Journal of Engineering
journal homepage: www.joe.uobaghdad.edu.iq
Number 2 Volume 26 February 2020

***Civil and Architectural Engineering***

# Influence of Additives on Permanent Deformation and Resilient Modulus of Recycled Asphalt Concrete

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## ABSTRACT

Tests were performed on asphalt concrete specimens with (101.6 mm in diameter and 101.6 mm in height), and the results were implemented for calculating permanent deformation and resilient modulus under repeated compressive stress with different levels of stresses (0.068, 0.138 and 0.206) MPa at 40 ºC. Two types of additives namely (carbon black-asphalt) and (SBR-asphalt) were tried as rejuvenators with three percentages of (0.5, 1 and 1.5) % by weight of asphalt cement along with two ratios of AC (1 and 2) % have been implemented as rejuvenator and blended with the reclaimed asphalt concrete. Aged materials were obtained from the site. 100% Reclaimed Asphalt Pavement material from the reclaimed mixture is implemented. A set of (3) specimens were prepared for every mixture; three specimens were tested under (repeated compressive stress) at each level of stress. The objective of this work was to study the effect of two types of additives (Styrene-Butadiene-Rubber (SBR) and carbon black) on the performance of recycled asphalt concrete mixture. It was concluded that the Resilient modulus (Mr) at (0.138 and 0.206) MPa stress level decreases by (14, 22 and 8) % and (22, 34 and 11) for reclaimed and recycle mixtures with (carbon black-asphalt and SBR-asphalt) respectively when compared with that at 0.068 MPa. Permanent deformation for recycled mixtures with (carbon black-asphalt and SBR-asphalt) increased by (65.9, 4.54) %, (146.6, 27.2) % and (79, 5.5) % at level of stresses (0.068, 0.138 and 0.206) MPa respectively when compared to reclaimed mixture.

**Keywords**: aged mixture, recycled mixture, carbon black, Styrene-Butadiene Rubber (SBR).

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Peer review under the responsibility of University of Baghdad.
https://doi.org/10.31026/j.eng.2020.02.12

Article received: 17/2/2019
Article accepted: 27/4/2019
Article published: 1/2/2020

# تأثير المضافات على التشوه الدائمي ومعامل المرونة للخرسانة الاسفلتية المعاد تدويرها

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**الخلاصة**

أجريت الاختبارات على عينات اسفلت بقطر 101.6 مم وبارتفاع 101.6 ملم واعتماد النتائج لغرض احتساب التشوه الدائم ومعامل المرونة تحت ضغط متكرر بمستويات مختلفة من الإجهادات (0.068 ، 0.138 و 0.206) ميجاباسكال عند درجة حرارة 40 مئوية . تم استخدم نوعان من المواد المضافة( اسود الكاربون - الإسفلت و مطاط ستيرين بوتادين - الأسفلت) والتي تعمل كمعاملات تدوير مع ثلاثة نسب من المواد المضافة (0.5 و 1 و 1.5) ٪ من (وزن الأسفلت المضاف) وباستخدام نسبتين من الاسفلت (1 و 2) ٪ وقد تم تنفيذها كمعاملات تدوير وبعدها تم مزجها مع الخرسانة الإسفلتية المستصلحة. واستخدمت (1.5٪) من أسود الكربون مع (1٪) من أسمنت الإسفلت وكذلك (1.5٪) من مطاط ستيرين بيوتادين مع (1٪) من الإسفلت . يتم تحضير المواد القديمة التي تم الحصول عليها من الموقع بنسبة 100٪ عينات خرسانة إسفلتية مستصلحة. تم إعداد مجموعة من (3) عينات لكل خلطه . تم اختبار ثلاثة عينات تحت اختبار (الإجهاد الانضغاط المتكررة) في كل مستوى من مستويات الاجهاد. تهدف هذه الدراسة إلى اكتشاف تأثير نوعين من الإضافات (مطاط الستايرين البيوتاديين (SBR) و اسود الكاربون ) على أداء خليط الخرسانة الإسفلتية المعاد تدويره. وقد أوضح أن نسبة النقصان في معامل المرونة عند مستوى اجهاد (0.138 و 0.206) ميجاباسكال بمقدار (14 ،22 ، 8) ٪ (22 ،34، 11) ٪ بالنسبة للخلطة الخرسانيه المستصلحه والخلطات المعاد تدويرها ب( اسود الكاربون - الإسفلت و مطاط ستيرين بوتادين - الأسفلت) عند مقارنتها مع معامل المرونة عند مستوى اجهاد (0.068) ميجاباسكال .اما التشوه الدائم ارتفع بنسبة (65.9 ، 4.54) ٪ ، (146.6 ، 27.2) ٪ و (79 ، 5.5) ٪ عند مستوى الضغوط (0.068 ، 0.138 و 0.206) ميغاباسكال على التوالي بالنسبة للخلطة المعاد تدويرها مع (اسود الكاربون - الإسفلت و مطاط ستيرين بوتادين - الأسفلت) عند مقارنتها مع الخلطه الاسفلتية المستصلحة .

**الكلمات الرئيسية :** الخلطة القديمة ، الخلطة المعاد تدويرها ،اسود الكاربون ، مطاط الستايرين البيوتاديين.

## 1. INTRODUCTION

In the mid-seventies of the past century, recycling strategies were used, **(AL-Shujairy, 2014**. The recycling of the pavement was generally considered as a financial arrangement **(Mcbee et al., 1979)**, **(Kallas, 1984)**, and **(Elian, 1989)**.

Recyclables and reuse essential raw material could repeat the valued benefits of asphalt. It is principally 100% reusable and itself, but with continually increasing, the prospect of recycling will continue to expand. Precisely due to its recyclability, the pavement is a highly valued natural resource and a generally sound invested for current and future generations. The recycling of asphalt is also confirmed as a financially successful modern technology, which is also ecologically, economically beneficial as well as contributes to the conservation of mineral resources. Enhancing and making the best use of reused asphalt creates sustainable meaning in providing the roads of the twenty-first century and the previous, **(European Asphalt Pavement Association, 2014)**

Consequently reusing material will be gainful. To emphasizing improvement, on accentuating development in the current era, reusing for asphalt is one of the effective , also proven restoration procedures, **(Shunyashree et al., 2013).** Such changes will affect the cost of the structure maintenance, both economically to the client and naturally to society in wide-ranging and any investment might be transitory, **(Nichollsa et al, 2014).** In latest years, attitudes to the environment have changed significantly, and preservation of assets has become an extremely important issue, hence and because of the expanded demand, limited aggregate and binder supply. HMA producers have begun utilizing RAP as a valued component in HMA. Therefore, there has been rehabilitated interest in expanding the measure of RAP used in HMA, **(Copeland, 2011).**There are few local studies on recycling process, **(Sarsam, 2007); (AL-Zubaidi, 2013); (Al-Saaidy, 1998),** and these studies encourage the adoption of the recycling, and to prepare some valued data on the right materials which can be used, as well as the of recycled asphalt mixtures performance. The objective of these studies was to explore the impact of recycling agents on recycled asphalt concrete mixtures.

## 2. CHARACTERISTICS OF USED MATERIALS

### 2.1 Aged Materials

The Reclaimed asphalt mixture was obtained by the rubblization of the asphalt concrete from the highway section in The Second Hindiyah Bridge which is located in the city of Tuwerij at Karbala province. This highway was constructed in 2012 by the Ministry of Construction and Housing. The rubblized section includes asphalt stabilized base coarse layer and one layer of binder coarse. The optimum content of asphalt cement of grade 40-50 utilized when constructing the road was equal to (4.7%) for binder layer of asphalt concrete. The main problem of this road is the uneven thickness in different places along the section, as well as the drop the sub-layers of this road due to high traffic loads that led to the dropping of asphalt concrete layer. The Reclaimed asphalt mixture obtained was guaranteed to be free from damaging substances and loam collected on the top surface. The reclaimed mixture was heated; combined and reduced to testing size as per **(AASHTO, 2013)**; a typical sample was exposed to ignition test based on **(AASHTO, T 308 )** procedure at National Center for Construction Laboratories and Research (NCCLR) to attain binder content and filler content; gradation and properties of aggregate. **Table 1** illustrates the properties of aged materials during construction and after ignition test. Two samples have been obtained randomly from old mixture, the gradation for the reclaimed aggregate obtained from these samples. These samples were exposed to the ignition test to separate binder from aggregate, then the aggregate was divided and sieved to several sizes to determine gradation for these samples. The variances between samples were in a slight degree, and the average gradation of the two samples obtained to be the aged aggregate gradation is shown in **Table 2** which demonstrates the gradation of job mix formula during construction of highway and reclaimed aggregate for binder layer which falls within Specification limits of Roads and Bridges, **(SCRB, 2003)**. **Fig.1** shows gradation of aggregates for the binder course layer.

**Table 1** Properties of aged materials after ignition test and during construction

| material | property | | value | |
|---|---|---|---|---|
| | | | After Ignition | During construction |
| Asphalt binder | Binder content % | | 3.84 | 4.7 |
| Aged Mixture | Marshall Properties | Stability (kN) | 17.532 | 10.8 |
| | | Flow (mm) | 2.966 | 3.5 |
| | | Bulk density (gm/$cm^3$) | 2.32 | 2.36 |
| | | Air voids (%) | 5.1 | 3.5 |
| | | Gmm (gm/$cm^3$) | 2.448 | 2.445 |
| Coarse aggregate | Bulk specific gravity (gm/$cm^3$) | | 2.62 | 2.597 |
| | Apparent specific gravity (gm/$cm^3$) | | 2.76 | 2.72 |
| | Water absorption % | | 0.83 | 1.02 |
| | Percent of Fracture % | | 93 | 95 |
| Fine aggregate | Bulk specific gravity (gm/$cm^3$) | | 2.67 | 2.65 |
| | Apparent specific gravity (gm/$cm^3$) | | 2.81 | 2.82 |
| | Water absorption % | | 1.52 | 1.61 |
| Mineral filler | Percent passing sieve no.200 | | 97 | 98 |
| | Specific gravity | | 3.10 | 3.15 |

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

| English sieves (in) | Standard sieves (mm) | (% Passing by Weight of Total Aggregate + Filler) | | | |
|---|---|---|---|---|---|
| | | During construction | | After ignition | Specification limit |
| | | Limit of job mix formula | Mix formula | % passing by weight | |
| 1 | 25 | 100 | 100 | 100 | 100 |
| ¾ | 19 | 92-100 | 98 | 96.5 | 90-100 |
| ½ | 12.5 | 76-88 | 82 | 86.5 | 70-90 |
| 3/8 | 9.5 | 62-74 | 68 | 72 | 56-80 |
| No.4 | 4.75 | 40-52 | 46 | 44 | 35-65 |
| No.8 | 2.36 | 30-38 | 34 | 31.5 | 23-49 |
| No.50 | 0.3 | 11-19 | 15 | 12 | 5-19 |
| No.200 | 0.075 | 4.6-8.6 | 6.6 | 5.85 | 3-9 |

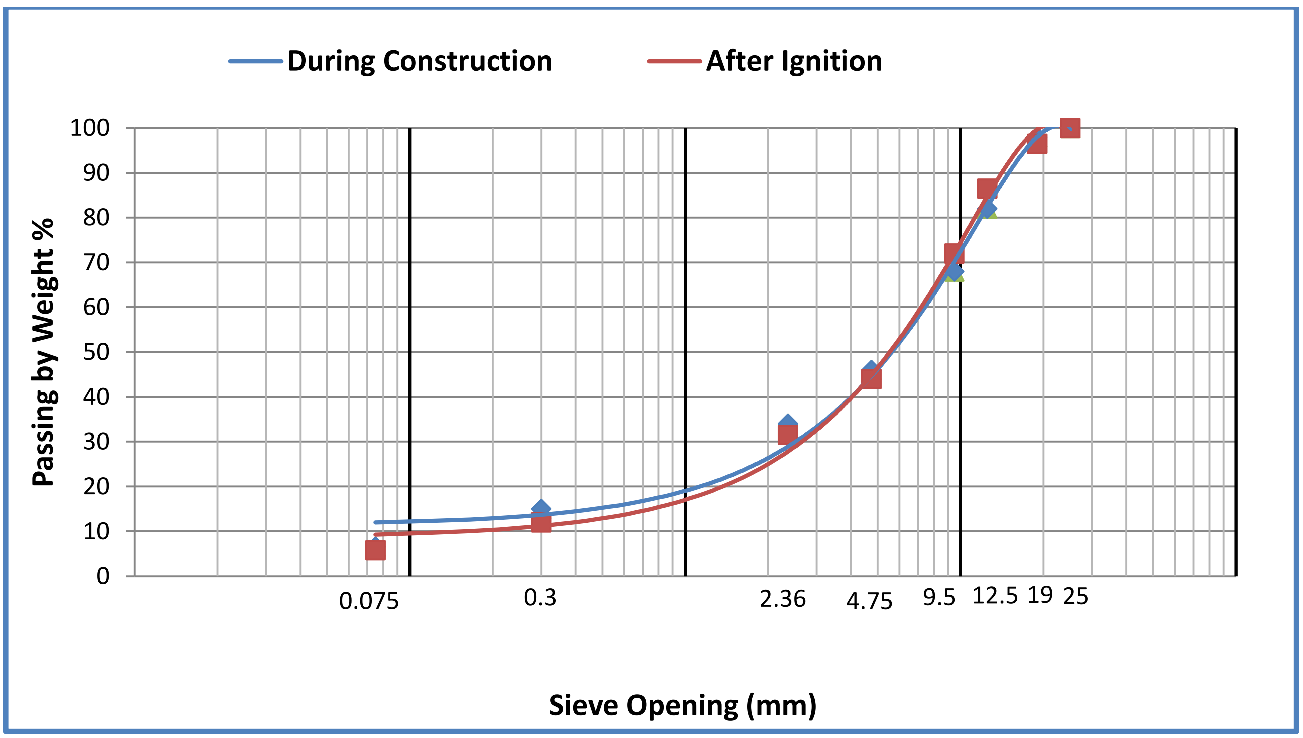


**Figure 1.** Gradation of aggregates for binder course layer .

## 2.2 Recycling Agents

Asphalt binder loses many of its oil components during construction and service, resulting in a high proportion of asphaltenes in the blend, which leads to increased stiffness and viscosity of the binder and decreases ductility, making the binder more hard and brittle. To recycle this hard and brittle aged pavement, the asphalt must be returned or changed to have the rheological properties of the original asphalt. This transformation is completed by adding liquid additives to the mixture being recycled; these additives have been called recycling agents or softening agents **(Jimenez, 1980); (Al-Qadi et al, 2007); (Hasan, 2012),** and **(AL-shujairy, 2014).**

2.2.1 Asphalt cement blended with carbon black

Asphalt cement of penetration grade (40-50) from Al-Dura refinery was mixed with 1.5% of carbon black (by weight of add asphalt cement) which was obtained from local market. Most commercially obtainable carbon blacks have particle diameters in the range of (100 to 500) nanometers and surface areas of (15 to over 100) $m^2$/g . Asphalt was heated to approximately 110ºC, and the carbon black was added gradually to the asphalt cement with thrilling until homogenous blend was accomplished. The mixing and thrilling sustained for thirty minutes by a mechanical blender. The properties of carbon black are presented in **Table 3.**

**Table 3.** Properties of carbon black.

| Property | ASTM Designation No. | Test result |
|---|---|---|
| Residue on Sieve No. 35 | D-1514 | 10 |
| Pour density gm/liter | D-1513 | 352.4 |
| Ash content % | D-1506 | 0.75 |
| PH | D-1512 | 7.5-9 |
| Specific Surface Area ($m^2$/g) | D-6556 | 36 |
| Oil absorption number | D-2414 | 122 |

2.2.2 Asphalt blended with Styrene-Butadiene Rubber (SBR)

Asphalt cement of penetration grade (40-50) from Al-Dura refinery was mixed with 1.5% of SBR (by weight of add soft asphalt), which was obtained from local market. Asphalt cement was heated to approximately 110ºC, and the SBR was added gradually to the asphalt cement with thrilling until homogenous blend was reached, the mixing and thrilling sustained for thirty minutes by a mechanical blender. SBR increases the ductility of asphalt cement. The Properties are presented in **Table 4.** While **Table 5** shows the physical properties of recycling agents. **Table 6** shows rheological properties of rejuvenators.

**Table 4.** Properties of SBR.

| Property | Value |
| --- | --- |
| specific gravity (g/$cm^3$ at 25 ºC) | 1 |
| Appearance | Milky, white, liquid |
| Chloride content | Nil |
| Butadiene (% by weight) | 40 |
| Mean part size (micro- nicle) | 0.17 |
| viscosity | Low |
| Toxicity | Nontoxic |
| Flammability | No tendency to flash or ignite |

**Table 5.** Physical properties of recycling agents.

| Property Value | Test Conditions | ASTM Designation No. | SCRB Specification | AC (40-50) | Recycle Agents | |
| --- | --- | --- | --- | --- | --- | --- |
| | | | | | SBR | Carbon Black |
| Penetration | 25ºc, 100gm, 5sec | D5-06 | 40-50 | 43 | 36 | 38 |
| Softening Point | - | D36-95 | - | 46 | 52 | 50 |
| Ductility | 25ºc, 5cm/min | D113-99 | >100 | >100 | >100 | >100 |
| Flash Point | Cleave land open cup | D92-05 | >232 | 275 | 315 | 298 |
| After Thin Film Oven Test D1754-97 | | | | | | |
| Retained Penetration of Residue | 25ºc, 100gm, 5sec | D5-06 | >55 | 57% | 45 | 51 |
| Ductility of Residue | 25ºc, 5cm/min | D113-99 | >25 | 73 cm | 53 | 62 |
| Loss on Weight | 163ºc, 50g , 5 hrs. | - | - | 0.32 | 0.22 | 0.27 |

**Table 6.** Rheological properties of rejuvenators

| Property<br>Value | AC (40-50) | AC + Carbon black | AC +SBR |
|---|---|---|---|
| Penetration index (PI), (No.) | -2.54 | -1.77 | -1.401 |
| Temperature of Equivalent Stiffness (TES) ,(°C) | -6 | -9 | -12 |
| Viscosity Temperature Susceptibility (VTS) ,(centipoises/kelvin) | 0.1494 | 0.1024 | 0.0753 |
| Penetration viscosity number (PVN) , (No.) | -1.0862 | -1.1478 | -1.1748 |
| Stiffness modulus (N/$m^2$) | $1 * 10^9$ | $3 * 10^9$ | $2 * 10^9$ |

## 3. EXPERIMENTAL PROGRAM

### 3.1 Preparation of Mixtures

3.1.1 Aged mixture

The aged mixture was obtained from the reclaimed material from the site then heated to 145ºC. The specimens were prepared for further testing to explore the performance after recycling. **Plate 1** shows reclaimed material.

**Plate 1.** Demonstrates a photo of RAP chunk from the site.

3.1.2 Preparation of recycled mixture

The recycled mixture consists of 100% (RAP), and recycling agents are blended together at specified percentages depending on the mixing ratio. At the beginning, RAP was heated to around 145 ºC, and recycling agent was heated to around 130ºC individually before it was added to the heated RAP, then 1.5 % (by weight of added asphalt cement) of the recycling agents were added and mixed for two minutes until all mixture was visually covered with recycling agent as addressed by **(Sarsam, 2007)** . The recycled mixture was prepared using two types of recycling agents: asphalt cement mixed with carbon black and asphalt cement mixed with SBR; finally the marshal specimens were prepared form the recycle mixture.

**3.2 Preparation of Cylindrical Specimens**

Twelve cylindrical specimens 4" diameter by 4" height (101.6 mm diameter by 101.6 mm height) were prepared following the technique depicted in the test method (**ASTM, D 1074**). As prepared before while production mixtures for "Marshall stability" (molds, pans, plungers, etc.) were heated in an oven. The asphalt mixture was added to the mold and twenty-five times spaded vigorously by preheated spatula with fifteen of beats conveyed around the border of the mold, and 10 of beats at random over the mixture. The mixture was compacted at temperature of (150 °C) under an initial load of 150 psi (1Mpa) to set the mixture against the sides of the mold. Then, the required load 3000 psi (40000 lb) was continued for (2 min). The specimens were kept at room temperature to cool for (24 hr). Cylindrical specimens were exposed to the following tests: The repetitive compressive loading (axial repeated load test) for different level of stresses (0.068 ,0.138 and 0.206 ) MPa at temperature of (40 °C), healing cycle for same specimens for different level of stresses (0.068, 0.138, and 0.206) MPa at temperature of (40 °C) and rutting potential. **Plate 2** demonstrates a set of prepared compressive specimens.

**Plate 2 .** Set of prepared compressive specimens.

## 4. REPEATED LOAD TEST

Axial load tests were carried out on specimens using Pneumatic Repeated Load System (PRLS). The device utilized for this test is illustrated by, **(Al-Bayati , 2006).** The tests were accomplished on the cylindrical samples, height (4 inches), and (4 inches) diameter, arranged for every mixture one sample. The repeated compressive stress was subjected to the sample and the permanent deformation was determined under the different stress levels were (0.068, 0.138, and 0.206 ) MPa at (40 ° C). Inside the type of rectangular wave was subjected compressive loading with a stable load frequency of (60 rpm), then the cycle of loading includes of use of the load repetitions for (0.1 sec) followed by (0.9 sec) of time of rest. **Plate 3** demonstrates specimen testing in (PRLS).

**Plate 3.** Sample testing in (PRLS).

## 5. RESULTS AND DISCUSSION

### 5.1 Influence Of Recycling Agent (RA) Types And Stress Level On Resistance To Permanent Deformation Under Repeated Compressive Stress

**Table 7** demonstrates the influence of the level of stress after (1000 loading cycles) on permanent microstrain of the recycled mixture with rejuvenators (carbon black-asphalt, SBR-asphalt) and reclaimed mixture in repeated compressive stress (0.068, 0.138, and 0.206) MPa at (40°C). The permanent microstrain of recycled mixture with (carbon black-asphalt and SBR-asphalt) rejuvenators are higher than reclaimed mix at various level of stresses , then (carbon black-asphalt) mixture had the highest permanent deformation rate than (SBR-asphalt) mixture because the penetration index of Carbon black – asphalt was higher than the penetration index for SBR – asphalt. **Fig. 2** illustrates the percent change of permanent microstrain for recycled mixture and aged mixture at variance level of stresses.

**Table 7.** Permanent microstrain after 1000 loading cycles under compression.

| Mix. type | MicroStrain at 40°c | | |
|---|---|---|---|
| | Stress level (MPa) | | |
| | 0.068 | 0.138 | 0.206 |
| Aged | 8800 | 10300 | 14400 |
| Carbon black | 14600 | 25400 | 25800 |
| SBR | 9200 | 13100 | 15200 |

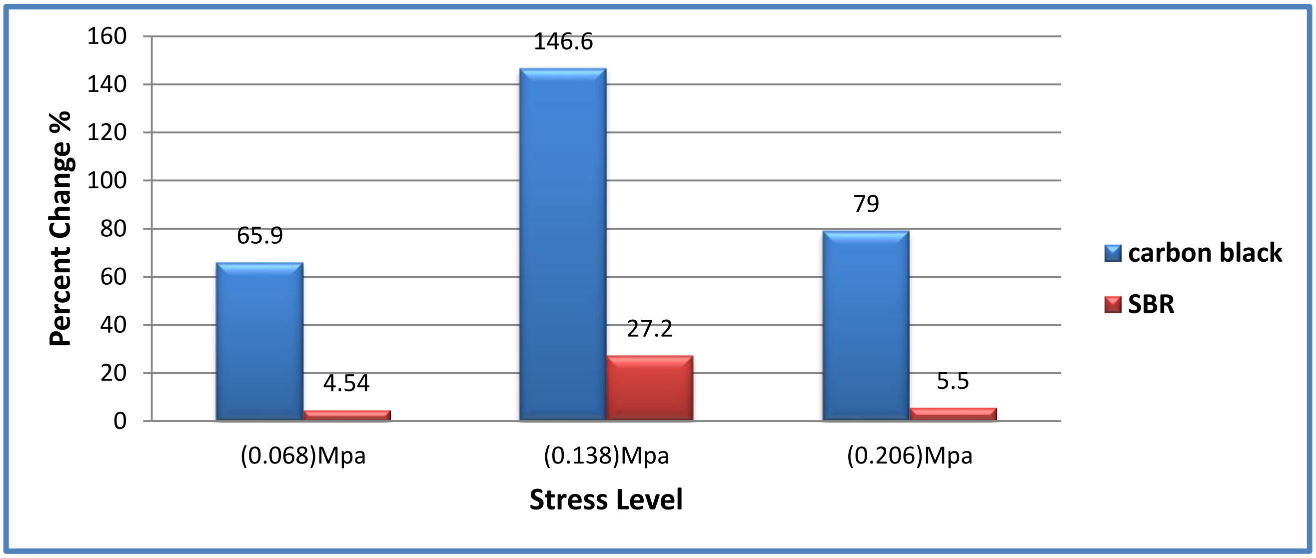


**Figure 2.** Percent of changes(%) in permanent micro-strain for recycled mixtures compared to the aged mixture under compression.

**Fig. 3, 4,** and **5**, show the influence of stress levels on permanent deformation for reclaimed mixture and recycled mixture with (carbon black-asphalt and SBR-asphalt rejuvenators). It was observed that the value of the intercept microstrain for the different mixtures increased when increased stress levels. The variation in intercept microstrain value presented in **Table 8**. The intercept microstrain increased by (101%, and 134 %) for stress levels were (0.138, and 0.206 ) MPa, respectively when compared with stress level (0.068 MPa) for reclaimed mixture. The intercept microstrain increased by (133.49, and 314.36)% for stress levels were (0.138 and 0.206) MPa, respectively when compared with stress level (0.068 MPa) for recycled mixture with (carbon black-asphalt). The intercept microstrain increased by (52.7, and 314.87)% for stress levels were (0.138, and 0.206) MPa, respectively, when compared with stress level (0.068 MPa) for recycled mixture with (SBR –asphalt). The percentage of variation in slope value is changed for different mixtures and different levels of stress. This occurs when stress increases, resulting in increased deformation of the mixtures and become less resistant to permanent deformities.

**Table 8.** Influence of stress level on permanent micro-strain parameter under compression.

| Stress level (MPa) | 0.068 | | 0.138 | | 0.206 | |
|---|---|---|---|---|---|---|
| Mixture type | Permanent Strain Parameter | | | | | |
| | Intercept Microstrain | Slope | Intercept Microstrain | Slope | Intercept Microstrain | Slope |
| aged | 277.31 | 0.4966 | 556.73 | 0.4227 | 648.9 | 0.4218 |
| carbon | 199.98 | 0.6152 | 466.95 | 0.5655 | 828.64 | 0.5036 |
| SBR | 402.29 | 0.4304 | 614.26 | 0.407 | 1669 | 0.3159 |

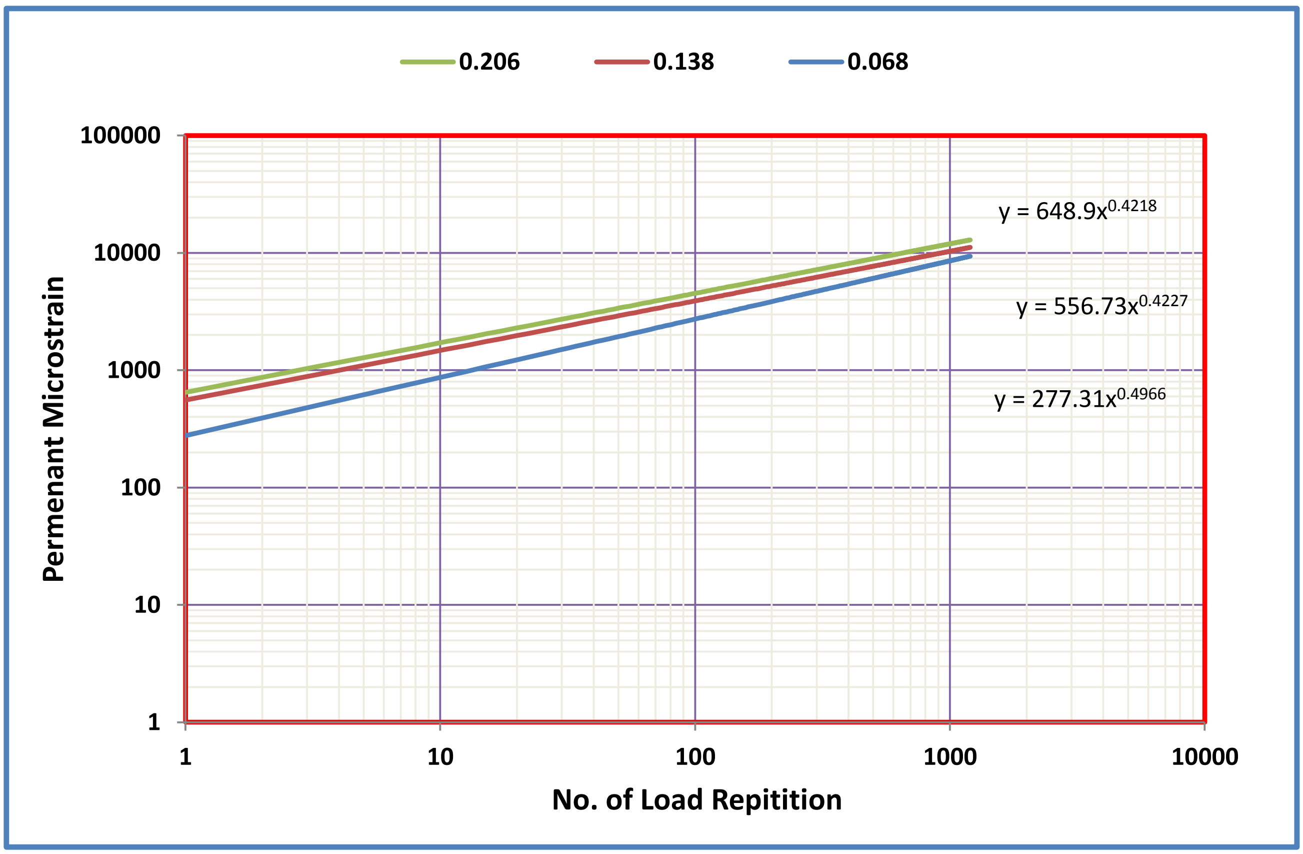


**Figure 3.** Typical relationship between strain and load repetition for aged mixture under stress level (0.068, 0.138, and 0.206) MPa.

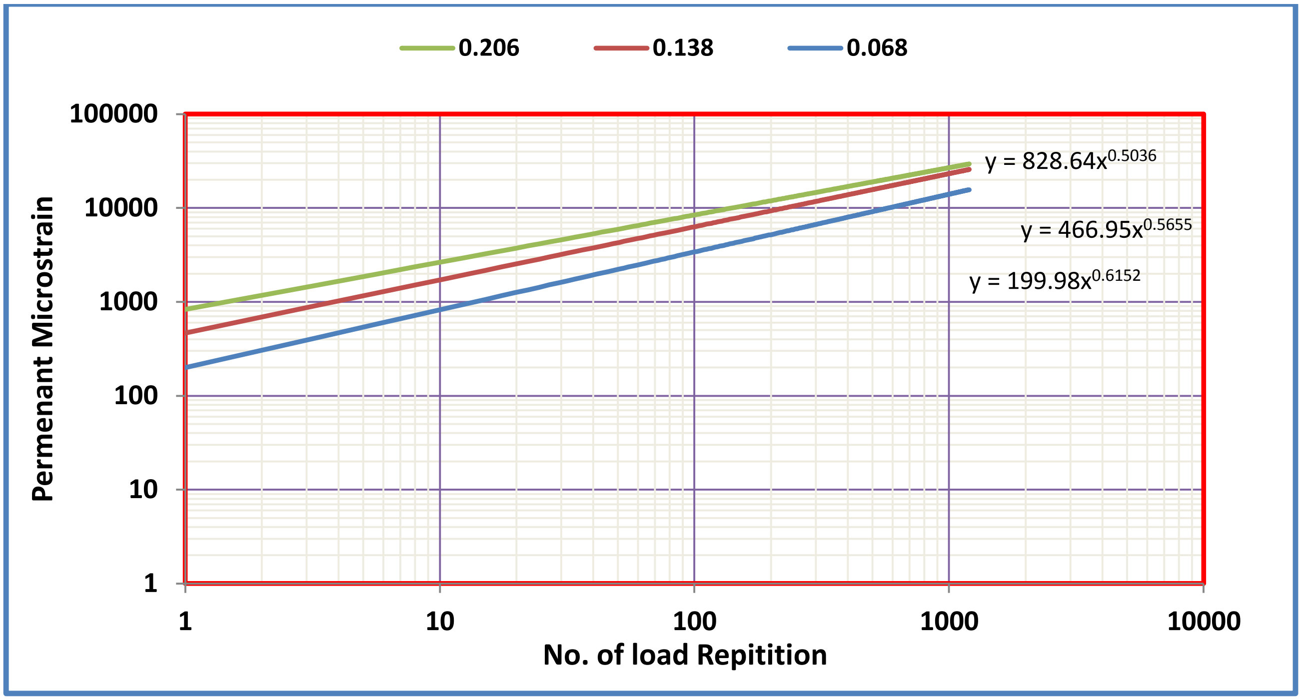


**Figure 4.** Typical relationship between strain and load repetition for (carbon black) mixture under level of stress (0.068, 0.138, and 0.206) MPa.

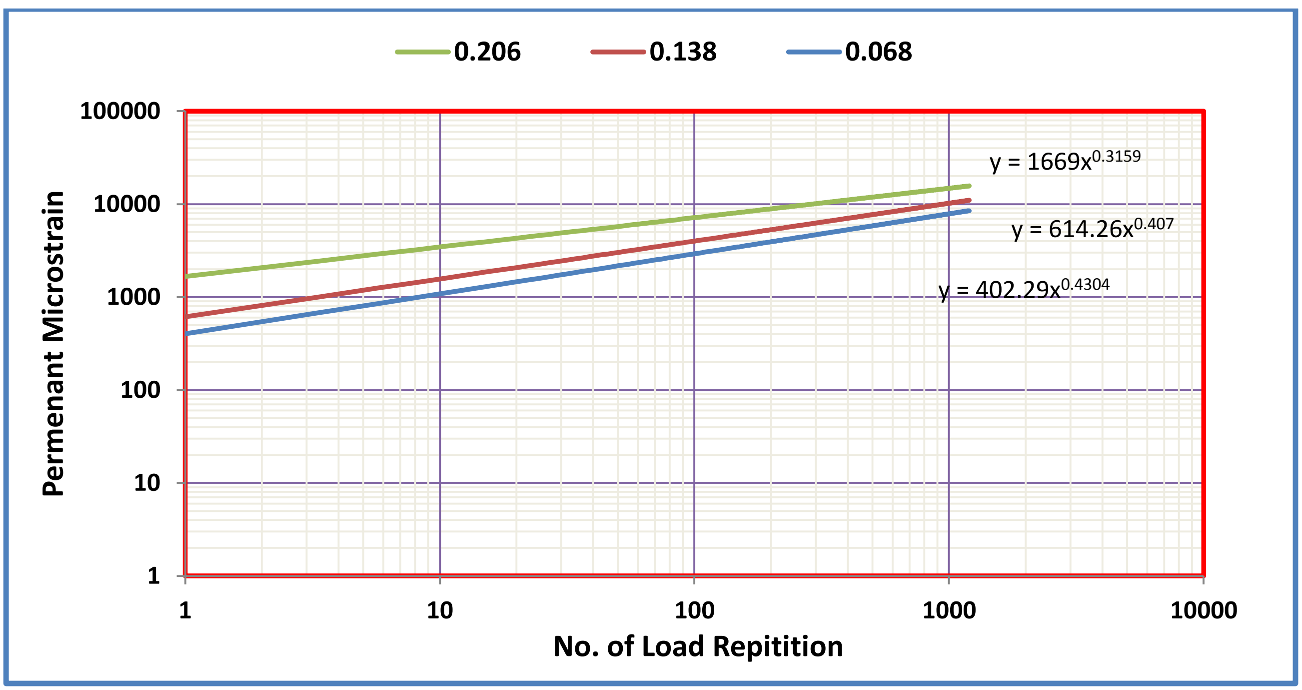


**Figure 5.** Typical relationship between strain and load repetition for (SBR) mixture under level of stress (0.068, 0.138, and 0.206) MPa

## 5.2 Influence of Recycling Agent (RA)Types and Stress Levels on Resilient Modulus (Mr) Under Compressive Stress

**Table 9** demonstrates the effect of the stress levels of (Mr) for recycled mixture with (carbon black-asphalt and SBR-asphalt) and reclaimed mixture under three levels of compressive stress (0.068, 0.138, and 0.206) MPa, at (40°C). The (Mr) decreases with an increase in the level of stress. The highest value of (Mr) could be accomplished at (0.068) MPa. (Mr) decreases by (14, 22, and 8)% and (22, 34, and 11) for reclaimed and recycled mixtures with (carbon black-asphalt and SBR-asphalt), respectively, when compared with Mr at 0.068 MPa. It can be noted that light traffic loads can be represented at a stress level of (0.068) MPa and this is due to asphalt cement properties where it is suitable for connecting the aggregates. The higher level of stresses at (0.138 and 0.206) MPa will have more tensile stresses which the mixtures are incapable to accommodate, and the (Mr) is declined. On the other side, lower level of stress at (0.068) MPa will not be appropriate for asphalt concrete to demonstrate its actual (Mr) property. When carbon black – asphalt is added, (Mr) was higher than that when SBR – asphalt was added because the stiffness modulus of carbon black – asphalt was higher than the stiffness modulus for SBR – asphalt. **Fig. 6** illustrates the variation in (Mr) for recycled and aged mixture.

**Table 9.** Resilient modulus value for recycled and aged mixtures under compressive stress at stress level (0.068, 0.138, and 0.206) MPa

| mix. type | Mr (kPa) at (40°c) | | |
|---|---|---|---|
| | Stress levels (MPa) | | |
| | 0.068 | 0.138 | 0.206 |
| Aged | 114912.667 | 98496.571 | 89931.652 |
| Carbon | 98496.571 | 76608.444 | 64638.375 |
| SBR | 62679.636 | 57456.3 | 55903.459 |

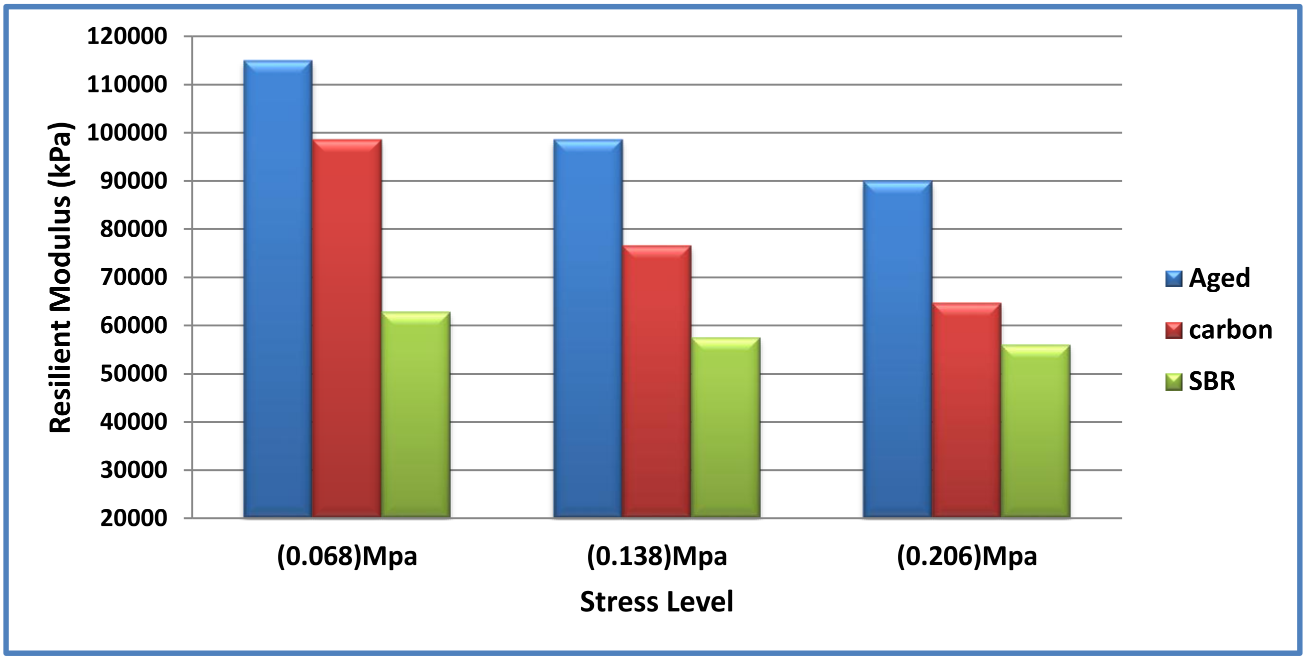


**Figure 6.** (Mr) Value for recycled and aged mixtures under compressive stress at stress level (0.068, 0.138, and 0.206) MPa

## 6. CONCLUSIONS

1- The percentage of variation in slope value is changed for different Mixtures and different levels of stresses. Permanent deformation for recycled mixtures with (carbon black-asphalt and SBR-asphalt) increased by (65.9 and 4.54 )%, (146.6 and 27.2 )%, and (79 and 5.5 )% at level of stresses (0.068, 0.138, and 0.206 ) MPa, respectively, when compared with reclaimed mixture.

2- For the reclaimed mixture, the intercept value increases when the stress level increases and the percentage of increases was (101% and 134%) for level of stresses at (0.138 and 0.206) MPa, respectively when compared for stress level of (0.068 MPa). For carbon black-asphalt recycled mixture, the percentage of rises is (133.49 and 314.36)% when compared at level of stress (0.068 MPa). At SBR -asphalt recycled mixture, the percentage of rise is (52.7 and 314.87)% when compared at level of stress (0.068 MPa).

3- Resilient modulus (Mr) decreases by (14, 22, and 8)% and (22, 34, and 11) for reclaimed and recycle mixtures with (carbon black-asphalt and SBR-asphalt ) respectively when compared with (Mr) resulting from 0.068 MPa

## NOMENCLATURE

AASHTO = American Association of State Highway and Transportation Official.

Mr = resilient modulus.

NCCLR = National Center for Construction Laboratories Research.

PRLS = pneumatic repeated load system.

RA = recycling agent

RAP = reclaimed asphalt pavement

SBR = styrene butadiene rubber

SCRB = state commission for roads and bridges.

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