CENTRAL ASIAN JOURNAL OF THEORETICAL AND APPLIED SCIENCE

https://cajotas.casjournal.org/index.php/cajotas

Volume: 06 Issue: 04 | October 2025 ISSN: 2660-5317

Article

Improving Iraqi Asphalt Paving Using Natural and Synthetic Additives

Muhannad Abdul Salam Othman[1], Ragheed Raad Faisal[2]

1. Nineveh Education, Nineveh, Iraq
2. Census and Training Department, Nineveh Education, Nineveh, Iraq

*Correspondence: mohothmn@gmail.com, ragheedraad99@gmail.com

Abstract: Improving the rheological properties of Iraqi asphalt used in paving through the addition of natural and synthetic polymers has become essential to enhance pavement performance under harsh climatic conditions. This study focuses on evaluating the standard specifications of Iraqi asphalt before and after modification to determine the impact of polymer additives on its physical and mechanical behavior. Laboratory tests were conducted to assess parameters such as penetration, softening point, viscosity, and temperature susceptibility. The results indicate that the inclusion of specific polymers significantly improves the asphalt's elasticity, stability, and resistance to deformation. Furthermore, the modified asphalt demonstrated better durability and adaptability to temperature variations, reducing the risk of cracking and rutting in hot weather regions. These findings confirm that polymer modification can effectively increase the efficiency and longevity of Iraqi asphalt, making it more suitable for modern road construction needs.

Keywords: asphalt, rheological modification, additives, polymers, pavement performance

Citation: Othman, M. A. S & Faisal, R. R. Improving Iraqi Asphalt Paving Using Natural and Synthetic Additives. Central Asian Journal of Theoretical and Applied Science 2025, 6(4), 822-837

Received: 10th Jul 2025
Revised: 16th Aug 2025
Accepted: 24th Sep 2025
Published: 13th Oct 2025

1. Introduction

Asphalt

It is a semi-solid or liquid substance, dark brown in color, with a high viscosity. It is a hydrocarbon compound produced as a waste product of the crude oil distillation process under pressure and heat [1].

Asphalt is known by several names. The term bitumen is used in Europe and is synonymous with asphalt in North America, the term asphalt is used to refer to mixture of bitumen with mineral materials [2].

Asphalt has a complex chemical composition depending on the method of its preparation and the origin of the crude oil from which it was derived [3].

It consists of hydrocarbon compounds with high molecular weights (300-2000 gm/mol) As a result of its high molecular weight it is believed to result from the aggregation and bonding of these compounds with each other [4].

Properties of Asphalt

Asphalt or bitumen is a thermoplastic material widely used as an adhesive in road paving Given the desirable properties of asphalt, which include flexibility, enabling it to withstand temperature differences that cause cracks as a result of sudden tension, as well as its resistance to permanent deformations (creep at high temperatures), and its resistance to load stresses resulting from variations in temperatures, rising and falling [5],

Asphalt is one of the components of asphalt concrete used in road construction and maintenance work, and it is also used in surfacing to prevent leaching Because of its high adhesion strength and flexibility [6].

Asphalt components

Asphalt is a heavy liquid substance with a viscosity that increases with decreasing temperature until it reaches the solidity limit. It consists mainly of hydrocarbons with paraffinic, naphthenic, and aromatic structures. It also includes cyclic and acyclic compounds containing nitrogen, sulfur, and oxygen, as well as small amounts of vanadium, iron, and nickel [7].

Nitrogen, oxygen, and sulfur compounds, along with mineral elements, affect the physical properties of asphalt. Polar mineral elements increase the interaction between the particles and affect the boiling point, solubility, and viscosity [8].

Asphalt is usually black in color and is produced from the distillation of crude oil, which remains in distillation towers as a heavy substance after the light and volatile materials are removed [9].

The nature of the physical properties of asphalt determines its use more than its chemical properties, due to its use in engineering applications and work [10].

There are several approved specifications for asphalt, which may be local or international, such as ASTM, AASHTO, and others, that determine its areas of use [11].

Uses of Asphalt

Asphalt has hundreds of uses. It is used in paving roads, streets, and airports, in the roofing coating, to prevent water leakage, in insulating materials and tiles, and to strengthen water storage areas and irrigation canals [12]. Asphalt is also used in the manufacture of varnish and inks, and asphalt layers are used to protect underground pipelines it from corrosion Asphalt is a thermoplastic material, is a good waterproofing agent, and is unaffected by most acids and salts [13].

2. Materials and Methods

Methods of preparing asphalt

Asphalt (bitumen) is generally the most widely used paving material due to its excellent ueses performance in terms of stability, durability, and water resistance.

Petroleum and other low-boiling materials are often extracted by distillation,The remaining oil is commonly called harvested crude, meaning "crude oil from which the highly volatile materials have been removed."

This oil can be used for fuel, and it can be further refined to extract asphalt and other products,By varying the refining methods, different types of asphalt can be obtained. For example, intumescent asphalt or oxidized asphalt can be obtained by blowing hot air into crude oil from which the highly volatile materials have been removed.

These types of asphalt are widely used in roofing, coatings, and other industrial applications,

Asphalt can also be formed naturally by deposition in holes, lakes, and rocks. Some of the natural deposits found in holes and lakes are pure, but most become mixed with water and other materials. The best-known type of these deposits is the one called bitumen there is also the frozen type of asphalt called glacissonite.

Reasons for the diversity of asphalt uses

The chemical inertness of asphalt, which is compatible with its physical properties, is what makes it eligible for wide uses in industry and construction since ancient times, and the nature of its physical properties is what determines the nature of the use.

Factors affecting asphalt properties

The durability of asphalt mixture defined the long-term resistance against aging and can be defined as the rate of change in the physical properties of the asphalt mixture over time,

The factors are

1. Asphalt mixture components

The components of the asphalt mixture affect the performance of the pavement, especially the aggregate, which constitutes a large percentage of the mixture Asphalt.

2. Aggregate gradation

The gradation of aggregates has a significant impact on the performance of asphalt pavement and the properties of the asphalt mixture, such as the voids between the aggregates and voids in mineral aggregate (VMA) filled with asphalt (VFA) (voids filled with asphalt), filler percentage and asphalt layer thickness around the aggregate.

3. Viscosity

One of the most important factors that are difficult to control its quality currently is the use of an asphalt material with a standard consistency of low viscosity, such as low-viscosity asphalt, class (100-85), which increases deformations compared to the use of asphalt with a standard consistency of high viscosity, class (50-40).

4. Grinding Strength

Grinding strength, which is the degree of cohesion of the asphalt mixture components under wheel loads, and the asphalt mixture's resistance to groove formation and creep.

5. Overlay Thickness

The thickness of the overlay layer plays the largest role in the process of transferring and distributing loads without damaging the overlay layer. Any decrease in the overlay thickness will lead to the layer cracking under the applied loads, thus failing the overall performance of the road (21, 22).

Types of Defects on the Surface of the Pavement Layer, The most important of these defects are:

1. Rutting: This is a depression in the road surface in the form of channels in the area of the vehicle tire path. It is considered a functional defect, as well as a structural defect.

Rutting is related to loads, and its causes include the weakness of the mix design materials in compressing the layers, in addition to insufficient compaction during implementation and the softness of the asphalt layer materials due to water leakage,

2. Creep: It is a long-term movement of a localized area of road surface in the direction of traffic. It occurs due to shear stress generated by vehicle movement in slope locations, weak surface paving layers, weak stability of the stone foundation and what is beneath the foundation, and large temperature differences between night and day.
3. Ripples: These are successive, close depressions and rises that occur at regular intervals and are considered a defect in the functional performance of asphalt pavements because they cause surface roughness, affect driving quality, and occur in locations In which the movement accelerates or slows down, and its causes also include weak stability of the asphalt mixture or weak foundation.
4. Asphalt squeezing: It is the upper transfer of asphalt binding materials in the asphalt pavement layers. These materials form a thin, reflective, glassy layer on the surface, making it sticky and shiny. This occurs as a result of increasing the quantities of asphalt binding materials.

Methods for Improving Asphalt Specifications

The process of improving the performance of asphalt mixture is accomplished in various ways using additives, and polymers represent the most commonly used additives in modification.

The process of modifying the rheological properties of asphalt with polymeric materials leads to the hardening of the asphalt and improving its resistance to temperatures. This is because increased hardening improves the asphalt's resistance to pothole formation in hot climates, in addition to improving the asphalt's performance at low temperatures. It is also noted that it improves the adhesion properties and cohesion.

Adding polymers and tire shreds to the asphalt mixture improves the physical and mechanical properties because they are a binding material and are used as fillers in some research, so there is no change in the chemical composition.

Researchers have been increasingly inclined over the last thirty years to use and add sulfur to improve the stability and compatibility of asphalt-polymer mixture.

It is believed that sulfur is chemically bound to the polymer and asphalt by forming sulfide bonds (RSR) or polysulfides (RXRS). Sulfur also acts as a crosslinking agent.

3. Results and Discussion

The Role of Polymers Added to Asphalt

Nowadays, with the development of vehicle types and sizes and the increasing demand for transporting people and goods that constitute heavy loads on roads, this can lead to the emergence of many problems in the surface layer of the pavement [14]. Therefore, the tendency has been to try to improve the surface layer, increase its efficiency, improve its performance, and increase its resistance to loads,

by adding various materials to asphalt mixture, including: polymers, mineral materials, glass wool, rubber, and other additives [15]. Adding styrene-butadiene rubber (SBR) to the asphalt mixture leads to an increase in the tensile strength ratio (TSR), as the increase in the tensile strength ratio depends on the concentration of styrene-butadiene rubber. Asphalt binds the elements together, and several natural or chemical materials are added in specific proportions to improve the properties of asphalt mixture in terms of elasticity, void ratio, and durability [16].

Types of asphalt

Asphalt is divided into two types:

1. Natural asphalt:

It results from the influence of nature in areas where crude oil has been present for a long time, where light materials evaporate due to the heat of the sun and wind, leaving the black asphalt material. In most cases, it contains impurities such as clay, shale, and sand. Natural asphalt deposits are found in Iraq in various areas in the form of asphalt rock, including Ain al-Jabha (45 km) west of Ramadi and Ain Abu Jir (Ain al-Nasla), in addition to several springs in the Hit district, such as Ain al-Tayf, al-Marj, al-Maamoura, Ain al-Burj, Ain al-Assad, and Ain al-Rahaliya south of Karbala, Jabal Makhoul in Baiji, and others [17].

2. Petroleum asphalt:

It is the industrially prepared preparation, where petroleum is distilled in refineries by exposing crude oil to high temperatures (in the range of -900-970C^0), where volatile vapors such as gasoline and kerosene are released, then the vapors of light diesel oil, and they are drawn off to be purified from impurities before use [18].

As for the remaining dense part, which is the diesel oil and fuel oil, it descends to a storage tank, then the remaining dense part is heated by hot steam between (290-270 C^0). The product of this process does not contain gasoline or kerosene, but rather contains heavy oils that are separated successively in the form of vapors such as diesel oil, followed by the vapors of heavy, dense paraffins, and in the end, tar oil or bitumen remains at the bottom of the tank, where it is drawn off and filled into barrels [19].

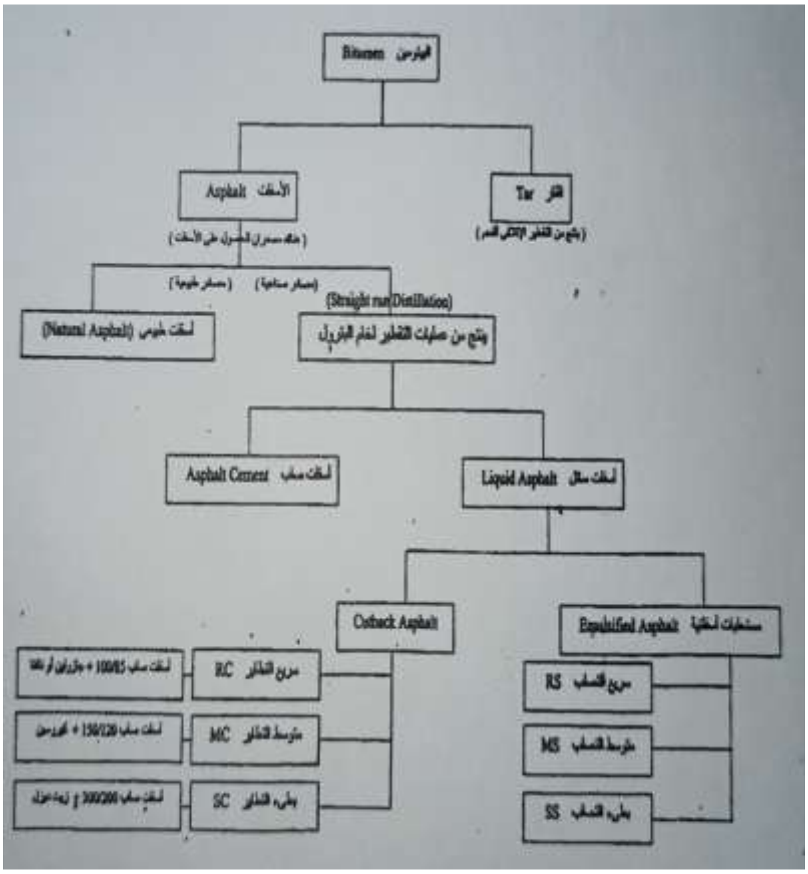

Figure 1. Sshows the classification of asphalt used in road works, paving materials, and asphalt mixture design using the Marshall method:

Advantages and disadvantages of asphalt

The most important advantages and benefits of using asphalt in paving are

1. An excellent natural adhesive.
2. Inexpensive
3. Available wherever oil is found.
4. Forms a solid and relatively durable material,when mixed with aggregate
5. An insulating material that prevents water from entering
6. A material capable of dampening sounds and vibrations

The disadvantages of using asphalt are:

1. It varies from one country to another because it depends on the source and type of oil produced by the country. Therefore, the chemicals that make up asphalt vary from one country to another, making it difficult to control its engineering properties [20].
2. It is greatly affected by temperature and other environmental factors. For example, the hardness (G) changes from (1-10000) times due to the change in the maximum temperature in the summer compared to the low temperature in the winter, as well as the large change in the phase angle, which is the relative measure of the distribution of asphalt between the elastic and viscous states [21].
3. It is affected by oxidation with age, becoming a brittle material that cracks and drips.
4. It cannot be handled at room temperature; it is only workable when heated to a high temperature.

The quality and quantity of asphalt depend on:

1. The type and source of crude oil.
2. The method by which the oil is refined [22].

Chemicals that make up asphalt

According to the American Society for Testing and Materials (ASTM), asphalt is defined as a dark brown to black adhesive material, whose main component is bitumen, a mixed of of hydrocarbon The types,

basic chemical compounds that make up asphalt depends on the type of solvent, which are [23]:

1. The solvent is heptane (n-heptane):
   Asphalt components are classified into two substances based on their solubility in n-heptane, and substances that do not dissolve in heptane, which are: Asphaltenes, which contribute to the hardness, consistency, and binding strength of asphalt [24]. This increases due to the conversion of polar aromatics into asphaltenes as a result of oxidation, loss of light materials, and merging of molecules [25].
2. Substances that dissolve in (heptane) are
   a. Saturates (S), which are paraffinic naphthenic hydrocarbons. Responsible for the change in hardness over time and are not significantly affected by the passage of time [26].
   b. Naphthenic aromatics (NA) are responsible for cracking over time, and plasticity decreases due to their conversion to polar aromatics
   c. Polar aromatics (PA) are responsible for elasticity and adhesion, and they increase or decrease due to the conversion of naphthenic aromatics into asphaltenes [27].

The four components above differ according to the proportion of the materials hydrocarbons that make up each of them, and the resulting varying effects on the properties of bituminous materials, which are determined according to the types Solvents and the method used to separate each one,

The combination of the four components in balanced proportions gives the bituminous material its cementitious action, Over time, the percentage of asphaltenes increases and the percentage of naphthenic aromatics decreases [28]. And Viscosity increases to several times, and tensile strength and cohesion decrease.

Therefore, the oxidation process causes an increase in the percentage of asphaltenes and a decrease in hydrogen due to its conversion to water and evaporation at high temperatures [29].

In general, asphalt molecules are either polar or nonpolar. Polar molecules give asphalt flexibility, and nonpolar molecules give asphalt viscosity,

At high temperatures, the bonding between asphalt molecules decreases that is, the change in viscosity is proportional to the change in temperature. Therefore, there must be a balance between polar and nonpolar molecules in asphalt concrete [30].

Mechanical and rheological properties of asphalt

Rheology is the science that studies the flow and deformation of fluids, taking into account the amount of applied load and the time of application of that load [31].

Asphalt is considered a rheological material because its properties and behavior depend on temperature and loading time.

Therefore, all asphalt and asphalt concrete tests, Therefore, the same applied load for a different period of time will have different properties and results depending on the temperature [32].

Slow loading is equivalent to high temperature, and fast loading is equivalent to low temperature Asphalt is called (visco-elastic) because it takes common properties from both types. At high temperatures, asphalt can be a viscous material, especially when heated to a temperature higher than ($100C^0$).

At low temperatures, it has a high compressive strength and regains its shape when the load applied to it is lifted, At medium temperatures, asphalt takes common properties from both types [33].

Figure (2) shows the effect of temperature and time on asphalt. The quantity in one hour at a temperature of ($60\ C^0$) is the same as in ten hours at a temperature of ($25\ C^0$)

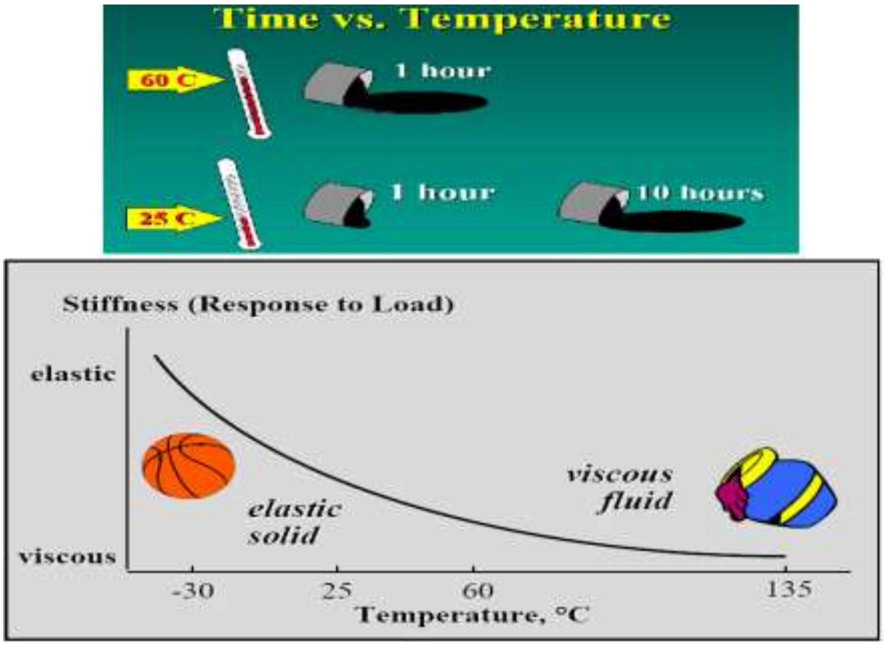

Figure 2. shows the effect of temperature and time on asphalt. The quantity in one hour at a temperature of (60 C^0) is the same as in ten hours at a temperature of (25 C^0)

The best types of asphalt used recently

Most of Iraq's paved roads are designed and implemented using asphalt paving using hot mix.

The paving consists of several layers to bear the loads imposed by vehicles, to mitigate the effects of weather conditions, and to achieve the basic goal of paving, which is to ensure safe and smooth movement [34].

Building the paving structure includes successful implementation so that it can perform multiple functions, including durability, safety, slip resistance, and water drainage [35]. The loads imposed on top of the paving cause stresses throughout the layers, and the surface layers bear greater stresses than the layers other, so the materials used in the surface layer that influences paving design are the most stress-resistant and most expensive materials to receive and withstand the greatest value of stresses [36].

Effective representation of paving materials is a major requirement for a successful, compliant, and practically effective design, which depends primarily on the properties of materials that are affected by external stimuli such as traffic load, quality of implementation, and conditions. Weather [37].

Various factors such as material properties, control over construction quality, traffic, and environmental conditions affect the durability of paving over time [38].

Paving consists of superimposed layers of specific materials placed over the natural ground layer to perform its primary purpose of bearing the applied traffic load [39].

Therefore, the design requires ensuring that the load is transferred to all successive layers without increasing the layer load beyond the load-bearing capacity of the upper asphalt mix layer (surface), which prevents water permeability to the lower layers, provides a smooth, cohesive surface, resists stresses caused by vehicle loads, and provides skid resistance to the surface without causing unnecessary tire wear [40].

Due to the many differences between the stiffness of the aggregate and the binder, the random boundaries of the binder, and the deformation resulting from loading, a wide distribution of stresses and strains occurs,

Stress-strain analysis of a material is the only means of determining many of its physical properties. From the results that can be obtained from the many analysis processes, the behavior of any part of the material can be predicted when placed under various working loads [41].

Stress and strain analysis is increasingly used to predict paving failure and the condition of the different layers in paving construction, taking into account the behavior of the material, which has become increasingly important, as the elastic behavior of the material is undesirable and unacceptable in paving analysis [42].

Studies have shown the mechanical difficulty of analyzing the stresses and strains of the asphalt mixture, the ideal distribution of asphalt in the hot mix, and the results of the distribution of stresses and strains [43].

Physical and Chemical Properties of Asphalt

1. Physical Properties:

These properties have a significant impact on determining the areas of use of asphalt. And The density of asphalt is close to the density of water, but in general, asphalt does not have a specific and constant density, as it varies depending on the chemical compositions of its components, the ratio of hybrid atoms, and the temperature [44],

The type of asphalt is determined on the basis of three properties: Viscosity, Softness, and Penetration [45],

2. Chemical Properties:

The chemical composition of asphalt is very complex and varies from one type to another, depending on the origin of the crude oil and the method of preparing the asphalt [46].

Asphalt is composed mainly of several hydrocarbons and traces of sulfur, oxygen, nitrogen, and other elements. The percentages of the chemical composition of bitumen molecules of the various elements usually vary from one material to another depending on the production conditions, the nature of the crude oil used, and the type of product, but they often range as follows:

1. Carbon (70-87%)
2. Hydrogen (7-14%)
3. Nitrogen (0-3%)
4. Sulfur (0-7%)
5. Oxygen (0-5%)

As for other mineral elements such as vanadium, iron, nickel, and calcium their percentages usually range between (0-0.03%)(44).

Modifying the physical and chemical specifications of asphalt

1. Modifying the physical specifications

In this method, asphalt is mixed with active materials such as: calcium hydroxide, calcium carbonate Portland cement and other fillers [47],

And Adding sulfur to asphalt in different proportions imparts different and desired properties to the resulting material. The specifications of the resulting asphalt are temporary and change after a short time. The reason is the phase separation phenomenon of the asphalt and sulfur mixture [48].

Another physical modification method is the addition of various polymeric wastes such as polyethylene, polypropylene, natural rubber, and damaged tire rubber. Perhaps the most important problem facing this type of modification is the complete or partial insolubility of the additives with the asphalt material,which results in a mixture with heterogeneous properties [49].

2. Modifying the chemical specifications

When blowing asphalt with air at temperatures around (180 c^0), a molecular oxidation process occurs for components with high molecular weights, and then their molecular weights increase, which leads to a change in asphalt characteristics such as viscosity, degree of softness, and plasticity properties [50].

Methods have emerged that aim to link the polymeric material to the hydrocarbon molecules of asphalt by treating the asphalt with polymeric materials. This reaction takes place via a catalytic alkylation reaction [51].

Theoretical Framework and Previous Studies:

By referring to the literature, we find many studies that have addressed the process of Modifying asphalt specifications using various methods and additives, including what was done by Jianying and his group. They studied the effect of epoxy content on the rheological properties of asphalt. The study showed excellent results for the specifications of treated asphalt in terms of good resistance to low and high temperatures and improvement in viscosity properties [52].

In another study, warm asphalt mix technologies were developed to produce asphalt at temperatures slightly above (100 C⁰), and it was found that they are sometimes better than conventional ones.

Warm asphalt mix technologies focus mostly on the binder (bitumen) by adding various additived to improve its properties. These technologies produce asphalt at temperatures between(110-140 C⁰), Figure 3 shows the position of warm asphalt mix among the various technologies, ranging from cold to hot mixes:

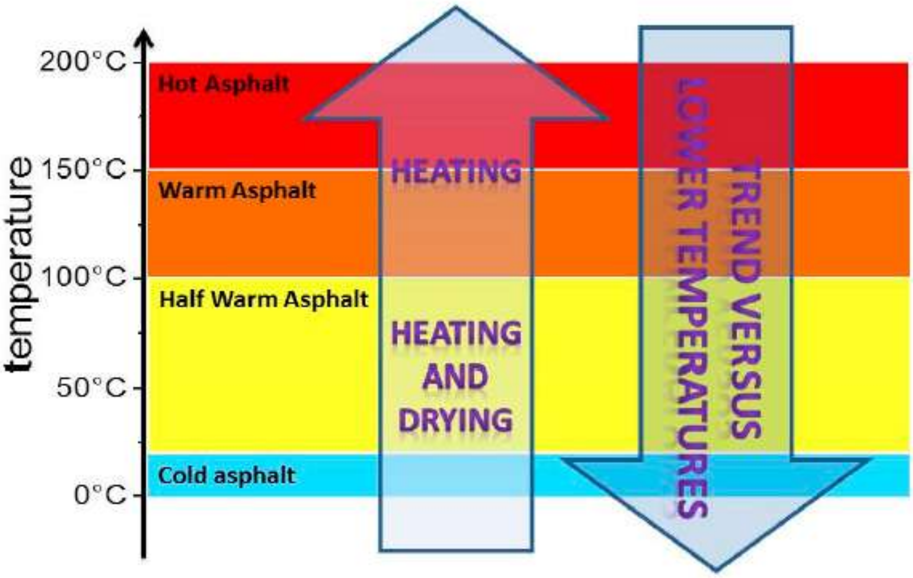

Figure 3. Position of warm asphalt mix among different technologies ranging from cold to hot mixes.

Asphalt (40-50), produced at the Dora Refinery (and not conforming to the surface layer specifications according to the limits of the Iraqi General Specifications for Roads and Bridges amended in, was approved as a raw material for preparing a new Iraqi oxidized asphalt with high mechanical and physical properties by adding some locally sourced chemical and polymeric additives to increase the hardness of the asphalt mixture. The study included treating the asphalt received from the Dora Refinery by blowing with air for different periods of time, after which oxidized asphalt mixtures with sulfur were prepared Rubber, activated carbon, and polymer were used in different weight ratios and different curing times. The results of the laboratory tests showed a clear development in the homogeneity of the prepared oxidized asphalt, giving it excellent specifications in terms of acceptance [53].

Xu and his group studied the thin film oven (aging) test on asphalt samples. Infrared spectroscopy was used to study the effect of different aging conditions to evaluate the performance of lignin-modified asphalt. They also studied the dynamic shear gauge test and the bending beam gauge test [54].

The results of both tests showed that adding lignin positively affects the performance, The study also indicated that lignin improved the flexibility of the asphalt binder and reduced the deformation of unrecoverable asphalt.

The study confirmed that adding lignin to asphalt improves the rheological properties of asphalt compared to the original. The results of the study indicated that lignin extracted from wood is a good equivalent to asphalt materials with economic abundance and environmental benefits [55].

Tang and his group studied the rheological properties of asphalt modified with polymer additives and sulfur. In this study, hybrid asphalt binders containing crumb rubber and styrene-butadiene styrene were prepared, and sulfur at different percentages,The results indicated that crumb rubber, styrene-butadiene-styrene, and sulfur help improve the high-temperature properties and elastic behavior of the asphalt binder.

The study recommended using 0.2-0.3% by weight of sulfur [56].

Pereze and his group studied the addition of lignin, a natural polymer extracted from hardwood shingles, to asphalt.

Since polymers improve the performance of asphalt mixture, this work investigates the possibility of using this industrial waste as a bitumen source in the production of asphalt mixtures [57].

The study demonstrated resistance to moisture damage, resistance to permanent deformation, and resistance to thermal exposure. The study concluded that it is appropriate to use industrial waste containing lignin in asphalt mixtures [58].

Eskandarseft et al. studied the effect of adding cellulose fibers with and without the use of elastic polymers and rubber to bitumen. The study showed that adding cellulose increased the softening point and viscosity, while adding rubber reduced the softening point and viscosity but increased the penetration of the compounds compared to those containing fibers without rubber content. The study concluded that the presence of rubber with cellulose fibers reduces hardness and increases the flexibility of the compounds [59]. Zaihed and his group studied the effect of lignin on the rheological properties of asphalt, including the degree of penetration, ductility, viscosity, weight loss percentage (aging), permeability, and flashing degree. The study noted an improvement in the rheological properties of asphalt with the addition of lignin. In this research, the effect of using lignin in modifying the rheological properties of asphalt was studied using the aerobic oxidation process [60].

Maharaj & Maharaj studied the physical properties of asphalt by adding low-density polyethylene, polyvinyl chloride, and used engine oil. The results showed that with increasing the concentration of used engine oil at ratios of (30-0), there was an increase in the resistance to stress cracking, accompanied by a decrease in the resistance to forming ruts in the street [61].

Dekhli et al. studied the rheological behavior of modified asphalt by adding ethylene vinyl acetate (EVA). The study provided asphalt models with rheological properties that can be used in the field of paving. There was a clear positive change in the measurements (degree of ductility, permeability, sensitivity to temperature) [62].

Djaffar et al. were able to study the rheological properties and storage stability of modified asphalt by adding Styrene-ethylene-butylene-styrene (SEBS) polymer, as the study confirmed the stability of the properties rheological permeability, ductility, penetration index, and temperature sensitivity of the modified asphalt through Measured after storage for a period of time [63].

Research Methodology and Procedures

This research relied on the experimental method by taking paving asphalt from the Qayyarah Refinery, and taking the required measurements of the degree of plasticity, elongation, and permeability of the original sample. Then, rheological modification was carried out on the asphalt by adding polyethylene (PE) and colophony with or without adding Sulfur to asphalt samples, and the required measurements of the degree of plasticity, elongation, and permeability were carried out after modification [64].

Practical Part

First - Materials Used

Table 1. Qayyarah Asphalt:Obtained from the Qayyarah Refinery, which is characterized by the specifications shown.

Specifications	Laboratory Value	Specification Limits
Elongation ($25C^0$, cm)	140	> 100
Degree of Flexibility (C^0)	55.0	49 - 58
Permeability (mm 100 gm, 5 sec 25 C^0)	42	40 - 50

2. Sulfur, as obtained from the Mishraq Sulfur General Company.
3. Colophony is an industrial material

4. Polyethylene is an industrial material.

Devices used in the research

1. **Elongation measuring device**

This device consists of a water bath at a temperature of (25 C^0) (Screw pulls a fixed mold from one end and the other is fixed to a moving base, and the speed is minute/cm^3). The measurement is taken until the model breaks. Elongation is the distance the asphalt material elongates when exposed to the effect of pulling at a constant speed, until the asphalt model breaks. The device is of Chinese origin, type (YUFENG), and the measurement was conducted according to the internationally approved American standard specifications (Table 1) [65].

2. **Permeability measuring device (Penetrometer):**

This device tests the permeability of solid and semi-solid bituminous materials. Permeability is a measure of the hardness of asphalt, or it is the consistency of the bituminous material expressed by the vertical distance into which the measuring needle is inserted.

The bituminous material is expressed as the vertical distance that the measuring needle penetrates the asphalt sample under certain conditions of temperature, load, and time. The distance traveled by the needle in the asphalt within 5 seconds is calculated and this distance is considered the permeability value. The device is of Chinese origin (YUFENG) type.
This test was conducted according to the internationally approved American standard specifications.

3. **Ring and Ball Apparatus:**

This device measures the plasticity of asphalt materials with plasticity ranging between (2000-30), The plasticity is the temperature at which the asphalt sample descends a distance of (2.54 cm) when heated at a precise speed (5), avoiding rapid heating, This test was conducted according to the internationally approved American standard specifications
ASTM D36-95 [66].

4. **Asphalt Treatment Apparatus**

The device consists of the following parts:

1. A large 200 ml glass beaker with three holes.
2. A thermometer attached to one of the side holes
3. (Heating Mantle) Cobra Heater.
4. Electric heater (Heating Mantle). A mechanical motor attached to the middle opening of the flask
5. An iron stand equipped with a clip to secure the flask.

(Experimental Method)

1. **Modifying the rheological properties of asphalt by chemical treatment:**

a. Place 200 grams of Qayyarah asphalt in the asphalt material treatment device described in the above paragraph (of the devices used), and add (1%, 2%, 3%) of polyethylene with (1%) sulfur. It is also prepared in the same way without sulfur.
b. Place 200 grams of Qayyarah asphalt in the asphalt material treatment device shown in the paragraph above (the devices used),

and add (1%, 2%, 3%) of rosin with (1%) sulfur, It is also prepared in the same way without sulfur [67]. and heat it to a temperature of (150 C^0), and mix the reactant well and raise the temperature of the mixture to (180 C^0) with continuous shaking for 60 minutes. Measurements of elongation, permeability, and degree of plasticity were carried out, and the results are listed in the tables. Modifying the rheological properties of asphalt with polymer additives is one of the most important methods used to obtain asphalt materials with rheological properties different from the original asphalt and suitable for use in many fields. Unaltered asphalt is more affected by temperature, as it has high ductility at high temperatures. It is also brittle and cracks quickly when temperatures decrease, while modified asphalt is characterized by being more ideal, elastic, and stable at different temperatures.

Moreover, it is more resistant to aging than the original asphalt. As shown, the practical part to place 200 grams of Qayyarah asphalt in the asphalt material processing device (shown in the paragraph above of the devices used, and (1%, 2%, 3%) of polyethylene with (1%) sulfur is added, and it is also prepared in the same way without sulfur.

On the other hand, 200 grams of Qayyarah asphalt is placed in the asphalt material processing device). As shown in the above paragraph of the devices used, (1%,2% ,3%) is added of rosin with (1%) sulfur and is also prepared in the same way without sulfur. and heated to a temperature of (150 C^0), the reactant was mixed well and the temperature of the mixture was raised to (180 C^0) with continuous shaking for 60 minutes,Elongation, permeability and ductility measurements were performed [68]. The results are as shown in the tables below:

Table 2. Rheological properties of the original and treated asphalt samples with different percentages of rosin at 180 C^O for 60 minutes.

Sample	Elongation ($25C^0$, cm)	Degree of Flexibility (C^0)	Permeability (mm 100 gm, 5 sec 25 C^0)
Original sample	140	55.0	42
1%	90	60	36
2%	120	61	33
3%	130	63	31

We note from the samples that by increasing the percentage of rosin, this process did not lead to a significant improvement in the specifications of the treated asphalt, as most samples witnessed an irregular deterioration in the elongation values (Table 2). The increase in the percentage of the additive mixed with the asphalt leads to the production of asphalt systems with lower quality rheological properties than lower percentages.

Table 3. Rheological properties of the original and treated asphalt samples with different percentages of rosin and the addition of 1% sulfur at180 C^0 for 60 minutes.

Sample	Elongation ($25C^0$, cm)	Degree of Flexibility (C^0)	Permeability (mm 100 gm, 5 sec 25 C^0)
Original sample	140	55.0	42
1%	140	60	31
2%	120	59	27
3%	100	57	25

Adding sulfur to modified asphalt models using rosin binds the polymer molecule to the asphalt molecule, increases the solubility of the polymer with the asphalt, and increases the bonding between the components.

The study notes that the effect of sulfur on modified systems lies in giving flexibility to the prepared systems,and the use of 1 % sulfur was based on previous studies that proved that this percentage is the best percentage that can be used to modify the rheological specifications of asphalt.

Table 4. Rheological properties of original and treated asphalt samples with different proportions of polyethylene at 180 C^0 for 60 minutes.

Sample	Elongation ($25C^0$, cm)	Degree of Flexibility (C^0)	Permeability (mm 100 gm, 5 sec 25 C^0)
Original sample	140	55.0	42
1%	140	60	37
2%	120	63	35
3%	85	64	31

The primary goal of thermogravimetric treatment of polymers is to obtain short polymer chains with a low molecular weight and convert them into powder (Table 4). The ease of interaction of the polymer with asphalt also leads to a decrease in the molecular weight of the polymer to approximately half of what it was before treatment, leading to an increase in the relatively free ends.

Thus, the effect on the rheological properties of asphalt is very large. Therefore, low-molecular-weight polymers require lower temperatures than high-molecular-weight polymers.

Increasing the percentage of added polymer led to an increase in the molecular weight of asphalt due to the association of high-molecular-weight polymer molecules with the asphalt

This is confirmed by recent studies that show that low polymer ratios are the preferred ratios for performing rheological modifications, as the polymer phase is dispersed in the continuous asphalt phase system.

We note from the results that the permeability value decreases, as the reason for this is that the polymeric material particles.

Table 5. Rheological properties of the original and treated asphalt samples with different ratios of polyethylene and the addition of 1 sulfur at 180 C^0 for 60 minutes.

Sample	Elongation ($25C^0$, cm)	Degree of Flexibility (C^0)	Permeability (mm 100 gm, 5 sec 25 C^0)
Original sample	140	55.0	42
1%	130	62	30
2%	40	67	27
3%	50	65	26

Increases the bonding strength between the asphalt and the added particles, thus giving the composite asphalt a higher hardness compared to the original unfilled asphalt sample, which gives a higher degree of permeability to its penetration (Table 5).

Table 6. Rheological properties of the original and treated asphalt samples with a different ratio (rosin: polyethylene) (1:1) of polyethylene at **180** C^0 for 60 minutes.

Sample	Elongation ($25C^0$, cm)	Degree of Flexibility (C^0)	Permeability (mm 100 gm, 5 sec 25 C^0)
Original sample	140	55.0	42
1%	120	62	34
2%	110	64	31
3%	60	66	28

The degree of plasticity increases with increasing proportions of additives, and the increase in the degree of plasticity is due to the arrangement of the molecules and their strong bonding with each other, especially when the temperature increases, which leads to fewer gaps between the chains linked to each other, thus providing better specifications (Table 6).

Table 7. Rheological properties of the original and treated asphalt samples (1:1) different polyethylene at **180** C0 for 60 minutes and the addition of 1% sulfur.

Sample	Elongation ($25C^0$, cm)	Degree of Flexibility (C^0)	Permeability (mm 100 gm, 5 sec 25 C^0)
Original sample	140	55.0	42
1%	90	64	29
2%	40	65	28
3%	40	66	26

The table shows that the mixture (rosin: polyethylene) (1:1) gives a desirable rheological modification at addition ratios up to 1% by weight. However, increasing the percentage of this polymer mixture leads to a deterioration in the rheological properties of modified asphalt (Table 7).

We note that with increasing the addition ratio of the mixtures, the values of permeability and elongation decrease, and the values of ductility increase. Therefore, low ratios of these polymer mixtures are preferred.

4. Conclusion

In addition, the used temperature of 180 C0 works to cause cleavage in the octa-sulfur ring and the formation of effective free radicals capable of reacting with the asphalt material, which leads to cross-linking between them and, consequently, causing a modification in the rheological properties of asphalt.

The table shows that the mixture (rosin: polyethylene) (1:1) gives a desirable rheological modification at addition ratios up to 1% by weight. However, increasing the percentage of this polymer mixture leads to a deterioration in the rheological properties of modified asphalt.

We note that with increasing the addition ratio of the mixtures, the values of permeability and elongation decrease, and the values of ductility increase. Therefore, low ratios of these polymer mixtures are preferred.

Recommendations

a. Use lower percentages of plastic waste or use different percentages on other sieves, where 66% of plastic waste was used as a percentage of coarse aggregate on sieve No. 4.06 mm to obtain better results.
b. Use the Super Pave method to prepare the asphalt mixture instead of the Marshall method.

Suggestions:

We can conduct a study to benefit from some of the prepared samples with high asphalt content in order to prepare activated carbon, given the great importance of this material in the process of reducing environmental pollution.

REFERENCES

[1] S. Parkash, Petroleum Fuels Manufacturing Handbook, New York, NY, USA: McGraw-Hill Companies, Inc., 2010, pp. 102–131.
[2] Asphalt Institute Inc. and European Bitumen Association, Eurobitume: The Bitumen Industry, A Global Perspective, 3rd ed., USA, 2015.
[3] L. W. Holtherly and P. C. Leaver, Asphaltic Road Materials, London, U.K.: Edward Arnold Ltd., 1967, pp. 17–24.
[4] Z. Stastna, L. Zanzotto, and O. Vacin, “Thermomechanical properties of several modified asphalts,” Journal of Applied Rheology, vol. 10, pp. 1–2, 134–134, 2000.
[5] Research Circular, Transportation Research Board, National Research Council, no. 499, Washington, D.C., USA, 2000.
[6] V. O. Bulatovic, V. Rek, and K. Markovic, “Study on polymer engineering,” Journal of Polymer Engineering Science, vol. 53, no. 11, pp. 2276–2283, 2013.
[7] J. F. Masson, L. Pelletier, and P. Collins, “Rapid FTIR method for quantification of styrene–butadiene type copolymers in bitumen,” Journal of Applied Polymer Science, vol. 79, no. 6, pp. 1034–1041, 2001.
[8] F. A. Henglein, Chemical Technology, London, U.K.: Pergamon Press, 1969, pp. 811–812.
[9] G. D. Hobson, Modern Petroleum Technology, 4th ed., London, U.K.: Institute of Petroleum, 1973, pp. 804–806.
[10] D. Lesueur, “The colloidal structure of bitumen: Consequences on the rheology and on the mechanisms of modification,” Advances in Colloid and Interface Science, vol. 145, pp. 28–42, 2009.
[11] Introduction to Asphalt, Asphalt Institute Manual Series No. 5 (MS-5), Asphalt Institute, 2001, pp. 2, 9–11, 14, 61.
[12] Asphalt Institute Inc. and European Bitumen Association, Eurobitume: The Bitumen Industry, A Global Perspective, 3rd ed., USA, 2015.
[13] J. M. Salman, “Preparation of a new Iraqi oxidized asphalt using local additives,” Journal of the City of Science College, Univ. of Iraq College, Basra, Iraq, vol. 14, no. 3, 2022.
[14] G. Polacco, J. Stastna, D. Biondi, F. Antonelli, Z. Vlachovicova, and L. Zanzotto, “Rheology of asphalts modified with glycidylmethacrylate functionalized polymers,” Journal of Colloid and Interface Science, vol. 280, pp. 336–373, 2004.
[15] J. C. Petersen, “A review of the fundamentals of asphalt oxidation: Chemical, physicochemical, physical property, and durability relationships,” Washington, D.C., USA, Oct. 2009.

[16] N. F. Ghaly, "Effect of sulfur on the storage stability of tire rubber modified asphalt," World Journal of Chemistry, vol. 3, no. 2, pp. 42–50, 2008.

[17] A. R. I. Al-Hadidy and A. T. Hameed, "The effect of sulfur waste and ABS on asphalt cement properties," Al-Rafidain Engineering Journal, vol. 19, no. 3, Jun. 2011.

[18] H. A. A. Ali and R. A. Yousif, "Effect of rubber modified asphalt on the permanent deformation of asphalt pavement," Unpublished study.

[19] J. C. Petersen, "Chemical composition of asphalt as related to asphalt durability," Transportation Research Record, no. 999, TRB, National Research Council, Washington, D.C., pp. 13–30, 1984.

[20] M. A. A. D. Al-Jabouri, "A study of the effect of adding copolymers and their various blends on the rheological properties of asphalt," Tikrit Univ., College of Education for Pure Sciences, Dept. of Chemistry, 2021.

[21] L. W. Corbett and R. E. Merz, "Asphalt binder hardening in the Michigan test road after 18 years of service," Transportation Research Record, no. 544, TRB, National Research Council, Washington, D.C., pp. 27–34, 1975.

[22] J. M. Salman, "Preparation of a new Iraqi oxidized asphalt using local additives," Journal of the City of Science College, Univ. of Basra, Iraq, vol. 14, no. 3, 2022.

[23] J. Knotnerus, "Bitumen durability: Measurement by oxygen absorption," Industrial and Engineering Chemistry, vol. 11, pp. 411–422, 1972.

[24] B. Shirkav, "Bitumen modification with polysulfide polymer prepared from heavy end waste," Iranian Polymer Journal, vol. 19, no. 5, pp. 3663–373, 2010.

[25] M. T. Awwad and L. Shabeeb, "The use of polyethylene in hot asphalt mixtures," Journal of Applied Sciences, vol. 4, pp. 390–396, 2007.

[26] J. C. Petersen, F. A. Barbour, and S. M. Dorrence, "Catalysis of asphalt oxidation by mineral aggregate surfaces and asphalt components," Proc. Assoc. of Asphalt Paving Technologists, vol. 43, pp. 162–177, 1974.

[27] K. P. Kelly and J. R. Butler, "Method of preparation of stable bitumen polymer compositions," U.S. Patent 6,180,697, Fina Technology, 1999.

[28] W. Guian, Z. Yong, Z. Yinxi, S. Kang, and F. Yongzhong, "Rheological characterization of storage-stable SBS-modified asphalts," Polymer Testing, vol. 21, pp. 295–302, 2002.

[29] M. S. A. S. B. Lashahr and H. A. Omar, "The effect of adding plastic waste on the properties of asphalt mixture," Proc. Second Conf. on Engineering and Technical Sciences 29, Univ. of Tripoli, Libya, 2019.

[30] A. H. Abdul et al., "Developing asphalt technology in Iraq using the SUPERPAVE system," College of Engineering, Al-Nahrain Univ., Baghdad, Iraq, 2016, p. 17.

[31] A. M. Ramadan, Pavement Materials and Design of Asphalt Mixtures Using the Marshall Method, Cairo, Egypt, 2006, p. 12.

[32] H. U. Bahia, Materials for Constructed Facilities, CEE/EMA 395 Lectures, Univ. of Wisconsin-Madison, Mar.–Aug. 2009.

[33] F. L. Roberts, P. S. Kandhal, E. R. Brown, D. Y. Lee, and T. W. Kennedy, Hot Mix Asphalt Materials, Mixture Design, and Construction, 2nd ed., Lanham, MD, USA: NAPA Educational Foundation, 1996.

[34] K. S. Alshamsi, "The behavior of HMA depends on the properties of the individual components and how they react with each other in the system," Louisiana State Univ., 2005.

[35] M. Zeghal, E. Y. Adam, O. Ali, and H. E. Mohammed, "Review of the new mechanistic–empirical pavement design guide: A material characterization perspective," Proc. Annual Conf. Transportation Association of Canada, Calgary, Alberta, 2005.

[36] A. H. K. Albayati, "Permanent deformation prediction of asphalt concrete under repeated loading," Ph.D. dissertation, Univ. of Baghdad, Iraq, 2006.

[37] C. Druta, "A micromechanical approach for predicting the complex shear modulus and accumulated shear strain of asphalt mixtures from binder and mastics," Ph.D. dissertation, Louisiana State Univ., USA, 2006.

[38] R. Phillips, Stress–Strain Analysis, California Institute of Technology, California, USA, 2005.

[39] B. Sukumaran, "Three-dimensional finite element modeling of flexible pavements," presented at the FAA Worldwide Airport Technology Transfer Conference, 2004.

[40] S. Kose, M. Guler, H. Bahia, and E. Masad, "Distribution of strains within hot-mix asphalt binders: Applying imaging and finite-element techniques," Transportation Research Record, no. 1728, Asphalt Binders, Washington, D.C., USA, 2000.

[41] T. M. Y. Saleh and Z. N. Mohammed, "Some performance properties of hot mix asphalt for the surface layer using Baiji asphalt," Al-Rafidain Engineering Journal, vol. 21, no. 4, 2013.

[42] R. N. Traxler, Asphalt: Its Composition, Properties and Uses, London, U.K.: Hall Ltd., 1961.
[43] G. D. Hobson, Modern Petroleum Technology, 4th ed., London, U.K.: Institute of Petroleum, 1975.
[44] L. W. Holtherly and P. C. Leaver, Asphaltic Road Materials, London, U.K.: Edward Arnold Ltd., 1986.
[45] G. Sell, The Petroleum Industry, Oxford Univ. Press, Oxford, U.K., 1963.
[46] A. Al-Frakh and A. A. Abu Shihada, "Chemical abstracts," Chem. Abstr., vol. 96, 1982.
[47] L. A. Saleh Al-Aqidi, M.Sc. thesis, Univ. of Mosul, College of Science, Dept. of Chemistry, 1992.
[48] D. E. Lio and G. Luciano, Chemical Abstracts, vol. 109, 1989.
[49] I. Al-Dabouni and L. Hamid, Oil: Origin, Composition, and Technology, Univ. of Mosul Press, 1st ed., 1986.
[50] Z. Shufen and D. Jiang, Chemical Abstracts, vol. 108, 1988.
[51] M. B. A. Aziz and S. O. Ayada, "Improving the specifications of bitumen heat as a surface finishing material using used tire rubber powder," Anbar Univ. J. of Pure Sciences, vol. 3, no. 3, 2009, ISSN 1991-8941.
[52] C. Peiliang, Y. Jianying, and C. Shuanfa, "Effects of epoxy resin contents on the rheological properties of epoxy–asphalt blends," Journal of Applied Polymer Science, vol. 118, pp. 3678–3684, 2010.
[53] C. O. Rossi, P. Caputo, S. Ashimova, A. Fabozzi, G. D'Errico, and R. Angelico, "Effects of natural antioxidant agents on the bitumen aging process: An EPR and rheological investigation," Applied Sciences, vol. 8, p. 1405, 2018.
[54] A. Abe et al., "The role of additives in warm mix asphalt technology: An insight into their mechanisms of improving an emerging technology," Nanomaterials, vol. 10, no. 6, p. 1202, 2020, doi: 10.3390/nano10061202.
[55] G. Xu, H. Wang, and H. Zhu, "Rheological properties and anti-aging performance of asphalt binder modified with wood lignin," Construction and Building Materials, vol. 151, pp. 801–808, 2017.
[56] N. Tang, W. Huang, J. Hu, and F. Xiao, "Rheological characterisation of terminal blend rubberised asphalt binder containing polymeric additive and sulphur," Road Materials and Pavement Design, vol. 19, no. 6, pp. 1288–1300, 2018.
[57] I. P. Pérez, A. M. R. Pasandín, J. C. Pais, and P. A. A. Pereira, "Use of lignin biopolymer from industrial waste as bitumen extender for asphalt mixtures," Journal of Cleaner Production, vol. 220, pp. 87–98, 2019.
[58] S. Eskandarsefat, B. Hofko, C. O. Rossi, and C. Sangiorgi, "Fundamental properties of bitumen binders containing novel cellulose-based polyfunctional fibres," Composites Part B: Engineering, vol. 163, pp. 339–350, 2019.
[59] M. Zaihed, A. Zarei, M. Zarei, and O. Janmohammadi, "Experimental determination of the optimum percentage of asphalt mixtures reinforced with lignin," SN Applied Sciences, vol. 2, no. 2, p. 258, 2020.
[60] R. Maharaj and C. Maharaj, "Physical properties of low-density polyethylene, polyvinyl chloride and used engine oil modified asphalt," Progress in Rubber and Recycling Technology, vol. 31, no. 3, 2015.
[61] S. Dekhli, K. A. Mokhtar, F. Hammoum, and D. S. Bachir, "Rheological behaviour of ethylene–vinyl–acetate (EVA) modified road bitumen," Journal of Applied Sciences, vol. 15, no. 3, pp. 444–455, 2015.
[62] S. Djaffar, D. Samy, and K. A. Mohammed, "Rheological properties and storage stability of SEBS polymer modified bitumen," International Journal of Engineering Science and Technology, vol. 5, no. 5, 2013.
[63] M. A. Al-Zubaidi, "Modification of the rheological properties of Beeje asphalt using different additives and the field of their uses," M.Sc. thesis, Univ. of Mosul, Iraq, 2013.
[64] American Society for Testing and Materials, ASTM D113–07, 2008.
[65] American Society for Testing and Materials, ASTM D5/D5M–13, 2013.
[66] American Society for Testing and Materials, ASTM D36–95, 2000.
[67] M. S. Jajo and A. K. Ahmed, "Modification of the rheological properties of asphalt cycled with thermoplastic polyurethane using microwave technology," Journal of Education and Science, vol. 29, no. 3, pp. 85–101, 2020.
[68] A. A. R. Hamdoun and M. A. Muwaffaq, "Chemically modifying the rheological properties of asphalt using epoxy–sulfur system," Journal of Education and Science, vol. 27, no. 2, pp. 20–29, 2018.