EPUBLIC OF IRAQ
MINISTARY OF HIGHER EDUCATION
AND SCIENTIFIC RESEARCH
BABYLON UNIVERSITY
COLLEGE OF ENGINEERING

OPTIMIZATION STUDY OF RUBBER BLENDS AND THEIR EFFECTS ON PASSENGER TYRE TREAD PROPERTIES

A thesis Submitted to
Materials Engineering Department
College of Engineering
University of Babylon

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (Ph.D.)

IN

MATERIALS ENGINEERING

BY
MUJED HADI ENAD AL- HATAMMI

Feb./٢٠٠٧ **Moharam/١٤٢٨**

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Supervised by

Dr. T. A. AL-Hattab **Dr. M. H. Hallim**

Feb./٢٠٠٧ **Moharam/١٤٢٨**

بسم الله الرحمن الرحيم

الله الذي جعل لكم الأرض قرارا والسماء بناءا وصوركم فأحسن صوركم ورزقكم من الطيبات ذلكم الله ربكم فتبارك الله رب العالمين * هو الحي لا اله إلا هو فادعوه مخلصين له الدين الحمد لله رب العالمين *

صدق الله العلي العظيم

سورة غافر

(الآيات (٦٣-٦٤

وزارة التعليم العالي والبحث العلمي
جامعة بابـــــــل
كلية الهندســـــة

دراسة أمثلية
الخلطات المطاطية وتأثيرها في خواص الجزء الملامس للأرض لإطار المركبات الصغيرة

رسالة مقدمة
إلى قسم هندسة المواد في كلية الهندسة جامعة بابل
كجزء من متطلبات نيل درجة دكتوراه فلسفة في هندسة المواد

من قبل المهندس
موجد هادي عناد الحاتمي

باشراف
الدكتور تحسين علي الحطاب والدكتورمهدي حسن حليم

٢٠٠٧ ١٤٢٨

الخلاصة

بشكل منفرد في عجنات SBR عالميا غالبا ما يستخدم مطاط الستايرن-بيوتاديين لاطار المركبات الصغيرة, وكما معروف ان (tread) مطاط الجزء الملامس للأرض مثل هذه التكنولوجيا لم تكن ملائمة لاجواء العراق الحارة جدا خصوصا في فصل الصيف مما يستدعي استهلاكا غير طبيعيا للاطار. بالاضافة الى عدم تلبيتها لمتطلبات وظروف الجو الحار عليه جرت محاولات للبحث في استخدام خلطات مطاطية تحوي كتلك التي تكون , SBR على انواع جديدة من المطاط مضافة الى المطاط الاساس أثناء الخدمة(حركة او دوران heat buildup معروفة بانخفاض حرارتها المتراكمة أو التي تمتاز بمقاومتها الحرارية العالية مثل مطاط NR الاطار) كالمطاط الطبيعي وهذين المطاطين الاخيرين EPDM ، ومطاط الاثيلينى بروبيلين CR النيوبرين يستخدمان لأول مرة في مطاط الجزء الملامس للأرض لإطار المركبات الصغيرة المنتج لاستقراريته الحرارية ومقاومته BR في القطر. استخدم أيضا مطاط البولي بيوتاديين استخدم كل نوع من هذه الأنواع . abrasion resistance العالية للبري او الحك الأساس بدرجات تحميل وزنية من ١٠ إلى ٦٠ SBR الأربعة مع مطاط لغرض معرفة أي من هذه النسب تحصل عملية التطوير او التحسين نحو pphr الامثلية Optimization.

أكثر من ٧٥ خلطة(عجنه) استخدمت في هذا العمل بنسب مختلفة لكل نوع من أنواع المطاط ، وقد تم تثبيت جميع النسب الوزنية الأخرى المكونة لكل خلطة ماعدا المطاط .الذي يتناقص بنفس النسبة مع تزايد كل نوع من المطاط المضافSBR الأساس ، ومعامل tensile strength اجريت فحوصات مختبريه مثل مقاومة الشد عند استطالة مقدارها ٣٠٠% ، والنسبة المئوية modulus (المرونة (المودلس ، ومقاومة hardness ، ومقدار الصلادة Elong. Percentage لاقصى استطالة ، والوزن النوعي. كذلك اجريت الفحوصات الأولية abrasion resistanceالحك cure ، وزمن الفلكنة scorch time للعجنات بجهاز الريوميتير مثل زمن الاحتراق .الأدنى والأقصى (torques)، والعزمين time

لغرض تقييم وتحليل نتائج هذا العمل من فحوصات مختلفة، جرت مقارنتها مع نتائج فحوصات العجنة القياسية(العجنة المستخدمة في إنتاج الجزء الملامس للارض بنسبة ١٠٠% او درجة تحميل SBR لإطار بابل) والتي يكون فيها المطاط الأساس ، وأيضا تمت المقارنة مع نتائج مستخدمة كمواصفات pphr وزنية مقدارها ١٠٠ .من قبل شركتي دنلوب وبابل standards قياسية

Supervisors Certification

We certify that this Thesis was conducted under our supervision at the Department of Materials Engineering, College of Engineering, University of Babylon as a partial fulfillment of the requirements for the degree of Doctor of Philosophy in Materials Engineering.

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Name:Assist.Prof. Dr. T.A.Alhattab	Name:Assist.Prof. Dr. M.H.Halim
Date: / /٢٠٠٧	Date: / /٢٠٠٧

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From raw materials department my respect and thanks for MR., Munir and engineer Akeel for their faithful help.

MUJID AL- HATAMMI

Certification of the Examining Committee

We are the Examining Committee certify that we read this thesis and examined the student in this content and in our opinion it is adequate as a thesis of the doctor of philosophy in Engineering of Materials with the grade (Very Good).

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ABSTRACT

Styrene-Butadiene Rubber SBR is often used as a single rubber in tread rubber compound (recipe) of passenger Tire Tread as recommended by the Dunlop Co., which is the technology supplier for the state Company of Tire industries. As it is known this technology is not exactly fulfilled the Iraqi climate requirements, because it is very hot here, especially in summer season, so it is necessary to do an optimization study by attempting new blends having more heat resistance or/and low heat buildup elastomers rather than SBR. Attempting blends from١٠ to ٦٠ (pphr) of new rubbers with base rubber SBR may lead to optimize some physico-mechanical properties or may not. Four elastomers are used for such optimization. Those elastomers are Natural rubber NR which is known for its low heat buildup, Polybutadiene rubber BR which is known for its heat stability, Neoprene (polychloroprene) rubber CR and Ethylene Propylene rubber EPDM which are known for their heat resistance. An addition is carried out with using three types of carbon black, N-٣٣٠HAF, N-٣٣٩HAF-HS and N-٣٧٥HAF. The **new trend** in this research is the blending of **EPDM** with styrene-butadiene rubber SBR are used here for the **first time** as one aspect of tire tread optimization, the same thing is also done with neoprene rubber **CR** sharing polybutadiene rubber **BR** with SBR rubber.

More than ٧٥ recipes were prepared of various (pphr) of tread rubber compound. The usual ingredients of all recipes were kept constant except tread rubber. Several tests were carried out such as tensile strength, modulus, elongation percentage, hardness, abrasion resistance and specific gravity. Rheometry tests were also done such as scorch time, cure time, maximum torque and minimum torque.

To evaluate the results of this work, it is essential to compare with control properties came as a result of using SBR alone in typical tread recipe on one hand and with certain standard specifications used by well known companies like Dunlop Co. and Babylon Tire Company. These specifications give upper and lower accepted limits for each property. Furthermore, mathematical criterion is used in order to obtain fruitful optimization depending upon compromise of mechanical properties of tire tread.

Results obtained from this study give different levels of optimization for the most mechanical properties depending on the type of elastomer used and reinforcing agent.

- With compromise the mechanical properties of tread compound are often optimized in the presence of **NR** within loading level ٣٠/٧٠ --- ٦٠/٤٠ pphr for the most three blacks.
- Introduction of **BR** in tread recipe takes part in optimizing properties within the range of ٤٠/٦٠ to ٦٠/٤٠ pphr for various values according to the effect of each black type.
- Optimization regarded by effects of **CR/BR** is valid for the loading level of ٤٠/٦٠ pphr with three blacks.
- **EPDM** increasing level is more active at loading points ١٠/٩٠ to ٥٠/٥٠ pphr for blacks N-٣٣٠ & N-٣٣٩ producing optimized mechanical properties of tread rubber. The typical recipes with black N-٣٧٥ are only ١٠/٩٠, ٢٠/٨٠ and ٣٠/٧٠ pphr.

List of Abbreviations

SYMBOL	MATERIALS
BR	**Butadiene Rubber**
BIIR	**Bromo-Butyl Rubber**
BIMS	**Brominated Isobutylene-Co-Para-Methylstyrene Rubber**
Br-SBB	**Neoprene Rubber Star-Branched Bromo-Butyl Rubber**
CR	**Choloroprene rubber**
CBS	**N-cyclohexyl-٢-benzothiazole sulfonamide**
CTP-١٠٠	**N-(cyclohexylthio)phthalimide**
CIIR	**Chloro-Butyl Rubber**
CTAB	**Measure for Surface Area of Carbon Black**
CC/g	**Cubic Centimeter Per Gram**
DBP	**Measure for Structure of Carbon Black**
dN.m	**Deci-Newton*Meter**
ESBR	**Emulsion Styrene-Butadiene Rubber**
ETA	**Extraction technique analysis**
EPDM	**Ethylene Propylene Rubber**
gI٢/١٠٠g	**Gram of Iodine Per ١٠٠ Grams**
HAF-HS	**High Abrasion Furnace High Structure**
HAF-LS	**High Abrasion Furnace Low Structure**
IRHD	**International Rubber Hardness Degree**

List of Abbreviations (Continued)

IR	ISOPRENE RUBBER
IBR	**Isoprene-Butadiene Rubber**
IIR	**Butyl Rubber**
ML(١+٤)١٠٠°C	**Mooney Viscosity of Rubber**
mg/Kg	**Mille-Gram Per Kilogram**
MPa	**Mega-Pascal**
M_H	**Maximum Torque**
M_L	**Minimum Torque**
NR	**Natural Rubber**
PPM	**Part Per Million**
pphr	**Part per hundred**
SMR	**Standard Malaysian Rubber**
SSBR	**Solution Styrene-Butadiene Rubber**
SIR	**Styrene-Isoprene Rubber**
SBR	**Styrene-Butadiene Rubber**
SIBR	**Styrene-Isoprene-Butadiene Rubber**
TMQ	**Polymerized(٢,٢,٤-trimethyl-١,٢-dihydroquinoline)**
WT%	**Weight Percentage**
٦PPD	**(N-(١,٣-dimethylbutyl)-N-phenyl-p-phenylenediamine)**

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CHAPTER ONE

Introduction

١-١- Introduction:

Tires provide the connection between a vehicle and the road upon which the vehicle travels, and are designed to transfer to the road as much as possible, the acceleration, braking, and directional forces that generated by the vehicle. These forces act on the road by the friction existing between the tread of the tire and the rough surface of the road. In addition, a tread should also provide other functional features, such as a comfortable and smooth ride.

These characteristics should be maintained when the tire tread is used under unusual operating conditions, such as when the tire is driven at excessive speeds, over less than ideal road surfaces, or when ambient temperature reaches high extreme which is the problem in Iraqi weather**[١].**

So, the tread is the major component of the tire on which the tire life is mainly dependent **[٢].** To obtain good operating and handling characteristics of the tire tread in service with long mileage life, it is essential to have a **well-designed tread** under a variety of service (traveling) conditions. Well-designed tread has **two aspects** where the **first one** is associated with outer tread form (band & pattern) in order to maximize the friction between the tread surface and the road for example, when operating over dry, wet, snowy, sandy, and icy surfaces. The main **second one** which is the present work concern is related to the **well-design compounds** of tread which must fulfill efficiently the essential requirements for a typical passenger tire tread including: resistance to abrasion, and to the closely related phenomena of cutting and chipping; reduced rolling resistance; resistance to cracking and to crack growth; adequate flexibility at the lowest temperature encountered in the service; a sufficiently high coefficient of friction between the tread an the road to minimize slipping and skidding; adequate adhesion of the tread to the carcass; sufficient stability of the material with time so that excessive deterioration does not occur in the normal life of the tire; and a moderate hysteresis so that excessive temperatures do not develop in service **[٣,٤].**

Most of the mentioned tread requirements can be reflected by so many physico-mechanical properties tested in the laboratory by specific tests wherein provide an indication for each requirement. The test is mainly classified into two major tests concerning unvulcanized test which related to Rheogeical measurements, and vulcanized test which related to abrasion resistance, hardness, tensile strength, modulus of elasticity, elongation percentage, and specific gravity.

Thus, to execute the second **well-designed compounds** of tire tread, it is required to operate an **optimization study** for the **physico-mechanical** properties during **attempting** new rubber blends or compounding new elastomers with SBR, such as natural rubber NR,polybutadiene rubber BR, chloroprene (neoprene) rubber CR, and ethylenepropylene rubber EPDM those used in tread recipes, where the modification of rubber properties through blending has been used increasingly in order to obtain comparatively low cost materials with improved properties.

However, as it is known to those having skill in such field, achieving an optimization of one or more of above tread physico-mechanical properties by varying the composition of the tread recipe usually diminishes the efficiency of one or more of the other properties. This is what is called “The Dilemma of Incompatibility” **[٥]** which is encountered in this work.

Achieving an optimization for all of tread characteristics by rubber blends composition for the tire tread is therefore **a challenge**. Even this problem can be solved by **compromise**; mechanical properties of tire tread would be less than their ideal values **[٦]**.

A tread recipe* is comprised of materials utilized by the researcher, wherein the two major materials are the rubbers and the reinforcing agents who are playing a great role in modifying, improving, and optimizing the tread compound rubber properties.

In general optimization carried out on tire tread recipe could be done either by modifying Reinforcing Agents, or modifying Elastomers (Rubbers) or **both of them** which is the subject of **This Work**.

Historically, passenger tire treads are commonly composed of one rubber compound of a styrene/butadiene copolymer (elastomer SBR) **[٦],** which is basically used to promote the traction characteristics for the tire tread, and to fulfill the other tread requirements. Such rubber blends of SBR are conventionally used as the major elastomer or a single elastomer component of the tread rubber compound. This is because tread traction on the road surface is usually a significantly desirable feature for the tire and, also, the SBR in its uncured state is restively easy to process.

Accordance with previous characteristics of tread, using a singular SBR as **a base rubber** is not sufficient to provide correlation between the mechanical properties, and there is no enough chance to improve it in one hand, and this SBR which is recommended by Dunlop Co. for Iraq country without taking in account the hot environment especially in summer season in the second hand. So, it is claimed to do an **optimization** during modifying the rubber blends of the tread recipes by the addition of different types of elastomers which have low heat buildup and high heat resistance with different (phr)s to SBR in addition to use three kinds of carbon black with different (phr)s.

The selection of the type of added rubber to be used with SBR in tread recipe depends on the technical requirements of the tread, the properties attainable by compounding, and economic factors. **So from this point the Present Work is established**.

---

*Recipe where it comes has the same meaning of Mix and Blend.

١-٢- Background:

١-٢-١- Tire Parts:

Eight basic parts to tire are [٧]:

١. **The Tread**, which is composed of band and pattern. It is the wear resistant component consisting of ribs designed for noise suppression and traction and grooves directional control, and cool running.

٢. **The Sidewalls**, which are the portions of the tire between the beads and the treads compounded of rubber with high flex a control the ride and provide support.

٣. **The Shoulder**, which is the upper portion of the sidewall just bellow the tread edge and affects tire heat behavior and cornering.

٤. **The Bead**, which is the structure composed of high tensile strength steel wire formed into hoops which function as anchors in tire assembly onto the rim of the wheel.

٥. **The Plies**, which are layers of fabric cord extending from bead to bead to reinforce the tire.

٦. **The Belts**, which are narrow layers of coated tire cord or rubber encased steel cords located directly under the tread in resist deformation in the footprint (i.e., the tire s contact patch on the road) and to restrict the carcass plies.

٧. **The Liner**, which is a thin layer of rubber inside the tire which contains compressed air; and

٨. **The Chafer**, which consists of narrow trips of material around the outside of the bead that protect the cord against weather distributes flex above the rim, and prevents dirt and moisture from getting into the tire. The passenger tire parts can be seen in figure (١-١) [٧].

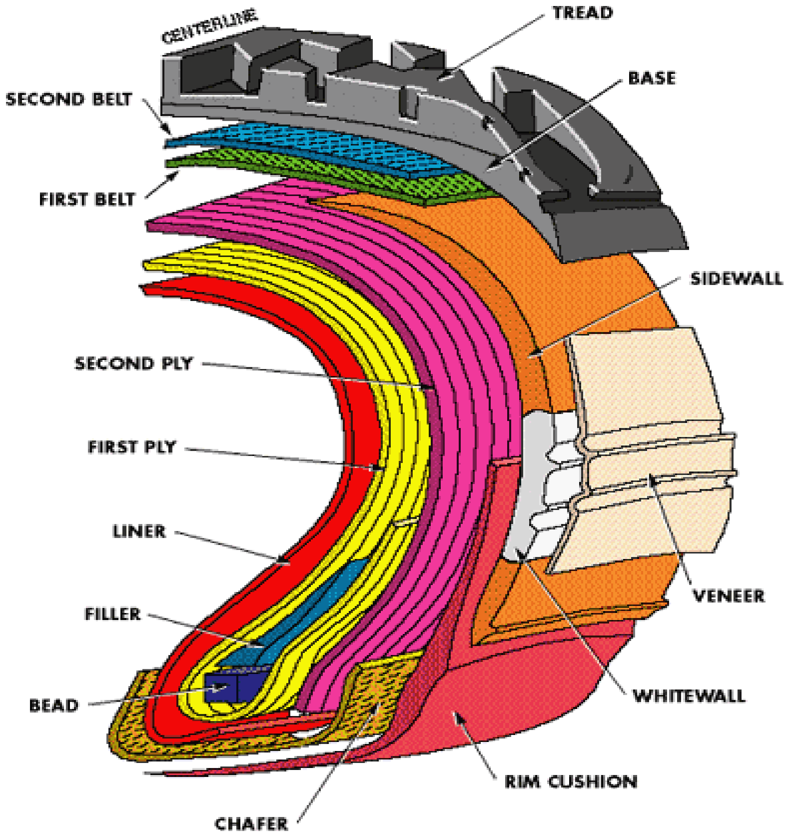


Fig.(١-١) Basic parts of tire.

١-٢-٢- Tread Pattern and Band

The performance properties of the tire depend on several characteristics of the tire construction **[٨]**. One of the construction characteristics of a tire is the **tread pattern** provided on its **tread band**. The tread pattern consists of a series of grooves criss-crossing the tread band both circumferentially and transversely, defining discrete solid blocks and ribs in the tread band as shown in fig.(١-٢) **[٩]**.The blocks and ribs are arranged to form a specific pattern. This pattern is varied depending on the expected use of the tire.

The tread pattern itself can also be optimized for different operating requirements. For example, the tread pattern can be designed to better abrasion resistance and to provide better handling in dry conditions, or can be designed to be more resistant to hydroplaning and to provide better traction on wet or snowy surfaces. The design of the tread pattern also has an effect on the comfort and smoothness of the ride of the tire. The tread pattern can help and maintain directional stability of the tire, and promote smooth and quiet rolling contact of the tire with road.

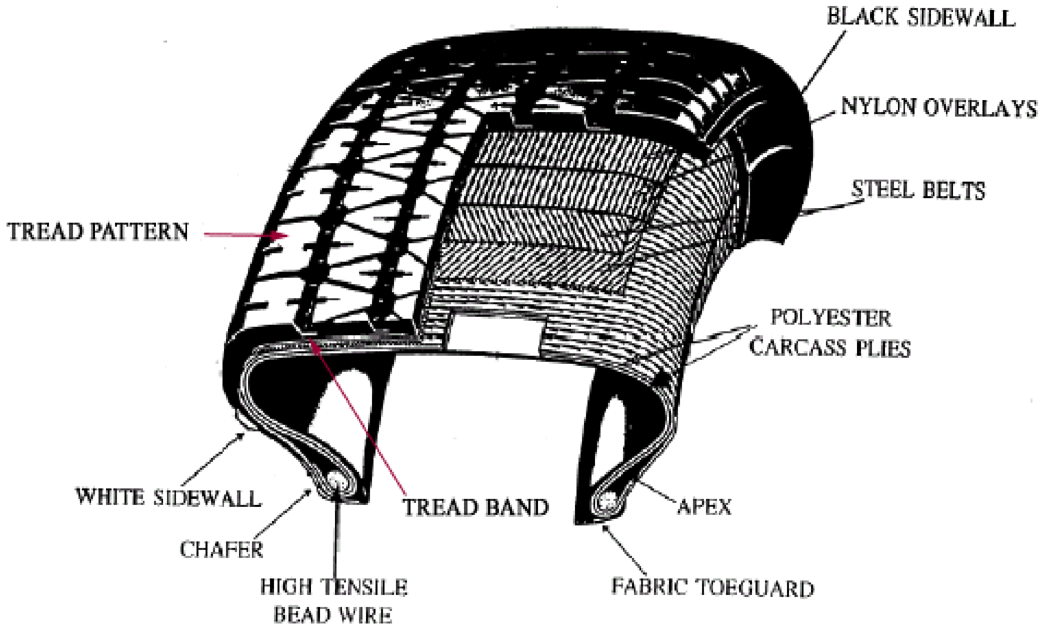


Fig. (١-٢) Tread band & pattern

١-٢-٢-١- Tread Pattern & Band Design Requirements

Once again, it can be emphasized that the conflicting requirements for tire tread designs of simultaneously providing good handling capabilities, a comfortable and smooth ride, good wear resistance, and low rolling resistance have been difficult to achieve **[٩].** This has resulted in various compromises in the design of conventional tire tread.

Compromises are made both in the materials used to construct the tread, especially the tread band of the tire, and also in the tread pattern that is formed on the tread band of the tire. Compromises are also made in the mechanical properties of the whole tread. The desire to provide good handling properties in all types of weather conditions and temperatures and to obtain a smooth and comfortable ride have thus required less than ideal selections in both the design of the tread pattern and in the compounds used to form the tread band.

It is also necessary for the tire tread to provide the vehicle with a smooth and comfortable ride. Tire treads that are designed for good handling tend to be made from stiffer compounds, which often give a harsher and less comfortable ride than softer, more pliable compounds. This can be a problem especially on long trips, because a harsher ride can contribute to driver and passenger fatigue **[٨,٩].**

Conventionally, attempts have been made to combine different elastomeric compounds in the construction of a tread band to meet the many demands imposed by **conflicting requirements for tire performance.**

١-٣- Optimization Concept

For a tire, it is often desired to optimize one or more of a tire tread mechanical properties which can naturally lead to optimize the tire tread characteristic, such as abrasion resistance, hardness, skid resistance, rolling resistance, and other properties by the choice of varying a tire tread's rubber composition**[٨]**.

Accordingly, for high performance tires, an increase in the rate of wear or abrasion of the tread might be acceptable where very good wet and dry traction of a tire tread is desired. Thus, rubber compound compositions intend to emphasize very good wet and dry traction for a tire tread may, however, often exhibit a relatively lower resistance to abrasion, higher rolling resistance and lower snow traction, and higher brittle point. These formulations usually contain a higher concentration of SBR as a major component of the recipe composition for such tire tread.

١-٤- COMPOUNDING:

Rubber compounding is essentially the science (and art) of selecting and combining ingredients to produce useful characteristics sufficient to perform satisfactorily under the conditions in which the end product is intended to be used. Perspective, the major factors influencing compounding decisions are cost, processing, and properties, not necessary that three factors are in the same importance [١٠]. In the rubber industry, the problem of selecting the basic raw materials for the preparation of a specific commercial product is usually assigned to the compounder [١١].

This background is necessary since some of the processes involve chemical reactions, of which vulcanization is the most important besides the reflected properties which is an engineering materials matter. In addition, chemical and physico-mechnical tests are necessarily applied to the final product for evaluating and analyzing the proper selection of the basic raw materials on one hand, and to evaluate and analyzing the final product properties as recommended on the other hand. Making a balance between them is the mission of the compounders and researchers, besides concerning with production of a serviceable product at a reasonable cost.

So, **compounding** can be defined as a process of mixing the basic raw materials in a certain recipe to obtain desired processing characteristics, ultimate properties of the finished product, and the cost control [١٢].

The **object of compounding** is to select the most suitable combination of materials in their correct proportion and to determine the treatment that the chosen combination shall undergo in the processes of mixing, forming, and vulcanization so that the finished rubber product is of the required

quality and is produced at the lowest possible **cost**. The operations of mixing, forming, and vulcanizing are the essential fabrication steps **[١٣]**.

١-٥ MATHEMATICAL CRITERION

The optimization which is based on experience and global standards is that which fulfilled the tire tread requirements, and is well known used in rubber technology. Furthermore, for engineering applications and, in order to obtain fruitful optimization based on compromises of most mechanical properties. It is suggested to use a new criterion considered as mathematical evaluation for this work. This criterion which is designed depending upon the reference **[١٤]**, has a product called Mujid Index. It is useful and can be used as a criterion in evaluation of performance for so many jobs in various fields. The basic use of such criterion recommended to consider the lower limits of Dunlop Co. standards as the base of optimization for mechanical properties obtained in this work. For having an equilibrium effect for each property requires multiplying by **characteristics value** suggested by the researcher with accordance of ASTMs and tire specifications of Dunlop **[١٥]** which can express the size and real effect of each property among others. Dividing by the lower limit of that property in standards would give the optimum base which can be used as the starting point of comparison for loading level in pphr for the rubber used in SBR tread recipe. This evaluation could be clarified by the table below:

Table (١-١) calculation table of mathematical criterion. [١٤]

Property (x)	**Lower Dunlop standard limit** (y)	**Characteristic value** (w)	**x/y for six steps (١٠-٦٠)pphr**	**(x/y)*w Multiplying by characteristics weight For each step.**
١.Tensile Strength (Mpa).	١٠.٠٠	٥	Property/١٠.٠	Property/١٠.٠×٥=**B١**
٢.Modulus (Mpa) at ٣٠٠٪ Extension.	٧.٠٠	٤	Property/٧.٠	Property/٧.٠×٤=**B٢**
٣.Elongation(%) at Break.	٣٥٠	٣	Property/٣٥٠.٠	Property/٣٥٠×٣=**B٣**
٤-HARDNESS (I.R.H.D)	٦٠.٠٠	٢	Property/٦٠.٠	Property/٦٠.٠×٢=**B٤**
٥-ABRASION Index	١٢٦.٠	٦	Property/١٢٦.٠	Property/١٢٦.٠×٦=**B٥**
٦-SPECIFIC GRAVITY	١.١١٥	١	Property/١.١١٥.	Property/١.١١٥×١)=**B٦**
TOTAL=MUJID Index				$\Sigma \mathbf{B}_i$

Mujid Index= $\Sigma \mathbf{B}_i = \Sigma (x_i/y_i) * w_i$ [١٤]

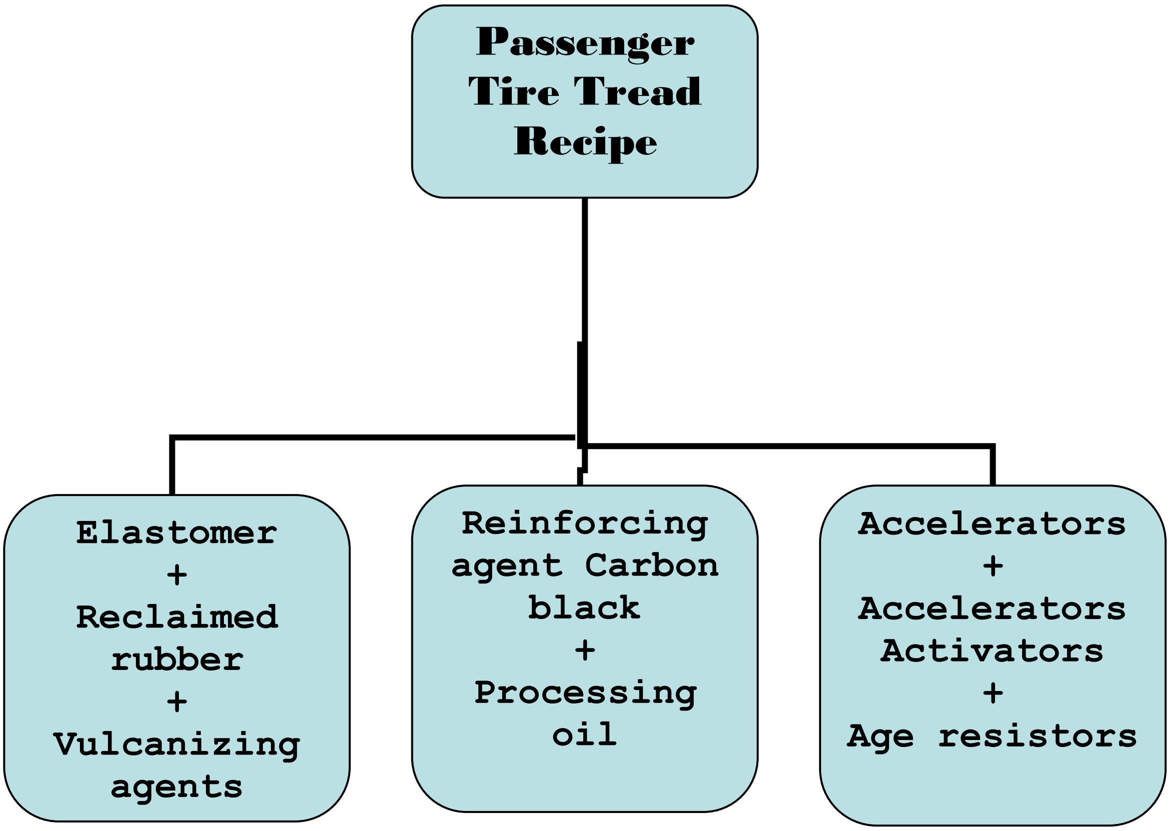
This calculations table is conducted on all mechanical properties for each elastomer mixed with base tread rubber compound SBR as it will be seen in appendix A, B, C and D. Increasing the values would give the degree of optimization with respect to the lower limits of standards even the control.

١-٦- TREAD RECIPE FORMULATION:

In order to aid the development of rubber compound, the various ingredients to be used are complied into a 'recipe'. Every recipe contains a number of components, each having a specific function either in processing, vulcanization, or end use of the product.

In general, the basic materials used in each recipe of tread rubber compound may be classified as follows and mentioned in the flow chart by the scheme (١-١) **[١٥,١٦]**.

١- The elastomers (natural, synthetic, reclaimed rubbers).
٢- Vulcanizing agents, accelerators with available (sulfur, organic peroxide, secondary vulcanizing agents, accelerators with available sulfur, metallic oxides).
٣- Accelerators.
٤- Accelerator activators and retarders.
٥- Age resistors (antioxidants, antiozonants, protective waxes).
٦- Processing aids, plasticizers, softeners, takifiers.
٧- Reinforcing agents.
٨- Inert fillers and diluents.
٩- Special purpose materials (abrasive, blowing agent, colors, deodorants, etc.).



Scheme (١-١) flow sheet of the main ingredients of tire tread recipe

All the ingredients used are normally given in amounts based on a total of ١٠٠ parts by weight of the rubber or combinations of rubbers. This notation is general listed as pphr (parts per hundred of rubber by weight). Thus, when comparing different recipes, the effect of varying any ingredient used is easily recognized when the physico-mechanical properties or processing characteristics are compared. So, it is recommended that many different materials with specific purposes are used in every recipe.

Before attempting to formulate the tread recipes it is of course essential to become familiar with the all basic properties of the various polymers currently available and to blend appropriate. It is also very carefully considered the following points:

١. The finished product must meet the service conditions required and it is, therefore, important to obtain all recommended information accurately, right at the start of the operations.
٢. It is also very important that the compound is designed at the right cost especially when used cheaper elastomers such as NR, BR, CR, and EPDM rubber, the exception is only with CR which is a little bit cost, however, it is used with very small quantities sharing BR for each recipe..
٣. Finally, any specified mechanical properties must be obtained consistently in the finished product and any improvement must be comparable with control and standard.

For the being work, it is intended to use new **formulations of passenger tire tread** considered as **recipe model** which can be illustrated in table (١-٢). This model is modified from the **control model** of tire tread recipe which is valid by the general state company for tires industries as shown in next table(٤-٣). The same ingredients are used in formulation table (١-٢) except with CR/BR formulation which included additional magnesium oxide (MgO) component. It is because vulcanization system of neoprene rubbers CR contains such material.

These new formulations of passenger tire tread carried out by blending or mixing certain types of rubber in pphr with the base rubber SBR. The addition of NR**,** BR**,** BR/CR**,** and EPDM rubbers to the base rubber SBR is performed by increasing the loading levels of those rubbers from ١٠ phr to ٦٠ pphr, by means of replacing an equal amount of SBR for each step by adding ١٠pphr.

Table (١-٢) shows formulations model for each replacing rubber filled with three types of carbon black as follows:

TABLE (١-٢) PASSENGER TIRE TREAD FORMULATIONS MODEL, SUGGESTED BY THE RESEARCHER INCLUDING FOUR RECIPES OF (١٠ TO ٦٠ pphr) OF ٤- Different Rubber Types WITH BASE RUBBER SBR-١٥٠٢.

	COMPOUND	pphr	pphr	pphr	pphr
١	**SBR ١٥٠٢**	٩٠-٨٠-٧٠-٦٠-٥٠-٤٠	٩٠-٨٠-٧٠-٦٠-٥٠-٤٠	٩٠-٨٠-٧٠-٦٠-٥٠-٤٠	٩٠-٨٠-٧٠-٦٠-٥٠-٤٠
٢	**Added Rubber**	**NR/١٠-٢٠-٣٠-٤٠-٥٠-٦٠**	**BR/١٠-٢٠-٣٠-٤٠-٥٠-٦٠**	**CR/BR/١٠-٢٠-٣٠-٤٠-٥٠-٦٠**	**EPDM/١٠-٢٠-٣٠-٤٠-٥٠-٦٠**
٣	Activator STEARIC ACID.	١.٥	١.٥	١.٥	١.٥
٤	Activator ZINC OXIDE.	٥.٠	٥.٠	٥.٠	٥.٠
٥	Anti-Ozonant (٦PPD).	١.٥	١.٥	١.٥	١.٥
٦	Anti-Oxidant (TMQ).	١.٠	١.٠	١.٠	١.٠
٧	PARAFFIN WAX	١.٠	١.٠	١.٠	١.٠
٨	PROCESS OIL	٢٠.٠	٢٠.٠	٢٠.٠	٢٠.٠
٩	***CARBON BLACK N-٣٣٠***	٧٠.٠	٧٠.٠	٧٠.٠	٧٠.٠
١٠	***CARBON BLACK N-٣٣٩***	٦٠.٠	٦٠.٠	٦٠.٠	٦٠.٠
١١	***CARBON BLACK N-٣٧٥***	٦٥.٠	٦٥.٠	٦٥.٠	٦٥.٠
١٢	Accelerator (CBS).	١.١	١.١	١.١	١.١
١٣	SULFUR	١.٧	١.٧	١.٧	١.٧
١٤	**MgO**	----	----	١.٦	----
١٥	Retarder (CTP.١٠٠)	٠.١٥	٠.١٥	٠.١٥	٠.١٥
١٦	Reclaim	١٣	١٣	١٣	١٣

١-٥- THE RESEARCH PROBLEM

As it is known, **climate in Iraq** is very **hot** especially in **summer season** wherein the temperatures reach more than ٧٠ ºC on the roads and more than ١٠٠ ºC in the tire tread rubber. Thus, high temperature would lead to deterioration of the tire and the recommended physico-mechanical properties specified by Dunlop may not fulfill the requirements of passenger tire tread through this hot environment. Therefore, to maintain good mechanical properties for tire tread versus such severe ambient temperatures, it is essential to do an optimization by the following trends

١. To try some other than SBR blends of rubbers that are known for their low-heat-buildup like natural rubber NR and/or elastomers that are known to be more temperature resistant such as chloroprene rubber CR and Ethylene-propylene rubbers EPDM or/and great heat stability and high abrasion resistance rubber like Polybutadiene rubber BR.

٢. To try medium-high structure carbon blacks (high abrasion furnace) at certain loading levels such as N-٣٣٠HAF, N-٣٣٩HAF-HS and N-٣٧٥HAF.

In general, for the optimization purposes, it is recommended to study the case of variation of the tread rubber compound which represents the base rubber SBR in the tread recipe. A variation is carried out by means of substitution of (pphr) for four elastomers instead of an equivalent (pphr) of SBR in tread recipe. Each elastomer is used singularly (except with CR which is shared with BR), for six runs of loading level (١٠-٢٠-٣٠-٤٠-٥٠-٦٠) pphrs with SBR of (٩٠-٨٠-٧٠-٦٠-٥٠-٤٠) pphrs.

١-٥-١ THE AIMS OF THIS W٠RK

The aims of this work are to optimize the effects of the blending and loading in pphr of various types of rubber with SBR, on physico-mechanical properties of passenger tire tread, where the SBR blended with:

١. Natural Rubber **NR**,

٢. Polybutadiene Rubber **BR**,

٣. Neoprene Rubber **CR** mixed with **BR** , and

٤. Ethylene-propylene Rubber **EPDM**,

By using three kinds of carbon black at specified pphr in each trend:

١. High Abrasion Furnace **N-٣٣٠** HAF,

٢. High Abrasion Furnace High Structure **N-٣٣٩** HAF-HS, and

٣. High Abrasion Furnace **N-٣٧٥** HAF as reinforcing agents where these recipes are represented by four models as illustrated by tables (١-٢).

This process is carried out by blending SBR with the mentioned four rubbers and keeping the other tread recipe ingredients those mentioned in control recipe table (٤-٣) fixed at their specified pphr.

To evaluate the results of this work obtained by these four formulation models, it is essential to compare with control properties being taken from using SBR lonely (١٠٠٪by weight or ١٠٠pphr) as the base rubber in the control tire tread recipe which clarified by table (٤-٤), and with other standards of Dunlop Co. and state Co. of Babylon Tire Industry as shown in table (٤-٢). In addition, mathematical criterion is used for evaluating the compromising mechanical properties of tread rubber compounds as indicated in previous table (١-١).

CHAPTER TWO

literature Survey

٢- LITERATURES SURVEY:

Many improvements have been made over the years in tread of pneumatic tires used on a car, sport utilities, vehicles, and other types of vehicles. While ٢٠,٠٠٠ miles was once considered excellent life for a passenger car tire, improved tire tread manufacturing and components mainly the rubber blends have now extended this by a factor of two to three under normal conditions.

Experimental studies have been done on tire tread formulations surveyed as follows:

Takiguchi [١٧] reported carbon black-filled tire treads of BR/NR blends with butyl rubber IIR, Bromo-butyl rubber BIIR, or chlorinated-butyl rubber CIIR improved the modulus and hardness which results in improving of the braking and traction performance on wet road surfaces compared to a SBR tread. Rolling resistance was improved, wear resistance was maintained.

Keller [١٨]studied carbon black-filled SBR/CIIR blends showing that as the percentage of CIIR was increased, rebound and elongation values decreased linearly and skid resistance increased linearly. Tire testing revealed that ٣٠phr CIIR was needed for a ٥٪ improvement in skid resistance. However, the relative tread wear was ٤٪ lower than the SBR/BR control in a low-severity road wear test.

Hirakawa and Ahagon [١٩]evaluated carbon black-filled BR/NR/CIIR treads, concluding that lower hysteresis and equal or better wet skid resistance could be obtained by using CIIR.

Zanzig and his team [٢٠]found that a pneumatic rubber tire having a tread of a rubber composition comprised of SBR and cis ١,٤- polybutadiene rubber are typically compatible and therefore, for the rubber compositions based upon such compatible rubber blends, low temperature physical properties are typically sacrificed for higher temperature physical properties of the rubber composition. For example, a tire tread wear property may be typically comprised with an increase in wet traction property when such compatible rubber blend is used for a tire tread rubber compositions. Further more, the cold brittle point temperature, tensile strength, modulus and hardness of the tire tread rubber composition may typically be raised with an increase in wet traction when a compatible blend of such elastomers is used for the tire tread rubber composition to render the tire tread less useful at very low operating temperatures.

Halasa, A. Farhan **[٦]** clarified in practice, the addition of a minor amount of natural rubber NR to the relatively high styrene containing styrene/isoprene copolymer elastomer SIR, in rubber composition, is considered to be normally useful to enhance uncured rubber composition process ability with minimum processing oil and processing additives which are considered to adversely offset abrasion resistance, and also considered to be important to contribute to tear resistance property and other mechanical properties for the tread rubber composition.

Takino and co-worker **[٢١]** reported that tire tread of SBR with CIIR/BIIR displayed the highest wet traction. Laboratory measurements showed that the tread had the highest volume loss.

Zanzig D., Aaron **[٢٢]**conclude that, use of the combination of BR (in the minority) and SIR (in the majority) elastomer blend is considered to be important in order to optimize, for the tire tread, both abrasion resistance (to enhance tread wear), and hysteresis (to enhance traction).

Yamaguchi and co-workers **[٢٣]**, used bromo-butyl rubber BIIR in blends of BR/NR to improve the balance of wear resistance measured in the laboratory, coefficient of friction on ice and tire operating stability or on wet road surface during enhancing of tensile strength, modulus, elongation and hardness of the tire tread rubber composition.

Fusco and Young **[٢٤],** reported that the blends of SBR with BIIR in carbon black-filled compounds increased tire wet traction, but decreased tread wear.

Wilson **[٢٥]** showed increased compound wet traction based on laboratory dynamic properties using SBR and BR blends with BIIR; however, abrasion loss also increased. He concluded that poor abrasion is an inherent property of butyl rubber.

Mroczkowski **[٢٦]** studied blends of BIIR, star-branched bromo-butyl rubber (Br-SBB) and brominated isobutylene-co-para-methylstyrene (BIMS) in carbon black/silica-filled SBR/BR compounds. Increased (**tangent delta)**[*] values at low temperatures (-٣٠ to ١٠ºC) and decreased tangent delta values at higher temperatures (>٣٠°C) were obtained compared to a carbon black-filled SBR/NR/BR tire tread; laboratory abrasion resistance was comparable.

[*] tangent delta; **tan δ=G"/G'** Where **G"** and **G'** are the loss and elastic moduli, this relation is used with dynamic modulus of tread rubber compound, where increasing of tangent delta means increasing of rolling resistance and decreasing of abrasion resistance and vice versa.

Costemalle, et al. [٢٧] reported that use of BIIR or BIMS increased the tangent delta values at (٠ºC) of carbon black-filled emulsion- SBR (ESBR) and solution-SBR (SSBR)/BR compounds.

Zanzig, et al. [٢٨] evaluated BR, isoprene-butadiene rubber IBR, and /or SBR blends with BIMS in silane-coupled silica-file compounds, and found increased tangent delta values at (٠ºC).

Kadomaru and Nakada [٢٩] increased tangent delta at (٠ºC) using ١٥phr BIMS in SBR.

Matsui and Ohhashi [٣٠] improved tire snow/ice wet performance while maintaining wear resistance using BIMS with SBR.

Hojo [٣١] used with carbon black and silane-coupled silica-filled NR, a hydrazide compound with BIMS to lower the heat generation and improve the wet gripping property.

Blok and his companions [٣٢] dealed with improving the process ability of the tire tread formulations which made by blending poly-butadiene rubber BR with high glass transition temperature, with high cis ١,٤-polybutadyiene rubber of low transition temperature that offer ultra low rolling resistance without sacrificing skid resistance, good traction or tread wear characteristics.

Yoshihisa and Kiyoshige [٣٣] studied silane-coupled silica-filled SBR/BIMS treads showing improved wet skid performance with comparable laboratory abrasion.

Heinrich, Gert, Hermann and others [٣٤], their studding is directed to a rubber compound for tire treads rubbers, in particular, tire tread rubbers of racing tire, that can be produced easily and in manner less harmful to the environment and that provides high skid resistance (high coefficient, good grip) of the tires made wherefrom, combined with reduction in the hardness at elevated temperatures.

The rubber compound blends comprised of styrene-butadiene co-polymer may be a solution polymerized as SSBR or emulsion polymerized styrene-butadiene copolymer ESBR or mixtures of SSBR and ESBR may be used as well. Other type of rubbers can be compounded in tread recipe, such as ethylene-propylene-diene rubber EPDM, butyl rubber IIR, styrene-isoprene-butadiene ter-polymer SIBR.

Sung W. Hong, **[٣٥]** studied high vinyl content polybutadiene and SBR which provide improved wet traction while maintaining low rolling resistance. Solution styrene butadiene rubber (SSBR) and chemically modified solution styrene butadiene rubber have been developed specifically for lower rolling resistance and better wear resistance.

Ezawa **[٣٦]** concluded that a single type or a combination of two or more types of natural rubber NR and or synthetic diene-base rubber ((examples of the synthetic diene-base rubber include synthetic poly-isoprene rubber (IR), poly-butadiene rubber (BR), styrene-butadiene rubber (SBR), acrylonitrile-butadiene rubber (NBR), chloroprene rubber (CR) and butyl rubber (IIR))) may be used as a component of tire tread. This rubber composition will provide tread with improved abrasion resistance while the excellent performance wet roads and low fuel consumption exhibited by a tread using a conventional rubber composition containing aluminum hydroxide.

Sabey & Lupton **[٣٧]** showed that butyl rubber compounds had the highest friction values and the lowest abrasion resistance on a variety of surface textures at all temperatures studied compare to NR, NR/SBR, SBR, oil extended-SBR, BR & EPDM elastomers. The skid resistance of the IIR compound maximized at about ٣٠ °C.

Heinrich **[٣٨]** reported that IIR has a low glass transition temperature (Tg), but very good wet skid resistance based upon laboratory wet friction coefficient measured using pendulum skid tester. IIR is a notable exception to the the general rule that the higher the (Tg), the higher wet skid, tensile strength, modulus, the lower elongation, and abrasion resistance.

Kikutsugi [٣٩] showed superior grip and durability for a CIIR/SBR blend in high speed running tires as it is come from ultra-tensile strength and modulus.

Hara and Muraoka [٤٠] reported that use of of BIMS increased wet grip performance and the "feeling of driver" in tire tests.

Noriko, et al. [٤١-٤٢] studied silane-coupled silica-filled BIIR/SBR and BIMS/SBR treads showing improved wet skid performance with comparable laboratory abrasion.

Walter, et al. [٤٣-٤٤-٤٥-٤٦-٤٧] reported BIMS use in place of SSBR in tread compounds improved the laboratory dynamics properties predictive of potential wet and winter traction, and rolling resistance. An all season passenger tire tread was modeled on the silica-filled BR-SSBR passenger tire tread formulation, and a passenger winter tire tread was modeled on formulations containing BR/NR٣٤, BR/NR/SBR, BR/NR/SSBR and BR/NR/HIIR. This investigation evaluates the use of various isobutylene-based elastomers with BR/NR winter passenger tire tread in both carbon black-filled and coupled-silica-filled systems. Particular emphasis is placed on the temperature dependence of tread compound dynamic properties obtained when the isobutylene-based elastomers are used, and effects on laboratory abrasion resistance.

Wei and Briggs [٤٨] reported that the rolling resistance of a vulcanizate of given composition,(NR٢٠, SBR٣٠,BR٢٠, SBR-LX٣٠, carbon black ٥٠ phr) based on a mixture of elastomers, can be reduced by masterbatching the rubber individually, with carbon black, before mixing. The rolling resistance is minimized when some fraction of the total rubber in the compound contains little or no carbon black while the remaining fraction has a carbon loading that higher than average. When each of the constituent polymer masterbatches contains an equal loading of black, rolling resistance and hardness tend to be high.

Experiments have also shown that SBR-LX cancan replace part of the natural rubber in a conventionally mixed compound with no reduction in rolling resistance, in spite of the fact that SBR is known to show higher hysteresis than natural rubber . it appears that the high initial Mooney viscosity of SBR-LX (high because of the labile cross-links) delays the acceptance of carbon black during the initial stages of mixing. Later, when the labile cross-links are broken, much of the carbon black has already become associated, and tends to remain, with the other polymers present in the mix. A similar effect was observed in the individually masterbatched components.

Stamhuis, et al. **[٤٩]** showed that CARIFLEX, S-١٢١٠ and S-١٢١٥ which are two solution-polymerized styrene-butadiene rubbers (S-SBRs) can be used for application in tire treads. S-١٢١٥ imparts a high wet grip and a low rolling resistance to tire tread vulcanizates. Howevere, due to its comparatively high glass-rubber transition temperature (Tg), this rubber leads to reduced abrasion resistance when compared to S-١٢١٠- based vulcanizates in a similar recipe. The latter rubber also gives a low rolling resistance due to high elongation and low tensile strength and modulus, but its low Tg results in a reduced wet grip in comparison to S-١٢١٥-based vulcanizates.

The vulcanizates properties of these of two rubbers can be adjusted by blending with other rubbers ,e.g.,natural rubber, polybutadiene rubber or high-styrene emulsion polymerized styrene-butadiene rubber.

A special case is a blend of the two S-SBR types with each other, which constitute a miscible pair. This enables the compound and vulcanizates balance of properties to be tailored as if they were based on a sole rubber intermediate between S-١٢١٥ and S-١٢١٠ by choosing the appropriate ratio of the two rubbers.

Cohen [٥٠-٥١] reported that the copolymers of isobutylene and cyclopentadiene improved the wet skid resistance of a carbon black-filled SBR/BR tread compound.

Rogers [٥٢] reported that the use of brominated isobutylene-co-para-methylstyrene and silane-coupled silica-filled in butadiene rubber/SBR compounds afforded increased tangent delta values at ٠ ºC and decreased tangent delta values at ٦٠ ºC in the laboratory tests, with only slight reductions in tread wear based on tire tests using sectional retreads.

Kuman and Chandra [٥٣] showed the influence of high *Cis* Polybutadiene rubber of different catalytic origins on physico-mechanical behavior of tire tread compounds, where they found that the ١, ٤ cis content of Cobalt-polybutadiene (Co-BR) and Nikal- polybutadiene (Ni- BR) was comparable. Stress-strain properties are better for Co-BR than that of the other. Abrasion loss was found to be comparable for all the BR studied. Co-BR showed better fatigue properties and a comparable heat development.

Guha & Biswas [٥٤] disclosed that there are different types of elastomers available for usage in high heat resistant compound. These types of elastomers are used a lone or after blending with two or more of such elastomers for high heat resistant application depending on the field service conditions [٥٥] these types of elastomers are generally known as thermo-stable elastomer. They found that the retained physico-mechanical properties of the rubber compounds after high temperature aging tests are greatly influenced with the introduction of silicone rubber EVM (Vinyl type) in blends with EPDM rubber. It can be seen from the physico-mechanical properties of the compounded rubber that the unaged properties of blends generally meet all the requisite criteria.

CHAPTER THREE

Materials Used

In

The New

Tread Recipe

٣- Materials Used In Tread Recipe Formulation:

٣-١- Elastomers:

The basic materials used as a matrix materials in tread recipe formulation are the following rubbers:

٣-١-١- Styrene-Butadiene Rubber SBR-١٥٠٢:

The most important synthetic rubber and the most widely used rubber in the entire world is SBR, a copolymer of STYRENE and BUTADIENE. Although the styrene-butadiene elastomers were originally manufactured during the World War II years as a rather mediocre replacement for the natural rubber, which was unavailable, they now stand on their own merits. A major reason for their popularity is cost. Quality, however, is also important since present day styrene-butadiene rubber often has better abrasion characteristics, and better crack initiation resistance than natural rubber. With their lower unsaturation styrene-butadiene rubbers also have better heat resistance and better heat aging qualities [٥٦].

In general, SBR can be produced by three polymerization techniques, cold emulsion, hot emulsion and solution polymerization. SBR١٥٠٢ which used in this work is a cold emulsion copolymer of styrene and butadiene prepared at a low temperature, usually ٥°C .It is also called 'cold SBR' which has properties superior to those of 'hot SBR' especially in tire products including tire tread.

Polymerization for manufacturing SBR carried out by the chemical reactions by which the monomer molecules of styrene and butadiene are converted into polymer (SBR) molecules as shown bellow [٥٧];

Butadiene + Styrene → SBR

$(CH_٢=CH-CH=CH_٢)+(CH_٢=CH)\longrightarrow[\sim CH_٢-CH=CH-CH_٢ \quad -CH_٢-CH\sim]_n$

$\qquad\qquad\qquad\quad | \qquad\qquad\qquad\qquad\qquad\qquad\qquad |$

$\qquad\qquad\qquad C_٦H_٥ \qquad\qquad\qquad\qquad\qquad\qquad C_٦H_٥$

SBR produced by emulsion polymerization usually contains about ٢٣٪ styrene randomly dispersed with about ٧٧٪ butadiene in the polymer chain. Most of the improving physico-mechanical properties and lower glass transition temperature of SBR is related to the high level of ***Cis***, structure in the polymer, conversely to the vinyl structure**[٥٨]**.

SBR used in the tread recipe which is manufactured by Turkish company PETKIM should fulfill the following requirements **[٥٩]**:

Characteristics	**Unit**	**Requirements**
Specific gravity (Typical)	$gm/cm^٣$	٠.٩٢
Volatile matter	%	٠.٧ maximum
Ash content	%	١.٠٠ maximum
ETA extract	%	٤.٧٥- ٧.٧٥+stabilizer
Bound styrene	%	٢٣.٥ ± ١.٠ maximum
Organic acid	%	٤.٧-٧.٢
Stabilizer	%	Advised by supplier
Viscosity ML(١+٤) ١٠٠°C		٥٢±٣

٣-١-٢- Natural Rubber NR (SMR٢٠):

NATURAL rubber is a naturally occurring ***Cis***-poly-isoprene.

$$[\sim CH_{٢}\text{-}\underset{\displaystyle CH_{٣}}{\underset{|}{C}} = CH\text{-}CH_{٢} \sim]_n$$

It consists of long, very regular hydrocarbon chains. At normal temperatures these chains are in constant thermal motion, which in the vulcanized rubbers the source of its elasticity. At lower temperatures, two phenomena occur which prevent this motion. At very low temperatures (about -٧٠°C) thermal motion stops and the rubber becomes glass-like, with rigidity typical of other glasses. The onset of this phenomenon occurs at somewhat higher temperatures and manifests itself by an increase in stiffness and hysteresis. The low glass transition temperature of natural rubber enables it to be at lower temperatures than many other rubbers **[٦٠,٦١]**.

The regularity of the molecular structure of natural rubber enables it to crystallize relatively easily at sub-ambient temperatures, also causing an increase in stiffness and hysteresis **[٦٢]**. If a rubber crystallizes in the strained state, complete recovery on removal of the load will not occur, and set will be observed **[٦١,٦٢]**. The rubber will recover, however, when the temperature is raised sufficiently to melt the crystals. The rate of crystallization is greatest at about -٢٥°C and increases if the rubber is in the strained condition. The rate can be controlled by varying the vulcanizing system and the conditions (time and temperature) of vulcanization **[٦٢,٦٣,٦٤]**.

The susceptibility of natural rubber to crystallization is not without its advantages, as strain-induced crystallization is responsible for the high strength of natural rubber vulcanizates over a wide range of temperature.

The high strength properties combined with the low hysteresis make natural rubber a valuable general-purpose rubber. When suitably compounded, vulcanized rubbers prepared from natural rubber can be used over a temperature range of -٦٠ to ١٠٠°C or more.

Raw natural rubber is a tough resilient material at ambient temperature, but under stress it undergoes plastic or irrecoverable flow, particularly at high temperatures. By introducing a relatively small number of chemical links between individual polymer chains the plastic flow of the rubber is overcome, while the elastic recovery of the material is unimpaired. The insertion of these chemical cross-links is the process known as vulcanization **[٦١]**.

In addition to the low cost of NR, selection of this rubber to be used in **tire tread** for the **present work** is mainly referred to the application of NR in rubber products which gives the product very useful technical characteristics of very good tensile strength, high resilience, excellent flexibility and resistance to impact and tear, **low heat-build-up** which is the main reason after its selection for such optimization, plus good 'green' strength and building tack. However, NR is less resistant to oxidation, ozone, weathering and a wide range of chemicals and solvents, mainly due to its unsaturated chain structure and non-polarity **[٦٠]**.

This rubber has the following requirements **[٥٩]**:

Characteristics	**Unit**	**Requirements**
Color coding		red
Specific gravity	Typical	٠.٩٢ gm /cm٣
Volatile matter	%	٠.٥ maximum
Ash content	%	١.٠٠ maximum

Acetone extract	%	٢.٠-٤.٠
Dirt (٤٥ microns)	%	٠.٢ maximum

٣-١-٣- POLY-BUTADIENE RUBBER BR:

POLYBUTADIENE rubber BR can be prepared in either emulsion or solution systems. Most is produced by solution polymerization. Three types of solution polymerized polybutadienes structure, those are high ***Cis,*** medium ***Cis***, and ***Cis*** polybutadiene rubber, wherein the last type used in the tire tread recipe related to this work as seen in the following scheme:

$$[\sim CH_{٢}-CH=CH-CH_{٢}\sim]_n$$

The mentioned structures also consist of mixed additional structures of trans and vinyl **[٦٥,٦٦]**. Present solution-polymerized ***Cis*** BR represents a compromise between process ability and performance. Because narrow molecular weight distribution and linearity, it displays low hysteresis loss, high resilience, and high abrasion resistance. However, such polymer does not mix well, and usually require special packaging because of high cold flow **[٦٥]**. To obtain easy processing compounds, and to improve desirable properties, BR may be blended with some rubbers like NR **[٣,٤]**.

Polybutadienes (BRs) rubber is usually vulcanized with sulfur curing system whether used alone or in blends **[٢١]**. BR is seldom used a lone, it is usually employed in the blends with other elastomers where it provides the desirable properties of the heat buildup and good resilience. It has excellent low and high temperature flexibility. Solution BRs are more resistant to oxidative scission than other rubbers and has great heat stability which can provide longer service life. This has become increasingly important in tires, which are subjected to continuous high temperature dynamic conditions **[٦٥,٦٧]**.

Tire service performance data for BR/SBR blends show how BR plus increased black and oil levels can be used to obtain better abrasion and chipping resistance than will SBR alone **[٦٨]**. As mentioned before, excellent

service properties of BR is after selecting this rubber in **our work** besides, it is usually cheaper than SBR.

BR to be used in passenger tire tread formulation which is manufactured by Turkish **PETKIM** has the following specifications **[٥٩]**:

Characteristics	**Unit**	**Requirements**
Specific gravity	Typical	٠.٩٠ gm /cm^{٣}
Volatile matter	%	٠.٧٥ maximum
Ash content	%	٠.٢٠ maximum
ETA extract	%	١.٠٠ max.+stabilizer
Stabilizer	%	As advised by supplier
Butadiene configuration.		
-*Cis*	%	٤١ typical
-*Trans*	%	٤٩ typical
-*Vinyl*	%	١٠ typical
Viscosity ML (١+٤) ١٠٠°C		٤٣±٥

٣-١-٤- Neoprene Rubber CR (Chloroprene):

Basically PlyCloroprene was introduced in ١٩٣١ by Du Pont and Thikol Corp., but it was unsatisfactory for tire when used alone especially in USA & Europe. This is because of it's poor mechanical properties at low temperatures **[١٠]**.

NEOPRENE is the generic name to chloroprene polymers (٢-chloro-١,٣-butadiene),

$$[\sim CH_{٢}-\underset{|}{C}=CH-CH_{٢}\sim]_{n}$$

The monomer, from which all Neoprenes are made, is produced by two major processes, the first one used acetylene, and the other used butadiene.

Today, most chloroprene is produced from butadiene. Neoprene CR type (GRT) which was used in this work, is emulsion copolymer composed of ٢, ٣-dichloro-١, ٣-butadiene and is not peptizable.

Neoprene GRT is a sulfur-modified, crystallization-resistant, and stabilized with a thuiram disulfide and a non-staining antioxidant. Crystallinity is an inherent property of poly-neoprene rubbers **[٦٩,٧٠]**. It varies in degree as the neoprenes crystallize more readily and to a greater extent than others.

Carbon blacks filler are used extensively in the loading of practical neoprene compounds. Furnace blacks are used for greater mechanical properties.

Although Neoprene is not widely used in manufacturing tire tread because it is often costly and has unfavorable low temperature properties, it is used in **this work** as a mix with BR at very low content to enhance weather properties, improve abrasive & wear resistance and to fulfill the hot environment requirements. As it is known, most of the Iraq country roads are covered by asphalts except that in high express ways therefore, it is required to use neoprene rubber in **tire tread** where oil resistance is a desired quality especially with elevated temperature in summer season which may reach more than (١٠٠ ºC) in tire tread rubber during tire cycling.

Thus, this type GRT and some other neoprenes are general purpose where they used in a variety of elastomeric applications, particularly molded and extruded goods, **tires**, coated fabrics and gaskets **[٧١]**.

Processing techniques for neoprene are similar to those used for other general purpose rubbers. The most important consideration is to avoid pre-cure or scorching. This can be done by holding heat history to minimum through the use of short mixing cycles and by mixing at the lowest possible temperatures[٧٢].

CHAPTER THREE

The vulcanization of neoprene compositions is dependent upon the presence of a metallic oxide; zinc oxide and magnesium oxide are used in most neoprene formulations. CR type GRT must be fitted with following requirements [٥٩]

Characteristics	Unit	Requirements
Physical form	Chips	----
Color	Light amber	----
Odour	Mild	----
Specific gravity	Typical	١.٢٣ gm /cm[٣]
Volatile matter	%	< ١.٠٠ maximum
Ash content	%	< ١.٠٠ maximum
ETA extract	%	٥.٠٠ maximum
Moisture	%	< o.٥
Crystalline rate	slow	----
Viscosity ML (١+٤) ١٠٠°C		٣٦-٥٥

٣-١-٥- Ethylene-Propylene Rubbers EPDM:

ETHYLENE-PROPYLENE rubbers are synthetic polymers of low density which have grown rapidly to the status of general-purpose rubbers though their outstanding resistance to oxygen, ozone and heat, coupled with ability to accept high loading of reinforcing agents, fillers, and plasticizers **[٧٣]**.

They are designated by ASTM as “M” class rubbers, having a chemically saturated polymer chain of poly-methylene type which accounts for their excellent resistance to degradation. The polymers EPDMs are polymerized from ethylene, probylene and a small percentage of a diene which provides unsaturation in side chains pendant from the saturated “back bone” **[٧٤]**. The type we have used is poly (ethylene- Co- Propylene- Diene), Polysar EPDM ٣٤٥ which is a ter-polymer of ethylene, propylene and a non-conjugated diene. The diene is ethylidene-norborene ENB. The typical ethylene/propylene ratio is ٥٩/٤١ and the ENB contents are considered “Medium” for EPDM rubbers as shown bellow **[٧١]**:

$$[(\sim CH_{٢}\text{-}\ CH_{٢} \sim)_{٣٧}(\sim CH_{٢}\text{-}\ \underset{\displaystyle CH_{٣}}{\underset{|}{C}}H\text{-}CH) \sim \text{diene} \sim]_n$$

As the name implies, the two principle raw materials for ethylene-propylene rubbers are ethylene and propylene. Both are readily available by reason of their very large volume use in plastics, fiber, etc. Several of these two monomers are used depending on the intended end use of the rubbers.

High ethylene concentration in EPDMs results in highly thermoplastic characteristics. At room temperature, the raw rubbers are very hard and

would appear to have extremely high moony viscosities. However, at mixing and processing temperatures; they soften to 'normal' properties**[٧٥]**. In the same fashion, compounds of high ethylene EPDMs have high uncured 'green strength' when cool and they mix, extrude, and calendar easily at elevated temperatures.

As is true with most elastomer, those EPDMs having a narrow bell-shaped distribution curve of molecular weights will yield the highest physico-mechanical properties. However, they are more difficult to mix on open mills, and compounded stocks may extrude or calendar more slowly than desired. Some EPDMs achieve better processibility by including some polymer of medium molecular weight such as SBR.

The later generation EPDMs are faster curing than those which came first, so that the majority of those types now in regular use will cure readily in allotted cure cycle times without difficulty. If it is necessary to obtain even faster cure rates, or to blend EPDM with other unsaturated polymers without loss of curing speed, EPDMs with higher concentrations of the diene, ethylidene-norborene ENB, are used. However, relatively slow curing EPDMs can be blended with other polymers, as in the case of tire white sidewall compounds and tire tread compounds of **this work**, to lend ozone resistance and high temperature resistance. Likewise, high ethylene EPDMs offer special blend properties with other polymers. Generally speaking, ٣٠ ppm of an EPDM replacing an equal amount of NR or NBR in a formulation will impart satisfactory ozone resistance to the vulcanizate **[٧١,٧٣,٧٥]**.

It is essential to know that Ethylene-propylene rubbers are used in tire compounds, mainly in the cover strip and white sidewall portions. The substitution of EPDM, and Royalene ٣٠١T, in particular, for part of the unsaturated polymers in these compounds improves the static and dynamic cracking resistance. Furthermore, an all-EPDM **tire** has been manufactured **[٧٦]**.

Besides, low cost products due to low specific gravity of EPDMs, the combination of unusual weather and **heat resisting properties**, variety of grades, and ability to accept high loading of filler, reinforcing agents, and oils have led to widespread uses of EPDMs including **tire tread compounds** which is aspect of **this work**.

The following requirements are fitted to Polysar EPDM rubber **[٥٩]**

Characteristics	**Unit**	**Requirements**
Physical form	Kg	Bale
Color		White to Gray
Odour	Slight	----
Specific gravity	gm /cm٣	٠.٨٦ gm /cm٣
Volatiles matter	%	٠.٧٥maximum
Volatiles at ١٠٥°C	WT%	٠.٣٠
Ash content	%	٠.٣٠ maximum
Ash at ٥٥٠°C	WT%	٠.٣٠
Viscosity ML (١+٨) ١٠٠°C		٣٠-٤٠
Stabilizer (A)		٠.١٥
Flash point	°C	>٣٠٠
Free Monomers	ppm	<١٠ Ethylene
	ppm	<١٠ Propylene
	ppm	٨٢٥ Diene
Antioxidant	PIIR	٠.١

٣-١-٦- Reclaimed Rubber.

A descriptive definition of reclaimed rubber is the product resulting from the treatment of ground vulcanized scrap rubber tires, tubes and miscellaneous waste rubber articles by the application of heat and chemical agents, followed by intense mechanical working, whereby a substantial "de-vulcanization" or regeneration of the rubber component to its original plastic state is effected, thus, permitting the product to be compounded, processed and re-vulcanized. Reclaiming is essentially de-polymerization; the combined sulfur is not removed. The product is solid for use as a raw material in the manufacture of the rubber goods with or without admixture with natural or synthetic rubber [٧٧].

A scientific definition of de-vulcanization, based on a definition of vulcanization by Ira Williams [٧٨], is: De-vulcanization is a change in vulcanized rubber which results in a decreased resistance to deformation at ordinary temperature. This definition disregards entirely any chemical agents or chemical actions involved. It requires only that the vulcanized rubber lose its elastic properties and become less resistant to compression, stretching or swilling.

The choice of the relative proportions of new and reclaimed rubber to be used in a compound depends completely upon its intended use. The of reclaimed in tire treads always results in a sacrifice of quality, e.g., abrasion resistance, whereas in carcass and bead insulations, reclaim produces no sacrifice in quality [٧٩].

Reclaimed rubber can play an important part in the function of general or specialized compounds especially as a softening agent with natural rubber.

Before the War it was used as an extender or cheapening agent, but at the present time it is used in its own right to confer special processing characteristics to specific compounds, e.g. to reduce nerve during processing,

to improve adhesion in certain rubber to metal bonds, and also to achieve good tack in friction compounds for use in so many rubber industries. Present day reclaim contains a fairly high percentage of synthetic rubber **[٨٠]**.

Reclaimed rubber available produced from whole tires manufactured in the site which represent the mixture of SBR, NR, BR and IR. It has the following characteristics **[٥٩]**;

Characteristics	**Unit**	**Requirements**
Specific gravity	gm /cm^{٣}	١.١٦ gm /cm^{٣}
Volatiles at ١٠٥°C	WT%	٠.٣٠
Ash at ٥٥٠°C	WT%	١٢.٠٠ maximum
Viscosity ML (١+٤) ١٠٠°C		٣٠-٨٠
Total hydrocarbon rubber	%	٤١-٤
Isoprenic rubber content (NR&BR)	%	٤٠ minimum
Carbon black	%	١٨-٢٨
Acetone extract	%	١٠-٣٠
Chloroform extract	%	١٠ maximum
Metal content	mm/Kg	٣٠ maximum

٣-٢- The Vulcanizing Agents:

These materials are necessary for vulcanization, since without the chemical cross-linking reactions involving these agents no improvement in physical properties of the rubber mixes can occur **[٥٢]**. The type of cross-linking agent required will vary with the type of the used rubber; anyhow the most common agent is sulfur, as it enters into reactions with the majority of the unsaturated rubbers to produce the vulcanizates.

٣-٢-١- Soluble Sulfur (Rhombic Sulfur):

Sulfur was first used by Goodyear in ١٨٣٩, but not surprisingly other elements from the same group in the periodic table as sulfur, such as selenium and tellurium will also function in a similar manner. These are used in specialized applications where good heat resistance is required **[٨١]**. Sulfur is vulcanizing agent of a yellow powder with particle size nominally blew ١٥٠ microns. The dispersiblity in the rubber is added by controlling the concentration of particles bellow ٤٥ microns.

The soluble sulfur has the following characteristics **[٥٩]**;

Characteristics	**Unit**	**Requirements**
Specific gravity	gm /cm٣	٢.١٠ gm /cm٣
Volatiles at ٨٠°C	%	٠.٥٠ maximum
Ash at ٥٥٠°C	%	٠.٢٠ maximum
Sulfur content	%	٩٩.٠ minimum
Matter insoluble in toluene	%	٠.٥٠ maximum
Mineral acidity (as H٢SO٤)	%	٠.٠٥ maximum

Iron content	mg/Kg	٣٠٠ maximum
Arsenic content	mg/Kg	٥.٠ maximum
Chancel fineness		٢٠-٤٠

Residue on ١٨٠ microns dry sieve	%	٠.٠١ maximum
Residue on ١٥٠ microns dry sieve	%	١.٠٠ maximum
Passing ٤٥ microns	%	٥٠.٠ maximum

٣-٢-٢- Magnesium Oxide (MgO):

It consists of magnesium oxide (٦٨٪) and dispersible organic binder (٣٢٪). Magnesium oxide is used as vulcanizing agent for Neoprene Rubbers CR. A blend of fine particle magnesium oxide powder and organic binder formed into powder with white color and wrapped with low melting point polyethylene to provide protection against atmospheric moisture and carbon dioxide. Specifications bellow is fulfilled **[٥٩]**;

Characteristics	**Unit**	**Requirements**
Specific gravity	gm /cm٣	٢.٢٠ gm /cm٣
Magnesium oxide content	%	٦٨±٣
Calcium oxide content	%	٢.٠ maximum
Loss on ignition at ٨٥٠°C	%	٢٦-٣٠
Volatiles at ١٠٥°C	%	١.٠٠ maximum
Copper content	mg/Kg	٢.٠ maximum
Manganese content	mg/Kg	٦٥٠ maximum

٣-٣- The Accelerators Used.

Second in importance only to the discovery of vulcanization was the discovery of the accelerators [٨٢]. The rate of vulcanization of rubber with sulfur a lone was extremely slow and has largely affected by the type and quality of the rubber used. Therefore, in combination with vulcanizing agents, these materials which are used in tread recipe and other rubber compounds shorten the vulcanization time (cure time) by increasing the rate of vulcanization. In most cases, the physical and mechanical properties of the products are also improved [٥٢]

The more active accelerators, the less sulfur is required in recipe and the lower is the minimum temperature at which the rubber compound can be cured in a reasonable time. Most accelerators have optimum limits of the concentration within which their effectiveness is most practical. The action of certain accelerators may be considerably influenced by other compound ingredients [٨٣].

The accelerators which have the widest application and are produced in greatest volume are the thiazoles and sulphenmides. They have the greatest ring in parts due to the combination of fast cure, good processing safety, high activity and solubility. One of these accelerators is CBS which has used in the tire tread recipe [٨٤].

٣-٣-١ N-Cyclohexyl-٢ Benzthiozole Sulphenamide CBS:

A sulfonamide accelerator CBS is N-cyclohexyl-٢-benzothiazole sulfonamide is used in the formulation of tread has the following properties [٥٩]:

Characteristics	Unit	Requirements

Specific gravity	gm /cm٣	١.٣٠ gm /cm٣
Volatiles at ٦٥°C	%	٠.٥٠ maximum

Ash at ٥٥٠°C	%	٠.٤٠ maximum
Residue on ٩٠ microns wet sieve	%	٠.٣ maximum
Active matter	%	٩٧ minimum
Melting point	°C	٩٧-١٠٥
Foreign matter (dirt)	%	٠.٠٥ maximum
Free MBTS	%	٠,٥٠ maximum
Free cyclohexylamine	%	٠.٥ maximum

٣-٤- The Activator Accelerators Used.

Zinc oxide and stearic (or other fatty acid) are generally found in all recipes based upon NR, SBR, BR, IR, IIR, and EPDM where they are used as activating materials and produce a uniform rate and state of cure in the compound.

However, they also appear in CR compounds but for different reasons. In this case, the fatty acid helps as an anti-roll sticking additive, whereas the zinc oxide is the vulcanizing agent. As well as zinc oxide, the oxides of the calcium, magnesium and lead (white, yellow and red respectively) may also be used, to confer special properties, such as increased water resistance in the case of the lead oxides **[٨١]**.

In general, these ingredients form chemical complexes with accelerators, and thus aid in obtaining the maximum benefits from an acceleration system by increasing vulcanization rates and improving the final product properties **[١١]**.

٣-٤-١٠- Zinc Oxide (٠.٢٥٪ Maximum Lead):

Vulcanization activator zinc oxide is a white powder or pellet in which the individual particles are predominantly nodular in form. The zinc oxide has the following characteristics [٥٩];

Characteristics	Unit	Requirements
Specific gravity	--	٥.٥٠ gm /cm٣
Volatiles at ١٠٥°C	%	٠.٢٥ maximum
Matter insoluble in acetic acid	%	٠.٣٠ maximum
Zinc oxide content	%	٩٩.٠ minimum
Loss in ignition	%	٠.٥ maximum
Lead content	%	٠.٢٥ maximum
Iron content	mg/Kg	١٥٠ maximum
Cadmium content	mg/Kg	٥٠٠ maximum
Copper content	mg/Kg	١٠ maximum
Manganese content	mg/Kg	٢٠ maximum
Chloride content	%	٠.٠٢ maximum
Matter insoluble in water	%	٠.٢٠ maximum
Mineral acidity	%	٠.٠٥ maximum
Nitrogen surface area	m٢/g	٣.٥-٦.٠
Particle size	micron	below ١.٠

٣-٤-٢٠ Stearic Acid (Iodine Value ٢٣Maximum):

Stearic acid is an organic acid used normally in combination with metal oxide (zinc oxide) to work as activating material for accelerators. Early researches have established the fact that rubber deficient in fatty acid is slow curing **[١١]**.

Fatty acids of carbon chain length predominantly $C_{١٦}$-$C_{١٨}$. A white waxy solid is available as a powder, flake, bead or pastille. Production from fish oils (which may contain high concentrations of polyunsaturated acids of carbon chain length above $C_{١٨}$) is not permitted since fatigue performance may be impaired **[٧٣,٨٤]**.

The stearic acid has the following characteristics **[٥٩]**;

Characteristics	Unit	Requirements
Specific gravity	--	٠.٨٥ gm /cm^{٣}
Titre value	°C	٥٢-٦٠
Iodine value	$gI_{٢}$/١٠٠g	٨ maximum
Acid value	mg KOH/G	١٩٥-٢١٣
Saponification value	mg KOH/G	١٩٥-٢١٥
Ash at ٥٥٠°C	%	٠.١٠ maximum
Volatile matter at ٦٥°C	%	٠.٥٠ maximum
Mineral acidity	%	٠.٠٢ maximum
Iron content	mg/Kg	٥٠.٠ maximum
Nickel content	mg/Kg	١٠٠.٠ maximum
Unsaponifible matter	%	١.٠ maximum

٣-٥- Age Resistors Used:

It is almost universally to add antioxidants and/or antiozonants to any polymer to impart improved and satisfactory aging properties in the cured compound. Some polymers, such as polychloroprene CR and especially butyl and EPDM already have well to excellent ‘build-in’ aging characteristics, but even here it is usual and advisable to add small quantities of these rubber chemicals for maximum results.

The earlier antioxidants used to help natural rubber life prolongation were based on various aromatic amines and phenols, and even today such materials are still used. It is usual to use quantities of the order of ١ part to ١٠٠ parts of polymer, but the amount obviously must and does depend on the service requirements of the product and also upon the actual basic polymer in the formulation. Some antioxidants are specific to the type of protection which they impart, and can be used to improve heat resistance, flex cracking, or improved resistance to weathering, which covers the attack of oxygen and ozone, plus ultraviolet light, temperature variations and moisture.

In addition to organic materials, various blends of microcrystalline/paraffin wax may be add, and in the correct quantity, dependent upon requirements, will bloom to the surface and form a protective surface film on the product. Provided the film is not broken, even some ozone resistance is imparted to the product.

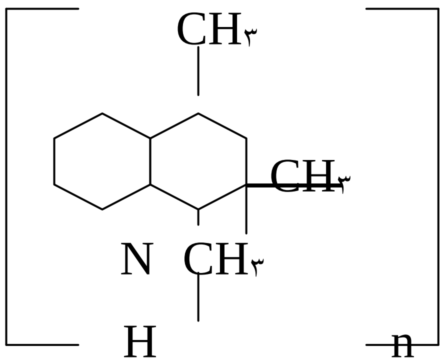
Ozone attack, however, is more sever than oxygen attack, and whilst most antioxidants impart some ozone resistance to a compound, if ozone is known to be present then extra antioxidant/antiozonant protection should be given [٨١].

In general, antioxidants, antiozonants, paraffin wax and other materials that are used to reduce aging processes in vulcanizates are called age resistors. They function by slowing down the deterioration of rubber products. The deterioration occurs through reactions with some external

materials that catalyze rubber failure, i.e., oxygen, ozone, light, heat, fatigue and atomic radiation **[١١]**. These external factors reduce the service life of the rubber compounds. Using of antioxidants like (TMQ) is reasonable. The amount of ozone in the air varies with geographical location and with season. The general concentration of ozone in air is about (٠ to ٦) parts per hundred million ($١٠^{٨}$). So, the rubber may undergo cracking without being compounded with materials that prevent ozone attack like (٦PPD). Inasmuch as the attack of ozone is a surface phenomenon, the use of a paraffin wax to bloom from the rubber to form an impermeable surface coating is useful in preventing attack **[٨٥]**.

٣-٥-١ Antioxidant (TMQ):

The composition of antioxidant TMQ is polymerized (٢,٢,٤-trimethyl-١,٢-dihydroquinoline).



It is a light brown solid of average molecular weight, typically ٥٠٠, available as flakes or pastilles and having the following specifications **[٥٩]**:

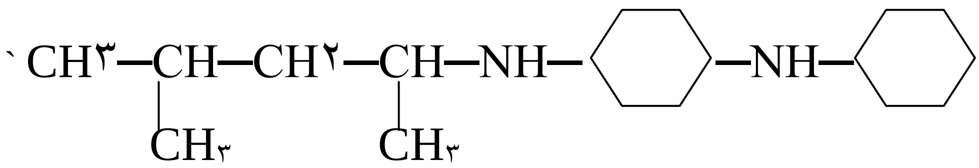
Characteristics	Unit	Requirements
Specific gravity	--	١.٠٨
Ash at ٥٥٠°C	%	٠.٤٠ maximum

Volatile matter at ٦٥°C	%	٠.٥٠ maximum
Infra-red spectrum		comparable with standard

Softening point	°C	٨٢-٩٢
Foreign matter	%	٠.٠٥ maximum

٣-٥-٢٠ Antiozonant (٦PPD):

Antiozonant ٦PPD is a material of composition [N-(١,٣-dimethylbutyl)-N'-phenyl-p-phenylenediamine].



Antidegradant of purple-brown flake or pastille also is available as a liquid in heated drums. It follows the following requirements **[٥٩]**.

Characteristics	**Unit**	**Requirements**
Specific gravity	--	١.٠
Ash at ٥٥٠°C	%	٠.٣٠ maximum
Volatile matter at ٦٥°C	%	٠.٥٠ maximum
Infra-red spectrum		comparable with standard
Melting point	°C	٤٤-٥٠
Foreign matter	%	٠.٠٥ maximum

٣-٥-٣- Protective Paraffin Wax:

Paraffin wax of a fully refined paraffin wax is macro-crystalline in structure, and should be a straight chain hydrocarbon with about twenty seven carbon atoms in the chain. Some cyclic paraffins should be present, but side chain branching should be minimal. It follows the recommended listed below **[٥٩]**:

Characteristics	Unit	Requirements
Specific gravity		٠.٩١
Ash at ٥٥٠°C	%	٠.١٠ maximum
Copper content	ppm	١٠.٠ maximum
Solubility in toluene		complete
Mineral acidity (as H٢SO٤)	%	٠.٠١ maximum
Microscopic examination		macro-crystalline
Refractive index at ٨٠°C		١.٤٣١٨
Firmness at ٤٠°C		comparable standard
Kinematic viscosity at ٩٩°C	cst	٣.٩٧

٣-٦- Processing Aids Used:

The processing aids or softeners are the materials can be added to rubber to either aid mixing, promote greater elasticity, produce tack, or extend a portion of the rubber hydrocarbon (without a loss in physical properties) **[١١]**.

Physical processing aids like process oil (paraffinic) do not react chemically with rubbers involved but function by modifying the physical characteristics of either the compounded rubber or the finished vulcanizate. In all cases, whether the softener is used as processing aids or to alter the finished product, it must be completely compatible with the rubber and the others compounding ingredients used in the recipe.

A processing aid plays one or more of the roles include the following list:

١. Speeds up the rate of polymer breakdown and also controls the degree of breakdown.

٢. Helps to disperse the other compounding ingredients especially blacks.

٣. Helps to reduce nerve within the compound, and also shrinkage during subsequent processing.

٤. Can impart building tack to the compound.

٥. Improved and more stable compound processing, especially in the compound preparation and molding areas **[٨٦]**.

٣-٦-١٠- PROCESS OIL:

Process oil (paraffinic) is highly saturated light spindle oil consisting essentially of saturated paraffin chains and has the following characteristics [٥٩]:

Characteristics	Unit	Requirements
Specific gravity		٠.٨٦-٠.٨٩
Ash at ٥٥٠°C	%	٠.١٠ maximum
Sulfur content	%	٥٠.٠ maximum
Matter absorbed by Concentrated sulfur acid	%	١٥.٠ maximum
Mineral acidity	%	٠.٠١ maximum
Copper content	ppm	١٠.٠ maximum
Aniline point	°C	٨٨.٠ minimum
Refractive index at ٢٠°C		١.٤٩ maximum
Mineral acidity	%	٠.٠١ maximum
Water content	ppm	٠.١٠ maximum
Test for presence of detergents		negative
Flash point	°C	١٨٨.٠ minimum

٣-٧- The Reinforcing Agents:

It is obvious that the use of rubber and elastomers largely depend on the action of reinforcing agents such as carbon black which is responsible for reinforcement effects. Reinforcement is only second to vulcanization as process used to enhance the mechanical properties of rubber compounds on one side and to make it a more useful material of commerce on the other side.

The general effects of carbon black on rubber properties are similar in all rubbers, being dominated mainly by surface area, "particle" size and "structure" level or aggregate size. High surface area, small "particle" size carbon blacks impart higher levels of reinforcement as reflected in tensile strength and resistance to abrasion and tearing. Higher hysteresis and poorer dynamic performance are the price paid for these improvements. Higher "structure" or aggregate size gives improved extrusion behavior, higher stock viscosities, improved "green" strength and higher modulus values[٧١]. A summary of the effects of carbon black "structure" and "particle" size on rubber processing and vulcanizate properties is listed in Table (٣-١).

Table (٣-١) [٨٦]
APPLICATIONS OF MAJOR RUBBER GRADE CARBON BLACKS

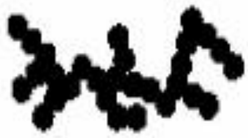
ASTM N-Type	Designation	General rubber properties	Typical uses
N-١١٠	Super abrasion (SAF)	High reinforcement	Special tire treads, airplane, off-the-road, racing tire; product for highly abrasive service
N-٢٢٠	Intermediate super abrasion (ISAF)	High reinforcement, tear resistance; good processing	Passenger and off-the-road tire treads, special service tires
N-٣٣٩,N-٣٤٧	High abrasion high structure (HAF-HS)	High reinforcement, modulus, and hardness; excellent processing	Standard tire tread blacks
N-٣٧٥	High abrasion medium structure (HAF-MS)	High reinforcement, medium modulus, and hardness; excellent processing	Standard tire tread blacks
N-٣٣٠	High abrasion (HAF)	Medium high-reinforcement, moderate modulus, good processing	Tire belt, sidewall, and carcass compounds; retread compounds, mechanical and extruded goods
N-٣٢٦	High abrasion low structure (HAF-LS)	Medium high-reinforcement, low modulus, high elongation, good fatigue resistance, flex resistance, and tear strength	Tire belt, carcass, and sidewall compounds
N-٥٥٠	Fast extrusion (FEF)	Medium high-reinforcement, high modulus and hardness; low die swell and smooth extrusion	Tire inner liners, carcass, and sidewall compounds, extruded goods and hose, inner tubes
N-٦٥٠	General purpose-high structure (GPF-HS)	Medium reinforcement, high modulus and hardness, low die swell and smooth extrusion	Tire inner liners, carcass, radial belt, and sidewall compounds, extruded goods and hose
N-٦٦٠	General purpose (GPF)	Medium reinforcement, medium modulus, good fatigue resistance, flex resistance, low heat buildup	Standard tire carcass blacks, tire inner liners, and sidewall, sealing rings, cable jackets, hose, soling, and extruded goods; EPDM compounds
N-٧٠٠Series	Semi-reinforcing (SRF)	Medium reinforcement, high elongation, high resilience, low compression set	Mechanical goods, footwear, inner tubes, floor mats, hose
N-٨٨٠	Fine thermal (FT)	low reinforcement, modulus, hardness, hysteresis, tensile strength, high elongation, tear strength, and flex resistance	Mechanical goods, gloves, bladders, tubes, , footwear uppers
N-٩٩٠	Medium thermal (MT)	low reinforcement, modulus, hardness, hysteresis, tensile strength, high loading capacity and high elongation	Mechanical goods, wire insulation and jackets, footwear, belts hose, packing, gaskets, o-rings, mountings, tire inner liners

Increased reinforcement, according to Dannenberg [٨٧,٨٨], has been defined as increased stiffness, modulus, rupture energy, tear strength, cracking resistance, fatigue resistance and most important abrasion resistance.

Reinforcing agents, especially carbon blacks, when they are properly dispersed in an elastomer, provides a high surface area uniformly distributed throughout the rubber matrix as is requisite for full reinforcement [٨٨,٨٩,٩٠]. Copolymer synthetics without reinforcing materials are too low in strength to warrant their consideration for use. For most types of service, relatively large amounts of materials known to increase physico-mechanical properties must be presented in any given formulation. Reinforcing agents include basically various kinds used for this purpose; are carbon black, clay, talc, and silica. They are usually used toreduce the cost or to enhance certain properties such as hardness, tensile strength, tear and abrasion agents

The major kind of reinforcing agents is carbon black, the most important properties of carbon blacks are; particle size, structure, physical nature of the surface, chemical nature of the surface, and particle porosity[٧١]. Basic characteristics of carbon black are listed on table (٣-٢).

Table (٣-٢) [٧]

Effective Points on Reinforcement of Rubber		Level on Reinforcement of Rubber Better→ → → → → → → → → →Poor
Particle Size (nm)* *Nanometer = 1m/m / 1 million	Diameter:10 - 500nm (But the size of Carbon Black which is used for a tire is 10 - 50nm.)	Smaller — Bigger
Structure of Particle		Dense — Coarse
Chemical Character of Particle Surface		
a)Hydrogen Adsorption	The quantity of Hydrogen that is adsorbed the function groups.	More — Less
b)Surface Oxygen Content	The quantity of Oxygen that is adsorbed the surface	More — Less

5. The Relation of Particle Size and Dispersion of Carbon Black in the Mixing Process

Rubber mixing accomplishes two necessary changes :

1. Softening of the rubber mix
2. Dispersal of carbon black and other ingredients in the rubber mix.
   In addition to that mentioned above in (4), the dispersion of carbon black in the rubber mix has a big influence on rubber properties.

A- Particle Size:

The particles of carbon black are not discrete but fused "clusters" of individual particles [٨٨]. The fusion is especially pronounced with very fine blacks. These aggregates can be seen in vulcanized rubber, so they appear to be the working unit. However, the reinforcement conferred by the black is not influenced to any extent by the size of unit but greatly by size of the particles within the unit.

B- Structure:

The term "structure" refers to the joining together of carbon particles into long chains and tangled three-dimensional aggregates. These primary aggregates can also form loose associations called "secondary structure" [٧]. This latter is weak and much of it is lost during pelletisation and the reminder when the black is mixed into rubber. The higher the structure of a carbon black, the more irregular the shapes of the aggregates, hence the less these aggregates are capable of backing together.

C- Physical Nature of the Particle Surface:

At the molecular level, carbon black is composed of very fine particular aggregates possessing an amorphous quasi-graphitic molecular structure. The edges of the graphic layer planes have unsatisfied carbon bonds which can act as chemical reaction sites [٨٨]. Large particle carbon blacks like thermal blacks have less active site, as the layer plane surfaces are at the surface of the particle.

The surface condition of the furnace black is influenced by additives in manufacture, such as sulfur compounds, water, oxides of metal from the reactor and small amounts of refractory materials from the furnace.

In case of thermal blacks produced in the absence of flame or air, the various organic functional groups are virtually absent[٨٩].

D- Particle Porosity:

The surfaces of carbon black particles are smooth owing to the attack on them by high temperature oxidizing gases immediately after their formation. Oxidation takes place at "Non-Graphic" atoms and can progress into the particle to give pores [٨٨].

In general terms, the smaller the particle size, is the poorer the processibility and the higher reinforcement. Reinforcement usually enhances tensile strength, abrasion resistance, modulus, and tear resistance, which is due to the finer particle size blacks.

The carbon atoms can be relatively un-reactive if they are an integral part of the layer plane, more reactive if attached to hydrogen atom, and very reactive if present a resonance-stabilized free radical.

E- Chemical Nature of the Particle Surface:

Carbon black consists of ٩٠-٩٩٪ elemental carbon. The other major constituents are (combined) hydrogen and oxygen. Hydrogen comes from original hydrocarbon and is distributed throughout the carbon black particle.

The principle groups present are phenolic, ketonic and carboxylic together with lactones **[٩٠,٩١]**. As heating in the range (٤٠٠-١٦٠٠°C) is necessary to devolatilise carbon black, it appears that the surface groups are not physically absorbed but are chemically combined. In addition to the oxygen and hydrogen groups carbon blacks may contain very small amounts of sulfur depending upon the nature of the hydrocarbons used in their manufacture.

Most of this sulfur is chemically combined and appears to be insert and does not cause cross-linking of rubber.

The role of physico-chemical nature of surface in the rubber reinforcement is still not fully understood. It has been postulated that a black with high structure gives a high modulus rubber, not because carbon black agglomerates restrict the cross-linked net work but because the high shear forces during mixing break these agglomerates down to give active free radicals capable of reacting with the rubber**[٥]**.

In formulation concerned tread recipe three types of carbon blacks are used as seen next:

٣-٧-١- High Abrasion Furnace Carbon Black N-٣٣٠ HAF:

A carbon black produced by the furnace Process. Medium-high reinforcement, moderate modulus and good processing.

N-٣٣٠ HAF has the following characteristics [٥٩]:

Characteristics	Unit	Requirements
Specific gravity		١.٨٠
Ash content at ٥٥٠°C	%	٠.٧٥ maximum
Heating loss at ١٠٥°C	%	٢.٥٠ maximum
Fines content	%	١٢.٠ maximum
Iodine number	mg/g	٨٢±٥
DBP number	CC/١٠٠g	١٠٢±٦
Compressed DBP	cm٣/١٠٠g	٨٨
Pour density	g/l	٣٧٠±٣٠
Tinting strength	%IRB	١٠٣±٥
CTAB surface area	m٢/g	٨٣±٥
Fines content bulk	%	٧(١٠) maximum
Fines content bags	%	١٢(١٥) maximum
Loss at ١٠٥°C-bulk	%	١.٠ maximum
Loss at ١٠٥°C-bags	%	٢.٥ maximum

٣-٧-٢- High Abrasion Furnace High Structure Carbon Black N-٣٣٩ HAF-HS:

A carbon black produced by the furnace process with the following specifications **[٥٩]**:

Characteristics	Unit	Requirements
Specific gravity		١.٨٠
Ash content at ٥٥٠°C	%	٠.٧٥ maximum
Fines content	%	١٢.٠ maximum
Iodine number	mg/g	٩٠±٥
DBP number	CC/١٠٠g	١٢٠±٦
Compressed DBP	cm٣/١٠٠g	١٠١
Pour density	g/l	٤٣٠±٣٠
Tinting strength	%IRB	١١٠±٥
CTAB surface area	m٢/g	٩٥±٥
Fines content bulk	%	٧(١٠) maximum
Fines content bags	%	١٢(١٥) maximum
Loss at ١٠٥°C-bulk	%	١.٠ maximum
Loss at ١٠٥°C-bags	%	٢.٥ maximum

٣-٧-٣- High Abrasion Furnace Carbon Black N-٣٧٥ HAF:

A carbon black produced by the furnace process with the following specifications **[٥٩]**:

Characteristics	Unit	Requirements
Specific gravity		١.٨٠
Ash content at ٥٥٠°C	%	٠.٧٥ maximum
Fines content	%	١٢.٠ maximum
Iodine number	mg/g	٩٠±٥
DBP number	CC/١٠٠g	١١٤±٦
Compressed DBP	cm٣/١٠٠g	٩٧
Pour density	g/l	٣٤٥±٣٠
Tinting strength	%IRB	١١٥±٥
CTAB surface area	m٢/g	٩٨±٥
Fines content bulk	%	٧(١٠) maximum
Fines content bags	%	١٢(١٥) maximum
Loss at ١٠٥°C-bulk	%	١.٠ maximum
Loss at ١٠٥°C-bags	%	٢.٥ maximum

٣-٨- The Retarding Agent (CTP-١٠٠):

Occasionally, in order to meet specific and difficult requirements, compounds are produced which are extremely 'scorchy' in their processing characteristics, and materials known as retarders may be added.

So, retarders are used to reduce the accelerators activity during processing and storage. Their purpose is to prevent scorch during processing and pre-vulcanization during storage. They should either decompose or not interfere with the accelerator during normal curing at elevated temperatures. In general, these materials are organic acids which function by lowering the pH of the mixture thus retarding vulcanzation **[٨٦]**.

CTP-١٠٠ with the composition N-(cyclohexylthio) phthalimide has the following characteristics **[٥٩]**:

Characteristics	Unit	Requirements
Specific gravity		١.٣٠
Volatiles at ٦٥°C	%	٠.٥٠ maximum
Ash at ٥٥٠°C	%	٠.٤٠ maximum
Residue on ٩٠ microns wet sieve	%	٠.٣ maximum
Active matter	%	٩٧ minimum
Melting point	°C	٨٩-٩٥
Foreign matter (dirt)	%	٠.٠٥ maximum
Residue on ٩٠ micron	%	٠.٣٠ wet sieve

CHAPTER FOUR

Experimental

Work

٤-١- INTRODUCTION:

Babylon tire tread recipe formulation (IT١٠٦٠) as shown in table (٤-١) **[١٦]**, used Styrene-butadiene Rubber SBR alone as recommended by Dunlop Company to the general state company for Babylon Tire industry. The product of formula in table(٤-١) is the phyisco-mechanical properties values for the passenger tire tread which are at least, the most suited(but not the same) to the conditions prevailing in Iraq country as suggested by the Dunlop Co., who is the supplier of Tire technology for the general state company for Babylon Tire industry **[١٧]**. This formulation of tire tread(IT١٠٦٠) is controlled by critical values considered as critical properties which had been evaluated over a long period of Dunlop experience and reflect Dunlop conditions and test equipment as shown in tables (٤-٢) **[١٧]**. These critical values are given as **standard** for evaluation of physico-mechanical properties.

Furthermore, the previous tire tread recipe formulation of Dunlop Co. mentioned in table (٤-١), has been modified by the general state company for Babylon Tire industry with another one considered as a control recipe for this work. That recipe formulation composed of (١٢) twelve of different materials as shown in table (٤-٣), where the base rubber is styrene-butadiene rubber SBR i.e used ١٠٠٪ SBR or ١٠٠ parts per hundred rubber compound by weight (pphr). Control physico-mechanical properties of this modified recipe can be seen in table (٤-٤).

TABLE (٤-١) [١٦]
DUNLOP RECIPE (BASIC) OF PASSENGER TIRE TREAD, ١٠٠ PHR OF SBR FILLED CARBON BLACK TYPE, N-٣٧٥.

	COMPOUND	phr
١	SBR ١٥٠٢	١٠٠.٠٠
٢	Activator STEARIC ACID.	١.٠
٣	Activator ZINC OXIDE.	١.٥٠
٤	Anti-Ozinant (٦PPD).	١.٥
٥	Anti-Oxidant (TMQ).	٠.٥٠
٦	PARAFFIN WAX	١.٠
٧	PROCESS OIL	٨.٠
١٠	*CARBON BLACK N-٣٧٥*	٦٢
١١	Accelerator (CBS).	١.٠
١٢	SULFUR	١.٧٥
١٣	Retarder (CTP.١٠٠)	٠.١٥
١٤	Reclaim	١٢.٠
	Total	٢١٥.٩٥

TABLE (٤-٢) [١٧,١٦]
COMPARATIVE PROPERTIES OF ١٠٠PHR SBR TREAD RECIPE FILLED WITH CARBON BLACK (HAF) RELATED TO THE Standards OF DUNLOP & Babylon Tires Company).

PROPERTY	STANDARDS	
• ٠DR Curing at ١٨٥ Ċ ASTM-D٢٠٨٤-٨٩	Dunlop	Babylon Tires
١.Scorch Time ($t_{S٢}$) min.	١.١—١.٧	١.٠—١.٨
٢.Cure Time ($t_{٩٠}$) min.	٣.١—٣.٧	٢.٨—٣.٧
٣.Max. Torque (M_H) dN.m	٣١.٠ Min.	٢٤.٠ Min.
٤.Min. Torque (M_L) dN.m	١٥.٨٢—٢٦.٢	٦-٢٠
• TENSOMETER ASTM-٤١٢		
١.Tensile Strength (MPa)*	١٠.٠ Min.	١٠.٠ Min.
٢.Modulus (MPa) at ٣٠٠٪ Extension	٧.٠ Min.	٧.٠ Min. at ١٥٠٪
٣.Elongation at Break (%)	٣٥٠ Min.	٢٧٥ Min.
• HARDNESS Tester/ASTM-D٢٢٤٠-٧٥	٦٠—٦٦	٥٩—٧٠
• Abrasion Resistance Index/B.S.٩٠٣PTA-٩	٥٠.٤٥*٢.٥=١٢٦.١٢٥	---

TABLE (٤-٣) [١٦]

CONTROL RECIPE(MODIFIED FROM BASIC RECIPE) OF ١٠٠ pphr SBR TREAD RECIPE FILLED WITH THREE TYPES OF CARBON BLACK AT SPECIFIED (pphr).

	COMPOUND	pphr	pphr	pphr
١	SBR ١٥٠٢	١٠٠	١٠٠	١٠٠
٢	Activator STEARIC ACID.	١.٥	١.٥	١.٥
٣	Activator ZINC OXIDE.	٥.٠	٥.٠	٥.٠
٤	Anti-Ozinant (٦PPD).	١.٥	١.٥	١.٥
٥	Anti-Oxidant (TMQ).	١.٠	١.٠	١.٠
٦	PARAFFIN WAX	١.٠	١.٠	١.٠
٧	PROCESS OIL	٢٠.٠	٢٠.٠	٢٠.٠
٨	***CARBON BLACK N-٣٣٠***	٧٠.٠	----	----
٩	***CARBON BLACK N-٣٣٩***	----	٦٠.٠	----
١٠	***CARBON BLACK N-٣٧٥***	----	----	٦٥.٠
١١	Accelerator (CBS).	١.١	١.١	١.١
١٢	SULFUR	١.٧	١.٧	١.٧
١٣	Retarder (CTP.١٠٠)	٠.١٥	٠.١٥	٠.١٥

TABLE (٤-٤) [١٧]

CONTROL PROPERTIES OF (MODIFIED RECIPE) ١٠٠PHR SBR TREAD RECIPE FILLED WITH THREE TYPES OF CARBON BLACK AT SPECIFIED (PHR).

PROPERTY	CARBON BLACK		
• ٠DR Curing at ١٨٥ Ċ ASTM-D٢٠٨٤-٨٩	N-٣٣٠ HAF ٧٠ pphr	N-٣٣٩ HAF-HS ٦٠ pphr	N-٣٧٥ HAF-LS ٦٥ pphr
١.Scorch Time ($t_{S٢}$) min.	١.٢٤	١.٢٦	١.٣٢
٢.Cure Time ($t_{٩٠}$) min.	٢.٩٨	٣.١٣	٣.١١
٣.Max. Torque (M_H) dN.m	٢٨.٦	٢٨.٠	٢٨.٤٣
٤.Min. Torque (M_L) dN.m	٥.٥	٦.٠	٥.٥
• TENSOMETER tests ASTM-٤١٢			
١.Tensile Strength (MPa)*	١٥.٥٠	١٤.١	١٤.٢٦
٢.Modulus (MPa) at ٣٠٠٪ Extension	٧.١٢	٩.٠	٨.٢
٣.Elongation at Break (%)	٣٨٨	٣٥٠	٣٦٥
• HARDNESS Tester/ASTM-D٢٢٤٠-٧٥	٦٣.٠	٦٤.٥	٦٤.٠
• Abrasion Resistance Index	٤٤.٤*٢.٥=١١١	٤٩*٢.٥=١٢٢.٥	٤٤.٤٢*٢.٥=١١١

The following chapter represents the technology approach of mixing and vulcanizing firstly, where they depend on the skill and experience of the worker in this field on one side, and the processing conditions on the other side, and the test results and measurements secondly, which may be impaired by either instrumental or procedural defects, although the most testing equipments used are computerized.

Precision problems that had been encountered were reduced by unity in test material, proper sampling and an adequate control of test conditions.

Mixing and vulcanization as it is known today are the result of the considerable work, efforts and contribution of countless workers in this field, since the discovery of vulcanization in ١٨٣٩ by Charles Goodyear. Thus, during mixing operation, in addition to uniform dispersion recipe ingredients, a definite time, temperature and order-of-addition schedule was followed for each batch. Vulcanization was also carried out with accordance of standardization.

Also, during experimental work, some points were emphasized as follows;

١. The processing methods of preparing raw materials, weighing, mixing and sampling are carried out with proper way.

٢. The in-process and final testing of the finished product so as to ensure consistency is valid and accurate.

٣. Vulcanizing system used is well known which can bring out develop and maximize the ultimate properties of the materials used.

٤. The capability of preparing tread recipe that composed of right materials cost.

The work has also faced some troubles as follows;

١. There is no chance to compare the test results carried out in laboratory with that on the road, because it is too costly and required much time.

٢. Raw materials stored by Babylon Tire Co., especially the chemicals may not with suitable storage temperature recommended by the supplier.

٣. Most of the polymers (elastomers) were in the storage for long period which may affect the results.

٤. Mixing with open mill is not efficient as in Bumbory where closed mixer is better than an open mill.

٤-٢- Mixing and Vulcanization:

٤-٢-١- Mixing:

Very briefly, the open mill mixing process is to masticate the polymers until an even and smooth band is formed around the front roller. The fillers and oil are added alternately followed by any small additions and finally the vulcanizing materials. During the whole operation, cutting and blending by hand rolling is carried out. So mixing is the first stage in the conversion of rubber and its compound ingredients into finished products **[٩١]**. It is particularly important in that it affects both the behavior of the compound in the subsequent forming operations and the performance of the finished product. There are three basic mixing methods, open mill, internal batch, and continuous.

Each tire tread recipe had one of the formulations mentioned in tables (١-١), was mixed by mill mixing way, where milling is the popular method used to mix rubber compounds in small batches especially in the laboratories, however, using of internal mixer such as Bumbory mixer machine is more efficient due to lower power consumption and better ultimate dispersion.

The mixing was carried out on available laboratory mill, rolls dimensions are: outside (١٥٠mm), working distance (٣٠٠mm), speed of the slow roll (٢٤ rpm) and gear ratio (١.٤). The roll mill has the facility of controlling the gab distance between the rolls and the rolls temperatures. The program of mixing is given in table (٤-٥). The mixing operation was executed on two stages. The first one (I) is called master batch consists of rubbers (including reclaimed), activators, antioxidants/antiozonants, reinforcing agent (carbon blacks) and process oil.

The second stage (II) is called the final batch which consists of the previous master batch, curing agent (sulfur), retarders and accelerators. In case of mixing CR with SBR the procedure is somewhat different, wherein CR needs firstly process oil to impart smooth mixing and blending with SBR. Then, for more efficient mixing adding of reinforcing agent is preferable followed by the other ingredients.

The conventional mixing procedure is to add process oil in the end of the first stage with carbon black in order to have optimum dispersion for the recipe ingredients. Adding of curing agent, accelerators and retarders at the end of the process is to prevent pre-vulcanization which may occur due to elevated temperatures.

In general, and in all operations it is most important to avoid pre-cure or scorching as a result of too much heat history. This means short mixing cycles at the lowest possible temperatures. Accordingly, mixing cycles call for activators, stabilizers, antioxidants, fillers with processing aids, and finally, accelerators and/or curing agents **[٨٦]**.

TABLE (٤-٥)
SCHEDULE ٠F MIXING CYCLES

No.	Mixing Steps	Period minutes
	Stage (I) Master Batch	
١-	Passing rubbers through rolls several times with decreasing a mill roll opening to ٠.٢ cm, at ٧٠°C.	١
٢-	Adding reclaimed rubber to the rubber in step -١- then banding with mill opening ١.٢cm to ٠.٢cm for several times.	٣
٣-	Adding of stearic acid.	١
٤-	Adding of zinc oxide.	٢
٥-	Adding of ٦PPD, TMQ, and Paraffinic Wax.	٣
٦-	Banding with gab ٠.٣cm and cutting of ٣/٤from each side for homogenization.	٣
٧-	Adding half of each carbon black and process oil.	٤
٨-	Adding the other half of each carbon black and process oil.	٤
٩-	Making three ¾ cuts from each side for homogenization.	٣
-	**Stage (II) Final Batch**	
١٠-	Cooling the **master batch** to the room temperature.	
١١-	Adding the sulfur to the master batch.	١
١٢-	Adding the accelerator (CBS).	١
١٣-	Adding the retarder CTP-١٠٠.	١
١٤-	Banding the recipe with mill opening at ٠.٣ to ٠.١ cm.	١
١٥-	Sheeting the batch to a minimum thickness of ٠.٦ cm at ٩٠-١٠٠°C.	٥
١٦-	Cooling the batch to room temperature.	
	TOTAL	٣٣

٤-٢-٢- Vulcanization:

In general, vulcanization is the industry term used to describe the process whereby rubbers are reacted with chemicals, usually in the presence of heat, to convert the uncured states into the generally accepted "Rubbery" or "Elastic" state. Natural rubber NR, SBR, polyisoprene IR, butyl IIR, EPDM rubber, nitrile NBR rubbers and others all react with sulfur and sulfur bearing chemicals to achieve this. However, with Neoprenes CR metallic oxides such as zinc oxide and magnesium oxide serve as the vulcanizing agents **[٨١,٨٦]**.

After tread rubber compounds had been properly mixed on the mill and shaped into sheets. The sheets were left for a certain time before vulcanized in clean polished molds in a vulcanizing press.

During vulcanization, the following changes occur:

١. The long chains of the rubber molecules become cross-linked by reactions with the vulcanization agent to form three-dimensional structure. This reaction transforms the soft weak plastic-like material into a strong plastic product.

٢. The rubber loses its tackiness and become insoluble in solvents and is more resistant to deterioration normally caused by heat, light and ageing processes.

In general, the vulcanization process implied that the vulcanizing press was primarily heated by electric source from ٣٠ to ٢٠٠ ±١°C and then, the empty mold was brought to vulcanizing temperature within (±١°C) in the closed press and held at this temperature for at least ٢٠ minutes before the uncured (unvulcanized) sheets were inserted. The press was capable of exerting a pressure of ٤٠ tones on the mold surfaces during the period of vulcanization. However, the sheets were vulcanized at different temperatures range and periods according to ASTM and Standards specified by the manufacturer Dunlop Company **[٥٩]**, and depending on the type of recommended test.

٤-٣- Laboratory Physico-Mechanical Tests

Physico-Mechanical testing involves measurement and evaluation of physico-mechanical properties. This could include certain categories of tests have emerged as being satisfactory adjuncts to development, research, quality control of production, and acceptance of rubber finished products [٩٢]. The methods chosen here are mostly those that have been standardized by The American Society for Testing and Materials (ASTM), which have been specified by manual instructions of Dunlop Company [٥٩].

Those tests are achieved to **ensure that the recipe**:

A- Are of the correct formulation.

B- Have suitable uniform processing characteristics, and

C- Predicting the major tire tread characteristics such as abrasive & wear resistance, hardness, traction, rolling resistance, skidding resistance and other properties.

The above three items can be **checked** as follows;

Item (A) is checked by measuring:

١- The maximum torque (M_H) generated by an Oscillating Disc Rheometer (ODR).

٢- The hardness and specific gravity of the cured compound.

These two tests can give an indication that formulation is designed with proper way i.e. phr of the recipe ingredients are active and recommended by the most standard formulations.

Item (B) is checked by measuring:

١. The viscosity (minimum torque M_L) of the uncured compound on an ODR.

٢. The scorch and cure time ($t_{S٢}$&$t_{٩٠}$) on an ODR.

These two tests reflect the processing ability of the whole materials that formed the recipe besides, it determines pre-curing time and

perfect curing time required for completion the vulcanization process of tread compounds **[٩٣]**.

Item (C) is checked by measuring:

١. **The tensile strength** of the cured compound by Tensometer.

This test is very important for predicting the strength properties such as tear resistance, fatigue resistance, loading capacity and traction especially when the tire undergoes unlikely conditions like under recommended inflation pressures, irregular rotation of the tire and driving principally on a relatively rough road surface at high speeds.

٢. **The modulus** of elasticity at ٣٠٠٪ extension of the cured compound which can predict with abrasion resistance the mileage of a tire **[٧٦]**. Modulus is also predicting the handling characteristics such as good driving especially during cornering.

٣. **The elongation** (extension) percentage % at break which can predict low temperature performance, resilience and heat buildup leading to impart the rolling, skidding resistance and traction where grip is inversely related to elasticity where the more elastic rubber cause in lower traction and vice versa **[٢٧,٢٩]**.

٤. **Abrasion resistance**. It is a measure of tread wearing that determines the tire life.

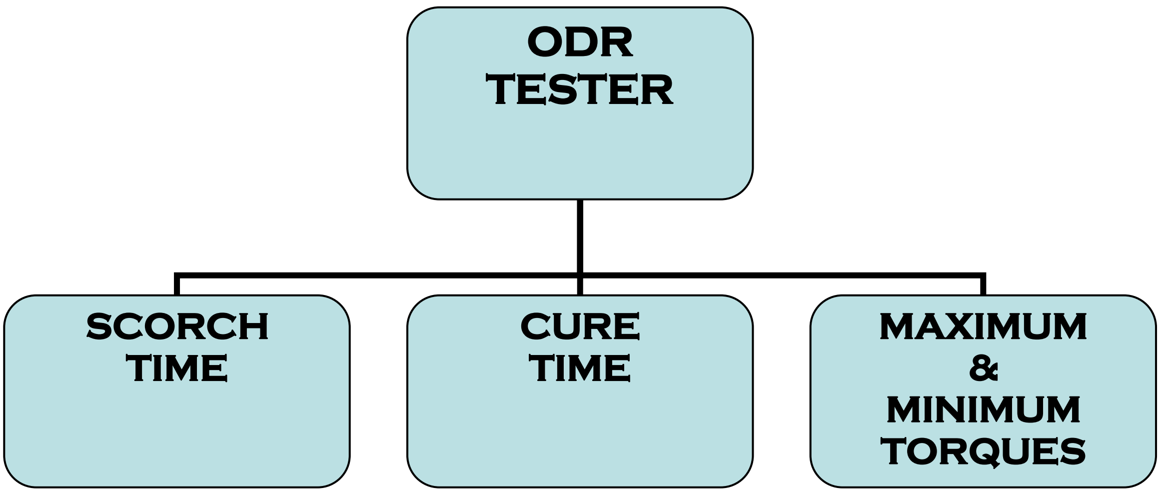
٥. **Hardness** which provide good traction and good handling characteristics for the tire tread however, it tends to give a harsher and less comfortable ride than softer **[٣٠,٣١,٣٢]**.

The testing procedures that followed are based on the test equipment which is used in Dunlop factories. The equipment items used are Monsanto ODR-٢٠٠٠ instrument, Monsanto Densitron tester, (Wallace Dead Load) Hardness tester, Akron abrasion tester, and Monsanto Tensometer T١٠ tester.

٤-٣-١٠ RHEOMETER (ODR) TESTS:

The need for an instrument to make measurements of some cure-dependent property continuously while cure is taking place and at curing temperature so that a curing curve can be produced with good precision has been satisfied with the cure meters, especially the O Rheometer or ODR-٢٠٠٠ **[٦٢,٨٤]**. Tests carried out Maximum Torque (M_H in dNm) which is a measure of modulus, Minimum Torque (M_L in dNm) which is a measure of viscosity of the blend, Scorch Time (**t**$_{S٢}$), is the time in minutes at which torque is (٠.٢ Nm) above M_L and Cure Time (**t**$_{٩٠}$), is the time in minutes at which torque is M_L+٠.٩(M_H-M_L). scheme (٤-١) shows the measured properties by Oscillating Disc Rheometer ODR.

SPECIFIC GRAVITY



scheme (٤-١) flow sheet of the measured properties by ODR.

The samples were prepared by cutting uncured compound sheet to give a test piece of constant volume. This test had been done according to ASTM-D ٢٧٠٥ & D٢٠٨٤-٨٩ **[٩٥]**.

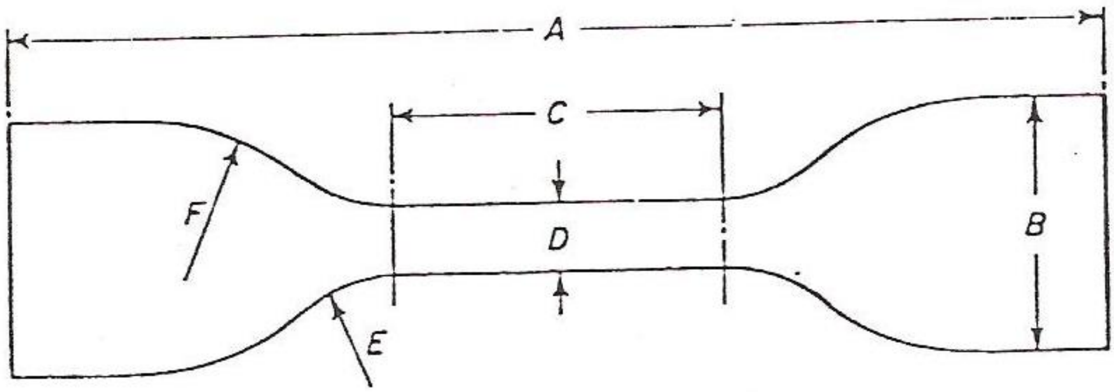
The ODR apparatus is usually used for testing the curing characteristics of compounded rubber samples as already mentioned in **A** and **B**. It has a heated and seal die cavity that contains an oscillating disk. The disk moves through a small arc that exerts a shear strain on the compound as it cures. The sample changes in stiffness as the chemical process proceeds and the resultant torque on the oscillating disk is measured with strain gauges and transferred to a recording system. This can take the form of a visual display, printed record and monitored comparison with computer assistance. A smooth continuous curve of the change in torque is automatically checked at pre-set values of time and stiffness **[٩٦]**.

These values were compared with standards of Dunlop and state company of Babylon tires. Time required for vulcanizing the sample was (٦ minutes) at ١٨٥°C **[٥٩,٩٦]**.

٤-٣-٢- Tensile Strength, Modulus, and Elongation% Tests:

The stress-strain test in tension, including ultimate tensile and elongation, is probably still the most widely used test in the rubber industry **[٩٧]**. The tensile, modulus and elongation properties of rubber depend both on the materials and the conditions of test, such as extension, temperature, humidity, specimen geometry and environmental or mechanical preconditioning. Therefore, rubbers were compared only when tested under the same conditions **[٩٨]**, and that really happened for the different recipes of tire tread.

Tensile Strength: This is defined as the force per unit of original cross-sectional area which is applied at the time of rupture of the dumbbell test specimen fig.(٤-١). It is calculated by dividing breaking force in Newtons by the cross-section of unstressed specimen in square meters.



Dimensions	Type 1 (mm)	Type 2 (mm)
A	115 minimum	75 minimum
B	25 ± 1	12·5 ± 1
C	33 ± 2	25 ± 1
D	6·0 +0·4 −0·0	4 ± 0·1
E	14 ± 1	8 ± 0·5
F	25 ± 2	12·5 ± 1·0

Fig. (٤-١) Dumbbell sample for rubber test piece.

Modulus: The term modulus, or stress, is used to express the amount of pull in Newton per square meter required to stretch the test piece to a given elongation. It expresses resistance to extension, or stiffness in the vulcanized rubber.

Once again, in the common parlance of rubber technology the stress required for a given elongation is used to represent the material stiffness. This quantity is called the modulus. A ٣٠٠٪ modulus, for example, means the stress required to produce a ٣٠٠٪ elongation. In mechanical engineering usage, however, the term *modulus* is defined as the ratio of stress to strain. If this ratio is constant the material is said to be obey Hook's law and the constant is called *Young's modulus* or *modulus of elasticity*. In practice, the term *Young's modulus* is often used to represent the ratio of stress to strain even in situations where it may vary with change in elongation [٩٧].

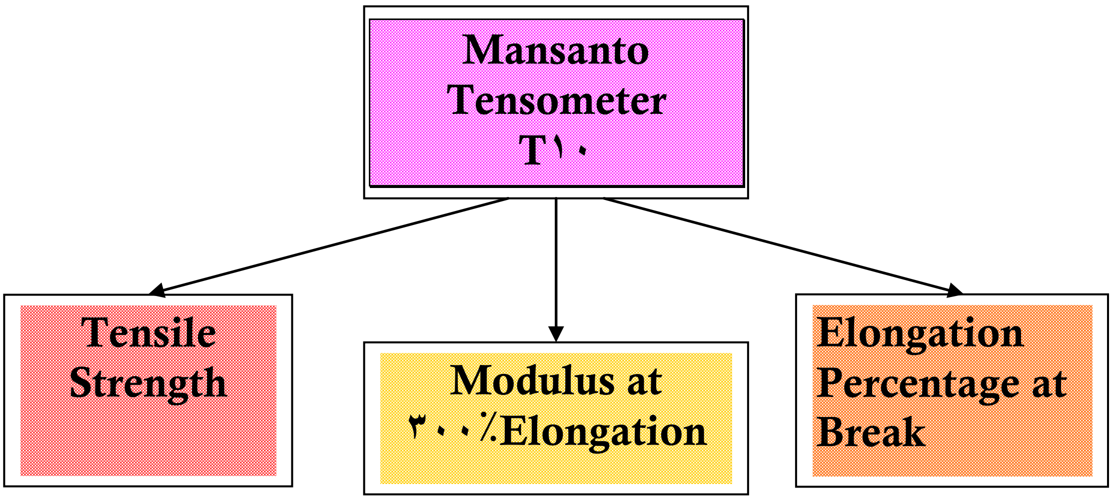
Elongation: The term elongation is used to describe the ability of rubber to stretch without breaking. To describe this property as measurement, it is more accurate to refer to it as "ultimate elongation", since its value, expressed as percent of the original length, is taken at the moment of the rupture **[٩٩]**.

Tensile strength and elongation properties serve as an index to the general quality of a rubber compound. Rubber compound less than ٦.٩ MPa in tensile strength are usually poor in most **mechanical properties** and those with tensile strength over ١٥.٧ MPa are usually good in most mechanical properties **[٩٨]**.The above three tests were carried out by using Monsanto T١٠ Tensometer equipment and according to ASTM-D٤١٢ **[٥٩]**.

CHAPTER FOUR

Monsanto T١٠ Tensometer Equipment:

This testing equipment is controlled by a microprocessor together with a plotter and pneumatic sample holder. It is designed for testing tensile strength, modulus and elongation percentage at break as seen in scheme (٤-٢).



Scheme (٤-٢) flow sheet of properties tested by Tensometer T١٠ tester.

This microprocessor together with a plotter and pneumatic sample holder assists in obtaining a written record of each test more independent of the operator, who supplies dimensional and identification information and fits the test piece in the testing equipment before starting the test. This gives improved consistency compared with manual methods of measuring extension and mechanical methods of measuring loads.

In addition to above equipment, the following are also required [٥٩]:

١. Wallace sample press.
٢. Dumbbell die-BSI, type ١/ASTM type C.
٣. Micrometer dial gauge.

Dumbbell die sample has advantages of its easy preparation, breakage in a predetermined area, means for following the elongation, and the immense accumulated background[١٠٠].

٤-٣-٣- Hardness Test:

In most widely used hardness tests, the resistance of the material to the surface indentation under rigidly standardized conditions is measured by pressing a hardened indenter of standard shape into the surface of the material under specified load. The area of indentation or the depth of penetration is measured and designed a numerical value such as IRHD and shore units. The objective of a hardness test is to measure the elastic modulus of the rubber compound under condition of small strain. This test is conducted on rubbers in accordance with ASTM D٢٢٤٠-٧٥, D١٤١٥-٦٨, and D٥٣١-٧٨. For metals and certain plastics and rubber the most common methods bear the names of Brinell, Vickers, and Rockwell [١٠١].

٤-٣-٤- Specific Gravity Determination:

The consideration of the compound volume rather than weight is a very important thing, it is employed in compound design and cost, in calculating the correct weight to fill an internal mixer of given capacity.

When the compound formulation, the types, amount and specific gravities of the rubber and the other ingredients of recipe are known, it is quite simple to calculate the specific gravity of the compound.

Determination of specific gravity yields for Archimedes base which states that the apparent loss in weight of a body immersed in a liquid equal to the weight of the liquid displaced [١٠٣].When the weight of the body and the weight of equal volume of water is known, therefore the specific gravity can be determined which is, by the definition, the ratio of.

Weight of a given vol. of body/Weight of equal vol. of water

Thus, **S.G** = [Wt. of body in air/(Wt. in air–Wt. in water)] $*$ S.G of liquid

٤-٣-٥- Abrasion resistance test:

This property in rubber may be defined as the resistance to wearing away by rubbing or impact in service [٩٩].

Many laboratory tests have been devised and investigated, but practically all of them have been found deficient in one way or another when it comes to serving as a tool for predicting service life. This is because the conditions of the road are some thing different from that in testing abraders [٦٢].

Wear involves removal of surface material which, for tire tread, includes such divers mechanisms as removal of chunks by cutting, high speed, tear, degradation of surfaces to low molecular weight material which can transfer to opposing surface, and even degradation to gaseous products.

In general, there are four broad categories of tire tread wear depending on the different wear mechanisms which may coexist simultaneously.

These are as follows [١٠٤]:

١- Hysteresis wears. ٢- Abrasive wear. ٣- Wear due to squirming motion. ٤- Tread reversion.

Temperature is, of course critical to each of these mechanisms and the temperature cycle at the tread surface during a tires rotation on the pavement is not well known. In spite of these problems, abrasion resistance tests can be useful if the range of validity is recognized.

High tire operating temperatures are caused by the thermo-mechanical stresses produced within the tire, especially when driving at high speed and on curvy roads, and tend to reduce the life of the tire. At low temperatures, the elastomeric compounds of the tire tread tend to wear less, but also provide less friction with road and, thus, reduced handling performance. At higher temperatures, some of the performances are increased but resistance to wear is degraded [١].

This test was carried out in accordance with British standard B.S ٩٠٣ PTA-٩ by using Akron Abrader.

CHAPTER FIVE

Results

&

Discussion

CHAPTER FIVE

٥-١- Introduction

Tread is one of the most important part of the passenger tire because it undergoes mechanical wear, heat build up, and whether conditions besides, it is responsible for wet and dry grip, rolling, high friction coefficient and taking part of safety drive.

Evaluating of those characteristics above and others could be predicted by physico-mechanical properties of tread rubber vulcanizate as previously mentioned in chapter four article (٤-٣) page ٦٠. For scheduling results and discussion purposes they are grouped into two main categories in accordance with the testing procedure.

Cure or Rheometric properties is the first category which implying scorch time, cure time, maximum and minimum torques. **Scorch time** ($t_{s٢}$) is the time for the torque to increase ٠.٢N.m above the minimum torque, where

cure time (t٩٠) is the time for the torque to increase above the minimum torque by ٠.٩٠ of the difference between the maximum and minimum torque readings in general, it is also defined as the time required during the vulcanization step for the compounded rubber to reach the desired state of cure. **Maximum torque (M_H)** is a measure of stiffness (modulus & hardness) of the rubber, and thus varies with number of cross-links as vulcanization proceeds, and **minimum torque (M_L)** is usually a measure of rubber compound viscosity.

The second category is the **physico-mechanical properties** including **tensile strength, modulus, elongation, hardness, abrasion resistance and specific gravity.** In order to improve those major mechanical properties it is necessary to **optimize the recipe of the tread rubber by means of blending one or more types of elastomer in (phr)s with the base rubber SBR using different kinds of carbon black.**

In this work optimization is mainly concerned with the mechanical properties, however, "cure properties" is also optimized to ensure that the process-ability and formulation acceptability are within the standard limits and be comparable with control properties.

Comparison has conducted on the properties which have been tested in the laboratory and mentioned through the chapter of experimental work, with control recipe properties specified in previous table (٤-٤), which have taken **a single** elastomer **(SBR١٥٠٢)** as the base rubber compound filled with three black types on one side, and also with standard properties mentioned in table (٤-٢), by the Dunlop Co. and State Co. of Babylon Tires on the other side. For easier comparison control properties are also listed on all result tables in the following chapter. Comparison has also made in between the similar properties depending on the type of reinforcing agent (carbon black), meeting the most effective values on the range between upper and lower limits of standards. Obtaining better values than control properties is the **target of optimization.**

Optimization is agreed and significant:

١. when the followings reach extreme values (around the upper limits):

A/ scorch time ts٢ and maximum torque M_H.

B/ tensile strength, modulus, and abrasion resistance.

C/ Elongation percentage.

٢. when the followings reach lower values (around the lower limits):

A/ Cure time t٩٠ and minimum torque M_L.

B/ specific gravity.

Optimization of hardness is more suited with the average between upper limits and lower limits of standards. In general, the optimization which is based on experience and global standards is that which fulfilled the above requirements, and is well known used in rubber technology.

٥-٢- Effect of Increasing Loading Level (amount) of NR in Tread Recipe (NR/SBR) Filled with three Blacks

٥-٢-١: Introduction

Generally, natural rubber NR (SMR٢٠) can be vulcanized with other unsaturated elastomers to broaden the range of properties available to the tread rubber compound. Blends of NR with other rubbers are a very useful way either to replace a particular rubber or extend the allocation of a particular rubber **[١٠٦]**.

As a chemical analysis blending of NR and SBR gives rise almost to block copolymers. Blends of NR/SBR are expected to be heterogeneous since NR and SBR are different both physically and chemically **[١٠٦]**. Difference in physical properties would increase non-uniformity in mixing as shown by some investigators **[١٠٧]**.

NR/SBR blends or recipes lead to improve some properties for some extent, and then improvement decreases or becomes stable at the final loading level steps, this is referred mainly to the over cure (reversion) which often associated with NR vulcanizates. Reversion can be avoided by modifying accelerators and/or accelerator activators which tend to elongate the vulcanization period. In this work this faults can not be avoided because the recipe ingredients can not be changed other than elastomer. Changing of any type of ingredients leads to increase the variables which may deviate the object of this work.

As ageneral, guide synthetic rubbers require more accelerators and less sulfur than does natural rubber. This is because in the polymer chain there is a proportion of non-vulcanisable structure which does not require sulfur and in say, SBR; this reduces the reactivity of the butadiene sections of the chain. There is also an important and noticeable difference between SBR and natural rubber with regard to the smaller difference of speed between various classes of accelerator. This is what could be described as ultra fast in NR and become medium fast in SBR **[٨٦]**. As formulation is considered with no

chance for changing parameters other than those mentioned in the objective of this work, the above recommendation is not exactly executed which lead to affect the mechanical properties.

Effects of increasing amount of NR can be shown with more details through the following properties:

٥-٢-٢- Cure Properties:

Results on tables (٥-٢, ٣, ٤) as indicated in appendix A illustrated the cure properties of **model NR formulation** of tread compound as be shown in previous table (١-٢) filled with blacks N-٣٣٠HAF, N-٣٣٩HAF-HS, and N-٣٧٥HAF respectively.

It is obvious that the increasing of NR in SBR blends by means of replacing the same pphr of SBR for ٦ runs in recipe, affects the cure properties which could be discussed as follows:

Comparison & Evaluation.

١. It is recommended to have a comparison for the results obtained in table (٥-٢) with the control properties taken from the control recipe of ١٠٠phr or ١٠٠wt%SBR and with Babylon and Dunlop Co., standards.

The mentioned results can show;

- Reducing the scorch time from ١.٢٤ to ١.٢١٨ minutes and cure time from ٢.٩٨ to ٢.٧١ minutes is clear by the data above. It can be seen that there is a gradual reduction in scorch and cure time values with respect to the control data begin from ٢nd run until the last run. Comparison with standards specified in previous table (١-٢) shows that scorch time is matched with the most range of the same specified data recommended by the Babylon Tire Co. and Dunlop Co., however, all runs (١٠-٦٠) phr of NR have not met the upper limit of those

standards. It is the same thing for cure (vulcanization) time which is certainly applicable to the standards especially with Babylon Co. standard. Reducing of scorch and cure times is primarily referred to the effects of NR loading. Basically, fatty acids are normally present to ١-٢ wt% in natural rubber. Hence, increasing of fatty acid in recipe leads to shorter scorch time and cure time. Furthermore, high unsaturating degree of NR is also responsible for accelerating the vulcanization process **[١٠٨]**.

- Maximum torque (M_H) has increased from ٣١.٢ to ٣٢.٥٣dNm through the first (٣ runs) of NR loading levels, and then decreased for the last (٣ runs), ending with ٢٨.٠dNm. Also, the minimum torque (M_L) which gives an indication to the viscosity of the blend (recipe) has directly increased from ٥.٥٥ to ٦.٥١dNm.

- In case of comparison of maximum and minimum torque with control, it is found that they are acceptable by both standards. Maximum torque has increased by ١.٥٣dNm above the minimum limit of Babylon Tire Co. imparting good modulus of tread rubber compound. Meanwhile ٥٠/٥٠ and ٦٠/٤٠ runs are shown corresponding values to the control. The inherent reversion of NR is after the reduction of maximum torque **[١١]**.
- Minimum torque increases gradually with respect to control and minimum limit of Babylon Tire Company. In fact, high Mooney viscosity of natural rubber leads to those results **[٦٢]**.

٢. Variation of cure properties mentioned in table (٥-٣) above depends mainly upon loading level of NR, as NR increases in recipe, scorch time decreases and cure time decreases as well, this gives an indication that both of them are shortened as follow;

- Decreasing scorch time and cure time from ١.٢٦ to ١.٢٠ minutes and from ٣.١٠ to ٢.٧٢ minutes respectively. Since, the cure properties

show acceptability with limits of standards and control for all runs, vulcanization and formulation of those recipes have correlated relation in proper way.

- Raising the values of maximum and minimum torques through the range of loading NR from ٢٩.٢ to ٣١.١١dNm and from ٦.٢٧ to ٦.٨٠dNm respectively. Over cure due to increasing NR in recipe causes either stiffening or softening the rubber compound. Consequently, causes either increasing or decreasing in the maximum torque **[٩٣]**.

٣. Table (٥-٤) clarifies the results of increasing NR loading level from ١٠ to ٦٠ pphr in tread recipe NR/SBR shows the followings;

- Values of scorch and cure time gradually decrease from ١.٢٥ to ١.١١ minutes and from ٢.٨٠ to ٢.٢٦ minutes. It can be seen that scorch time and cure time have decreased less than control, but they are still within the limits of the other two standards except for cure time which deviates for the last two runs. Deviation under the lower limit of Babylon Co., standard is mainly attributed to NR amount and carbon black type.
- Maximum torque slightly increases with the first (٣ runs), and then decreases for the other (٣ runs), initial and final values are ٢٩.٥٢ and ٢٨.٧٨dNm. Minimum torque is directly proportional with NR loading by increasing from ٥.٥٤ to ٦.٩٨dNm for (٦ runs). Decreasing of maximum torque for the last three runs is the same for that reported with N-٣٣٠.

٥-٢-٣- Mechanical Properties:

Tables (٥-٥, ٦, ٧) as indicated in appendix A illustrated the physico-mechanical properties of tread rubber with NR filled with blacks N-٣٣٠HAF, N-٣٣٩HAF-HS, and N-٣٧٥HAF as previously reported in table (١-٢).

Properties of recipe used SBR alone have to be considered as control properties. Recipes were prepared by the increasing amount of NR with corresponding decreasing of SBR in tread rubber compound have been used for the optimization purposes; however, increasing of NR in tread recipe requires more sulfur and fewer accelerators than with SBR alone which may affect the recipe properties **[١٠٩]**. Optimization can be achieved through a comparison with the control and the other two standards. So, the following effects could be discussed.

Comparison & Evaluation.

١. Table (٥-٥) reports down the following results of increasing NR loading level from ١٠ to ٦٠ pphr in tread recipe NR/SBR ;

- Tensile strength has risen significantly during ٣٠/٧٠---٥٠/٥٠ runs, and then reduced for the last run ٦٠/٤٠ phr. A comparison with control clarifies an important advantage through that range of NR loading. If those properties of ٦ runs compared with the other standards, it is obvious that the increment is higher than minimum limit of Dunlop & Babylon Co. by amount of ٨.٩٨MPa which represent about ٩٠٪ enhancement above the lower limit.
- In the same way modulus has increased for the first three runs more than the control, and then slightly decreased for the last three runs. Comparison with control shows ٣.٨MPa an increasing value of modulus, and when comparing with standards the modulus increased ٣.٩٣٥MPa with respect to minimum limit. Improvement of tensile strength and modulus in existence of NR is due to the ability of the vulcanizate to crystallize readily on stretching. The crystallites thus formed function as reinforcing agents. Decreasing the tensile and

modulus especially at the last step is referred to the lack of sulfur which is formulated basically for١٠٠phr of SBR, besides, reversion phenomenon accompanied with NR during vulcanization **[١٠٩]**.

- Elongation percentage at break has increased directly for all runs. Increasing of elongation is more effective if compared with control and it is nearly one half the standard minimum value at the last run. As elongation is an inherent property of NR, therefore, it is reflected on the NR vulcanizates with other rubber such as SBR.
- Hardness increases slightly for ٦ runs indicating a range of increasing starting with ٦٣ to ٦٤ (I.R.H.D) upper the control hardness. However

comparison with standards leads to have acceptable results matched with the range of those standards for all runs. More cross-links of NR with sulfur and SBR cause in such hardness **[٩٣]**.

- Abrasion resistance index increases for all ٦ runs exceeding Dunlop standard especially at the ٦th run and imparting a remarkable advantage, also it can be noticed a large increment comparing with the control. Low heat buildup and high resilience of NR is after such increasing of abrasion index **[٩٣]**.
- Specific gravity indicates a little bit reduction especially through the ٦th run; this is due to lower specific gravity of NR if compared with SBR a lone **[١١٠]**. Results are accepted by Babylon requirements because of covering most of its range, but can not be comparable with Dunlop standard because being out the range.

٢. Table (٥-٦) expresses the following results of increasing NR loading level from ١٠ to ٦٠ pphr in tread recipe NR/SBR ;

- There is a noticeable increasing of tensile strength starts with ١٦.٠٨MPa, then continues till ١٦.٦٣٦MPa before reaching ١٥.٦٦٠MPa at the ٦th run. If compare the raising of tensile strength to the control property, it can be seen a medium difference between the control and first run by amount of ٢MPa, meanwhile the other runs is serially

increased by a little amount. When the tensile strength for six runs is with black N-٣٣٠, except that increasing of tensile here is slight because joining of crystalline rubber NR and high structure black N-٣٣٩ always gives such result **[٦١]**.

- Modulus has a significant increasing in magnitudes for all runs, if compare with the control. However, it is more effective than other minimum limits of the standards by ٣.٢MPa especially through ٤th & ٥th runs.
- Elongation percentage gradually increases with significant difference in values until ٤th run, and then reverses for the other consecutive runs.

Comparing with the control shows about ٦٠٪ improvement at the ٤th run, this gives an indication that elongation has been advanced, meanwhile comparing with the standards indicates a significant enhancement. Increment of elongation percentage often comes from introduction of NR in tread recipe, resulting in good resilience and low hysteresis, and thus reduces heat buildup **[١٠٧]**.

- The available results reflect a little progress of hardness particularly at ٥th and ٦th run comparing with control. When comparison has done on these data with respect to standards, it is clear that they are within the limits for each one and having ١١.٥٪ development of the lower limits. Increasing of hardness may refer to high structure of reinforcing agent N-٣٣٩ besides more dense cross-links of NR due to increasing of loading level **[١٠٨]**.
- Abrasion index increases with large rate for the final four steps indicating a great improvement comparing with standards and control. It is essential to have such important optimization that contributes in extending the tread life.
- Specific gravity is often decreased but with a higher rate if compared with that filled N-٣٣٠, this is because of the higher specific gravity for

Carbon black N-٣٣٩, however the specific gravity is still fitting the standards.

٣. Table (٥-٧) shows the following results of increasing NR loading level from ١٠ to ٦٠ phr in tread recipe NR/SBR ;

- Tensile strength has increased directly with the increasing of NR loading level for all runs showing a remarkable improvement. Increasing of tensile strength indicates clearly the great role played by NR on the recipe properties. Increment of tensile strength is ٣٨.١% of the control particularly at ٦th run (٦٠/٤٠).Comparison with the two standards tensile strength is nearly twice the minimum limits which clarify a strike advantage.

- Modulus has increased in the same manner of tensile strength but with simple graduate if compared with control modulus. Comparing with standards shows sensible increase by about ١.٦٩MPa above the lower limit.
- It can be seen that increasing of NR level accompanied by similar increasing of elongation percentage. Elongation characteristic has been improved for all runs if compared with the control and standards. Evaluation of this result is the same as mentioned with N-٣٣٠ & N-٣٧٥.
- It is quite apparent from the data presented in the table (٥-٧) that optimization covers most of the mechanical properties mentioned above. Nature of NR and recommended properties of black N-٣٧٥ have taken part to appreciate for such optimization.
- Increasing of hardness has conducted on the last ٤ runs if compared with the control; besides it is agreed with other standards. Increasing has occurred in simple amount for the last ٤ runs due to the medium structure of reinforcing agent N-٣٧٥ **[١١]**.

- Results of abrasion index go up from ١١٣ to ١٤٨ and appear a medium increment if compared with standards, meanwhile comparing with the control shows a large improvement.
- It is clear that specific gravity has fitted the Babylon standard and being relatively stable for the most runs. Existing of equilibrium between NR and SBR specific gravity amount and N-٣٧٥ loading may create like this result **[١٠٩]**.

٥-٢-٣- Comparison of Mechanical Properties of NR/SBR Filled with Three Blacks

٥-٢-٣-١-Tensile Strength;

Figure (٥-١) shows the tensile strength property of tread rubber compound [NR/SBR] reinforced by three types of black, N-٣٣٠HAF, N-٣٣٩HAF-HS and N-٣٧٥HAF.

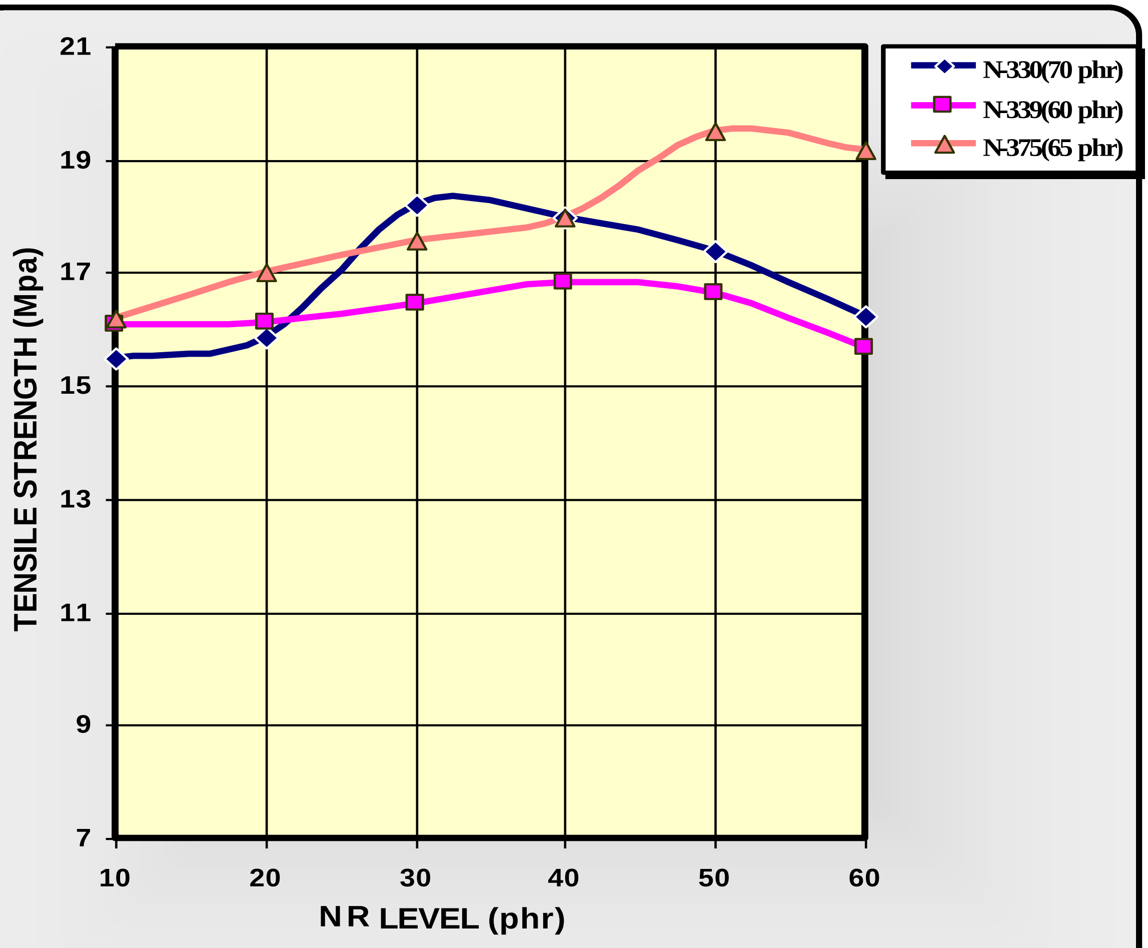


FIG.5-1 Tensile Strength Versus(phr)s of NR Filled 3-Types of Carbon Black

It can be seen from the figure above that the tread rubber compound (NR/SBR) with ٦ gradual increments of NR has different tensile strength depending on the reinforcing agent (carbon black). Tensile strength of recipe filled with black N-٣٧٥ has good advancement if it is compared with other recipes filled with N-٣٣٠ and N-٣٣٩ respectively. This is referred to the

nature of NR and black N-٣٧٥ that has a small particle size and medium structure where the role of structure reverses itself depending on whether the polymer (rubber) is crystalline or amorphous. In other word, the small particle size and medium structure blacks with crystalline polymer provide high tensile, meanwhile; the same black characteristics with amorphous polymer provide low tensile strength **[١١١]**.

-٢-٣-٢- Modulus;

Figure (٥-٢) indicates modulus of elasticity of three types of tread compound rubber (NR/SBR) each one filled with specified carbon black.

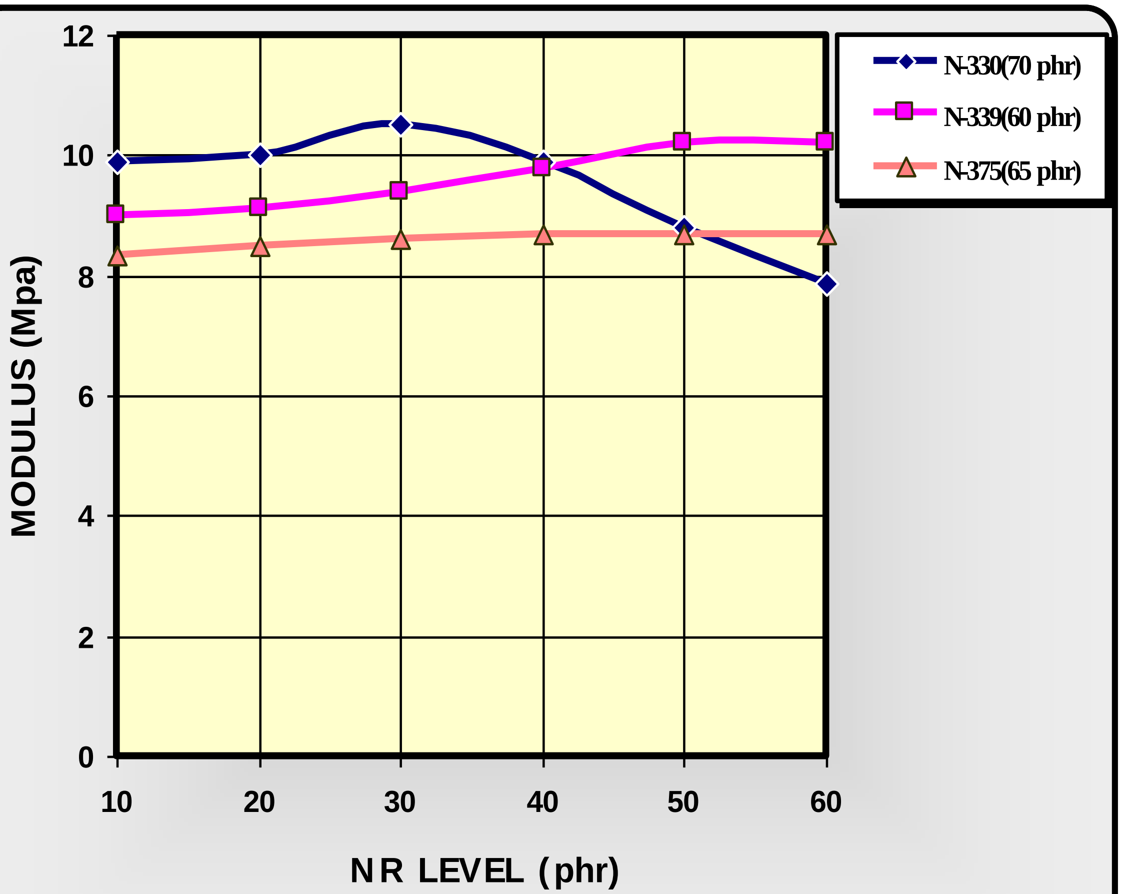


FIG.5-2 Modulus Versus (phr)s of NR Filled 3-Types of Carbon Black

The above figure clarifies the comparison between moduli referred to three tread recipes. It is noticeable that the recipes filled with black N-٣٣٩ have increased modulus along NR loading level. This is normally attributed to the high degree of black aggregates (high structure) where “the higher

structure blacks produce the higher modulus” **[١١١]**. Recipe filled with N-٣٧٥ shows a simple gradual increasing of modulus, because it is classified as medium structure black. Modulus of recipe filled with N-٣٣٠ shows an improvement nearly at mid loading level of NR before it goes down for the end of loading. Interpretation of this improvement refers preliminary to higher loading (٧٠phr) and low structure of N-٣٣٠ and susceptibility of NR to crystallization **[١١٠]**. Collapsing of N-٣٣٠ modulus attributed to sulfur vulcanization systems which give in particular lower moduli and increase compression set **[٦١]**.

-٢-٣-٣- Elongation Percentage @ break;

Figure (٥-٣) expresses the elongation percentage for three individual tread recipes (NR/SBR) reinforced by blacks N-٣٣٠, N-٣٣٩ and N-٣٧٥.

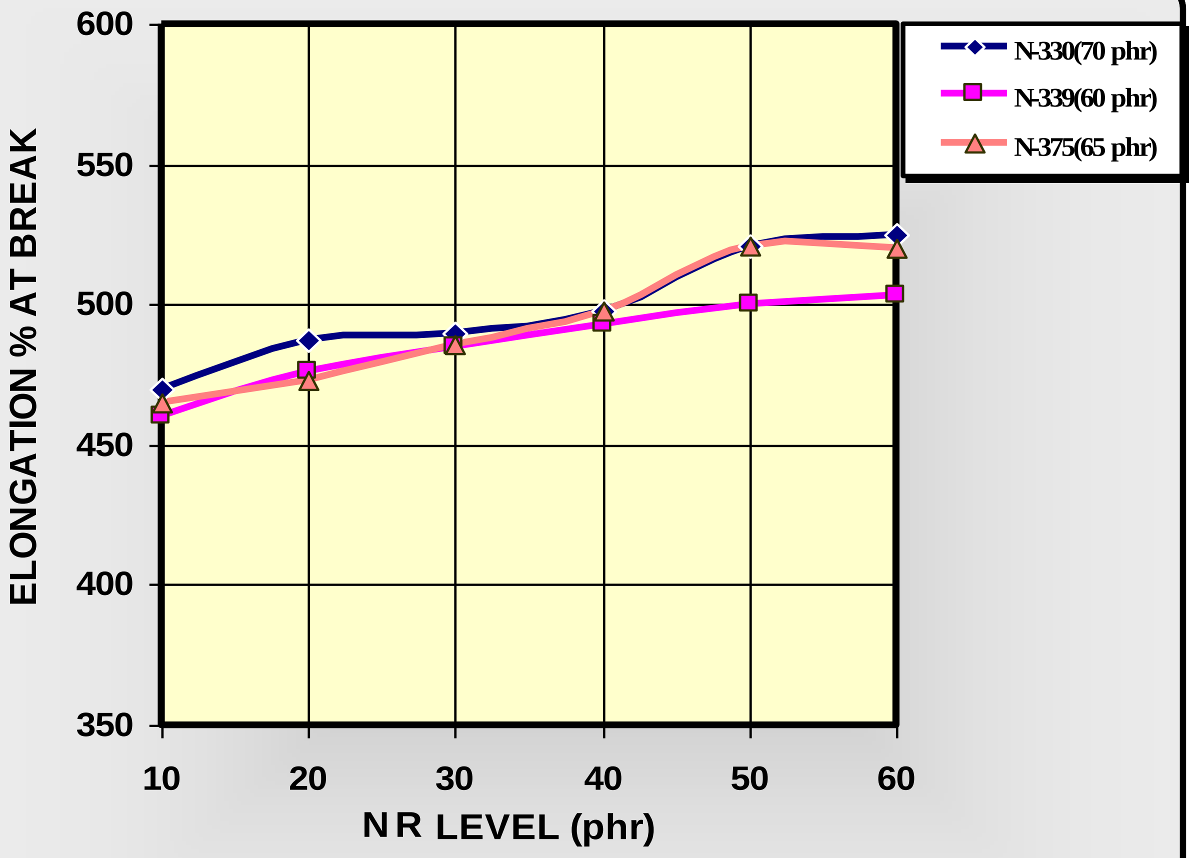


FIG.5-3 Elong.% Versus (phr)s of NR Filled 3-Types of Carbon Black

The increase of elongation percentage for the blends is remarkable; blend with N-٣٣٠ and N-٣٧٥ has a significant advancement if compared with N-٣٣٩ blend. This may attribute to the amount and nature of reinforcing agent. Like modulus properties, elongation is basically a function of carbon black structure, with higher elongation produced with lower structure blacks and vice versa **[٧٥]**. This can be appeared in blends of low elongation those have high structure black N-٣٣٩. Also, elongation affected by (Tg) of the rubber as for low (Tg) having by NR which improve mechanical properties along wide range of temperatures [٦١].

-٢-٣-٤- Hardness;

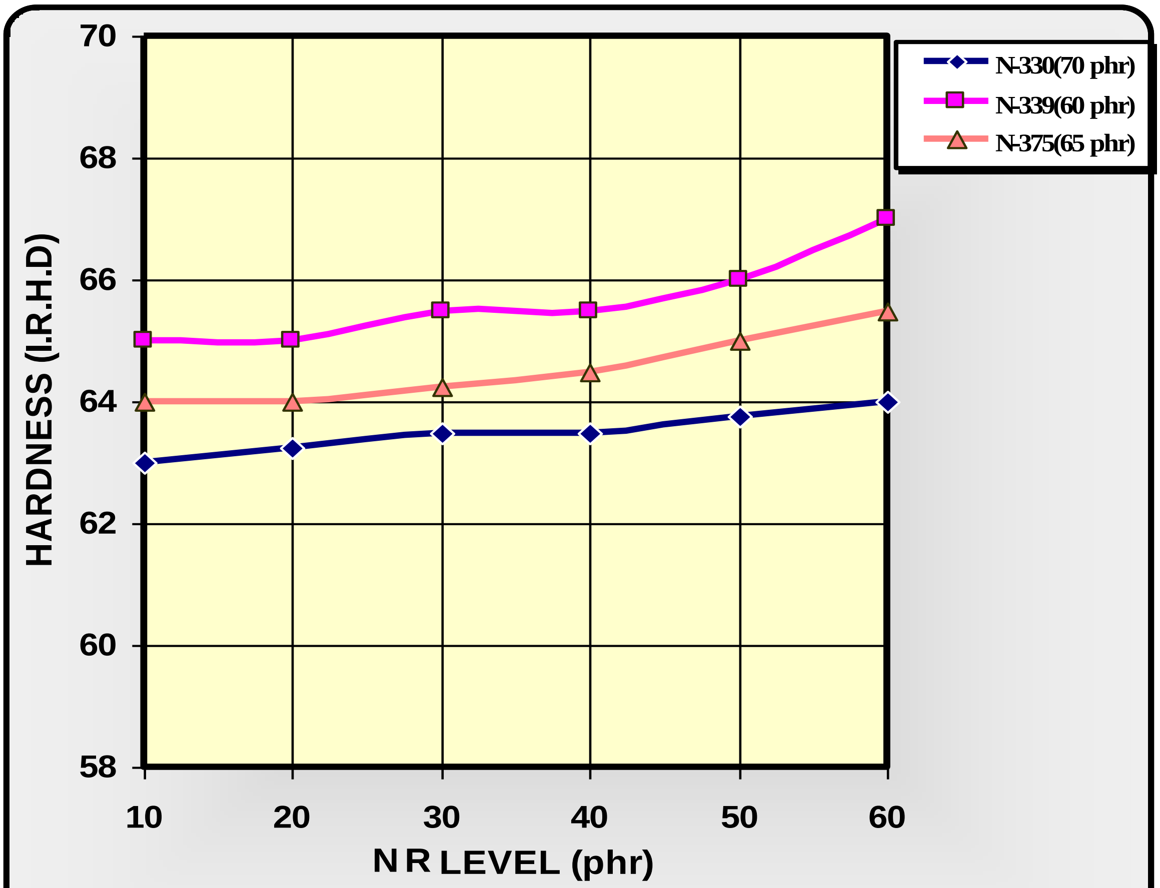


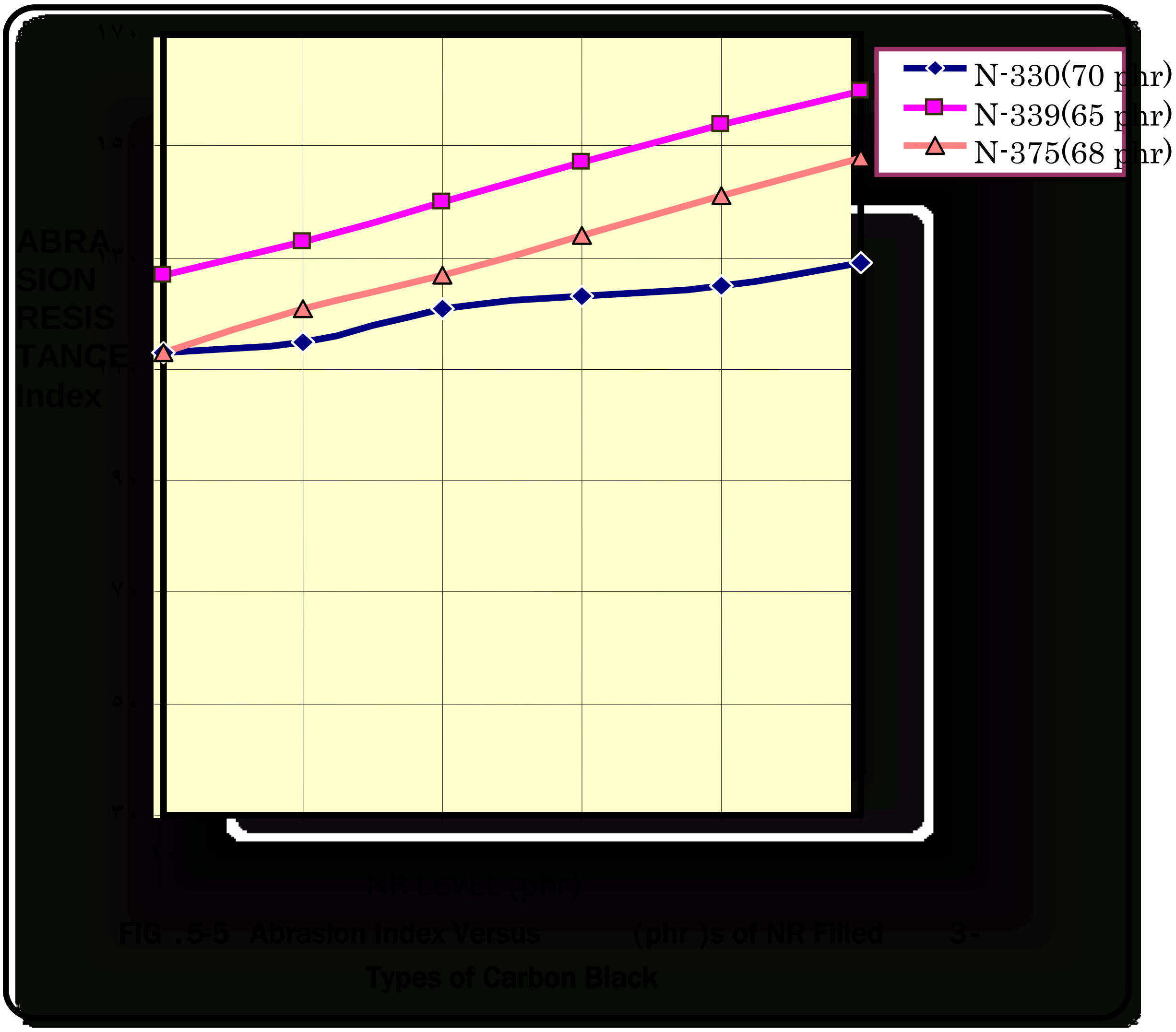
FIG.5-4 Hardness Versus (phr)s of NR Filled 3-Types of Carbon Black

Figure (٥-٤) shows the hardness of three recipes each filled with one type of carbon black.

A curve used to indicate the compound rubber filled with N-٣٣٩ discloses properly the increase of hardness with loading level of NR; meanwhile other recipes of N-٣٧٥ and N-٣٣٠ respectively have also proportional increase if they are compared with each other and have less degree comparing with recipe of N-٣٣٩. Evaluation of these results depends mainly upon amount and type of reinforcing agent used on one side, and on the natural rubber characteristics on the other side. With carbon blacks hardness is controlled by structure, particle size and loading with higher structure blacks producing the highest hardness at equal particle size [٧٥].

-٢-٣-٥- Abrasion Index;

Figure (٥-٥) declares the abrasion resistance index of three rubber mixes filled with three blacks.



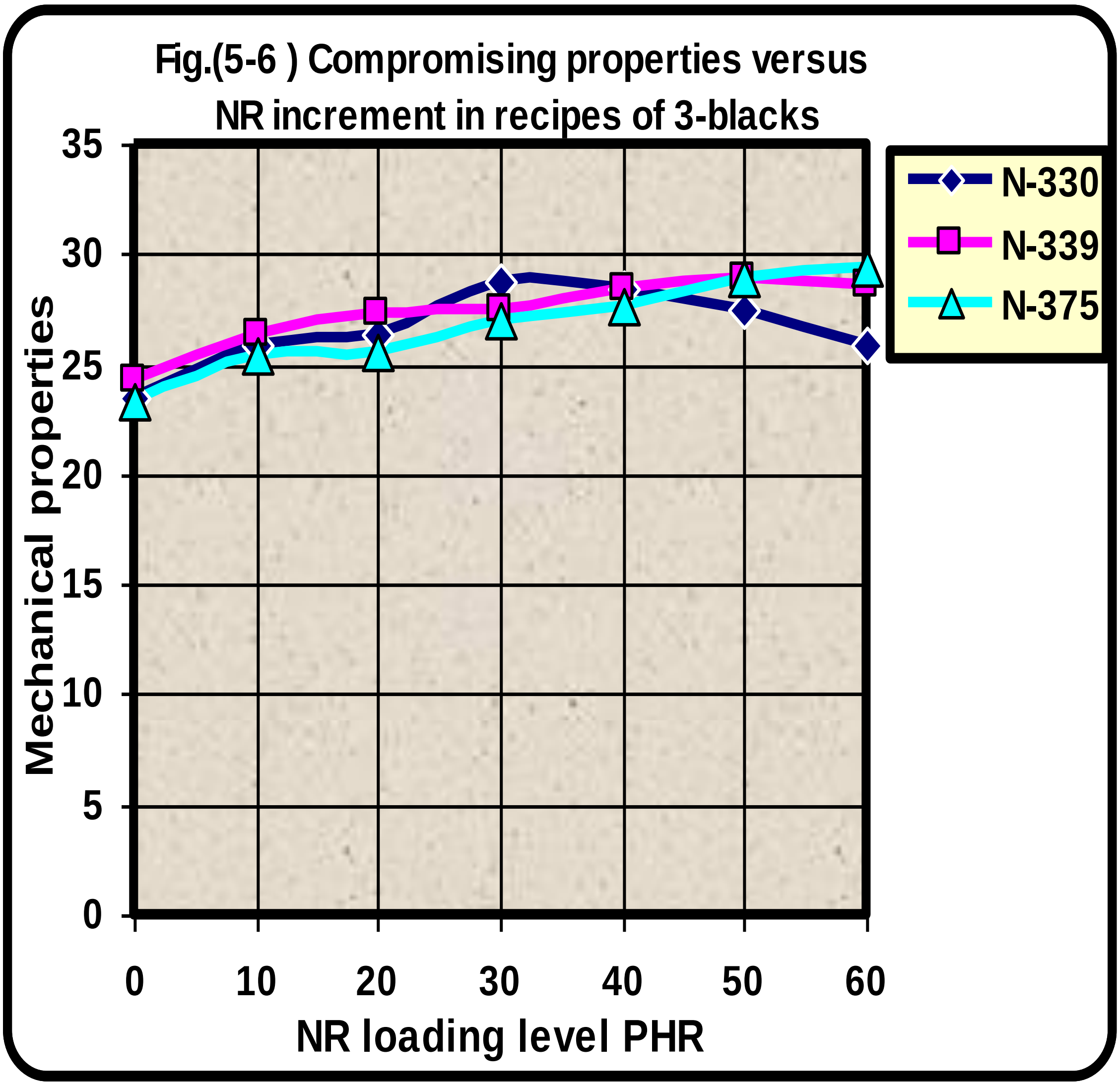
Abrasion depends on various factors and no one laboratory test method can be expected to simulate the different service conditions in which rubber components such as tires operate [٦٢].

As it can be seen from figure (٥-٥) that the abrasion resistance of three tread rubber compounds have an improvement in such away they have got proper optimization starting with recipe of N-٣٣٩, N-٣٧٥ and N-٣٣٠ serially. The increase of abrasion resistance is basically related to the NR specifications and high structure black N-٣٣٩. This is because the furnace

black (N-٣٣٩) is made from oil instead of gas. These oil blacks have a greater tendency to form carbon gel and bound rubber, which lead to better abrasion resistance **[٧٥]**.

٥-٢-٤- Mathematical Evaluation:

As it is known in rubber technology not all the mechanical properties could be optimized in the same level for the rubber compound, thus, compromise is recommended. To carry out such compromise a mathematical evaluation is used as a new criterion for evaluating most of the mechanical properties for each recipe. During this criterion, it is easily recognized the most optimized recipe which contains the typical properties by tables (٥-٥, ٦, ٧)A, appeared in appendix **A** and the following figure ٥-٦.



It can be seen from the three tables ٥-٥ up to ٥-٧ and figure (٥-٦) that compromising properties is clearly associated with recipe of ٣٠/٧٠ PHR for black N-٣٣٠, meanwhile recipes ٥٠/٥٠ and ٦٠/٤٠ PHR show compromising properties for blacks N-٣٣٩ & N-٣٧٥ respectively. Improvement of total mechanical properties refers preliminary to the susceptibility of NR to crystallization**[٧٥,١١٠]**.

٥-٣- Effect of Increasing Loading Level (amount) of BR in Tread Recipe (BR/SBR) Filled with three Blacks

٥-٣-١: Introduction.

Early in the development of solution polybutadiene rubbers it is noted that these polymers have certain desirable properties when compared to SBR and NR. These included a high tolerance for extender oils, excellent abrasion resistance and outstanding hysteresis properties **[١١٢,١١٣]**. It is also compatible with SBR producing great elasticity and good resistance to stiffening at low temperatures **[٦٦]**.

Blends of BR/SBR can show excellent carbon black wetting and dispersion. Addition BR to SBR at low loading level improves traction on icy and snowy roads, while mixing with high loading level improves traction in service without wet skidding if it is used with higher level of carbon black and oil **[١١٢,١١٤]**. Blends of BR/SBR can show also fast curing comparing with SBR a lone. This is because sulfineamide accelerators are basically designed for SBR vulcanization, thus, for BR these accelerators are more efficient resulting in over cure vulcanizates. We have to mention a noticeable fact that the vulcanizing agent sulfur must be more than that in model BR formulation which specified by single SBR **[٧٥]**. So, for this reason the mentioned properties may be affected.

٥-٣-٢- Cure Properties

Tables, (٥-٨), (٥-٩) and (٥-١٠) indicate the results of cure properties of **model BR formulation** for tread compound as be shown in appendix **B**;
The following discussion is carried out:

Comparison & Evaluation.

It is obvious that the increasing of BR in SBR blends (BR/SBR) by means of replacing the same phr of SBR for ٦ runs (١٠/٩٠----٦٠/٤٠) in recipe, and for three kinds of black affects the cure properties as follows:

- Scorch time and cure time are normally shortened as BR increases in BR/SBR recipe for blacks N-٣٣٠, N-٣٣٩ and N-٣٧٥ respectively. They are faster than control property and matched the Babylon Co. standard limits, however, final two runs of N-٣٣٩ and three runs of N-٣٧٥ cure time are being out the standard range. As blends of black N-٣٣٠ have longer scorch time if compared with N-٣٣٩ & N-٣٧٥ blends. So it can be considered more save than others.
- Basically, the combination of rubber kind, vulcanizing agent, accelerator, activator, accessory materials chosen for a particular compound determines its curing rate **[٧٥]**. This can give an indication for the effects of BR compound rubber and kind of black on the mentioned tabulated results. In general, the reduced curing time results in cost savings, and the amount of over cured rubber at the surface of tread is reduced **[٧٥]**.
- Maximum torque and minimum torque have increased in gradual steps with increasing level of BR in recipe. They perform adequately the standard requirements and control properties but, in different levels depending on the type and amount of blacks. Since, BR is more viscous in existence of carbon black where Mooney viscosity changes about ٠.٩(ML-٤) units for each change of one part of carbon black, minimum torque is readily increased with the loading level of BR **[٦٥]**.

٥-٣-٣- PHYSICO-MECHANICAL PROPERTIES

Tables (٥-١١, ١٢, ١٣) positioned in appendix **B** display physico-mechanical properties affected by substitution equivalent phr of BR rubber instead of SBR rubber for six runs in tread recipe BR/SBR of model BR formulation reinforced by three kinds of black.

Comparison & Evaluation.

Results illustrated in tables (٥-١١, ١٢, ١٣) can be evaluated by the followings;

- Tensile strength increases slightly for the first ٤ steps, and then comes down for the rest ٢ steps. This happens for all recipes filled with three blacks but not in the same level. The comparison with the control indicates a slight improvement of ٢٤.١%, meanwhile comparing with standards shows about ٧٧% of lower limit especially for the third step of N-٣٧٥ blends.
- Modulus increases generally as BR increases in recipe for all used blacks. Enhancement of modulus is clearly shown with both N-٣٣٩ and N-٣٧٥. It is known that at the same curative level the inherently lower modulus and tensile strength and better hysteresis properties of poly-butadiene rubber are reflected in the properties of the blend compounds. But if the Mooney viscosity of BR in such blends increases, modulus and resilience increase slightly and heat build-up decreases; ultimate tensile strength and elongation remain relatively constant **[٦٥]**.
- Elongation of N-٣٣٠ and N-٣٧٥ blacks increase relatively for ٤ runs; it is rather stable for the other runs. In addition, elongation of N-٣٣٩ blend increases fairly but not for all runs where two runs last has low

values. A comparison with the control displays a large improvement even with standards. The increase of elongation percentage for blends of black N-٣٣٠ presents a great advantage if it is compared with others of N-٣٧٥ and N-٣٣٩.

- For recipes of N-٣٣٩ and N-٣٧٥, hardness increases significantly if it is compared with the control meanwhile, for N-٣٣٠ hardness increases slightly by about ٣.١% of the control hardness. All of those recipes are still within the well-known standards. High structure and small particle size of carbon black are after the high hardness **[٧٥]**.
- Apparently, increasing of BR in tread rubber compounds is accompanied by increasing of abrasion resistance for ٣ types of carbon black as mentioned in tables above. Therefore, the improvement of abrasion resistance is ٤١.٤% for both N-٣٣٠ and N-٣٧٥ recipes if it is compared with the control meanwhile, N-٣٣٩ tread recipe has ٤١.١% improvement.

- As BR has lower specific gravity (٠.٩٢) **[١١٥]** than SBR, it can be seen clearly there is a gradual decrease in specific gravity for blends of three black types. For N-٣٣٠ blends it decreases slightly without deviating the standards, the same thing is thus with N-٣٧٥ blends for all steps. Specific gravity of N-٣٣٩ blends decreases relatively more than the others, this may related to the low density of carbon black N-٣٣٩ and its low loading level principally

٥-٣-٣- Comparison of Mechanical Properties of BR/SBR Filled with Three Blacks

٥-٣-٣-١- Tensile Strength;

It can be seen from fig. (٥-٧) that three blends of BR/SBR filled with different kinds of carbon black, as BR increases in each blend tensile strength for those blends is going to be relatively identical especially after step ٤٠/٦٠ of BR/SBR composition.

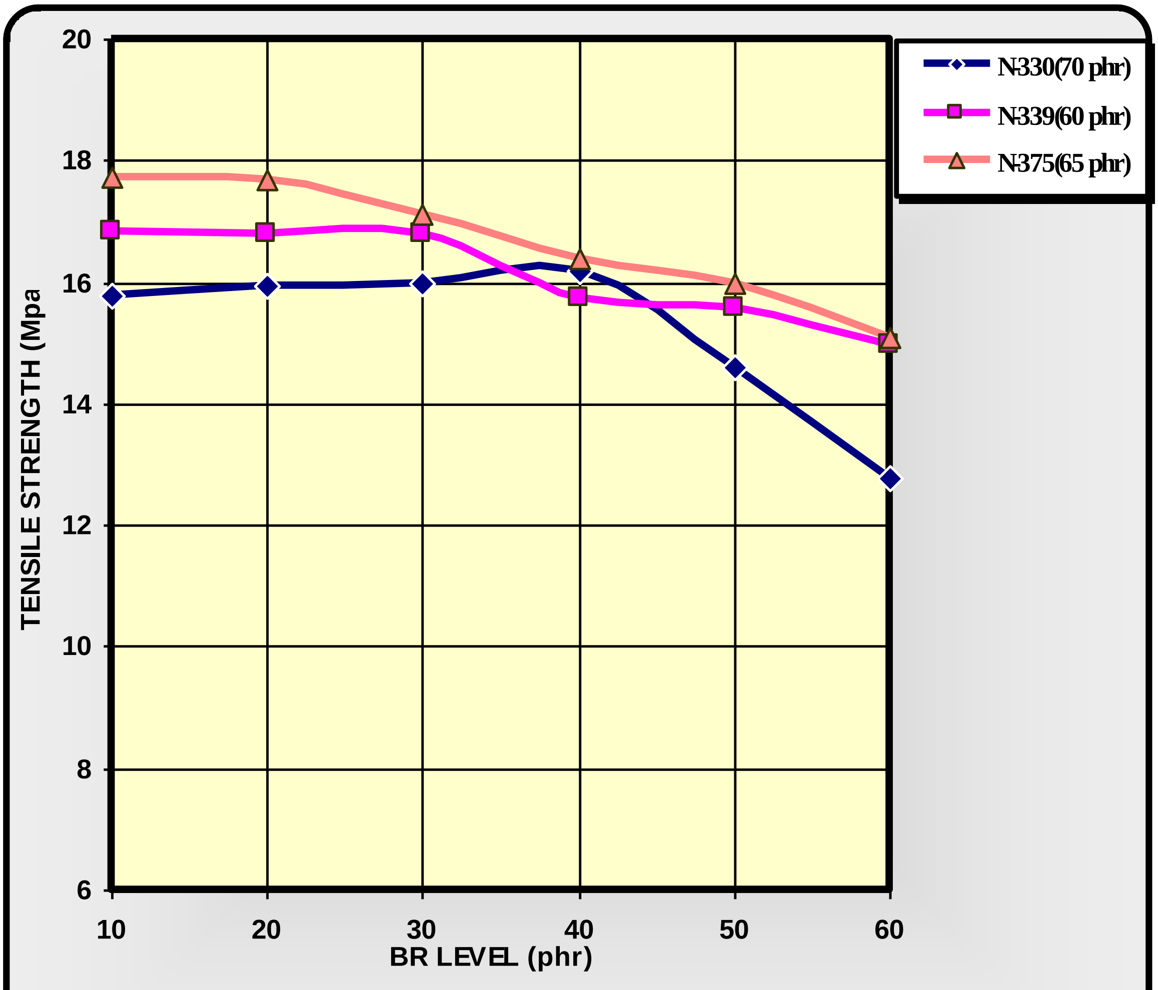


FIG.5-7 Tensile Strength Versus (phr)s of BR Filled 3-Types of Carbon Black

Thus, increasing of BR in blends for the first three steps leads to an increase of the tensile strength for all black types especially with N-٣٧٥ however, three blends are simply decreased for the last ٣-steps.

The inherently lower tensile strength and modulus and better hysteresis properties of BR are reflected in properties of the blend compounds **[٤٧]**, so for this reason may low tensile strength here is attributed.

-٣-٣-٢- Modulus;

Figure (٥-٨) displays that with increasing of BR in tread recipe, moduli have increased also with diverse levels although the difference is not high.

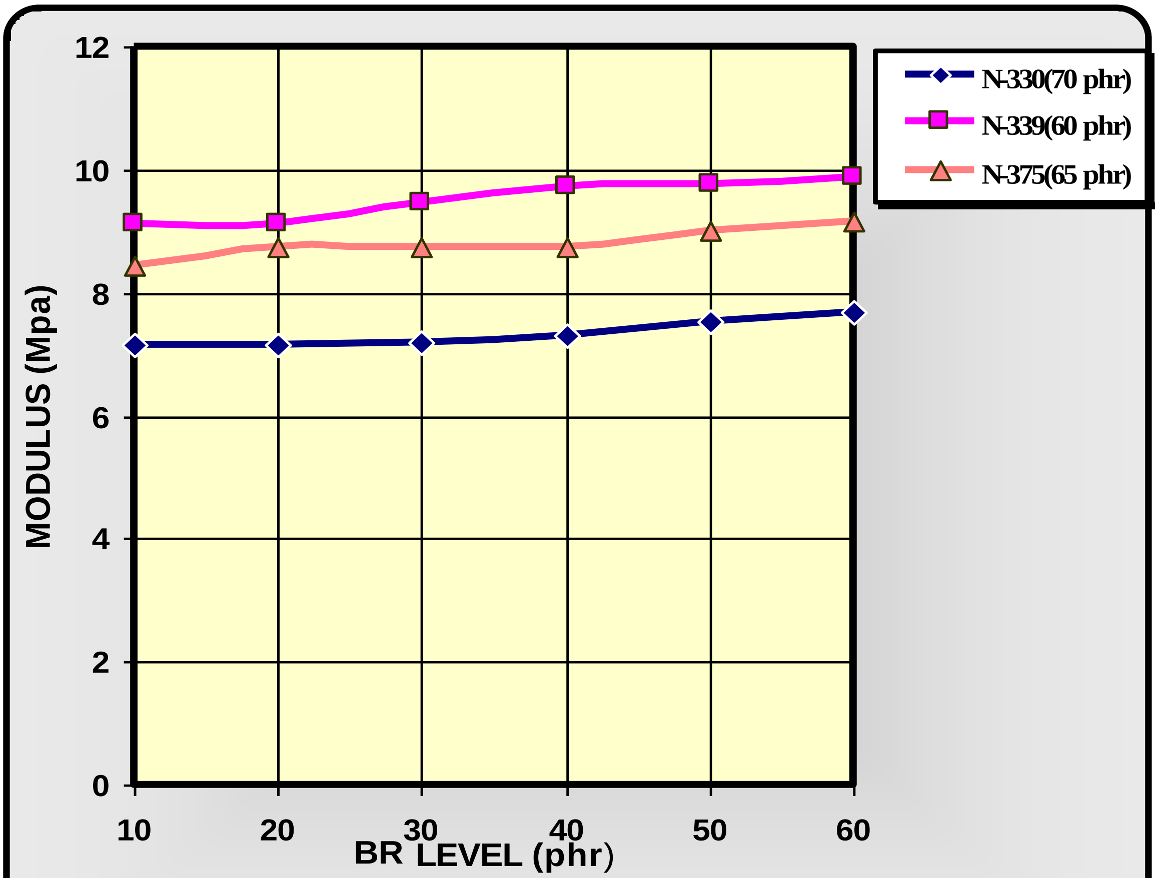


FIG.5-8 Modulus Versus (phr)s of BR Filled 3-Types of Carbon Black

Recipes of several compositions of BR especially at ٦th step filled with black N-٣٣٩ have the upper values of modulus among the other recipes of blacks N-٣٧٥ and N-٣٣٠ respectively. Principally, higher loading and structure of black N-٣٣٩ with respect to others are the reason of its higher modulus **[٧٥]**.

-٣-٣-٣- Elongation percentage (%) @ break;

Elongation percentage has different levels at the first run ١٠/٩٠ of BR/SBR according to the type of black and the tread compound composition. Blends of black N-٣٣٠ & N-٣٧٥ represent the optimized characteristic of elongation for the most loading level phr of BR.

Blend of N٣٣٩ has increased slightly until run ٤٠/٦٠ and then for other runs as indicated in fig. (٥-٩). As we have used process oil which is lighter than aromatic oil, this leads to low Mooney viscosity of BR causing an increment of elongation especially with black N-٣٣٠ due to optimum

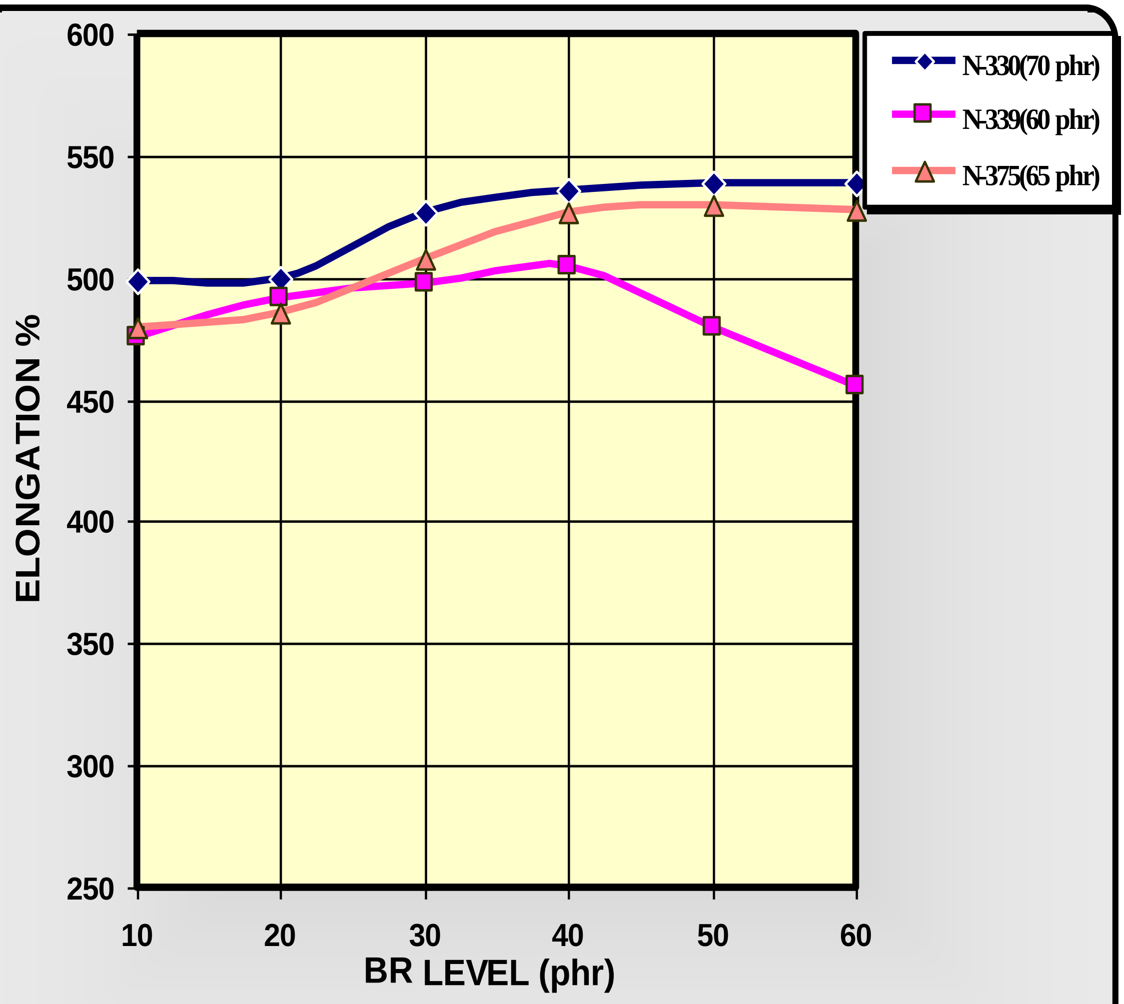


FIG.5-9 Elong.% Versus (phr)s of BR Filled 3-Types of Carbon Black

-٣-٣-٤- Hardness;

Fillers N-٣٣٠, N-٣٣٩ and N-٣٧٥, and increasing of BR loading in tread recipe play a great role in determining the hardness as clarified by the figure (٥-١٠) underneath.

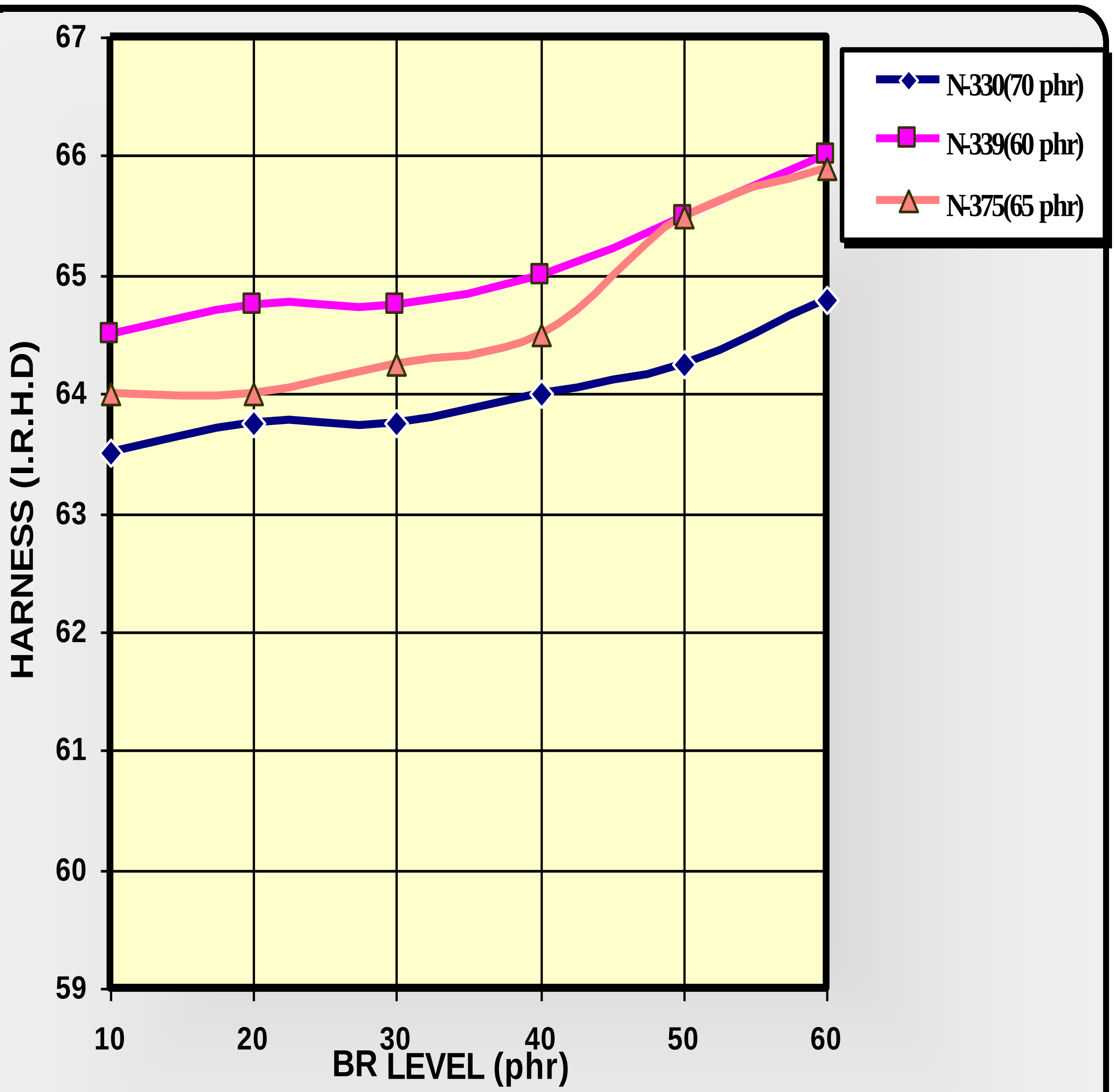


FIG.5-10 Hardness Versus (phr)s Of BR Filled 3-Types of Carbon Black

As seen hardness with black N-٣٣٩ has always increased for all steps leading the other blends, this gives an indication that blends with increased BR level associated with black N-٣٣٩ have an improvement if compared with two other blends of blacks N-٣٧٥ & N-٣٣٠ respectively.

Incorporation of black N-٣٣٩ with BR in BR/SBR tread recipe which has a great tendency to associate with high aggregate size (high structure) fillers results in enhancing hardness in such compounds [١١٠].

-٣-٣-٥- Abrasion Index;

What available in figure (٥-١١) is an evidence for the high abrasion resistance accomplished by mixes having an increased BR as an elastomer and N-٣٣٩ as reinforcing agent.

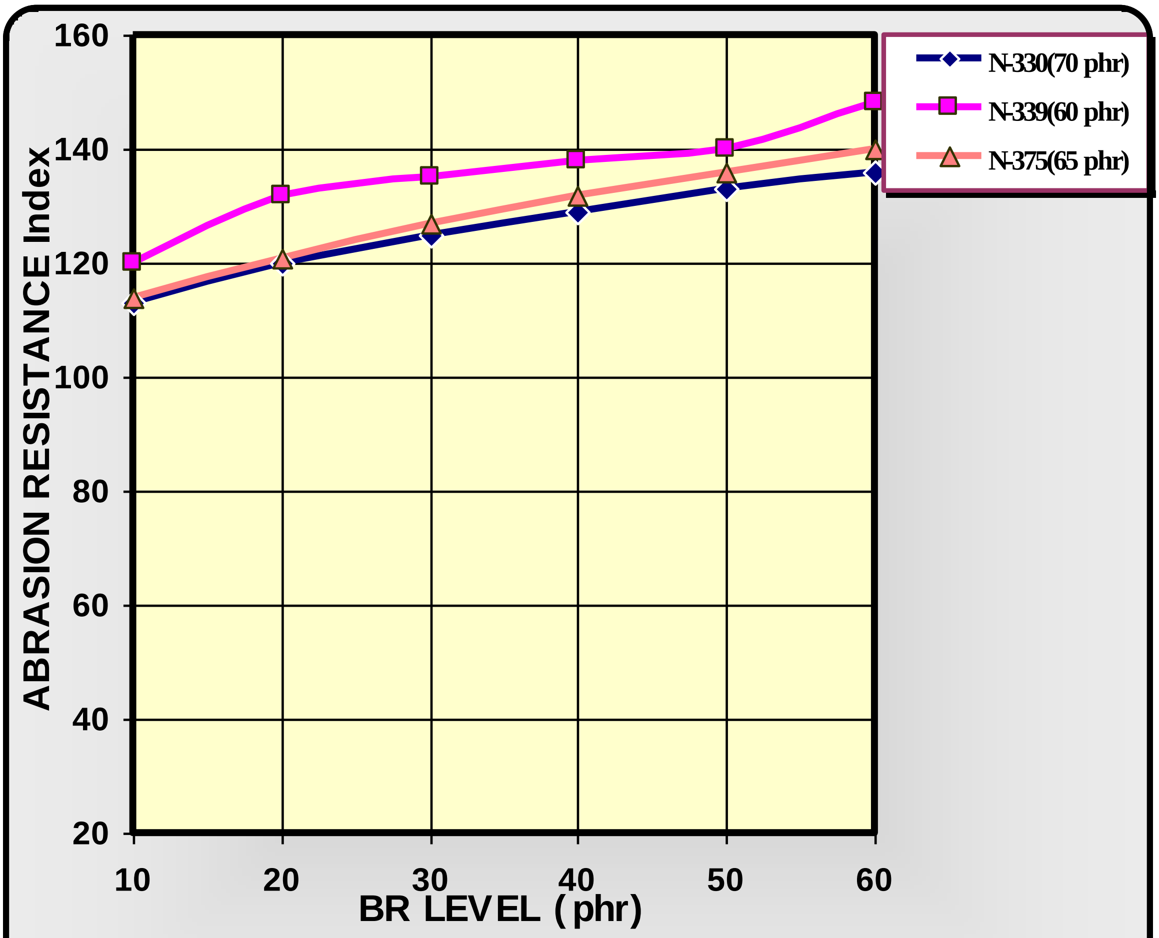
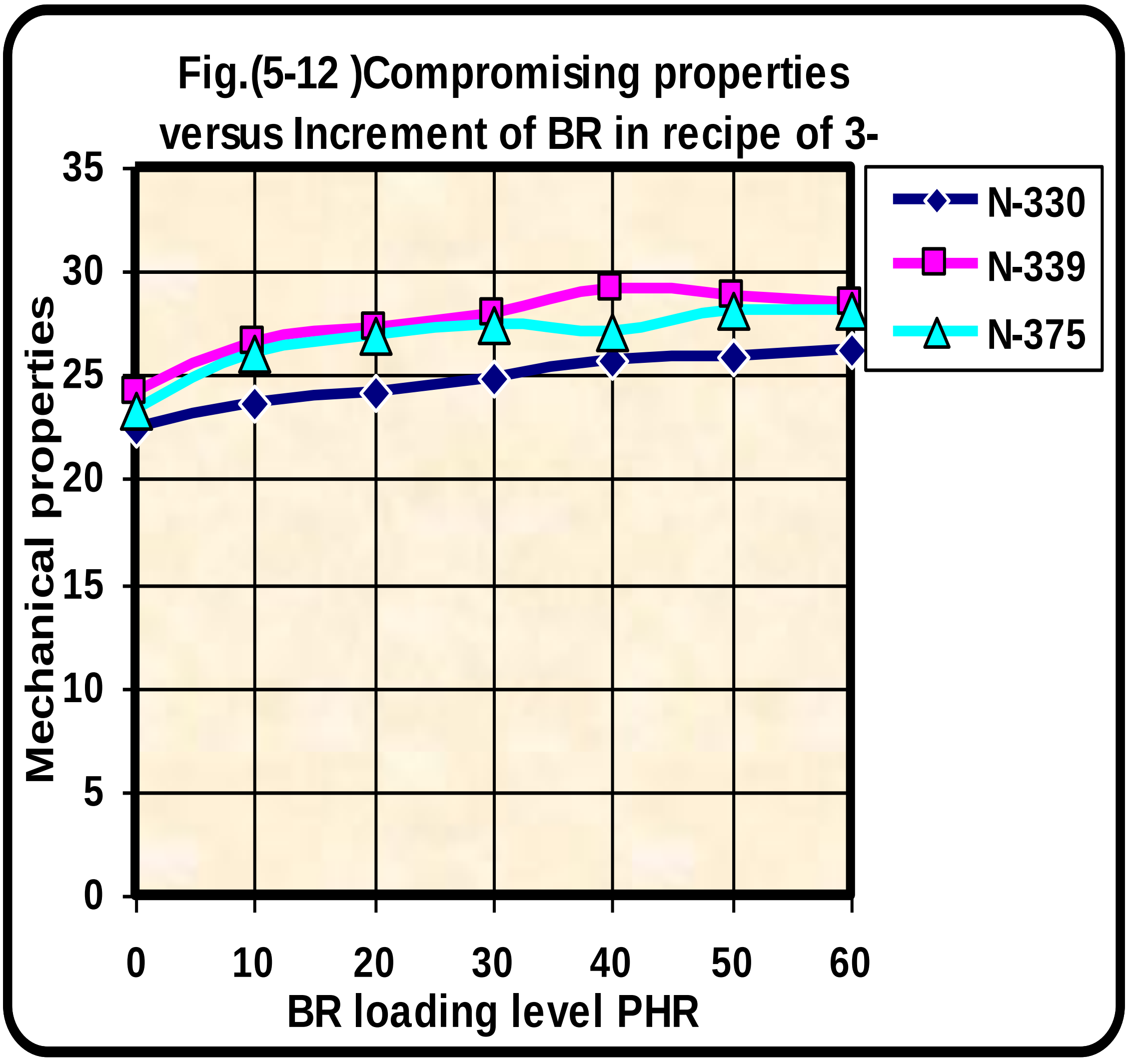


FIG.5-11 Abrasion Index Versus (phr)s of BR Filled 3-Types of Carbon Black

The other two mixes of blacks N-٣٣٠ & N-٣٧٥ are less pronounced than the increase of abrasion resistance of N-٣٣٩ mix even though they increase in the same manner. This result could be enhanced where recipe with higher levels of BR, increasing carbon, and oil levels maintains or gives improved abrasion performance **[٤٧]**.

٥-٣-٤-Mathematical Evaluation:

The following figure ٥-١٢ and tables show the values that estimated by some calculations as it has done in table (٥-١) which is mentioned in appendix **B** later.



From the tables and the above figure, it can be seen that compromising properties for recipe ٤٠/٦٠ PHR of BR/SBR is most optimized with blacks N-٣٣٩, meanwhile recipes of ٣٠/٧٠ & ٦٠/٤٠ having compromising properties with blacks N-٣٧٥ & N-٣٣٠ respectively. As modulus, elongation, hardness, and abrasion resistance had improved with blacks N-٣٣٩& N-٣٧٥ when individually used, the total mechanical properties could show the same mprovement due to the high lever level of BR and blacks loading[٤٧, ٧٥].

٥-٤- Effect of Increasing Loading Level (amount) of CR/BR in Tread Recipe (CR/BR/SBR) Filled with three Blacks

٥-٤-١:Introduction:

It is already known that chloroprene rubber (CR) provides a very useful all-round balance of properties. Its vulcanizates show moderate resistance to swilling in hydrocarbon oils and greases, combined with good resistance to low temperature stiffing. They also show good resistance to heat aging, to oxidation and, in particular, to attack by ozone. The chemical resistance of the vulcanizate is also generally good **[١١٦,١١٧]**.

In general, blends neoprene with other elastomers are used occasionally to provide certain properties which are not obtained with either elastomer alone, or to meet the service requirements of the finished product at lower cost than could be achieved with CR alone.

GRT neoprene can be blended in some proportions with other elastomers such as SBR, by doing so, it is possible to achieve some improvement in the processing characteristics such as scorch and cure time or vulcanizate mechanical properties.

A blend shared between (CR/BR) in one part and SBR in the other part is particularly designed for tire tread rubber , in order to proceed lower cost, offer some technical advantages and improve major mechanical properties. That blend has better crystallization resistance, lower brittleness temperature and better mechanical properties than neoprene a lone. Other important properties such as oils, weather, heat, flex, flame and ozone resistance increase as the amount of CR is increased.

It is evident that CR can be compounded to produce practical vulcanizates having characteristic properties over the following range:

Tensile strength ------------ Up to ٢٥.٥٨ MPa

Elongation percentage ----- Up to ٩٠٠٪

Hardness (shore) ---------- ٢٠ to ٩٠

Compression set ----------- As low as ١٠٪

Resilience ------------------ Up to ٨٥٪

Of course, no single compound will reflect the extremes of the ranges shown above [٦٨].

Increasing of (CR/BR) in tread blend (CR/BR/SBR) leads to the following effects;

٥-٤-٢- Cure Properties

Results in tables (٥-١٤, ١٥, ١٦) display the cure properties of **model CR/BR formulation** that mentioned in previous table (١-٢) for tread compounds filled with blacks N-٣٣٠HAF, N-٣٣٩HAF-HS, and N-٣٧٥HAF respectively.

Comparison & Evaluation.

Results in tables (٥-١٤, ١٥, ١٦) display the cure properties which could be discussed as follows:

- The introduction of CR in tread recipe has taken part in decreasing both scorch time and cure time for three blacks. Their decreasing is in different levels depending on the kind of carbon black, where blends of N-٣٣٩ for ٤ steps are with safety scorch time and optimum cure time. Other blends are enough fast to deviate out the control and standards especially with final two steps.

  As it is known, magnesium oxide is vulcanizing agent for CR, but also serve other functions such as a scorch retarder during processing. Because it has a high surface area to volume ratio, exposure of magnesium oxide to moisture and the air can cause loss of activity leading to fast scorch time and cure time. Cure time of CR is affected by all types of carbon black, but variations in PH of the blacks have only a slight effect [٧٢].

- Maximum and minimum torques have increased for all steps, they are comparable especially with blends of N-٣٣٩ and N-٣٧٥. Advantage of

maximum torque with about ٥٥٪ of control can be shown in table

(٥-١٦), minimum torques increase nearly in the same level for all blacks.

The amount of CR and kind of blacks govern the degree by which maximum and minimum torques increase. The other thing is that CR imparts stiffness in blends with SBR and other in highly extended compounds and thereby aid increasing of maximum and minimum torques **[١١٨]**.

٥-٤-٣- Mechanical Properties

Tables (٥-١٧), (٥-١٨), and (٥-١٩) as indicated in appendix **C** illustrated the physico-mechanical properties of model CR/BR formulation of tread compound filled with three kinds of black.

Comparison & Evaluation.

Generally, results reported in the three tables (٥-١٧, ١٨, ١٩) show raises of tensile strength, modulus and low elongation percentage as the content of CR in blends of tread CR/BR/SBR increase simultaneously.

- The increase in the tensile strength for three kinds of black is raised by ١٤٪ of control and ٦٢٪ of minimum limit of standard however, it goes down for last two runs (٥٠/٥٠, ٤٠/٦٠) especially with tables (٥-١٧, ١٨).
- In the same manner modulus increases slightly for blends of black N-٣٣٠, and increases largely with blacks N-٣٣٩ and N-٣٧٥. A comparison with the control and standard gives a good improvement for the first ٤ runs. Last steps of blacks N-٣٣٠ and N-٣٧٥ shows nil modulus because of collapsing the elongation down ٣٠٠٪ at those steps. It is normally shown that elongation is either relatively constant or coming down with increasing of CR in blends, except in the first ٣ runs of N-٣٣٠ where elongation has increased relatively.

- As crystallinity is an inherent property of poly-chloroprene [٧٠,١١٩]. It is regarded as the main source of strength properties such as tensile, modulus and hardness, besides, reduction in elongation percentage.
- Hardness becomes progressively larger as CR is increased with blends of N-٣٣٩, N-٣٧٥ and N-٣٣٠ respectively. Accordingly, there is a large enhancement of those blends if it is compared with the control especially with N-٣٣٠ blends and they cover the complete range between upper and lower limit of standards by about ١٣.٦٪ the lower limit.
- The rise of CR in tread recipe causes an increase of abrasion resistance represented by abrasion index. This is quite clear in mixes of black N-٣٣٩, with ٥٤% upper the control. It is, thus happened with other two black's recipes N-٣٣٠, and N-٣٧٥, but with lower level compared with blends of N-٣٣٩. As for recipe of blend N-٣٣٩, blends of blacks N-٣٣٠ and N-٣٧٥ have improved abrasion resistance by ٣٨.٧٪ and ٣٩٪ respectively.
- However, data on specific gravity of blends CR/BR/SBR increase with increasing of CR amount, all of them are not necessary to be matched with the control or the standards range. The first ٥ steps of blends filled black N-٣٣٩, ٣ steps of N-٣٧٥ black and ١ step of N-٣٣٠ black are in practical fulfill the standards requirements. The higher specific gravity (١.٢٣) of CR [٦٩,٧٠] results in higher specific gravity of neoprene blends as it is already shown.

٥-٤-٣- Comparison of Mechanical Properties of CR/BR/SBR Filled with Three Blacks

٥-٤-٣-١- Tensile Strength;

Figure (٥-١٣) shows that tensile strength increase with CR/BR loading for three types of black, although maxima occur at ٤th run for all recipes.

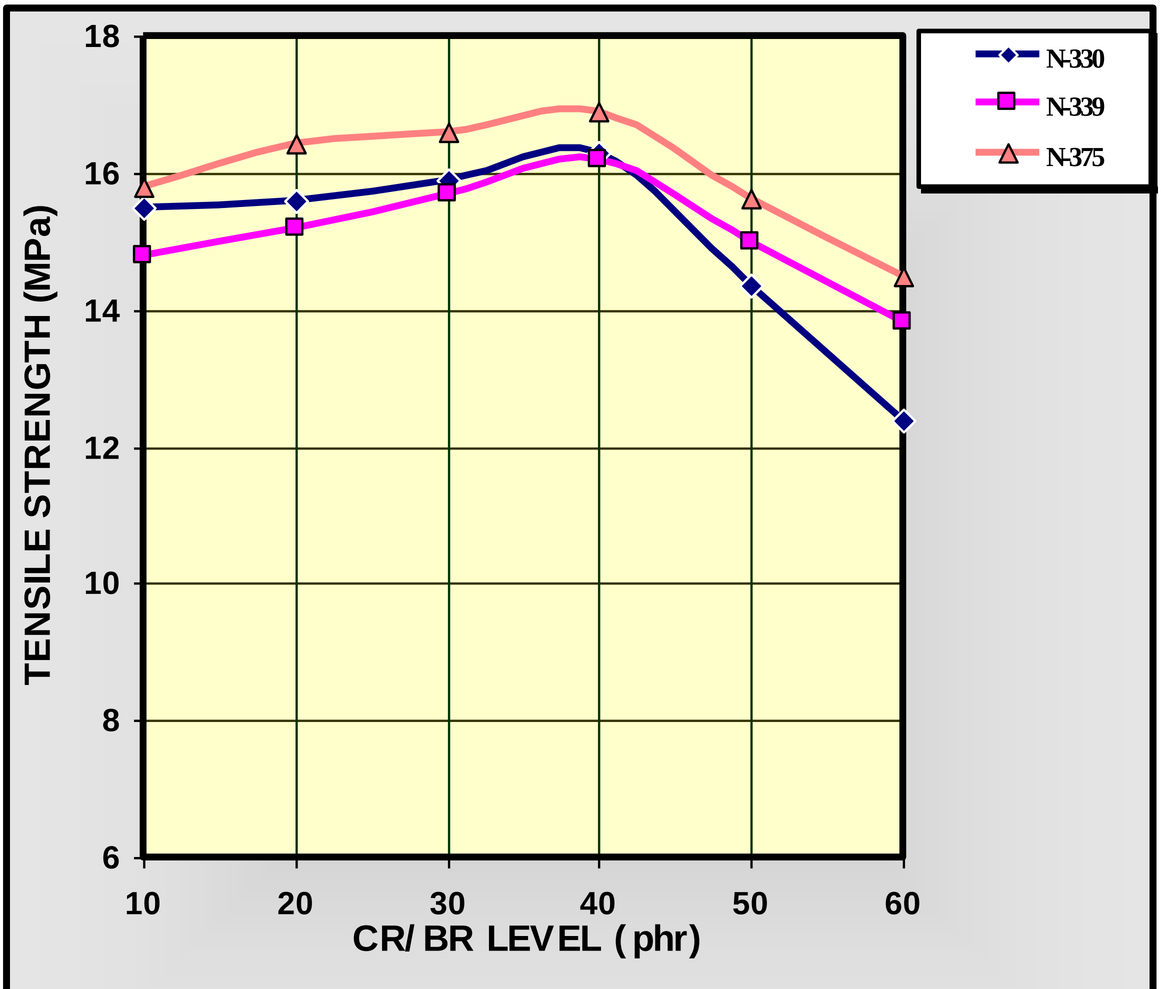


FIG.5-13 Tensile Strength Versus (phr)s of CR/BR Filled 3-Types of Carbon Black

Reduction in recipe CR/BR/SBR tensile strength for the last three runs is due to over cure of CR which is often inherent phenomenon for some general purpose neoprenes CR [٦٩,٧٠]. Tread vulcanizate of CR/BR/SBR filled with N-٣٧٥ is the optimized one between the other blacks especially at the ٤th loading level of CR/BR.

-٤-٣-٢- Modulus;

As it is clear from figure (٥-١٤) modulus of N-٣٧٥ is preferable, but only for five steps meanwhile, modulus of N-٣٣٩ has continuous effect for all loading steps of blends composed of CR/BR/SBR wherein considered as optimized property.

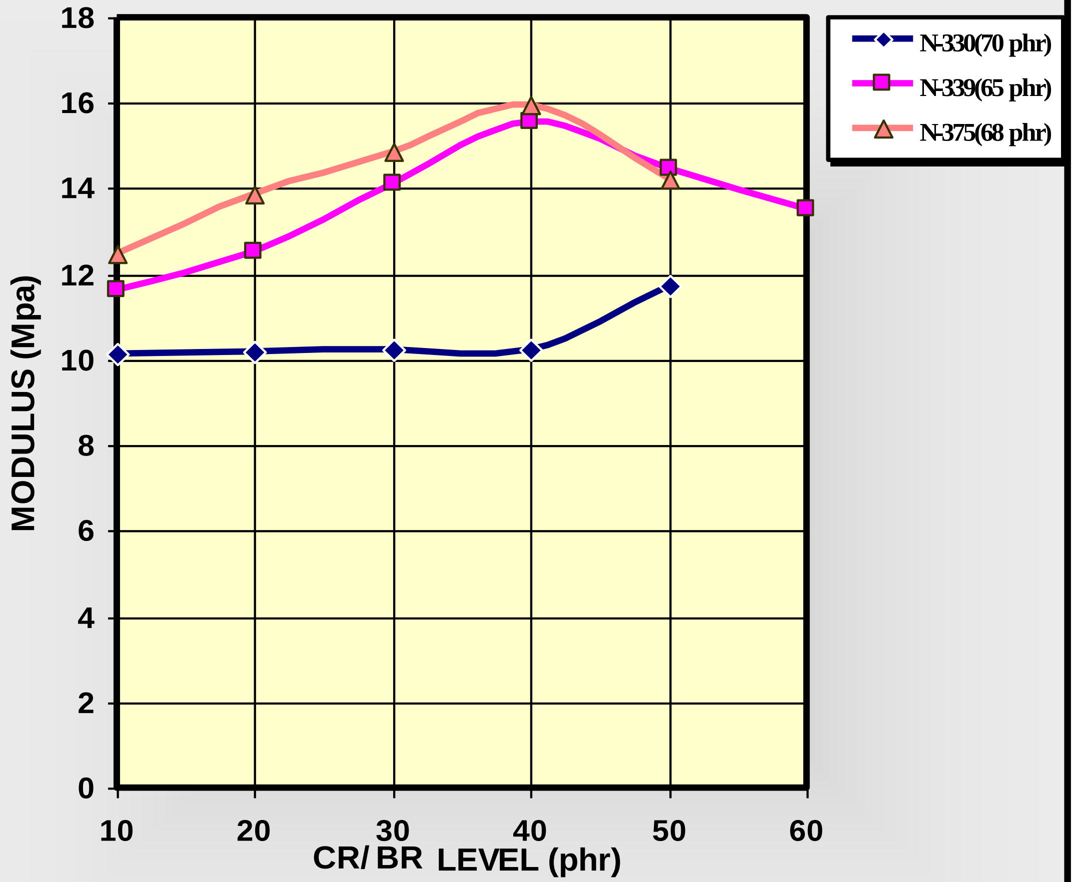


FIG.5-14 Modulus Versus (phr)s of CR/BR Filled 3-Types of Carbon Black

Interpretation of low modulus of N-٣٣٠ blend compared with other black blends may refer to that mentioned as for tensile strength and to low particle size and structure of black N-٣٣٠.

-٤-٣-٣- Elongation Percentage @ Break;

In spite of its being less for last two steps, elongation % is the optimized property with black N-٣٣٠ as shown in figure (٥-١٥). Other blends of blacks N-٣٧٥ & N-٣٣٩ have lower elongation percentage values.

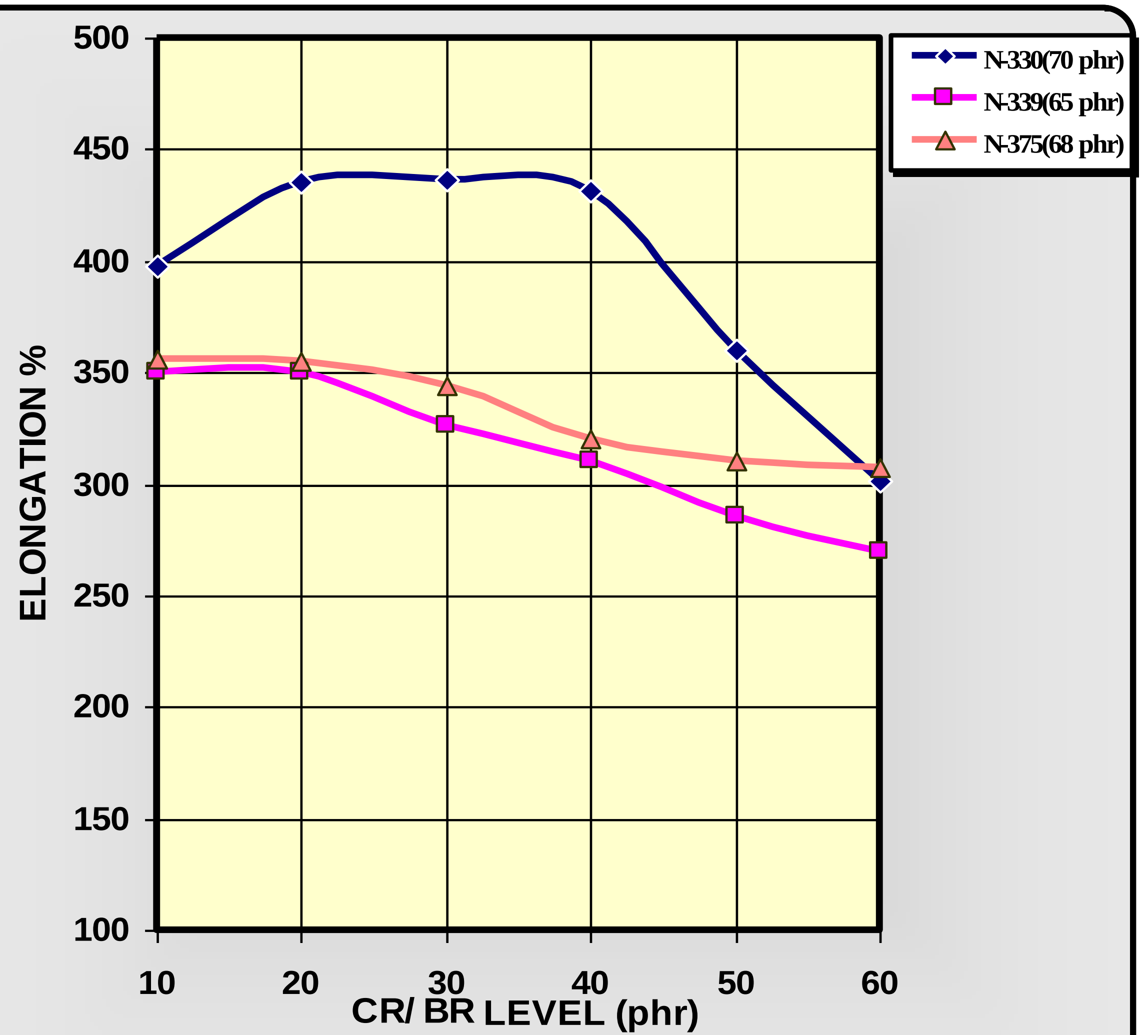


FIG.5-15Elong.% Versus (phr)s of CR/BR Filled 3-Types of Carbon Black

-٤-٣-٤- Hardness;

Hardness of tread vulcanizate reinforced by black N-٣٣٩ as shown in figure (٥-١٦) is so far optimized rather than other two blacks who are competitive and have the same fashion.

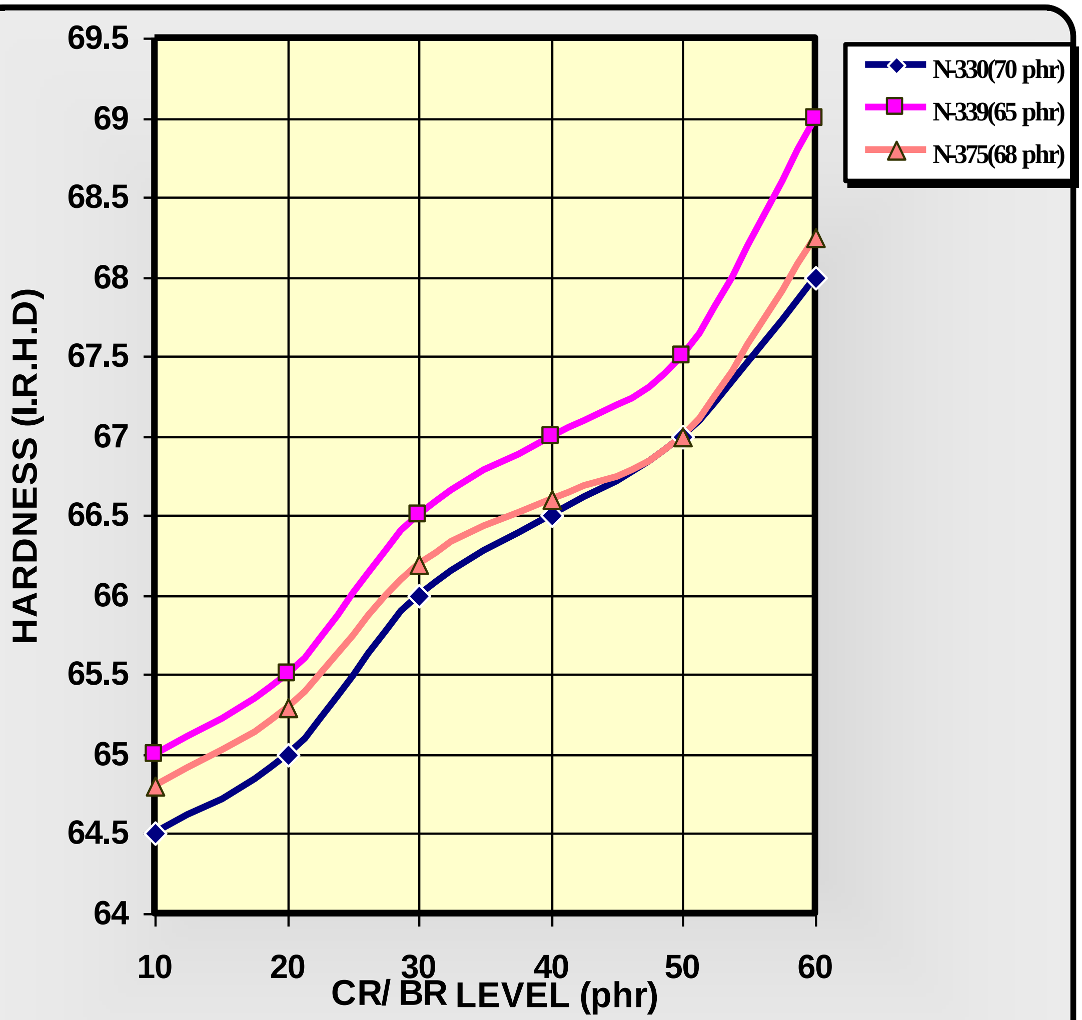


FIG.5-16 Hrdness Versus (phr)s of CR/BR Filled 3-Types of Carbon Black

Since carbon black N-٣٣٩ has a small particle size and high structure, hardness of its recipe increases largely indicating a promise improvement with continuous loading of CR/BR in tread blend. This is agreed with evaluation saying that, stiffness or hardness can be increased with an improvement in strength properties and high abrasion furnace high structure blacks. **[١١,٦١]**.

-٤-٣-٥- Abrasion Index;

It can be seen from figure (٥-١٧) that the most optimized abrasion resistance is with the vulcanizate of black N-٣٣٩, as well with the vulcanizates of black N-٣٧٥ and N-٣٣٠ respectively however, they are in lower level than the first.

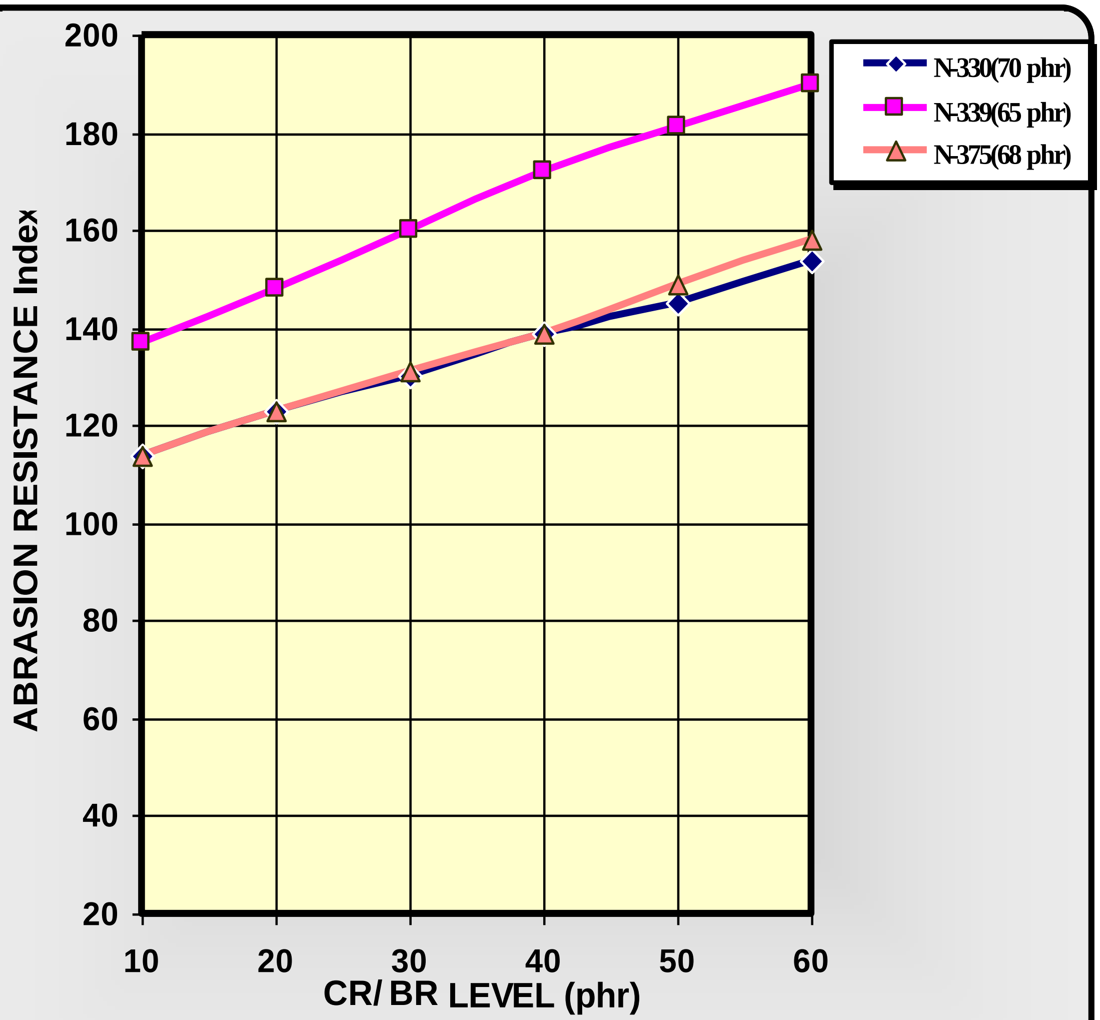
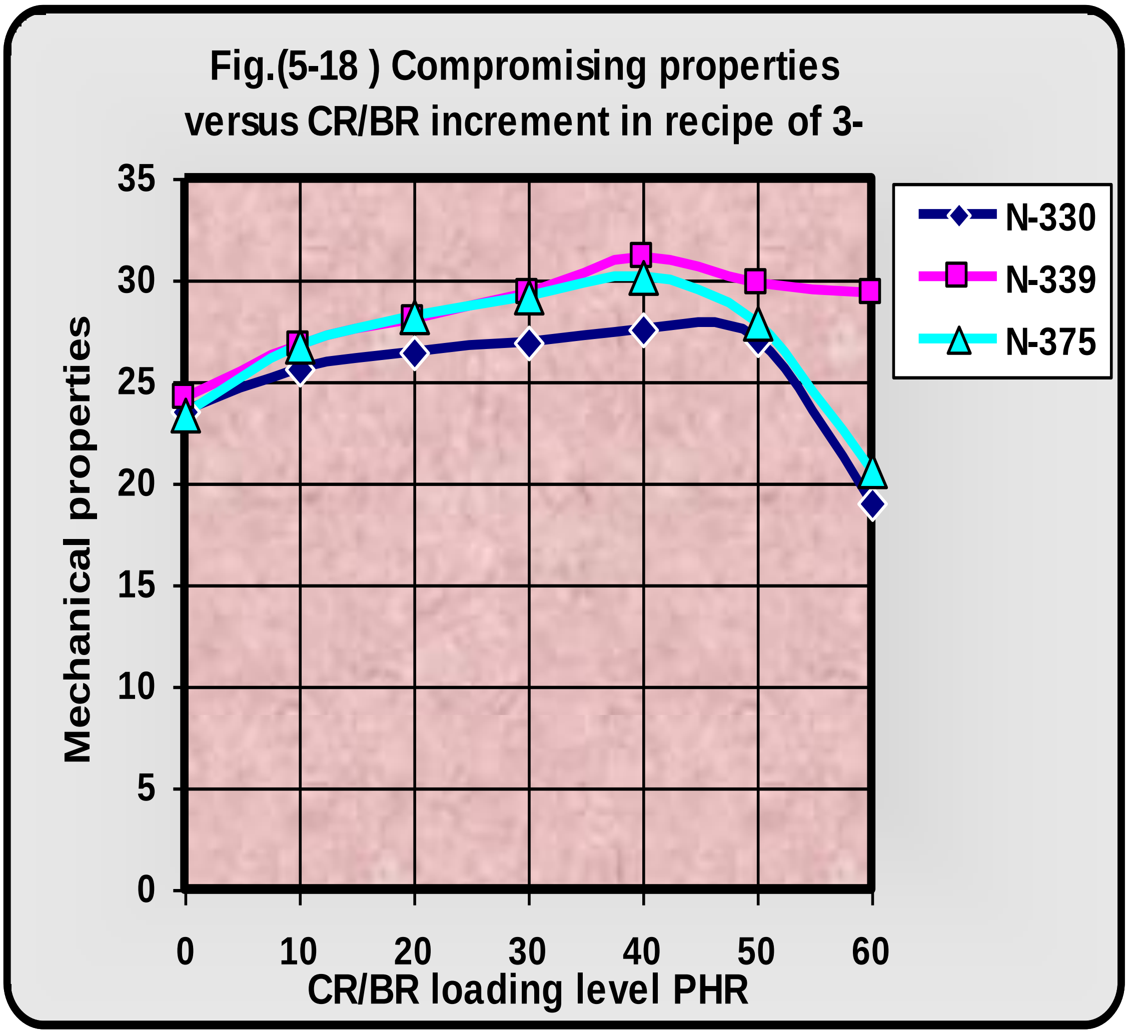


FIG.5-17 Abrasion Index Versus (phr)s of CR/BR Filled 3-Types of Carbon Black

As increasing of CR in tread recipe which is principally responsible of excellent mechanical wear resistance, black N-٣٣٩ is also taken part the same responsibility. According to ASTM٢٠٠٠ the high abrasion resistance is a characteristic of CR **[١١٤]**.

٥-٤-٤- Mathematical Evaluation

This could be seen by tables in appendix **C** and the following figure (٥-١٨).



It is essential to mention that with accordance of mathematical criterion, compromising properties of tread recipe ٤٠/٦٠ of CR/BR/SBR has optimized for three blacks. Advancing of mechanical properties between ٣٠/٧٠ and ٦٠/٤٠pphr of CR/BR/SBR with black N-٣٣٩ mainly refers to the high structure and very small particle size of that black type and crystallinity which is an inherent property of poly-chloroprene and the main source of strength properties **[٧٠,١١٩]**.

٥-٥- Effect of Increasing Loading Level (amount) of EPDM in Tread Recipe (EPDM/SBR) Filled with Blacks

٥-٥-١: Introduction.

EPDM rubber is amorphous ter-polymer like other non-crystallizing polymers. Mechanical properties of the unfilled EPDM are rather poor, and consequently, reinforcing agents are added.

Introduction of EPDM as the general purpose tire rubber of the future- the next SBR has been followed by a tremendous amount of work on the development of EPDM grades for various components of passenger car tires. Probably the most importance of these works and our work is the development of a polymer and a compound which, in combination, would give a balance of good tread-wear and skid resistance which is equal to present-day first grade passenger tires[٧٣].

EPDM has a very low level unsaturation compared with other polydiene elastomers such as SBR. A recipe adjusted to give a rapid, practical cure rate in EPDM will be exceedingly fast and cause over-cures in SBR. Conversely, a recipe written for SBR will cause only light; under cures in EPDM. It is, therefore, difficult to achieve a good, tight co-cure of a blend of EPDM and SBR. It is, however, often desirable to blend elastomers for applications requiring a combination of properties not found in one or another alone.

A more important application for EPDM in blends with another rubber such as SBR is to provide ozone resistance without participating significantly in co-cure with host rubber which comprises the major portion of the blend as in tread recipe for Babylon Tire. This technique is also used to enhance the ozone and weathering resistance of tire sidewalls.

٥-٥-٢- Cure Properties

Tables (٥-٢٠), (٥-٢١), and (٥-٢٢) as indicated in appendix **D** illustrated the cure properties of **model EPDM formulation** of tread compound as shown in previous table (١-٢) filled with blacks N-٣٣٠HAF, N-٣٣٩HAF-HS, and N-٣٧٥HAF respectively.

Comparison & Evaluation.

- Data mentioned in the last tables (٥-٢٠, ٢١, ٢٢) display that the increasing of EPDM is followed by increasing of scorch and cure time for all blends of three blacks. It can be seen that scorch time and cure time of N-٣٣٩ are longer than those blends of N-٣٣٠ and N-٣٧٥. All scorch and cure time of blends filled with three kinds of black are increased above control and are compatible with standards range especially with upper limits. As scorch is longer for so much within the range, it offers sufficient safety for consequence processing. But the long time of cure rate is disadvantageous goal resulting in increasing cost and helps in more reversion. Anyhow all those results are acceptable and accomplished a significant enhancement. The low level of unsaturation blends of EPDM with SBR, leads to more save time rather than previous blends of NR, BR, and CR with SBR **[٧٣]**.
- Blends of reinforcing agent N-٣٣٩ express gradual increase of maximum torque as well minimum torque as shown in table (٥-٢١).
- Concerning the data of final ٦th step (٤٠/٦٠) of EPDM/SBR, there is an advantage of ٣١٪ and ٣٦٪ for higher maximum and minimum torques respectively if compared with control. Maximum and minimum torques of blends with N-٣٣٠ and N-٣٧٥ as shown in tables (٥-٢٠, ٢٢) are relatively comparable with each other and are enhanced with respect to control by average of ٧MPa and ٣MPa for max. and min. torque respectively.

٥-٥-٣- Mechanical Properties

Tables (٥-٢٣, ٢٤, ٢٥) as indicated in appendix **D** display mechanical properties affected by substitution an equivalent phr of EPDM rubber instead of SBR rubber for six runs in tread recipe EPDM/SBR of model EPDM formulation reinforced by three kinds of black.

Comparison & Evaluation.

All results which were taken from the tables (٥-٢٣, ٢٤, ٢٥) listed in appendix confirming the great role playing by EPDM increasing amount in tread recipe composed of EPDM/SBR. These effects can be mentioned by means of the type of reinforcing agent as we will see in the followings:

- To some extent, tensile strength values of recipes N-٣٣٠, N-٣٣٩ and N-٣٧٥ are somewhat identical to each other, as shown in tables (٥-٢٣, ٢٤, ٢٥). As related to above mentioned recipes, the first ٣ runs have raised to a significant level implying improvements of ٥١٪, ٦٧٪ and ٤٩٪ for the three kinds of blacks if compared with standards respectively.
- Modulus of the recipes filled with three blacks increase directly with increasing amount of EPDM for only three runs of N-٣٧٥ followed by five runs of N-٣٣٩ and N-٣٣٠, meanwhile other runs are having nil values. The increase of modulus is larger than standards by an enhancement of about ٧٨.٥% for higher modulus blends of the three kinds of blacks respectively.
- It can be seen that elongation for ٣- types of carbon black has decreased for the last ٤ steps, in spite of its increasing for the first ٢ steps. They are still within the two standards especially Babylon one even though, there is a noticeable reduction.
- Except with blends of N-٣٣٠ which increase significantly if they are compared with the control, other two blends of blacks N-٣٣٩ and N-٣٧٥ increase progressively with a large scale of hardness comparing

with standards. Enhancement of N-٣٣٩ recipe may reach about ١٦.٦٪ of the lower limit.

- As mentioned earlier, it can be concluded that the tensile strength, modulus, elongation and hardness have been affected by many factors related mainly to the amount of EPDM, such as joining low viscose coaster oil which is existed principally in the recipe with EPDM results in weaken strength properties, and insufficient cure time which leads to under cure vulcanizates **[٧٣,٧٤]**.
- The abrasion resistance of N-٣٧٥ blends is the best one among other recipes wherein increased by ٢٩.٧٪ relative to control, meanwhile N-٣٣٠ and N-٣٣٩ recipes increased by ٩.٠٪ and ٢٦.٨٪ respectively.
- Up to ٤th step of all recipes filled three kinds of black, specific gravity of tread rubber compound EPDM/SBR meets the two standards requirements and decreases down the control recipes however, it dose not deviate the lower limit of Babylon standard except the last two steps. The advantage of the reduced unit costs in the fabrication of finished rubber products can be related to the low specific gravity of EPDM. Therefore, a low specific rubber compound will yield more finished articles than a high gravity compound **[٧٣]**.

٥-٥-٣- Comparison of Mechanical Properties of EPDM/SBR Filled with Three Blacks

٥-٥-٣-١- Tensile Strength;

The figure underneath (٥-١٩) shows slightly the difference between three tread vulcanizates filled with three blacks during six steps of EPDM loading. As it is clarified by the curves, only ٣-steps of EPDM loading level have fulfilled the optimization requirements.

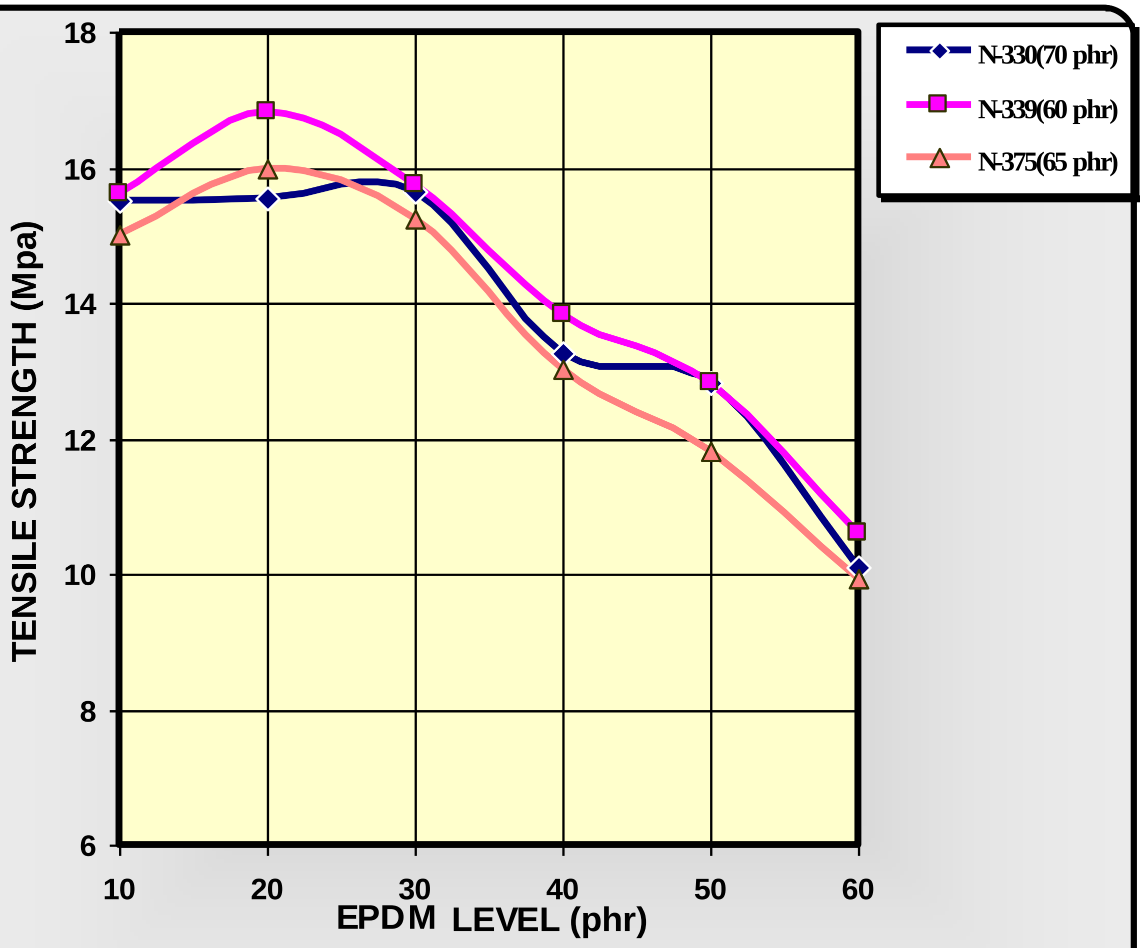


FIG.5-19 Tensile Strength Versus (phr)s of EPDM Filled 3-Types of Carbon Black

The tensile strength of recipe with black N-٣٣٩ has drawn the attention among the others. In amorphous polymers such as EPDM the carbon blacks have a quite difference effect on the tensile properties. Curried compounds containing small particle-size-high structure carbon blacks produce optimum tensile strength at lower loadings [٧٥]. Under cure associated with EPDM vulcanizate is after the reduction in strength properties for the last three runs.

-٥-٣-٢- Modulus;

As it can be seen from the figure (٥-٢٠) that modulus of mixes (EPDM/SBR) varies at the ending points depending on the kind of carbon black. Modulus of mix reinforced by N-٣٣٩ is in advance of those filled N-N-٣٧٥ & ٣٣٠ however, it vanishes after (٥٠/٥٠) loading level of EPDM in tread mixes of EPDM/SBR. As N-٣٣٠ black having high structure, it is responsible for high modulus for such recipes.

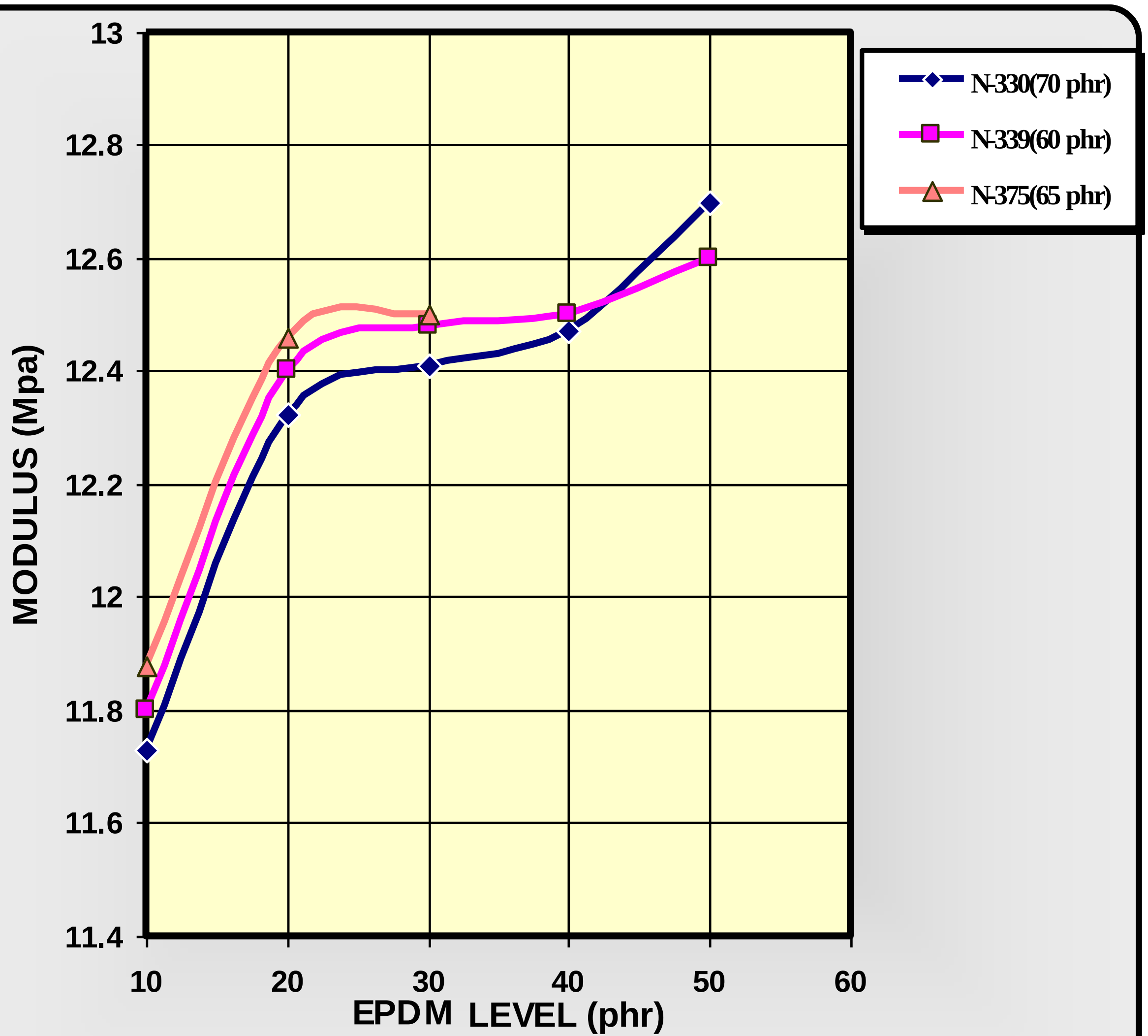


FIG.5-20 Modulus Versus (phr)s of EPDM Filled 3-Types of Carbon Black

-٥-٣-٣- Elongation Percentage @ break;

The comparison of tread rubber compounds filled with three kinds of black displays that these blends have nearly comparable elongation properties especially with blends of N-٣٣٠ & N-٣٧٥ respectively as shown in figure (٥-٢١). As estimation, tread blends of N-٣٣٠ has got the proper improvement due to its low structure and medium particle-size, although it fails to be optimized for the last three loading steps. As it is mentioned earlier the reduction of strength properties is related to the high loading of EPDM which is subjected to under cure.

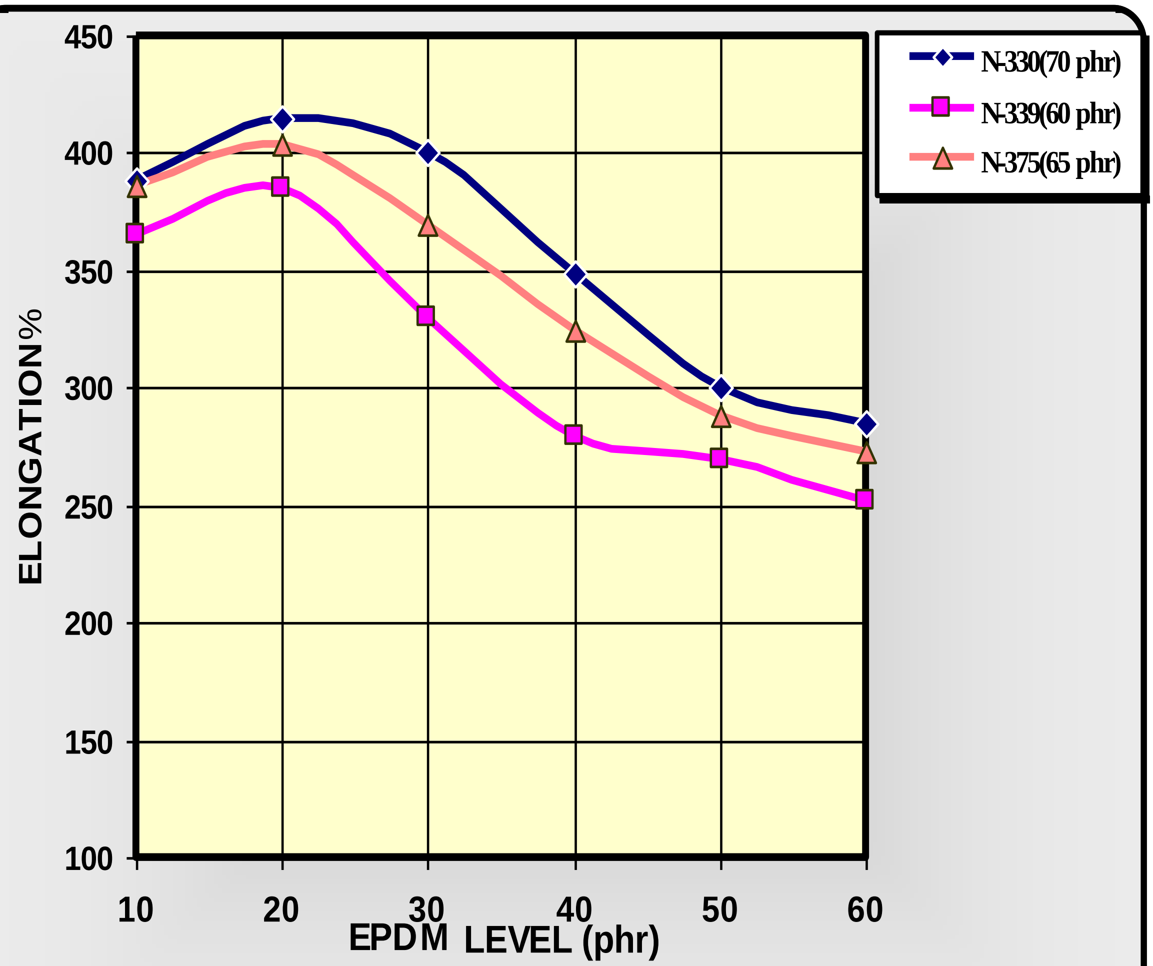


FIG.5-21 Elong.% Versus (phr)s of EPDM Filled 3-Types of Carbon Black

-٥-٣-٤- Hardness;

Figure (٥-٢٢), shows the hardness of recipe filled black N-٣٣٩ has an advancement among two black recipes of N-٣٧٥ and N-٣٣٠.

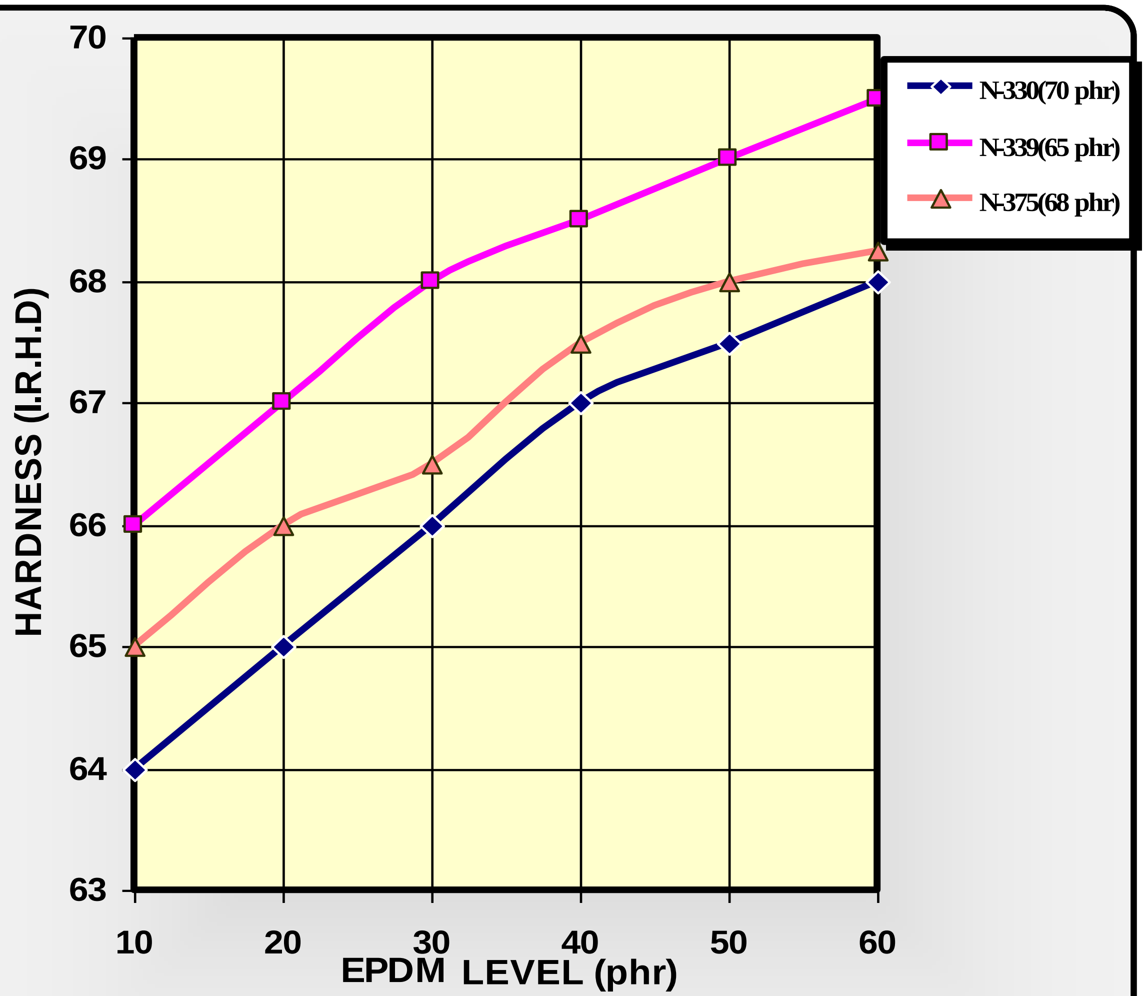


FIG.5-22 Hardness Versus (phr)s of EPDM Filled 3-Types of Carbon Black

It is clear that increasing of EPDM in all blends results in increasing of hardness property for the three black blends in addition to black effects. Blends those mentioned above having an optimizing hardness are at the maximum loading level of EPDM in the tread recipe especially with high structure black N-٣٣٩.

-٥-٣-٥- Abrasion Index;

Figure (٥-٢٣) underneath discloses that abrasion resistance index has increased for blends of blacks N-٣٣٩, N-٣٧٥ & N-٣٣٠ respectively. In addition to the effect of black mainly N-٣٣٩ on abrasive wear resistance of the tread rubber compounds, EPDM has also a great role in improving that characteristic, this is because EPDM has a low glass transient temperature which offers better low temperature properties **[٧٥]**.

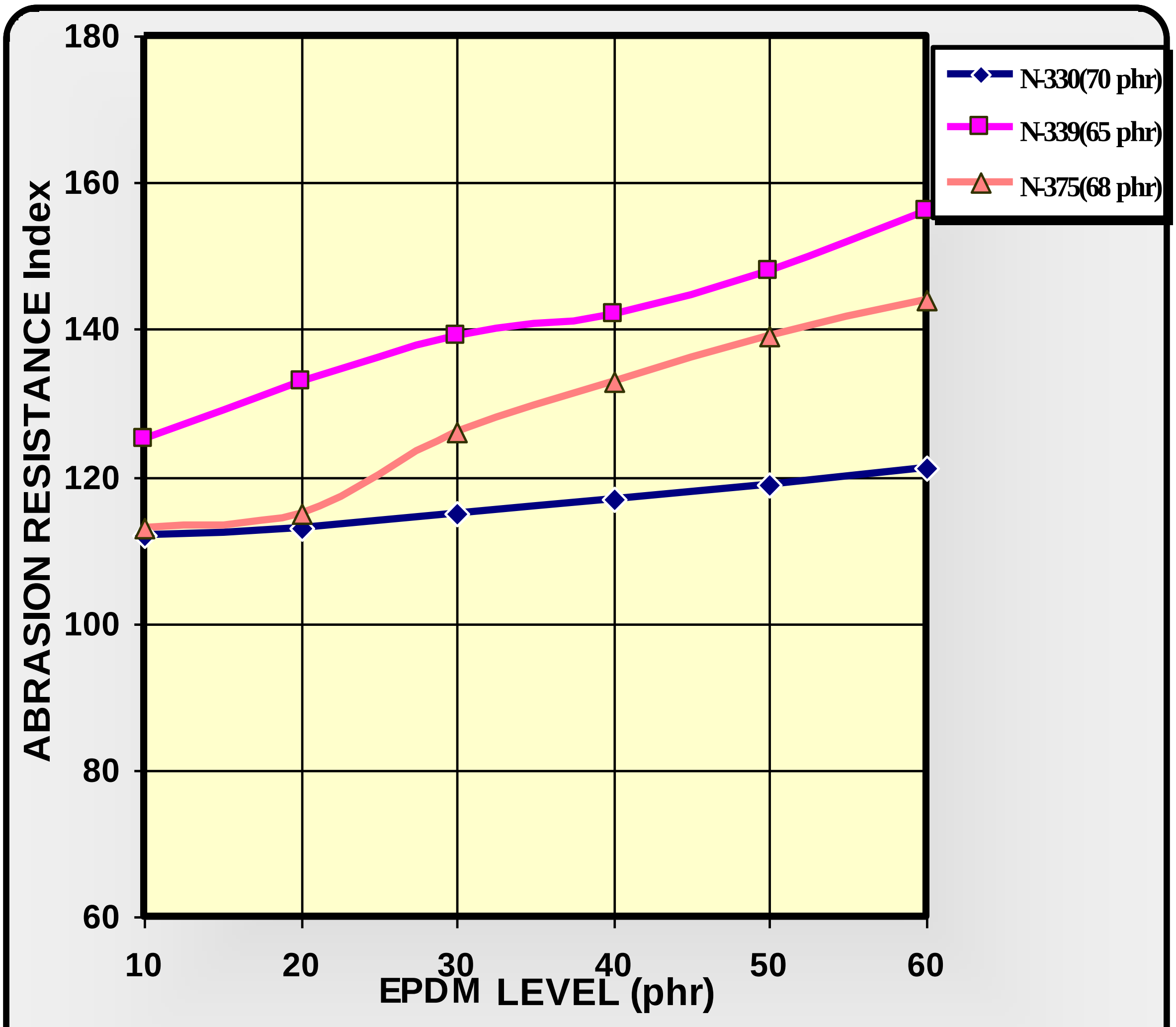
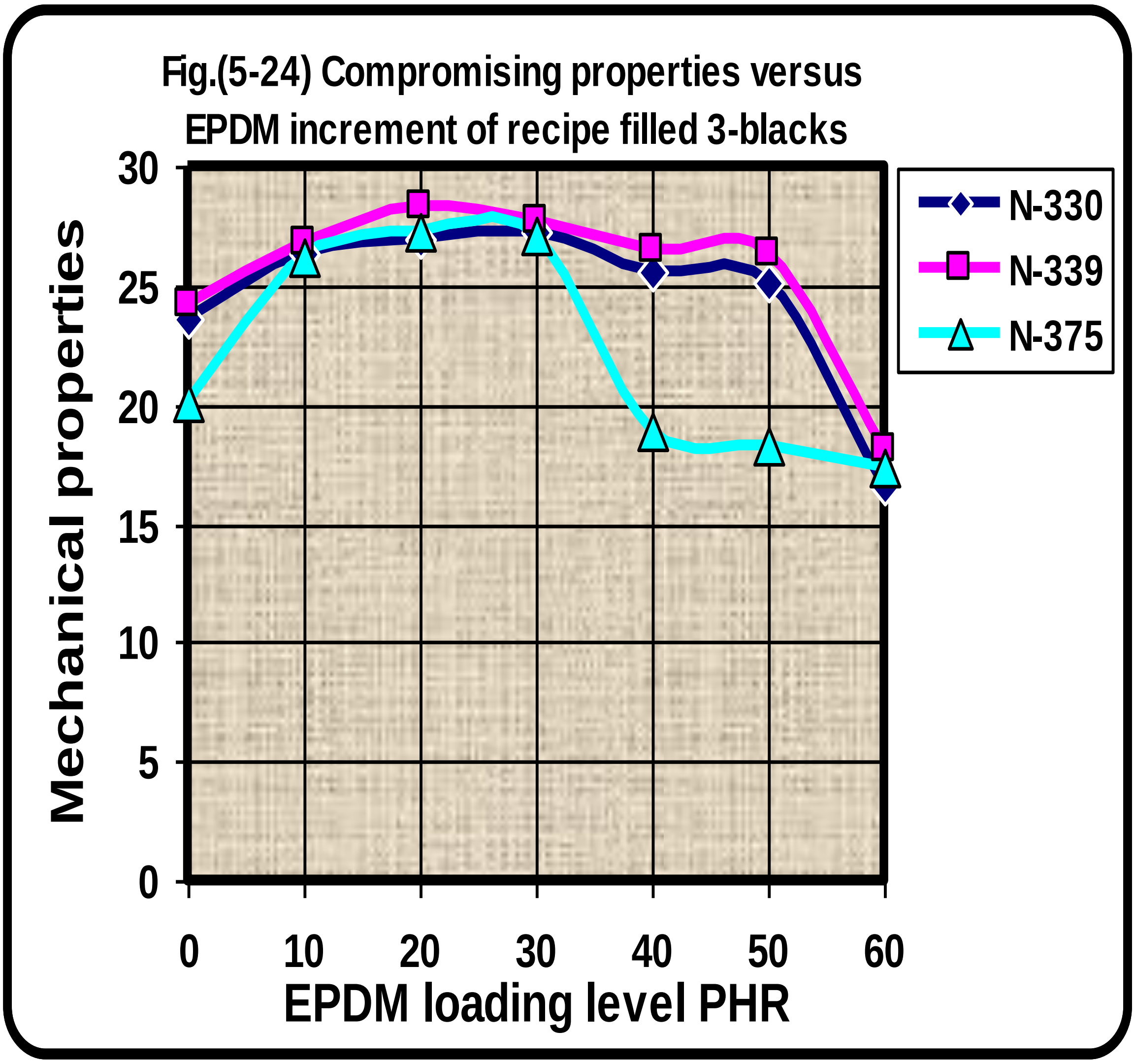


FIG.5-23 Abrasion Index Versus (phr)s of EPDM Filled 3-Types of Carbon Black

٥-٥-٤- Mathematical Evaluation



When regarding the figure above, compromised properties are really optimized for recipes (١٠/٩٠--- ٥٠/٥٠) with blacks N-٣٣٠ & N-٣٣٩. The typical recipes with black N-٣٧٥ are only ١٠/٩٠, ٢٠/٨٠, and ٣٠/٧٠. Under cure associated with EPDM vulcanizates is after the reduction in physico-mechanical properties after the third run especially with black N-٣٧٥ due to small particle size and medium structure **[٧٥]**.

CHAPTER SIX

Conclusions

&

Recommendations

٦-١- CONCLUSIONS:

Regarding the results the work has obtained, it is required to conclude those which are optimized as a result of blending or mixing different types of elastomer such as natural rubber NR, polybutadiene rubber BR, neoprene rubber CR and ethylene propylene rubber with the base tread rubber styrene-butadiene rubber SBR. Three kinds of carbon black such as N-٣٣٠, N-٣٣٩, and N-٣٧٥ at specified loading degrees are used for reinforcement purpose.

As the obtained properties are not optimized in the same degree, that is when some of them get higher level of optimization, some others do not do so, thus, a compromise is necessary to be predominated. The compromised properties are estimated by using mathematical criterion as clarified before.

A conclusion is concentrated on the four main items including the followings;

٦-١-١- Conclusions of NR/SBR optimized properties for ٣-blacks.

It is found that the most improved mechanical properties due to increasing NR loading level in tread rubber are as follows;

١. For the vulcanizates filled with N-٣٣٠ tensile strength and modulus have the most improved values at ٣٠/٧٠ phr of tread recipe NR/SBR which can be considered as optimized results with respect to others phr, elongation is also optimized at recipes of ٥٠/٥٠ & ٦٠/٤٠ as well abrasion resistance. Hardness and specific gravity have the most

٢. When filling with black N-٣٣٩ tensile, modulus, and elongation are optimized at ٤٠/٦٠, meanwhile hardness, abrasion resistance and specific gravity are improved at recipe of ٦٠/٤٠. With a compromise typical recipes are taken as ٣٠/٧٠ ----- ٦٠/٤٠ NR/SBR compositions.

٣. The most optimized tensile strength, modulus, elongation, hardness, abrasion resistance and specific gravity are being at ٦٠/٤٠ recipe. As optimum recipes having effective mechanical properties, compromise is true for those with compositions of ٣٠/٧٠----- ٦٠/٤٠ NR/SBR filled with N-٣٧٥.

٦- ١- ٢- Conclusions of BR/SBR optimized properties for ٣-blacks.

The most enhanced mechanical properties by means of increasing loading level of BR in SBR tread compound are stated down;

٤. Maximum values of tensile and elongation are with blends of ٣٠/٧٠ and ٤٠/٦٠ and modulus, hardness, abrasion index and specific gravity have optimized values at ٦٠/٤٠. One optimized recipe of full mechanical properties can be determined at ٤٠pphr of BR.

٥. In case of reinforcing by black N-٣٣٩ tensile and elongation are optimized at ٤٠/٦٠, other mechanical properties such as modulus, hardness, abrasion resistance and specific gravity are also optimized like with black N-٣٣٠ at ٦٠/٤٠. Recipe composed of ٤٠/٦٠ BR/SBR can be considered as the main optimized one taking in account

٦. compromise of all properties. As effective enhanced recipes range of compositions ٣٠/٧٠, ٤٠/٦٠, and ٥٠/٥٠ is considered.

٦- ١- ٣-Conclusion of CR/BR/SBR optimized properties for ٣-blacks

Similarly, conclusions of results obtained from blending CR/BR with SBR as tread rubber compounds can be mentioned bellow;

٧. Blending of CR/BR and SBR with filler N-٣٣٠ at ٤٠/٦٠ gives more enhanced tensile and modulus whereas, blends at ٦٠/٤٠ give also more enhanced hardness and abrasion index. Blends consist of ٣٠/٧٠ and ١٠/٩٠ give optimum properties of elongation and specific gravity respectively. Single blend of compromised properties which offers typical use is with composition of ٤٠/٦٠.

٦- ١- ٤- Conclusion of EPDM/SBR optimized properties for ٣-blacks

EPDM and SBR show a spectrum of mechanical properties depend on EPDM amount in tread recipes filled with three blacks N-٣٣٠, N-٣٣٩ & N-٣٧٥ accordingly as follow;

٨. Use of black N-٣٣٠ results in optimum tensile, modulus and elongation which are associated with PHR ٣٠/٧٠. ٦٠/٤٠ recipe gives rise to better Hardness and abrasion resistance whereas specific gravity is optimized at ٤٠/٦٠. Recipes of composition ٢٠/٨٠ & ٣٠/٧٠ can be considered as optimum among others especially ٢٠/٨٠ PHR recipe.

٩. Optimization is carried out on tensile and elongation at ٢٠/٨٠, modulus at ٥٠/٥٠, hardness and abrasion resistance at ٦٠/٤٠ recipe, and specific gravity at the range of ١٠/٩٠----٤٠/٦٠pphr of EPDM/SBR tread rubber. In accordance with the compromise it is convenient to regard recipes of ٢٠/٨٠ & ٣٠/٧٠ as typical, although some of their properties are optimized for a little degree.

٦-٢- RECOMMENDATIONS:

According to previous work, the following recommendations are drawn:

١. As the work remarks to add four types of elastomer for the base tread rubber SBR-١٥٠٢, it is recommended to study each of the added elastomers as a single work itself with regarding the followings;

A- Extend the loading level more than ٦٠/٤٠ pphr.

B- Use other than carbon HAF, such as SAF, ISAF and/or mixed silica.

C- Select the convenient vulcanization system that can be more fitted with the type of elastomer.

D- Measure or determine additional mechanical properties such as tear resistance, fatigue resistance, rebound, heat build up and others.

٢. Modifying the type and/or amount of some recipe ingredients especially accelerators and activators may lead to better optimization for the tread rubber.

٣. Viscous-Elastic study which is a new approach in studying the performance of the tire tread can be carried out in parallel with this work. A comparison of the results gained by those two studies is essential.

٤. This work can be conducted on a simulation study with a suitable program.

٥. This study can be tried on the truck tire tread taking in account some modifications that fulfill the study requirements.

٦. Other than previous elastomers, new additions can be used in this work such as chloro-butyl and bromo-butyl.

٧. Such study must be covered by benefit study for creating a balance between cost versus quality.

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APPENDIX

APPENDIX

APPENDIX -A-

TABLE ٥-٢

EFFECT OF BLENDING NR WITH SBR ON THE CURE PROPERTIES OF passenger TIRE TREAD, RECIPE Filled With BLACK (N-٣٣٠).

PROPERTY	**CONTROL RECIPE ١٠٠ wt% OF SBR ٠٫٠ wt% OF NR**	**NR Level (phr) in Tread Recipe OF NR/SBR.**					
٠DR Curing at ١٨٥ Ċ		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Scorch Time (**$t_{S٢}$**) m.m.	١٫٢٤	١٫٢٤	١٫٢٣٥	١٫٢٣	١٫٢٢٥	١٫٢٢	١٫٢١٨
٢.Cure Time (**$t_{٩٠}$**) m.m.	٢٫٩٨	٢٫٩٨	٢٫٩٠	٢٫٨٦	٢٫٨٠	٢٫٧٧	٢٫٧١
٣.Max.Torque (**M_H**) dN.m	٢٨٫٦	٣١٫٢	٣١٫٩	٣٢٫٥٣	٣٠٫٥	٢٨٫٥	٢٨٫٠
٤.Min. Torque (**M_L**) dN.m	٥٫٥	٥٫٥٥	٥٫٦٢	٦٫١	٦٫٣٦	٦٫٤٢	٦٫٥١

TABLE ٥-٣

EFFECT OF BLENDING NR WITH SBR ON THE CURE PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٩).

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠٫٠wt% OF NR	NR Level (phr) in Tread Recipe OF NR/SBR.					
٠DR Curing at ١٨٥ Ċ		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Scorch Time ($t_{S٢}$) min.	١٫٢٦٠	١٫٢٦٠	١٫٢٦٠	١٫٢٥٠	١٫٢٥٥	١٫٢٤٠	١٫٢٠٠
٢.Cure Time ($t_{٩٠}$) min.	٣٫١٣٠	٣٫١٠٠	٣٫٠٠٠	٢٫٩٣٠	٢٫٨٢٠	٢٫٧٦٠	٢٫٧٢٠
٣.Max.Torque (M_H) dN.m	٢٨٫٠٠	٢٩٫٢٠	٢٩٫٤٧	٢٩٫٧٥	٣٠٫٣٨	٣١٫٠٢	٣١٫١١
٤.Min. Torque (M_L) dN.m	٦٫٠٠	٦٫٢٧	٦٫٢٩	٦٫٥٩	٦٫٧٦	٦٫٧٨	٦٫٨٠

TABLE ٥-٤

EFFECT OF BLENDING NR WITH SBR ON THE CURE PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٧٥).

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠٫٠wt% OF NR	**NR Level (phr) in Tread Recipe OF NR/SBR.**					
٠DR Curing at ١٨٥ Ċ		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Scorch Time (**$t_{S٢}$**) m.m.	١٫٣٢	١٫٢٥	١٫٢٥	١٫١٣	١٫١٢٥	١٫١١	١٫١١
٢.Cure Time (**$t_{٩٠}$**) m.m.	٣٫١١	٢٫٨٠	٢٫٧٧	٢٫٧٢	٢٫٧٢	٢٫٢٦	٢٫٢٦
٣.Max.Torque (**M_H**) dN.m	٢٨٫٤٣	٢٩٫٥٢	٣٠٫٧١	٣٢٫٦٠	٣٠٫٩٣	٢٩٫٨٦	٢٨٫٧٨
٤.Min. Torque (**M_L**) dN.m	٥٫٥	٥٫٥٤	٥٫٦٣	٦٫٢٥٥	٦٫٧٦	٦٫٨٠	٦٫٩٨

TABLE ٥-٥

EFFECT OF BLENDING NR WITH SBR ON MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٠)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF NR	NR Level (pphr) in Tread Recipe OF NR/SBR.					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	١٥.٥	١٥.٤٩	١٥.٨٨	١٨.٩٨	١٧.٧٩٢	١٧.٨٨١	١٥.٢٣
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٧.١٣	٩.٨٩	٩.٩٥	١٠.٩٣٥	٩.٨٧٧	٨.٨٢	٧.٨٦
٤.Elongation(%) at Break.	٣٨٨	٤٧٠	٤٨٧	٤٩٠	٤٩٨	٥٢١	٥٢٥
HARDNESS (I.R.H.D)	٦٣.٠	٦٣	٦٣. ٥	٦٣.٥	٦٣.٥	٦٣.٧٥	٦٤
ABRASION Index	١١١	١١٣	١١٥	١٢١	١٢٣	١٢٥	١٢٩
SPECIFIC GRAVITY	١.١٣٥	١.١٣٥	١.١٣٤	١.١٣٤	١.١٣٣	١.١٣٣	١.١٣٢

TABLE ٥-٦

EFFECT OF BLENDING NR WITH SBR ON MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٩)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF NR	NR Level (phr) in Tread Recipe OF NR/SBR.					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	١٤.١	١٦.٠٨	١٦.١١٦	١٦.٤٦٤	١٦.٨١٢	١٦.٦٣٦	١٥.٦٦٠
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٩.٠	٩.١٠	٩.١٢٧	٩.٣٩٤	٩.٧٦١	١٠.٢١	١٠.٢٢
٤.Elongation (%)at Break.	٣٥٠	٤٦٠	٤٧٦	٤٨٥	٤٩٤	٤٨٥	٤٧٨
HARDNESS (I.R.H.D)	٦٤.٥	٦٥.٠	٦٥.٠	٦٥.٥	٦٥.٥	٦٦.٠	٦٧.٠
ABRASION Index	١٢٣	١٢٧	١٣٣	١٤٠	١٤٧	١٥٤	١٦٠
SPECIFIC GRAVITY	١.١٤٢	١.١٤١	١.١٤٠	١.١٣٨	١.١٣٥	١.١٣٣	١.١٣٣

TABLE ٥-٧
EFFECT OF BLENDING NR WITH SBR ON MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٧٥)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF NR	NR Level (phr) in Tread Recipe OF NR/SBR.					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	١٤.٢٦	١٦.٢	١٧.٠	١٧.٥٤٣	١٨.٠	١٩.٥٢	١٩.٧
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٨.٢	٨.٣٤	٨.٤٩٢	٨.٥٩١	٨.٦٨	٨.٦٨٥	٨.٦٩
٤.Elongation (%)at Break.	٣٦٥	٤٦٥	٤٧٣	٤٨٦	٤٩٣	٥٠٠	٥٠٣
HARDNESS (I.R.H.D)	٦٤.٠	٦٤.٠	٦٤	٦٤.٢٥	٦٤.٥	٦٥	٦٥.٥
ABRASION Index	١١١	١١٣	١٢١	١٢٧	١٣٤	١٤١	١٤٨
SPECIFIC GRAVITY	١.١٢٦	١.١٢٦	١.١٢٥	١.١٢٤	١.١٢٤	١.١٢٣	١.١٢٣

TABLE ٥-٥A
Total a mount of MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE of NR & SBR Filled With BLACK (N-٣٣٠)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF NR	NR Level (phr) in Tread Recipe OF NR/SBR.					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	٧.٧٥	٧.٨٥	٧.٩٥	٩.٤٩	٨.٩٥	٧.٨	٧.٥٨
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٤.٠٦	٥.٦٥	٥.٦٨	٤.١	٤.١٥	٤.٣	٤.٣٨
٤.Elongation(%) at Break.	٣.٣٢	٤.٠٢٨	٤.١٧٤	٤.٢	٤.٢٨	٤.٣١	٤.٣١
HARDNESS (I.R.H.D)	٢.١	٢.١	٢.١١	١.٩١	١.٩١	١.٩٢	١.٩٤
ABRASION Index	٥.٢٨	٥.٣٨	٥.٤٧٦	٥.٩٦	٦.٥٨	٦.٩٥	٧.٣٨
SPECIFIC GRAVITY	١.٠١٨	١.٠١٨	١.٠١٧	١.٠٠٧	١.٠٠٦	١.٠٠٥	١.٠٠٥
total	٢٣.٥٢٨	٢٦.٠٢٦	٢٦.٤٠٧	٢٦.٦٦٧	٢٦.٨٧٦	٢٦.٢٨٥	٢٦.٥٩٥

Table (٥-٦)A
Total a mount of MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE of NR & SBR Filled With BLACK (N-٣٣٩)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF NR	NR Level (phr) in Tread Recipe OF NR/SBR.					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	٧.٠٥	٨.٠٤	٨.٥٥	٨.٠٥٨	٨.٤٠٦	٨.٣١٨	٧.٨٣
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٥.١٤	٥.٢	٥.٢١٥	٥.٣٦٨	٥.٥٧٧	٥.٨٣٤	٥.٨٤
٤.Elongation (%)at Break.	٣	٣.٩٤٣	٤.٠٨	٤.١٥٧	٤.٢٣٤	٤.١٥٧	٤.٠٩٧
HARDNESS (I.R.H.D)	٢.١٥	٢.١٦٦	٢.١٦٦	٢.١٨٣	٢.١٨٣	٢.٢	٢.٢٣
ABRASION Index	٥.٨٥	٦.٠٤	٦.٣٣	٦.٦٦	٧	٧.٣٣	٧.٦٢
SPECIFIC GRAVITY	١.٠٢٤	١.٠٢٣	١.٠٢٢	١.٠٢	١.٠١٨	١.٠١٦	١.٠١٦
total	٢٤.٢١٤	٢٦.٤١٢	٢٧.٣٦٣	٢٧.٤٤٦	٢٨.٤١٨	٢٨.٨٥٥	٢٨.٦٣٣

TABLE ٥-٧A
Total a mount of MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE of NR & SBR Filled With BLACK (N-٣٧٥)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF NR	NR Level (phr) in Tread Recipe OF NR/SBR.					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	٧.١٣	٨.١	٨.٥	٨.٧٧	٩	٩.٧٦	٩.٨٥
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٤.٦٨	٤.٧٥	٤.١٧	٤.٩١	٤.٩٦	٤.٩٦	٤.٩٦٥
٤.Elongation (%)at Break.	٣.١٢٨	٣.٩٨٥	٤.٠٥٤	٤.١٦٥	٤.٢٢٥	٤.٢٨٥	٤.٣١١
HARDNESS (I.R.H.D)	٢.١٣٣	٢.١٣٣	٢.١٣٣	٢.١٤١	٢.١٥	٢.١٦٦	٢.١٨٣
ABRASION Index	٥.٢٨	٥.٣٨	٥.٧٦٢	٦.٠٤٧	٦.٣٨	٦.٧١٤	٧.٠٤٧
SPECIFIC GRAVITY	١.٠١	١.٠١	١.٠٠٩	١.٠٠٨	١.٠٠٨	١.٠٠٨	١.٠٠٧
total	٢٣.٣٦١	٢٥.٣٥٨	٢٥.٦٢٨	٢٧.٠٤١	٢٧.٧٢٣	٢٨.٨٩٣	٢٩.٣٦٣

APPENDIX-B-

TABLE ٥-٨

EFFECT OF BLENDING BR WITH SBR ON THE CURE PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٠).

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF BR	Increasing of BR Level From ١٠ to ٦٠ (phr) in Tread Recipe BR/SBR					
٠DR Curing at ١٨٥ Ċ		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Scorch Time ($t_{S٢}$) m.m.	١.٢٤	١.٢٤	١.٢٤	١.٢٣٥	١.٢٣	١.٢٢	١.٢٠
٢.Cure Time ($t_{٩٠}$) m.m.	٢.٩٨	٢.٨٧	٢.٨٤	٢.٨٢	٢.٧٨	٢.٧٣	٢.٧٠
٣.Max.Torque (M_H) dN.m	٢٨.٦	٣٠.٢٨	٣٣.٠٧	٣٣.٦٥	٣٤.٣٨	٣٥.٢٣	٣٦.٩٨
٤.Min. Torque (M_L) dN.m	٥.٥	٦.٠٣	٦.٣	٦.٤٥	٦.٨٧	٦.٥٣	٦.١٥

TABLE ٥-٩

EFFECT OF BLENDING BR WITH SBR ON THE CURE PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٩).

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF BR	Increasing of BR Level From ١٠ to ٦٠ (phr) in Tread Recipe BR/SBR					
٠DR Curing at ١٨٥ Ċ		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Scorch Time ($t_{S٢}$) min.	١.٢٦	١.٢	١.١٧	١.١٧	١.١٦	١.١٣	١.١١
٢.Cure Time ($t_{٩٠}$) min.	٣.١٣	٣.٠	٢.٩٦	٢.٧٧	٢.٧٠	٢.٢٦	٢.٠٣
٣.Max.Torque (M_H) dN.m	٢٨.٠	٣٢.٢٤	٣٤.٤٦	٣٤.٨٨	٣٥.٠	٣٥.٢٨	٣٥.٥١
٤.Min. Torque (M_L) dN.m	٦.٠	٦.١٥	٦.١٥	٦.١٦	٦.١٨	٦.١٨	٧.٩٢

TABLE ٥-١٠

EFFECT OF BLENDING BR WITH SBR ON THE CURE PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٧٥).

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF BR	Increasing of BR Level From ١٠ to ٦٠ (phr) in Tread Recipe BR/SBR					
٠DR Curing at ١٨٥ Ċ		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Scorch Time ($t_{S٢}$) min.	١.٣٢	١.٢٣	١.١٢	١.٠٦	١.٠٤٥	١.٠٢	١.٠
٢.Cure Time ($t_{٩٠}$) min.	٣.١١	٢.٨٩	٢.٨١	٢.٧٠	٢.٤٥	٢.٣٨	٢.٣٢
٣.Max.Torque (M_H) dN.m	٢٨.٤٣	٣١.٦	٣٤.٩٦	٣٥.٠	٣٥.٤٤	٣٧.١٢	٣٨.٣٠
٤.Min. Torque (M_L) dN.m	٥.٥	٦.٣١	٦.٣٣	٦.٤١	٦.٤٧	٦.٥١	٦.٥٧

TABLE ٥-١١
EFFECT OF BLENDING BR WITH SBR ON MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٠)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF BR	Increasing of BR Level From ١٠ to ٦٠ (phr) in Tread Recipe BR/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	١٥.٥	١٥.٧٨	١٥.٩٣	١٦.٠	١٦.١٩٤	١٥.٦٣	١٥.١٨٤
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٧.١٢	٧.١٥	٧.١٦	٧.٢١	٧.٢٨٨	٧.٥٥	٧.٦٩١
٤.Elongation (%)at Break.	٣٨٨	٤٩٩	٥٠٠	٥٢٧	٥٣٦	٥٣٩	٥٣٩
HARDNESS(I.R.H.D)	٦٣.٠	٦٣.٥	٦٣.٧٥	٦٣.٧٥	٦٤.٠	٦٤.٢٥	٦٤.٨
ABRASION Index	١١١	١١٣	١٢١	١٢٧	١٤٠	١٤٨	١٥٧
SPECIFIC GRAVITY	١.١٣٥	١.١٣٤	١.١٣٣	١.١٣٢	١.١٣١	١.١٣٠	١.١٢٩

TABLE ٥-١٢
EFFECT OF BLENDING BR WITH SBR ON MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٩)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF BR	Increasing of BR Level From ١٠ to ٦٠ (phr) in Tread Recipe BR/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	١٤.١	١٥.٣١	١٦.٠٢٨	١٦.١٤٨	١٦.٢٨٥	١٥.٥٦	١٤.٩٨٢
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٩.٠	٩.١٣	٩.١٣٣	٩.٤٨	٩.٧٢٩	٩.٧٨	٩.٨٨٣
٤.Elongation (%)at Break.	٣٥٠	٤٨٦	٤٩٢	٤٩٨	٥٠٥	٤٨٠	٤٥٦
HARDNESS(I.R.H.D)	٦٤.٥	٦٤.٥	٦٤.٧٥	٦٤.٧٥	٦٥.٠	٦٥.٥	٦٦.٠
ABRASION Index	١٢٣	١٣٤	١٤١	١٤٦	١٦٧	١٧٢	١٧٤
SPECIFIC GRAVITY	١.١٤٢	١.١٣٠	١.١٢٩	١.١٢٨	١.١٢٧	١.١٢٥	١.١٢٣

TABLE ٥-١٣
EFFECT OF BLENDING BR WITH SBR ON MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٧٥)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF BR	Increasing of BR Level From ١٠ to ٦٠ (phr) in Tread Recipe BR/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	١٤.٢٦	١٧.١٣	١٧.٦٩٥	١٧.٧١	١٦.٣٨٥	١٦.٠	١٥.٠٧٣
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٨.٢	٨.٤٥	٨.٧٥	٨.٧٥١	٨.٧٥٣	٩.٠	٩.١٥٦
٤.Elongation (%)at Break.	٣٦٥	٤٨٠	٤٨٦	٥٠٨	٥٢٧	٥٣٠	٥٣٠
HARDNESS(I.R.H.D)	٦٤.٠	٦٤.٠	٦٤.٢٥	٦٤.٥	٦٤.٥	٦٥.٥	٦٥.٩
ABRASION Index	١١١	١١٤	١٢١	١٢٧	١٣٢	١٥٤	١٥٩
SPECIFIC GRAVITY	١.١٢٦	١.١٢٦	١.١٢٦	١.١٢٥	١.١٢٥	١.١٢٤	١.١٢٤

TABLE ٥-١١B
Total a mount of MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE OF

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF BR	Increasing of BR Level From ١٠ to ٦٠ (phr) in Tread Recipe BR/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	٧.٧٥	٧.٨٩	٧.٩٦٥	٨	٨.٠٩٧	٧.٨١٥	٧.٥٩
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٤.٠٦٨	٤.٠٨٥	٤.٠٩١	٤.١٢	٤.١٦٤	٤.٣١٤	٤.٣٩٤
٤.Elongation (%)at Break.	٣.٣٢٥	٤.٢٧٧	٤.٢٨٥	٤.٥١٧	٤.٥٩٤	٤.٦٢	٤.٦٢
HARDNESS (I.R.H.D)	٢.١	٢.١١٦	٢.١٢٥	٢.١٢٥	٢.١٣٣	٢.١٤١	٢.١٦
ABRASION Index	٥.٢٨	٥.٣٨	٥.٧٦٢	٦.٠٤٧	٦.٦٦٦	٧.٠٤٧	٧.٤٧٦
SPECIFIC GRAVITY	١.٠١٨	١.٠١٧	١.٠١٦	١.٠١٥	١.٠١٤	١.٠١٣	١.٠١٢
Total	٢٣.٥٤١	٢٤.٧٦٥	٢٥.٢٤٤	٢٥.٨٢٤	٢٦.٦٦٨	٢٦.٩٥	٢٧.٢٥٢

BR & SBR Filled With BLACK (N-٣٣٠)

TABLE ٥-١٢B
Total a mount of MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE OF BR & SBR Filled With BLACK (N-٣٣٩)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF BR	Increasing of BR Level From ١٠ to ٦٠ (phr) in Tread Recipe BR/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	٧.١٣	٨.٥٦٥	٨.٨٤٧	٨.٨٥٥	٨.١٩٢	٨	٧.٥٣٦
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٤.٦٨	٤.٨٢٨	٥	٥	٥	٥.١٤٢	٥.٢٣٢
٤.Elongation (%)at Break.	٣.١٢٨	٤.١١٤	٤.١٦٥	٤.٣٥٤	٤.٥١٧	٤.٥٤٢	٤.٥٤٢
HARDNESS(I.R.H.D)	٢.١٣٣	٢.١٣٣	٢.١٤١	٢.١٥	٢.١٥	٢.١٨٣	٢.١٩٦
ABRASION Index	٥.٢٨	٥.٤٢٨	٥.٧٦٢	٦.٠٤٧	٦.٢٨٥	٧.٣٣٣	٧.٥٧١
SPECIFIC GRAVITY	١.٠١	١.٠١	١.٠١	١.٠٠٩	١.٠٠٩	١.٠٠٨	١.٠٠٨
Total	٢٣.٣٦١	٢٦.٠٧٨	٢٦.٩٢٥	٢٧.٤١٥	٢٧.١٥٣	٢٨.٢٠	٢٨.٠٨٥

TABLE ٥-١٣B
Total a mount of MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE OF BR & SBR Filled With BLACK (N-٣٧٥).

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF BR	Increasing of BR Level From ١٠ to ٦٠ (phr) in Tread Recipe BR/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	٧.٠٥	٧.٦٥٥	٨.٠١٤	٨.٠٧٤	٨.١٤٢	٧.٧٨	٧.٤٩١
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٥.١٤	٥.٢١٧	٥.٢١٦	٥.٤١٧	٥.٥٤	٥.٥٦	٥.٦٤٧
٤.Elongation (%)at Break.	٣	٤.١٦٥	٤.٢١٧	٤.٢٦٨	٤.٣٢٨	٤.١١٤	٣.٩٠٨
HARDNES(I.R.H.D)	٢.١٥	٢.١٥	٢.١٥٨	٢.١٥٨	٢.١٦٦	٢.١٨٣	٢.٢
ABRASION Index	٥.٨٥	٦.٣٨١	٦.٧١٤	٦.٩٥٢	٧.٩٥٢	٨.١٩	٨.٢٨٥
SPECIFIC GRAVITY	١.٠٢٤	١.٠١٣	١.٠١٢	١.٠١١	١.٠١	١.٠٠٩	١.٠٠٧
Total	٢٤.٢١٤	٢٦.٥٨١	٢٧.٣٣١	٢٧.٨٨	٢٩.١٣٨	٢٨.٨٣٦	٢٨.٥٣٨

APPENDIX –C-

TABLE ٥-١٤

EFFECT OF BLENDING CR/BR WITH SBR ON THE CURE PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٠).

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF CR/BR	Increasing of CR/BR Level From ١٠ to ٦٠ (phr) in Tread Recipe CR/BR/SBR					
٠DR Curing at ١٨٥ Ċ		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Scorch Time ($t_{S٢}$) m.m.	١.٢٤	١.٢	١.١٧	١.١٧	١.١٦	١.٠	٠.٩٤
٢.Cure Time ($t_{٩٠}$) m..m.	٢٩.٨	٢.٨	٢.٧٩	٢.٧٥	٢.٦٩	٢.٢٣	١.٩٧
٣.Max.Torque (M_H) dN.m	٢٨.٦	٢٩.٠	٢٩.٢١	٣٢.٥٥	٣٧.٦٨	٣٧.٩٧	٣٨.١٢
٤.Min. Torque (M_L) dN.m	٥.٥	٧.٣	٧.٦	٧.٦٥	٧.٤٧	٨.٧٨	١٠.٨٣

TABLE ٥-١٥

EFFECT OF BLENDING CR/BR WITH SBR ON THE CURE PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٩).

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF CR/BR	Increasing of CR/BR Level From ١٠ to ٦٠ (phr) in Tread Recipe CR/BR/SBR					
٠DR Curing at ١٨٥ Ċ		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Scorch Time ($t_{S٢}$) m.m.	١.٢٦	١.٢٦	١.٢٣	١.٢٠	١.١٨	١.١٥	١.١٣
٢.Cure Time ($t_{٩٠}$) m.m.	٣.١٣	٣.١٣	٣.٠	٢.٨٤	٢.٦٨	٢.٤٢	٢.٤٠
٣.Max.Torque (M_H) dN.m	٢٨.٠	٣٠.١	٣١.٠٣	٣٣.٢	٣٥.٢٦	٣٦.٤	٣٧.٣٨
٤.Min. Torque (M_L) dN.m	٦.٠	٧.٣٤	٧.٥٦	٧.٧١	٧.٩٤	٨.٩٨	١٠.٤٤

TABLE ٥-١٦

EFFECT OF BLENDING CR/BR WITH SBR ON THE CURE PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٧٥).

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF CR/BR	Increasing of CR/BR Level From ١٠ to ٦٠ (phr) in Tread Recipe CR/BR/SBR					
٠DR Curing at ١٨٥ Ċ		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Scorch Time ($t_{S٢}$) m.m.	١.٣٢	١.٢٤	١.١٨	١.١٦	١.١٢	١.١١	١.٠٩
٢.Cure Time ($t_{٩٠}$) m..m.	٣.١١	٣.١٠٥	٣.١	٣.٠٧	٣.٠٢	٣.٠٢	٣.٠٢
٣.Max.Torque (M_H) dN.m	٢٨.٤٣	٣٠.٧٧	٣٢.٨٧	٣٤.٦٥	٣٦.٧	٣٨.٣٦	٤٠.٣٨
٤.Min. Torque (M_L) dN.m	٥.٥	٦.٨٧	٧.٢٥	٧.٤٩	٧.٧٤	٨.٨٤	١٠.٤١

TABLE ٥-١٧
EFFECT OF BLENDING CR/BR WITH SBR ON MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٠)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF CR/BR	Increasing of CR/BR Level From ١٠ to ٦٠ (phr) in Tread Recipe CR/BR/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	١٤.١	١٤.٧٩	١٥.١٨٦	١٥.٦٨	١٦.١٩٧	١٤.٩٨	١٣.٨١٥
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٩.٠	١١.٦٣	١٢.٥٢٥	١٤.١٢	١٥.٥٥٤	١٤.٤٨	١٣.٥٤٧
٤.Elongation (%)at Break.	٣٥٠	٣٥٠	٣٥٠	٣٢٦	٣١٠	٢٨٦	٢٦٩
HARDNESS (I.R.H.D)	٦٤.٥	٦٥.٠	٦٥.٥	٦٦.٥	٦٧.٠	٦٧.٥	٦٩.٠
ABRASION Index	١٢٣	١٣٧	١٤٨	١٦٠	١٧٢	١٨١	١٩٠
SPECIFIC GRAVITY	١.١٤٢	١.١٤٢	١.١٤٣	١.١٤٥	١.١٤٨	١.١٥٦	١.١٦٦

TABLE ٥-١٨
EFFECT OF BLENDING CR/BR WITH SBR ON MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٩)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF CR/BR	Increasing of CR/BR Level From ١٠ to ٦٠ (pphr) in Tread Recipe CR/BR/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	١٥.٥	١٥.٥	١٥.٥٨٩	١٥.٨٩	١٦.٢٩٢	١٤.٣٤	١٢.٣٩٣
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٧.١٢	١٠.١٥	١٠.٢٠٦	١٠.٢٢	١٠.٢٣٢	١١.٧١	------
٤.Elongation (%)at Break.	٣٨٨	٣٩٨	٤٣٥	٤٣٦	٤٣٢	٣٦٠	٣٠١
HARDNESS (I.R.H.D)	٦٣.٠	٦٤.٥	٦٥.٠	٦٦.٠	٦٦.٥	٦٧	٦٨
ABRASION Index	١١١	١١٤	١٢٣	١٣٠	١٣٩	١٤٥	١٥٤
SPECIFIC GRAVITY	١.١٣٥	١.١٥٤	١.١٦٨	١.١٧٢	١.١٧٧	١.١٨٥	١.١٩٢

TABLE ٥-١٩
EFFECT OF BLENDING CR/BR WITH SBR ON MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٧٥)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF CR/BR	Increasing of CR/BR Level From ١٠ to ٦٠ (pphr) in Tread Recipe CR/BR/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	١٤.٢٦	١٥.٧٨	١٦.٤٣٣	١٦.٥٩	١٦.٨٨٢	١٥.٦٣	١٤.٤٨٢
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٨.٢	١٢.٤٦	١٣.٨٧٢	١٤.٨٦	١٥.٩٤٢	١٤.٢	------
٤.Elongation (%)at Break.	٣٦٥	٣٦٥	٣٥٥	٣٤٤	٣٢٠	٣١٠	٣٠٧
HARDNESS (I.R.H.D)	٦٤.٠	٦٤.٨	٦٥.٣	٦٦.٢	٦٦.٦	٦٧.٠	٦٨.٢٥
ABRASION Index	١١١	١١٤	١٢٣	١٣١	١٣٩	١٤٩	١٥٨
SPECIFIC GRAVITY	١.١٢٦	١.١٣١	١.١٣٨	١.١٥٢	١.١٦١	١.١٦٦	١.١٧١

TABLE ٥-١٧C
Total a mount of MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE OF CR/BR/SBR Filled With BLACK (N-٣٣٠)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF CR/BR	Increasing of CR/BR Level From ١٠ to ٦٠ (pphr) in Tread Recipe CR/BR/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	٧.٧٥	٧.٧٥	٧.٧٩٤	٧.٩٤٥	٨.١٤٦	٧.١٧	٦.١٩٦
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٤.٠٦٨	٥.٨	٥.٨١	٥.٨٣٢	٥.٨٤٦	٦.٦٩	------
٤.Elongation (%)at Break.	٣.٣٢٥	٣.٤١١	٣.٧٢٨	٣.٧٣٧	٣.٧٠٢	٣.٠٨٥	٢.٥٨
HARDNESS (I.R.H.D)	٢.١	٢.١٥	٢.١٦٦	٢.٢	٢.٢١٦	٢.٢٣٣	٢.٢٦٦
ABRASION Index	٥.٢٨	٥.٤٢٨	٥.٨٥٧	٦.١٩	٦.٦١٩	٦.٨١	٦.٩٠٤
SPECIFIC GRAVITY	١.٠١٨	١.٠٣٤	١.٠٤٧	١.٠٥١	١.٠٥٥	١.٠٦٢	١.٠٧
Total	٢٣.٥٤١	٢٥.٥٧٣	٢٦.٤٠٢	٢٦.٩٥٥	٢٧.٥٨٤	٢٧.٠٥	١٩.٠١٦

TABLE ٥-١٨C

Total a mount of MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE OF CR/BR/SBR Filled With BLACK (N-٣٣٩)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF CR/BR	Increasing of CR/BR Level From ١٠ to ٦٠ (pphr) in Tread Recipe CR/BR/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	٧.٠٥	٧.٣٩٥	٧.٥٩	٧.٥٩٣	٨.٠٩٨	٧.٤٩	٦.٩٠٧
٢.Modulus (Mpa) at ٣٠٠٪ Extension.	٥.١٤	٦.٦٤٥	٧.١٥٧	٨.٠٦٨	٨.٨٨٨	٨.٢٧٤	٧.٧٤١
٣.Elongation (%)at Break.	٣	٣	٣	٢.٧٩٤	٢.٦٥٧	٢.٢٤٥	٢.٣٠٥
HARDNESS(I.R.H.D)	٢.١٥	٢.١٦٦	٢.١٨٣	٢.٢١٦	٢.٢٣٣	٢.٢٥	٢.٣
ABRASION Index	٥.٨٥٧	٦.٥٢٣	٧.٠٤٧	٧.٦٢	٨.١٩	٨.٦٢	٩.٠٤٧
SPECIFIC GRAVITY	١.٠٢٤	١.٠٢٤	١.٠٢٥	١.٠٢٧	١.٠٢٩	١.٠٣٦	١.٠٤٥
Total	٢٤.٢٢١	٢٦.٧٥٣	٢٨.٠٠٢	٢٩.٣١٨	٣١.٠٩٥	٢٩.٩١٥	٢٩.٣٤٥

TABLE ٥-١٩C

Total a mount of MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE OF CR/BR/SBR Filled With BLACK (N-٣٧٥)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF CR/BR	Increasing of CR/BR Level From ١٠ to ٦٠ (phr) in Tread Recipe CR/BR/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	٧.١٣	٧.٨٩	٨.٢١٦	٨.٢٩٥	٨.٤٤١	٧.٨١٥	٧.٢٤١
٢.Modulus (Mpa) at ٣٠٠٪ Extension.	٤.٦٨٥	٧.١٢	٧.٩٢٦	٨.٤٩١	٩.١٠٩	٨.١١٤	------
٣.Elongation (%)at Break.	٣.١٢٨	٣.١٢٨	٣.٠٤٢	٢.٩٤٨	٢.٧٤٢	٢.٦٥٧	٢.٦٣١
HARDNESS(I.R.H.D)	٢.١٣٣	٢.١٦	٢.١٧٦	٢.٢٠٦	٢.٢٢	٢.٢٣٣	٢.٢٧٥
ABRASION Index	٥.٢٨٥	٥.٤٢٨	٥.٨٥٧	٦.٢٣٨	٦.٦١٩	٦.٠٩٥	٧.٥٢٣
SPECIFIC GRAVITY	١.٠٠٩	١.٠١٤	١.٠٢	١.٠٣٣	١.٠٤١	١.٠٤٥	١.٠٥
Total	٢٣.٣٧	٢٦.٧٤	٢٨.٢٣٧	٢٩.٢١١	٣٠.١٧٢	٢٧.٩٥٩	٢٠.٧٢

APPENDIX-D-

EFFECT OF BLENDING EPDM WITH SBR ON THE CURE PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٠).

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF EPDM	Increasing of EPDM Level From ١٠ to ٦٠ (phr) in Tread Recipe EPDM/SBR					
٠DR Curing at ١٨٥ Ċ		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Scorch Time ($t_{S٢}$) min.	١.٢٤	١.٢٤	١.٢٤	١.٢٩	١.٣٥	١.٣٧	١.٣٩
٢.Cure Time ($t_{٩٠}$) min.	٢.٩٨	٢.٩٨	٣.٠٣	٣.٠٣	٣.٠٥	٣.٦	٣.١٨
٣.Max.Torque (M_H) dN.m	٢٨.٦	٣٠.٦٣	٣١.٧٣	٣٣.٥٦	٣٥.٨٣	٣٥.٨٥	٣٥.٨٨
٤.Min. Torque (M_L) dN.m	٥.٥	٦.٦٨	٦.٧٤	٧.٤٢	٧.٧٢	٧.٧٨	٧.٨٦

TABLE ٥-٢١

EFFECT OF BLENDING EPDM WITH SBR ON THE CURE PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٩).

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF EPDM	Increasing of EPDM Level From ١٠ to ٦٠ (phr) in Tread Recipe EPDM/SBR					
٠DR Curing at ١٨٥ Ċ		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Scorch Time ($t_{S٢}$) min.	١.٢٦	١.٣٢	١.٣٤	١.٤١	١.٥	١.٥١	١.٥٢
٢.Cure Time ($t_{٩٠}$) min.	٣.١٣	٣.١٦	٣.٢٠	٣.٢٥	٣.٣٨	٣.٤٥	٣.٥٢
٣.Max.Torque (M_H) dN.m	٢٨.٠	٣٠.٥	٣٣.٣٥	٣٤.٠	٣٤.٨٧	٣٦.٦	٣٨.١٦
٤.Min. Torque (M_L) dN.m	٦.٠	٧.١٢	٧.٢٣	٧.٥٦	٧.٨٥	٨.١٥	٨.٤٣

TABLE ٥-٢٢

EFFECT OF BLENDING EPDM WITH SBR ON THE CURE PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٧٥).

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF EPDM	Increasing of EPDM Level From ١٠ to ٦٠ (phr) in Tread Recipe EPDM/SBR					
٠DR Curing at ١٨٥ Ċ		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Scorch Time ($t_{S٢}$) min.	١.٣٢	١.٣٦	١.٤١	١.٤١	١.٤٣	١.٤٦	١.٤٩
٢.Cure Time ($t_{٩٠}$) min.	٣.١١	٣.١١	٣.١٢٠	٣.١٢٦	٣.١٣٠	٣.١٣٧	٣.١٤
٣.Max.Torque (M_H) dN.m	٢٨.٤٣	٢٩.٣٤	٣٠.٨٠	٣١.٢٦	٣٢.٧٠	٣٣.٩٨	٣٥.٦٨
٤.Min. Torque (M_L) dN.m	٥.٥	٦.٢٨	٦.٢٩	٧.٢١	٨.١٢	٨.٢٨	٨.٤٥

PROPERTY	CONTROL RECIPE ١٠٠wt%	Increasing of EPDM Level From ١٠ to ٦٠ (pphr) in Tread Recipe EPDM/SBR

TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	١٥.٥	١٥.٥١	١٥.٥٣٧	١٥.٨٥	١٣.٢٥٣	١٢.٨١	١٠.١١
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٧.١٢	١١.٧٣	١٢.٣٢٣	١٢.٤١	١٢.٤٧٣	١٢.٧٠	------
٤.Elongation (%)at Break.	٣٨٨	٣٨٨	٤١٥	٤٠٠	٣٤٩	٣٠٠	٢٨٥
HARDNESS(I.R.H.D)	٦٣	٦٧.٠	٦٧.٥	٦٨	٦٩	٦٩	٦٩
ABRASION Index	١١١	١١٢	١١٣	١١٥	١١٧	١١٩	١٢١
SPECIFIC GRAVITY	١.١٣٥	١.١٣٤	١.١٣٢	١.١٢٦	١.١١٧	١.١٠٩	١.١٠٩

TABLE ٥-٢٣
EFFECT OF BLENDING EPDM WITH SBR ON MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٠)

TABLE ٥-٢٤
EFFECT OF BLENDING EPDM WITH SBR ON MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٣٩)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF EPDM	Increasing of EPDM Level From ١٠ to ٦٠ (phr) in Tread Recipe EPDM/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	١٤.١	١٥.٦١٢	١٦.٨٢٨	١٥.٧٦	١٣.٨٢٠	١٢.٨٤	١٠.٥٩٦
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٩.٠	١١.٨	١٢.٤	١٢.٤٨	١٢.٥	١٢.٦	------
٤.Elongation (%)at Break.	٣٥٠	٣٦٥	٣٨٥	٣٣٠	٢٧٩	٢٧٠	٢٥٢
HARDNESS (I.R.H.D)	٦٤.٥	٦٦	٦٧	٦٨	٦٨.٥	٧٩.٠	٦٩. ٥
ABRASION Index	١٢٣	١٢٥	١٣٣	١٣٩	١٤٢	١٤٨	١٥٦
SPECIFIC GRAVITY	١.١٣٥	١.١٣٤	١.١٣٢	١.١٢٦	١.١١٧	١.١٠٩	١.١٠٩

TABLE ٥-٢٥

EFFECT OF BLENDING EPDM WITH SBR ON MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE Filled With BLACK (N-٣٧٥)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF EPDM	Increasing of EPDM Level From ١٠ to ٦٠ (phr) in Tread Recipe EPDM/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	١٤.٢٦	١٥.٠	١٥.٩٩	١٥.٢٤	١٣.٠١	١١.٨٢	٩.٩٢٢
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٨.٢	١١.٨٨	١٢.٤٥٩	١٢.٥	------	------	------
٤.Elongation (%)at Break.	٣٦٥	٣٨٦	٤٠٤	٣٧٠	٣٢٤	٢٨٨	٢٧٣
HARDNESS (I.R.H.D)	٦٤	٦٥	٦٦	٦٦.٥	٦٧.٥	٦٨	٦٨.٢٥
ABRASION Index	١١١	١١٣	١١٥	١٢٦	١٣٣	١٣٩	١٤٤
SPECIFIC GRAVITY	١.١٢٦	١.١٢٠	١.١١٦	١.١١٥	١.١١٤	١.١٠٠	١.٠٩٢

TABLE ٥-٢٣D

Total a mount of MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE OF EPDM & SBR Filled With BLACK (N-٣٣٠)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF EPDM	Increasing of EPDM Level From ١٠ to ٦٠ (pphr) in Tread Recipe EPDM/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	٧.٧٥	٧.٧٥٥	٧.٧٦٨	٧.٩٢٥	٦.٦٢٦	٦.٤٠٥	٥.٠٥٥
٣.Modulus (Mpa) at ٣٠٠٪ Extension.	٤.٠٦٨	٦.٧٠٢	٧.٠٤١	٧.٠٩١	٧.١٢٧	٧.٢٥٧	------
٤.Elongation (%)at Break.	٣.٣٢٥	٣.٣٢٥	٣.٥٥٧	٣.٤٢٨	٢.٩٩١	٢.٥٧١	٢.٤٤٢
HARDNESS (I.R.H.D)	٢.١	٢.٢٣٣	٢.٢٥	٢.٢٦٦	٢.٣	٢.٣	٢.٣
ABRASION Index	٥.٢٨	٥.٣٣٣	٥.٣٨١	٥.٤٧٦	٥.٥٧١	٥.٦٦٦	٥.٧٦٢
SPECIFIC GRAVITY	١.٠١٨	١.٠١٧	١.٠١٥	١.٠٠٩	١.٠٠١٨	٠.٩٩٤	٠.٩٩٤
Total	٢٣.٥٤١	٢٦.٣٦٥	٢٧.٠١٢	٢٧.١٩٥	٢٥.٦١٦٨	٢٥.١٩٣	١٦.٥٥٣

TABLE ٥-٢٤D

Total a mount of MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE OF EPDM/SBR Filled With BLACK (N-٣٣٩)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF EPDM	Increasing of EPDM Level From ١٠ to ٦٠ (pphr) in Tread Recipe EPDM/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	٧.٠٥	٧.٨٠٦	٨.٤١٤	٧.٨٨	٦.٩١	٦.٤٢	٥.٢٩٨
٢.Modulus (Mpa) at ٣٠٠٪ Extension.	٥.١٤٢	٦.٧٤٢	٧.٠٨٥	٧.١٣١	٧.١٤٢	٧.٢	------
٣.Elongation (%)at Break.	٣	٣.١٢٨	٣.٣	٢.٨٢٨	٢.٣٩١	٢.٣١٤	٢.١٦
٤-HARDNESS(I.R.H.D)	٢.١٥	٢.٢	٢.٢٣٣	٢.٢٦٦	٢.٢٨٣	٢.٣	٢.٣١٦
٥-ABRASION Index	٥.٨٥٧	٥.٩٥٢	٦.٣٣٣	٦.٦١٩	٦.٧٦٢	٧.٠٤٧	٧.٤٢٨
٦-SPECIFIC GRAVITY	١.٠١٨	١.٠١٧	١.٠١٥	١.٠٠٩	١.٠٠١٨	٠.٩٩٤	٠.٩٩٤
Total	٢٤.٢١٧	٢٦.٨٤٥	٢٨.٣٨	٢٧.٧٣٣	٢٦.٤٨٩٨	٢٦.٢٧٥	١٨.١٩٦

TABLE ٥-٢٥D

Total a mount of MECHANICAL PROPERTIES OF passenger TIRE TREAD RECIPE OF EPDM/SBR Filled With BLACK (N-٣٧٥)

PROPERTY	CONTROL RECIPE ١٠٠wt% OF SBR ٠.٠wt% OF EPDM	Increasing of EPDM Level From ١٠ to ٦٠ (pphr) in Tread Recipe EPDM/SBR					
TENSOMETER		١٠/٩٠	٢٠/٨٠	٣٠/٧٠	٤٠/٦٠	٥٠/٥٠	٦٠/٤٠
١.Tensile Strength (Mpa).	٧.١٣	٧.٥	٧.٩٩٥	٧.٦٢	٦.٥٠٥	٥.٩١	٤.٩٦١
٢.Modulus (Mpa) at ٣٠٠٪ Extension.	٤.٦٨٥	٦.٧٨٨	٧.١١٩	٧.١٤٢	------	------	------
٣.Elongation (%)at Break.	٣.١٢٨	٣.٣٠٨	٣.٤٦٢	٣.١٧١	٢.٧٧٧	٢.٤٦٨	٢.٣٤
٤-HARDNESS(I.R.H.D)	١.٩٢	٢.١٦٦	٢.٢	٢.٢١٦	٢.٢٥	٢.٢٦٦	٢.٢٧٥
٥-ABRASION Index	٢.٢١	٥.٣٨١	٥.٤٧٦	٦	٦.٣٣٣	٦.٦٢	٦.٨٥٧
٦-SPECIFIC GRAVITY	١.٠٠٩	١.٠٠٤	١.٠	١.٠	٠.٩٩٩	٠.٩٨٦	٠.٩٧٩
Total	٢٠.٠٨٢	٢٦.١٤٧	٢٧.٢٥٢	٢٧.١٤٩	١٨.٨٦٤	١٨.٢٥	١٧.٤١٢

كما وجرى تحليل النتائج باستخدام معيار رياضي لغرض تحديد العجنات المثـــــــــــــالية

(Optimized or Typical Recipes) والتـــي تحـــوي علـــى اكثـــر الخـــواص توافقا Compromise.

أعطـت النتـائج التـي تـم الحصـول عليهـا علـى مسـتويات مختلفـة مـن الوصـول إلـى درجـات الامثلية فيما يخص الخواص الميكانيكية اعتمادا على نـوع المطـاط واسـود الكـاربون المسـتخدمين وكمايلي:

- فقد تم بالتوافق (Compromise) اعتبار العجنـات ذات درجـات التحميل الوزنيـة pphr من ٧٠/٣٠ الى٤٠/٦٠ ذات أمثلية او قد تم تحسينها باستخدام المطاط الطبيعي **NR** مع الانواع الثلاثة لاسود الكاربون .
- واعتبـار العجنـات مـن ٨٠/٢٠ إلـى ٥٠/٥٠ pphr قد تـم تحسـينها باسـتخدام مطـاط **BR** ومع الانواع الثلاثة لاسود الكاربون ايضـا .
- أما عجنات مطاط النيوبرين **CR** فقد جرى تحسينها بين ٧٠/٣٠ و٦٠/٤٠ pphr .
- باستخدام مطاط الاثيلين بروبيلين **EPDM** فان العجنات بين ٩٠/١٠ الـى٥٠/٥٠ pphr قد تم تحسين خواصها الميكانيكية باستخدام اسود الكاربون N-٣٣٠ واسود الكلربون N-٣٣٩ ،أمـا العجنـات المثاليـة لاسـود الكـاربون N-٣٧٥ فهـي كـلا مـن ٩٠/١٠، ٨٠/٢٠ و٧٠/٣٠ pphr .