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Research Article

Laboratory and Field Test Equipment for Optimization of the Asphalt Pavement

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Keywords

Asphalt mixtures, Internet of Things, Remote Sensing, Geospatial Information System, laboratory equipment.

Abstract

This work introduces the laboratory equipment and tests performed on the materials and samples of bitumen and asphalt. The results showed that advanced technology includes Remote Sensing (RS) facilities, advanced sensors, modems and data logger systems help the maintenance of asphalt. The intelligent maintenance of asphalt mixtures brings more stability and less fatigue value. This fact indicates that the modified samples were more resistant to shear stress by intelligence maintenance. Also, the results of resilience modulus tests, deformation as well as fatigue tests showed that organic compound was able to improve the properties of asphalt mixtures in all situations. This work also investigated the Geospatial Information System (GIS) as a low-cost, high-precision, and rapid method for identifying fatigue values. Finally, this work showed that (GIS) can be linked to new techniques including Remote Sensing (RS) and the Internet of Things (IoT) which can be serious subjects for future research in the field of pavement engineering.

1. Introduction

The Marshall test is a popular and proven method to measure the load and flow rate of asphalt specimens, beginning with compaction into molds using manual or automated Marshall Compactors and conditioning in a water bath at the specified temperature. Asphalt maintenance and quality control testing services are as follows:

- Field Compaction Control during placement with Nuclear Gauge.
- Coring for thickness & density (ASTM 5361).

Complete laboratory analysis of bituminous mix, including: Superpave (ASTM D6925).

- Marshall Test (ASTM D6926).
- MTRD (Maximum Theoretical Relative Density).

These tests show the new techniques were able to improve the properties of asphalt mixtures in all situations. In this work, by using different percentages of Rhamnolipid Biosurfactant (0, 2 and 4 ratios to the bitumen weight) based on the Geospatial Information System (GIS) as bitumen modifiers, the properties of bitumen, as well as hot mix asphalt, have been investigated. Tests including Flashpoint, dynamic shear rheometer, bending beam rheometer and rotational viscosity were done on modified bitumen samples. The test revealed that by adding Rhamnolipid Biosurfactant to bitumen, viscosity and the rutting parameter of the super-pave were enhanced so that the bitumen high-temperature operations, has decreased by one degree. On the other hand, Rhamnolipid Biosurfactant has reduced fatigue and thermal cracks that reached the requirements of low and intermediate temperatures of super-pave. Furthermore, for modified

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asphalt samples, repeated axial load, uniaxial creep, resilience modulus, Marshall stability, flow and indirect tensile fatigue tests have been done. In consequence, adding more Rhamnolipid Biosurfactant improves the mechanical behavior of the asphalt mixture. In the Marshall stability and flow evaluation, the results indicate that adding more Rhamnolipid Biosurfactant causes more stability and low flow value. This fact shows that the modified samples were more resistant to shear stress. Correspondingly, the results of resilience modulus tests as well as fatigue tests showed that Rhamnolipid Biosurfactant was able to improve the behavior of asphalt mixtures in all situations [1-8].

Many research have been done on the use of additives in the preparation of asphalt mixtures to increase their ability against loads. According to these studies, a number of these additives, according to the predictions, have shown good performance against loads, but so far no research has been done on adding natural microorganisms to bitumen and modifying it and evaluating the mechanical properties of the resulting asphalt mixture. And most of the current research in this field has only evaluated the performance of bitumen. Due to the unique characteristics of biosurfactants, it is expected that there will be significant differences in the behavior of the resulting asphalt mixtures with conventional asphalts. For this reason, in the present study, the mechanical behaviors of asphalt mixtures containing rhamnolipid biosurfactant additives with 2% and 4% by weight of bitumen have been evaluated [9-12].

2. Methods

2.1. Acceleration Chamber Test

Before premium paving, the effects of long-term aging of bitumen were not considered in the specifications for bitumen adhesives. The Accelerated Aging Chamber; PAV test was developed by Sharp to simulate the long-term aging of bituminous adhesives in asphalt mixtures. Since bitumen is used to prepare asphalt mixtures, which have not yet gone through the stages of time erosion, so the time wear of the asphalt mixture in the asphalt plant and at the pavement site should be considered. In this study, the effects of long-term wear were investigated by performing an aging chamber test, in which the asphalt mixture, which was in short-term wear conditions, was placed inside the greenhouse to simulate the conditions for long-term wear. The description of this experiment is given in AASHTO-PP1 (Figure 1).

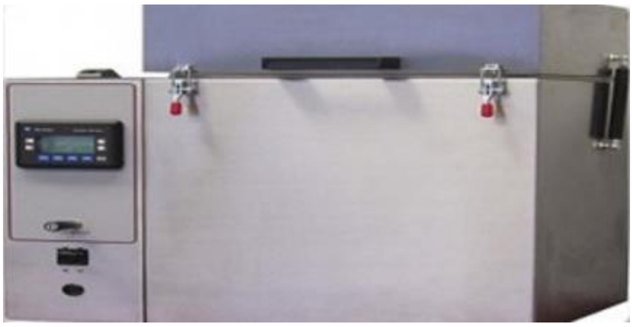

Figure 1. The rapid aging chamber testing device of Isfahan J Oil Company

2.2. Dynamic Section Rheometer (DSR) Test

Due to the dependence of bitumen behavior on temperature and loading time, the optimal test for bitumen adhesives should include both factors. This capability has been developed in experimental machine tools called dynamic rheometers, dynamic shear rheometers or oscillating shear rheometers [13-18].

Rheometers are great for testing bitumen because they can evaluate both time and temperature effects. In this study, by performing a dynamic shear rheometer (DSR) test, rheological properties (phase difference angle and shear modulus) were measured at medium and high temperatures. In this experiment, bitumen was placed between two parallel plates, one fixed and the other oscillating. All DSR experiments were performed for premium 10-radian per second adhesive, which is approximately 59.1 Hz (rpm) (Figure 2).

Figure 2. The geometric dynamic shear testing device of Isfahan J Oil Company

2.3. Rotational Viscometer (RV) Test

AASHTO-TP48 standard describes the test method for determining the viscosity of bituminous adhesives using a rotary viscometer. This experiment was used for modified and unmodified bitumens. The rotary viscometer automatically determined the rotational viscosity by measuring the required torque while maintaining a constant rotational speed of the rotating plate immersed in the bitumen. For bituminous adhesives, especially modified bitumens, to be easily pumped and moved in hot mixing equipment or to be easily mixed with stone materials at the mixing temperature, their non-aging hardness according to the specifications should be a maximum of three poses and for all grades of bitumen Obtain 135 degrees Celsius.
Determination of the viscosity of the adhesive at temperatures other than 135°C may be required. The viscometer can be used in the development of temperature-viscosity tables to estimate mixing temperatures and densities in the mixing design. Most organizations use equi-viscous or viscous temperatures in their mixing schemes. In other words, when mixing with rock materials and the density of the samples, regardless of the degree of temperatures of the adhesive, they are adjusted according to

the limits of specific and uniform changes in its viscosity. For this purpose, the rotary viscometer can be set to another temperature and the test repeated [19, 20].

In addition, the RV test can be used to compare the effects of different additives on the viscosity and fluidity of bitumen (Figure 3).

Figure 3. The apparatus for rotating Reometric testing of Isfahan J Oil Company

2.4. Bending Beam Rheometer (BBR) Test

It is not entirely reliable to perform a bitumen hardness test at a low temperature with a dynamic shear strength measurement rheometer. Therefore, Sharp researchers developed a bending beam rheometer (BBR) to accurately evaluate the properties of adhesives at low pavement temperatures. The two dynamic shear and flexural beam tests predict the hardness behavior of the adhesives over a wide range of temperature changes (Figure4).

In this study, by performing the BBR test, the number of fluctuations or creep of the adhesive material under constant load and at constant temperature was measured. The BBR test temperature depends on the lowest pavement operating temperature. In which the bituminous adhesive behaves more like an elastic solid. This test was performed on adhesives that had aged in two experiments with an accelerating aging chamber and a thin rotating glaze, so this test measured the functional properties of the adhesive that had been subjected to hot mixing as well as aging during service. By applying a constant load to the bitumen beam and the fluctuation of the beam center for all 4 minutes, the creep hardness test (S) and the value of m were calculated. The m parameter is the second parameter determined from the flexural beam test results. The value of m showed the rate of change in creep stiffness versus time. This value was also calculated automatically with the bending beam software [21-25].

Figure 4. The apparatus for bending beam Rheometer testing of Isfahan Oil Company

2.5. Direct Traction Test (DTT)

Although hardness can also be used to estimate failure or strength, for some adhesives (especially modified bitumens) the ratio between hardness and strength properties is not well known. Therefore, in order to measure the strength and ability against tensile stress before failure (strain at fracture), another test called direct tensile test should be performed. Bitumens that withstand considerable stress before fracture are called ductiles, and those that break without much fracture are called brittle. It is important that the bitumen adhesive be able to withstand minimal tension. Harder bitumens are generally more brittle and softer bitumens are more elastic.

The creep stiffness measured by the BBR is not sufficient to fully describe the bitumen capacity against pre-fracture elongation. For example, some adhesives have high creep hardness, but can be stretched further before fracture. As a result, Sharp researchers have developed a special specification system to adapt to these rigid but elastic adhesives. These materials, on the one hand, have relatively high creep stiffness and, on the other hand, can have reasonable elastic behavior at low temperatures. The direct tensile test applies only to adhesives with a BBR creep hardness of between 300 and 600 MPa. If the creep hardness is less than 300 MPa, there is no need to perform the test, which was the case in the present study [26-30].

3. Results and Discussion

Today, the works of some researchers show that non-toxic agents like oils with an organic base can improve the properties of bitumen and asphalt bitumen. The use of different oils in bitumen improves the mechanical function of asphalt, likewise, improving the properties of the bitumen binder. The studies about the properties of asphalt mixtures due to the oils with an organic base have significant importance for Iran as a country in which roads are paved by hot mix asphalt.

In this work, by using different percentages of Rhamnolipid Biosurfactant (samples of 2% and 4% of Rhamnolipid Biosurfactant), the properties of bitumen as well as hot mix asphalt, by advanced technology includes Remote Sensing (RS) facilities, advanced sensors, modems and data logger system have been investigated. The results of this work were derived from various experiments. The ten samples were analyzed due to the tests that were performed under the same laboratory conditions.

3.1. Rhamnolipid Biosurfactant

Rhamnolipid biosurfactant in oil phase was prepared from Parto Company of Simorgh Biotechnologists located in Ghaemshahr city, the specifications of which are given in Figures 5 and 6.

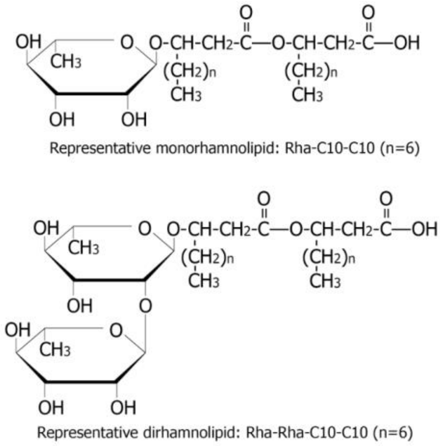

Figure 5. The composite structure of biosurfactant rhamnolipid

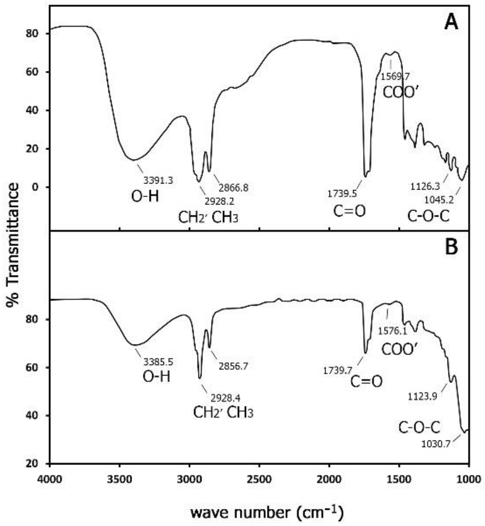

Figure 6. FTIR analysis of biosurfactant rhamnolipid

3.2. Modified Bitumen Bi-surfactant Rhamnolipid

Silverson device (Figure 7) was used to modify bitumen with rhamnolipid biosurfactant. Bitumen and modifier were mixed at 140 ° C for 60 minutes at 2500 rpm. Performance tests were performed on modified bitumen.

Figure 7. Silverson device

3.3. Making Marshall Test Samples

According to the aim of this study, which is to investigate the mechanical properties of hot asphalt mixtures containing rhamnolipid biosurfactant in the amount of bitumen percentage, it was decided to make 3 samples for each percentage of bitumen and 3 replicates for each and to be tested by Marshall and to determine their optimal bitumen values. To make Marshall samples, mixtures of 1200 g of asphalt with granular aggregates were aggregated according to the aggregation described in 3-2-1 and were prepared with bitumen percentages (4.5 to 7, with an increase of 0.5%). To prepare each sample and to simulate heavy traffic, 75 cylinders were applied to each side of the sample. The number of samples made for the Marshall Test is 60. After determining the optimal amount of bitumen by Marshall test, 81 samples were made to perform dynamic tests on the percentage of optimal bitumen to be evaluated. The total number of samples made in this study is 141 as shown in (Table. 1) [4, 31-33].

Table 1. Type and number of experiments performed in this research

No.	Experiment Name	The objective of the Experiment	Number of iterations	Numbers of Experiments
1	Marshall strength	The optimal amount of bitumen	3	60
2	Resistance modulus	Determining the modulus of resistance	3	27
3	Fatigue	Determine the life of fatigue	3	18
4	Frequent axial load and creep	Determination of grooving potential	3	36
				141

3.4. Nottingham Asphalt Testing Machine

The Nottingham Asphalt Testing Machine was used to perform non-destructive tests on asphalt samples made in this study (Figure 8). This machine was built in 1980 to determine the mechanical properties of asphalt mixtures under dynamic loading conditions. The basis of the operation of this device is to determine the mechanical behavior of the asphalt mixture with the help of stiffness tests by an indirect tensile method due to repeated loading, uniaxial creep, fatigue by indirect tensile method and axial creep with repeated loading. The Poisson's ratio is typically considered to be 0.35, which is the best value to show the behavior of asphalt materials. This coefficient was one of the input data of the device before the test [34-36].

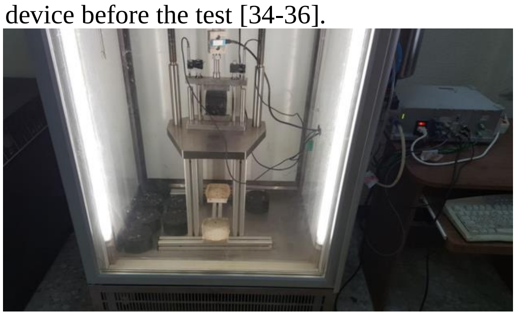

Figure 8. Nottingham test machine of University of Guilan [36]

3.5. Marshall Testing Machine.

Marshall test machine was used to determine the strength and flow of asphalt mixtures (Figure 9).

Figure 9. Marshall Testing Machine of Guilan Soil Mechanics Laboratory [37, 38]

3-6-Comparison With Other Research

In a study by Zamanis et al., The effect of six rejuvenators on the fatigue behavior of asphalt mixtures was investigated. Six additives including waste vegetable oil, waste vegetable grease, organic oil, industrial wood oil, aromatic extraction oil and waste engine oil, each with a weight percentage of 12% were combined. Engine oil has the shortest failure cycle and therefore the worst fatigue behavior compared to other rejuvenating oils and therefore has the highest probability of fatigue failure. However, all samples showed longer fatigue life than the base mixture. Fatigue performance improvement for all samples was between 5 and 38%. Organic oil-modified bitumens have the best performance compared to other modified bitumens. Containing 4% rhamnolipid biosurfactant increased by 213%. This indicates the excellent performance of bitumen modified with rhamnolipid biosurfactant against fatigue of asphalt mixtures. Comparing the results of this study (Fig. 10) with the results of 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 [37-39].

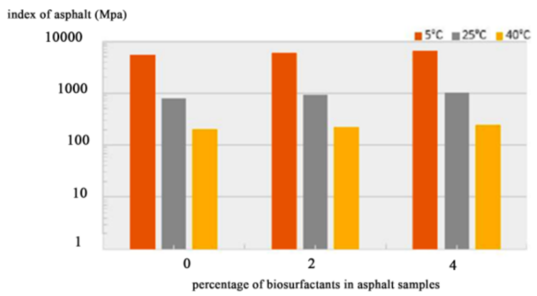

Figure 10. Results related to the resilience index of asphalt samples containing different percentages of biosurfactants

4. Conclusion

Roads are the national assets of any country that provide transportation possibilities among different points, essentially. Furthermore, the cost of road construction has increased over time, hence, its maintenance or preservation is a critical job which can benefit the society as a whole. Thus, researchers have conducted extensive tests to distinguish the causes of failure and maintenance methods, 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. Previous research showed that the use of different oils in bitumen improves the mechanical function of asphalt, likewise, improving the properties of bitumen binder. Along with previous research, in this study, using different percentages of Rhamnolipid Biosurfactant (0, 2 and 4 ratios to the betumen 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 the 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 the fatigue and thermal cracks and has met the requirements of 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. This work also investigated the Geospatial Information System (GIS) as a low-cost, high-precision, and rapid method for identifying the RAP. Finally, this work showed that (GIS) can be linked to a new technique which includes Remote Sensing (RS) and Internet of Things (IoT) which can be interesting subjects for future research in the field of pavement engineering.

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