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Influence of Liquid Asphalt on Resilient Modules and Permanent Deformation of Recycled Asphalt Concrete

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ABSTRACT

Tests were performed on Marshall samples and were implemented for permanent deformation and resilient modulus (Mr) under indirect tensile repeated loading (ITRL), with constant stress level. Two types of liquid asphalt (cutback and emulsion) were tried as recycling agents, aged materials that were reclaimed from field (100% RAP), samples were prepared from the aged mixture, and two types of liquid asphalt (cutback and emulsion) with a weight content of 0.5% were utilized to prepare a recycled mixture. A group of twelve samples was prepared for each mixture; six samples were tested directly for ITRL test (three samples at 25˚C and three samples at 40˚C), an average value for ITRL for every three samples was calculated (ITRL for unconditioned samples). The other six samples were placed in volumetric flask 4000-ml heavy-wall glass filled with water at 25˚C under a vacuum pressure of (3.74 kPa) for 5 to 10 minutes. Then the samples were put in deep freeze for 16 hours at -18˚C. The samples were frozen then were transported to a water bath at 60ºC for 24 hours. Then they were soaked in a water bath for 1 hour at 25ºC and tested for the ITRL test (three samples at 25˚C and three samples at 40˚C), the average value of ITRL for every three samples was calculated (ITRL for conditioned samples). It was concluded that the reduction in (Mr) at the Conditioned test as compared to the Unconditioned test was (29.5%, 22.27% and 9.09%) at 25˚C, while at 40˚C, the reduction was (21.28%, 15.53%, and 17.89%) for aged and recycled mixtures with (cutback), and (emulsion) respectively. The change in permanent deformation at the Conditioned test as compared to Unconditioned one was (76.19%, 75.61% and 53.22%) at 25˚C, while at 40˚C it was (56.48%, 35.19%, and 78.33%) for aged and recycled mixtures with (cutback), and (emulsion) respectively.

Key words: recycled mixture, aged mixture, liquid asphalt, cutback, emulsion.

تأثير الاسفلت السائل على معامل المرونة والتشوه الدائمي للخرسانة الاسفلتية المعاد تدويرها

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الخلاصة

اجريت الاختبارات على عينات مارشال، وتم تنفيذها لإيجاد التشوه الدائم ومعامل المرونة تحت الاحمال المتكررة للشد غير المباشر مع مستوى اجهاد ثابت. سيتم اختبار نوعين من الاسفلت السائل (القطران والمستحلب السائل) كعوامل إعادة تدوير للمواد القديمة التي تم الحصول عليها من الموقع بنسبة(100)%. وسيتم تحضير النماذج من الخلطة القديمة ونوعين من

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معاملات التدوير(القطران والمستحلب السائل)وبنسبة (0.5)% من وزن الخلطة لاستخدامها كمعاملات لإعادة التدوير. وتم اعداد اثني عشر عينة لكل خليط، واختبرت ست عينات مباشرة لاختبار الاحمال المتكررة للشد غير المباشر(ثلاث عينات بدرجة 25 مئوية وثلاث عينات بدرجة 40 مئوية)و حساب معدل القيمة لكل ثلاث عينات (الشد غير المباشر للأحمال المتكررة غير معرض لضرر الرطوبة).العينات الست الاخرة وضعت في قارورة حجمية 4000 مل ذات جدران زجاجية سميكة مملؤة بالماء بدرجة 25 مئوية تحت ضغط الفراغ من (3.74 كيلو باسكال) لفترة(5الى 10) دقيقة. ثم وضعت العينات في تجميد عميق لمدة 16 ساعة في درجة (-18) مئوية ونقلت العينات المجمدة بعد ذلك الى حمام مائي عند 60 درجة مئوية لمدة 24 ساعة. ثم غمرت في الماء لساعة واحدة بدرجة 25 مئوية واختبرت العينات لاختبار الشد غير المباشر تحت الاحمال المتكررة (ثلاث عينات بدرجة 25 مئوية وثلاث عينات بدرجة 40 مئوية) و حساب معدل القيمة لكل ثلاث عينات (الشد غير المباشر للأحمال المتكررة معرض لضرر الرطوبة) واستنتج ان الانخفاض في معامل المرونة للفحص المعرض لضرر الرطوبة بالمقارنة مع الفحص الغير معرض لضرر الرطوبة كان(29.5% ،22.27 % و 9.09%) في درجة 25 مئوية. بينما في درجة 40 مئوية الانخفاض كان(21.28% ، 15.53% ، و 17.89%) للخلطة القديمة والخلطات المعاد تدويرها مع(القطران والمستحلب السائل)على التوالي. وكان التغير في التشوه الدائم للاختبار المعرض لضرر الرطوبة بالمقارنة مع الاختبار الغير معرض لضرر الرطوبة (76.19% ، 75.61% و 53.22%) في درجة 25 مئوية ، بينما في درجة 40 مئوية كان (56.48% ، 35،19% و 78.33%) للخلة القديمة والخلطات المعاد تدويرها مع (القطران والمستحلب السائل) على التوالي.

الكلمات الرئيسية: الخلطة المعاد تدويرها ، الخلطة القديمة ،الاسفلت السائل ،القطران ،المستحلب السائل.

1. INTRODUCTION

Recycling is the operation of converting or using waste materials to obtain new products to benefit from the use of fresh materials, reduce air pollution, reduce energy use and contaminate water, as most substances are non-renewable. The current trend is to reduce new materials and energy consumption. In recent years the usage of recycled materials in pavements has become a progressively widespread pursuit in pavements. This is exclusively true for flexible pavements like hot mixture asphalt materials that are milled off road surfaces of existing and recycled for usage in construction of pavements. A well-recognized solution for deposing recycled materials of pavements is to incorporate them into base and sub-base applications for the construction of highway. Potential savings in construction cost and time have made the utilize of such recycled hot mixture asphalt an attractive alternative to engineer of the highways. Reclaimed asphalt pavement (RAP) also makes it possible to replace some of the binder that would be used in the mix already, making less need for as much virgin binder. Due to the aging of the RAP, it is also notably stiffer, which can lead to rutting resistance, moisture susceptibility, and increased strength than the softer virgin binders, **Al-Qadi, 2007.** Yet, the stiffness may lead to other problems, such as cracking, but there are many additives that can be combined with the RAP to alleviate this problem. this work is aimed to encourage adopting recycling, and recycled mixtures performance.

2. CHARACTERISTICS OF MATERIALS

2.1 Aged Materials

The reclaimed asphalt mixture was reached through the reclaimed of binder course layer of asphalt concrete of the highway. The highway had various cracks with heavily deterioration and ruts occurring on the surface. The bitumen mixture of reclaimed was guaranteed to be free from loam and deleterious substances collected on the upper surface. The reclaimed mixture was subjected to ignition test after heating, according to the procedure, **AASHTO T 308** of the National Center for Construction Laboratories and Research Laboratories (NCCLR) to find binder, filler content, gradation, and aggregate characteristics. The characteristics of the aged materials after ignition test presented in **Table 1.**

Table 1. Properties of aged materials after ignition test.

Material	Property		Value
Asphalt binder	Binder content %		5.46
Coarse aggregate	Bulk specific gravity		2.59
	Apparent specific gravity		2.63
	Water absorption %		1.071
	Wear% (Los Angeles abrasion)		23%
Fine aggregate	Bulk specific gravity		2.601
	Apparent specific gravity		2.823
	Water absorption %		1.94
Mineral filler	Percent passing sieve no.200		98%
	Specific gravity		2.85
Aged Mixture	Marshall Properties	Stability	17.4
		Flow	3.05
		Air voids	5.21%
		Bulk density	2.329
		Gmm	2.465

The old (reclaimed) aggregate of the aged mixture was identified. Four samples were randomly selected from the material stack process to isolate the binder from aggregate. Samples were exposed to test ignition and were then combined and separated into different sizes for calculating the gradient for every sample. **Table 2** shows the old aggregate gradient for four samples.

Table 2. Gradation of old (reclaimed) aggregate obtained from the aged mixture.

Sieve no.	Sieve size (mm)	% passing by weight	SCRB Specification 2003
			Binder course
1½"	37.5	---	---
1"	25.4	---	100
3/4"	19	99	90-100
1/2"	12.5	91	70-90
3/8"	9.5	81	56-80
No.4	4.75	61	35-65
No.8	2.36	45	23-49
No.50	0.3	16	5-17
No.200	0.075	6.6	3-9

Table 2 illustrates that the gradation of old (reclaimed) aggregate for the binder layer has slight deviation from the Specification limits of Roads and Bridges**, SCRB, 2003.**

2.2 Recycling Agents

2.2.1 Cutback liquid asphalt

Medium curing cutback liquid asphalt from Al-Dura refinery was used for recycling in this research. The properties of medium curing cutback liquid asphalt are presented in **Table 3.**

Table 3. Properties of medium curing cutback liquid asphalt.

property	Test Conditions	ASTM Designation	value
Kinematic viscosity	60°C	D2170	42
Flash point	-	3143	52
Residue from distillation	360°C	D402	63
percent volume by different Tests on residue from distillation:			
Viscosity	60°C	D2171	67
Ductility	25°C	D113	132
Solubility in trichloroethylene	-	D2042	0.2
Water	-	D95	0.13

2.2.2 Emulsion liquid asphalt

Cationic emulsion liquid asphalt from the Ministry of Industry and Minerals was used for recycling in this research. The properties of cationic emulsion liquid asphalt are presented in **Table 4.**

Table 4. Properties of cationic emulsion liquid asphalt.

property	Test Conditions	ASTM Designation	value
Viscosity,pa s	50°C	D7496	235
Storage stability,time	24-h	D6930	0.7
Particle Charge	-	D7402	positive
Sieve Test	-	D6933	0.063
Tests on Residue from Distillation			
Penetration, 25°C	25°C,100g,5 S	D5	57
Ductility,cm	25°C, 5 cm/min	D113	59
Solubility in trichloroethylene, or N-Propyl B	-	D2042	113

3. EXPERIMENTAL PROGRAM

3.1 Preparation of Mixtures

3.1.1 Reference mixture (aged mixture)

The aged mixture was obtained from the reclaimed material from the field. It was heated to 145ºC and samples were prepared for further testing to investigate the performance after recycling. **Fig. 1** show reclaimed material.

Figure 1. Reclaimed material.

3.1.2 Preparation of a recycled mixture

The recycled mixture consists of a 100% reclaimed mixture and a mixed recycling agent (RA) together in percentages defined according to the blending proportions. First, the reclaimed mix was heated to about 160° C. The liquid asphalt was added to the hot RAP in the required amount; the liquid asphalt was added in a 0.5% of the mixture weight and mixed for 2 minutes till all the mix was coated visually with an RA as reported by**, Sarsam, 2007**. The recycled mixture was prepared using two types of liquid asphalt: cutback and emulsion.

3.1.3 Preparation of accelerated short term aged recycled mixture

Recycled mixtures have been heated to 130° C to become loose and then in the shallow trays diffuses with a thickness of 3 cm and subjected to one cycle of the accelerated aging process by storing inside an oven for 4 hours at 135° C according to the procedure Superpave**, AASHTO (SP2).** The mix was stirred every 30 minutes during the short term aging process to prevent the outside of the mixture from aging more than the inner side because of the increased air exposure. After completing the accelerated aging process, Marshall samples, cylindrical samples were constructed after the material was heated to 150 °C.

3.2 Preparation of Marshall Specimens

It is a cylindrical sample of (4 inches) and height (2.5 ± 0.05) inches. The Marshall mold, spatula, and hammer were heated to squeeze the hot plate to a temperature of 150° C. The mold assembly was placed on the compaction pedestal and 75 blows on the top and the bottom of the sample were applied with specified compaction hammer of 4.535 kg sliding weight, and a free fall in 457.2 mm (18 inches). The temperature of the mixture immediately and before the compaction temperature was (150°C). The sample in the mold was left to cool for 24 hours at room temperature and then it was extracted from the mold utilizing mechanical jack. Marshall samples were subjected in the Indirect Tensile Repeated Load Test (ITRL), **Sarsam, 2015.**

4. INDIRECT TENSILE REPEATED LOAD TEST (ITRL)

The ITRL test identified by**, ASTM D4123** "Method of Standard Test for Indirect Tension for Mr of mixtures of Bituminous " was conducted utilizing the (PRLS). The apparatus used for this purpose is described in details by**, Al-Bayati, 2006.** Marshall Samples was performed tests. For each mix, a group of twelve samples was prepared; six samples were tested directly for ITRL test (three samples at 25˚C and three samples at 40˚C). The average value ITRL for every three samples was calculated (ITRL for unconditioned samples). The other six samples were placed in volumetric flask 4000-ml heavy-wall glass filled with water at 25˚C under a vacuum pressure of (3.74 kPa) for (5 to 10) minutes. The samples were put in the deep freeze for 16 hours at -18˚C. The samples were frozen then were transported to a water bath at 60ºC for 24 hours. Then they were soaked in a water bath for 1 hour at 25˚C and tested for indirect tension repeated load test ITRL (three samples at 25˚C and three samples at 40˚C). The average value ITRL for every two samples was calculated (ITRL for conditioned samples). The total number of the Marshall size samples was 24 for the ITRL test. In tests, the loading of repetitive is applied to the diametral sample, and the resilient vertical strain was measured under the repetition of the load. Loading diametral is applied with frequency a constant loading of 60 cycles/min and the cycle of loading comprises of application of the load repetitions for 0.1 sec load by 0.9 sec of the period of rest to simulate the test case described by Shell Nomograph that was taken up in**, Yuder,** and **Witczak,**

1975. The temperatures of testing of 25 and 40 ºC were utilized, and the stress level applied was 20 psi.

The test process utilized in this work are summarized as follows:

1. Place the sample in the chamber of testing at 25 ºC and 40ºC for 120 minutes to bring it to test temperature and to permit for a uniform distribution of temperature inside the sample.
2. After completion of the sample "setup", the dial gauge is appointed to zero reading in the equipment of test to the identified stress level. The pressure actuator is set. The timer (both rest port and loading port) is also appointed to the desired load and the duration of rest.
3. A video camera is located at an appropriate place to cover the view of dial gauge reading and set able to begin recordings.
4. The permanent deformation after repeated stress application was recorded.

The analysis of acquired deformation data includes the following:

1. Determination of the permanent deformation at the load repetitions following: (1, 10, 50, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000,1100 and 1200) or till the sample failed.
2. The permanent strain (εp) is computed by applying the following equation, **Yoder,** and **Witczak, 1975**:

$$\varepsilon p = \frac{pd * 10^6}{h} \qquad (1)$$

where:

εp: permanent strain (mm/mm).

pd: reading of dial gauge for permanent strain (1degree=0.01 mm).

h: specimen diameter (mm).

3. At a load repetition of (50 to 100), the resilient deformation was determined.
4. The resilient strain (εr) and (Mr) were computed as follows:

Resilient strain:

$$\mathcal{E}\boldsymbol{r} = \frac{rd}{h} \qquad (2)$$

where:

εr : vertical resilient strain (mm/mm).

rd: reading of dial gauge for vertical resilient strain (1 degree =0.01 mm).

h: specimen diameter (mm).

$$Mr = \frac{\sigma}{\varepsilon r} \qquad (3)$$

Where:

Mr: resilient modulus (N/mm^2).

σ: repeated diametral stress (N/mm^2)

εr: vertical resilient strain (mm/mm).

The permanent vertical strain is measured as a function of load applications number, stress 20psi, at 25 and 40ºC. Perceiving the fact that the lower permanent strain is identified with, the lower effectively for corrugation and rutting. **Fig. 2** shows part of the core conditioning process and **Fig. 3** shows the pneumatic repeated load system.

Figure 2. Part of the core conditioning process.

Figure 3. Pneumatic repeated load system.

5. RESULTS AND DISCUSSION

5.1. Effect of Recycling Agent Types on Resilient Modulus (Mr) Under ITS

The resilient modulus (Mr) represents the ratio of applied stress to the recoverable strain that takes place after the applied stress has been removed. The frequency of load application used is 1 Hz, with load duration of 0.1 sec and a resting period of 0.9 sec. The Mr is a measure of materials responses to load and deformation. Generally, higher modulus indicates greater resistance to deformation. Mr was determined at a stress level of 0.138 MPa, temperature 25 and 40°C on two stages (Unconditioned and Condition). Testing procedures are by the standard test method for an indirect test for Mr of bituminous mixtures**, ASTM D4123.** Mr of the aged mixture is significantly higher than the values obtained for recycled mixtures; this could be attributed to the stiffer mixture obtained (aged mixture) before recycling. **Table 5** shows the Resilient Modulus value for mixtures. The Mr decreases, when the temperature increases from 25˚C to 40◦C. Also it can be noted from **Table 5**, the Mr decreases from unconditioned to the conditioned stage. **Table 6** shows the percentage of changes in Resilient Modulus for recycled mixtures with (cutback and emulsion) compared to the aged mixture. While **Table 7** shows the percentage of decline in Resilient Modulus for aged and recycled mixtures with (cutback and emulsion) at condition test compared to the same mixtures at the unconditioned test. From the results and when adding liquid, the asphalt exhibits a reduction in resilient modulus compared with the aged mixture since it was believed that excess asphalt would reduce the interparticle connection, causing more lubrication action which reduces the strength properties, hence a decrease in the Mr.

Table 5. Resilient modulus value for aged and recycled mixtures.

Mix. Type	Resilient Modulus (KPa) (Unconditioned)		Resilient Modulus (KPa) (Conditioned)	
	25˚C	40˚C	25˚C	40˚C
aged	267200	213846	188376	168336
cutback	206358	158984	160386	134281
emulsion	169050	153773	153673	126252

Table 6. Percent of reduction in Mr for recycled mixtures compared to the aged mixture.

Test of the mixture at	Recycled mixtures with	
	cutback	emulsion
25˚C Uncondition	22.77	36.73
40˚C Uncondition	25.65	28.09
25˚C Condition	14.85	18.42
40˚C Condition	20.23	25

Table 7. Percent of reduction in Mr for aged and recycled mixtures at condition test compared to the same mixtures at the unconditioned test.

Test at	Recycled mixtures with		
	aged	cutback	emulsion
25˚C	29.5	-22.27	9.09
40˚C	21.28	-15.53	17.89

5.2 Effect of Recycling Agent Type on Resistance to Permanent Deformation

The indirect tensile tests present that the permanent vertical plastic strain is measured as a function of the number of load applications at stress level = 0.138 Mpa (20 psi) and temperature (25 and 40) ˚C on two-stage (Unconditioned and Conditioned) as illustrated in **2.3** from this work. Three specimens were tested for each type of mixture, and the mean value was found for each case, and a Power model is often fitted to the accumulated permanent deformation curve. It is likely the most generally utilized equation of permanent deformation. In this work, the next classical power model utilized**, Barksdale, 1971:**

$$\mathcal{E}p = aN^{b} \quad (4)$$

where, a and b are the intercept and slope of the curve in log-log space. Consequently, the permanent strain at N=1 represents the intercept (a), where N is load cycles number. The higher the value of intercept, the larger the strain and hence the larger the potential for permanent deformation as mentioned in the Superpave study conducted**, Witczak, et al., 1999.** While slope (b) represents the rate of change in the permanent strain as a function of the change in loading cycles (N) in the log-log scale. A high slope value for a blend indicates an increase in the material deformation rate hence less resistance against rutting. A blend with a low slope value is preferable as it prevents rutting distress mechanism at a slower rate**, GUL, 2008.** To evaluate the permanent deformation, test the three selected parameters were permanent deformation, intercept, and slope measured in 1000 cycles. The consequences of these parameters were presented in **Table 8** and **Table 9. Fig. 4, 5, 6** and **Fig. 7** show the effect of recycling agent on permanent microstrain. Identifying the fact that the lower permanent deformation is correlated to the lower sensitivity for corrugation and rutting, it means that resistance to permanent deformation for aged mixture higher than recycled mixture, for example at 1000 cycles the permanent deformation for (cutback and emulsion) were (2235 and 3083) microstrain respectively at 25˚C (Unconditioned), while for aged mixture, it was (1596) Microstrain. From results shown in **Table 8** it appears that the recycled mix with (emulsion) had the highest permanent deformation value as compared to recycled mixture with(cutback) at 25˚C(Unconditioned), while at 40˚C (Unconditioned) the recycled mix with (cutback) had the lowest permanent deformation value compared to the recycled mixture with (emulsion). But also it had the highest permanent deformation value at 40˚C compared to the same mix at 25˚C. Also in general and from **Table 8** and **Table 9,** it can be seen that the permanent deformation of the recycled mixtures at (Conditioned) was more than the permanent deformation of the same mixtures at (Unconditioned). From **Table 8** and **Table 9**, the intercept, slope, and permanent deformation are significantly impacted by temperature. For example, the slope, intercept, and permanent deformation at the 1000 cycle increased, when the temperature increases from (25 to 40) ˚C. This implies that the rate of plastic distortion increases with the temperature increasing.

This agrees with the results of**, Al-Bayati, 2006; Abed, 2010; Hilal, 2011** and **Al-Shujairy, 2014.**

Table 10 presents the percentage of changes in permanent deformation for recycled mixtures (emulsion and cutback) compared to the aged mixture. While **Table 11** shows the percentage of changes in permanent deformation for recycled mixtures (cutback and emulsion) at Condition test compared to the same mixtures at Unconditional test. It can be noticed that aged mixtures before recycling exhibits lower potential for deformation compared with the recycled mixture (cutback and emulsion) at unconditioned and conditioned stages, this may be attributed to the stiff nature of the aged mixtures. The deformation increases when the temperature increases from 25 ° C to 40 ° C. This is due to the type of asphalt which leads to a decrease in the bonding of the aggregates when the temperature increases.

Table 8. Slops, intercepts, and permanent microstrain at 1000 cycle value for aged and recycled mixtures (unconditioned).

Mix.Type	25˚C			40˚C		
	Intercept Microstrain	Slope	Permanent Microstrain @1000cycle	Intercept Microstrain	Slope	Permanent Microstrain @1000cycle
Aged	289.2	0.2319	1596	408.72	0.2792	3543
Cutback	340.9	0.2464	2235	503.71	0.3191	5912
Emulsion	333.21	0.2792	3083	459.63	0.2977	4652

Table 9. Slops, intercepts, and permanent microstrain at 1000 cycle value for aged and recycled mixtures (conditioned).

Mix.Type	25˚C			40˚C		
	Intercept Microstrain	Slope	Permanent Microstrain @1000cycle	Intercept Microstrain	Slope	Permanent Microstrain @1000cycle
Aged	415.26	0.2548	2812	509.77	0.3077	5557
Cutback	411.99	0.2949	3925	590.12	0.3403	7993
Emulsion	490.95	0.2917	4724	647.71	0.337	8296

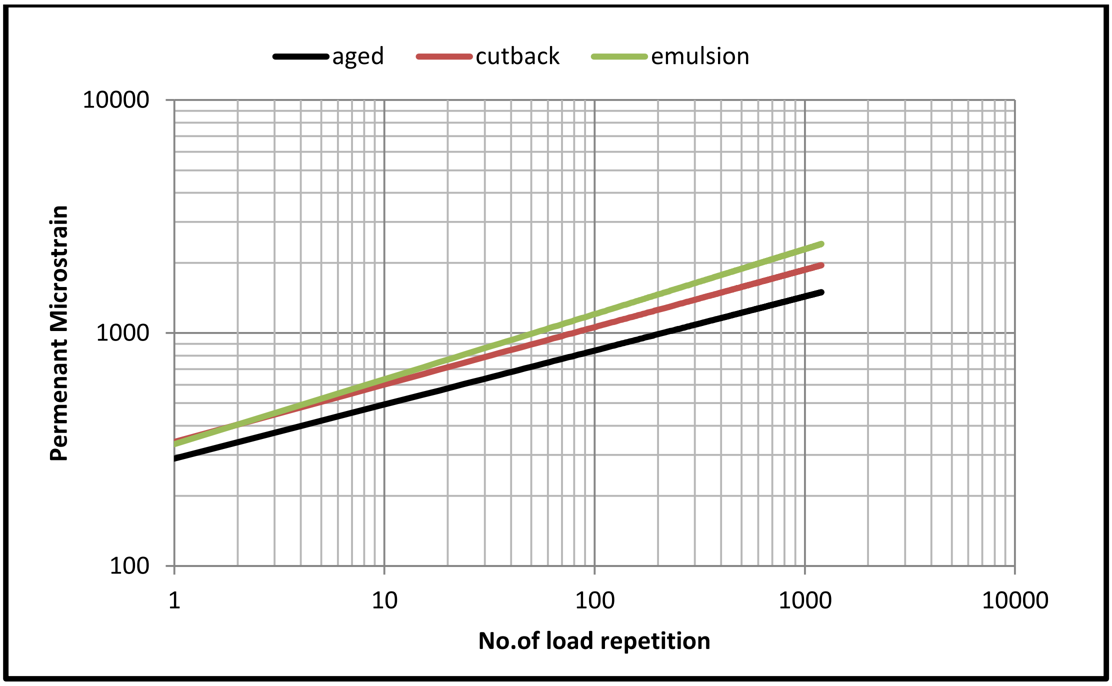

Figure 4. Typical relationship between strain and load repetition for (aged and recycled mixtures) at (25°c) unconditioned.

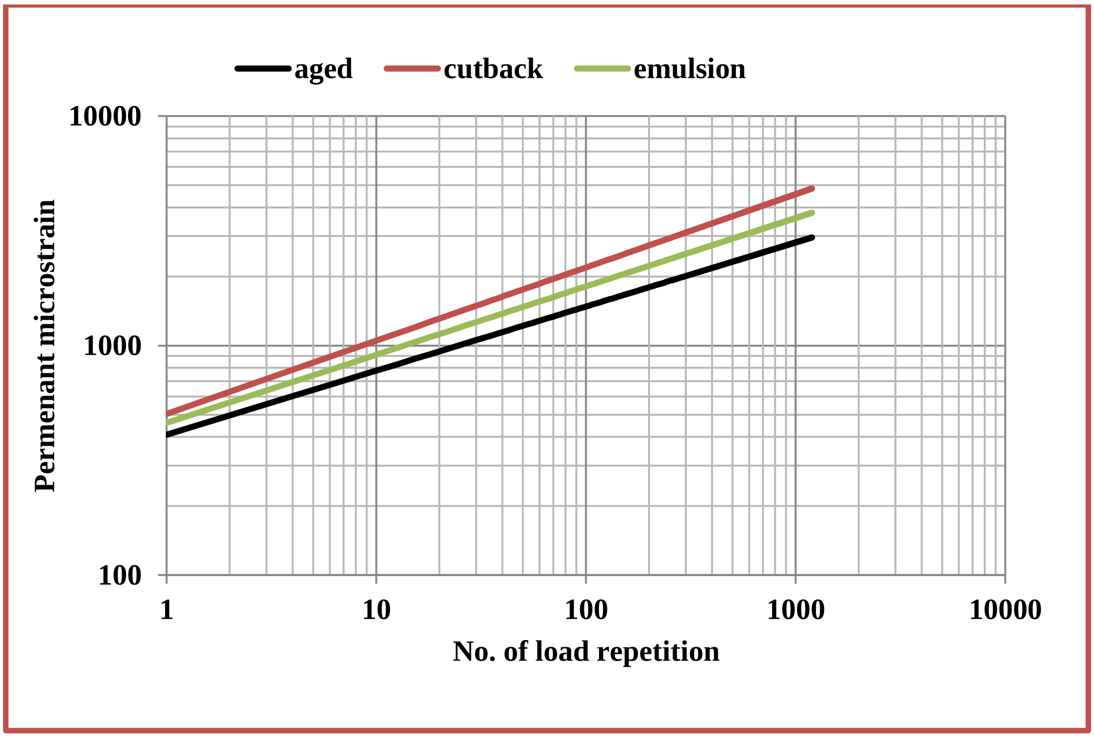

Figure 5. Typical relationship between strain and load repetition for (aged and recycled mixtures) at (40°c) unconditioned.

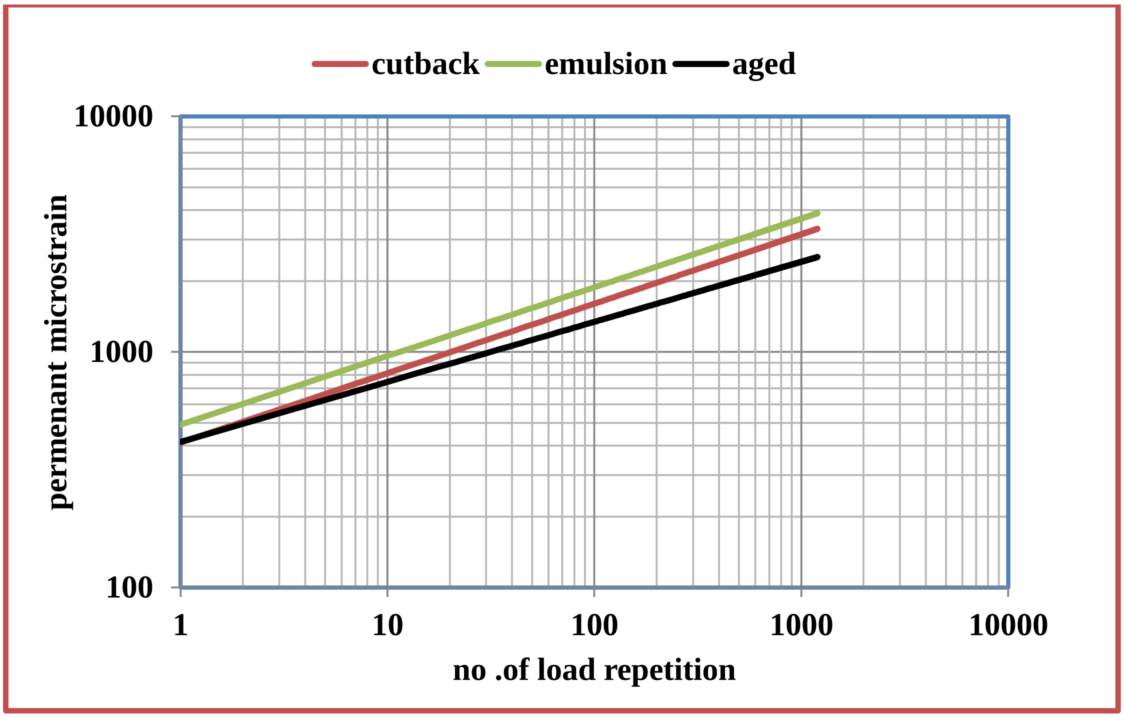

Figure 6. Typical relationship between strain and load repetition for (aged and recycled mixtures) at (25°c) conditioned.

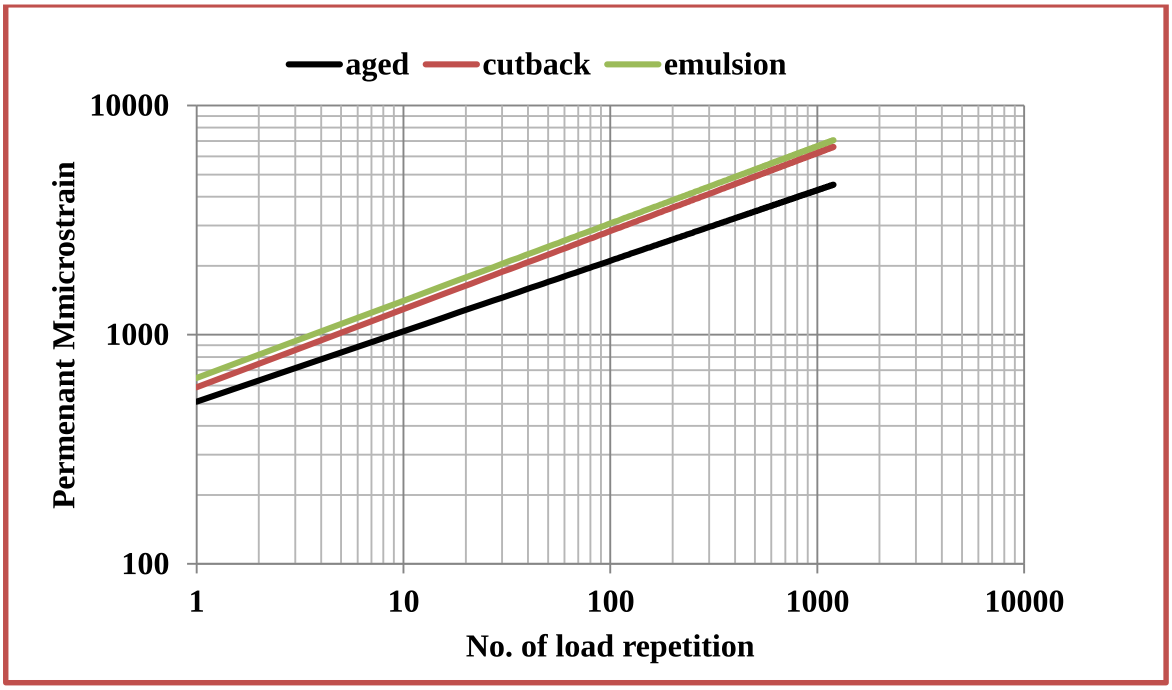

Figure 7. A typical relationship between strain and load repetition for (aged and recycled mixtures) at (40°C) conditioned.

Table 10. Percent of changes in permanent deformation for recycled mixtures compared with the aged mixture.

Test of the mixture at	Recycled mixtures with	
	cutback	emulsion
25˚C Unconditioned	40.03	93.17
40˚C Unconditioned	66.86	31.3
25˚C Conditioned	39.58	67.99
40˚C Conditioned	43.83	49.29

Table 11. Percent of changes in permanent deformation for aged and recycled mixtures at condition test compared to the same mixtures at the unconditioned test.

Test at	Aged mixture	Recycled mixtures with	
		cutback	emulsion
25˚C	76.19	75.61	53.22
40˚C	56.48	35.19	78.33

6. CONCLUSIONS

1- The importance of indirect tensile testing using repeated load to demonstrate the behavior of different asphalt materials and comparison between them.

2- The percent of reduction in resilient modulus (Mr) for unconditioned test was (22.77%, and 36.73%) at 25˚C, while at 40˚C, it was (25.65%, and -28.09%) for recycled mixtures with (cutback), and (emulsion) respectively as compared with aged mixtures.

3- The percent of the decline in (Mr) for the conditioned test was (14.85%, and 18.42%) at 25˚C, while at 40˚C, it was (20.23%, and 25 %) for recycled mixtures with (cutback), and (emulsion) respectively as compared with aged mixtures.

4- The percent reduction in Mr at Conditioned test as compared to Unconditioned test was (29.5%, 22.27%, and 9.09%) at 25˚C, while at 40˚C, it was (21.28 %, 15.53% and 17.89%) for aged and recycled mixtures with (cutback), and (emulsion) respectively.

5- The percent change in permanent deformation at Conditioned test as compared to unconditioned test was (76.19%, 75.61%, and 53.22%) at 25˚C, while at 40˚C it was (56.48%, 35.19% and 78.33%) for aged and recycled mixtures with (cutback), and (emulsion) respectively.

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8. NOMENCLATURE

RAP = reclaimed asphalt pavement

RA = recycling agent

NCCLR = national center for construction laboratories research.

AASHTO = American Association of State Highway and Transportation Officials.

ITRL = indirect tension repeated load.

Mr = resilient modulus.

PRLS = pneumatic repeated load system.

SCRB = state corporation for roads and bridges.