Effect of Aggregate Gradation on Rutting of Thin Asphalt Overlay

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Abstract. Permanent deformation (rutting) of asphalt pavements has a major impact on the service life of pavements. Rutting reduces the performance of the pavement and produces serious hazards for highway users. Due to the axle loads incensement, and high local summer temperature, rutting became the major distress in flexible pavements for many countries. Recently, thin asphalt overlay (TAO) is recommended as a significant remedy technique for deteriorated pavements. Aggregates are one of the main structure materials asphalt paving mixtures, whereas, aggregate properties remarkably effected on the asphalt pavements performance. Aggregate gradation is representing the significant feature of aggregates that affecting permanent deformation of traditional hot mix asphalt (HMA) thick pavement layers. The aim of this study is to examine the influence of aggregate gradation differences on rutting features of modified TAO mixtures that comprising waste polymers. The evaluation process included the preparation of polymer modified asphalt (PMA) comprising two types of additives, namely, Crumb Rubber Modifier (CRM) and Low-Density Polyethylene (LDPE). CRM and LDPE in the form of fines that have a particle size under 250 um were used as additives to liquid neat asphalt, individually and collectively by weight of virgin asphalt; i.e., PMA included 15.0% of CRM and (2.5. %, 5.0%, 7.5% and 10.0% of LDPE. Three types of aggregate gradations were used, i.e. 12.5, 9.5 and 4.75mm, Nominal maximum aggregate size, (NMAS). The Superpave mix design system was adopted in volumetric proportioning of prepared mixtures, while Wheel Tracking (WT) test was used to determine the rut depth characteristics for prepared mixtures. about 30 asphalt concrete specimens were prepared to forecast the TAO behavior concerning permanent deformation for wearing course type III A and B according to State Corporation of Roads and Bridges in Iraq, while for 4.75mm, NMAS (sand asphalt layer) an abroad specification was used. Results demonstrated that the aggregate gradation plays a vital role in increasing permanent deformation for several type of TAO mixtures. Also, the addition of CRM by 15% to the neat asphalt led to an increase in the resistance of the mixture to permanent deformation. Moreover, PMA with LDPE became hardener (higher viscosity) which led to increase binder stiffness, whereas a consequent is stiffening the mixture. Therefore, optimizing aggregate gradation with PMA including waste polymers can limited the rutting occurrence distinguishably

Keywords. Aggregate Gradation; Ground Tire Rubber; Hot Mix Asphalt; Low-density Polyethylene; Thin asphalt overlay; Rutting, wheel-track testing.
1. Introduction

The distress that representing the most vital type of load-associated distresses is permanent deformation that happening in the systems of flexible pavement. It is related with rutting in the wheel pathway, which changes gradually as the number of load repetitions accumulates [1]. Many factors are affecting rutting of asphalt pavements which can be categorized into three groups. The first group is the external causes which comprises traffic and environmental conditions. The second group is the internal causes which deal with the outcome of asphalt binder, aggregate, and mix properties on the rutting behavior of asphalt pavement. The third group contains the structural environments which include the influence of thickness of layer of the pavement system on rutting resistance [2]. With respect to external factors it is well-known that the rutting is largely began by traffic loading, but climate can also has a great effect, particularly when the pavement subgrade suffers seasonal differences mixture performance [5, 6].

On the other hand, mineral aggregates play an important role in the performance of asphalt mixtures. Aggregates constitute about 85% of total volume of asphalt mixtures [7]. Some researcher believe that the element that is frequently noticed as the most effective parameter causing rutting is the properties of aggregates [8]. Because at high temperatures, the asphalt will become softer and less viscous therefore, the aggregates in HMA are carrying all the applied traffic loading [2]. Stakston and Bahia also showed that rut resistance is “highly dependent on aggregate grading”, and if that mixes have the best possible materials may be fail without a proper gradation [9].

On the other side, modifications of asphalt is aimed to enhance both the life time and performance of pavements. Thereby they provide advantage for both the environment and economic sectors [10]. As the asphalt binder is responsible for the viscous-elastic behavior of asphalts pavement, it shows a great portion in determining many parts of road performance, particularly resistance to deformation and cracking. So to perform asphalt binder, modification is needed to enhance several binder properties. For example, improving binder stiffness can increase the hot mix asphalt stiffness, that lead to performance improvement of the asphalt mixture at high temperature, consequently this is reducing the rutting. By choosing a proper asphalt modifier, the service life of the pavement can be increased [11]. As indicated in many studies, it is found that the deformation resistance, high-temperature stability, and flexibility of asphalt binder are all improved after waste tire rubber and recycled polyethylene were added [12-14]. These studies stated that the adding of ground tire rubber to bitumen, increase viscoelastic moduli and viscosity at high in-service temperatures. Similarly, Polyethylene was also used as asphalt modifier. Appiah et al reported that using recycled plastic contains predominantly of polypropylene and LDPE into pure bituminous concrete mixture will increase its durability and service life [15]. The modified asphalt concrete with LDPE shows resistance to deformation compared to the unmodified mixes.

Thin asphalt overly (TAO), is a maintenance technique that has been proven as a cost effective and high performance remedy method [5]. Such technique is limited by the thickness of the layer with not more than 3.8 mm, where that affecting the selected NMAS, and the percentage of the asphalt binder due to high surface area. For a thin asphalt layer, stone-on-stone friction, increase the stiffness of HMA and interlock between aggregates are the principal mechanisms against rutting. This is attained by one of the two subsequent approaches, both of which result in a reduction in the permanent strain. The first approach is to harden the asphalt binder so that the total viscous-elastic response of the asphalt is reduced. The second approach is the coarse and fine aggregate gradation effect. In this research two types of waste polymers were used, i.e., waste LDPE and CRM as asphalt modification. Waste LDPE proposed with different percentage (i.e. 2.5, 5, 7.5, and 10) % by weight of the total asphalt binder and CRM with (15) % by weight of total asphalt binder to improve the properties of asphalt binder. Also, three types of aggregate gradation 4.75, 9.5 and 12.5 mm, NMAS are nominated to investigate the effect of coarse and fine aggregate gradation on rutting mechanisms. This research is aimed to investigate the combined effect of gradations and waste polymer inclusion on the permanent deformation resistance of TAO mixtures.
2. MATERIALS

The main materials used in this study were traditional materials include asphalt cement, graded aggregate, and mineral filler, they were locally available now and widely employed in the Iraq for the projects of pavement construction. The properties of these materials were evaluated by classical type of tests and the gained results were compared with the Iraq specification requirements SCRB-R/9 [16]. Moreover, the Superpave method specification requirements followed wherever it indicated as presented in following sections. On the other hand, PMAs were prepared using CRM and LDPE. One type neat asphalt cement binder (40-50) penetration graded binders from Al-Daurah refinery was considered, its physical properties are shown in Table 1.

Table 1. Physical Properties of Asphalt Cement

| Property                              | ASTM Designation | Test result | SCRB specification |
|---------------------------------------|------------------|-------------|--------------------|
| Penetration at 25 °C,100 gm,5 sec. (0.1 mm) | D-5              | 47          | (40-50)            |
| Ductility at 25 °C, 5 cm/min. (cm)     | D-113            | >100        | >100               |
| Flash 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%           |
| Specific gravity at 25 °C             | D-70             | 1.04        |                    |

To fulfill the objective of this study three kinds of aggregate gradations were used in this work, where under thin asphalt overlay definitions, a NMAS of 12.5, 9.5 and 4.75 mm were selected. Routine Laboratory tests were conducted to determine the basic aggregates properties. Table 2 shows the test results of aggregate (coarse and fine) together with the specification limits as set by the SCRB. Tests results show that the chosen aggregate met the SCRB and Superpave specifications.

Table 2. Physical Properties of Coarse and Fine Aggregates

| Property                                              | ASTM Designation | Coarse Aggregate | Fine Aggregate | SCRB Specification | Superpave Specification |
|-------------------------------------------------------|------------------|------------------|----------------|--------------------|-------------------------|
| Bulk Specific Gravity                                  | C-127 and C-128  | 2.58             | 2.60           |                    |                         |
| Apparent Specific Gravity                             | C-127 and C-128  | 2.63             | 2.69           |                    |                         |
| Percent Water Absorption, %                            | C-127 and C-128  | 0.729            | 1.419          |                    |                         |
| Percent Soundness Loss by Sodium Sulfate Solution, %   | C-88             | 2.08             | 3.20           | 12%                | 10-20                   |
| Percent Wear (Loss Angeles Abrasion), %                | C-131            | 15               | ------         | 30% max.           | 35-45                   |
| Percent Flat and Elongated Particles, %                | D-4791           | 1                | ------         | 10 Max             | 10 Max                  |
| Fractured Pieces, %                                    | C-117            | 96               | 90 Min.        | 95 Min.            |                         |
| Passing sieve NO.200, %                                | C-142            | 1.07             | 2.66           | 3% Max             |                         |
| Clay lumps, %                                          | D-2419           | 49               | 45 Min.        | 45 Min.            |                         |

The coarse and fine aggregates were sieved according to ASTM specification (Annual Book of ASTM Standards, Section 4, Construction, Vol. 04.03, Road and Paving Materials; Pavement Management Technologies, American Society for Testing and Materials for dense graded mixtures. Table 3 through Table 5 display aggregate gradation with specification limit according SCRB, Superpave and ASTM
specifications. It is worth mentioned the mid-range of each specified sieve size by such specification were used.

**Table 3.** Selected Gradations for NMAS (12.5 MM) Asphalt Concrete Mixtures

| Sieve size | % passing by weight of total aggregate filler | Specification limits for wearing coarse (SCRB) | Superpave Specification | Restricted Zone |
|-------------|---------------------------------------------|-----------------------------------------------|-------------------------|-----------------|
| Standard sieves (mm) | English sieves (in) | Specification limits |                                    |                |                |
| 19          | 3/4''                                      | 100                                           | 100                     | 100             | -               |
| 12.5        | 1/2''                                      | 95                                            | 90-100                  | 90              | 100             | -               |
| 9.5         | 3/8''                                      | 83                                            | 76-90                   | -               | 90              | -               |
| 4.75        | No.4                                       | 59                                            | 44-74                   | -               | -               | -               |
| 2.36        | No.8                                       | 35                                            | 28-58                   | 28              | 58              | 39.1 39.1       |
| 1.18        | No.16                                      | 23                                            | -                       | -               | -               | 25.6 31.6       |
| 0.6         | No.30                                      | 16                                            | -                       | -               | -               | 19.1 23.1       |
| 0.3         | No.50                                      | 11                                            | 5-21                    | -               | -               | 15.1 15.1       |
| 0.075       | No.200                                     | 6                                             | 4-10                    | 2               | 10              | -               |

**Table 4.** Selected Gradations for NMAS (9.5 MM) Asphalt Concrete Mixtures

| Sieve size | % passing by weight of total aggregate filler | Specification limits for wearing coarse (SCRB) | Superpave Specification | Restricted Zone |
|-------------|---------------------------------------------|-----------------------------------------------|-------------------------|-----------------|
| Standard sieves (mm) | English sieves (in) | Specification limits |                                    |                |                |
| 12.5        | 1/2''                                      | 100                                           | 100                     | 100             | -               |
| 9.5         | 3/8''                                      | 95                                            | 90-100                  | 90              | 100             | -               |
| 4.75        | No.4                                       | 70                                            | 55-85                   | -               | 90              | -               |
| 2.36        | No.8                                       | 35                                            | 32-67                   | 32              | 67              | 47.2 47.2       |
| 1.18        | No.16                                      | 23                                            | -                       | -               | -               | 31.6 37.6       |
| 0.6         | No.30                                      | 16                                            | -                       | -               | -               | 23.5 27.5       |
| 0.3         | No.50                                      | 11                                            | 7-23                    | -               | -               | 18.7 18.7       |
| 0.075       | No.200                                     | 6                                             | 4-10                    | 2               | 10              | -               |

**Table 5.** Selected Gradations for NMAS (NO.4) Asphalt Concrete Mixtures, [17]

| Sieve size | % passing by weight of total aggregate filler | ASTM Specification |
|-------------|---------------------------------------------|---------------------|
| Standard sieves (mm) | English sieves (in) |                         |
| 9.5         | 3/8''                                      | 100                 |
| 4.75        | No.4                                       | 90                  | 80 100              |
| 2.36        | No.8                                       | 83                  | 65 100              |
| 1.18        | No.16                                      | 60                  | 40 80               |
| 0.6         | No.30                                      | 45                  | 25 65               |
| 0.3         | No.50                                      | 24                  | 7 40                |
| 0.075       | No.200                                     | 6                   | 2 10                |

The mineral filler is a non-plastic material that passed sieve No. 200 (0.075mm). The used filler in this study is limestone dust gained from Karbala lime factory. The physical properties of the filler used are presented in Table 6.

**Table 6:** Physical Properties of the Used Filler

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

Two types of waste polymers, namely, LDPE and CRM as asphalt modifiers. LDPE was supplied from Al Tobji recycling factories in Baghdad City, which is a waste green granule, Figure 1-a, it recycled from
collected waste plastic bags, and normally it ended for producing plastic recycle shopping bags. LDPE properties as follows: Density= 0.918 g/cm³, Melt index, g/10 min= 2.0 and Tensile strength, Mpa= 20. CRM was supplied from Al-Najaf tires factory, which is a black granule (size 250 micron) with a specific gravity of (1.13), it is a recycled rubber obtained by mechanical shearing or grinding of used tires into small coarse crumb rubber, Figure 1-b. It is a sustainable production created from remains rubber that is ground and pulverized into different mesh sizes. It has been found that at least 15 % rubber by weight of the total blend is usually necessary to provide acceptable properties of asphalt-rubber that the reason of using of 15% CRM and that supported by ASTM D 6114 [18].

![Figure 1. Used waste polymers, a) LDPE, b) CRM](image)

3. SAMPLES PREPARATION
Specimen was prepared using heat rectangular metal mold and tools to compaction temperature with dimension of (12 cm thickness x 30 cm width x 40 cm length). The required mixture batch was 11000 grams. Generally, two test specimens were prepared for each test. The dimensions of the slab specimen used in this work are 40x300 x 400 mm. The asphalt mixture prepared and mixed of course, fine aggregate, filler and binder at specific temperature of 170 °C. Asphalt mix design procedures have used equiviscous temperature ranges for selecting laboratory mixing and compaction temperatures. The purpose of using equiviscous mixing and compaction temperatures in laboratory mix design procedures is to normalize the effect of asphalt binder stiffness on mixture volumetric properties. However, the increased usage of highly modified asphalt binders frequently resulted in unusually high equiviscous mixing and compaction temperatures the aggregates and asphalt were mixed in mixing bowel on hot plate for three minutes until asphalt had sufficiently coated the surface of the aggregates. Then, the compaction achieved by using roller compactor machine to get 4% air void to insure the real case in field and to make for condition specimen according to BS (EN 12697-22) for Wheel-Track Test (WTT). Then compacted slab specimens is allowed to cool at normal room temperature on a clean, flat surface until cool to the touch. All specimen were kept at this temperature for 2 hours period to testing. It is worth mentioned that the each 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 increased air exposure. Tests were conducted at optimum asphalt content for three types of aggregate blends and for all types of mixtures that having several types of additives in different percentage. The total number of specimens for this part was 30 specimens.
4. TESTING
Wheel-Track Test (WTT) was used to measure the permanent deformation resistance in accordance with BS (EN 12697-22)[19]. The device is advanced to test rutting depth and to assess the permanent deformations or rutting resistance of HMA pavement specimens under the certain conditions to simulate the influence of traffic. This test provides information about the rate of permanent deformation from a moving, concentrated load. Wheel-Tracking Machine (WT) is used to compute the premature failure susceptibility of HMA due to weakness in the aggregate structure, inadequate binder stiffness, or moisture damage and measures the rut depth and number of passes to failure. Wheel-Tracking Machine is an electrically powered machine capable of moving a 203.2-mm (8-in.) diameter, 47-mm (1.85-in.) wide rubber wheel over a test specimen. The load on the wheel is 705 ± 4.5 N (158 ± 1.0 lb.). The wheel reciprocates over the specimen, with the position varying sinusoidal over time. The wheel makes 52 ± 2 passes across the specimen per minute. The maximum speed of the wheel, reached at the midpoint of the specimen, is approximately 0.305 m/s (1 ft./s) [19], The wheel-tracking device will stop when 20,000 passes have occurred, or when the test has achieved the maximum rut depth. Specimen was prepared as mention previously in Roller Compactor Device using Heat rectangular metal mold and tools to compaction temperature with dimension of (12 cm thickness x 30 cm width x 40 cm length), two test specimens for each test were prepared. Specimen thickness must be at least twice the nominal maximum aggregate size, generally yielding a specimen 38 to 100 mm (1.5 to 4 in.) thick. 40 mm thickness samples were selected to accommodate all gradation layer requirements. A temperature of (60 Cº) was used to evaluate their effect in addition to the effects of physical properties of polymers on performance of asphalt mixtures. At least two readings at the center of specimen are recorded for each case at specified number of loading cycles to calculate rut depth directly under rolling length of wheel on the sample surface to simulate the longitudinal depressions in the wheel paths of the road surface.

5. RESULTS AND DISCUSSIONS
Wheel-Track Test (WTT) was used to measure the permanent deformation resistance in accordance with BSI (EN 12697-22) of the compacted mixtures in a reciprocating rolling-wheel compactor device has been designed to prepare slab specimens.

Table 7. Effect of NMAS on Rut Depth (mm)

| Mix Type  | Modified Type | NMAS  | No. of Cycles | Rut Depth, (mm) |
|-----------|---------------|-------|---------------|-----------------|
| Control   | Control       | NO.4  | 1500          | 20              |
| Control   | Control       | 9.5 mm| 10000         | 17.41           |
| Control   | Control       | 12.5 mm| 10000        | 15.07           |

Figure 2. Percentage Reduction on Rut Depth Due to the Effect of Nominal Maximum Aggregate Size

It is obvious from the analysis of the data shown in Table 7 and Figure 2 that the gradation of 12.5mm, NMAS has the higher resistance to permanent deformation (lower rut depth) followed by the mixture of 9.5mm, NMAS as compared with the mixture of No. 4, NMAS. During temperature increasing in summer
seasons or in hot climate area and that represents the basic condition of occurring the rutting and permanent deformation in HMA layers but the asphalt binder became soft because the reduction in viscosity under the effect of high temperature. So, the aggregate plays the important role to carry the traffic loading therefore, the aggregate gradation and the NMAS represents the important factors affecting in resisting of the permanent deformation. The result confirm that the permanent deformation resistance increases with increasing the nominal maximum aggregate size as a result of make the basic structure of the mix such that the traffic is supported by direct stone on stone contact and to ensure that the mix will not densify under traffic. Previous research studies realize the important role of the coarse aggregate that plays in the rutting behavior of HMA stability and the role of coarse aggregate morphologies. In dense graded asphalt mixes, coarse aggregate size and shape properties are believed to some extent contribute to the rutting resistance of asphalt concrete of aggregate and air voids. Moreover, the results disclosed the need for increase the resistance of the asphalt binder to resist the subjected load under high in service temperatures. However, polymers could be a vital approach, while waste polymer could add sustainable touch.

Table 8 depicts the results of wheel tracking test for asphalt control mixtures and modified asphalt mixtures for three selected types of aggregate gradation mixtures.

| Mix Type       | Modified Type            | NMAS | Rut Depth, (mm) at 1500 cycles | Rut Depth, (mm) at 10000 cycles |
|----------------|--------------------------|------|--------------------------------|---------------------------------|
| Control        | Control                  | NO.4 | 20                             | 20                              |
| CRM            | 15%CRM                   | NO.4 | 7.97                           | 20                              |
| CRM/LDPE2.5    | 15%CRM+2.5%LDPE          | NO.4 | 1.41                           | 2.67                            |
| CRM/LDPE5      | 15%CRM+5%LDPE            | NO.4 | 1.85                           | 4.12                            |
| CRM/LDPE7.5    | 15%CRM+7.5%LDPE          | NO.4 | 1.30                           | 2.03                            |
| CRM/LDPE10     | 15%CRM+10%LDPE           | NO.4 | 0.63                           | 1.19                            |
| LDPE7.5        | 7.5%LDPE                 | NO.4 | 2.60                           | 4.99                            |
| Control        | Control                  | 9.5 mm | 5.41                        | 17.41                           |
| CRM            | 15%CRM                   | 9.5 mm | 2.30                        | 4.71                            |
| CRM/LDPE7.5    | 15%CRM+7.5%LDPE          | 9.5 mm | 0.75                        | 1.26                            |
| LDPE7.5        | 7.5%LDPE                 | 9.5 mm | 1.75                        | 2.29                            |
| Control        | Control                  | 12.5 mm | 3.20                     | 15.07                           |
| CRM            | 15%CRM                   | 12.5 mm | 0.90                        | 3.10                            |
| CRM/LDPE7.5    | 15%CRM+7.5%LDPE          | 12.5 mm | 1.01                        | 1.36                            |
| LDPE7.5        | 7.5%LDPE                 | 12.5 mm | 0.49                        | 0.67                            |

The attained results characterized the average values of the maximum rutting depth for two specimens that occur at number of cycles (passes) of loading from WT test, rutting depth and number of cycles for different mixtures with or without CRM and LDPE. It can be seen from Table 8 that the modified asphalt mixtures have higher permanent deformation resistance as compared with control mixtures for types of mixtures which give a clear indications of the effect of polymers on behavior of performance in which the (rut depth) for mixtures. The rutting resistance of modified mixtures effected by the type and physical properties of modifier and concentration of modifiers. The effects of physical properties of polymers on the rutting (permanent deformation) resistance for No.4, NMAS modified mixtures are shown in Figure 3. The value of rutting depth for the control asphalt mixture is (20mm at 1500 NO. of Cycles,), it’s quickly failed and that means this mix type unable to stand under such distresses. Thus, it is vital to find out ways to improve the HMA by modifiers to be able to stand under such distresses. By the analysis of test results the modifier has profound effect by decreasing rutting depth and increasing resistance to permanent deformations. Figure 3 shows the effect of polymer types on the performance of the mixtures and the effect of polymers concentrations on rut depth. It can be noted that the modified mixtures by (15 % CRM)
have rutting depth (7.97mm) @1500 cycles, as compared with control mix at 60 ºC, that means it has high resistant to permanent deformation and that returned to good interaction and bonded of softer particles with asphalt binder at blending process.

![Figure 3. Effect of Polymer Type and percentage on Rut Depth, for NO.4, NMAS Mixture @ 1500 Cycles](image)

On the other hand, asphalt mixtures modified by different percentage of LDPE in addition to 15% CRM have rutting depth (1.41mm,1.85 mm, 1.30mm and 0.63 mm) for (2.5%:15%, 5%:15%, 7.5%:15%, 10%:15%) CRM: LDPE, respectively, these mixtures have lower rut depth than modified mixtures by (15% CRM, at 60 Cº) and that gives a good indication about the uses of LDPE in addition to CRM when the rut depth is reducing as compared with No.4, NMAS control mixture. The rutting depth decreasing by increasing in percent of LDPE polymer. Increases of percent of concentration LDPE corresponded decreasing on the rutting depth, so the mixtures have 7.5% and 10% (LDPE & 15% CRM) are better than other mixtures because it has high molecule weight (high density) that gives a high stiffness to better resistance of permanent deformation.

When using the waste LDPE only by 7.5% without 15% CRM in the mixture of No.4, NMAS, results shows that rutting depth increasing higher at a certain amount than the modified asphalt mixtures by CRM and LDPE together. That confirms an indication about the effect of CRM when blended with LDPE, the admixture of polymers CRM: LDPE together increasing the stiffness of binder during the high temperature by increasing the softening point and decreasing the penetration. Other indicators of physical tests results that indicate the asphalt binder became more stiffness and that it is especially required for this kind of fine aggregate mixtures because it must be noted that at high temperature seasons or on hot climate area the asphalt binder became softer and more viscous so, the aggregate play the main role for carrying the traffic loading therefore it very important increasing the stiffness of asphalt binder for fine aggregate mixtures.

Figure 4 and 5 show that when 15% content by total percentage of asphalt binder of CRM used, the permanent deformation resistance increases through the index of rut depth reduction. It should be noted that the same trend occurs at the mixture of 12.5mm, NMAS and 9.5 mm, NMAS. This results is due to increase in viscosity of the film; increase in viscosity at high temperature leading to increase in binder stiffness. Also, the addition of LDPE in the asphalt binder in the presence of CRM that reduce the rut depth thus, improve the performance of HMA and increase the resistance to rutting. The use of the relatively hard asphalt cement in pavement construction produces mixtures with higher interlock between the aggregates that increasing resistance to permanent deformation. But when using the soft binder will lubricate the aggregate particles to such an extent that mixture will lack internal friction and become unstable.
For the comparison between the three types of mixtures in the presence of waste polymers (CRM and LDPE) it can be seen that the largest NMAS of 12.5 mm is the lower rut depth followed by the mixture of 9.5mm, NMAS and No.4, NMAS, when adding 15% CRM and 7.5 % LDPE. It can be seen the permanent deformation resistance increases for the mixture of 12.5mm, NMAS as compared with the mixture of 9.5mm and No.4, NMAS respectively, and that support the fact that the rut depth reduces by stiffer binder as a result of cross linking effect of LDPE polymer.

6. CONCLUSION
For the mixtures evaluated in this study, the following findings are derived:

1. The TAO mixture with 12.5 mm, NMAS introducing the best performance against rutting, while TAO with 4.75mm, NMAS has the highest amount of permanent deformation for control and modified mixtures. That support the fact about the importance of aggregate gradation and NMAS in permanent deformation resistance.

2. Adding polymers as CRM increases the resistance to permanent deformation, for 4.75 mm, NMAS mixture the adding of CRM reduces the rut depth to 60% as compared with 4.75mm, NMAS control mixture. The same trend for other mixtures for example, 12.5 mm, and NMAS mixtures the reduction in rut depth about 79% as compared to control mixture of 12.5 mm, NMAS.
3. Asphalt mixtures modified by different percentage of waste LDPE in addition to 15% CRM have rutting depth has lower rut depth than modified mixtures by (15% CRM, at 60 C°), the uses of waste LDPE in addition of CRM adding value of rut resistance performance of TAO mixtures.
4. Increases of percent of waste LDPE concentration to 7.5% and 10% (LDPE & 15% CRM) is offering better rut resistance than other mixture because it has high molecule weight (high density) that gives a high stiffness to better resistance of permanent deformation.

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