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Research Paper

Evaluation of performance characteristics of asphalt mixture reinforced with palm tree fibers

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Abstract

Despite the high cost of paving the roads in Iran, according to experts, the useful life of asphalt is expected to be only 3 to 5 years. Due to the abundance of palm trees, the objective of this study is to determine the resistance of palm fiber-reinforced asphalt mixtures as an additive and asphalt modifier. In this study, four types of mixtures were prepared. The first mix was prepared as a control and non-fibrous mixture, and the second type were mixed with 0.1% and the third type with 0.3% and the fourth type with 0.5% weight of asphalt mixture of palm fiber. Six samples were prepared for each mixture, three samples were dried and three others were tested after partial saturation and moisture treatment with a melting and freezing cycle (24 samples). The Semi-Circular Bend Test (SCB), Marshall Stability of bituminous mixture, flow tests, indirect tensile strength, resilient modulus and moisture damage were assessed. The results of indirect tensile strength test showed that the use of palm fiber in dry condition at all percentages of 0.3, 0.4 and 0.5% improves the resistance. In saturated state, for fibers added up to 0.3% results were positive, but for more fibers, the results were negative. For moisture sensitivity parameter of the asphalt mixtures of the addition of fiber up to 0.3%, the least moisture damage was observed. The results of the resilient modulus of the mixtures showed that using 0.3% fiber had better result than other percentages and control sample.

Keywords: Asphalt, Modifiers; Palm fiber; Indirect tensile strength; Marshall test

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1. Introduction

Road transport is particularly important because of the major contribution it has to the transportation of goods and passengers, as well as its flexibility, low cost, global coverage and wide range of activities in the country and its impact on the growth and development of other economic sectors of the country. To achieve this goal and create comfortable, fast, safe and secure road transportation it is essential to have a suitable pavement. The statistics show that over the past 50 years, most investments have been made to building roads rather than other public infrastructure [Modarres and Hamedi, 2016]. Unfortunately, according to experts, despite the high costs of asphalt pavements in Iran, the useful life of asphalt is expected to be 3 to 5 years; in the developed countries it is estimated to be about 12-15 years [Mirzababaei et al. 2018].

Bitumen is the main element of asphalt mixtures. Although the percentage of this material in the asphalt is negligible, it has an important role in determining the mechanical properties of the product. Bitumen gradually softens as temperature increases, which also causes wrinkling on the surface of the asphalt. On the other hand, as temperature decreases bitumen becomes brittle, and cracks to appear on the surface of the asphalt. That is why the reinforcement of asphalt, and consequently that of bitumen is so important. This can be achieved by modifying the properties of asphalt and improving the bearing capacity and tensile strength of the asphalt by additives and arming the asphalt concrete; fiber is one of these additives [Hadizadeh, Ghasemi, 2016]. The large palm gardens in the southern areas of Iran and their waste is one of the most significant sources of fiber in this field. The palm trees leave a large amount of waste matter in the pruning season each year, which most farmers burn them away. These waste materials are cheap and abundant, have a relatively high resistance and tensile strength, low density and are easy to mix with soil, which make them easy to use for soil improvement, as they improve soil properties and also reduce environmental problems. The waste from palm gardens has fibrous texture and is similar to geotextiles [Kavussi and Saebi, 2018]. In this research, palm fiber is considered as an asphalt reinforcing fabric. Therefore, this study aims to investigate the effect of different palm fiber amounts of the behavior and properties of asphalt mixtures.

2. Literature Review

In recent years, many studies have been conducted on the use of natural fibers. In this study, we followed the limitations of laboratory study on the use of fiber and wastes of palm trees in the construction industry [Esmaeili and Ghale Noi, 2012]. Studies have shown that some fibers have a higher tensile strength than bitumen. Therefore, the fibers have the potential to increase the tensile properties of the bitumen and substantially increase the system cohesion [Howaidi, Al-Suhaibani, Alsoliman, 2016, Q.U, Zhao, 2016, Boukhattem et al. 2018].

In research of The effect of polyolefin-aramid fibers on performance of hot mix asphalt The results showed that the rutting and cracking resistance improved incrementally by increasing the fiber content, and the fatigue performance enhanced by adding up to 0.05% fiber and then leveled out by increasing the amount of fiber [Ziari et al, 2020].

Maurer showed that fibers play a better role in reducing the asphalt subsidence than polymer additives [Maurer, Malasheskie, 2016]. In a study, it was shown that by adding synthetic fibers to asphalt, the strength and resistance of the structure against fatigue increases, but the fracture of the structure also increases, that is because of the fact that it is away from the continuous mechanical environment [Cleven, 2013]. Maher and Gary showed that the resistance of the sand reinforced with palm fiber increases as fiber dimensions, fiber percentages and fiber friction area with soil increases [Maher, Gray, 1990].

In research of Crack resistance of hot mix asphalt containing different percentages of reclaimed asphalt pavements and glass fiber. Therefore, in this study, the cracking behavior of asphalt mixtures containing different percentages of RAP material in combination with glass fibers was investigated using the semi-circular bending (SCB) fracture tests at temperatures of −15, 0 and 15 °C. The results showed that using up to 0.12% glass fiber lead to a significant enhancement of resistance of all mixtures of crack initiation and propagation. Moreover, it was found that the negative impact on RAP material on the crack resistance of asphalt mixtures is reversible to a great extent using 0.12% glass fiber, and 100% RAP mixtures are applicable without any significant reduction in crack resistance [Ziari et al, 2020].

Ahmed et al., used a single axial compression test to check palm fiber in palm silty sands. In this study, the fibers were coated into acrylic styrene butadiene. The results showed that the use of coated fibers increases the shear strength. Also, reinforcing the sands with 0.5% of coated fibers with a length of 30 mm causes a 25% increase to friction angles and a 35% increases to adhesion [Ahmed, Bateni, Azmi, 2010]. Otoko et al., added palm fibers to clay. Using a single-axial compressive strength tests, they found that as the fiber percentage increases, compressive strength, ultimate modulus and ultimate strain increases too. They also found that palm-reinforced clay had an adverse effect on the clay inflammatory properties [Otoko, Ephriam, Ikegboma, 2014].

Tapkin found that asphalt samples reinforced with polypropylene fibers produced with optimum bitumen content, demonstrated a higher Marshall stability and fatigue resistance, meanwhile their fluidity and reflective cracks decreased [Tapkin, 2015]. Al-Hadidy and Yi-Qiu have investigated the use of polypropylene fibers in the SMA mixture. As the percentage of polypropylene increases, initially the amount of fluidity reduced considerably and then increased. Besides, as the percentage of polypropylene increases, the percentage of voids decreases as well [Al-Hadidy, Yi-Qiu, 2016].

Goli et al., have investigated the effect of polymer Lucobit on stripping. The results showed that 2%, 4% and 6% Lucobit, by which the PG58 will be upgraded to PG64, PG 70 and PG 76, respectively [Goli, et al. 2018].

Nazarinasab, Ghasemi, Marandi, (2018) present a series of tests of modified bitumen and porous asphalt with steel slag powder (SSP) and crumb rubber (CR). The results of research demonstrated that it was feasible to replace partial CR with SSP. SSP can not only increase the softening point and ductility, but also reduce the penetration degree.

Kazemi (2012) found that at 20 °C and 45 °C, the static creep test showed that the addition of polyester and acrylic fiber as much as 0.3% of asphalt mixture weight had no positive effect on improving the properties of its Wheel-Track Test and even slightly increases the steady strain after one hour of loading and the strain remains steady after an hour. Taherkhani and Kazemi (2018) found that the use of fibers leads to a reduction of the persistent strain at ambient temperature, so that the lowest amount of persistent strain is observed in a mixture containing 0.5% carbon fiber with a length of 10 mm. In a study conducted in 2015 on polypropylene fiber reinforced asphalt mixtures, polypropylene fibers were used for asphalt modification. The fibers were mixed in dry form of bituminous materials and test specimens were made for usual asphalt and fiber-reinforced asphalt. Then, to compare the performance of these two types of asphalt, various tests were conducted on the samples. The results show that the fiber-reinforced asphalt has higher Marshall Stability than ordinary asphalt [Shah Husseini, Amiri, 2015].

In a study, polypropylene and polyester fibers were used to modify asphalt mixtures, and resilient modulus, fracture energy and tensile strength of asphalt samples were measured. The results showed that the fracture energy in the samples increased by 50 to 100 percent, indicating an improvement in the stiffness of the samples; however, the resilient modulus and tensile strength did not change significantly [Jenq, Liaw, Lieu, 2014]. In a study, the performance of hot asphalt and adjusting the bitumen with Nano materials was evaluated based on superior mix design. In this study, bitumen was adjusted to silica (SiO2). Nano-powders were mixed with bitumen base of 0.1, 0.3, and 0.5% of the mixture. The results showed that the best performance were obtained for the asphalt with Nano-modified bitumen 0.3% [Hashmiyan, Kavussi, 2010].

In a research, zycotherm nanomaterial as a new chemical additive and Sasobit as the most commonly used organic material, were evaluated and compared. In order to investigate the moisture sensitivity of the mixtures, an indirect tensile strength tests and resilient modulus tests were conducted. The results showed that zycotherm nanomaterial, in addition to reducing the mixing and density temperature, improved the moisture sensitivity of asphalt mixtures as compared to the hot mix of control asphalt and sasobit mixtures [Behbahani, Ayazi, Shojaee, 2018]. In a research Laboratory evaluation of the effect of synthetic Polyolefin-glass fibers on performance properties of hot mix asphalt, the results indicated that using up to 0.12% of the synthetic fiber by weight of total mixture enhanced the performance of the mixture in all studied aspects as the Polyolefin component helped the elastic behavior and rutting resistance, and the high strength glass fibers improved the tensile strength, fatigue and crack resistance. However, increasing the amount of polyolefin-glass fiber to 0.18% had some adverse effect on resilient modulus, fatigue, fracture, and tensile resistance of the mixtures [Ziari and Moniri, 2019].

According to studies, some of which were discussed in review of literature, some research has been conducted on the effect of synthetic fibers such as polypropylene fibers on bitumen, or various natural fibers in the construction industry. However, there is no comprehensive scientific evidence of the impact on palm tree fibers on bitumen and mechanical properties of asphalt, which is still innovative. In southern Iran, as there is a large amounts of palm fibers considered as waste material, a new idea was presented to use these materials to optimize and refine the asphalt, at least in the southern regions of Iran.

3. Methodology

In this study, indirect traction, Semi-Circular Bend Test (SCB), resilient modulus and Marshall Stability tests were used to evaluate the characteristics of the mixtures. All tests conducted in this study were carried as per ASTM and AASHTO.

3.1 Palm fibers properties

Palm fibers have different lengths and diameters. Table 1. Shows Chemical and physical Composition (%) of palm fibers. The moisture absorption properties of the fibers were checked by soaking the tested sample fibers and weighing them in the two-hour intervals. The changes in size, both in length and width were measured over 24 hours. These fibers are naturally texture and have fibrous threads. The primary fibers were separated from the palm trees and their thick edges were removed after dusting. The remaining fiber content was then cut by special scissors into smaller parts. The fiber sheets were cut into 20-30 mm long pieces (Fig. 1) and were prepared for use of the laboratory samples.

Table 1. Chemical and physical Composition (%) of palm fibers

Property	Percentage
Celluose	43.05
Hemicelluloses	27.48
Lignin	29.78
Density(gr/cm^3)	0.895
Tensile strength (MPa)	100–400
Young's modulus (GPa)	2.75
Fiber Length	20-30 mm

Figure 1. Palm fibers chopped by a machine

This research is a laboratory study. Samples were prepared according to four standards mixing methods: sample with no fiber (control sample), samples containing 0.1, samples containing 0.3%, samples containing 0.5% palm fibers. At least six samples were taken for each mix, of which three samples were in dry state and three other samples were tested after partial saturation and moisture treatment with a melting and freezing cycle (24 samples). The weight of each asphalt mixture sample was 1200 gr, and according to the standards its voids were 7 ± 0.5.

Samples were produced in control mixture and fiber-reinforced mixtures. Then, the experiments were carried out on two sets of samples. Consumables consists of aggregate, bitumen and palm fibers. The aggregate used of this study consist of coarse aggregate (gravels), fine aggregate (sands), and fillers (grains passing through Sieve NO. 200). Also, the bitumen of the Isfahan refinery with a penetration grade in 60/70 (Table 2), and palm fibers were used for reinforcing the mixtures in several percentages.

Table 2. Specifications for non-additive bitumen

Specifications	Bitumen grade 60/70	Test Methods
Specific gravity at 25 ° C	0.99	ASTM D-70
Penetration grade at 25 ° C	66	ASTM D-5
Softening point (° C)	52	ASTM D-36
Ductility at 25 ° C	118	ASTM D-113
Flash point	260	ASTM D-92

The samples of bituminous paving mixtures were prepared as per ASTM D1559. For specimen weighing 1200 gr, the weight percent retained on each sieve was determined for each gradation. Then the stone materials were heated at 160 to 170 °C for 24 hours until the water in its grains

¬was evaporated. The natural fibers were added to the mixer after weighing the stone materials, before bitumen was added. Pure bitumen was heated indirectly at a temperature of about 132 °C until it melted completely. To determine the optimum bitumen content of each grading, the specimens were prepared for different percentage of bitumen. The percentages of bitumen were 4%, 4.5%, 5%, 5.5%, 6% and 6.5%, and three samples were prepared for each grading in each percentage of bitumen.

3.2 Preparation of Laboratory Samples

As per the Marshall method, cylindrical samples of a diameter of 10 cm and a height of 25.6 cm was compacted by 75 strikes to each side. In this research, a Gyratory compression was used. After 24 hours of compaction, samples were brought out of the Gyratory set. The parameters of the actual Specific Gravity of compacted asphalt, compressive strength of asphalt, deformation of asphalt and percent of voids in asphalt were calculated and the diagrams were plotted.

3.3 Typical Asphalt Testing Processes

The laboratory plan is divided into two parts. The first part relates to making samples, performing Marshall Test, and determining the optimum bitumen content. The second part include providing the samples of performing functional tests such as indirect tensile strength, Semi-Circular Bend Test (SCB) and resilient modulus. By measuring the weight of each specimen, after gradual cool, in the air and immersed in water, the Specific Gravity of the compacted mix, and the maximum Specific Gravity of the samples were determined as per ASTM-D2726 and ASTM-D2041, respectively.

3.4 Marshall Stability and Flow Tests

To conduct Marshall compressive strength and deformation tests, the specimens were placed in a hot water bath at 60 ± 10 °C for 30 minutes, the arrangement of the specimens in the bath should be such that all specimens can be tested after 30 to 40 minutes. Then samples were loaded by Marshall Jack, and the amount of deformation was also observed and recorded. Due to the unevenness of the sample sizes and the uneven distribution of loads on the surfaces, it is necessary to adjust the compressive strength of the specimens according to their thickness.

3.5 Resilient Modulus Test

Resilient Modulus tests was performed according to ASTM D4123-82 standard. The input parameters of the machine included a standard temperature of 25 °C with a frequency of 1 Hz, and 0.1 seconds of loading, and 0.9 seconds of rest. The Poisson coefficient is estimated to be 0.35. An applied force of about 15% of indirect tensile strength was used.

3.6 Indirect Tensile Strength Test

This test was performed using the standard ASTM-D6931 method, and indirect loading tests were performed with Marshall Jack and speed of 50.8 mm/min. The samples were loaded with the direction of diameter and the force required to break the samples was measured and the tensile strength of the samples was calculated from the following relation (Equation 1):

$$st = \frac{2000P}{\pi t D} \qquad (1)$$

Where:

P: Maximum load in kilonewton (KN)

t: sample height in meters

D: Sample diameter in meters

St: Indirect tensile strength in kilopascals

3.7 Moisture Sensitivity Test

Standard Method of Test of Resistance of Compacted Asphalt Mixtures (AASHTO T283) is the most common test method of determining the moisture sensitivity of asphalt mixtures. The resistance of the samples of moisture is shown by the TSR in percent, which is calculated according to relation (E.q 2). The amount of ITS in equation 2 is the mean value for samples of saturated and dry conditions. The minimum value of TSR should be 80%, and the higher the TSR is, the higher the resistance to the moisture.

$$\mathrm{TSR} = \frac{\text{Saturated ITS}}{\text{Dry ITS}} \qquad (2)$$

3.8 Semi-Circular Bend Test (SCB) Test

In order to determine the low temperature performance, the Semi-Circular Fracture Fracture Test (SCB) was used with the help of UTM device. This experiment was performed according to the AASHTO TP 105-13 standard. All samples were tested at -10. C. Using the UTM device, the load values were determined against the linear load displacement of the bending half-disc samples. In other words, the vertical displacement diagram of the load jaw was plotted against the load and the area below the graph was recorded as the resistance to failure at low temperatures. For this test, first asphalt cylindrical specimens made with the help of a cutting machine, bending half-disc (SCB) specimens with a diameter of 15 cm and a thickness of 2.5 cm with central cracks with a length of 1.5 cm and a width of 1.5 mm were created.

4. Results

4.1 Results of Stone Materials Test

The grading graph of aggregates used in this study, according to grading number III of the Iranian Regulations, is depicted in Fig. 2, which shows the results of the weight percent of stone mixes passed through the sieves in the grading Table 3.

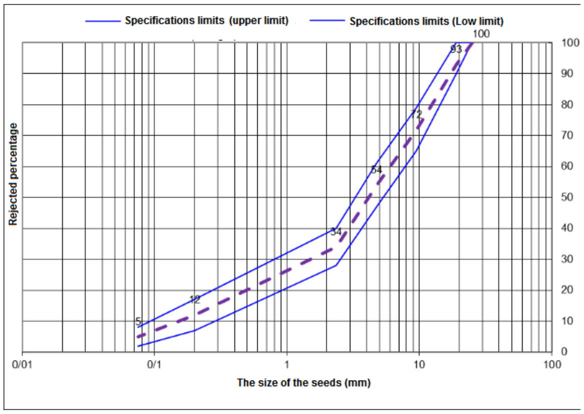

Figure 2. Grading Curve

Table 3. Grading of aggregate blends

sieve size	grading number II I	weight percent of the mixing ratio of aggregates	specifications
1	100	100	100
3/4	90-100	93	90-100
3/8	56-80	72	65-79
4	35-65	54	47-61
8	23-49	34	28-40
50	5-19	12	7-17
200	2-8	5	2-8

The results of the tests, determining the quality of materials are shown in Table 4. As shown in Table 4, the selected aggregates have met all the requirements and regulations, and are suitable for Binder Asphalt 0-25.

Table 4. The test results for the quality of aggregates

<table>
<tr><th>Specifications</th><th>Amount (percent)</th><th>Test standards</th><th colspan="2">Test Titles</th></tr>
<tr><td>30% ></td><td>18%</td><td>AASHTO T96</td><td colspan="2">Los Angeles wear</td></tr>
<tr><td>12% ></td><td>1%</td><td rowspan="2">AASHTO T104</td><td>Fine-grained</td><td rowspan="2">weight drop caused by sodium sulfate</td></tr>
<tr><td>8% ></td><td>2%</td><td>Coarse</td></tr>
</table>

				grained
-	90%		ASTM D5821	Fracture on one side or more
80% <	86%		ASTM D5821	Fracture on two sides or more
95% <	More than 95%		AASHTO T182	Bituminous adhesion to materials
25% >	23%		(BS-812)	Ductility
50% <	78%		AASHTO T176	Sand value of SE (Fine-grained materials)
4	NP	Plasticity Range	AASHTO T89.90	The Atterberg limits
non-plastic	Indeterminate	flow limit		

The results of the moisture absorption properties of the fibers showed that the maximum water absorption after 24 hours was 171%. The changes in the width and length of the fibers were reported 11.08% and 2.53% respectively (Table 5).

Table 5. Palm Fiber Characteristics

Characteristics	Value
Water absorption in 24 hours	171%
Cross sectional increase (in 24 hours)	2.53
Increase in length (in 24 hours)	11.08
Maximum Tensile Resistance (MPa)	67.31
Special gravity	0.89
Modulus elasticity	600
Average diameter (mm)	0.34

4.2 Results of Marshall Test

The results of the Marshall test were evaluated to determine the amount of bitumen; various parameters such as flow and Marshall Stability of asphalt mix were also assessed (Fig. 3 to 6).

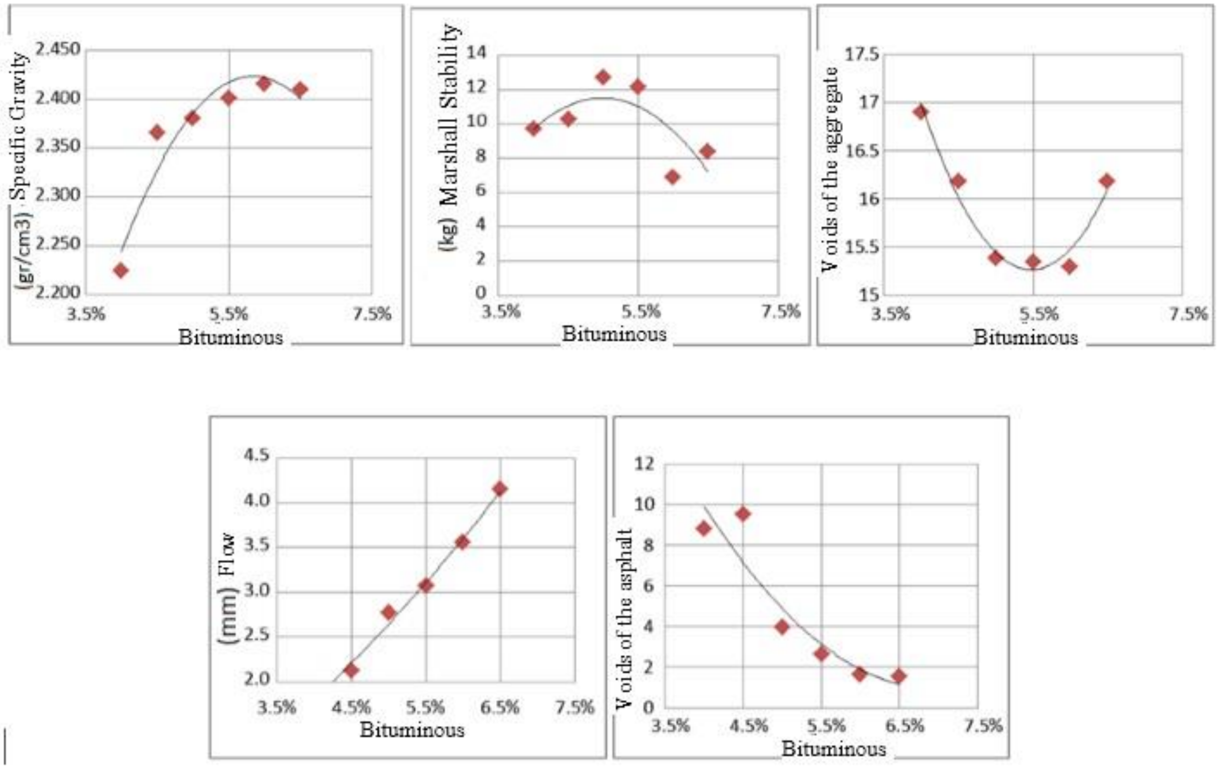

Figure 3. Optimum bitumen determination graphs for the control sample

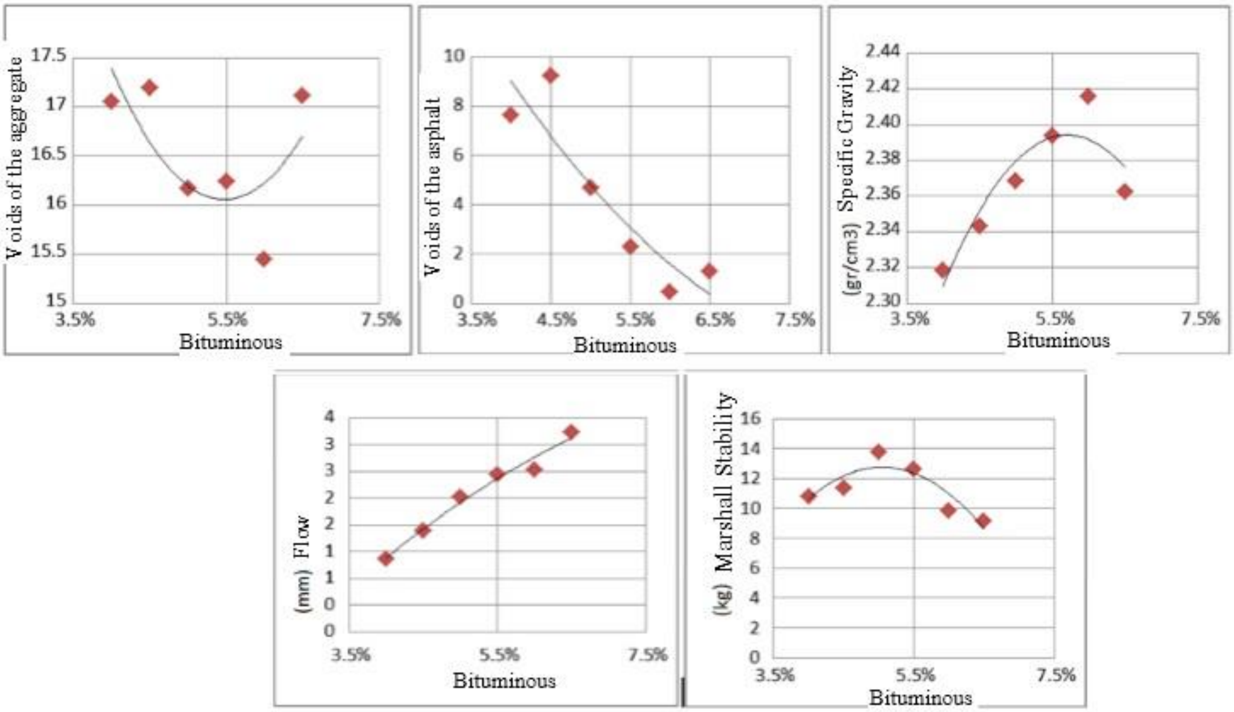

Figure 4. Optimum bitumen determination graphs for the sample containing 0.1% of the fiber

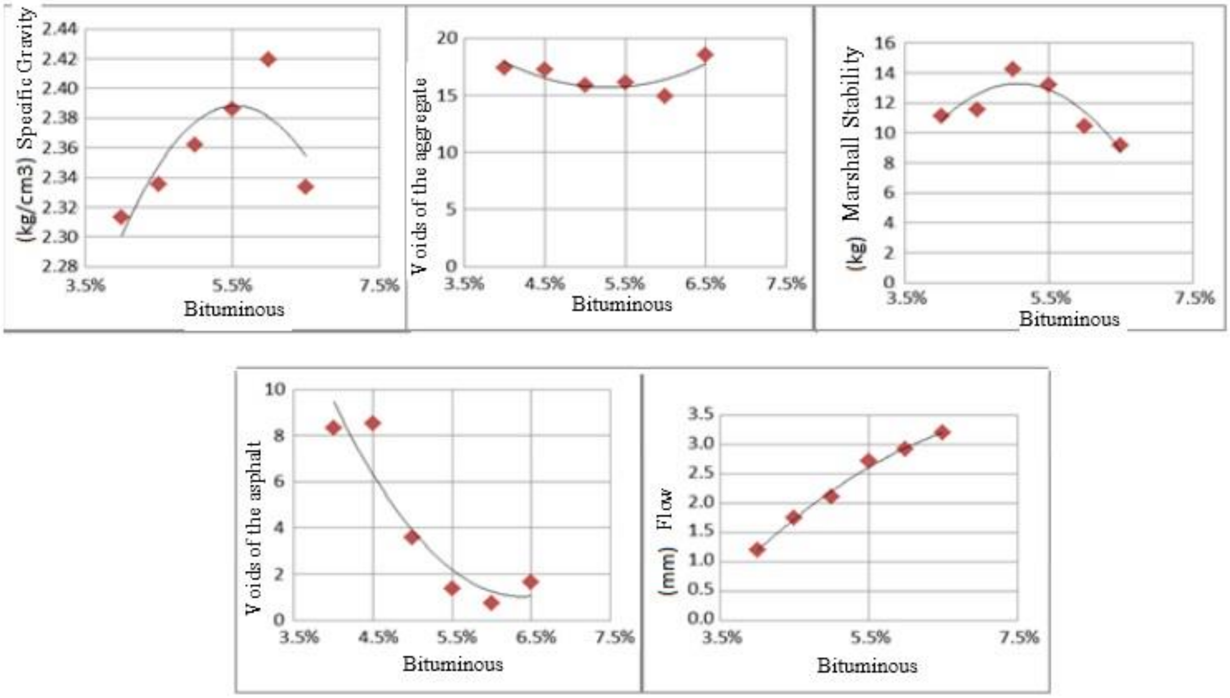

Figure 5. Optimum bitumen determination graphs for a sample containing 0.3% of the fiber

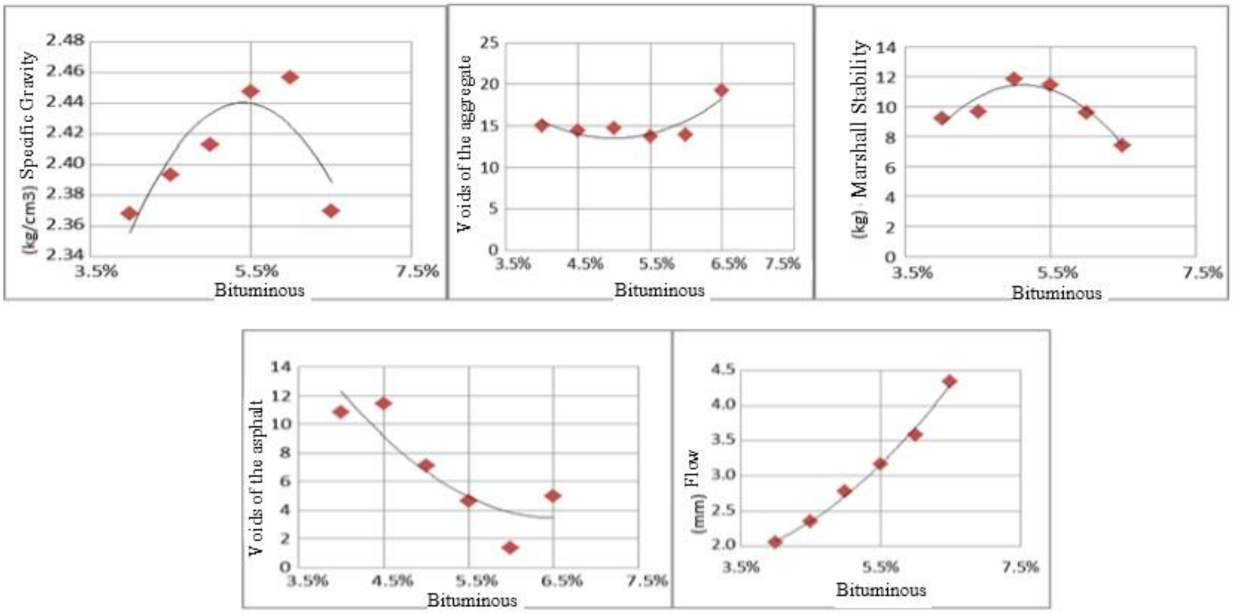

Figure 6. Optimum bitumen determination graphs for a sample containing 0.5 fiber

According to the above graphs, the percentage of optimum bitumen for the control sample is equal to 5.1, for the sample containing 0.1% of the palm fiber it is equal to 5.38, for the sample containing 0.3%, it is equal to 5.2, and for 0.5 % of the palm fiber, and it is equal to 5.46.

4.3 Results of Indirect Tensile Test

This experiment was carried out in both dry and saturated conditions. As shown in Fig. 7, the addition of fibers adds to the dry tensile strength of the samples, as the mixture containing 0.3% of the palm fiber has the highest indirect tensile strength. However, this amount is very close to the indirect tensile strength of the mixture containing 0.5% fiber. In total, the indirect tensile strength at best has improved on 10%. However, in the case of indirect tensile strength, the saturation conditions are different; in such cases up to 0.3% of the additive has added to the indirect tensile strength, but by increasing the amount of additive to 0.5%, the indirect tensile strength decreased and tensile strength even reached to less than that of the control sample.

The resistance of the samples of moisture is shown by the TSR in percent. The moisture sensitivity value is obtained by dividing the saturation resistance to that of dry matter, and is expressed in percentage. This parameter is illustrated with the control sample and the modified samples of Fig. 8.

As shown in the indirect tensile strength, the above graph shows that the optimal value is 0.3%, and the negative effect appears if more fiber is added.

4.4 Results of Resilient Modulus Test

According to the test results of the resilient modulus, all the percentages have a positive effect on the modulus, but this effect of the sample containing 0.5% fiber is less than the sample containing 0.3% fiber; therefore, the amount of this fiber for the planning was considered 0.3% (Fig. 9).

4.5 Results of Semi-Circular Bend Test (SCB) Test

The results of the bending half-disk mechanical failure test (low temperature performance test) for loads with a linear displacement rate of 0.005 mm / s to the complete failure of the sample at test temperature of -10. C are shown in Figure 10. As shown in Figure 10 and 11, adding 0.5% fiber to the base bitumen improves the fracture toughness of the asphalt mixture at -10 (C (low temperature performance) by more than 25%. By reinforcing the specimens, the palm fibers increase the strength and durability of the modified asphalt mixture against the stresses caused by vehicles at low temperatures and reduce their brittleness at low temperatures.

By adding date palm fibers, the brittle behavior of the asphalt mixture is improved and the slope of the curve is reduced in the load-displacement diagram. Also, the maximum bearing force and the area under the curve of fiber samples have increased (Figure 11).

The highest tolerable force was obtained in the sample with 0.1% of palm fibers and the lowest in the sample without additives. Palm fibers increase the ductility of bitumen at low temperatures and increase the modulus of elasticity of bitumen by placing them between the bitumen particles.

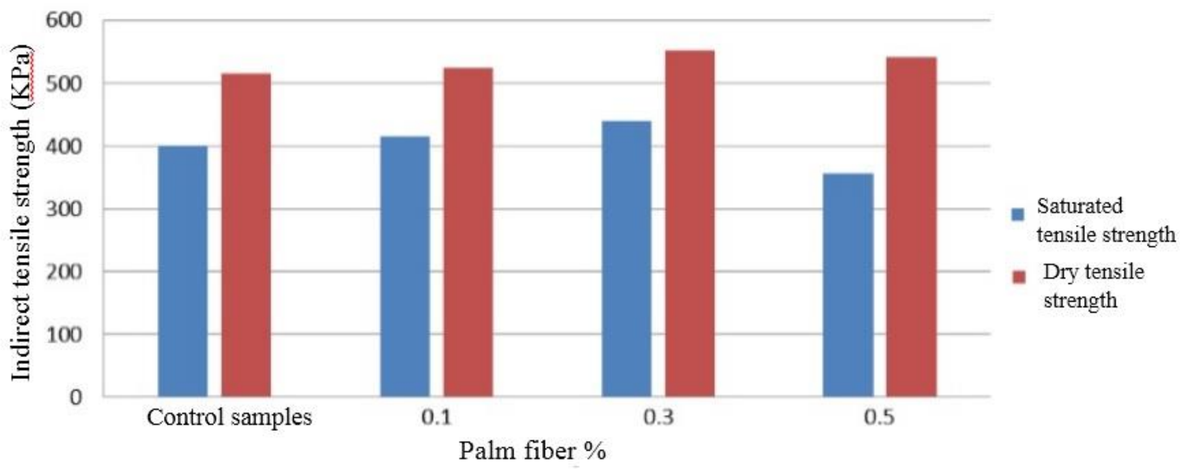

Figure 7. Indirect tensile strength of the samples

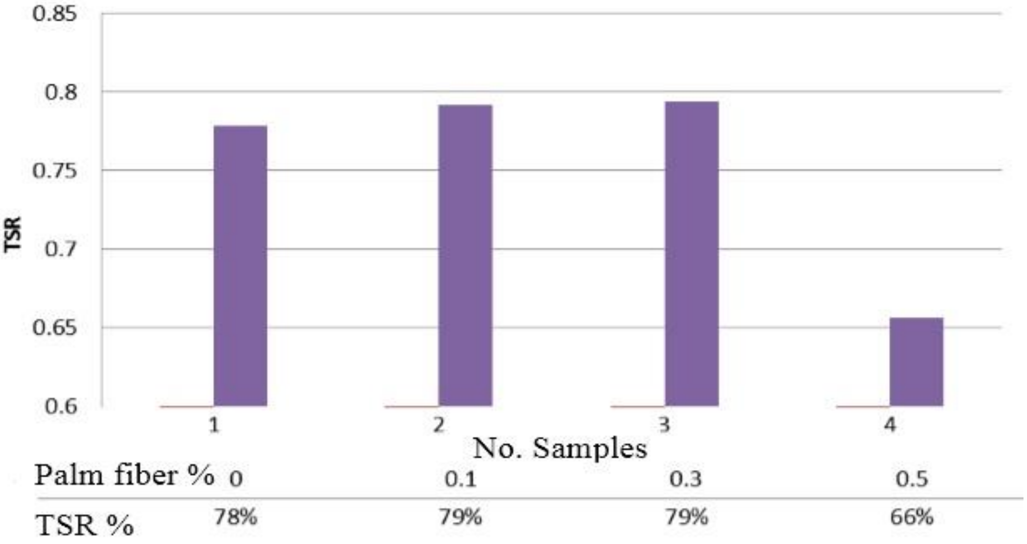

Figure 8. TSR coefficient for control sample and reinforced samples

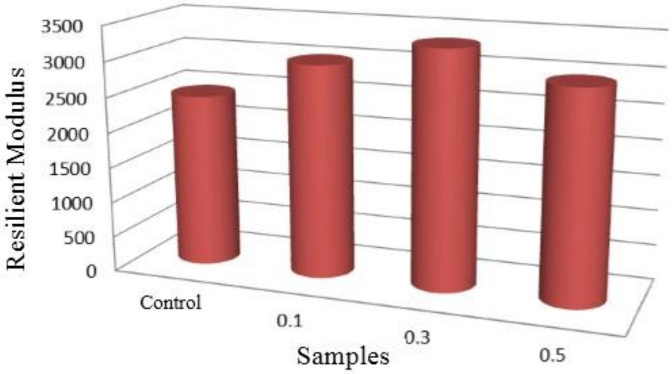

Figure 9. Resilient modulus for the control sample and reinforced samples

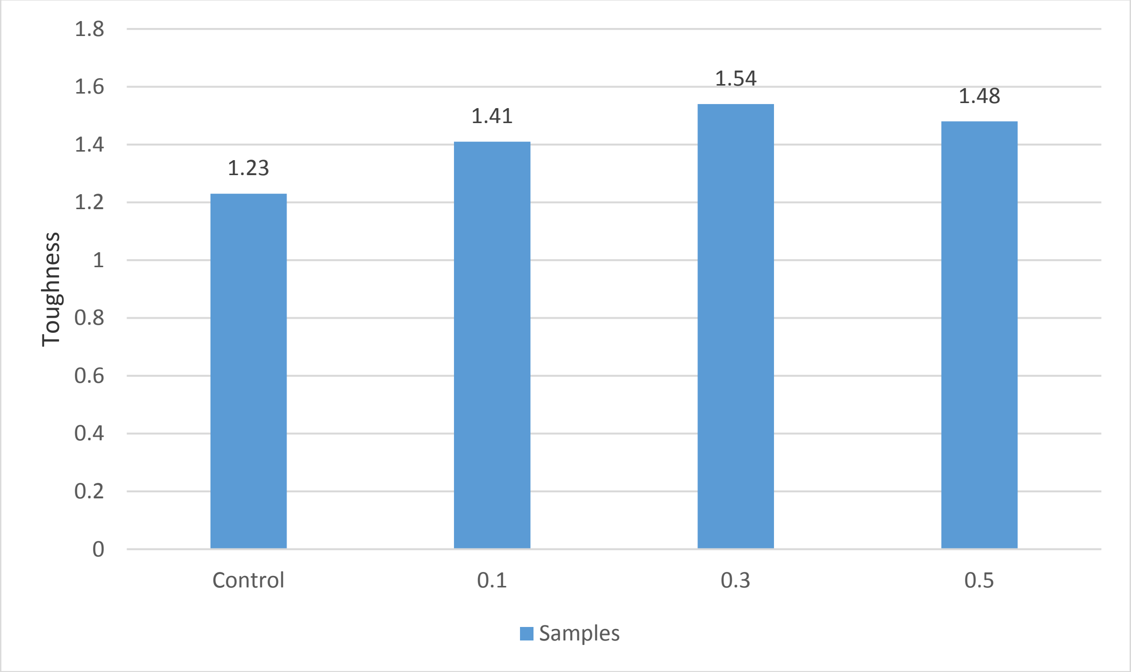

Fig. 10. Fracture toughness of the asphalt mixture at -10 (C (low temperature performance) in Control sample and reinforce sample N/mm$^{1.5}$)

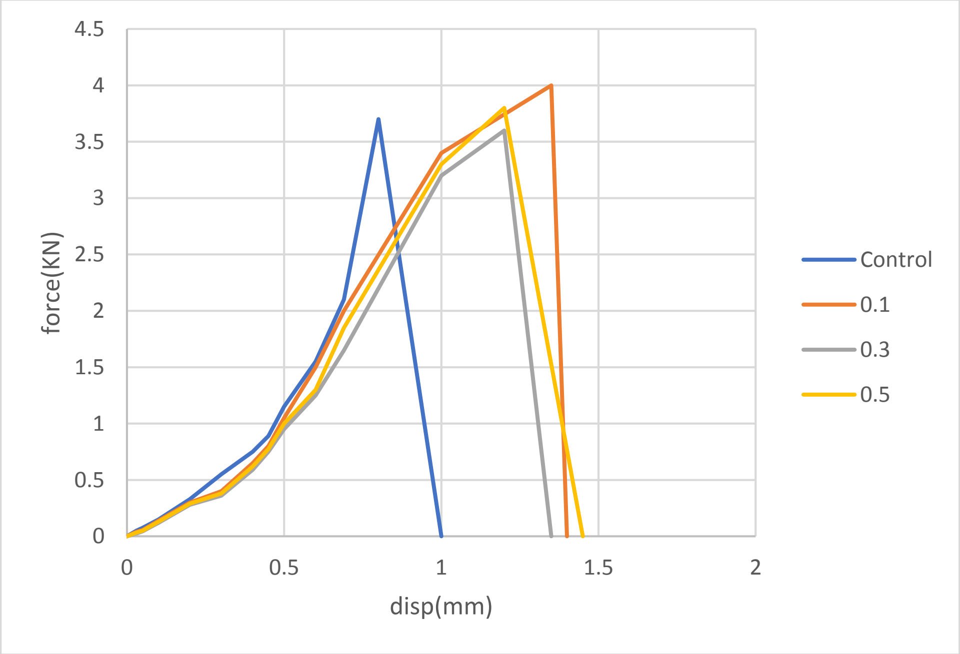

Fig. 11. Force-displacement of the asphalt mixture at -10

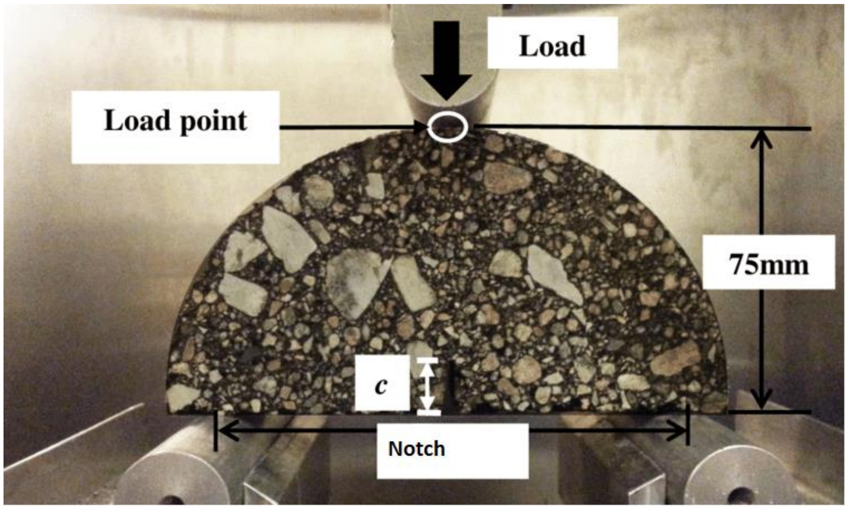

Fig. 12 Semi-Circular Bending (SCB) fracture test for asphalt mixtures at -10

5. Conclusions

Today, the use of additive and asphalt modifier in asphalt concrete are common because of the increased traffic and higher number of roads. In this experimental study, the effect of palm tree fiber on asphalt samples was investigated. Palm fiber with its own special properties was used as a natural fiber in reinforcing the samples, and laboratory samples were made with different percentages of this fiber. According to research findings, we may conclude that the use of palm fiber in asphalt mixtures will improve the functional properties of the asphalt. The main conclusions that can be drawn as following:

The results of this laboratory study showed that the addition of palm fibers improves the intermediate and low performance of asphalt mixtures. This additive also increases the resistance of the asphalt mixture against the stripping and separation of bitumen from aggregates due to moisture.

The results of the palm fiber contents influence on volumetric properties are presented in Figure 3-6. It is obviously that adding different contents of palm fiber has generally increased the density, voids filled with asphalt, and it has rationally reduced the air voids and voids in mineral aggregate of asphalt mixtures. The increased density of investigated mixtures shown in Figure 3-6 might be attributed to an increase in their cohesion due to the increase of fiber contents.

Palm fibers increase the adhesion between bitumen particles and asphalt aggregates, resulting in a stronger bond between bitumen and aggregates. As a result, at medium temperatures, the indirect tensile strength in dry and saturated conditions and the modulus of resistance also increase.

Moreover, it was found that the fibers improved the performance of paving mixtures against the anticipated most important distresses such as permanent deformation, fatigue cracking, and thermal cracking.

The results generally show that asphalt mixtures containing palm fiber can result in asphalt mixtures that have higher resistance and fatigue life and have a better performance. The most important results of this research are as follows:

1. As with the results of Marandi et al. (2008), Hadizadeh and ghasemi (2016), Kavussi and saebi (2017), palm fiber has significant effects on samples. According to results of indirect tensile test, in dry condition palm fiber at all percentages improved indirect tensile strength. In saturated condition, with fiber added up to 0.3%, positive results were observed, but adding more than 0.3%, namely 0.5% the negative values were reported.

2. The results of the TSR parameter indicating the moisture sensitivity of the asphalt mixture showed that adding up to 0.3% of the fiber would improve the moisture sensitivity.

3. The results of the resilient modulus test showed that the use of 0.3% fiber had better result than other percentages and the control sample. In this research, 0.3% of palm fiber is recommended as the optimum amount.

6. References

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