Modification of Asphalt Mixture Performance by Rubber-Silicone Additive

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Abstract:

This study is the second stage of the paper "Studying the Effect of Rubber- Silicone on Physical Properties of Asphalt Cement". The present study examines the effect of additives on asphalt mixture performance. Asphalt mixture has been designed by Marshall Method for determining the optimum asphalt content and geophysical properties of mix according to ASTM (D-1559). Rubber-silicone at different percentages (1%, 2%, 3% and 5%) was added to asphalt binder. Six specimens of asphalt rubber silicone mixture (ARSM) for each percentage are prepared and evaluated according to Marshall method. Diametric tensile creep test ASTM (D-1075) at 60 C^o was used to evaluate permanent deformation and modulus of elasticity for ARSM. The study showed that the Rubber-Silicone has more effects on performance of asphalt mixture by increasing the Marshal stability, air voids, and reducing the flow and bulk density compared with the original mix. It also increases the flexibility properties of the mix and this appears from reducing the permanent deformation at test temperature (60C), the reduction percent is about (30 to 70) %.

Keywords: asphalt mixture, modification, additives, rubber-silicone, performance

1. Introduction

Polymer modified asphalt binders (PMBs) are becoming wider spread in road building to meet today's high traffic loading. Many efforts are directed towards modifying the asphalt or paving mixture properties to get superior performance and serviceability under local conditions and to economize the construction of pavement [1].

There have been many investigations on polymer modified asphalt binders as counter measure to prevent plastic flow [2]. Modification of bitumen with polymers decreases its temperature susceptibility chiefly by increasing its ring and ball softening point, increases its cohesion and modifying its rheological characteristics [3]. The purposes of modification include: increase the viscosity at the high temperature, increase the flexibility and elasticity of binders at the low temperature, improve the adhesion to aggregates, and improve high thermostability and aging resistance [4].

The aim of this paper is to study the effect of rubber silicon on the performance of asphalt mixture for different percent of added (1%, 2% 3% and 5%) by weight of binder. For this purpose the performance changes were evaluated by Marshall Tests and diametric tensile creep test at $60C^o$.

2. Review of Literature

The properties of asphalt important for its consideration as a paving material are its rheological properties, adhesion, and durability [3]. Since the highway engineer is usually limited in his choice of asphalt source, there is need for a practical way to improve asphalt quality by the addition of modifying ingredients. In this regard it is believed that PMBs may improve durability and wear resistance [6].

Reclaim rubber obtained from used tyres, polyethylene in the form of low density (LDPE), styrene-butadiene-styrene copolymer, latex are used for modification of asphalt cement and test sections were found to perform satisfactorily [5].

During World War II a number of synthetic elastomers were developed and since then several of these also have been used as additives for asphaltic materials in road construction. The data shows that the properties of an asphalt-rubberized with natural rubber latex can be varied not only by the amount of rubber but also by using different amounts of sulfur. Also it shows that the properties of asphalt-rubberized with natural rubber latex containing small amounts of sulfur compare quite favorably with the properties of asphalt-rubberized with synthetic rubbers [7].

At the end of fifties there has been more interest in using rubber with asphaltic materials for surface treatments and seal coat construction. It has been observed that rubberized binders used in this type of construction were tougher, and they reduced the tendency of the surface to crack and bleed, and improved aggregate retention [7].

In Sweden size of rubber particles in asphaltic pavement was evaluated. Large rubber particles (1/16 in to 1/4 in) were used into an asphalt pavement. It was determined that using (3-4)% by weight of rubber is sufficient for increasing skid resistance, and durability as well as reducing noise level [8].

Fernando et al. [9] found that natural rubber with its inherent chemical constitution, is an excellent organic polymer for incorporation into asphalt in order to produce a superior form of road binder. The resultant binder is more viscous at high temperature, more flexible at low temperature, more resistance to distortion and more durable.

Hugo et al. [10] described three test methods which may be usefully employed to study the properties of bitumen-rubber binders and asphalt, sliding plate rheometer tests for binder-rubber blinders and indirect tensile strain measurement and freeze-thaw test for bitumen-rubber asphalt.

Mahabir Panda et al. [11] used reclaim low density polyethylene (LDPE) from carry-bags of goods for modifying asphalt mixture performance as fatigue life, resilient modulus, resistance to moisture susceptibility in addition to Marshal Characteristics.

Wladyslaw Milkowski [12] used polyethylene as an additive to achieve asphalt concrete of much higher stability and lower thermal susceptibility. Adding polyethylenes (PE) in small percentage reduced penetration, raised the softening point and increased the shear strength of asphalt joints.

Lee et al. [13] found that the additive of polyethylene and chlorinated polyethylene to asphalt binders does significantly increase their low temperature fracture toughness and fracture energy.

Taher [14] showed that increasing the low density polyethylene (LDPE) percentage results in decreasing the susceptibility of asphalt cement for temperature.

3. Materials and Tests

3.1 Asphalt Cement

All data presented in this study had been conducted in the Road laboratory of Civil Engineering Department in Anbar University. One binder of asphalt cement was tested, from Daurah Refinery with a grade of (40-50) penetration. The physical properties (according to ASTM Specification) of this type are illustrated in **Table (1)**.

3.2 Additive

Rubber-Silicone was used with asphalt binder; it is available in the local market. Rubber-Silicon was added to binder at different percent (1%, 2%, 3% and 5%) by weight of asphalt binder. Rubber-Silicone was added to binder at a temperature (150) C^0 with a stirrer for (20) minute.

4. Aggregate (Coarse and Fine Materials)

Crushed aggregates are used in this work with a fixed dense gradation for all the specimens and from Al-Jaraishe source. The middle limits of the (19 mm) size dense gradation has been selected as a basic gradation in accordance with (ASTM D-3515) as shown in **Figure (1)**

1. **Mineral Filler**

One type of filler is used in this work which was Limestone dust (Karbala Factory).

2. **Test Methods**

The following tests were used in this work to evaluate the asphalt concrete mixture:

1- resistance to plastic flow (Marshall Stiffness)
2- Permanent Deformation (diametric tensile creep test)

6.1 Preparation of Mixtures

The aggregates are first dried to constant weight at (110 C^0), separated into the desired sizes and recombined with mineral filler in order to meet the required gradation for each specimen. The aggregates are then heated to a temperature of (155C^0) before mixing with asphalt cement. The asphalt cement is heated to a temperature, which produces a kinematic viscosity of (170±20) centistokes up to (163C^0) as an upper limit. Then, asphalt cement is weighed to desired amount and added to the heated aggregates, and mixed thoroughly until all aggregate particles are coated with asphalt.

6.2 Resistance to Plastic Flow (Marshal Method)

This method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixture loaded on the lateral surface by means of the Marshall apparatus according to (ASTM D-1559). The test specimens were compacted using one compact effort, which is (75) blows/end.

The bulk specific gravity density (ASTM D-2726), theoretical (maximum) specific gravity (ASTM D-2041) and percent air voids (ASTM D-3203) are determined for each specimen.

Marshall Stability and flow tests are performed on each specimen according to the method described by (ASTM D-1559). The cylindrical specimen (2.5" (62.5 mm) height * 4" (101.6 mm) diameter) is compressed on lateral surface with a constant rate of (50.8 mm/min) until the maximum load is reached. The maximum load resistance and corresponding flow values are recorded. Three specimens for each combination are prepared and the average results are reported.

6.3 Creep Test

The diametric indirect tensile creep test has been used for testing asphalt mixture to determine the permanent deformation and the stiffness of asphalt mixture by measuring the strain – time value. The same Marshall specimens have been used in this test. The specimens were left to cool at room temperature for (24) hours, after which they were placed in water bath at the specific test temperature of (60C^0) for (30) minutes before the test is conducted. The strain (deformation) was recorded at a strain time of loading and unloading (0.1, 0.25, 0.5, 1, 2, 4, 8, 15, 30, 45, and 60 minutes). The test was conducted while the specimen was submerged in water bath maintained at the test temperatures (60C^0) with a static constant stress of (14.5 psi = 0.1 MPa). The vertical strain calculated from the measured deformation is determined as follows:-

$$\varepsilon = \Delta H / H_o \quad mm/mm \tag{1}$$

Where:

ΔH = the total measured vertical deformation at a certain loading time,
H_o = the original diameter of the specimen.

The stiffness modulus of the mixture is calculated by:

$$(S_{creep})t = \sigma / \varepsilon \quad N/mm^2 \tag{2}$$

Where:

σ = stress of test (14.5 psi (0.1 MPa)

7. Results and Discussion

The first result of this work was the selection of the optimum asphalt content depending on Marshal Stability, stiffness and flow, bulk density, theoretical gravity density, and air voids. This optimum percentage (4.3%) was used with different percents of Rubber Silicon for preparing asphalt rubber-silicone mixture (ARSM).

The data of studying the effect of Rubber-Silicone on asphalt mixture had been evaluated in the laboratory and arranged in **Table (2)**.

- ***Properties of ARSM***

Data of **Table (2)** are presented in the following figures:

Figure (2) shows the effect of rubber-silicone on Marshall Stability. Stability increases rapidly with increasing rubber-silicone content until (2%) after that there are reducing in the stability. The stability increases about (30%) compared with original mixing.

Figure (3) shows the effect of rubber-silicone on Marshall flow. Flow decrease with increasing the rubber silicon contents.

Figure (4) shows the effect of rubber-silicone on Marshall stiffness.

$$\text{Marshall Stiffness} = (\text{Marshall Stability} / \text{Marshall Flow}) \ (kN/mm) \tag{3}$$

Marshall Stiffness increases with increasing the rubber-silicone contents. The rate of increasing is very high as shown in **Figure (4)**.

Figure (5) shows the effect of rubber-silicone on Maximum bulk density. The rubber-silicone content has insignificant effect on maximum bulk density.

Figure (6) shows the effect of rubber-silicone on bulk density of mixture. Increasing the rubber silicon content decreases the bulk density of mixture because rubber-silicone is less dense than asphalt cement.

Figure (7) shows the effect of rubber-silicone on the percentage of air voids in mixture. Air voids increase with increasing rubber-silicone content because of the decrease in the bulk density of mixture with increasing rubber-silicone, while the maximum bulk density remains the same nearly for all mixes.

Figure (8) shows the effect of rubber-silicone content on diametric indirect tensile creep test under constant static load (0.1 MPa) at temperature of test (60C). Increasing of rubber-silicone content reduces the rate of deformation, and the percentages of (2 and 3) have the same effect on rate of deformation.

Figure (9) shows the effect of rubber-silicone content on permanent deformation at (60C^o) and the percentage of reduction is about (30% to 70%). This indicates that the rubber-silicone increases the flexibility properties of the asphalt mixture.

Figure (10) shows the effect of rubber-silicone content on stiffness modulus of asphalt mixture at (60C^o). The stiffness modulus of asphalt mixture increases with increasing the rubber-silicone content as a result for that the rigidity of the mix at high temperature increases so that, the permanent deformation was reduced.

8. Conclusion

The study shows that adding the Rubber-Silicone to asphalt binder has the following effects on the performance of asphalt mixture:

1- Increasing the Marshal stability, air voids, and reducing the flow and bulk density compared with the original mix.
2- Increasing the flexibility properties of the mix and this appears from reducing the permanent deformation at test temperature (60C), the reduction percentage is about (30% to 70%) compared with the original mix without adding Rubber-Silicone.

Study the effect of Rubber-Silicone on the performance of asphalt mixture at low temperature.

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Table (1): Physical Properties of Asphalt Cement.

Test	Unit	Daurah (40-50)
Penetration at 25 Cº	0.1 mm	45
Ductility at 25 Cº	Centimeter	+100
Softening Point	Cº	50
Flash Point	Cº	351
Specific Gravity	---	1.033
Kinematic Viscosity	cst.	270

Table (2): Properties of Asphalt Rubber-Silicone Mixture (ARSM)

No	% Rubber Silicon	Marshall Properties					
		Stability k	Flow mm	Stiffness kN/mm	% Air voids	Theoretical Density	Bulk density gm/cm^3
1.	0	9.2	2.8	3.286	7.1	2.488	2.31
2.	1	11.1	2.7	4.111	7.05	2.485	2.31
3.	2	12.01	2.4	5.004	7.7	2.481	2.291
4.	3	11.2	2.4	4.667	7.8	2.48	2.283
5.	5	10.8	2.1	5.143	8	2.477	2.28

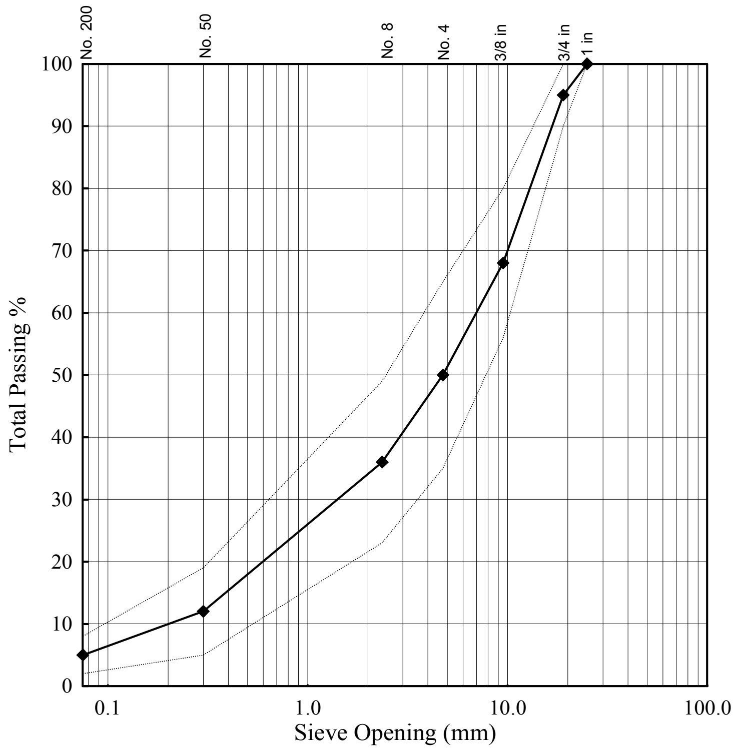
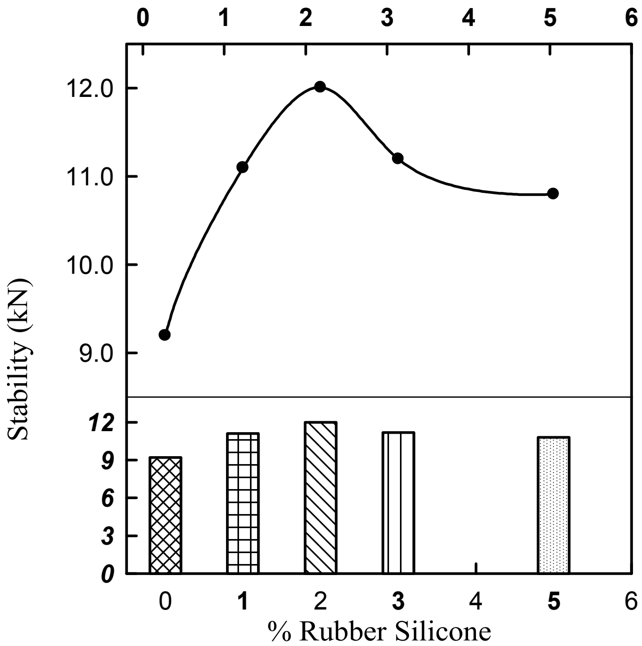
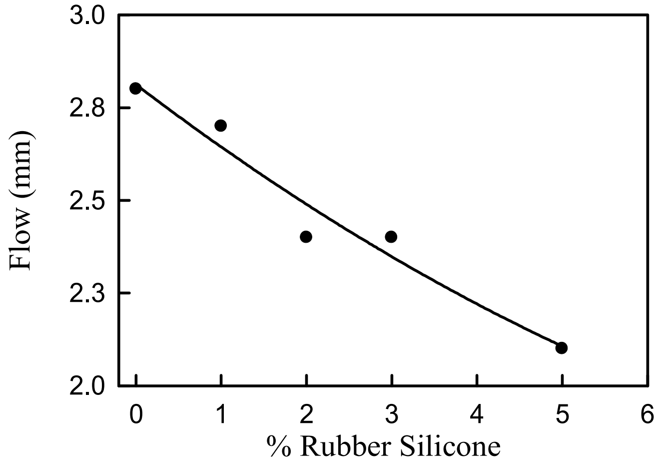


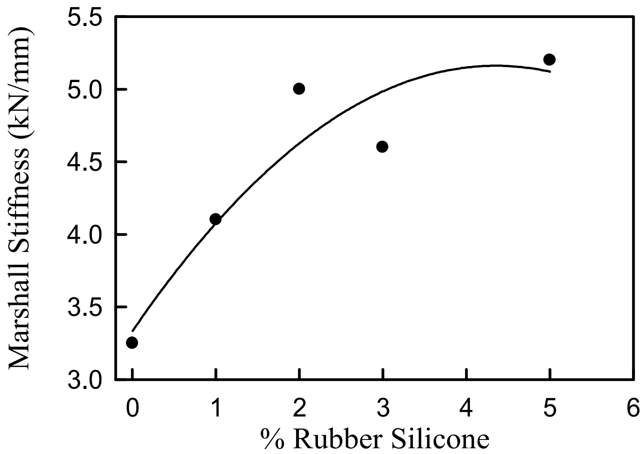
Figure (1): Specification Limits and Selected Gradation of Aggregate Maximum Size (19 mm)



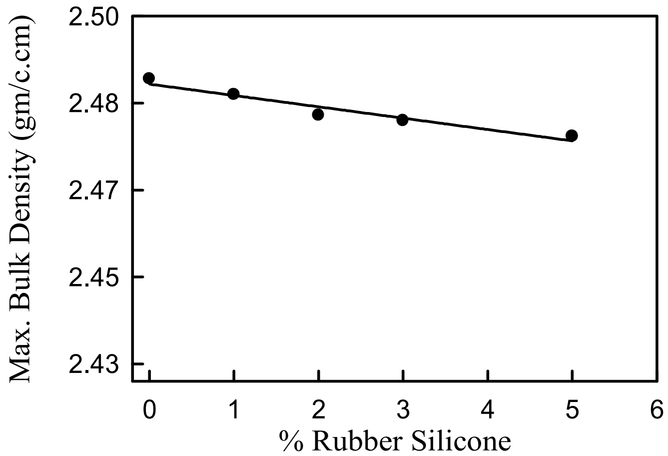
Figure(2): Effect of Rubber Silicone Additive on Marshall Stability of Asphalt Mixture



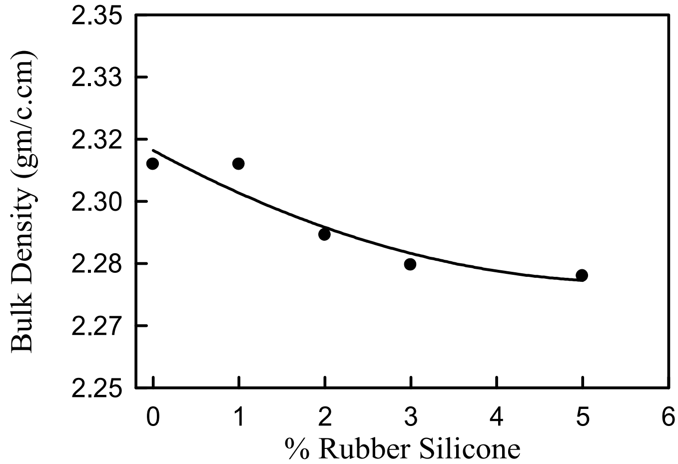
Figure(3): Effect of Rubber Silicone Additive on Marshall Flow of Asphalt Mixture



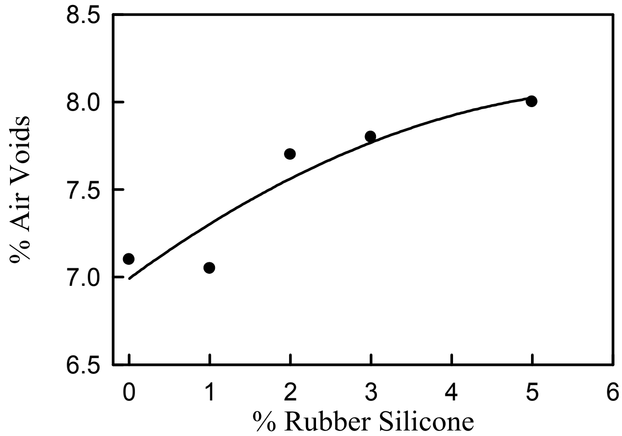
Figure(4): Effect of Rubber Silicone Additive on Marshall Stiffness of Asphalt Mixture



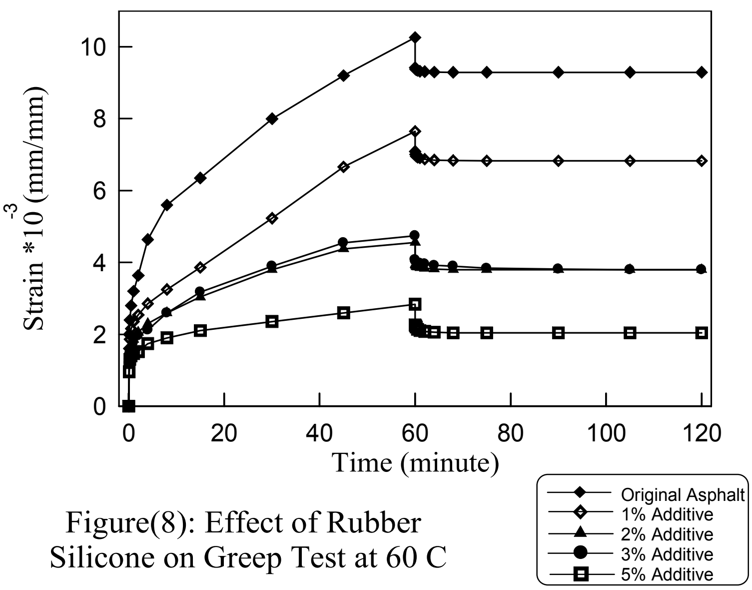
Figure(5): Effect of Rubber Silicone Additive on Max. Bulk Density of Asphalt Mixture



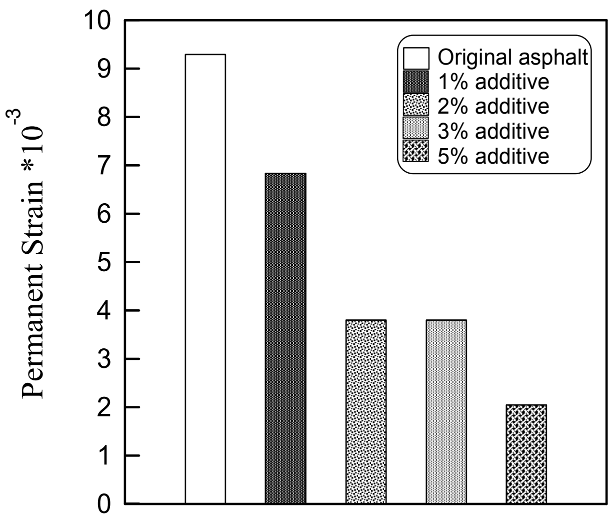
Figure(6): Effect of Rubber Silicone Additive on Bulk Density of Asphalt Mixture



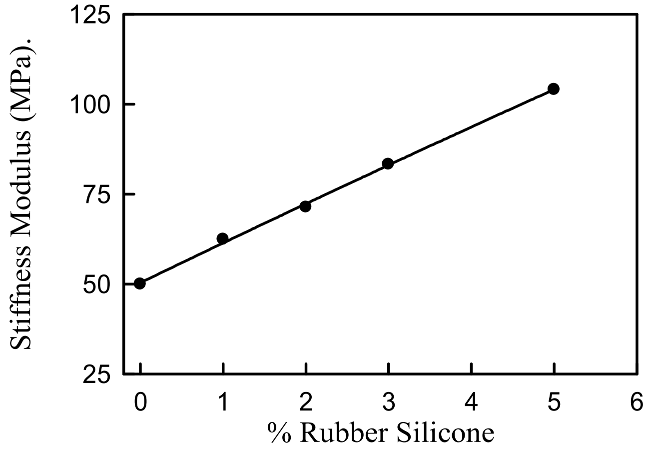
Figure(7): Effect of Rubber Silicone Additive on Percentage Marshall Air Voids of Asphalt Mixture



Figure(8): Effect of Rubber Silicone on Greep Test at 60 C



Figure(9): Effect of Rubber Silicone Content on Permanent deformation at (60C)



Figure(10): Effect of Rubber Silicone Additive on Initial Stiffness Modulus (Mo) of Asphalt Mixture at (60C)

تحسين اداء الخلطة الاسفلتية باضافة المطاط السلكوني

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ملخص:-

هذه الدراسة تمثل الجزء الثاني والمكمل لدراسة تأثير إضافة المطاط السلكوني على الخواص الفيزيائية لمادة الإسفلت الإسمنتي.البحث تناول دراسة تأثير إضافة المطاط السلكوني على أداء الخلطة الإسفلتية. صممت الخلطة الإسفلتية بواسطة طريقة مارشال لتحديد المحتوى الامثل للإسفلت وتحديد الخواص الجيوفيزيائية للخلطة بموجب المواصفة الأمريكية القياسية تحت البند ASTM D-1559 .أضيف المطاط السلكوني الى الإسفلت كنسبة وزنية بنسب مختلفة (1%، 2%، 3%، 5%) وتم إعداد ستة نماذج من الخلطة الإسفلتية المضاف إليها المطاط لكل نسبة وقيمت بموجب طريقة مارشال.كما قيمت التشوهات الدائمية للخلطة عن طريق فحص الكلل للشد القطري بموجب المواصفة القياسية الأمريكية ASTM D-1075 عند درجة حرارة (60) م وتحديد معامل الجساءة لها.

أظهرت الدراسة ان لإضافة المطاط السلكوني تأثير كبير على اداء الخلطة الإسفلتية من خلال زيادة قوت الثبات و نسبة الفراغات وتقليل مقدار التشوه والكثافة الكلية بالمقارنة مع الخلطة الأصلية. بالإضافة الى ذلك فقد ازدادت خاصية المرونة للخلطة من خلال تقليل التشوهات الدائمة عند درجة الحرارة (60) م حيث تراوحت نسبة التقليل من (30 الى 70)%.