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Research Article

Some Aspects of Research for Reclamation of Asphalt Based on Remote Sensing (RS)

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Keywords

Data logger,
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Laboratory equipment,
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Abstract

This research aims to study the bitumen structure components and tests to get a better understanding of bitumen, which is one of the main components of asphalt mixtures. In this work, a brief explanation of other research findings on the organic compound was investigated. Moreover, a review of previous research conducted with bitumen that was modified with different oils was made, eventually. By comparing the results of this study and previous studies, it can be concluded that samples containing rhamnolipid biosurfactant had a better behavior against fatigue compared to samples made with bitumen modified with other oils. The present project was equipped with Remote Sensing (RS) facilities, sensors, modems and a data logger system. Modern technology through advanced sensors and modems was applied for the detection of asphalt mixtures data.

1. Introduction

Roads are the national assets of any country that provide communication possibilities among different points, essentially. Furthermore, the cost of road construction has increased over time, hence, its maintenance or preservation is a critical job that can benefit society. Thus, researchers have conducted extensive tests to distinguish the causes of failure and maintenance methods [1, 2], which can be used to achieve further benefits from this national treasure. Considering that most of the main roads are paved by hot mix asphalt, studies about the properties of asphalt mixtures have significant importance [3].

Previous research showed that the use of different oils in bitumen improves the mechanical function of asphalt, likewise, improving the properties of bitumen binder. They showed the generating of desirable asphalt with the aid of natural, non-toxic, and finally improved the asphalt pavement quality by Remote Sensing (RS) facilities, sensors, modems and data logger systems based on modern technology.

Finally, they emphasized that the following subjects can be expected from future works [4-10]:

- Does the compressive strength of asphalt samples increase by using the modified bitumen of Rhamnolipid Biosurfactant?
- Does the tensile strength of asphalt samples increase by using the modified bitumen of Rhamnolipid Biosurfactant?
- Does the resilience modulus of asphalt samples increase by using modified bitumen of Rhamnolipid Biosurfactant? to generate desirable asphalt with the aid of natural, non-toxic, and finally improved the asphalt pavement quality. Finally, the following subjects can be expected from this work:

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- Does the compressive strength of asphalt samples increase by using modified bitumen of Rhamnolipid Biosurfactant?
- Does the tensile strength of asphalt samples increase by using the modified bitumen of Rhamnolipid Biosurfactant?
- Does the resilience modulus of asphalt samples increase by using the modified bitumen of Rhamnolipid Biosurfactant?

Along with previous research, in this study, using different percentages of Rhamnolipid Biosurfactant (0, 2 and 4 ratios to the bitumen weight) as bitumen modifiers, the properties of bitumen as well as hot mix asphalt have been investigated. Flashpoint, dynamic shear rheometer, bending beam rheometer and rotational viscosity tests were carried out on modified bitumen samples. The results showed that adding Rhamnolipid Biosurfactant to bitumen decreased the viscosity and rutting parameter of the super pave so that the bitumen high-temperature operations, has declined one degree. On the other hand, Rhamnolipid Biosurfactant has reduced fatigue and thermal cracks and has met the requirements of the low and intermediate temperature of super pave. Moreover, for modified asphalt samples, tests of Marshall stability, flow, resilience modulus, repeated load axial, uniaxial creep and indirect tensile fatigue were carried out. The results illustrated that adding more Rhamnolipid Biosurfactant improves the mechanical properties of the asphalt mixture. In the Marshall stability and flow evaluation, the results showed that adding more Rhamnolipid Biosurfactant can bring more stability and less flow value. This fact indicates that the modified samples were more resistant to shear stress. Also, the results of resilience modulus tests, deformation as well fatigue tests showed that Rhamnolipid Biosurfactant was able to improve the properties of asphalt mixtures in all situations [11].

By partial chromatography, bitumen is divided into four main groups with similar rheological properties and the same reactivity. These components are:

• Asphaltene

The molecular mass of asphaltene is about 1000 to 100000 and they are polar compounds. Whereas asphaltenes are viscous compounds, they stabilize the bitumen mixture. Asphaltenes are chemically similar compounds to resins, except that asphaltene contains more awkward atoms such as nitrogen, oxygen as well as sulfur than resins.

• Polar aromatics (resin compounds)

The molecular mass of polar aromatics is about 500 to 50,000 and they are polar compounds. They have strong adhesion properties. Used as a cosolvent for oil and asphaltene. When bitumen oxidizes, it is the resin that takes in oxygen and turns into asphaltene. When bitumen turns into two separate phases of gel-cell, it is the ratio of asphaltene to resin that provides the amount of gel to cell in the bitumen.

• Non-polar aromatics (petroleum compounds)

The molecular mass of petroleum compounds is about 300 to 20,000. Aromatics in bitumen are polar and non-polar. Both types have aromatic rings and are dense in bitumen. Polar aromatics are blackish brown while non-polar aromatics are yellow.

• Saturated compounds

The molecular mass of saturated compounds is about 300 to 1500. They are rather branched or unbranched aliphatic hydrocarbons but may also have cyclic compounds. These compounds are non-polar or white viscous oils that contain most of the bitumen wax compounds.

Research on bitumen shows that when bitumen is extracted with benzene, the following compounds are found in it:

• Aromatic hydrocarbons
• Biphthyls
• Anthracene or phtharacene
• Oxygenated compounds
• Fatty acid methyl esters 6- Methyl Aliphatic ketones.

Heat operations have also been performed on hydrogen-rich and low-hydrogen bitumen. This heat treatment has been performed between temperatures of 200 to 500 degrees Celsius. After the procedure, the test products which were bitumen-soluble chloroform, vaporized bitumen, and insoluble residues, were investigated. The non-aromatic components in them remained in the bitumen and there were large amounts of unsaturated non-hydrocarbons in the evaporated bitumen.

The hydrocarbons obtained from the bitumen heat were significantly different from those of raw bitumen: higher gravity, higher asphaltene content, higher viscosity, and lower boiling point of distillation than raw bitumen. Atomic bitumen had less hydrogen, and if we want to use this bitumen in refineries, the content of sulfur and nitrogen atoms must be reduced to increase the atomic H / C ratio.

Bitumen fumes contain large amounts of aromatic polycyclic compounds. Other research shows that sulfur compounds are higher in bitumen and more concentrated than other molecules of the same weight [12].

2. Methods

This work led to raising the following suggestion for improvement of modeling for evaluation of (RAP) containing Rhamnolipid Biosurfactant:

• Make the connection between (GIS), (RS), and (IoT) for rapid data intercommunication to zoning the (RAP) in a little time up to one second.
• Conceptual modeling for prediction of the mechanical behavior due to (RAP).
• Improvement of (RS) facilities equipped with data loggers, (IoT), and GEO-database intercommunication process.
• Evaluate the effect of Biosurfactant on moisture sensitivity of hot asphalt samples.
• Evaluate the use of calcareous stone materials and compare it with siliceous stone materials.

The most important factor in the structure and morphology of bitumen is the composition of bitumen, and we conclude that the structure of bitumen is a colloidal composition of asphaltene, which is stabilized by polar aromatics in large amounts of aromatic naphthene and saturated compounds. Research on the composition of different types of bitumen shows that asphaltenes make up 2 to 4%, polar aromatics 27 to 47%, aromatic petroleum products 19 to 51% and saturated compounds 2 to 10% of bitumen hydrocarbons [13].

Research on the ratio of hydrogen to carbon represents that all the investigated bitumen has six major compounds: alkanes, mono and dicycloalkanes, alkyl benzenes, naphthenic benzenes as well as Diatromates are abundant on average in bitumen with 4 or 5 sub-branches [14].
Asphaltene obtained by repeated sedimentation methods, including alkyl chains or alkylene bridges, often appears as a substitute in the coal molecular network. The heat of asphaltene showed that most of the gaseous compounds were formed by the cleavage of weak bonds such as alkyl-alkyl-ether and strong bonds such as bridges between semi-aromatic and methyl groups on aromatic rings in the asphaltene structure.

The interpretations obtained from the analysis of elements in bitumen is that the types of bitumen include about 82 to 88% carbon, 8 to 11% hydrogen, less than 1.5% oxygen, less than 1% nitrogen, less than 6% sulfur and a very small amount of metallic or non-metallic elements. In the bitumen's structure, aromatics play a major role in their properties, though the role of saturated compounds cannot be ignored [15-17].
Biosurfactants are unique dual molecules that are widely used to remove organic and metallic pollutants from the environment. Due to their environmental compatibility, Biosurfactants decompose easily in nature and are non-toxic. The results of biosurfactant production in the presence of different carbon sources showed that gasoline and glycerol were well used by bacteria as a source of carbon and energy and the culture medium surface tension was reduced from 79 to 39 and 37 [18].

Biosurfactants also have surfactant properties, such as reduced surface tension and interfacial tension. The tendency to use biosurfactants because of their advantages such as low toxicity, biodegradability, and effectiveness in a wide range of PH and temperatures has increased, significantly. Notable emulsification of Rhamnolipid Biosurfactant from waste materials, as a green biomaterial, promises to reduce the problem of waste accumulation and hydrophobic oil contaminants. The results of the research showed that Biosurfactants increase the adhesion of sand to asphalt [19]. Due to their non-toxic nature and their production from renewable sources, research has shown that the use of biosurfactants in various applications has increased. Rhamnolipids have two hydrophilic and hydrophobic ends. They have the property of cleaning soil contaminants, and their use has increased.

3. Results and Discussion

In a study, the effect of natural oil extracted from wood waste on the high temperature behavior of modified bitumen was studied. In this study, wood oil with 2% by weight of 5% and 10% in three intact states (containing 15-30% moisture), touched and heated at 110 ° C (containing 5-8% humidity) and modified by 4% Polyethylene polymer was used to modify the bitumen and DSR and MSCR tests were used to obtain the groove mark which is a measure of high-temperature endurance of bitumen, bitumen recovery percentage and irreversible creep percentage. As shown in Figure 1, the results of the dynamic shear rheometer test show an increase in the parameter and a decrease in the phase angle, and consequently, an increase in the groove sign with an increase in the percentage of modifier oil. Since increasing this criterion results in improved behavior at high bitumen temperatures, the use of waste wood bio-oil in bitumen modification can improve its behavior at high temperatures. According to Figure 1, from the MSCR test, the addition of wood oil reduced the irreversible creep and increased the bitumen recovery percentage, indicating an improvement in the strength and elasticity of the bitumen at high temperatures. Also in this study, statistical experiments were used to evaluate the percentage of improvement of properties and showed that wood oil had a significant effect on bitumen modification. In this study, they found that the results of MSCR and DSR tests were slightly different. In the DSR test, intact wood oil behaved worse compared to the other two cases due to the high moisture content of the intact wood oil, while in the MSCR test, the wood oil combined with the polymer, performed weaker, which could be due to Polymer failure at high temperature [20] (Figure 2).

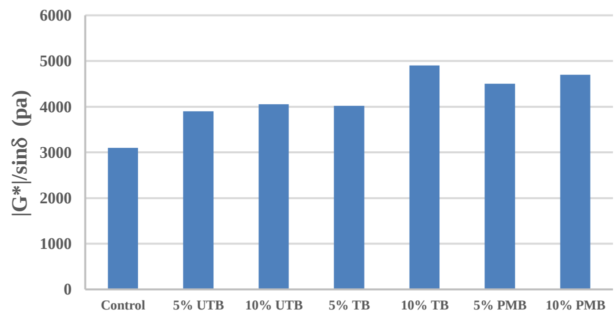

Figure 1. Rutting index based on the results of Yang X et al. [20]

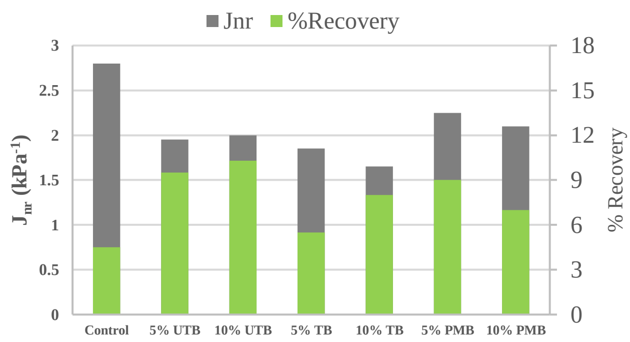

Figure 2. Irreversible creep and recovery percent based on findings of Yang X et al. [20]

In a study by Sam et al. On PG 15-25 hard bitumen, the effect of natural oils derived from oilseed and sunflower seeds was investigated. In this study, samples containing 71.4% natural bitumen, 17.9% vegetable oils and 10.7% bitumen were tested to investigate their temperature behavior. Glass conductivity temperature obtained from the DSC results showed that these waste vegetable oils have a lower glass conductivity temperature than bitumen, so the bitumen obtained by combining with these oils has a lower glass conductivity temperature. According to Table 1, the evaluation of the DSC test shows that by reducing the glass conductivity temperature by adding vegetable oils used in the research to bitumen, the behavior at low bitumen temperature is improved, which reduces the possibility of thermal failure at low temperatures is one of the benefits of using these oils [21].

Table 1. The glass conductivity temperature and melting temperature based on research of Somé SC et al. [20]

Material	Glassy transition temperature (T_g)	Melting temperature (T_f)
Waste rapeseed oil	-30.90 ºC	-2.6 ºC
Waste sunflower oil	-44.3 ºC	-5.65 ºC
P15/25 bitumen	-24.07 ºC	-
P35/50 bitumen	16.4 ºC	-
Bend with waste rapeseed oil	-37.8 ºC	-
Bend with waste sunflower oil	-35.1 ºC	-

Shirzad et al. Evaluated the potential of using sunflower oil as a rejuvenator in the asphalt self-healing process in microcapsules in their research. In this study, two types of bitumen, PG 70-22 and PG 76-22 were combined with rejuvenating oil obtained from sunflower plant with a weight percentage of 5% by weight of bitumen, and the usable temperature interval of bitumen as the interval between the maximum and the lowest temperature at which bitumen is expected to behave appropriately is defined by the bitumen sharp experiments. As the usable temperature range of bitumen is shown in Table 2, the use of sunflower oil has positively improved both the low and high-temperature behavior of bitumen [22].

Table 2. Operating temperature range based on the research of Shirzad S et al. [21]

Blend type	Continuous PG grading	PG grading	UTI
70-22	72.8-22.18	70-22	95
70.22 aged	84.1-20.8	82-16	105
70.22 aged + sunflower oil	77.4-30.1	76-28	108
70.22 aged + PennzSuppress	83.5-18.22	82-16	102
76.22	77.9-24.7	76-22	103
76.22 aged	91.9-19.7	88-16	112
76.22 aged + sunflower oil	80.0-32.5	76-28	113
76.22 aged + PennzSuppress	88.6-22.91	88-22	112
RAP	98.6-3.99	94-4	103
RAP + sunflower oil	86.6-16.68	82-22	103
RAP + PennzSuppress	96.6-6.21	94-4	103

In Finney et al.'s research, the heating process was used to produce bio-oil from pig manure and the adhesive from the manure oil refraction process was used to modify PG 64-22 bitumen. Bitumen fracture temperature has been calculated by bending beam rheometer test to investigate the behavior at low bitumen temperature and groove mark by DSR test to study the behavior at high bitumen temperature. According to Table 3, the failure temperature decreased with increasing oil percentage, which indicates an improvement in cracking at low bitumen temperatures. Bitumen with a higher groove mark should have more resistance to grooving and therefore better performance at high temperatures, while according to Figure 3, with increasing oil percentage, bitumen performance at all temperatures than base bitumen Has decreased [23].

Table 3. Failure temperature based on Fini EH et al. [22]

Binder	Cracking temperature (ºC)
PG 64-22	-31.7
BMB-2 (2%)	-33.1
BMB-5 (5%)	-34.7
BMB-10 (10%)	-36.3

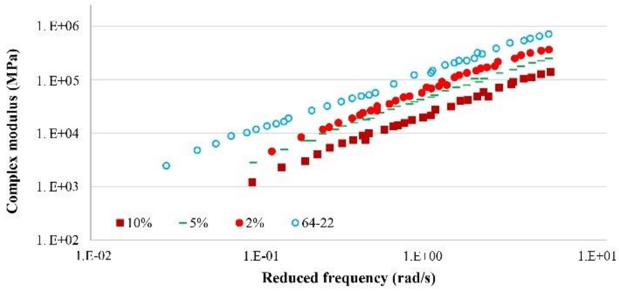

Figure 3. Irreversible creep and recovery percent based on findings of Yang X et al. [19]

In a study of Azahar WNAW et al. On 60-70 bitumen, the effect of frying oil waste on bitumen temperature sensitivity was investigated. In this study, frying oil pulp with 3, 4 and 5 percent by weight of bitumen was used in both modified and unmodified forms. The softening point was calculated as the mean temperature at which the bitumen temperature sensitivity is expected to decrease as it rises, as shown in Figure 4-6, which shows a decrease in the modified bitumen softening point. According to the results of the DSR test, shown in Figure 2-6, the value of G * / Sinδ for bitumen modified with intact waste oil decreased, while for bitumen modified with untreated oil up to a temperature of about 57 Celsius increased and had no effect at higher temperatures. In estimating the fracture temperature in this study, the modified frying oil showed a higher breaking point at 70 ° C compared to the unrefined oil at 64 ° C. In this regard, bitumen containing modified frying oil at low temperatures Has shown better performance [24].

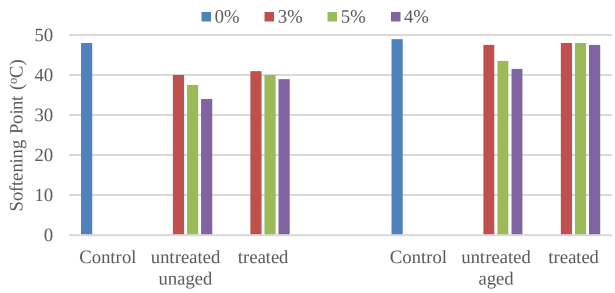

Figure 4. The point of softening under the conditions of aged and not aged based on the research of Azahar WNAW et al. [24]

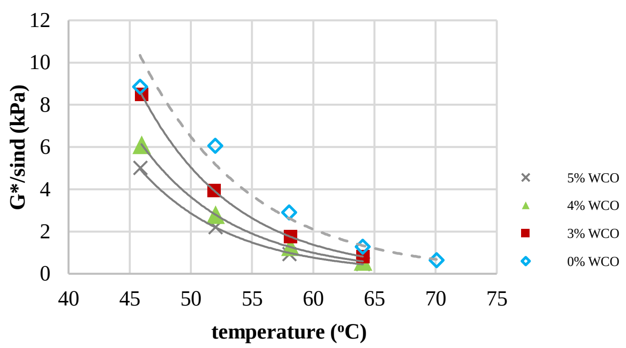

Figure 5. Indication of the Rutting under the intact oil conditions based on the research of Azahar WNAW et al. [24]

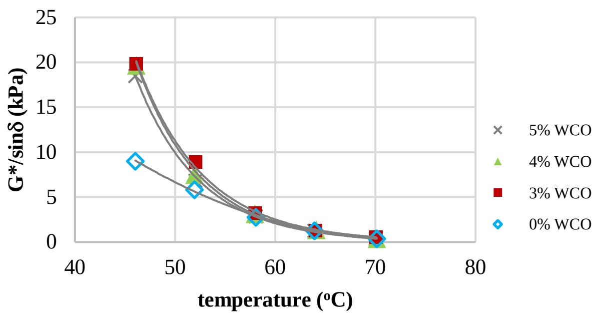

Figure 5. Indication of the Rutting under the Touched oil conditions based on the research of Azahar WNAW et al. [24]

In the study of Ali et al., The effect of five oils on the fatigue behavior of asphalt mixtures was investigated. The first rejuvenator, naphthenic oil, the second rejuvenator, a paraffinic oil obtained from the refining of grease oil was used, the third rejuvenator obtained from the aromatic extraction of natural oil refined with polar aromatic oil, the fourth rejuvenator, oleic acid as a product with fatty acid obtained from It is vegetable oil and the fifth rejuvenator of industrial pub oil. In addition, an evaluation of the behavior of a polymer-modified bitumen compared to the behavior of five oils in mixing with recycled asphalt was used to evaluate the softening of the asphalt mixture. Tested samples include asphalt mixture with PG 76-22, asphalt mixture with PG 76-22 and 25% recycled asphalt, asphalt mixture with PG 76-22 and 45% recycled asphalt, asphalt mixture with 25% recycled asphalt and rejuvenators and asphalt mixture with 45 % Recycled asphalt and rejuvenators were considered. The shear modulus curves from the DSR test resulted in a smaller value compared to the base bitumen. According to the results, the use of rejuvenators studied in this study, when producing recycled asphalt, can improve the resistance of asphalt against fatigue failure [25].

4. Conclusions

The purpose of this work was to improve the properties of bitumen. This led to improving the mechanical properties of hot asphalt mixtures. The present work also investigated the (GIS) as a low-cost, high precision, and rapid method for identifying the (RAP). Finally, this work showed that (GIS) can be linked to new techniques includes (RS) and (IoT) which can be serious subjects for future research in the field of pavement engineering.

Suggestions for future research

This work led to raising the following suggestion for future research:

• Make the connection between (GIS), (RS), and (IoT) for rapid data intercommunication to zoning the (RAP) in a little time up to one second.

• Improvement of (RS) facilities equipped with data loggers, (IoT), and GEO-database intercommunication process.

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