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# Assessment of Recycled Asphalt Concrete Flexibility

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## ABSTRACT

*The flexibility of surface mixture that is increasingly degraded over time relies primarily on the operability of asphalt concrete paving. The disposal of such properties may be a sustainability step. The study was carried out using the reclame asphalt concrete RAP pavement and recycled asphalt concrete comprising the cutback and emulsion rejuvenators, beam specimens of 400 mm lengths, 80 mm wide and 50 mm depth. In a four-point loading device under 200 load cycles at 20°C setting, beam specimens were subjected to repetitive flexural stresses with PRLS pneumatic loading system. The loading sequence for each cycle is 0.1 second load duration and 0.9 seconds of rest period. With Linear Variable Differential Transformer LVDT, the vertical deformation of the beam at medium range was measured. For different mixtures the robust module was measured and contrasted. The tensile strain for recycled mixtures of asphalt with reduction and emulsion was observed to be (58 and 31) percent greater than the mixture of RAPs at 20°C respectively. For recycled mixtures of reduction and emulsion relative to the mixture of Rap, the reduction of the robust module under repetitive flexual stress was of (79% and 34.7)..*

***Key Words: Reclaimed asphalt concrete, recycling, beam, flexure, repeated loading, Resilient Modulus.***

## 1. Introduction

By recycling the reclaimed lightweight paving products, the resilience of the asphalt concrete floor may be accomplished. The recycled asphalt pavement RAP content can be obtained through milling of current distressed pavement surfaces, (Sarsam, 2007). (Sarsam, 2007). Boden recycling is a safe choice since it is a mechanism that supports the atmosphere and the economy. RAPs could lead to an economical, environmentally friendly process when paving is reconstructed; (Al-Qadi et al, 2007). Recycling is the practise of reusing the original concrete components that no longer support the traffic efficiently. The effect on fatigue activity of recycled asphalt concrete by three forms of recycling substances with nanomaterials was studied (Sarsam and AL-Shujairy, 2014). Specimens of beam were engineered and checked under repeated loading with fatigue resistance. Three chosen parameters, the angle, intercept and the rut depth, have been tested to determine fatigue life and have been assessed at 5000 cycles. In contrast with the recycled mixture, the control mixture is more prone to rolling, while the recycled mixtures are more tensile. The durability of RAP after recycling was investigated in terms of rutting resistance and fatigue life on beam specimens by (Sarsam and AL-Shujairy, 2015). (Sarsam and AL-Shujairy, 2015). It was concluded that the fatigue increased by (608, 66, and 265) percent for recycled mixtures of (Soft Ac, Soft Ac + Silica Fumes and Soft Ac + Fly ash) respectively when contrasted with aged mixture. (Zaumanis et al, 2016) tested a 100% recycling principle, ascertained if mixtures such as asphalt mixtures would work, and if yes, create a 100% recycled asphalt design process. In order to validate the real rejuvenation of aged binder, chosen rejuvenators were used for comprehensive rheological, micromechanical and chemical characterisation studies. The final evidence of rejuvenation was a set of 100 percent RAP blend studies. The findings revealed that a major increase in the low temperature cracking resistance can be accomplished with an acceptable mix design and choice of rejuvenators, thus offering a moisture and rut tolerant combination. A long-term performance that is equivalent to the reference virgin blend has been obtained through the usage of such rejuvenators. A framework was built on the basis of these results to produce 100% recycled asphalt mixtures. The usage of high concentrations of RAP (Behnood 2019) means that it may contribute to longevity issues such as cracking and ravelling owing to seriously old bituminous links. Rejuvenators were used frequently for the resolution of this issue and for mitigating the issues relevant to the usage of old binders. The viscoelastic and rheological properties of RAP-containing asphalt mixtures can be enhanced. (Bańkowski, 2018) Laboratory and field experiments were conducted to check the suitability of 50% RAP bitume mixtures in relation to fatigue life. The longevity of mixture and pavement system life is evaluated. Fatigue life was evaluated. The findings of experimental experiments were explored on the fundamental properties of bindings and mixtures as well as on the results of specialised tests such as fatigue existence and rigidity. The result was that incorporating RAP deteriorated the exhaustion characteristics slightly. In order to maximise the proportion of utilisable RAP, RAP samples were obtained (Pradyumna and Jain, 2014), and lab tests were performed. In this analysis the recycling agent was also used and by weight of the bitumen contained in RAP, a dose of the recycling agent was found to be 10%. The properties of mixture compared and their performance were compared with virgin mixtures, which were prepared in laboratory, and commercially disponible RAP. (McDaniel et al, 2012) investigated the consequences of using RAP in asphalt surface mixtures with low or uncertain aggregate values, in order to determine maximum RAP content allowed to ensure sufficient friction. The impact of RAP on thermal cracking on the possible admissible RAP contents were then studied. The trials revealed that the inclusion of low quality RAP products influenced the friction and cracking resistance of the mixtures, but that smaller RAP volumes did not work. The frictional performances of the manufactured laboratory and the field sampled RAP materials were 25% acceptable, but 40% dubious. (Lin et al., 2012) analysed the effects of the attachment of the three recycling agents to asphalted concrete of varying ratios (from 10 percent to 40 percent). The research involves a number of measures intended to assess the disparity in tensile strength and stability performance of the Marshall specimens between the three recycling agents. The findings indicate the inclusion of the recycling agent improves the intensity and resilience of indirect tensile. The purpose of this study is to test the versatility of 100% RAP recycling with cutback and emulsion. In terms of absolute, irreversible and durable Microstrain, the deformation activity of beam specimen under repetitive flexural stresses is controlled. Rejuvenators will determine their impact on the robust modular and traction tension..

**Methods and Materials:**

**Reclaimed Asphalt Concrete Pavement Materials RAP**

Rubbling of the binder coursing layer of the asphalt concrete of the highway segment of the province of Babylon culminated in the reclamed asphalt concrete flooring substance RAP. This path is badly damaged by different cracking and rutting processes. The asphalt recovered mixture created was ensured that the leaf and loam that normally gathered on the pavement surface were clear of deleterious substances. Two representative sample samples of RAP were subject to ignition processing according to the (AASHTO T 308, 2013) method of obtaining the total gradation, binder and filler quality and characteristics of the aggregate. This substance was obtained from the road portion, combined and reduced to the testing dimension according to the American Association of State Highway and Transport Officials (AASHTO, 2013). Following the ignition test Table 1 reveals the properties of RAP components.

Six samples were chosen randomly from the content stack rubbling phase after the gradation study of RAP was calculated. The effects of these experiments were insulated from the aggregate by the ignition test. In order to measure gradation for each study, the sum was seven and divided into different size. The spectral variations were slight, and the average graded gradation of six samples is seen in Figure 1, which indicates that the RAP aggregate gradient for the binder path layer shows the fine side of road and bridge requirements (SCRB, 2003). The asphalt concrete paved RAP is seen in Figure 2..

**Table 1. Properties of RAP 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, kN | 17.4 |
| | | Flow, mm | 3.05 |
| | | Air voids, % | 5.21 |
| | | Bulk density, gm/cm$^3$ | 2.329 |
| | | Maximum theoretical density, Gmm, gm/cm$^3$ | 2.465 |

## Rejuvenator Agents

As a recycling agent focused on available literature (Sarsam and AL-Janabi 2014); and 2 forms of liquid bitumen were introduced as a specialist in recycling; (Sarsam and Mahdi, 2019-a). The medium healing cut MC-30 and cationic emulsion rejuvenators are applied..

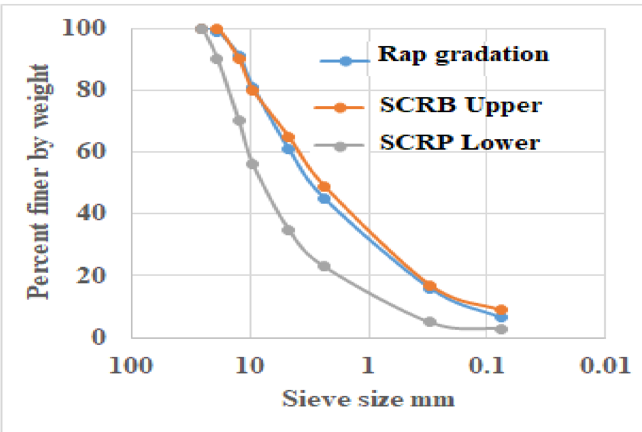


**Figure 1. Gradation of RAP (reclaimed) aggregate obtained from the field**

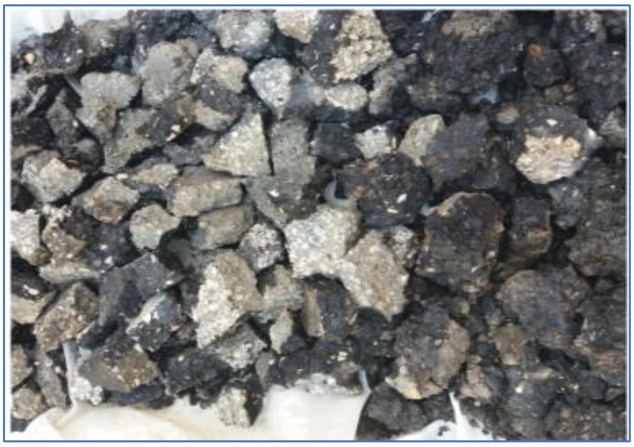

**Figure 2. Reclaimed asphalt concrete (RAP).**

## Cutback Bitumen

The Dura refinery medium curing cutback MC-30 as one of the recycling agents was applied in this study. Table 2 displays the features of the cutback.

**Table 2. Properties of medium curing cutback as obtained from Dura refinery.**

| Property | Test conditions | (ASTM,2003) designation | Value |
|---|---|---|---|
| Kinematic viscosity | 60°C | D2170 | 42 |
| Flash point | – | 3143 | 52 |
| Distillate, volume percent of total distillate | 225°C<br>260°C<br>315°C | D402 | 23<br>47<br>89 |
| Residue from distillation | 360°C | D402 | 63 |
| **Residue from distillation** | | | |
| Viscosity | 60°C | D2171 | 67 |
| Ductility | 25°C | D113 | 132 |

## Emulsified Bitumen

As one of the recycling agents for this investigation, cationic emulsion received from the Ministry of Industry and Minerals has been applied. The emulsion characteristics are seen in Table 3.

**Table 3. Properties of cationic emulsion as supplied by the manufacturer.**

| Property | Test conditions | (ASTM, 2003) designation | Value |
|---|---|---|---|
| Saybolt-Furol Viscosity | 50°C | D245 | 235 |
| Storage stability | 24-h | D6930 | 0.7 |
| Particle charge | | D7402 | Positive |
| Sieve test | – | D6933 | 0.063 |
| Distillation:<br>Oil distillate, by volume of emulsion, %<br>Residue, % | – | D6997 | 7<br>93 |
| **Tests on residue from distillation** | | | |
| Penetration, 25°C | 25°C, 100g, and 5 S. | D5 | 57 |
| Ductility | 25°C and 5 cm/min | D113 | 59 |
| Solubility in trichloroethylene, % | ---- | D2042 | 100 |

## Recycling Process of RAP Mixture

The method for recycling performed in the inquiry comprises 100% recycled RAP pavement and recycling agent combined according to the mixing ratio at defined percentages. Firstly, RAP has been heated to about 160°C, whereas the liquid asphalt has been conditions at room temperature of 25°C and applied 0.5 percent in weight to the heated RAP and combined for two minutes, before the whole mixture has been visually recycled as modified by the recycling agent (Sarsam and Saleem, 2018-b). Two types of liquid bitumen were used to process the recycled asphalt mix: the medium cationic and cationic emulsion. The regenerators will decrease the viscosity of aged bitumen and render the recycled asphalt concrete mix more stable, and the durable strain can also be improved.

## Short-term Aging of Recycled Mixture

Due to the limited viscosity of cutback asphalt, the recycled asphalt mixture with cutback bitumen has low adhesion, and so short term ageing has been calculated to reduce the volatile material and improve the cutback viscosity. The recycled asphalt mix was heated to 135°C and then sprayed over a shallow 3- cm thick tray and aged in a 135°C oven for 4 hours, as per the Superpave method (AASHTO, 2013). Per 30 minutes, the asphalt mixture was aged at short ageing, such that the exterior of the mixture was not aged longer than the inside due to greater exposure to air. Recycled samples were subject to a reduction phase, while recycled samples were not subjected to a process of this kind since they demonstrate sufficient cohesion. Figure 3 indicates the mechanism of short ageing.

**Figure 3. Short term aging of recycled RAP**

## Preparation of Beam Specimen

Beam specimens were prepared with a length of 400 mm, a width of 80 mm and a depth of 50 mm. The steel mould comprises of four sides of a 127 mm regular C-channel steel segment connecting with steel bolts and a 10 mm steel base plate, to create concrete beam prototypes. A typical press compression machines, with a capability of 25.7 kPa, have been employed on an asphalt mixing platform to ensure standardised load for the recycled asphalted concrete mixtures. The pressure is held at the goal volume density of 2 372 gm./cm3 and the optimal thickness at 25.7 kPa for 2 min at 140oC. The beam specimen obtained has a normal dimension (ASTM, 2003). The prepared beam samples and the preparation phase are shown in Figure 4. Overnight the mould was cooled and the beam was extruder from the mould. Information of the goal density have been reported elsewhere (Sarsam and Saleem, 2018-b).

**Figure 4. Preparation of the asphalt concrete beams**

## Repeated Flexural Stresses Testing

For repeated flexural beam testing, it was introduced the four-point loading method with a free turning beam retaining connection at every loading and reaction point. In the third centre position of the beam, pure bending was planned for utilizing the four-point loading. A typical measure for microscracking ability were the amount of load cycles that induced beam discomfort. In the experimental nature of the flexural strap fatigue test, the comprehensive factor variables are that the stress level is 138 kPa, which has been chosen as the target for a medium traffic load. A load of 138 kPa was introduced in rectangular wave shape and the loading rate is 0.1 seconds long for each loop, with a steady 60 cycle loading duration per minute and 0.9 seconds long for each cycle. The vertical variations were tested with Linear Variable Differential Transformer LVDT during the beam test in the mid-span. A number of pressures has been chosen to allow specimens to fail in a 100-100,000 range. The test temperature of 20°C has been identified since the micro cracking normally takes place at an intermediate temperature of approximately 20°C.

The upper point of the beam was set by an aluminium steel road that helped the LVDT to catch the variance in deflecting. Visual camera filmed the repetitive loading procedure to track the deformation during the whole evaluation. The vertical deflection during the mid-range beam test was determined by means of a responsive dialling gauge and the deflections were recorded in the video at different time intervals, and checked for strain finding at any amount of cycles desired for each test..

**Figure 5. Beam Specimen in the PRLS testing chamber**

As demonstrated in Figure 6, the resilient deformation in terms of the change in microstrain increases gently as the number of load repetitions proceeds. It can be observed that the reclaimed asphalt concrete before recycling exhibit lower resilient deformation as compared to that of recycled mixture.

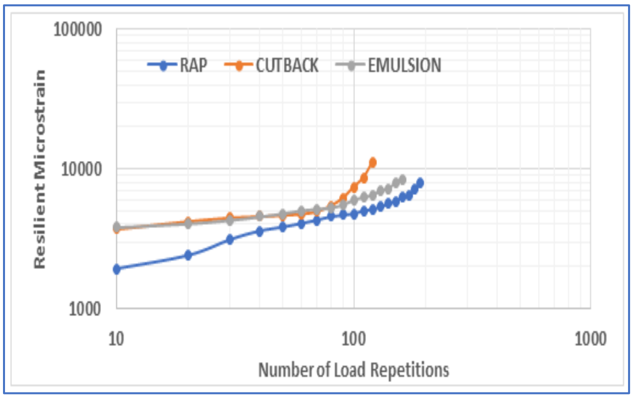


**Figure 6. Flexibility of Recycled Asphalt Concrete in terms of Resilient Strain**

The higher viscosity of the old asphalt binder can contribute this to the stiffer nature of the recovered mixture. This result is in strong agreement (Sarsam and Mehdi, 2019-b). When rejuvenating agents are used for RAP, more stability is added in the combination, since the viscosity of the binder is reduced. There is a greater resistance than emulsion-treated RAP in the RAP treatment. This may be because the kerosene of the bitumen reduction was able to dissolve the old binder in the RAP during the process of blending, although the emulsion was not able to dissolve. In contrast with the products recycled, the rejuvenator handled with RAP demonstrates lower effect tolerance to repetitions. The duty life loss is (36.8 and 15.7) percent relative to the recovered material for the reduction and emulsion treatment of RAP respectively. Similar findings have been recorded (Behnood, 2019). This may mean that the 100% recycled RAP application for usage on the grounds of the limits of the current inquiry cannot be recommended.

### Influence of Rejuvenator Type on Tensile Strain.

The tension of the strain was 0.138 MPa, a 20° C test temperature, while the load application frequency used was 1 Hz for a 0.1 second load interval, whereas the remainder was 0.9 seconds. The strain test for beam samples of the scale (400 x 80 x 50) mm was performed. The tensile strain at 150 load repeatments was chosen as a guide for comparison to determine the resistance to overall deformation. The impact of Rejuvenator on the overall microstrain tensile is seen in Figure 7. The lowest tensile strain for reused mixtures was obviously obtained relative to recycled mixtures, and the recycled mixture with cutback bitumen had a strong tensile strain compared to a recycled blend with emulsified bitumen. For recycled mixtures of reduction and emulsion, the tensile strain improved by (58 and 31) percent relative to the RAP. This may be due to improved versatility by rejuvenators in the RAP.

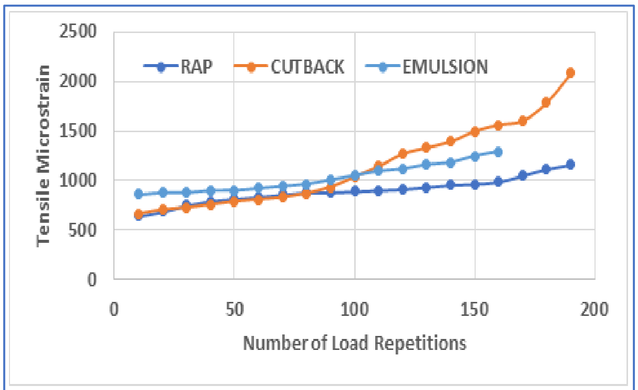


**Figure 7. Influence of Rejuvenators on Total Tensile Strain**

### Influence of Rejuvenator Type on Permanent Strain

As demonstrated in Figure 8, the permanent microstrain exhibit no significant variation as the loading proceeds, this may be attributed to the fact that most of the permanent strain occurs at the early stage of load repetitions. It can be observed that higher permanent strain is associated with implication of rejuvenators. RAP treated with Cutback bitumen exhibit higher permanent strain as compared to emulsion treated RAP. This may be attributed to impact of kerosene in dissolving the aged bitumen of the RAP and decrease its viscosity and increase the flexibility of the RAP material during the mixing process. Similar findings were reported by (Lin et al, 2011) and (Sarsam and Saleem, 2019). The increment in permanent microstrain was (40.8 and 22.2) % for cutback and emulsion treated RAP respectively as compared to RAP material before recycling.

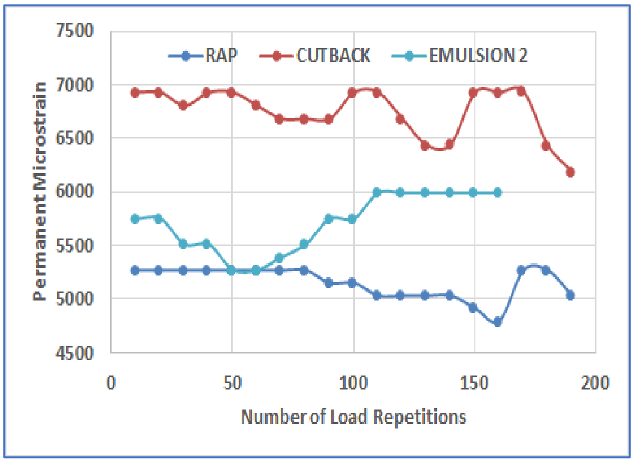


**Figure 8. Influence of Rejuvenators on Permanent Strain**

## Influence of Rejuvenator Type on Resilient Modulus

Module of resistance Mr was estimated at 0,138 MPa stress and 20°C test temperature. The Rejuvenator's effect on Mr under repetitive flexural stress as seen in Figure 8. The Mr decreases with the amount of freight repetitions. It should be observed. The Mr for the restored bending mixture was higher than Mr for the recycled mixture with the cutting and emulsion. In the other side Mr was stronger than the recycled mixture with emulsion for recycled mixture with cutback, up to 100 load repeats. The more versatile aspect of the reduced handled RAP may be due to this action. In the case of recycled mixtures of cutback and emulsion compared with the rape mixture, the percentage decrease of MR under 150 replicates of flexure tension was respectively (79 and 34,7). The higher viscosity of the elderly linking agent can be due to the recovered content which is steeper relative to the recycled blend. These results are compatible with the work (Al-Qadi et al, 2007) and and (Sarsam and Mahdi, 2019-b).

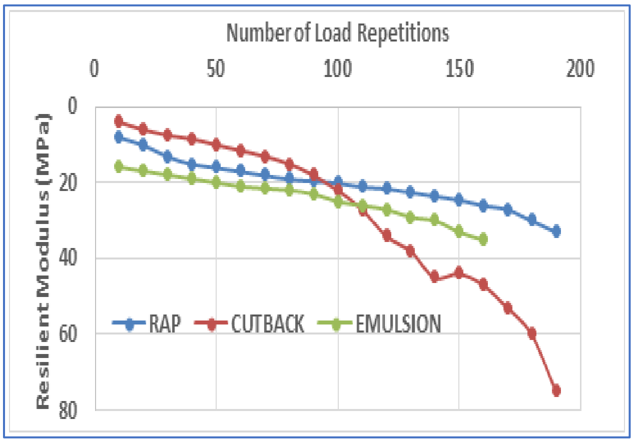


**Figure 9. Resilient Modulus Mr for mixtures.**

## Conclusion:

- The following assumptions may be made on the basis of the research programme:
- ¨Última effect on the flexibility of recycled asphalt concrete by increasing the durable strain of the rejuvenator in the recycled asphalt concrete material.
- os For cutback and emulsion care of the RAP, the duty life loss of the recovered material is (36.8 and 15.7) percent respectively. For use in wearing course use, 100% of recycled RAP is not recommended.
- B: The rise for recycled mixture with cutback and emulsion is 58 and 31 percent for the tensile strain under repeated flexurous tension at the temperature of 20°C, as opposed to the regenerated mixture.
- § The percent drop in durable modules Mr is (79 and 34.7) percent, respectively, relative to those in the recovered combination (cutback and emulsion).

- · A percent rise in permanent microstrain (40.8 and 22.2) compared with the RAP content processed before recycling was found for the reduction and emulsion respectively.
- • A sample portion of reclaimed 100% RAP with cutback and emulsion is advised to check the field efficiency in mixing, proliferation and mixture serviceability .

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