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Impact of Waste Plastic on the Mechanical Properties of Asphalt Concrete Mixes

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Abstract

Adjusted asphalt mixes enable the production of an asphalt binder with better viscoelastic characteristics that maintains balance over a wider temperature range and under more demanding loading conditions.

Use of waste plastic adjusted bituminous binder is the solution to achieve the needed performing standards for the roads of today. It shows to be a reasonable, empirical, and economic way. This paper was made to estimate the impact of bituminous modifier on the mechanical properties of bituminous mixes. The traditional bituminous of penetration (40-50) in grade was utilized in the test, adjusted with waste plastic at five various adjustment levels in particular 0%, 2%, 4%, 6% and 8% by weight of bituminous.

Bituminous mixes were equipped at choice optimum bituminous (4.5%) and then tested to assess their mechanical characteristics that comprise Marshall Properties, indirect tensile strength, resilient modulus and permanent. The mechanical features have been assessed utilizing uniaxial repeated loading test. From the practical findings, it can be found that the mixtures adjusted with plastic have indicated an enhanced permanent deformation properties besides superiority elastic characteristics as a distinguished by resilient modulus. The addition of 4 wp to the bituminous mixtures showed a clear improvement in the mixtures and create more permanent bituminous mixes with best serviceability.

Keywords: Bituminous, Waste plastic, Indirect tensile strength, Permanent deformation, Resilient modulus.

1. Introduction

The performance of hot mixed asphalt in tropics and subtropics countries has been frustrated by harsh weather conditions, with pavement surfaces failing after a several months of building and uniquely reminding the design life. The principle distress contributor to failing in bituminous mixture in Iraq are permanent deformation and fatigue cracking , Such as distresses are impacted by the rheological characteristics of the bituminous in the bituminous road [1].

Low temperatures and aged bituminous of maximum viscosity are associated with thermal cracking and fatigue cracking, whereas maximum temperatures and rheology approaching Newtonian conduct are associated with permanent deformation [2], [3]. A typical asphalt should have an appropriate elastic conduct at maximum temperatures to prevent permanent deformation, and less viscosity at lower temperatures to avoid thermal cracking and fatigue. The use of modifiers has resulted in significant improvements in bituminous quality. To

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date, two types of changes have been proposed. Crumb rubber (CR) and polymer modifiers are used in these applications. Many research have demonstrated that substituting artificial and natural polymers for the binder boosts viscosity and moisture resistance while lowering temperature susceptibility and flow tendency ,[1,4 and 5]. CR and recycled plastic have been used as asphalt modifiers in bituminous concrete mixes, and they have exchanged a ratio of mineral aggregates[3],[6].

Polymer-adjusted bituminous combines a small percentage of polymers with bituminous to improve physical properties. Residue tires are the primary source of raw material for crumb rubber modified adjusted bituminous [7]. However, worries regarding decreased road performance and higher construction costs have limited the use of secondary bituminous and aggregates in such projects. As a result, research into bettering the design and performance of bituminous pavement surfaces is still ongoing [8].

Arabani and Pedram [9] reported that enhancing the rheological characteristics of asphalt by mixing with artificial polymers, such as rubber and plastics, is a common method to enhance asphalt quality. Polymer-adjusted asphalt has better resistance to water and temperature. In this paper, an attempt has been made to utilize plastic waste in asphalt concrete mixes. The goal was to maximize the use of recovered trash while also assessing the engineering properties of the bitumen concrete mix.

2. Material characterization

Bituminous , aggregate ,filler and waste plastic as an additive utilized in the test have been described as utilizing routine type of experiments , the findings checked them with State Corporation for Roads and Bridges specifications [10].

2.1. Plastic Waste:

Plastic waste is one of the most important additives that are added to the asphalt mixture. In addition to its importance in the asphalt mixture, it is a major factor in getting rid of it and cleaning the environment. When using plastic waste in this experiment, it is cleaned well and then cut into rather small pieces. After that, it is ground to obtain what looks like coarse powder, and it is added as percentages to the asphalt, and these percentages are (0,2,4,6,8) %. A photograph waste plastic is appeared in Fig.1.

Fig.1 The waste plastic

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2.2. Bituminous:

The bituminous utilized in this study is grades penetration (40-50). It was obtained from the Dura refinery, in Baghdad. The bituminous characteristics are appeared in Table (1).

Table .1 Properties of Bituminous

Test	ASTM Designation	Asphalt Binder	SCRB specification
Penetration100 gm, 25 °C, 5 sec., 0.1 mm	D5	45	40-50
Rotational viscosity at 135◦C (cP.s)	D4402		
Specific Gravity	D70	1.02	
Ductility25 °C, 5 cm/min.	D113	>100	>100
Flash Point	D92	236	232 min
Softening Point (◦C)	D36	47	

2.3. Aggregate :

Crushed quartz was obtained for this investigation from the Amant Baghdad bitumen mixture facility in Al-Taji, whose source is the Al-Nibay quarry. To obtain the surface course gradation type III stipulated by the SCRB specification, the aggregates used in the test were sifted and blended in the appropriate ratios. [10] and. Figure 2 depicts the gradation plot.

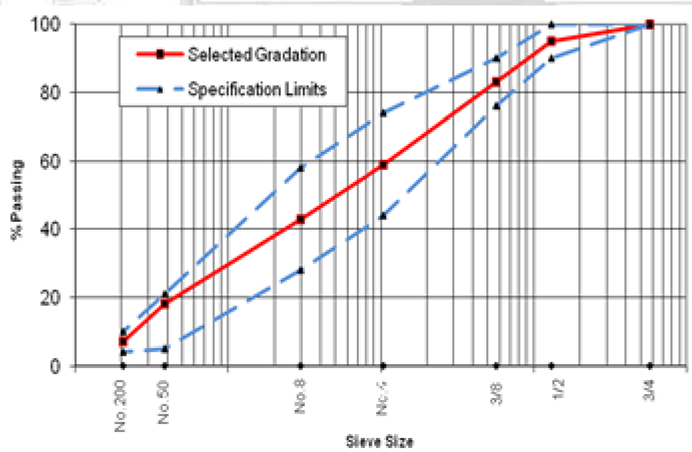

Fig.2 Aggregate Gradation

2.4. Filler:

The filler is non plastic substances which cross sieve No.200. Filler utilized in the test is limestone dust acquired from Amant Baghdad bituminous mixture factory.

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3. Experimental work

The empirical part was began by choosing 4.5% optimum bituminous content for control mixture and utilized in all other waste plastic (WP) adjusted mixtures remain coherence through the research. To check the impact of WP on the bituminous, bituminous and WP mixtures were equipped and tested utilizing the traditional bituminous experiments, (penetration and softening point test). The experiment findings were utilized in P.I account to estimate the impact of WP on the temperature sensitivity of bituminous. So, bituminous mixtures were made utilizing 0%, 2%, 4%, 6% and 8% WP by weight of bituminous and experimented to estimate the Marshall characteristics, Furthermore, the mechanical characteristics that contain indirect tensile strength, resilient modulus and permanent deformation. The mechanical features have been estimate utilizing uniaxial repeated loading .

3.1. Bituminous Test :

The penetration and softening point experiments were carried out in accordance with ASTM D5 and ASTM D 36 in order to achieve the impact of WP on the bituminous. Furthermore, the surface course gradation stipulated by the SCRB specification was obtained using the results of the penetration and softening point tests., the aggregates used in the test were sifted and blended in the appropriate ratios Temperature sensitivity refers to the change in the consistency parameter as a function of temperature.. In the Shell Bitumen Handbook[11], a classic technique to PI computation was presented using the following equation :

$$PI = \frac{1952-500\log(pen\ 25)-20\ sp}{50\log(\text{pen } 25)-\text{sp}-120} \quad (1)$$

3.2. Marshall Properties

Marshall samples were equipped according to the Marshall method as outlined in AI's manual series No.2 [12], utilizing 75 blows [10] of the automatic Marshall compactor on each face of the sample for each percent of WP. The samples were tested for Marshall stability, Marshall flow, density, percent air voids (AV), and percent voids in mineral aggregate (VMA).

3.3. Indirect Tensile Test

The moisture sensitivity of bitumen concrete mixtures was assessed using reference [13]. The (ITS), Tensile Strength Rate, is the result of the experience (TSR). In the past, a group of specimens were estimated for each mix based on the type step and compressed to 71% air voids using a variety of blows per face that ranged from (34 - 49) depending on the waste plastic alteration average. The group consists of six individuals and is divided into two subgroups; One group (control) was exposed to one cycle of icing and melting before being tested at 25°C, while another group (conditional) was exposed to one cycle of icing and melting before being tested at 25°C. The specimens were subjected to a compression force of 50.8mm/min acting parallel to a straight orthogonal diagonal level with 0.5 in. wide steel strips that were twisted at the surface with specimens.. The specimens failed by cleavage along orthogonal diameter. Then calculate ITS according to Eq. 1 of the conditional models (ITS_c) split by the domination specimens (ITS_d), that computes (TSR %) as Eq. 2.

$$\text{ITS} = \frac{2P}{\pi tD} \quad (2)$$

$$\text{TSR} = \frac{ITS_c}{ITS_d} \quad (3)$$

3.4. Uniaxial Repeated Loading Test

Uniaxial repeated loading experiments on cylindrical specimens (4 inch in diameter and 8 inch in height) were carried out using the pneumatic repeated load system (appeared in Fig. 3). Repeated compression loading with a stress level of 20 psi in the form of a rectangular wave and a fixed loading vibration of 1 Hz were established in these experiments (0.1 sec. load period and 0.9 sec. rest period). [14] describes the sample preparation method used in this experiment. The following equation is used to calculate permanent strain (p).:

$$\varepsilon p = \frac{pd \times 10^6}{h} \quad (4)$$

$$\varepsilon r = \frac{rd \times 10^6}{h} \quad (5)$$

$$M_R = \frac{\sigma}{\varepsilon r} \quad (6)$$

The linear log-log relationship between the number of load repetitions and the findings of this work's permanent deformation experiment is represented by the linear log-log relationship between the number of load repetitions and the findings of this work's permanent deformation experiment., Eq.7, which depicts the persistent microstrain described by[15] and [16].

$$\varepsilon_p = aN^b \quad (7)$$

Fig.3 The PRLS Machine

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4. Results and Discussion

4.1. Effect of WP on Bituminous:

The empirical findings for the impact of WP% on the bituminous characteristics are shown in following :

A minor reduction in penetration values was gained with raising WP % as appeared in **Fig .4**. The penetration decreases from (48%) to (33%), resulting in an increase in WP percent from 0% to 33%. (8 percent). The change minimizes the bituminous' temperature sensitivity, as indicated by the higher (PI) in **Fig. 6**.

Fig 5 depicts the softening point findings. It can be notied that the maximum softening point for the adjusted bituminous at a WP percent of 8% was (58 ºC) compared to the traditional bituminous (0 percent) WP of (48 ºC).

The allocation of fine WP in the base bituminous, which indicates stiffening of the mixtures, can be attributed to the enhancements of the previously described properties of the modified bituminous The decrease in penetration values was reversed, and the softening point value was increased. At a WP of 8%, better results were obtained.

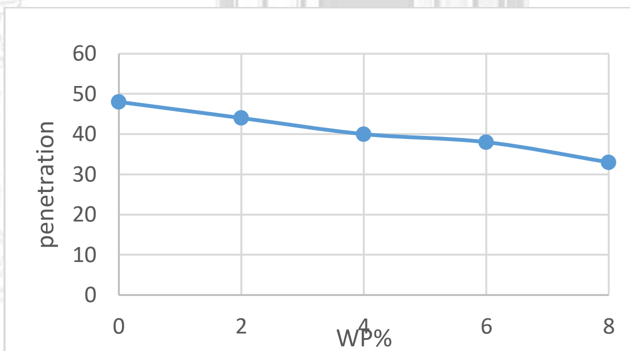

Fig.4 Impact of WP % on Penetration of Asphalt binder

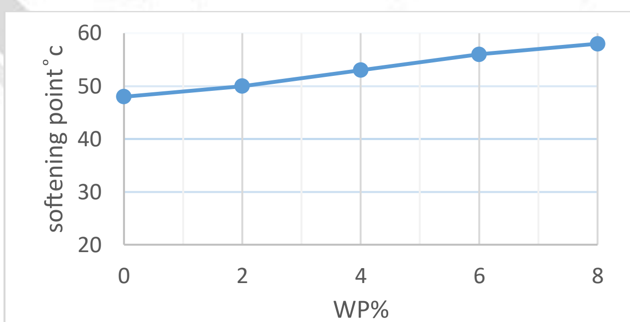

Fig.5 Impact of WP% on Softening Point of Asphalt binder

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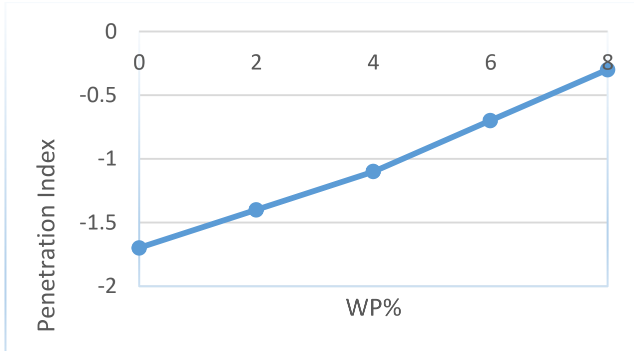


Fig.6 Impact of WP %on Penetration Index of Asphalt Binder

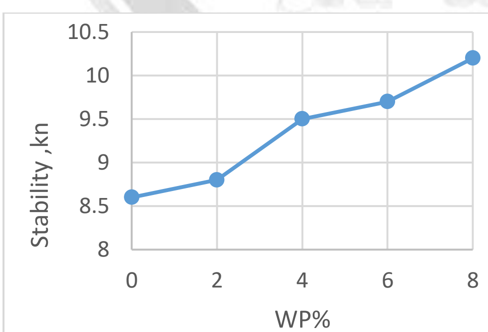
4.2. Effect of WP on Bituminous Mix Properties

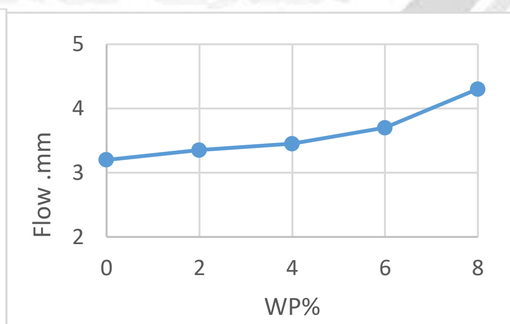
Findings were appeared in **Fig.7** the figures the following observations can be distinguished:

The value of Marshall Stability in adjusted bituminous mixtures is greater than that of the traditional bituminous mixture. It adjusted with (8%) WP has greater value of Stability by (20%) than the traditional mixture (0%) WP.

The adjusted bituminous produced mixtures with maximum flow values by (34%) at (8%) WP in comparative with the traditional mixture. Either the mixture density raised little with raising the WP %.

The plot of air voids versus WP% , the tendency noticed for the impact of WP % on AV values is precisely reverse to that noticed between WP % and density , for WP % ranged from (0 to 8) %, AV reduces with a percent of -0.09 % for per 1 % alter in WP % . The impact of WP% on (VMA) appeared in this curve, showing a reduction with a percent of -0.085 % for each 1 % alter in WP content, As the WP% increased ,it resulted in less gaps to be occupied by bituminous.





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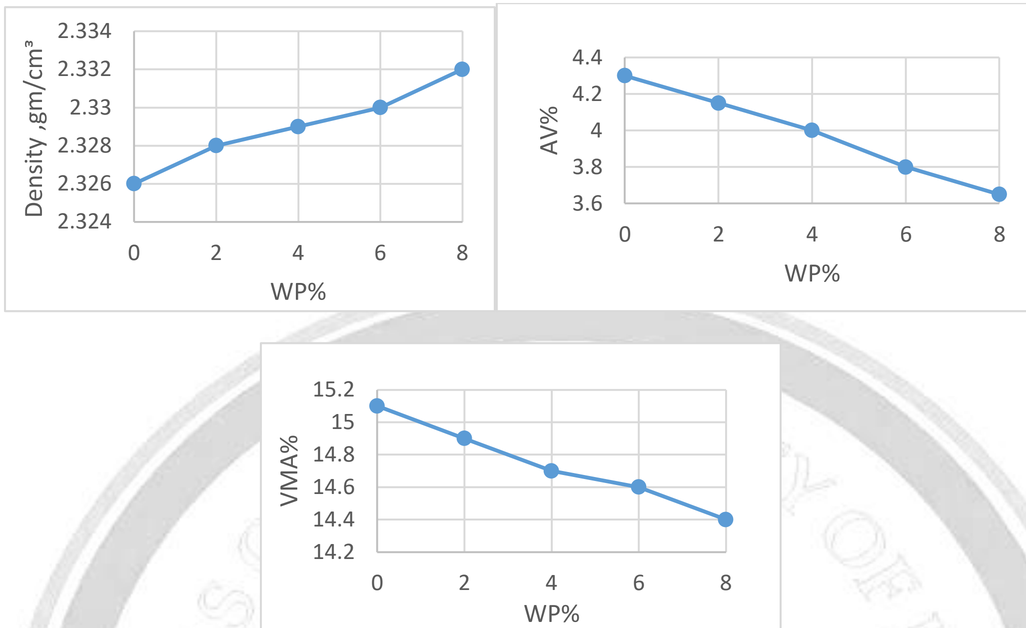

Fig.7 Impact of WP % on Marshall properties

4.3. Effect of WP on Moisture Susceptibility.

The results shown in Fig. 8 and Table 2 demonstrate how the tested WP contents affect the moisture sensitivity of bituminous mixes. ITS results for each control and conditional mixture approach linearly in comparison to the WP ratio with parameters of comparatively per 30% alter WP ratio for the last. It is encouraging to note that the development amendments in the ITS for mixtures containing WP and some asphalt are higher in the conditional mixtures than in the control mixtures.. Figure 8 depicts these findings and their relationship to the TSR, ensuring that resistance to moisture caused by damage is consolidated in bituminous pavement improved with WP.

Table 2 Results of moisture sensitivity test.

WP Content, %	ITS, kPa		TSR, %
	Control	Conditioned	
0	1032	824	80.0
2	1127	938	83.2
4	1357	1173	86.4
6	1455	1328	91.2
8	1470	1368	93.1

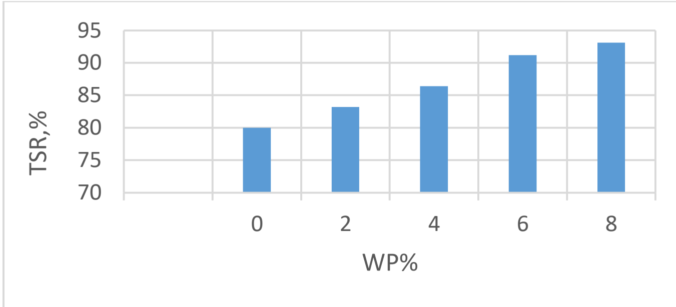

Fig.8 Impact of WP % on TSR.

4.4. Impact of WP on Resilient Modulus M_R

The values of M_R for the mixes with various WP % are showing in **Fig 9**. The findings refer to that WP modifier has a significant impact on the M_R values since the M_R raised by 17 % with raising WP % from (0- 8) % . Tensile stresses were increased in the horizontal side of the sample at the middle thickness plane when an axial spring load applied to it , which is in line with the basic of substance strength. The WP has an enhanced elastic retrieval so the adjusted bituminous mixes show maximum resilient modulus value as the WP % becomes higher.

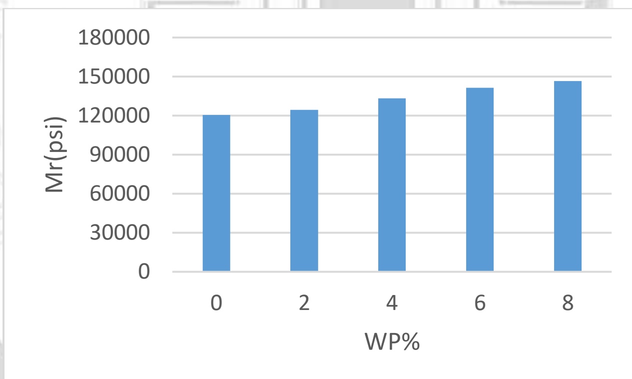

Fig.9 Impact of WP% on resilient modulus

4.5. Impact of WP on Permanent Deformation

According to the slope and intercept values in Fig.10, the examined WP percent has an impact on the plastic reaction of the substance. The lowest value for cumulative plastic strain with repeating load (slope) is related to WP percent of 4% (0.305). Also the WP % of 4 % showed the minimum intercept value of 90 microstrains. In addition the raise in WP % beyond 4 % resulted also in raising slope and intercept values since the mixtures offer more flexibility.

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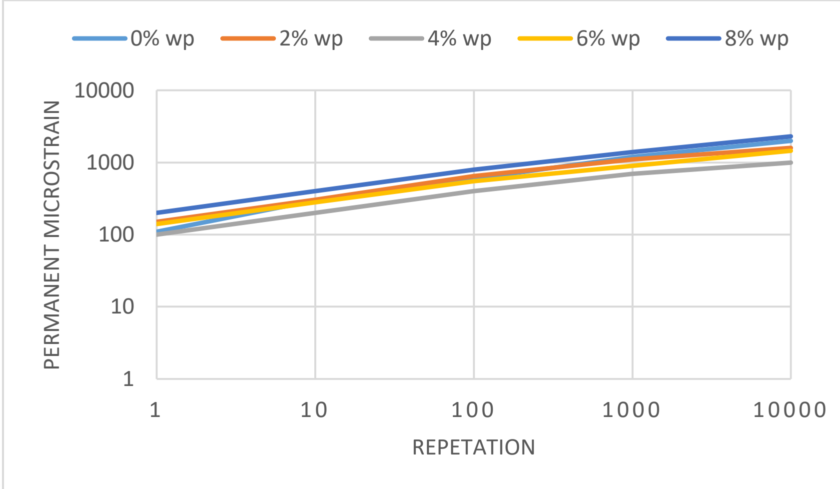

Fig.10 Impact of WP % on Permanent Deformation

5. Conclusion and recommendation

The following main consequences are made based on the findings of the research:

1- WP adjustment results a raise in asphalt cohesion (raise in softening point , reduce in penetration).The adjustment decreases temperature sensitivity of asphalt's, as shown by raising P.I.

2- In comparative to traditional mixtures with 0 % WP, bituminous mixtures adjusted with 8% WP has indicated a raising in Marshall stability at a rate of (20%) and flow at a rate of (34 %).

3- Both AV and VMA reduced a little with an addition of WP. AV reduces with a ratio of -0.09% for per 1 % alter in WP % and VMA reduces with a ratio -0.085% for per 1 % alter in WP %.

4- The addition of wp with a percentage ranging from (2-8) % shows an improvement in the elastic properties especially Mr. The value of Mr for mixtures with 8% of WP is 1.19 times greater than for mixtures with 0% of WP.

5- When adding 4% of WP as modifier, the bituminous mix appeared lower possibility for permanent deformation checked with traditional mixtures with 0 % WP. Both the Slope and intercept values reduced to 18 %. More addendum of WP undermining the resistance for the kind of distress.

6- The addition of 4 wp to the bituminous mixtures showed a clear improvement in the mixtures and create more permanent bituminous mixes with best serviceability.

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تأثير نفايات البلاستك على الخصائص الميكانيكية للخلطات الاسفلتية

علياء فالح العاني

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الخلاصة :

تمكّن خلطات الإسفلت المعدلة من إنتاج مادة رابطة ذات خصائص لزوجة مرنة أفضل تحافظ على التوازن على نطاق أوسع لدرجات الحرارة وتحت ظروف تحميل أكثر تطلبًا.

يعد استخدام مواد ربط البيتومين المعدلة من البلاستيك هو الحل لتحقيق معايير الأداء المطلوبة للطرق اليوم. إنها طريقة منطقية وتجريبية واقتصادية. في البحث ، تم إجراء لتقدير تأثير معدل البيتومين على الخواص الميكانيكية للخلائط البيتومينية. تم استخدام القار التقليدي للاختراق (٤٠-٥٠) في الاختبار ، وتم تعديله بنفايات البلاستيك عند خمسة نسب ضبط مختلفة على وجه الخصوص ٠٪ ، ٢٪ ، ٤٪ ، ٦٪ و ٨٪ وزن البيتومين.

تم تجهيز الخلائط البيتومينية باختيار نسبة اسفلت مثلى (٤.٥٪) ثم اختبارها لتقييم خصائصها الميكانيكية التي تشمل خصائص مارشال ، وقوة الشد غير المباشرة ، ومعامل المرونة والدائم. تم تقييم الميزات الميكانيكية باستخدام اختبار التحميل المتكرر أحادي المحور. من النتائج العملية ، يمكن العثور على أن المخاليط المعدلة بالبلاستيك قد أشارت إلى خصائص تشوه دائمة محسّنة إلى جانب خصائص معامل المرونة. ان أضافة استخدام ٤٪ من البلاستيك إلى الخلطات البيتومينية اظهرت تحنا واضح في الخلطات وخلق المزيد من الخلطات الدائمة مع افضل قابلية للخدمة.

طريقة العمل :

بدأ الجزء التجريبي باختيار ٤.٥٪ محتوى اسفلت مثالي لخليط التحكم والمستخدم في جميع المخاليط البلاستيكية الأخرى المعدلة (WP). للتحقق من تأثيرنفايات البلاستك على الخاطات الاسفلتية والبيتومين تم تجهيزها واختبارها باستخدام التجارب الاسفلت التقليدية (اختبار نقطة الاختراق والتليين). تم استخدام نتائج التجربة في حساب PI لتقدير تأثير نفايات الاسفلت على حساسية درجة حرارة البيتومين. لذلك ، تم عمل مخاليط البيتومين باستخدام ٠٪ ، ٢٪ ، ٤٪ ، ٦٪ و ٨٪ WP بالوزن من البيتومين وتم تجربتها لتقدير خصائص مارشال بالإضافة إلى الخصائص الميكانيكية التي تحتوي على قوة شد غير مباشرة ، ومعامل مرن وتشوه دائم. تم تقدير الميزات الميكانيكية باستخدام التحميل المتكرر أحادي المحور

الاستنتاجات :

يتم إجراء النتائج الرئيسية التالية بناءً على نتائج البحث:

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١- ينتج عن تعديل بنفايات البلاستك زيادة في تماسك الأسفلت (زيادة في نقطة التليين ، وتقليل الاختراق) ، ويقلل الضبط من حساسية درجة حرارة الأسفلت ، كما هو موضح في ارتفاع P.I.

٢- بالمقارنة مع الخلائط التقليدية مع ٠٪ WP ، فإن الخلائط البيتومينية المعدلة بنسبة ٨٪ WP أظهرت ثبات مارشال مرتفعًا بنسبة (٢٠٪) وتدفق بنسبة (٣٤٪).

٣- تم تقليل كل من AV و VMA قليلا بإضافة WP. ينخفض AV بنسبة -٠.٠٠٩٪ لكل ١٪ تغيير في WP٪ ويقلل VMA بنسبة -٠.٠٨٥٪ لكل ١٪ تغيير في WP٪.

٤- تمت إضافة WP بنسبه تراوحت بين (٢-٨)٪ وقد ظهرت خاصية مرونة محسنة بالاضافة الى Mr ، ان قيمة معامل المرونة للمخاليط التي تشمل ٨٪ WP كانت اكبرب ١.١٩ مرة للمخاليط مع ٠٪ WP.

٥- عند إضافة ٤٪ من WP كمعدّل ، ظهر المزيج البيتوميني أقل احتمالاً للتشوه الدائم الذي تم فحصه باستخدام الخلائط التقليدية بنسبة ٠٪ WP.

٦- اظهرت اضافة ٤% من WP الى الخلطات البيتومينية تحسنا واضحا في الخلطات البيتومينية الدائمة مع أفضل قابلية للخدمة.

الكلمات الدالة: البيتومين، نفايات البلاستيك، مقاومة الشد غير المباشرة، التشوه الدائم، معامل المرونة.

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