Tests are carried out on samples which had been prepared as shown in section (3.6.1) according to ASTM D412 [57]. Monsanto T10 tensometer shown in Figure. (3.3) was used . The test sample was movable at speed of 500 mm/min. The tear resistance tests were carried out by using ASTM –D624 [58].

Figure (3.3) Monsanto T10 Tensometer

3.3.4Equipment of Hardness

The International Hardness test is used in the measurement of the penetration of rigid ball (according to Brinall method) into the rubber specimen. The diameter of the ball is equal to 2.5 mm; sample for hardness prepared in section (3.6.4), under specified conditions. The measured penetration was converted to the International Rubber Hardness Degrees (IRHD), the equipment shown in Figure. (3. 4). The scale of degrees is so chosen that zero represents a material having elastic modulus equal to zero and 100 represents a material of infinite elastic modulus. The scale covers all the normal ranges of hardness. The tests were carried out according to ASTM D 1415 specifications [59].

Figure (3.4) Equipment of Hardness

3.4 Moulds

3.4.1 Mould for Tensile Set Tests

To prepare samples from each recipes, the slice for the above tests with a dimension of (150 * 150 * 2.5) mm was prepared by using a mould which consists of three parts. The middle one in a dimension of (395 * 160 * 2.5) mm contains two sections with (150 * 150 * 2.5) mm dimension fixed on base of (395 * 160 * 10) mm and covered with a cover of the same dimension as that of the base for regulation of thickness as shown in Fig. (3.5).

Figure (3.5) : Mould of test sample for tensile set.

3.4.2 Mould for Testing Hardness

For preparing samples of hardness, rebound resilience and density tests, the mould of the laboratories of Tires Company was used. The mould consists of three parts , the middle part has the dimension of (200 * 180 * 4) mm which contains nine circular equivolume cavity with (40 mm) in diameter and 4 mm thickness, while one of other two parts is the bottom base and the other is a cover , they have a dimension of (200 * 180 * 10) mm as shown in Fig. (3.6).

Figure (3.6) : Mould of samples for testing hardness, rebound resilience and specific gravity.

3.4.3 Component of Ternary Batches

Table (3.6) Ingrediant of the Ternary composite.

MATERIALS	RECIPE 1	RECIPE 2	RECIPE 3
SBR	**60**	**30**	**40**
NR	**30**	**60**	**60**
BR	**10**	**10**	**0**
ZnO	**1**	**1**	**1**
C.W.	**0,10,20**	**0,10,20**	**0,10,20**
C.B.	**50**	**50**	**50**
Stearic acid	**2**	**2**	**2**
MBS	**1**	**1**	**1**
Sulfur	**1.5**	**1.5**	**1.5**

3.5 Preparation of SBR /BR_{CIS} ,SBR/NR, SBR/NR/BR_{CIS} Composites

The batches recipe were prepared by using mill laboratory shown in Fig.(3.7) by the steps shown in Table (3.7).

Table (3.7) steps for making a recipe

STEP	DESCRIPTION	TIME (min)
1	(SBR+NR+BRcis) were passed between the two rolls mill several times with decreasing the distance between the two rolls to the extent of (0.5 – 1) mm and followed mixing processe and calendaring to get homogenous batch.	5
2	.Zinc oxide was added and step 1 was repeated.	5
3	Stearic acid was added and step 1 was repeated.	5
4	Paraphenic was added and the addition was taken place by	5

	1 ml per minute with step 1 was repeated.	
5	Accelerator MBS was added and step 1 repeated.	5
6	Antioxidant 6PPD was added and step 1 repeated.	5
7	C.B& Cement waste (group 1,2,4) or reclaim (group 3,5) with processing oil was added gradually and step 1 repeated.	10
8	Sulfur was added and step 1 repeated	5
9	The mixing process was continued for more time in order to get a good homogenization and with a thin thickness (1-2 mm).	

3.6 Preparation of Mechanical Tests samples

3.6.1 Preparation Samples for Tensile set

The samples are prepared according to the following steps :

1- Heating the mould shown the Figure (3.6) up to 100^{o}C

2-Removing the mould from the oven with protecting gloves and lubricating all its sides.

3-After preparation of the mould, an appropriate quantity of batch was put in the mould.

4-Placing the mould of tensile in the thermal press to less than 20 MPa and at temperature of 160 °C for 20 minutes

5-After Vulcanization time, the mould was opened and the slice was removed and left for 12 hours for cooling at room temperature.

6-The test samples (dumbbell specimen) for tensile are shown in Figure. (3.7) and sample for tear resistance were cut from the vulcanized slice as shown in Figure. (3.8). The cutting was done by using hand press.

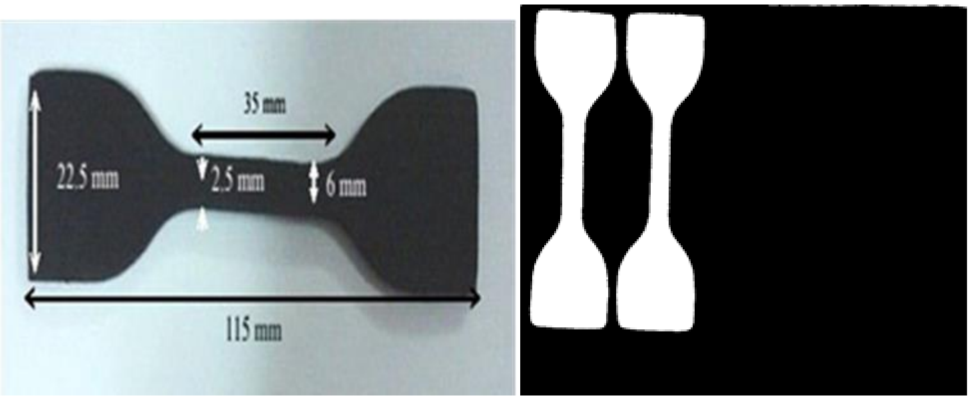


Figure (3.7) a) Dumbbell specimen b) Slice after cutting

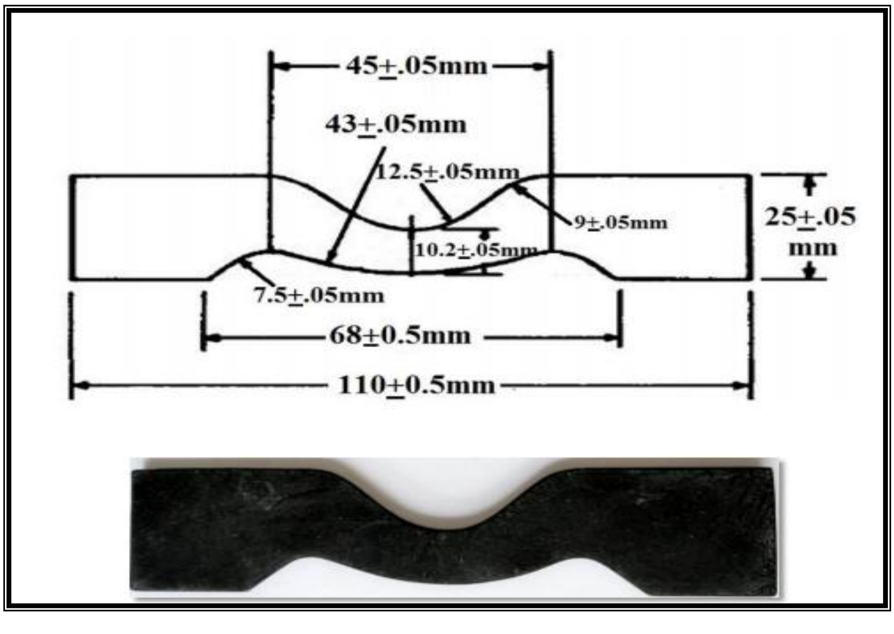


Figure (3.8) Sample for abrasion wear test

3.6.2Preparation of samples for abrasion wear test

The samples are prepared according to following steps :

1.Heating the mould shown in Figure. (3.6). up to 100 °C .

2.Removing the mould from oven with protective gloves and lubricating all its sides .

3.After preparation of the mould, an appropriate quantity of recipe was put in the mould

4.After putting the cover on the mould in thermal press less than 20MPa and at temperature of 160 °C for 20 min took place.

5. After vulcanization time, the mould was opened and the samples were removed from the mould and left 20-24 hour at room temperature.

Chapter Four

Results, Discussion and Conclusions

4.1 Introduction

This chapter presents all results obtained with wide range for different damping and mechanical properties. The discussion of theoretical and .experimental results for the following samples is also covered

1. Recipes of SBR/BRCIS, SBR/NR, SBR/NR/BRCIS blends with addition of different ratios by the mixture of industrial scrap such as cement waste with carbon black, this work was carried out through five groups.
2. Selection of the blend recipe that is satisfying the better mechanical, damping properties.
3. Blend recipes which were reinforced with Carbon black proportion of 50% by changing the ratios of cement waste before and after aging in order to obtain the properties close to those listed in standard tenders.

The results of aging effects on the mechanical properties such as hardness, tensile strength, elongation, tear resistance, compression of prepared samples are also included in this chapter[25].

4.2 Results and discussion

4.2.1 Hardness

The hardness of the five groups was examined by the shore. these results are shown in figures (4.1), (4.2) and (4.3) it indicate that the addition of the (BR_{cis}10) filler showed a marked increase in hardness, this result is expected because of more fillers incorporated in the rubber matrix. It is well known that the addition of the filler in rubber compounding leads to a linear increase in materials hardness; moreover, this attributed due to the presence of carbon black resulted increasing number of highly active sites leads to active crosslinking sites between the rubber chains and rubber- BR_{cis}0 interaction and filling the vacuums between the rubber chains. Attributed to the increase of the crosslinking density of NR, SBR, BR_{cis} molecular chains with increased aging time[36,37]. Figures (4.1),(4.2) show increasing in hardness at increase the loading ratio of cement waste when the ratio of SBR is more than NR,BR. In addition figure (4.3) illustrated that the hardness of all composites decreased with increase loading ratio of cement waste when the ratio of NR increased higher than (50)in these composites, this attributed to happen over cure or over vulcanization this may be result break in NR rubber chain instead of cross-linking .

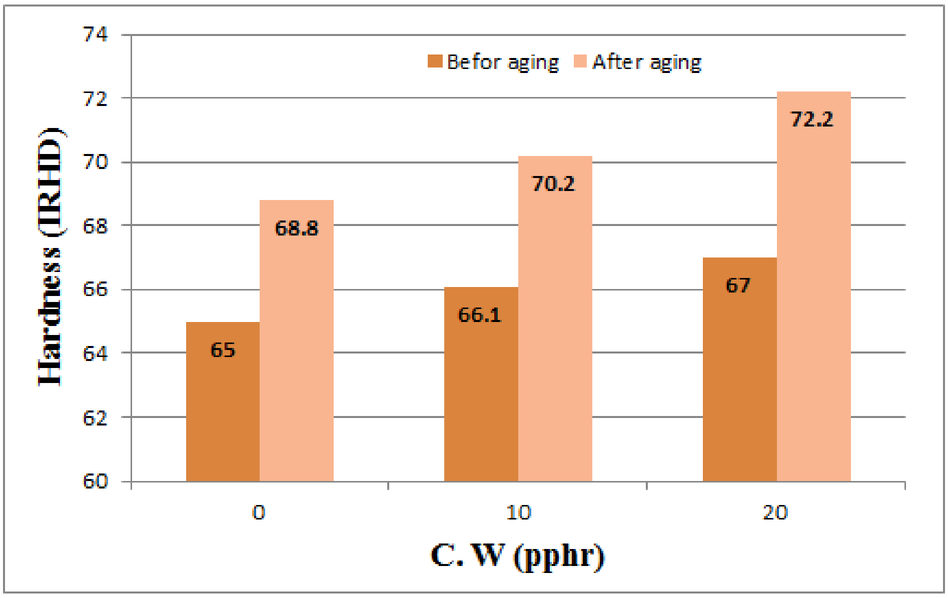


Figure 4.1 : Relationship between hardness and the leading ratio of cement waste for (NR40\SBR60\CB50) composites.

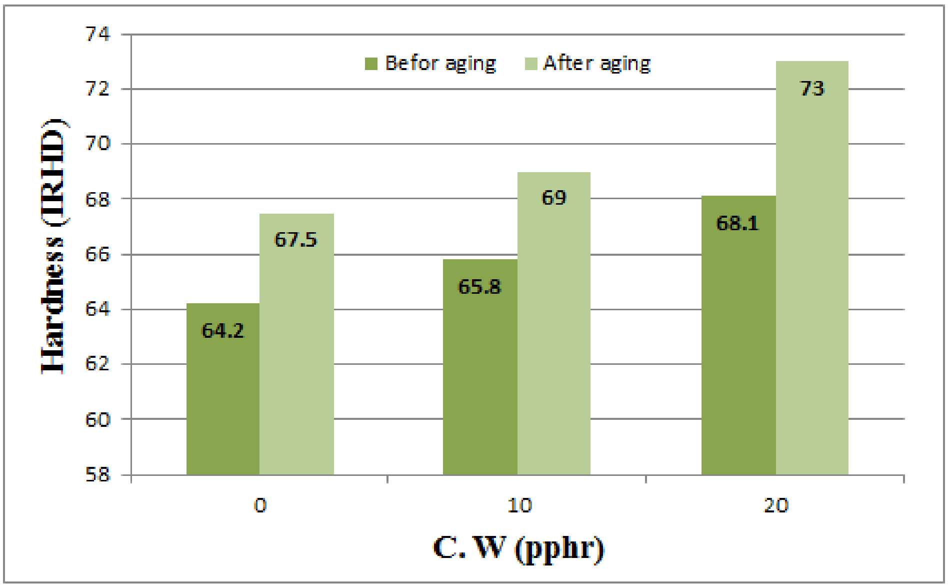


Figure 4.2 : Relationship between hardness and the leading ratio of cement waste for ($NR30\backslash SBR60\backslash BR_{cis}10\backslash CB50$) composites.

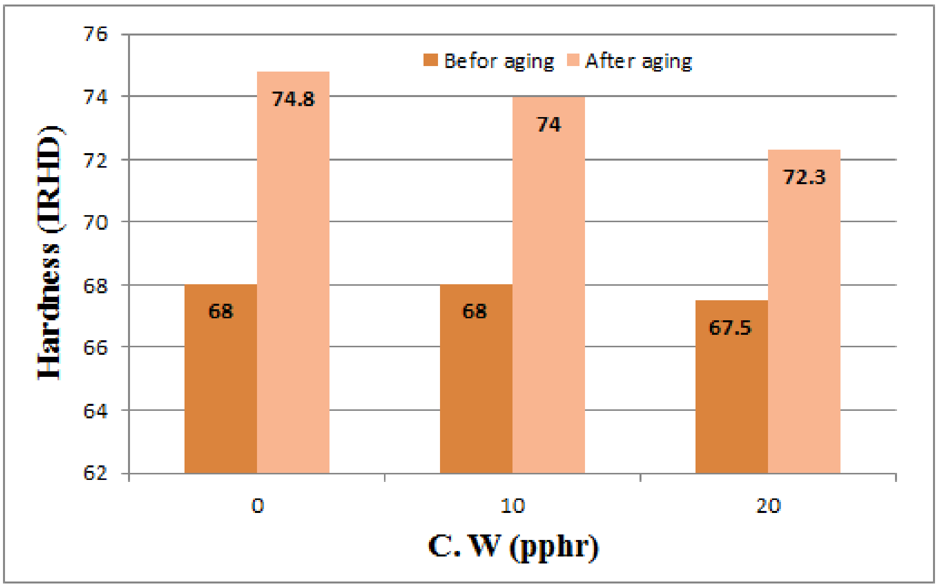


Figure 4.3 : Relationship between hardness and the leading ratio of cement waste for ($NR60\backslash SBR30\backslash BR_{cis}10\backslash CB50$) composites.

4.2.2 Tensile strength

Figures (4.4), (4.5) and (4.6) show the decrease in the tensile strength as cement waste loading level increases because of this decreasing the interaction between these filler and rubber blends chain so happen waste aggregation in the waste composites and creating micro cracks in the composites. . Attributed to the increase of the crosslinking density of NR, SBR, BRcis molecular chains with increased aging time. The figures (4.4),(4.5) show decreasing in tensile strength at increasing the loading ratio of cement waste when the ratio of SBR is more than NR,BR. In addition figure (4.6) illustrated that the tensile strength of all composites decreased with increase loading ratio of cement waste when the ratio of NR increased higher than (50)in these composites, this attributed to happen over cure or over vulcanization this may be result break in NR rubber chain instead of cross-linking .

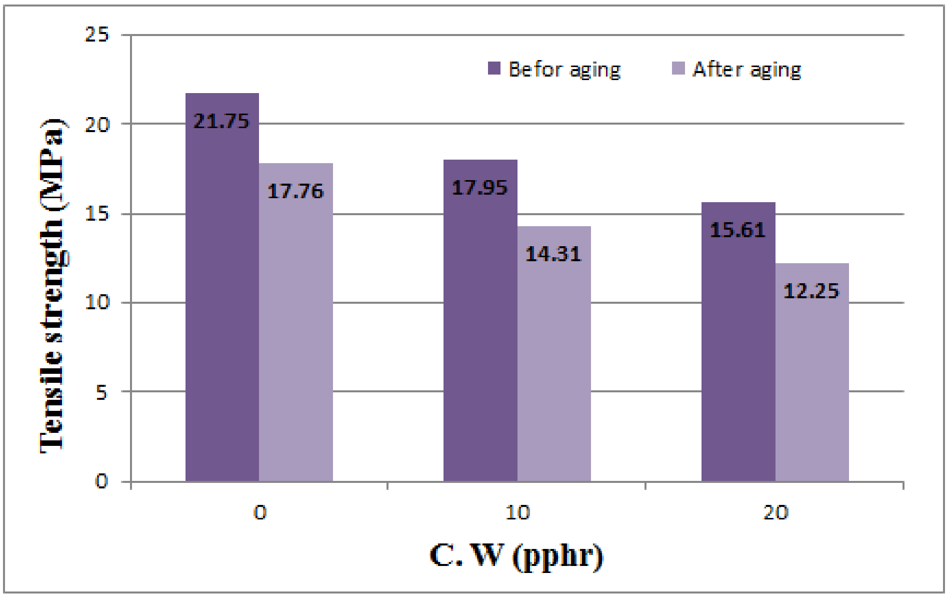


Figure 4.4 : Relationship between tensile strength and the leading ratio of cement waste for (NR40\SBR60\CB50) composites.

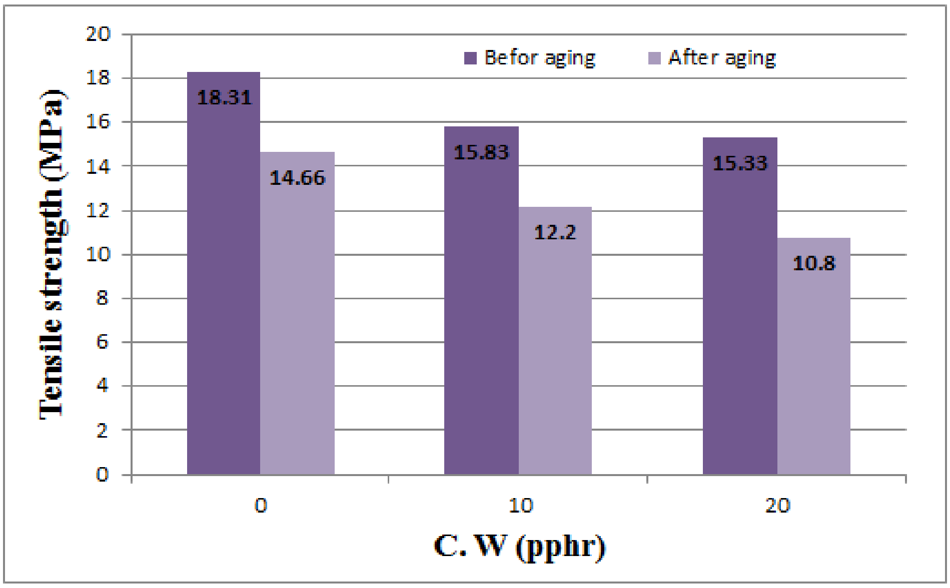


Figure 4.5 : Relationship between tensile strength and the leading ratio of cement waste for (NR30\SBR60\BR$_{cis}$10\CB50) composites.

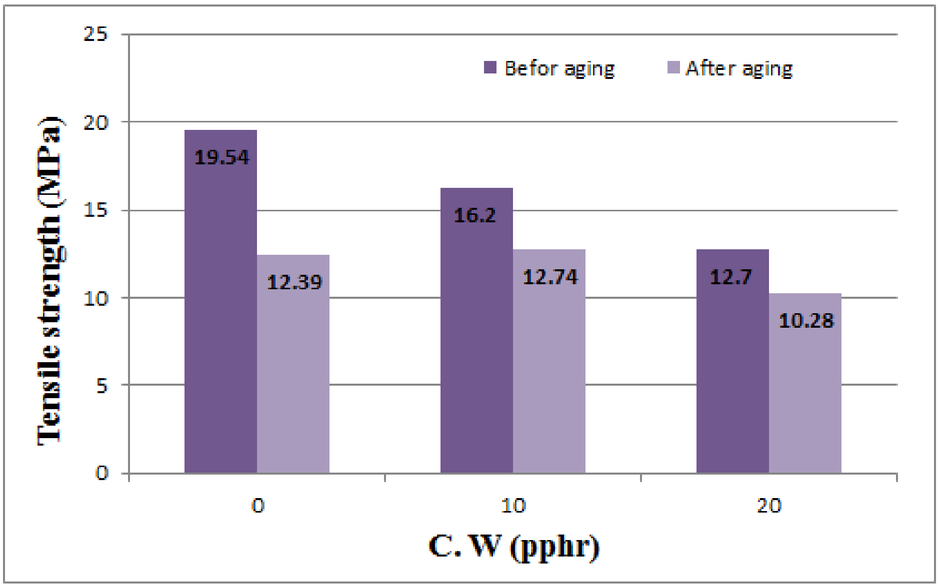


Figure 4.6 : Relationship between tensile strength and the leading ratio of cement waste for (NR60\SBR30\BR$_{cis}$10\CB50) composites.

4.2.3 Elongation

The elongation of Prepared mixtures was examined by the shore, the results are shown in figures (4.7), (4.8) and (4.9) it indicate that the addition of the (BR$_{cis}$10) filler showed a marked decrease in elongation, this result is expected because of more fillers incorporated in the rubber matrix. It is well known that the addition of the filler in rubber compounding leads to a linear increase in materials hardness;. The figures (4.7),(4.8) show decreasing in elongation at increase the loading ratio of cement waste when the ratio of SBR is more than NR,BR. In addition figure (4.9) illustrated that the elongation of all composites decreasing with increase loading ratio of cement waste when the ratio of NR increased higher than (50)in these composite, this attributed to happen over cure or over vulcanization this may be result break in NR rubber chain instead of cross-linking .

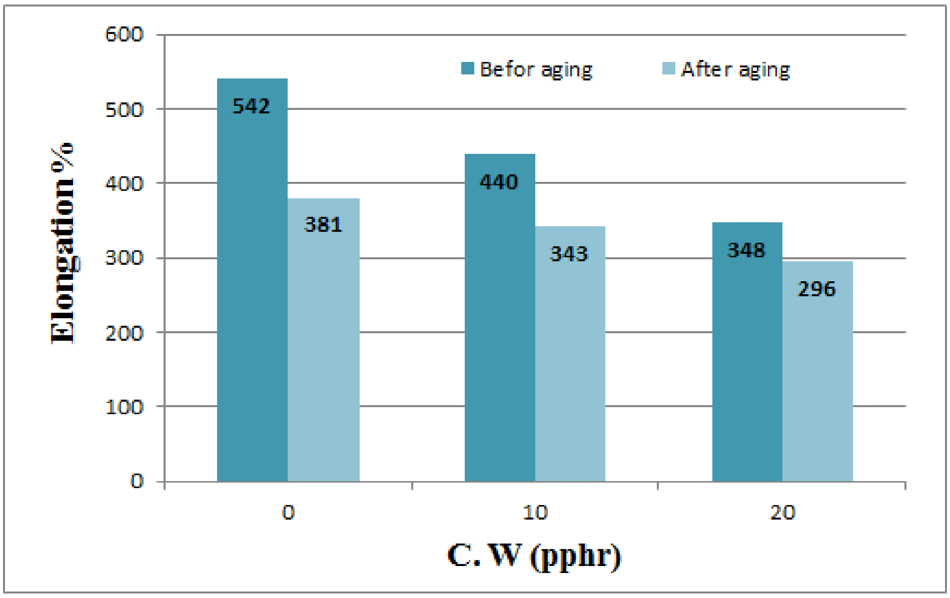


Figure 4.7 : Relationship between elongation and the leading ratio of cement waste for (NR40\SBR60\CB50) composites.

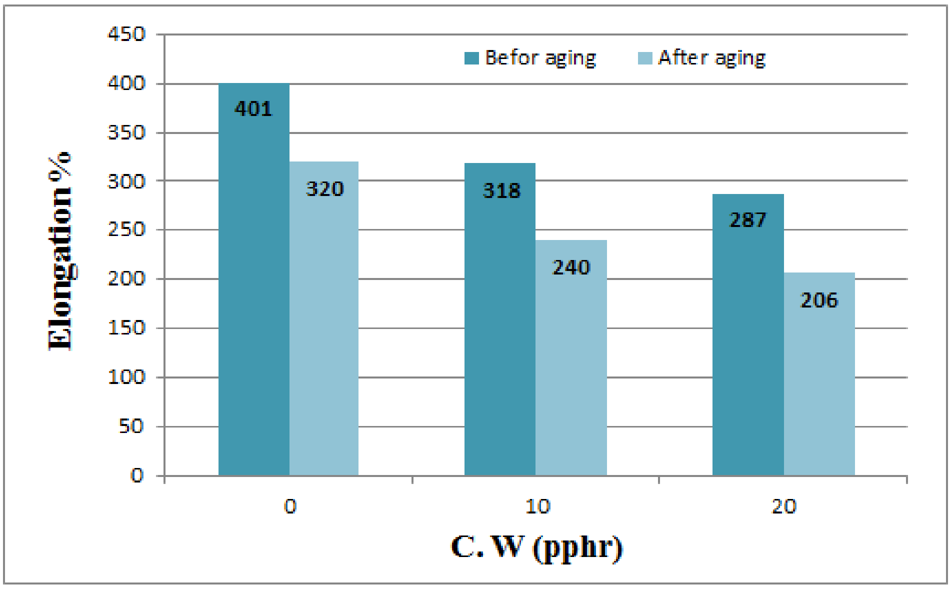


Figure 4.8 : Relationship between elongation and the leading ratio of cement waste for (NR30\SBR60\BR$_{cis}$10\CB50) composites.

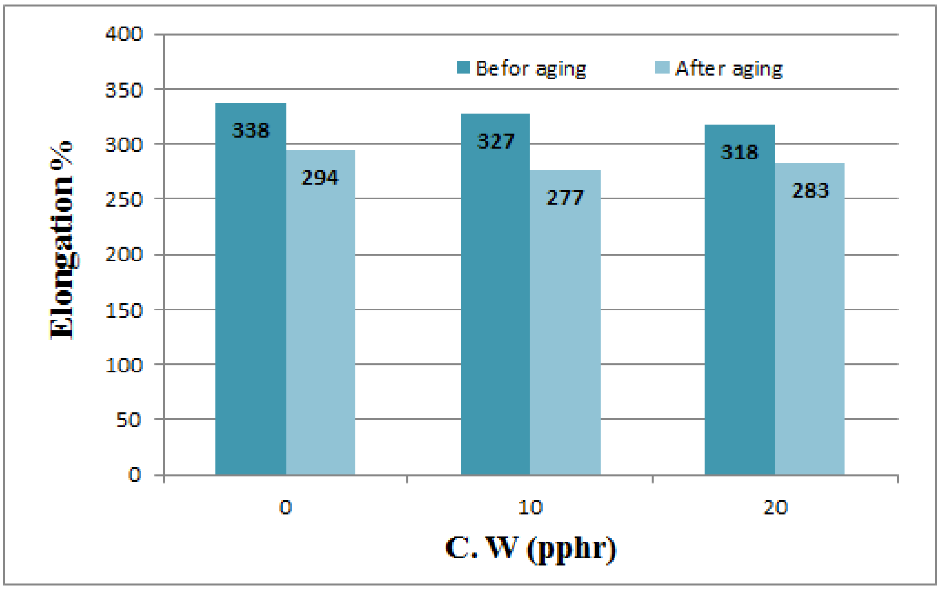


Figure 4.9 : Relationship between elongation and the leading ratio of cement waste for (NR60\SBR30\BR$_{cis}$10\CB50) composites.

4.2.4 Elastic Modulus

The elastic modulus of five groups was examined by tensometer device, the effect of loading level of C.B, waste or C.B, reclaim for the five groups shown in the Figures (4.10), (4.11) and (4.12). These figures show that the increment of mixed C.B, waste or C.B, reclaim leads to an increase in the elastic modulus at 100% for all recipes due to the presence of carbon black resulted an increasing number of high adsorption active sites leads to active crosslinking sites in the compound [60]. So increasing the interaction of mix C.B ,waste with the rubber blends chain resulting in more physical bonds and an increase in surface activity which gives high elastic modulus. Figure (4.10) shows decreasing in elastic modulus at increasing the loading ratio of cement waste when the ratio of SBR is more than NR,BR but in figure (4.11)show increasing in elastic modulus after aging. In addition figure (4.12) illustrated that the elastic modulus of all composites decreased with increase loading ratio of cement waste when the ratio of NR increased higher than (50)in these composite, this attributed to happen over cure or over vulcanization this may be result break in NR rubber chain instead of cross-linking .

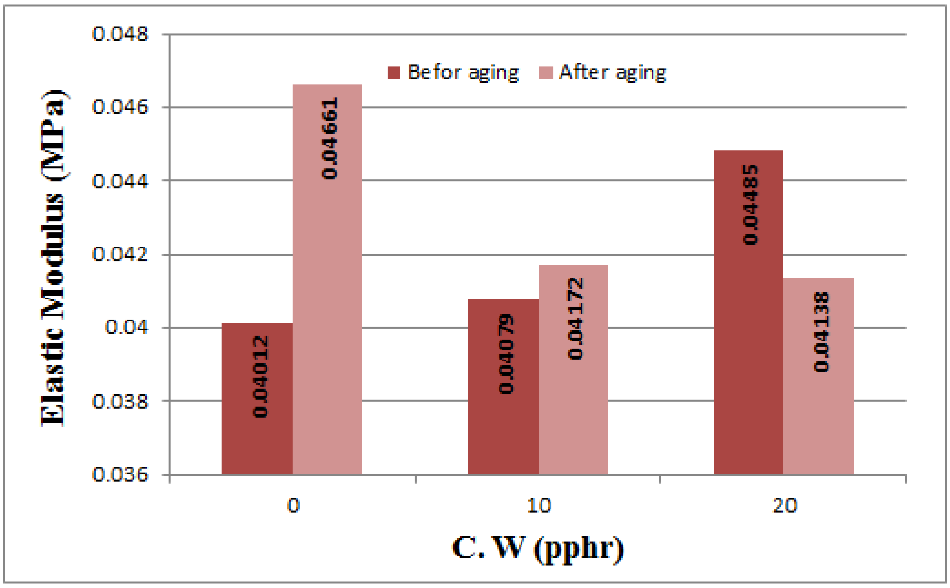


Figure 4.10 : Relationship between elastic modulus and the leading ratio of cement waste for (NR40\SBR60\CB50) composites.

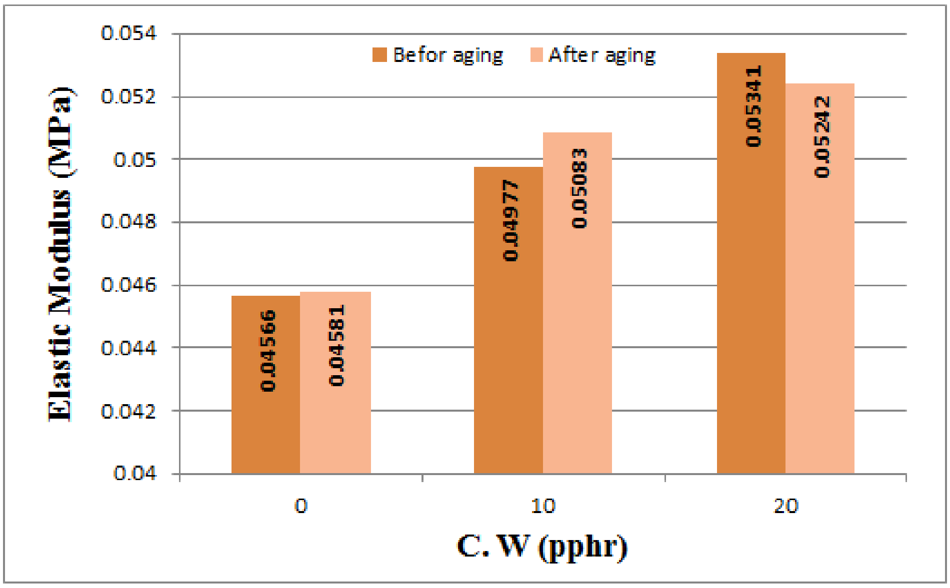


Figure 4.11 : Relationship between elastic modulus and the leading ratio of cement waste for (NR30\SBR60\BR$_{cis}$10\CB50) composites.

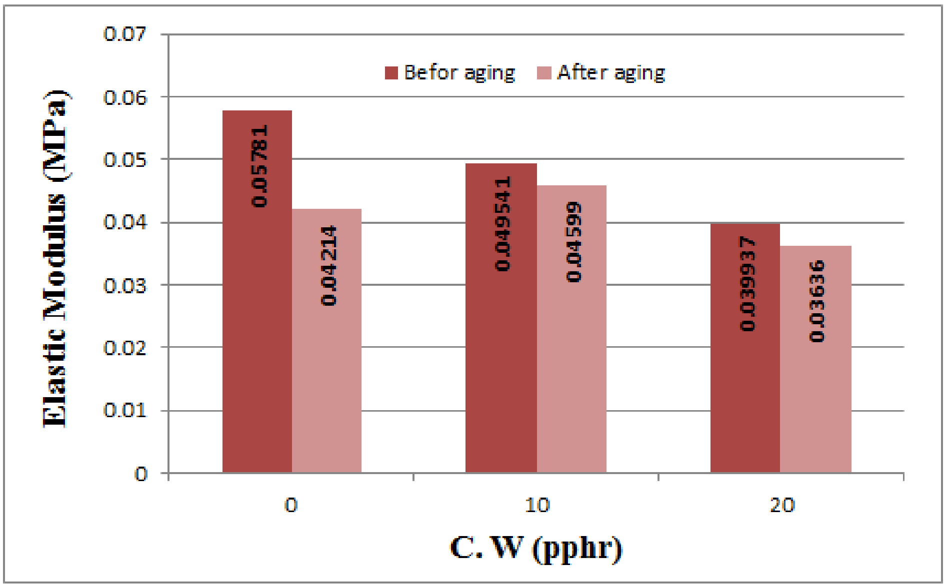


Figure 4.12 : Relationship between elastic modulus and the leading ratio of cement waste for (NR60\SBR30\BR$_{cis}$10\CB50) composites.

4.2.5 Tear resistance

Figures (4.13), (4.14) and (4.15) illustrated the relationship between tear resistance values and loading level of reclaim and cement waste, from this figure indicated a decrease in the tear strength of the vulcanizes with increasing cement waste. In the same time, there is a significant increase in tear strength of the vulcanizes with increasing of the crosslinking between the rubber chains. Attributed to the increase of the crosslinking density of NR, SBR, BRcis molecular chains with increased aging time. The figures (4.13),(4.14) show decreasing in tear resistance at increase the loading ratio of cement waste when the ratio of SBR is more than NR,BR. In addition figure (4.15) illustrated that the elongation of all composites decreasing with increase loading ratio of cement waste when the ratio of NR increased higher than (50)in these composite.

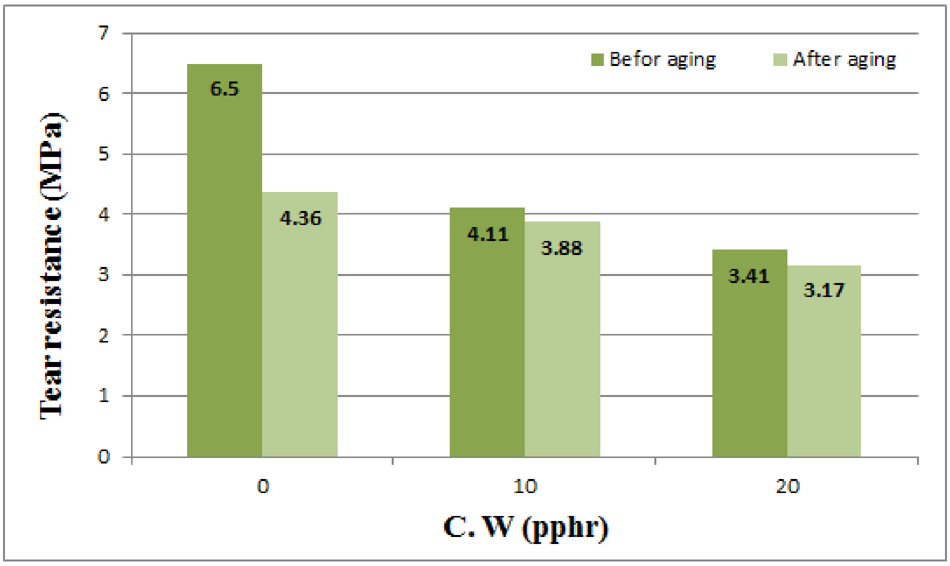


Figure 4.13 : Relationship between tear resistance and the leading ratio of cement waste for (NR40\SBR60\CB50) composites.

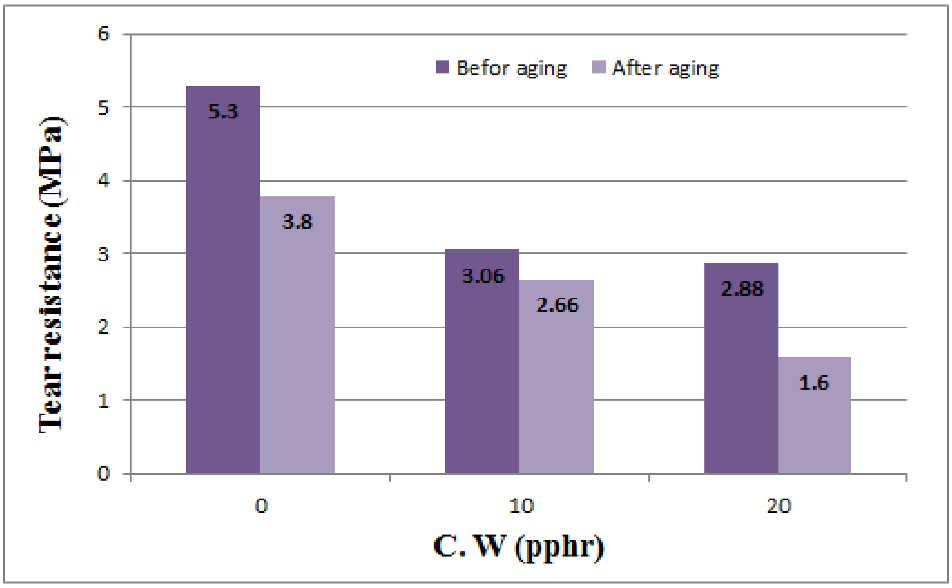


Figure 4.14 : Relationship between tear resistance and the leading ratio of cement waste for (NR30\SBR60\BR$_{cis}$10\CB50) composites.

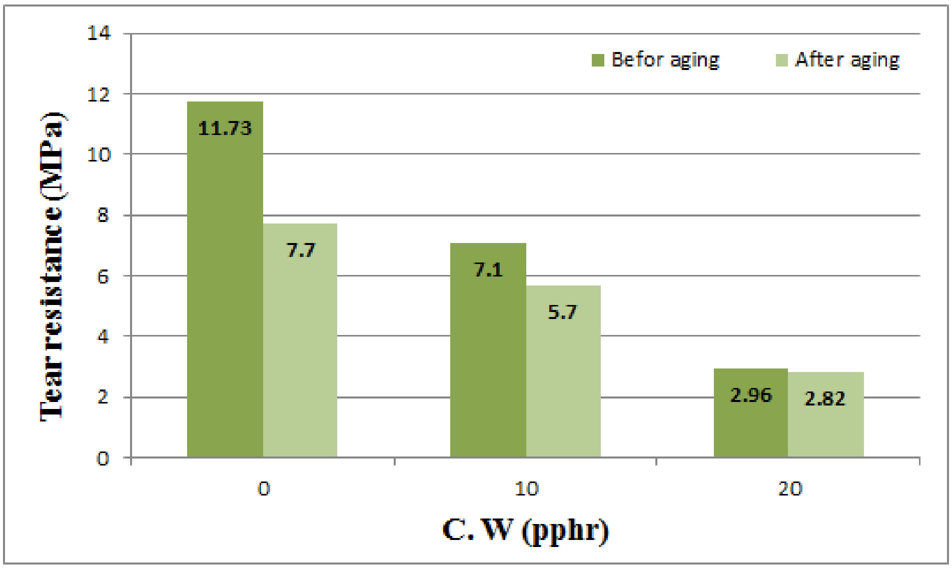


Figure 4.15 : Relationship between tear resistance and the leading ratio of cement waste for (NR60\SBR30\BR$_{cis}$10\CB50) composites.

4.3 Conclusions

1. Hardness increase with increasing loading level for cement waste before and after aging.
2. Tensile strength and elongation were decreasing before and after aging.
3. Elastic modulus increase before aging while, decrease after aging.
4. Tear resistance decrease before and after aging.

4.4 Future Works

1. Study the mechanical properties of (NBR\NR\CW) rubber composites and the effect of aging.
2. Preparation the rubber composites (NBR\SBR\Br$_{cis}$) reinforced with different ratio of carbon black.
3. Synthesis the ternary blends (NBR\NR\SIR) with different ratio of C.B.
4. Study the rheological properties of (NBR\NR\CW) rubber composites.
5. Study the damping properties of (NR\SBR\CW\10).

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الخلاصة

تضمن البحث تحضير الخلائط الثلاثية ($NR40/SBR60/Br_{cis}0$) و ($NR30/SBR60/Br_{cis}10$) و ($NR60/SBR30/Br_{cis}10$) المدعمة بنسبة ثابته من أسود الكاربون (50 pphr) ، ومن ثم تدعيمها و تقويتها بنسب مختلفة من (Cement waste) و هذه النسب هي (0, 10, 20).

تم دراسة الخواص الميكانيكية أو خواص الشد مثل Tensile strength ، Elongation ، Elastic modulus ، Tear resistance حيث تم قياسها بواسطة جهاز Universa\Fensometer وفقاً للمواصفات العالمية (ASTM)(D624) وكذلك خاصية الصلادة Hardness(2240)أجريت بواسطة جهاز (Share A Hardness) وفقاً للمواصفة و كل هذه الخواص أجريت قبل و بعد التعتيق حيث لوحظ أن الصلادة قد ازدادت مع زيادة نسبة التحميل لمادة (Cement waste). أما الخواص الأخرى مثل قوة الشد ، الأستطالة ، معامل المرونة و مقاومة التمزق فقد قلت مع زيادة نسبة التحميل قبل و بعد التعتيق.

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة بابل
كلية التربية للعلوم الصرفة
قسم الفيزياء

خصائص الشد للخلائط الثلاثية المطاطية (NR/SBR/BR) المدعمة بغبار الأسمنت كمادة مالئة

بحث مقدم

إلى مجلس كلية التربية للعلوم الصرفة في جامعة بابل
وهي جزء من متطلبات نيل درجة الدبلوم العالي
تربية/ فيزياء المواد وتطبيقاتها

من قبل الطالب

زهراء عباس حميد عمران

بكالوريوس تربية فيزياء
(جامعة بابل **2018** م)

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قسم الفيزياء

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