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IMPROVE THE WAXY ASHPALT CONCRETE MIXTURE PROPERTIES USING CRUMB RUBBER AS AN ADDITIVES

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ABSTRACT

For more than half a century, asphalt cement used in Egyptian road construction was produced by distillation of crude oils from the fields in the Red Sea area. At the early seventies, the production from the Suez refinery was halted, and asphalt cement was produced from newly discovered crude oil fields in the Egyptian western desert. However, many problems were accompanied by severe creep deformations towards pavement edges and near the median curbs, and Pavement service life dropped from 15 years to about 3 years. This research had studied the effect of adding Crumb Rubber from recycled tires as additive in the mixture by rations 1%, 2%, 3%, 4%, and 5% to bitumen in the asphalt mixture to improve the performance of the waxy asphalt and compare the result with 3 control samples. The optimum bitumen content was determined using the Marshall method. The bitumen range region was set according to each mixture's bitumen demand. The relationship between traffic volume and stability describing the effect of applying the additive by varied ratios will be tabulated, as well as the flow, stability, and penetration values.

Using Crumb Rubber from recycled tires as additive used in this study improved the waxy asphalt mixture properties and it is recommended to be used under heavy traffic loads as the marshal stability results show ascending increase from ١٠٢٩ kg to 1252 kg by increasing the percentage of Crumb Rubber as additive from 1% to 5%. Also, it is recommended in warm weather as the penetration test results show increasing values from 2.96 mm to 3.025 mm and decrease in rutting wheel tracking test value reached 2.2 mm depth at 10000 total Passes.

KEYWORDS: Waxy asphalt, Crumb Rubber, recycled tires, asphalt additives.

تحسين خصائص الخلطة الاسفلتية الشمعية باستخدام بدرة المطاط كإضافة بالخلطة

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الملخص

يهدف هذا البحث الى تحسين خواص الخلطة الاسفلتية الشمعية و خصوصا فى الاجواء الحارة , و لذلك تم استخدام (بدرة مطاط من الإطارات المعاد تدويرها) مضافة بنسبة ١٪ من الى ٥٪ إلى البيتومين في خليط الأسفلت لتحسين أداء خليط الأسفلت الشمعي و تم اخذ فى الدراسة متوسط نتائج ٣ عينات من كل نسبة مختلفة مضافة لمحتوى الاسفلت ومقارنة النتيجة مع متوسط نتائج ٣ عينات بدون اضافات.حيث تم استخدام طريقة مارشال لتحديد محتوى البيتومين الأمثل للخلطة الإسفلتية التقليدية. تم إنتاج ثلاث عينات متطابقة لكل بديل. تم عمل اختبارات للخلطة الاسفلتية لقياس التدفق والثبات والاختراق لبيان العلاقة بين حجم المرور والاستقرار موضحًا تأثير استخدام الإضافات المختلفة بنسب مختلفة. حيث يوصى به في الطقس الدافئ باستخدام كسر بدرة المطاط من الإطارات المعاد تدويرها كمادة مضافة حيث أظهرت نتائج ثبات الحركة زيادة تصاعدي من ١٠٢٩ كجم إلى ١٢٥٢ كجم عن طريق زيادة نسبة مطاط الفتات كمادة مضافة من ١٪ إلى ٥٪ تراوحت القيم من ٢,٩٦ مم إلى ٣,٠٢٥ مم وانخفاض قيمة اختبار تتابع العجلة الذي وصل إلى ٢,٢ مم. بـ ١٠٠٠٠ تمريره إجمالية.

الكلمات المفتاحية : أسفلت شمعي ، بدرة مطاط ، إطارات معاد تدويرها ، إضافات أسفلت

1. INTRODUCTION

Asphalt cement used in Egyptian road construction was produced by distillation of crude oils from the fields in the Red Sea area. These asphalt cements were successfully used in hot asphaltic mixtures and produced roads with a good and successful service record. In the early seventies, the production from the Suez refinery was halted, and asphalt cement was produced from newly discovered crude oil fields in the Egyptian western desert. However, the new asphalts caused serious performance and construction problems.

These problems were accompanied by severe creep deformations towards pavement edges and near the median curbs, Preliminary field core samples tested in the laboratory indicated that these construction and performance problems could be attributed to the considerable wax content in the asphalt cement. Studies by Metwally et al. (1975) showed that the wax content for the asphalt cement produced from the western desert region ranges from 5 to 15%, which is substantially higher than the generally accepted wax-content limit of 2.5 to 4%.

It was found that the natural wax in bitumen , due to the refining process, is lower in content and of the type that must not be particularly detrimental to the properties of bonding or asphalt concrete, for example, plastic cracking or deformation usually appears in asphalt concrete pavements due to the nature of bitumen waxy; However, wax can form during the refining stages with hydrocracking (Soenen et. al., 2004).

In the case of blown and/or wax-modified bitumen in road construction (often used in some countries such as the United States and Canada to meet SHRP bond specifications), the effects on the properties of asphalt concrete in general may differ (Hesp 2004).

The effects on the characteristics of asphalt concrete in general may change in case of blown and/or wax-modified bitumen in road construction (frequently utilized in some countries. (Hesp 2004).

Using recyclable accouterments in roads projects is one of the cases that its related diligence has attained expansive experience about the use of by-products in asphalt. Exemplifications of wastes that is used in asphalt fusions, including glass baking furnace rubbish, ash attained from the incineration of external waste, crushed slipup, plastic, rubber attained from waste tires, waste glass, and waste rubber greasepaint. Still, successfully used from these products is depending on a full disquisition of the sources, their characteristics and generally is done at a low position. Due to the deficit of tip space and environmental issues, recovering old tires feel necessary.

One of the cases of its linked vigilance has had a high effect on the use of by-products in asphalt in road construction when recyclable accouterment is used. Glass baking furnace waste, ash from the burning of external waste, crushed slipup, plastic, rubber from waste tires, waste glass, and waste rubber greasepaint are examples of wastes that have been employed on asphalt fusions. Still, effective use of these items requires a thorough examination of the sources and their properties, which is usually done from a low vantage point. Recovery of old tires appears to be important because to a lack of tip space and environmental concerns.

Collecting and storing these tires not only produce pollution but expensive and in addition, there's a possibility of fire as well. Given that the tire pieces are sluggishly decomposed, chancing a result for their use and reducing the environmental hazards caused by their burial in the environment is essential (Bidaki et al., 2012). The application of waste crumb rubber as a modifier raw material in the asphalt has been considerable for experiments over the many decades. Researches carried out in the manufacture of rubber asphalt pavement indicate the reduction of pavement consistency, an increase of pavement life, getting less light refraction rate, and less traffic noise, also reduction in maintenance costs, reduction of pollution, and help the environment.

In 2007, Wang et al. studded the effect of crumb rubber modifiers on the sensitivity of high temperature surface admixture. In his study, they estimated the effect of crumb rubber on the high-temperature sensitivity on the surface admixtures. The evaluation was carried on in two parts first, the properties of the modified and unmodified bitumen in a wide range of experiment. Also, the rutting resistance of modified admixtures is compared with conventional.

The study's findings revealed that bitumen formulated with crumb rubber performs better in terms of rut resistance (Wong and Wong, 2007). In 2005, (Tortum et al., 2005) used the Marshall Test results to determine the best conditions for using tire rubber in asphalt concrete. Grained scruple rubber, emulsion temperature, aggregate gradation, crumb rubber quantum, density temperature, bitumen quantum, and fusion moment were all used as experimental variables. The system of dry mixing crumb rubber in asphalt concrete was used in this study. The findings of this study revealed that rubber asphalt fusions have better Marshall's resilience than traditional admixtures.

Previous experiments have shown that using leftover rubber grease paint as a bitumen modifier had the best results.

2. MATERIAL AND METHODS

To achieve the aim of this study improving the waxy asphalt mixture properties experimental program was performed through different experimental tests used in this study Marshal stability, flow, penetration and rutting load wheel tracking test was the main experiments used. The experimental tests used crumbed rubber from recycled tyers as additives and compare the result with 3 control samples.

For traditional and modified asphalt mixtures, the Marshall technique was employed to estimate the optimum bitumen content. For each option, three identical samples were created. The bitumen range region was set according to each mixture's bitumen demand. The values for flow, stability, and penetration will be tabulated and the relation between traffic volume and stability explaining the effect of using the crumbed rubber as additive by different ratios 1%, 2%, 3%, 4%, and 5% to the bitumen in the asphalt mixture

2.1 ADDITIVE MATERIAL PROPERTIES

Crumb Rubber from recycled tires added by 5 different ratios used in this research

The additives are mixed as a ratio from the bitumen content properties can be summarized in table (1).

Table 1: Crumb Rubber from recycled tires properties

Crumb Rubber (from tires)	
Technical index	**Value**
Density g/cm3@25°C	0.83
Appearance	Black Powder
Melting Point	600 °C
Average Particle Size	80 μm – 1.6 mm
Elongation (%)	420
Carbon black content	29%
Rubber content	54%

To achieve a standard mix for wearing surface 4C, virgin materials include coarse aggregates type 1 dolomite, fine aggregates type 2 dolomite, crushed sand, natural sand, white filler, and Bitumen PG (60/70).

3. EXPERIMENTAL WORK AND RESULTS

Some eligibility tests should be applied to materials to check material properties and compare the results to Egyptian specifications. In addition, these tests were performed to design a control (standard) mix using Marshall. The tests applied are divided as following.

3.1 ELIGIBILITY TESTS APPLIED ON MATERIALS

Sieve analysis on the Aggregates, sand, and white filler

- Abrasion experiment.
- Resistance to abrasion of small size coarse aggregate by use of Los Angles Machine.
- Aggregate Specific Gravity and Absorption
- Bitumen adhesion experiment.

3.1.1 Sieve analysis results

According to the American Association of State Highway and Transportation Officials, aggregate components were subjected to a sieve analysis test in order to meet criteria (AASHTO). The results of the sieve analysis for the ingredients in the mixture are summarized in Table (2). According to the American Association of State Highway and Transportation Officials, several trials are required to find the ideal mix ratio that meets standards (AASHTO).

Table 2: from the accepted percentages according to the design

Sieve Size		Coarse Aggregates type 2		Fine aggregates type 1		crushed sand		Natural sand		white filler		Blend	Specs Limits	
(inch)	(mm)	% Pass	% Blend	% Pass	% Blend	% Pass	% Blend	% Pass	% Blend	% Pass	% Blend	% Pass	L.L	U.L
1"	**25.00**	100.0	25.0	100.0	20.0	100.0	37.0	100.0	15.0	100.0	3.0	**100.0**	100.0	100.0
3/4"	**19.00**	60.0	15.0	100.0	20.0	100.0	37.0	100.0	15.0	100.0	3.0	**90.0**	80.0	100.0
3/8"	**9.50**	3.8	1.0	70.1	14.0	100.0	37.0	100.0	15.0	100.0	3.0	**70.0**	60.0	80.0
#4	**4.75**	0.0	0.0	7.5	1.5	100.0	37.0	100.0	15.0	100.0	3.0	**56.5**	48.0	65.0
#8	**2.36**	0.0	0.0	0.2	0.0	75.0	27.8	78.0	11.7	100.0	3.0	**42.5**	35.0	50.0
#30	**0.60**	0.0	0.0	0.2	0.0	41.5	15.4	61.0	9.2	100.0	3.0	**27.5**	19.0	36.0
#50	**0.30**	0.0	0.0	0.2	0.0	31.2	11.5	23.0	3.5	98.1	2.9	**18.0**	13.0	23.0
#100	**0.15**	0.0	0.0	0.2	0.0	19.4	7.2	6.7	1.0	93.9	2.8	**11.0**	7.0	15.0
#200	**0.075**	0.0	0.0	0.1	0.0	7.1	2.6	1.7	0.3	85.9	2.6	**5.5**	3.0	8.0

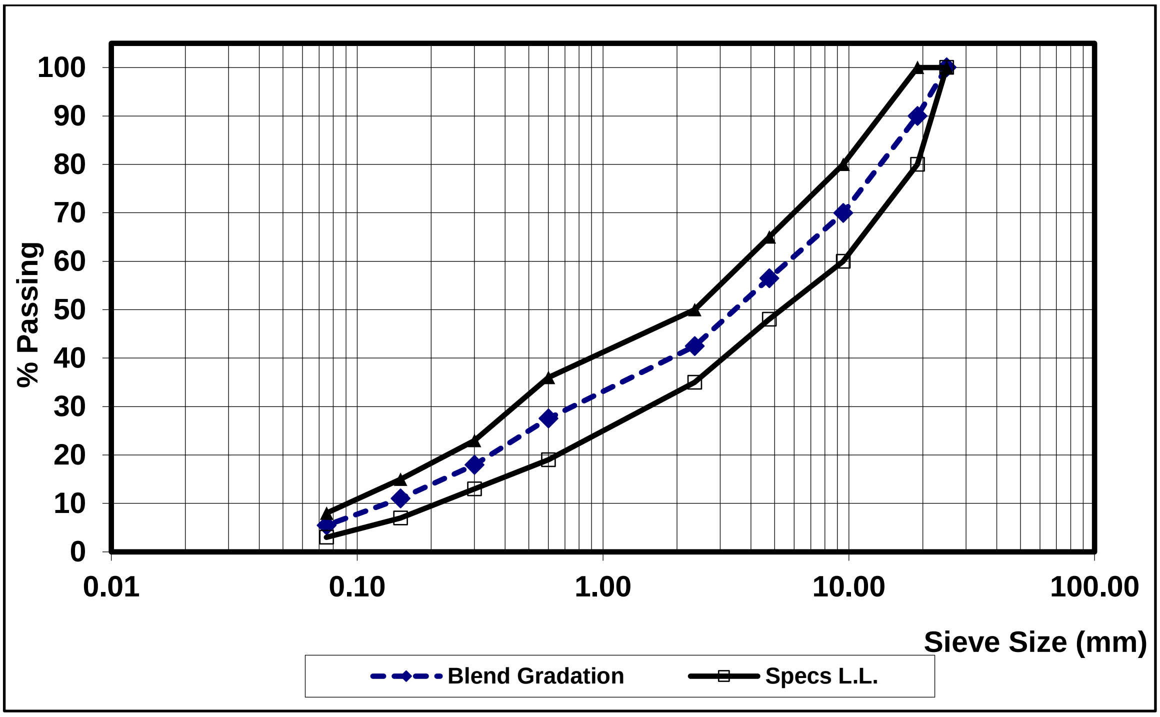

Fig 1 :% Passing vs. Sieve Analysis for Blend and Specs Limits

Table (2) and figure (1) show that the percentages of the various aggregate components, and thus the overall quantity of components, meet the requirements for 4C wearing surface layers as follows:-

Coarse Aggregates type 2 = 25%

Fine aggregates type 1 = 20%

crushed sand =37%

Natural sand = 15%

white filler =3%

3.1.2 Eligibility test results for virgin materials

Results of general property tests in the laboratory Table 1 shows the aggregate. According to the American Association of State Highway and Transportation Officials, a sieve analysis was performed on aggregate components to meet specifications (AASHTO). The results of the sieve analysis for the ingredients in the mixture are summarized in Table (3). According to the American Association of State Highway and Transportation Officials, several trials are required to find the ideal mix ratio that meets standards (AASHTO). The rest of the eligibility tests performed on materials including crushing test, absorption and specific gravity of the material, Loa Angles (L.A) abrasion loss test, Bitumen adhesion test results are summarized in Table (3 and 4).

Table 3: Eligibility tests results for virgin material

<table>
<tr><th colspan="7">Crushing test</th></tr>
<tr><td colspan="4">Specimens</td><td>Coarse Aggregates Type 2</td><td>Fine Aggregates Type 1</td><td>Egyptian specifications</td></tr>
<tr><td colspan="4">Crushing Ratio (%)</td><td>0.4</td><td>0.5</td><td>Not more than 1 %</td></tr>
<tr><th colspan="7">Absorption and Specific gravity the of material</th></tr>
<tr><td>Specimens</td><td>Coarse Aggregates Type 2</td><td>Fine Aggregates Type 1</td><td>Natural sand</td><td>Crushed sand</td><td>White filler</td><td>Egyptian specifications</td></tr>
<tr><td>% Absorption</td><td>2.5</td><td>1.65</td><td></td><td></td><td></td><td>Not more than 5 %</td></tr>
<tr><td>Total unit weight</td><td>2.59</td><td>2.61</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Dry unit weight</td><td>2.655</td><td>2.653</td><td>2.72</td><td>2.79</td><td>2.88</td><td></td></tr>
<tr><td>Apparent unit weight</td><td>2.752</td><td>2.735</td><td></td><td></td><td></td><td></td></tr>
<tr><th colspan="7">Los Angeles (L.A.) abrasion loss test</th></tr>
<tr><td colspan="2">Specimens</td><td colspan="2">Coarse Aggregates Type 2</td><td colspan="2">Fine Aggregates Type 1</td><td>Egyptian specifications</td></tr>
<tr><td colspan="2">Abrasion ratio after 100 rounds</td><td colspan="2">6.3</td><td colspan="2">7.2</td><td>Not more than 10%</td></tr>
<tr><td colspan="2">Abrasion ratio after 500 rounds</td><td colspan="2">23.5</td><td colspan="2">26.5</td><td>Not more than 40%</td></tr>
<tr><th colspan="7">Bitumen adhesion test</th></tr>
<tr><td colspan="2"></td><td colspan="2">Coarse Aggregates</td><td colspan="2">Fine Aggregates</td><td>Egyptian specifications</td></tr>
<tr><td colspan="2">Result</td><td colspan="2">Samples have a good adhesion with bitumen</td><td colspan="2">Samples have a good adhesion with bitumen</td><td>Good adhesion with bitumen</td></tr>
</table>

3.2 MARSHAL TEST

The Marshal test was carried out using asphalt ratios of 4.75 percent, 5 percent, 5.25 percent, and 5.5percent. A total of 12 samples were utilized in this experiment (three samples for each bitumen ratio).

- Stability.
- Flow
- Density

The readings of flow and stability of the marshal test are summarized in Table (4-7).

Fig 2: Marshal stability- flow test

Table 4: Specific gravity values along with flow and stability values from Marshall Tester

Specimen number	1	2	3	4	5	6	7	8	9	10	11	12
Bitumen ratio	4.75			5.0			5.25			5.5		
Density of specimen	2.346	2.344	2.318	2.38	2.37	2.362	2.371	2.360	2.369	2.389	2.391	2.386
Average Density (gm/cm3)	2.336			2.371			2.366			2.388		
Stability	824	840	881	917	964	971	1034	1022	1023	935	925	927
Average stability (Kg)	848			951			1026			929		
Flow (mm)	2.45	2.5	2.35	2.6	2.8	2.65	2.95	2.85	2.9	3.05	3	3.1
Average flow (mm)	2.43			2.68			2.9			3.05		

From Table (4) it can be concluded that the optimum bitumen content is (5 + 0.25) from the entire design mix with penetration value 64 and Egyptian code criteria shown in Table (5).

Table 5: Design criteria from design curves in Marshal to obtain optimum bitumen content

Design criteria	Final Result	Specifications
The specific gravity for the mix	2.366 Ton / m3	
Stability	1026 Kg	Not less 900 Kg
Flow (0.01”)	(0.01”) 2.9	From 2 to 4 mm
Air voids	3.5%	From 3 to 5 %

3.3 ASPHALT PROPERTIES WITH BITUMEN MIXED WITH ADDITIVES:

The properties of Asphalt with and without additives were experimented with in Ain shams university highway asphalt lab.

Figure 3 show the relation between temperature and viscosity to show the ideal temperature for additives with bitumen with ratios from 1% to 5% including viscosity that meets 280 Centistoke viscosity which was considered ideal for bitumen 60/70 used according to Egyptian specifications.

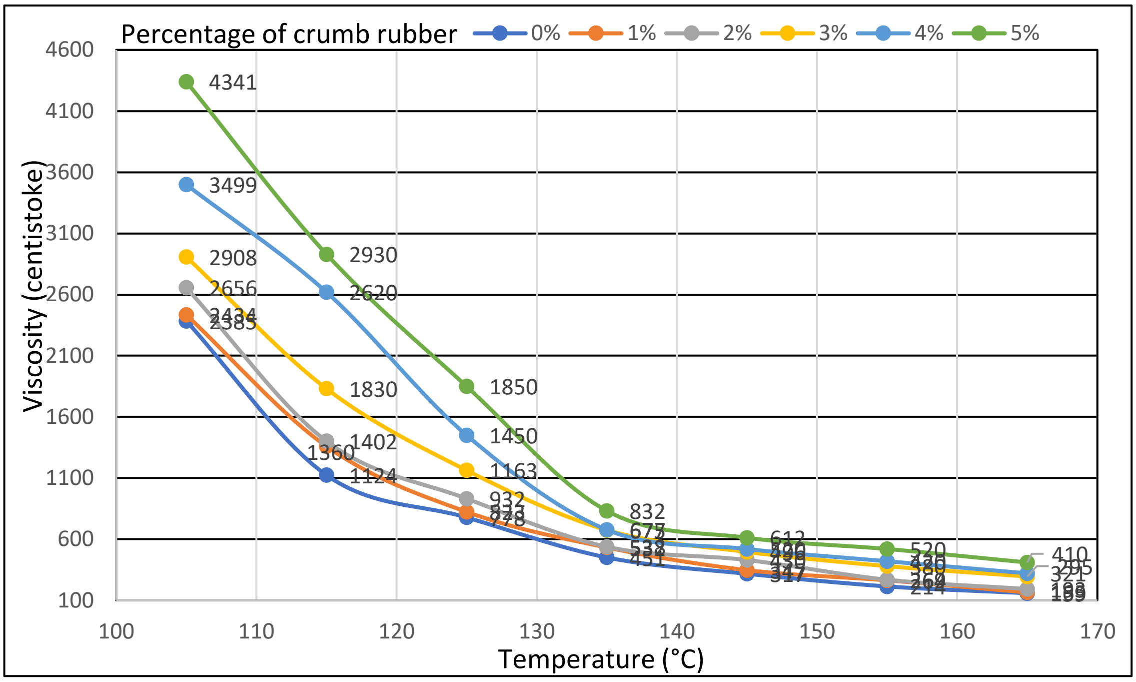

Fig 3: Relation between viscosity and temperature by adding crumb rubber

3.4 THE STABILITY TEST RESULTS (Marshal Test)

In this experiment, 18 samples were considered the experiment 3 samples was used as a control without any additives and 3 samples for each the additives used, each additive used was experimented by 5 different percentage added from the bitumen in the asphalt mixture to study the improvement of the mixture with the additives and best percentage that gives the best result. The following table shows the results of the stability test on the samples.

3.4.1 Effect of changing Crumb Rubber from recycled tires ratio as additives on stability test results.

changing Crumb Rubber from recycled tires ratio from 0% to 5% leads to an increase in stability by approximately 0.3 % by adding 1% Crumb Rubber from recycled tires as additives, 9.3 % by adding 2% Crumb Rubber from recycled tires as additives, 22.4 % by adding 3% Crumb Rubber from recycled tires, 25.8 % by adding 4% Crumb Rubber from recycled tires as additives and 22 % by adding 5% Crumb Rubber from recycled tires as additives.

Table 6: Stability test results in kg on the samples using crumb Rubber from recycled tires as additives with 5 different percentages.

Additive % from bitumen in asphalt mixture	0% (control)		1%		2%		3%		4%		5%	
	Value	average	Value	average	Value	average	Value	average	Value	average	Value	average
Crumb Rubber from recycled tires	1034	**1026**	1027	**1029**	1128	**1122**	1260	**1256**	1294	**1291**	1258	**1252**
	1022		1032		1118		1255		1278		1249	
	1023		1029		1120		1254		1292		1250	

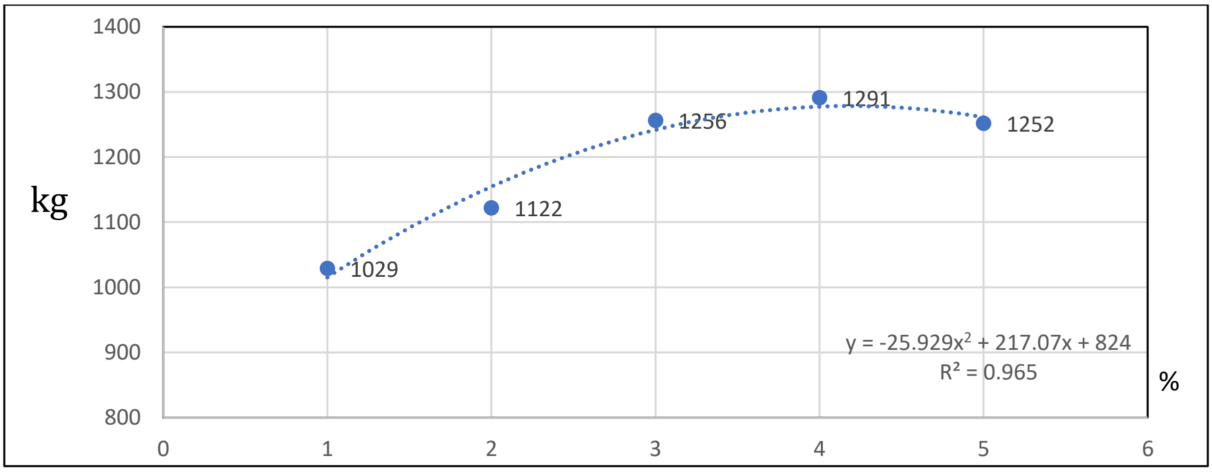

Fig 4: Stability results for Crumb Rubber from recycled tires as additives

3.5 THE FLOW TEST RESULTS

In this experiment, 18 samples were considered the experiment 3 samples was used as a control without any additives and 3 samples for each the additives used, each additive used was experimented by 5 different percentage added from the bitumen in the asphalt mixture to study the improvement of the mixture with the additives and best percentage that gives the best result. The following table shows the results of the flow test on the samples.

3.5.1 Effect of changing Crumb Rubber wax ratio as additives on flow test results

Changing Crumb Rubber from recycled tires ratio from 0% to 5% leads to increase flow values by approximately 2 % by adding 1% Crumb Rubber from recycled tires as additives, 2.4 % by adding 2% Crumb Rubber from recycled tires as additives, 2.7 % by adding 3% Crumb Rubber from recycled tires as additives, 2.75 % by adding 4% Crumb Rubber from recycled tires as additives and 4.5 % by adding 5% Crumb Rubber from recycled tires as additives.

Table 7: Flow test results on the samples using crumb Rubber from recycled tires as additives with 5 different percentages.

Additive % from bitumen	0%(control)		1%		2%		3%		4%		5%	
	Value	average	Value	average	Value	average	Value	average	Value	average	Value	average
	2.95		2.9		2.95		3		3		3	
Crumb Rubber from recycled tires	2.85	2.9	3	2.96	2.975	2.967	2.95	2.975	2.95	2.983	3	3.03
	2.9		3		2.975		2.98		3		3.08	

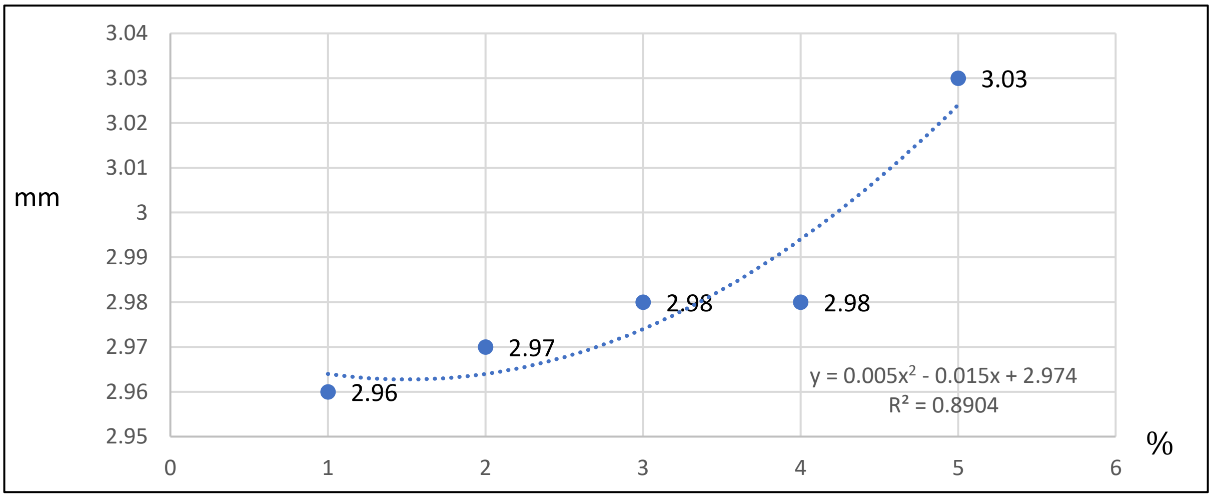

Fig 5: Flow test results for Crumb Rubber from recycled tires

3.6 THE PENETRATION TEST RESULTS ON BITUMEN SAMPLES RESULTS

In this experiment, 6 samples were considered the experiment 1 sample was used as a control without any additives and 1 sample samples for each the additives used, each additive used was experimented by 5 different percentage added from the bitumen in the asphalt mixture to study the improvement of the mixture with the additives and best percentage that gives the best result. The following table shows the results of the penetration test on the samples.

3.6.1 Effect of changing Crumb Rubber from recycled tires ratio additives to penetration test results

Changing Crumb Rubber from recycled tires ratio from 0% to 5% leads to a decrease in penetration values reached 48 mm by adding 1% Crumb Rubber from recycled tires as additives, 47 mm by adding

2% Crumb Rubber from recycled tires as additives, 46 mm by adding 3% Crumb Rubber from recycled tires as additives, 43 mm by adding 4% Crumb Rubber from recycled tires as additives and 42 mm by adding 5% Crumb Rubber from recycled tires as additives.

Table 8: The penetration test results in (mm) for the samples using additives Crumb Rubber from

Additive % from bitumen	0	1	2	3	4	5
Crumb Rubber from recycled tires	64	48	47	46	43	42

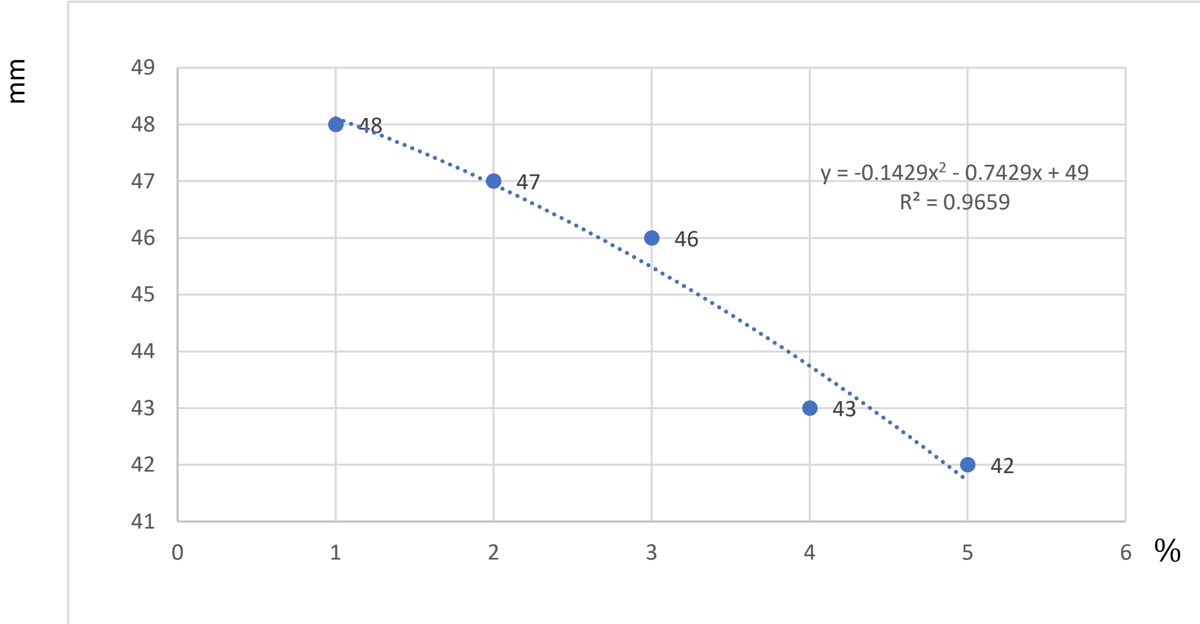

Fig 6: The penetration test results for Crumb Rubber from recycled tires

3.7 LOAD WHEEL TRACK RUTTING (LWTR) TEST RESULTS.

The results for rut depths from the LWTR test show the effect of using crumb rubber from recycled tires with 5 different percentages added to the bitumen to study the improvement of the bitumen asphalt mix the summarized results can be shown in the following figure

3.7.1 Effect of changing Crumb Rubber from recycled tires ratio as additives to LWTR results

The results for rut depths from the LWTR test show the effect of using from 1 to 5% Crumb Rubber from recycled tires as an additive.

The result shows a decrease in rutting depth by increasing the ratio of Crumb Rubber from recycled tires as additives by 3.38 mm by adding 1% Crumb Rubber from recycled tires as additives, 3.25 mm by adding 2% Crumb Rubber from recycled tires as additives, 2.85 mm by adding 3% Crumb Rubber from recycled tires as additives, 2.52 mm by adding 4% Crumb Rubber from recycled tires as additives and 2.2 mm by adding 5% Crumb Rubber from recycled tires as additives.

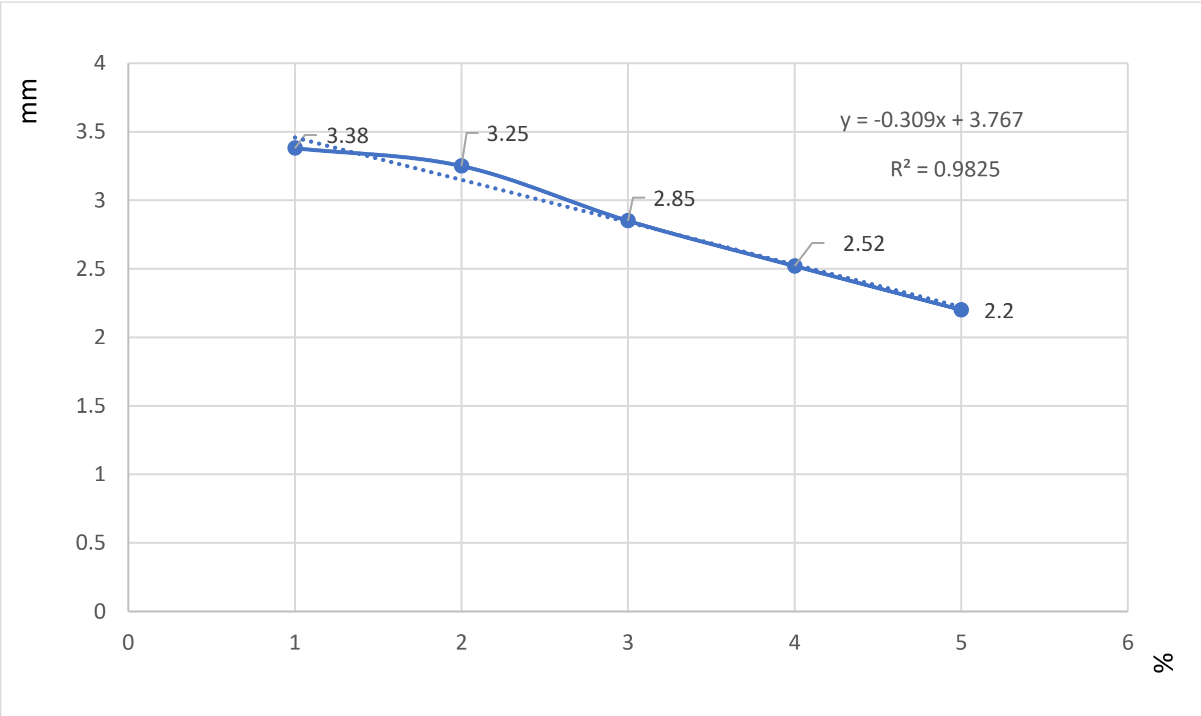

Fig 7 :Load wheel track rutting test results for Crumb Rubber from recycled tires.

4. CONCLUSION AND DISCUSSION

4.1 CONCLUSION OF ADDING CRUMB RUBBER FROM RECYCLED TIRES AS AN ADDITIVE TO THE WAXY ASPHALT MIXURE

It was concluded from the experiment results that using Crumb Rubber from recycled tires as additive by ratios from 1% to 5% used to improve the waxy asphalt mixture properties is recommended to be used under heavy traffic loads and also recommended in warm weather countries due to the following reasons.

- The stability results show ascending increase from 1029 kg to 1252 kg by increasing the percentage of Crumb Rubber as additive from 1% to 5% from the bitumen content, all the values reach more than 900 kg indicating the ability of the crumbed rubber from recycled tires to show good performance under heavy loads as an additive.

- The results show a slight increase in flow values by increasing from 2.96 mm to 3.025 mm by increasing the percentage of Crumb Rubber as additive from 1% to 5% (4.5%) more than control sample at 5% Crumb Rubber as an additive to bitumen
- The results show a decrease in penetration value by increasing the percentage of the Crumb Rubber as additive from 1% to 5% as additive till reached 42 mm at 25°C.
- The results show a decrease in LWTR value reached 2.2 mm depth at 10000 total Passes.

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