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Effect of Additives Types and Contents on Permanent Deformation

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ABSTRACT

The permanent deformation (rutting) of asphalt concrete is considered one of the major distress that affect the performance of pavement structures. It is one of the major form of distress a bowel-shaped depression in the wheel paths gradually with increasing number of load applications. Heavy axle loadings besides high pavement summer temperature and high loading repetitions enhance the problem of rutting in Iraq.

The asphaltic paving mixture is normally subjected to various detrimental types of distresses during its service life. These distresses are caused by load, weather, and construction practices, and /or deficient materials. Some of these serious distresses include rutting (permanent deformation), shoving, stripping, and fatigue cracking which finally may lead to completed failure of pavement at the same time. Such distresses will reduce the performance of asphalt pavements, which is not only causes inferior ride quality to motorists but also yields higher life-cycle cost. Some of the mentioned distresses are associated with the asphalt cement binder and can be controlled significantly by modifying the material with chemical additives

The purpose of this study is to evaluate the effect of additives type and content on the permanent deformation out by preparing asphalt mixtures specimens using aggregate from Al-Nibaay State, (40-50) grade asphalt from dourah refinery and two types of additives Rubber with different content (1.5,3, 4.5, 6, 7.5 &9)% by weight of asphalt and wool with different content (3, 6, 9,&12)% by weight of asphalt . Compacted mixtures were tested to determine Marshall Stability , Indirect Tensile Strength(ITS) and permanent deformation. Two different tests temperatures' (20-40ºC) were employed in the creep test and one temperature (25ºC) were used in indirect tensile test to investigate the susceptibility of these mixes to change in temperature. According to the study results, using of the Rubber in mix more effective than Wool additives. A total of 63 Marshall Specimens is prepared and tested by Marshall method , Indirect tensile and Creep tests.

تأثير انواع المضافات ومحتواها على التشوه الدائمي في التبليط الاسفلتي

الخلاصة

التشوه ألدائمي (التخدد) في التبليط الإسفلتي يعتبر من أهم أشكال الفشل المؤثرة في كفاءة التبليط الإنشائية حيث يسبب سواقي ممتدة على طول مسار الإطار تتطور تدريجيا" بزيادة عدد المركبات . نتيجه لزيادة أحمال المحاور وارتفاع درجات الحرارة في الصيف وتكرار الحمل العالي تعتبر من الأسباب الرئيسية للتخدد في العراق.

يتعرض التبليط الإسفلتي إلى إشكال متعددة من الفشل خلال فترة حياته ناتجة من الأحمال و الظروف البيئية و ظروف إنشاء التبليط و بعض انواع الفشل المختلفة تتضمن و المواد الغير صالحة و (التخدد, الشقوق , التموج ,و شقوق الكلل وغيرها) هذه الأنواع من الفشل تقلل من كفاءة ألتبليط الإسفلتي .

إن الغرض من هذه الدراسة هو تقييم تأثير أنواع المضافات و محتواها على أداء الخلطة الإسفلتية. تم عمل دراسة مختبريه تفصيلية بتحضير نماذج خلطات إسفلتية و ذلك باستعمال الركام من مقلع النباعي, و إسفلت ذو تدرج (40-50) من مصفاة الدورة, و اثنان من المضافات (المطاط (1.5, 3, 4.5, 6, 7.5, و 9%) من وزن الإسفلت و ألياف الصوف بنسبة (3, 6, 9 و 12%) من وزن الإسفلت) حيث تم اختبارهما في المختبر. تم اختبار الخلطات الإسفلتية لتقييم التأثير على ثبات مارشال, قوة الشد الغير مباشر و التشوه الدائم. تم اختيار في درجتي حرارة (20-40 °م) في اختبار فحص الزحف و تم اختيار درجة (5-25 °م) في فحص الشد الغير مباشر لتحري سهولة تأثر هذه الخلطات للتغير في درجة الحرارة. تشير النتائج إلى إن إضافة المطاط أكثر فعالية من مضافات الألياف. تم تحضير 63 نموذج مارشال و فحصت باستخدام (فحص مارشال, فحص قوة الشد غير مباشر و الزحف) بعدد من درجات الحرارة.

Key Words: Permanent deformation, creep test, tensile strength , Wool & Rubber.

1- Introduction

The design of asphalt paving mixtures is a multi –step process of selecting asphalt and aggregate materials and their proportioning to provide an appropriate compromise among several variables that affect the mixture behavior.

Consideration of external factors such as traffic, loading and climates is part of the design process. Performance factors that are of concern in any design include at least the following goals.

a. Minimizing the potential for rutting.
b. Minimizing the effect of low temperature cracking.
c. Reducing the effect of water.
d. Providing adequate skid resistance for pavement surface.

As many of the nations Interstate and other highways approach the end of their design life, the need for dependable rehabilitation techniques becomes increasingly important. Rehabilitation procedures include preventing the cracks in the existing pavement. Either Portland cement concrete (PC) or (A), from working through a new pavement layer and prematurely starting the failure process. Such cracks are known as reflection cracks [Sherman (1982)].

The function of a pavement is to carry traffic safely, smoothly and economically from one location to another (Yoder and Witczak, 1975).However, various factors such as material properties, construction quality control, traffic, and the environment collectively act over time to reduce the original smoothness of the pavement. In flexible pavements, this reduction in pavement smoothness or serviceability will ultimately lead to failure or an intolerable level of roughness. The most common forms of load associated distresses leading to a reduction in serviceability for flexible pavements, permanent deformation (rutting) and fatigue cracking. According to the AASHTO design equation for flexible pavements, a 1.1 inch rut depth will reduce the Present Serviceability Index (PSI) of a relatively new pavement, having no other distress, from 4.2 to 2.5 (AASHTO,1988).

Rutting in flexible pavements develops gradually with increasing numbers of load applications, usually appearing as longitudinal depressions in the wheel paths accompanied by small upheavals to the sides as shown in Figure (1).

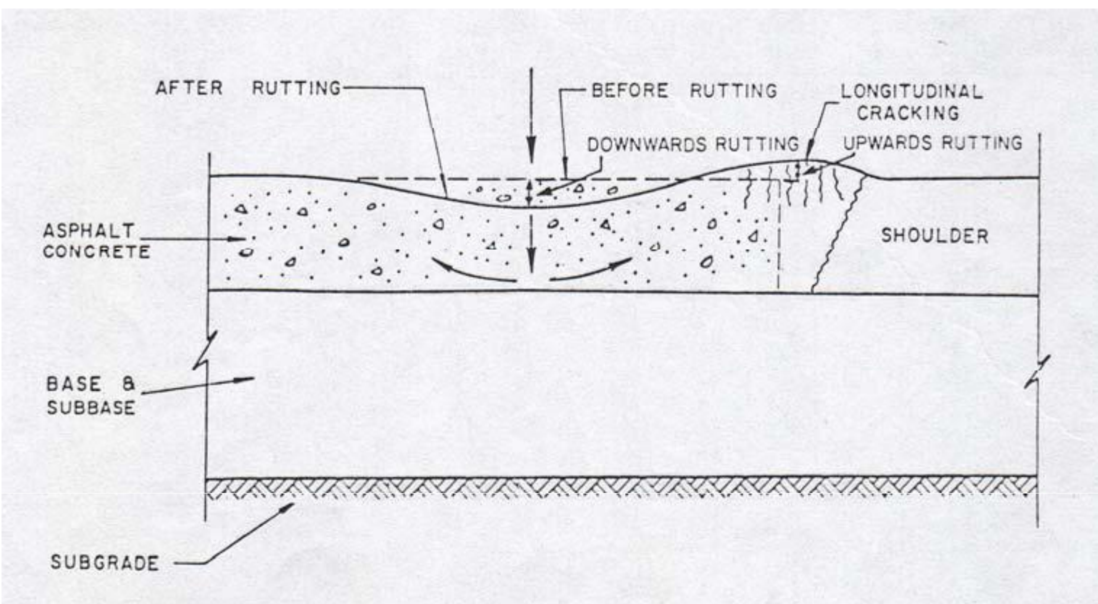


Figure (1) Rutting in Flexible Pavement

It is caused by a combination of densification (decrease in volume and, hence, increase in density) and shear deformation can occur in any one or more of the pavement layers as well as in the sub grade. Although the rutting problem must be addressed for structural and economic reasons, the concern for permanent deformation may also be related to traffic safety. Pavement rutting can cause operating hazards such as loss of vehicle control during lane changes and hydroplaning due to the accumulation of water in the wheel path In Iraq, within about one year after construction, rutting distress was observed at several locations in the highways due to the high axle loading and the hot summer days (Yassoub, 2005).

Traditionally, flexible pavement design considers the permanent deformation problem indirectly using the maximum level of rutting allowed for the entire pavement structure. This is made based on the assumption of the allowable magnitude of compressive stress or strain in the top of the subgrade rather than predicting its actual magnitude within the pavement layers. In order to achieve a reliable estimate of the pavement rutting, one must consider loading, material and environmental variables when developing the law at which permanent deformation accumulate for a certain pavement layer on the basis of laboratory works. One of the basic requirements for this law is to test the material in the lab under an environment which satisfactorily simulate the field conditions.

2- Objective of the Study

The main object of this study is to evaluate permanent deformation for two additives types with different contents.

3- Materials

a-Aggregate

The (crushed) aggregate used in this work is brought from the hot mix plants of Ammanat Baghdad at (AL-Tagi).The source of the aggregates is from Al-Nibaee quarry. gradation type of aggregate has been used in this study as shown in Table (1).

Table (1): Gradation of the Aggregate for Surface Course.

Sieve Size	Sieve Opening (mm)	Percentage passing by Weight of total Aggregate					
		Finer Surface Course					
		Specification Limit [S.O.R.B]	SHRP				Selected gradation
			Control points		Restricted zone		
			Min	Max	Min	Max	Type I
3/4	19	100		100			100
1/2	12.5	90-100	90	100			95
3/8	9.5	76-90		90			83
No.4	4.75	44-74					59
No.8	2.36	28-58	28	58	39.1	39.1	43
No.16	1.18				25.6	31.6	32
No.30	0.6				19.1	23.1	25
No.50	0.3	5-21			15.5	15.5	16
No.100	0.15						10
No.200	0.075	4-10	2	10			5

The physical properties of the aggregate (coarse and fine) is shown in Table (2).

Table (2): Physical Properties of Nibaee Aggregates

Property	***Coarse Aggregate***	***Fine Aggregate***
Bulk Specific Gravity (ASTM C127 and C128).	*2.618*	*2.63*
Apparent Specific Gravity (ASTM C127 and C128).	*2.693*	*2.6802*
Percent Water Absorption (ASTM C127 and C128).	*0.486*	*0.61*
Percent Wear (Los-Angeles Abrasion) (ASTM C131).	*27.1*	*……*

b- Mineral Filler

The mineral filler used is Portland cement . Table (3) shows the physical properties of filler.

Table (3):Physical Properties of Filler (Cement).

Property	*Results*
Specific Gravity	*3.12*
%Passing sieve No.200 ASTM C117	*96*

c- Asphalt Cement

The asphalt cement used in this study is of (40-50) penetration grade. Table (4) shows the physical properties of Asphalt Cement.

Table (4): Physical Properties of Asphalt Cement.

Test	*Unit*	*Penetration -Grade (40-50)*	*S.C.R.B Spec .for (40-50) pen-grade*
Penetration (25 ˚C, 100g, 5sec) ASTM D5.	*1/10 mm*	47	40-50
Ductility (25 ˚C, 5 cm/min). ASTM D 113.	*cm*	+100	≥ 100
Softening point (ring & ball). ASTM D 36.	*˚C*	51.25	50-60
Flash point (cleave land open cup) ASTM D 92.	*˚C*	310	≥ 240
****After Thin-Film Oven Test ASTM D 1754***			
Penetration of residue.	*1/10mm*	32	
Ductility of residue.	*cm*	107	

d- Additive Materials (Reclaimed Tire Rubber and Wool)

- Rubber recovered from used tires is brought from Babil Tires factory at Al- Najaf city. The particle gradation is obtained from is shown in Table (5)

Table (5): Gradation of Reclaimed Tire Rubber.

Sieve Size	*Percentage Passing by weight of total Rubber*
No.10	*100*
No.20	*92.08*
No.50	*20.0*
No.150	*17.0*
No.200	*0.0*

The unit weight of rubber particles is 0.95.

- Wool is typically added to the mix at percentage (3,6,9, &12)% by weight of Asphalt , properties is shown in table(6)

Table (6): Properties of Wool

Properties	*Results*
Density	*1.45 gm/cm*^{3}
Color	*Black*

4- Indirect Tensile Strength Test:

The indirect tensile strength test is used to determine the tensile properties of the asphalt concrete which can be further related to the cracking properties of the pavement. Low temperature cracking, fatigue and rutting are three major distress mechanisms. Numerous researches have been conducted relating the tensile strength of asphalt mixtures to the performance of asphalt pavements (Anderson *et al.*, 2001; Zhang *et al.*,2001). This test is summarized in applying compressive loads along a diametrical plane through two opposite loading strips. This loading configuration develops a relatively uniform tensile stress perpendicular to the direction of the applied load and along the vertical diametric plane which ultimately causes the specimen to fail by splitting along the vertical diameter *(Thomas W. K., 1977).* The test was performed at (5, 25ºC), the test provide information on:

1- Tensile strength
2- Fatigue characteristics and,
3- Permanent deformation characteristics of pavement materials.

The indirect tensile strength (I.T.S) is calculated, as follows:

$$I.T.S = \frac{2Pult}{\pi tD} \qquad \ldots\ldots\ldots\ldots..(1)$$

Where:

Pult= Ultimate load up to failure (N).

t =Thickness of specimen (mm), and

D = Diameter of specimen(mm).

5- Creep test:

Creep is a second important measure of modified asphalt performance, its ability to elastically recover deformation. Since asphalt pavement are designed to be flexible, they must quickly return to their original configuration after loading. *(Muncy, H,W, et al, 1987)*. The static creep test method was performed at (20, 40ºC) with applied stress 0.1 MPa to determine the resistance to permanent deformation.

6- Result and Discussion

1. Marshall Properties at Optimum Asphalt Content (O.A.C)

The Marshall properties determine at optimum asphalt content for the Original mix for the two types of additives (Reclaimed Tire Rubber & Carbon fiber) are reported in Tables (7), (8), &(9).

Table (7): Marshall Properties of the Original Mix.

Asphalt Content Percent	***Bulk Density (gm/cm^3) Gmb***	***Voids in Total Mix (VTM) %***	***Marshall Stability (KN)***	***Marshall Flow (mm)***	***Voids in Mineral Aggregate (VMA) %***	***Voids Filled with Asphalt (VFA)%***
4.25	2.369	5.35	11.20	2.4	14.47	60.3
4.75	2.382	4.15	13.35	2.6	14.45	70.3
5.25	2.397	2.85	13.75	3.1	14.36	80.0
5.75	2.425	1.00	10.5	3.6	13.82	90.2
6.25	2.420	0.5	9.8	4.8	14.45	90.6
O.A.C 5.02	2.403	3.10	13.47	2.8	14.21	78.9

Table (8): Marshall Results of Reclaimed Tire Rubber Mixture at Optimum Asphalt Content (as average of three Marshall Specimens).

Marshall Properties	Rubber Content %						
	0	1.5	3	4.5	6	7.5	9
Stability (kN)	13.47	13.35	13.65	14.3	15.5	14.8	14.2
Flow (mm)	2.8	2.23	2.25	2.35	2.5	2.55	2.6
Bulk Density (gm/cm^3)	2.403	2.37	2.361	2.359	2.356	2.342	2.321
V.T.M %	3.10	3.401	3.567	3.77	4.783	5.037	5.12
V.M.A%	14.21	15.59	15.74	16.15	16.85	17.1	17.89
V.F.A%	78.9	78.18	77.34	76.66	71.61	70.54	71.38

Table (9): Marshall Results of Wool Mixture at Optimum Asphalt Content (as average of three Marshall Specimens).

Marshall Properties	Wool Content %				
	0	3	6	9	12
Stability (kN)	13.47	13.68	14.5	13.83	12.58
Flow (mm)	2.8	3.3	3.7	4.6	4.78
Bulk Density (gm/cm^3)	2.403	2.371	2.37	2.392	2.322
V.T.M %	3.10	4.46	4.772	4.37	5.4
V.M.A%		16.93	16.96	17.07	18.189
V.F.A%	78.9	73.66	71.86	68.58	65.58

6% of Rubber & 6% of Wool gives maximum stability & minimum flow .this percent to tested by indirect and creep test.

Figure (2) shows the indirect tensile strength test for rubber & carbon fiber at 25ºC.

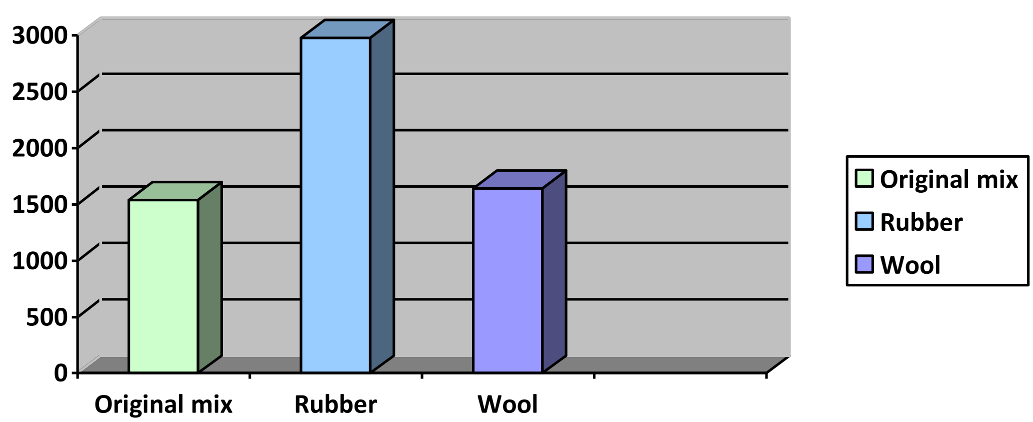
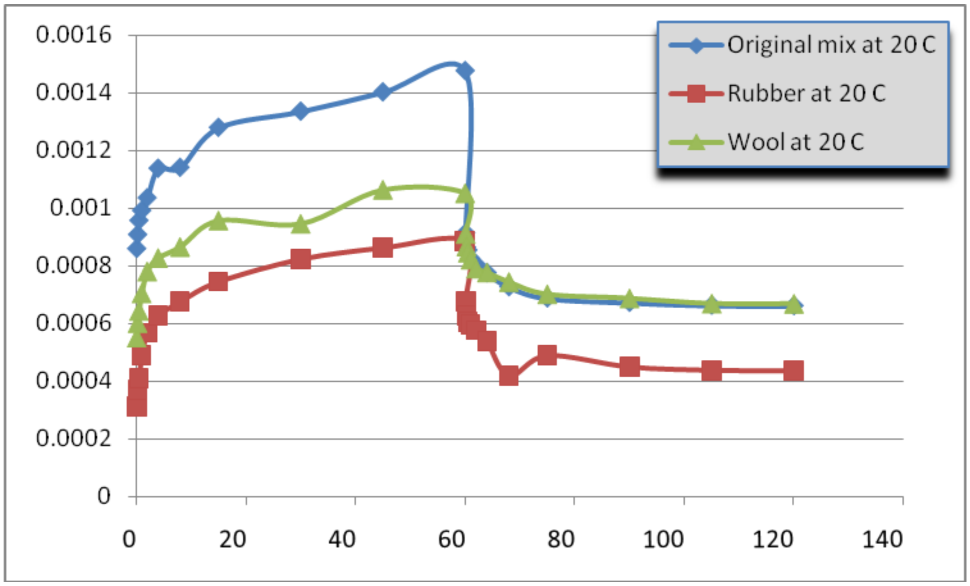


Figure (2): Indirect Tensile Strength Result in(Kpa).

Figure (3) and (4) show the creep test for rubber and wool at 20ºC and 40ºC

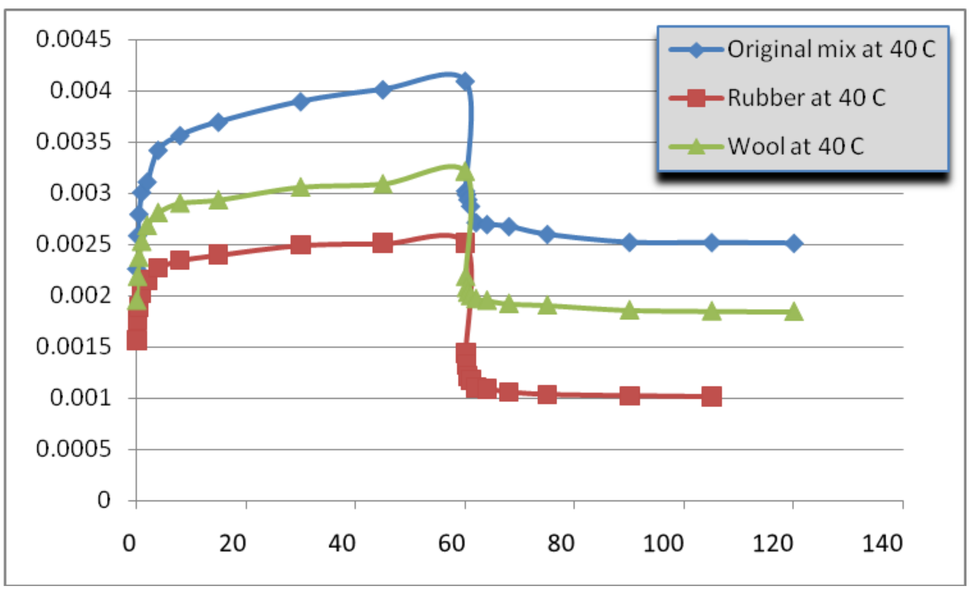
Strain, (mm/mm)



Time (min)

Figure (3): Creep Test Result at 20 C

Strain, (mm/mm)



Time (min)

Figure (4): Creep Test Result at 40 C

7- Conclusions:

For the type of asphalt, aggregate, & mixture compositions with two types of additives investigated in this study and within the limitations of the test program, the following points are concluded:

- The best Rubber content is 6% , led to increase Marshall Stability, Indirect tensile Strength & reduce Permanent Deformation as compared with original mix.
- The best Wool content is 6% , led to increase Marshall Stability, Indirect tensile Strength & reduce Permanent Deformation as compared with original mix.
- Rubber is more effective to reduce Permanent Deformation as compare with Wool.

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