The effect of sustainable materials on fatigue cracking of thin overlay asphalt mixture

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Abstract. The life of the pavement affected by several factors that play a main role in the performance of asphalt pavement, one of these factors the failure modes, can be represented the important factors that reduced the service life of flexible pavements. Fatigue cracking failure of all the types of failures modes, it is still considered the most common failure mode in recent years. Improvement the performance of pavement by good field works or by enhancing the properties of HMA mixtures represents the essential target by engineers to reduce the maintenance cost and to mitigate potential safety problems. Therefore, this study aims to assess the effect of polymer modified asphalt (PMA); waste material namely crumb rubber with low density polyethylene (LDPE) were used as a combined admixture or as single additive as a sustainable material to enhance the fatigue properties of thin overlay asphalt mixture. 15% of 250-micron crumb rubber was added, while 2.5, 5, 7.5, and 10 % LDPE were added to produce PMA. The flexural beam fatigue test was performed at temperature of (20 °C) to describe the fatigue life of modified thin overlay asphalt mixtures. Results exhibit the vital role of crumb rubber in increase the fatigue life of the mix as compared to conventional mixtures, while LDPE showed a significant role in increase fatigue life of thin overlay asphalt mixture. Fatigue life increase when the 15% of Crum Rubber Modifiers added to the binder. Also fatigue life increase when low density polyethylene (LDPE) added for a high percentage; from the analysis of the result that asphalt mixtures contain (7.5% and 10%) low density polyethylene (LDPE) in addition of 15% of Crumb Rubber Modifier (CRM) achieved the best fatigue life because of the effect of modifiers properties such as flexibility, elasticity, as well as laboratory conditions. Thus, this emphasis the ability of waste material to enhance the asphalt mixture and upgrade such mixture in a sustainable approach.

Keywords: thin overlay asphalt mixture; asphalt mixtures fatigue life; flexural bending, low density polyethylene, crumb rubber.

1. Introduction

One way to understand the behavior of asphalt mixture is to consider distress types to which asphalt pavement exposed that engineers try to avoid [1]. HMA mixes were suitably designed to provide asphalt pavement in the site has the capability to resist the different kinds of distress that may be exposed it during the service life of facility [2]. Among these distresses can occur in an asphalt pavement. One of the most common types of cracking is fatigue cracking [3]. Fatigue, or alligator, cracking appears on a pavement surface as a series of interconnected cracks that resemble the skin of an alligator. Alligator cracking is a load-related distress because it is caused by fatigue failure of the asphalt concrete surface and is aggravated by repeated traffic loads [4, 5]. This distress will appear initially as longitudinal cracking in the wheel paths for an extended length that will eventually network outward into “alligator” cracks as they mature[6]. This
type of early onset fatigue cracking can result in total pavement failure well before the intended design life is reached [7, 8]. Fatigue cracking is often related to weakening of the base course or subgrade, insufficient pavement thickness, excessive loading [2]. Also, Asphalt Institute [1] stated that fatigue cracking is primarily related to air voids and asphalt binder properties have a significant effect on fatigue resistance. As the percentage of air voids in the pavement increases, either by design or by lack of compaction, pavement fatigue resistance is drastically reduced. Concurrently, fatigue cracking can result from poor layer bonding, while fatigue cracking is associated with structural failure, it is often not recognized as a poor bonding problem. Paving projects that receive little or no tack coat can experience widespread fatigue cracking [7]. Asphalt mixture behavior can explain by the brief mechanism, when a wheel load is applied to a pavement, the primary stresses that are transmitted to the HMA are vertical compressive stress, shear stress within the asphalt layer and horizontal tensile stress at the bottom of the asphalt layer. The HMA must be internally strong and resistant to compressive, tensile and shear stress to prevent deformation within the mixture. The material must have enough tensile strength to withstand tensile stress at the base of the asphalt layer to resist crack initiation, which results in fatigue cracking after many load applications [1]. Alligator cracking starts at the bottom of the asphalt layer, where the tensile stress and strain under a wheel load is highest. The cracks propagate up to the pavement surface where they first appear as parallel longitudinal cracks in the wheel paths. Under repeated traffic loads, further deterioration takes place, and the cracks begin to interconnect, forming many angular pieces that look like an alligator’s skin or chicken wire. Alligator cracking may also occur from top-down cracking of an asphalt pavement [5, 9].

The increasing in traffic volume and the increasing demands placed on the performance of asphalt concrete pavements all that have accelerated a need for improve and modify the HMA by different procedures to mitigate potential safety problem and to reduce the maintenance cost. The modification of paving grade asphalt has been practiced for a number of years [8, 10, 11]. Modified asphalt binders are sometimes generically referred to as “polymer-modified asphalts” or PMAs. In actuality, modified asphalt binders may be produced in a number of ways including polymer and chemical modification, although polymer modification is the most prevalent [7, 12, 13]. The use of a polymer-modified asphalt binder can significantly improve the fatigue resistance of an asphalt mixture[13, 14]. The most effective method to improve a pavement’s fatigue resistance is to increase the overall structural thickness, as thicker pavements reduce the tensile stresses in the asphalt layer[7]. So, when using thin layers as a final surface course this is accomplished by using polymers make asphalt mixtures more flexible and that in turns reduces the tensile stress under the HMA layer. Polymers can be divided in several categories according to several criteria adopted in their classification. Two broad classes of polymers used in asphalt modification are polyolefins and styrenic polymers, these polymers categorized based on the polymerization of polymers molecules, e.g.; Polyolefins are so named because they are based on the polymerization of molecules containing a simple double bond or olefin while styrenic polymers are so named because they are based on polystyrene that has been copolymerized with other small molecules most commonly butadiene[12]. Polyolefin polymers include polyethylene and the most common comonomer used to produce styrenic polymers is butadiene. Polymers can also be classified according to the way in which monomers form when polymerized or the behavior of these polymers when exposed to high temperature, e.g., when monomers are polymerized, and they form long-chain polymers. Some types of these polymers, called thermoplastics, soften when heated, enabling them to be re-formed. Some examples of thermoplastic polymers include nylon, polyethylene. By contrast, some monomers, when polymerized, connect to form a three-dimensional network. These types of polymers, called thermosts, are permanently (irreversibly) set in shape. Some examples of thermoset polymers include epoxy resins and vulcanized rubber[12]. Polymers can also be classified based on physical properties. Depending on their behavior when stretched with sufficient force, polymers are classified as plastomers (plastics) or elastomers (rubbers or elastics). When stretched, plastomers will yield and remain in their stretched position when the load is released. Elastomers will yield under load (stretch) but will return to their original shape when the load is released. Generally speaking, most polyolefins such as low-density polyethylene behave as plastomers, while crumb rubber modification behave as elastomers. Polymer medication stiffens the asphalt binder at high temperatures and depending upon the type of modifier can also alter the phase angle. Elastomers tend to reduce the phase angle at the
upper specification temperature making the asphalt binder more “elastic-like” or recoverable. The plastomers tend also to stiffen the binder at the upper specification temperature but have a much lesser effect on the phase angle. Polymer modification has a minimal effect on the low temperature properties but is said to enhance the fatigue properties of asphalt cement [11, 15].

It is worthy to mention that the thin asphalt overlay (TAO) course is surface course used to increase the service life of pavement i.e., as protective layer and can be constructed with different nominal maximum aggregate size (NMAS)[5, 16]. Many state agencies specify 38mm (1.5 in.) as a maximum HMA thickness when used this TAO for maintenance approach and 12.5-mm (0.5-in.) NMAS for their interstate highway surface mixtures[5, 17].

The main objective of this present study is to display the effect of polymer modified asphalt (PMA); namely, waste material namely crumb rubber (CRM) with low density polyethylene (LDPE) were blended using wet process as a combined admixture or as single additive to determine the different mix design characteristics on the fatigue behavior of thin overlay asphalt mixture. Superpave method of bituminous mix design was carried out and the bituminous mixtures contain different NMAS and with and without waste polymers material.

2. Materials

In this research work, one type of asphalt cement was used with (40-50) penetration grade from Al-Daurah refinery was nominated. The physical properties and tests of the asphalt cement used are shown in Table (1). Two types of aggregate gradations were selected for the preparation of the asphalt concrete specimens of the flexural beam fatigue test. These NMASs were (12.5 mm, 9.5 mm). The physical properties and tests of the aggregates used are shown in Table (2) and the physical properties of mineral filler used are presented in Table (3), The filler used in this research is a non-plastic material, limestone dust filler materials, obtained from a local factory in Iraq mostly passing sieve No.200 (0.075mm). The gradation of two types of aggregate are shown in Table (4) and Figures (1 and 2). It is worthy to mention that the used materials in this study are dependent mainly on the availability of these materials in the local market and they are increasingly commonly used in roads paving in Iraq

Table 1: Physical Properties of Asphalt Cement

| Property                              | ASTM Designation | Test result | SSRB specification |
|---------------------------------------|------------------|-------------|--------------------|
| Penetration (25 °C,100 gm,5 sec)      | D-5              | 47          | (40-50)            |
| Ductility (25 °C, 5 cm/min), (cm)     | D-113            | 150         | >100               |
| Flashing point (Cleveland open cup), (°C) | D-92            | 245         | Min.232            |
| Softening point, (°C)                 | D-36             | 52          |                    |
| %Solubility in trichloroethylene      | D-2042           | 99.2        | Min. 99%           |
| Viscosity, 135 (Pa. sec)              | D-4402           | 0.775       | Min. 0.4           |
| Viscosity, 165 (Pa. sec)              | D-4402           | 0.112       |                    |
| Specific gravity at 25 °C             | D-70             | 1.04        |                    |
| Residue from thin-film oven test      |                  |             |                    |
| Retained penetration, % of original   | D-5              | 69          | Min. 55            |
| Ductility at 25 °C, 5 cm/min (cm)     | D-113            | 68          | Min. 25            |
### Table 2: Physical Properties of Coarse and Fine Aggregates

| Property                                      | ASTM Designation | Coarse Aggregate | Fine Aggregate | SCRB Specification |
|-----------------------------------------------|------------------|------------------|----------------|--------------------|
| Bulk Specific Gravity                         | C127, 128        | 2.58             | 2.60           | ------             |
| Apparent Specific Gravity                     | C127, 128        | 2.63             | 2.69           | ------             |
| Percent Water Absorption                      | C127, 128        | 0.729            | 1.419          | ------             |
| Percent Soundness Loss by Sodium Sulfate Solution | C88              | 2.08             | 3.20           | 12% Max.           |
| Percent Wear (Loss Angeles Abrasion)          | C131             | 15               | ......          | 30% max.           |
| Percent Flat and Elongated Particles          | D4791            | 1                | ......          | 10% Max            |
| Passing sieve NO.200, %                       | C117             | 1.07             | 2.66           |                    |
| Clay lumps, %                                 | C142             | 0.42             | 2.8            | 3% Max             |
| Fractured Pieces, %                           | -                | 96               | ......          | 90% Min            |
| % Sand Equivalent                             | D2419            | ......            | 49             | 45% min.           |

### Table 3: Physical Properties of the Mineral Filler

| Property                                      | Test Result |
|-----------------------------------------------|-------------|
| Bulk Specific Gravity                         | 2.70        |
| Percent Passing Sieve No. 200                 | 95          |

### Table 4. Selected Gradations for Asphalt Concrete Mixtures

| Sieve Size | NMAS (12.5 MM) | NMAS (9.5 MM) |
|------------|----------------|---------------|
|            | Percent Passing % | Superpave specifications | Percent Passing % | Superpave specifications |
| inch/mm    | Selected gradation |                      | Selected gradation |                      |
| 3/4 19     | 100              | -                        | 100               | -                      |
| 1/2 12.5   | 95               | 90                       | 100               | 90                     |
| 3/8 9.5    | 83               | 76                       | 90                | 90                     |
| No.4 4.75  | 59               | 76                       | 70                | 90                     |
| No.8 2.36  | 35               | 28                       | 58                | 35                     |
| No.16 1.18 | 24               | 28                       | 23                | 32                     |
| No.30 0.6  | 16               | 16                       | 16                | 16                     |
| No.50 0.3  | 11               | 11                       | 11                | 11                     |
| No.200 0.075 | 6               | 4                        | 10                | 6                      |

|                  | 2               | 2                        | 2                  | 2                      |

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Superpave method criteria has been utilized for designing two different kinds of asphalt mixes. Under equviscous temperature conditions the specimens have been mixed and compacted corresponding to 0.170±0.02 Pa·sec and 0.280±0.03 Pa·sec, respectively. To measure the viscosity for neat asphalt binder type, Brookfield rheometer (rotational viscometer device has been utilized at two different temperatures 135 °C and 165 °C according to ASTM D4402. The values of mixing and compaction temperatures for (40-50) penetration graded can be shown in Table 5.

**Table 5:** Mixing and Compaction Temperature for Asphalt Binder

| Temperature                  | Asphalt Binder |
|------------------------------|----------------|
| Mixing temperature, °C.      | 155            |
| Compaction temperature, °C.  | 145            |

As regarding to the waste materials as additives used in this study, two types of polymers have been used Crumb Rubber Modifier (CRM) and Low-Density Polyethylene (LDPE) and they differ in terms of their behavior and properties, one over the other. In spite of mixed-polymer modification, such as the
combination of elastomeric and plastomeric polymers, is not commonly used owing to the cost of using two polymers in the asphalt modification process may make the combination undesirable. However, it is possible that the addition of an elastomeric polymer to a plastomeric modifier could enhance low-temperature characteristics while maintaining high temperature stiffness and that one of the main objectives of this research and this opinion was confirmed in the asphalt institutes publications [7, 12].

Firstly, Crump Rubber Modifier (CRM) was used from tires factory in Al-Najaf / Iraq is a black granule (size 0.250 mm), specific gravity (1.13 gm./cm³), and this type is recycled from used tires. One dosage 15% of binder weight was mixed with neat asphalt binder using wet process at a certain blending time and temperature. In actuality the selection of such percentage was based on the recommendation of previous studies [12, 18] also, as defined in ASTM [19] as follows “A blend of asphalt cement, reclaimed tire rubber, and certain additives in which the rubber content is at least 15 percent by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling in the rubber particles.”

The size of the CRM particles has been determined in this study as (250 micron) to fulfill the requirements that have been confirmed by many studies have shown that the properties of rubberized asphalt binder especially the viscosity property in a CRM asphalt binder is strongly related to the CRM particle size, and other factors such as reaction time, and tire rubber content in the blend [11, 12]. However, in this work the blending temperature was in the range of (170ºC) to (180ºC) for 30 minutes. Tables (6) presents the physical properties and the viscosity characteristics when determined by a rotational viscometer according to ASTMD-4402 for modified asphalt binder by CRM

| Property                              | ASTM Designation | Test result (CMR) | SCR specification |
|---------------------------------------|-----------------|-----------------|------------------|
| Penetration (25 ºC,100 gm,5 sec)      | D-5             | 31              | (40-50)          |
| Ductility (25 ºC, 5 cm/min). (cm)     | D-113           | 12.8            | >100             |
| Flash point (Cleveland open cup), (ºC)| D-92            | >232            | Min.232          |
| Softening point, (ºC)                 | D-36            | 57              |                  |
| Viscosity, 135 (Pa. sec)              | D-4402          | 1.425           | ---              |
| Viscosity, 165 (Pa. sec)              | D-4402          | 0.301           | ---              |

Concurrently, Low density Polyethylene (LDPE) used in this study as a waste material, which was brought from (Al Tobiji) factories in Baghdad City/ Iraq, it is a waste green granule. In this study, LDPE as a polymer was utilized in the form of solid particles and it was added to the binder directly to significantly enhance the physical characteristics of the neat binder. The physical properties of modified asphalt binder by LDPE polymer in addition of CRM are shown in the Table (7). Polymer asphalt is prepared similar to CRM as mention previously by using the wet process when the LDPE is added to the binder before introducing it in the asphalt concrete mix. A mechanical mixer was manufactured with high shear mixing force and a multi-mixing speed up to 3500 rpm. Also, a heating system was erected to conserve the heating temperature of the binder during mixing process. It should be noted that plastic wastes, which generally includes the following materials (i.e., carry bags, detergents, water bottles and wrappers of biscuits, etc.) combines two very important benefits when it used in asphalt modification approach which are obtaining better asphalt pavement and the benefit of decreasing cost in addition to solve problems related to management in asphalt industries. Polyleolefin such as Polyethylene (PE) include 60% of these plastic wastes materials. Thus, it is obvious that polyethylene would be more effective and economical in asphalt paving industries than other modifier materials[20].
Table 7. Physical properties of modified asphalt with 15% CRM &/or LDPE

| Property                  | ASTM Designation | Test result |
|---------------------------|------------------|-------------|
| Penetration (25 °C,100 gm,5 sec) | D-5              | 22  20  20  16  29 (40-50) |
| Ductility (25 °C, 5 cm/min). (cm) | D-113            | 13  6  5  2.5  35  >100 |
| Flash point, (°C)         | D-92             | >232  >232  >232  >232  >232 Min.232 |
| Softening point, (°C)     | D-36             | 54  58  63  70  62 ------ |

The viscosity test results of modified asphalt binder by different percentage of LDPE in addition to the presence of 15% CRM characterized in Table (8). The test consequences illustrate that the viscosity of the modified asphalt binder with composite admixtures of 15% CRM: LDPE additives of ratios of 15: 2.5, 15: 5, 15: 7.5 and 15:10 respectively, and single pure of 7.5% LDPE was improved as the amount of those polymers increased than the neat asphalt binder.

Table 8. Viscosity of Different Amounts of CRM: LDPE and Single LDPE

| Asphalt Binder Type       | % Additives | Viscosity, Pa. Sec |
|---------------------------|-------------|--------------------|
|                           |             | @ 135 °C           | @ 165 °C           |
| Control                   | 0           | 0.775              | 0.156              |
| CRM: LDPE                 | 15:2.5      | 3.545              | 0.669              |
| CRM: LDPE                 | 15:5        | 6.958              | 1.300              |
| CRM: LDPE                 | 15:7.5      | 15.680             | 5.913              |
| CRM: LDPE                 | 15:10       | 16.000             | 9.175              |
| LDPE                      | 7.5         | 2.655              | 0.528              |

3. Testing Program

For fatigue capacity of HMA, a four-point bending load test were conducted in this study to evaluate the performance of the prepared beam specimens under repeated loading. Test configuration involved exposing a constant flexural strain repeatedly under 5 HZ at ambient temperature (20 °C), till the stiffness degrades of about 50% of the initial stiffness, since at such point the micro cracks tend to initiate.

The Standard specifications that define laboratory conditions and details related to this type of performance test in AASHTO T 321[21], “Determining the Fatigue Life of Compacted Hot-Mix Asphalt (HMA) Subjected to Repeated Flexural Bending” or ASTM D7460. Unlike cylindrical specimens which are often produced using the Superpave gyratory compactor, beam specimens are most often produced using a rolling wheel or linear kneading compactor. After production, specimens are cut to the desired test dimensions of 63-millimeter (2.5-inch) width by 380-millimeter (15-inch) length by 50-millimeter (2-inch)
thick. The target percentage of air voids in the test specimen is usually $7 \pm 1\%$ to represent the expected in-place density of the asphalt mixture. Two or more specimens are tested at a specified temperature and strain level varying from 250 to 750 $\mu$m. The selected deflection level (peak-to-peak strain level) is such that the specimen will undergo a minimum of 10,000 load cycles before its stiffness is reduced to a 50% of initial stiffness that represents specimen failure in the testing plan.

It worth to be mentioned that are two strategies to perform fatigue test. Either by applying constant stress and obtaining various strain values or apply constant strain to achieve stress behavior. Previous research confirmed that the constant strain testing mode might be suitable for thin asphaltic pavement layer, while the other testing strategy suits the thick ones. In other words, the first previously mentioned testing program is suitable for flexible stiff material, while the second one suits the stiffer materials relatively.

Since the study focuses on behavior of thin asphalt layer, the constant strain load testing method were adopted for testing prepared HMA specimens.

### 4. Sample Preparation

The fatigue beam specimen was prepared according to AASHTO T 321 [21]. The asphalt mixture that consisted of course, fine aggregate, filler and binder at specific temperature were prepared and mixed by electrical -mechanical mixer for 120 second until asphalt sufficiently coated the surface of the aggregates according to 7th-Edition of Asphalt institute book “Asphalt Mix Design Methods, MS-2”[1]. In order to prevent the mixture outside from aging more than the inner side due to increased air exposure, the mix was stirred every 30 minutes through the short-term aging process, then the 7 % air void achieved by roller compaction machine according to EN12697-33 [23]. After that the slab was sliced to the required dimension for stiffness or fatigue tests. Tests were conducted at optimum asphalt content for the three selected types of aggregate mixtures. The mixtures of NMAS 12.5 mm and 9.5mm have optimum AC of 4.5% and 4.8%, respectively. Preparation of test specimens’ conditions are cleared in Table (9). The total number was (24 beams).

### Table 9. Preparation Condition of Flexural Fatigue Test Specimens

| Parameter                                           | Standard          | Used Value for Thin Asphalt Overlay |
|-----------------------------------------------------|-------------------|-------------------------------------|
| Asphalt temperature °C                              | 150-165           | 150                                 |
| Aggregate temperature °C                            | 170               | 170                                 |
| Mix temperature °C                                  | 130-180           | 150                                 |
| Temperature compaction                               | (135- 155) °C     | 145 °C                              |
| Test temperature °C                                 | 25 ± 1            | 25± 1                               |
| Number of specimens                                 | 3                 | 3                                   |
| Compaction (Roller compactor machine) rectangular   | Compacted to 7 ± 0.5% air void | Compacted to 7 ± 0.5% air void      |
| metal mold dimensions                               | 12 cm thickness x 30 cm width x 40 cm length | 12 cm thickness x 30 cm width x 40 cm length |
| The required mixture weight                         | -                 | approximately 13000 grams           |
| The shape of specimens                               | Beams             | Beams                               |
| The dimensions of the beam specimen                  | 50=6 mm high, 63±6 mm wide and 380 mm long | 50=6 mm high, 63±6 mm wide and 380 mm long |
| Conditioning time of mixture                         | 2 hr. or 4hr at compaction temperature. | 2 hr. at compaction temperature.   |

### 5. Results

The physical tests results of modified asphalt binder as shown through Tables (6, 7, 8 and 9) that the rheological characteristics are enhanced by the adding of CRM and LDPE. After blended with CRM and LDPE, asphalt binder display increasing in softening point, viscosity and decreased penetration that means...
the CRM/LDPE modified asphalt binder in high and intermediate temperature range become more stiff (harder) and more resistant to deformation. Overall, the test results show that properties of modified asphalts binder by CRM or LDPE in terms of rheological characteristics are mainly dependent on the polymers content. In general, more LDPE content produces more obvious modification influence, and a big improvement in mechanical characteristics can be attained by utilizing a combination of both CRM and LDPE. In the CRM/LDPE modified asphalt binder network by polymers is developed, and its formation is significantly affected by the amount of both polymers (CRM and LDPE).

To show the effect of 15% CRM content blended with the binder used in this study on fatigue life under testing temperature of 20 °C and, different levels of strain were applied. Table (10) and Figure (3) depict the effect of 15% CRM on fatigue life in the mixtures of No.4, 9.5 mm and 12.5 mm, NMAS. The analysis of the Figure (3) shows that when 15% CRM is used, the fatigue life increases by 36% and 21 % when compared with control mix (at 250 μƐ, 20°C for 9.5 mm and 12.5mm NMAS mixtures, respectively). Where the increase in fatigue life in small NMAS is higher than in coarser ones, which might be due to the percentage of the binder content and the resilient elastic strength that added by CRM.

| Mix type | NMAS | Asphalt content | CRM Content | Fatigue life, Nf |
|----------|------|----------------|-------------|-----------------|
|          |      |                |             | 250μƐ | 450μƐ | 750μƐ |
| C12.5    | 12.5 | 4.5            | 0           | 9100  | 250   | 126   |
| C9.5     | 9.5  | 4.8            | 0           | 10300 | 338   | 256   |
| CRM12.5  | 12.5 | 4.5            | 15          | 11500 | 519   | 468   |
| CRM9.5   | 9.5  | 4.8            | 15          | 16000 | 541   | 476   |
Due to the increasing of microstrains level, the fatigue life reduces. It is clear from the results analysis of Table (10), fatigue life reduces by 97% as increasing in micro strain from 250 μƐ to 450 μƐ and reduces 50%, also as increasing in microstrain from 450 μƐ to 750 μƐ, (at the control mixture 12.5mm NMAS). Also (at the mixture 12.5mm NMAS, CRM 15% Mix) the fatigue life decreases by 95% when microstrain increases from 250μƐ to 450μƐ and fatigue life reduces by 10% as microstrain increases from 450 μƐ to 750 μƐ. This may be attributed to the fact that higher loading accumulation causes premature cracking or distress, this is confirms by [24].

However, the results imply that introducing rubber increase mix fatigue life which highly prefer for flexible pavement layers in general and for overlay layer in specific and that confirms by some other study [25, 26] who presented that the blending of binder with CRM would increase the fatigue and thermal cracking resistance. Finally, from the mentioned earlier results. It should be noted that the addition of CRM by 15% percentage to the asphalt binder led to an increase in the fatigue life of the mixture owing to the role of waste materials plays another direction that the mixture became more flexible.

Figure (4) and Table (11) depict the effect of LDPE only and combination with CRM on fatigue life in the mixtures of 12.5mm and 9.5mm NMAS. The analysis of the Figure (4) shows when 15% content by total percentage of asphalt binder of Crumb Rubber Modifier (CRM) in addition of 7.5% LDPE that increasing occur in fatigue life by 40% and 39% for 9.5mm and 12.5 mm NMAS mixtures, respectively in term of comparing it with control mix (at 250 μƐ, 20°C), but when used the 7.5% LDPE only the fatigue life decreases by 32% and 45% for 9.5mm and 12.5 mm NMAS mixtures respectively in term of comparing it with control mix (at 250 μƐ, 20°C).
Figure 4. Effect of CRM and LDPE on Fatigue Life (Nf) (at 250 μƐ, 20°C)

Table 11. Effect of Polymers Type on Initial Stiffness (Mpa)

| Mix Type (NMAS, mm) | Additives % | Micro strain Level, μƐ |
|---------------------|-------------|------------------------|
|                     |             | 250 | 450 | 750 |
| 12.5                | 0           | 7350 | 2566 | 874 |
| 12.5                | 7.5%LDPE+15%CRM | 3000 | 162 | 195 |
| 12.5                | 7.5%LDPE    | 3200 | 347 | 281 |
| 9.5                 | 0           | 5300 | 1620 | 374 |
| 9.5                 | 7.5%LDPE+15%CRM | 2000 | 127 | 123 |
| 9.5                 | 7.5%LDPE    | 2550 | 276 | 261 |

It was observed during the laboratory work and the analysis of data. When 7.5% of Low-Density Polyethylene (LDPE) only added that reduces the fatigue life of asphalt mixture. So, we can conclude the LDPE content 7.5% in addition of 15% CRM increases the fatigue life for all types of mixtures because the asphalt mixture contains 7.5% (LDPE) and 15% (CRM) have a better fatigue life at all microstrain levels as compared with control asphalt mixtures and the same reasons as mention previously.

6. Conclusions

The fatigue life parameter of HMA mixtures represents important indicator of the fatigue and fracture characteristics, from the test results of controlled strain fatigue beam for two types of aggregate gradation mixtures with one types of neat asphalt binder and several types of modifies asphalt binder introduces the following conclusions:

1. The physical properties of asphalt binder affected considerably by using the waste polymers as additives through increasing the values of softening point and viscosity and reducing the penetration point value and ductility test results.
2. The fatigue life of HMA affected significantly by aggregate gradation used. Fatigue life increased by (12%) for control mixture at 250 micro strain has 9.5 mm NMAS as compared with mixture has 12.5 mm NMAS.
3. Fatigue life increased by (28%) for 9.5 mm NMAS modified mixture by 15% CRM as compared with control mixture at 250 micro strain. Also, when adding 15% of CRM to the
asphalt binder the modified mixture of 12.5 mm NMAS has been increased in fatigue life by 21% as compared with control mixture has 12.5 mm NMAS.

4. The fatigue life reduces when increasing of micro strains level, fatigue life reduces by 97 % as increasing in micro strain from 250 μƐ to 450 μƐ and reduces 50 %, also as increasing in micro strain from 450 μƐ to 750 μƐ, (at the control mixture 12.5mm NMAS). Also (at the mixture 12.5mm NMAS, CRM 15% Mix) the fatigue life decreases by 95% when micro strain increases from 250μƐ to 450μƐ and fatigue life reduces by 10% as micro strain increases from 450 μƐ to 750 μƐ.

5. Low Density Polyethylene (LDPE) plays a main role in increasing the fatigue life of modified asphalt mixture when adding to the neat asphalt binder as additive in addition to 15% CRM, the test results depicts that that increasing occur in fatigue life by 40% and 39% for 9.5mm and 12.5 mm NMAS mixtures, respectively in term of comparing it with control mix ( at 250 μƐ, 20°C), but when used the 7.5% LDPE only the fatigue life decreases by 32% and 45% for 9.5mm and 12.5 mm NMAS mixtures respectively in term of comparing it with control mix (at 250 μƐ, 20°C).

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