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Impact of Rejuvenators Type on Physical Properties of Aged Asphalt Cement

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Abstract

Recycling can be considered as one of the measures of sustainable methods. The physical traits of the asphalt mixture under the influence of accelerated aging (Long and Short–Term) for asphalt concrete were assessed. Asphalt cement (40-50), aggregate with 12.5 mm nominal extreme size and limestone dust as filler of the mineral was used for the preparation of asphalt concrete mixture. At the optimum content of the asphalt and asphalt of 0.5 percent below and above the optimum value, specimens were prepared by using Marshall Method. Two types of polymers as recycling agents were used (Polyethylene of Low Density and Crumb Rubber) with (0.5, 1 and 1.5) % by weight of the binder. The indirect tensile test was used for the mixtures at 25 ºC and double punch test at 60 ºC. It was determined that the use of (asphalt binder mixed with rubber) as the agent of recycling showed improved performance than the other kind of recycling agent. The indirect tensile strength at 40 ˚C of the recycled mixture was higher than that the control mixture. Punching shear strength was decreased by 84 %, temperature susceptibility was decreased by 69.6 % and the resistance to moisture damage increases by3.3 % at optimum asphalt content.

Keywords: Recycling; Short and Long –Term; Crumb Rubber; Polyethylene.

1. Introduction

The rheological traits of binders for the aged asphalt restoring, Recycling agents are yield with physical, chemical features by increasing molecular mobility, asphaltene to maltene ratio to be reached, improving dispersive power of the continuous maltene phase, and. Thus decreases the viscosity, stiffness, and embrittlement of the recycled asphalt, and rises the ductility [1]. The advantages derived when using recycled materials are to reduce the demand for natural resources such as aggregate and asphalt and to be cost-effective, for this reason, recycling of aged asphalt concrete pavements has been demonstrated [2]. Liquid antistrip agents was added to asphalt, and this was used to decrease the susceptibility of AC mixes to damage of moisture and at the same time reduce the interaction of the material with water and reported the effects of Liquid antistrip agents (LAS) on surface tension of bitumen, which is provided reduction in surface tension due to increase in (LAS) concentration [3]. Tran et al. (2016) studied the effect of recycling agent (RA) on performance of asphalt pavement by preparing three mixture consisted of: (a) reference mixture containing 30% RAP with an SBS-modified PG 70-22 binder with no RA; (b) 40% RAP combine with the similar PG70-22 binder with RA; and (c) 25% RAP with 5% RAS mix using an efficient PG 64-22 with RA. The volumetric traits of the three mixes and their gradations were extremely comparable, the dosages of RA were determined for the 40% RAP and 25% RAP/5%

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RAS mixes to attain the same level of field performance as the reference mixture through their resistance to moisture damage [4].

With various Asphalt percentages, Asphalt concrete specimens have been constructed in the laboratory, and subjected to indirect tensile strength, Marshall Traits, and flexural strength determinations by using together gap and dense gradations of aggregates. By using the super pave procedure, the Asphalt concrete was then undergo to accelerated aging, from the aged Asphalt concrete, additional collection of specimens were constructed and tested for the same previous properties. Recycling agent which was prepared in the laboratory was added to the aged Asphalt concrete, and then the procedure of specimen construction and testing was repeated, recycling agents have an activist influence on Asphalt concrete in general traits [5].

Four kinds of the agents that were recycled (studied (oil), (oil + rubber of crumb), (cement of soft grade asphalt), and (asphalt cement + Sulphur powder), were utilized to make mixtures that is recycled. A total of 54 compressive strength specimens and54 Marshall Specimens of (aged asphalt concrete mixtures, virgin, recycled) underwent the test of Tensile Strength Ratio. It was concluded that the mixture with recycle (oil + rubber) and the value of Tensile Strength Ratio with 50% content of old materials was higher when it compared to other mixtures that were recycled. Tensile Strength Ratio of more than 75% for all recycled mixtures [6].

By subjecting the asphalt concrete that is recycled to accelerated aging, after recycling procedure aged specimens were made and tested for moisture damage resistance. The results recycling with (cement of soft asphalt mixed with silica fumes) have been shown development in the moisture damage resistance about 76.17 % compared to the parallel aged mixture before the procedure of recycling. For unconditioned specimens, ITS lower than of aged before the procedure of recycling mixtures by 64.1% [7]. For recycled mixtures properties, important enhancement in stability of Marshall was seen comparing to aged mixture due to assess the asphalt concrete performance of recycled mixtures with Marshall test. The enhancement percentage was (185%, 198%, 97%, 135%) for agents that were recycled (Soft Ac, Ac + Sulphur, Oil, Oil + Rubber consecutively. It has been seen that the Marshall Stability presence of aggregates RAP and asphalt in the "RAP Mix" have enhanced. Which can be returned to the fact that RAP comprises hardened asphalt that will have the results that stability increment and this return to the reason of higher asphalt viscosity [8].

Sarsam and Mahdi (2019) studied two kinds of additives Which have been blended with asphalt binder to form the recycling agents, carbon black and styrene-butadiene-rubber (SBR) with three percentages (0.5, 1, and 1.5)% by weight of asphalt cement and with two percentages of asphalt cement (1 and 2)% and blended with the old asphalt concrete. Recycled Asphalt concrete samples were prepared and by using the Marshall compaction were tested. It was noted that when 1.5% of carbon black or SBR were additional to 1% of asphalt cement the Marshal stability was reached the greatest value. Adding 2% asphalt cement with carbon black or SBR achieves superior flow value than that of 1% asphalt binder with additives. SBR additive achieves superior voids content, VMA, and a higher percentage of voids filled with asphalt when compared to carbon black regardless of the asphalt content. Indirect tensile strength ITS lowers by (34 and 43) %. Temperature susceptibility lowers by (50 and 86) %, while the punching shear strength decreases by (21 and 41) %. The opposition to damage of moisture rises by (109 and 121) % following recycling with carbon black- asphalt [9].

An attempt was made by Sarsam and Al-Delfi (2015) to prepare 72 Core samples were gotten from the samples of the slab and by using Marshall Mix design method, for every kind of mixtures, optimum asphalt content was founded. Tests were made for the cores for indirect tensile strength (ITS), at 3 temperatures of testing of (0, 20, and 40 ºC). Lessening the temperature of the test led to bigger ITS for all kinds of mixtures. ITS rises when the content of the asphalt was bigger at (20 and 0 ˚C), while at 40 ˚C, ITS drops when the best content of asphalt was bigger or reduced. Coal fly ash displays more tensile stress resistance to than limestone dust when used as a filler of the mineral at diverse conditions of testing, [10].

Karim (2018) used SBS polymer which has been added to the asphalt mixture consisting of domestic asphalt pavement. RAP percentage (30% by weight of mixture) was utilized. Percentages of SBS polymer used were 3, 4 and 5% by weight of asphalt, three test methods are utilized to determine the asphalt mixtures: Marshall Stability and flow test, indirect tensile strength test and double punch shear test. It can be observed that the leakage in ITS for mixtures consisting of SBS is lesser than mixtures without SBS, also Marshall stability and punching strength raise with the raises of SBS percentages and the flow wane with the increase of SBS polymer. It was showed that addition of SBS polymer mend the performance of mixtures and it was observed that 5% of SBS modified mixture gave the finest results due to mend mechanical traits of the mixture contrast with the reference mixture. It was observed that ITSR, Marshall stability and punching strength increased by 5%, 26.4% and 74.8%, correspondingly, while Marshall flow lower by 10.5% when blending 5% of SBS polymer to asphalt mixture [11].

Pradyumna (2016) studied two types of recycling agent as RA-1 and RA-2which have been prepared in the laboratory and commercially available, 10% by weight of bitumen as the first type recycling agent and 8% as RA-2. Tensile Strength Ratio (TSR) values obtained for RAP containing mixes are superior when compared to the mix with no RAP which visibly indicates that mix through with RAP is fewer susceptible to the damage of moisture when compared to the mix with no RAP. This result additional confirms the improved resistance of RAP mixes towards damage of moisture. The specimens prepared with RA-2 had exposed superior results when compared with RA-1. The results more prove the increased opposition of RAP mixes to damage of moisture [12].

Aging bitumen was mixed with 2, 4, 6 mass% and 8 mass% of waste non-biodegradable polyvinyl chloride (PVC), and make the data gained, we can deduce that Viscoelastic and mechanical traits of the aged bitumen showed that using 6 mass% WFPVC into the aged bitumen resulted in the most increase in the softening point (about 11 °C), shore 'A' hardness, and tensile strength compared with the blank sample [13]. Wen et al. (2012) were performed the IDT tests in accordance with AASHTO T322, PG 58-28 asphalt, two types of aggregates: recycled concrete aggregate (RCA), and virgin aggregate (basalt) were used, they concluded that the IDT decreased when the RCA percentage increased [14].

Sarsam and AL-Zubaidi (2015) by using (cement of soft asphalt mixed with silica fume) as an agent for recycling presented improved performance than the other kinds of the agent of recycling. Punching shear for (short Long) term aging after recycling showed strength greater than that of mixed with recycle by 34% at optimum of asphalt [15].

Based on ASTM D6926 Samples compacted 75 blows per face which prepared with different percentages of RAP and different percentages of foamed. For 72 hours samples were cured at 40°C for duration of 24 hours previous to testing. Samples were put in water at 25 °C. And by loading a cylindrical sample through its vertical diametric plane at 50 mm/min deformation rate and test temperature (25 °C). Results show that all mixes surpass the minimum strength condition, 0.15 MPa. With the rise of the foamed bitumen content to the highest value the ITS increases, any increase above the highest value in foamed bitumen results in a decline in the ITS value. Adding 2% of foamed bitumen achieved the highest ITS value [16].

AL-Zubaidi (2013) stated that to assess the susceptibility of asphalt mixture to moisture, the ITS and tensile strength ratio (TSR) test was directed. It is observed that the TSR values, excluding the mix of virgin, were greater than 85%, by using RAP in modified mixtures provided increasing the ITS and TSR values, decreasing the virgin asphalt binder content, and thus enhancing the resistance of moisture of HMA mixtures [17].

The estimation of RAP and RAP-virgin aggregate road base and sub-base materials is studied. From the writing investigation it was noted that the RAP material can be recycled and used in the base course with new or virgin aggregates to an amount of 10 to 100% RAP in presence of stabilizing materials such as fly ash, lime, cement, foamed bitumen etc. which enhances the strength and durability of the RAP mix [18].

Al-Humeidawi (2016) stated that by using two kinds of polymers (Novolac and PVA) as modifiers with different ratios to make Polymer Modified Bitumen (PMB) for evaluation the rheological traits of binder and mechanical traits of Hot Mix Asphalt (HMA). The mechanical traits of HMA were estimated by Marshall Stability test, Retained Marshall Stability test, indirect tensile strength test, Tensile Strength Ratio (TSR), and striping test. The results of tests showed that the Novolac modifier mends the cohesion traits of binder and the adhesion of binder to aggregate. The PVA modifier mostly enhances the adhesion of binder to aggregate with less degree of that of using Novolac. Both modifiers significantly mend sensitivity to moisture and lower the stripping of HMA. Also, the results showed that the addition of 2% of Novolac to binder to make PMB acts the optimum option. The HMA with PMB Novolac 2% mends the Marshall Stability, Retained Marshall Stability, and TSR by 45%, 14% and 44% respectively [19].

Over the last years, the use of polymers-modified asphalt/mixtures has been increased. The performance of the asphalt mixture varies with the polymer .It was found that the performance of asphalt concrete mixtures can be improved as a result of polymer addition [20].

The main objective of the research is to evaluate the effect of the polymers such as polyethylene (low density) and crumb rubber as recycling agents on the physical properties of aged asphalt mixtures (Indirect Tensile Strength, Temperature Susceptibility, Double Punching Shear and resistance to moisture damage(TSR) and their potential to improve those traits.

2. Materials and Methods

The research methodology was divided into three stages, the first stage covered obtaining the optimum asphalt content by using Marshall method after applying short and long term aging to asphalt mixture, then determine the physical properties of asphalt concrete mixture. The second stage includes the design of the asphalt mixture with various percent of Polyethylene (Low density) and determine the physical traits of the recycling agent. The third stage includes determination of the physical traits for recycling agent (asphalt binder mixed with crumb rubber) and compared these results with the control mixture.

The materials were chosen from present material used in the construction of the road in Iraq and locally existing such as aggregate, asphalt cement, mineral filler, Polyethylene, and Crumb rubber.

2.1. Asphalt Cement

In this study, one kind of asphalt cement (40-50) of penetration graded was obtained from Al-Nahrawan Asphalt Factory of the Ministry of Housing and Construction. The physical properties of the asphalt cement are shown in Table 1.

Table1. Physical Properties of Asphalt Cement

Test Procedure ASTM [13]	Result	Unit	SCRB Specification [21]
Penetration (25 °C, 100 g, 5 sec) ASTM D 5	43	1/10	40-50
Ductility (25 °C, 5 cm/min). ASTM D 113	167	cm	≥ 100
Softening point (Ring and Ball). ASTM D 36	54	°C	--
After Thin-Film Oven Test ASTM D-1754			
Retained penetration of original, % ASTM D 946	87	%	> 55
Ductility at 25°C, 5 cm/min, (cm) ASTM D-113	147	cm	> 25
Loss in weight (163 °C, 50 g, 5 h)% ASTM D-1754	0.32	%	--

2.2. Fine and Coarse Aggregates

The aggregate used in this paper was obtained from the Nahrawan quarry. Sand Crusher was used as fine aggregate (passing sieve No. 4 and retained on sieve No. 200). The sizes of coarse aggregate range between 1/2 in (12.5 mm) to No. 4 (4.75 mm) according to SCRB specification (2003).

2.3. Mineral Filler

One kind of mineral filler (Limestone) has been used, that was obtained from Al-Nahrawan plant. It is thoroughly dry and free from lumps or aggregations or fine particles, Table 2 shows the physical properties of aggregate and mineral filler.

Table 2. Physical properties of aggregate and mineral filler

Material	Property	value
Coarse aggregate	Bulk specific gravity	2.39
	Apparent specific gravity	2.414
	Water absorption (%)	1.323
	Wear % (Los Angeles abrasion)	13.05
Fine aggregate	Bulk specific gravity	2.727
	Apparent specific gravity	3
	Water absorption (%)	3.333
Mineral filler	% passing sieve 200	96
	Specific gravity	2.68

2.4. Selection of Aggregates Gradation

In this study, the selected gradation was according to the specification of (SCRB 2003). Wearing Course of (12.5 mm nominal) extreme size, Table 3 and Figure 1 show selected aggregate gradation.

Table 3. Specification Limits and Selected Gradation of HMA Mixtures for Wearing Course

Standard sieves (mm)	Passing by weight of total aggregate (%)	
	Passing by weight (%)	Specification limit
12.5	100	100
9.5	95	90-100
4.75	70	55-85
2.36	49.5	32-67
0.3	15	7-23
0.075	7	4-10

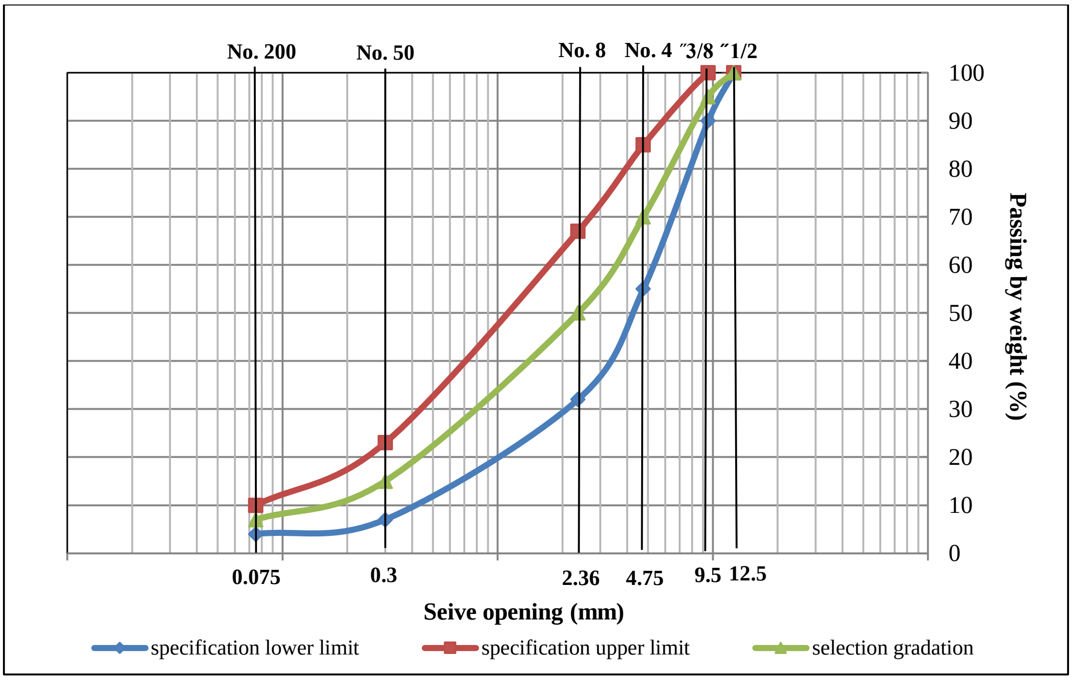

Figure 1. Nominated aggregate gradation and specification limits (SCRB 2003)

2.5. Polyethylene (Low Density)

Polymers, found to be suitable for blending with asphalt, have a melting temperature not more than 180 °C. The storage temperature was 160°C and should be stirred at a speed of 200 rpm when mixed with asphalt. Table 4 shows the Mechanical and Thermal Properties of Polyethylene (Low Density).

Table 4. Mechanical and Thermal properties of Polyethylene

Properties	Unit	Value
Tensile strength	MPa	10
Tensile Elongation	%	>350
Flexural Modulus	MPa	8
Hardness (Shore D)	-	50
Vicat Softening point	°C	88
Brittleness Temperature	°C	< -175

2.6. Crumb Rubber

At ambient temperature, the crumb rubber modifier was generated by mechanical shredding and was obtained from factory of tires at AL-Najaf governorate; it is recycled from used tires, Table 5 shows grain sizes distribution of crumb rubber.

Table 5. Grain sizes distribution of crumb rubber

Sieve No.	Sieve Size(mm)	Passing by weight%
No. 16	1.18	100
No. 30	0.9	78
No. 50	0.3	25
No. 200	0.075	0

3. Preparation of Recycled Asphalt Cement

Recycled asphalt is prepared, asphalt cement has been heated to (150 °C) and then blended with (Polyethylene Low Density) with different content (0.5, 1 and 1.5 % by weight of asphalt cement) and by using special mixer, it was prepared in the laboratory at a mixing speed of about 200 rpm and raised temperatures (160 °C) for 60 minutes to encourage the physical and chemical reaction of the components.

4. Recycled Asphalt Cement Preparation

By using the wet process, recycled asphalt is prepared. Asphalt cement has been heated to a 150 °C and then mixed with a crumb rubber with different content (0.5, 1 and 1.5 % by weight of asphalt) at a mixing speed of about 1500 rpm for 60 minutes, it was set in the laboratory using exceptional manufactured mixer to allow the physical and chemical reaction of the components. Throughout the mixing process, the crumb rubber exhibit dispersion and interacts with the asphalt.

5. Preparation of Aged Mixture by Short and Long Term Aging

For preparing the mixture, the aggregate was first sieved, washed and dried to 110 ºC and mineral filler as Limestone dust were combined with fine and coarse aggregates to achieve the gradation in section (2.4). Before mixing, the combined aggregate and filler heated to (160 ºC) and the asphalt cement (40-50) heated to a temperature of (150 ºC) to generate a kinematic viscosity of (170±20) centistokes, then the combined aggregate and filler was mixed with asphalt cement till all aggregate were covered with asphalt cement for 2 minute and then the mix was subjected to

***Short Term Aging**:* The mixture was putting in pans in an oven as shown in Figure 2. The mixture was heated to (135 ºC) for 4 hour; the mix was turned each 30 minutes as per Superpave procedure to maintain uniform conditioning.

The asphalt mixture was sited in the mold of preheated Marshall assembly of 4 inch (101.6 mm) in diameter and 2.5 inch (63.5 mm) in height, before pouring the mixture into the mold of Marshall, the mold and spatula was increase in temperature and anon-absorbed paper was putting in the bottom of mold, then spaded the mixture with the heated spatula 15 times about the perimeter and 10 times in the inner. Then, 75 blows on the bottom and top of the sample were used with a compaction hammer of 4.535 kg weight, and a free fall in 18 inch (457.2 mm) , the temperature of mixture earlier to compaction was (150 ºC) .

The sample in mold left to cool for 24 hour at a room temperature then it was removed from mold by mechanical jack.

***Long Term Aging**:* The loose mixture which subjected to short term ageing and compacted according to ASTM D1559 and after Marshall specimen extracted from the mold was heated for 120 hour at 85C$^{\circ}$ according to AASHTO R30.After that the test, specimens left to cool at room temperature at least 16 hour, these specimen was prepared for testing. Figure 3 shows loose mix for long term aging and Figure 4 shows Marshall Specimens.

Figure 2. Loose mix for short term aging

Figure 3. Compacted mix for long term aging

Figure 4. Marshall Specimens

6. Laboratory Test of Asphalt Concrete

6.1. Indirect Tensile Strength Test and Temperature Susceptibility

Marshall specimen were used in this test and the procedure was done according to (ASTM D6931-07). At two different temperature (25 and 40 ˚C) for 30 minute, the specimens were located in water bath after cooling at room temperature for 24 hour, then they were placed on a center of perpendicular diametrical plane among two parallel loading strips (12.7 mm) in wide. By versa tester machine, perpendicular compressive load at rate 2in/min undergo until the dial gage reading extended the extreme load resistance. This test used to evaluate the temperature susceptibility as shown in equation (1) and tensile strength for mixture as shown in Equation 2. Figure 5 illustrated Indirect Tensile Strength Device.

$$TS = \frac{(ITS)t1-(ITS)t2}{(t2-t1)} \tag{1}$$

Where; TS: temperature susceptibility of mixture (kPa/˚C), (ITS) t1: indirect tensile strength at t1=25˚C, (ITS) t2: indirect tensile strength at t2 = 40 ˚C.

Indirect Tensile Strength:

$$ITS = \frac{200*P}{\text{Л}*t*D} \tag{2}$$

Where; ITS = indirect tensile strength (kPa), P = maximum load resistance (N), T=thickness of specimen immediately before test (mm), D = diameter of specimen (mm).

Figure 5. Indirect Tensile Device

6.2. Indirect Tensile Strength Ratio Test

The procedure of this test was done according to ASTM D4867 to assess the damage of moisture of mixture, the specimens were prepared (six specimen), three of them were experienced for indirect tensile strength by placing in water bath at 25 ˚C for 30 minute then computed the average value of (ITS) as SI (ITS for unconditioned specimens) and by placing the other three specimen in volumetric flask heavy –wall glass of 4000 ml filled with water at room temperature 25 ˚C and for (5-10) minute applied the vacuum of 28 mm Hg (3.74kPa), by this procedure the three specimen were conditioned and could be obtained 55 to 80% saturation degree level , after that placed the specimen in freeze at -18˚C for 16h, then specimens were placed for 24 hours in water bath at 60˚C , then they were moved to water bath for 1 hour at 25˚C after that the specimens were experienced for indirect tensile strength and computed the SII(ITS for moisture conditioned specimens) by averaging value of indirect tensile strength of specimens. From Equation 3, the tensile strength ratio could be calculated.

$$TSR = \frac{SII}{SI} \times 100 \tag{3}$$

TSR: indirect tensile strength ratio (%)

SI: average value of ITS for unconditioned specimens (kPa)

SII: average value of ITS for conditioned specimens (kPa)

6.3. Double Punch Test

The asphalt stripping binder measurement from the aggregates, it was used double-punch method was developed by Jimenez at the University of Arizona (1974); there is much research on this test Solaimanian et al. (2004) [22]. Marshall specimen was conditioned in water bath for 30 minute at 60˚C. The test was initiated by the cylindrical specimen central loading is set perpendicularly among the platens of loading of the test machine and pressed by two steel punches, the diameter of steel punch is 1in (25.4 mm) situated concentrically on cylinder top and bottom surfaces and loaded at a rate of 1 in/min (25.4 mm/min) until failure. At maximum opposition to load, the reading of dial gage was recorded. Figure 6 shows Double Punch test device. From Equation 4, the punching strength was computed:

:

$$\sigma t \ = \ \frac{p}{\pi(1.2bh-a^2)} \tag{4}$$

Where; P: maximum load (N), σt: punching stress (Pa), b: radius of specimen (mm), a: radius of punch (mm), h: height of specimen (mm).

Figure 6. Double Punch Test Apparatus

7. Results and Discussion

From Figure 7, it can be observed that tensile strength of aged asphalt mixture(control mixture) at (25 °C)increases with increasing percentage of asphalt content, such results concur with Sarsam and Al-Delfi (2015) [10]. The Tensile strength of asphalt concrete at (25°C) increases with increasing percentage of Polyethylene at optimum Asphalt content (5.3%) and the highest value was obtained at 1.5 % of polyethylene which ITS value increased by 8.883 % compared to control mixture.

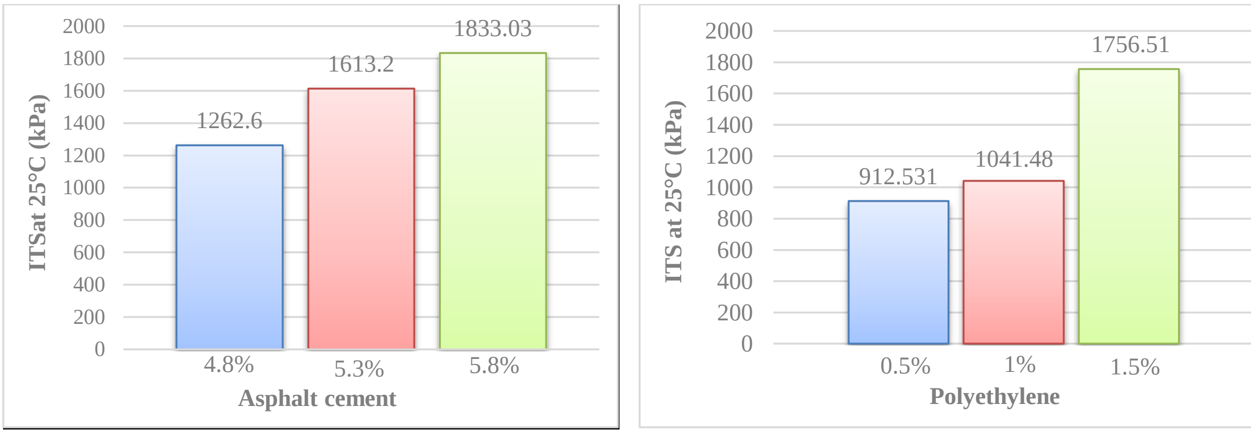

Figure 7. Indirect Tensile Strength of asphalt concrete mixture and asphalt concrete mixture with recycling agent (polyethylene (low density))

From Figure 8, it can be noted that temperature susceptibility increases with increasing percentage of asphalt content for control mixture , This detection is similar with that obtained by Sarsam and AL-Zubaidi(2015) [7] also Temperature susceptibility increases with increasing percentage of polymer(polyethylene) and decreased by 43.981 % at 0.5 % of polyethylene compared to control mixture at optimum asphalt content 5.3 %.

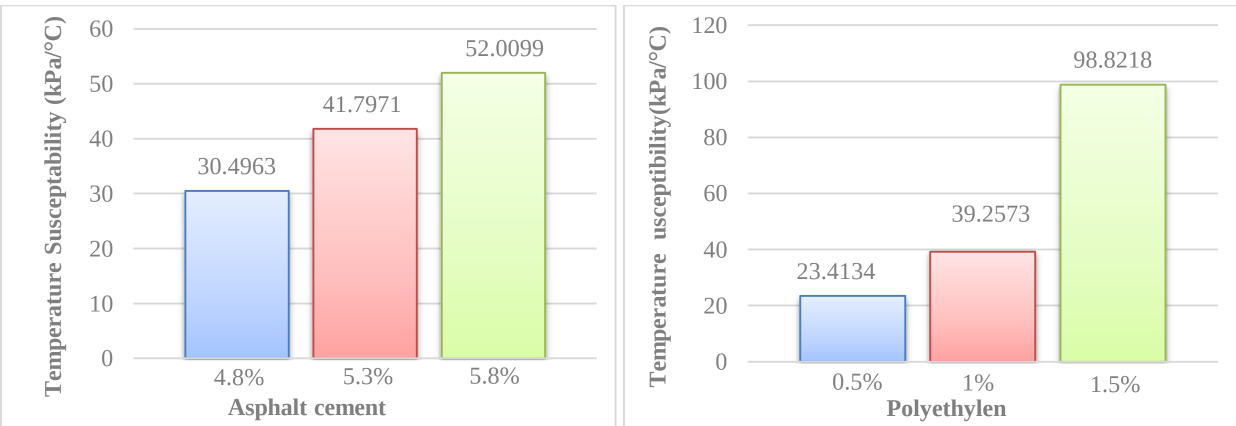

Figure 8. Temperature Susceptibility of asphalt concrete mixture and asphalt concrete mixture with recycling agent (polyethylene (low density))

When Marshall specimens tested under Double Punch test, the results showed that the punching shear decreases with increasing percentage of asphalt content and decreases with increasing percentage of polyethylene at optimum asphalt content 5.3% which decreased by 72.34% at 1.5% polyethylene. Figure 9 illustrates the Punching Shear at different percentage of Asphalt cement and different percentage of Polyethylene

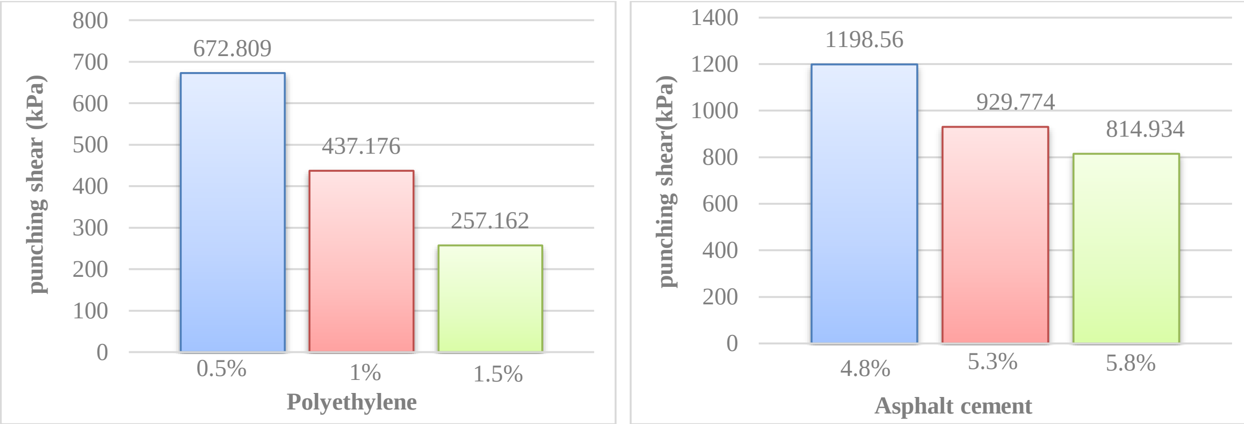

Figure 9. Punching Shear of asphalt concrete mixture and asphalt concrete mixture with recycling agent (polyethylene (low density))

From Figure 10, it can be observed that TSR results for asphalt mixture rises with rising asphalt content percentage such result concur with AL-Zubaidi (2013) [8]; And at 1.5% of polyethylene achieved the highest value at optimum asphalt content, the variation percentage was 3.93% compared to control mixture.

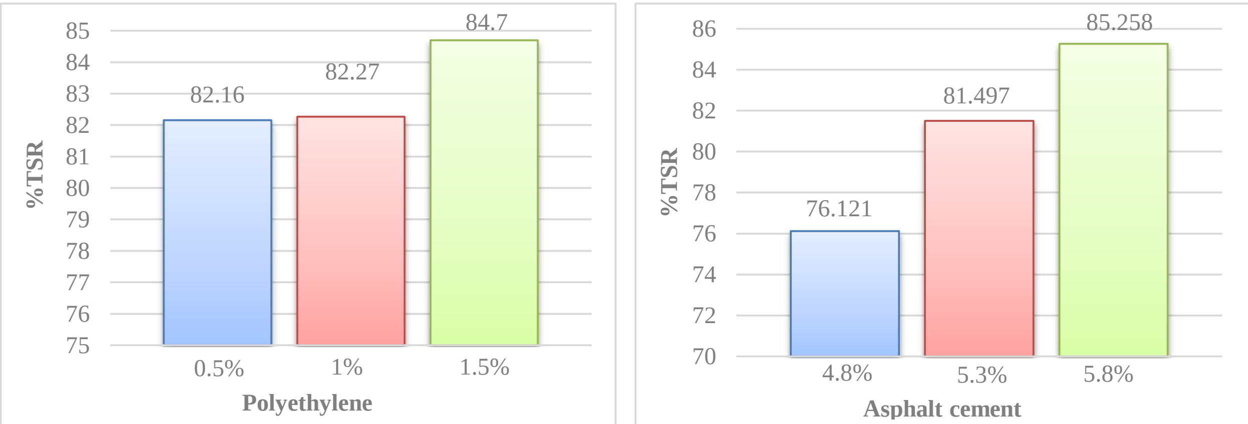

Figure 10. TSR of asphalt concrete mixture and asphalt concrete mixture with recycling agent (polyethylene (low density))

From Figure 11, it can be noted that at 40 °C, the ITS values for aged asphalt mixture (control mixture) rises with rising of asphalt content percentage and when crumb rubber was added in proportions 0.5, 1, 1.5 % the results showed that ITS value increases with increasing percentage of polymer the increment was 24 % for 1.5 % crumb rubber at optimum asphalt content 5.3 % compared to control mixture.

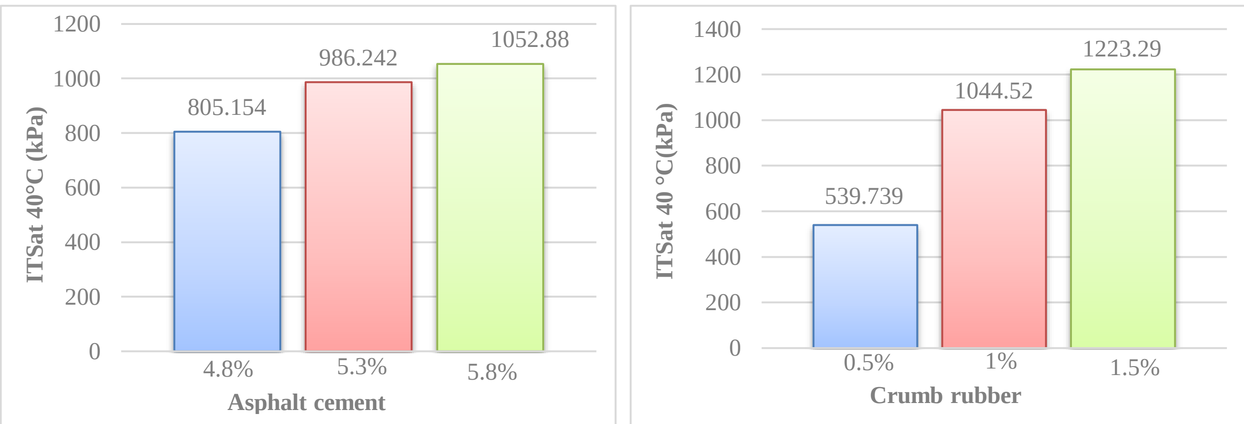

Figure 11. Indirect Tensile Strength of asphalt concrete mixture and asphalt concrete mixture with recycling agent (crumb rubber)

Temperature susceptibility drops with increasing crumb rubber percentage at optimum asphalt content 5.3%. The percentage of variation is 69.619% for 1.5% of crumb rubber comparing to control mixture. Figure 12 shows the shows the results of Temperature Susceptibility.

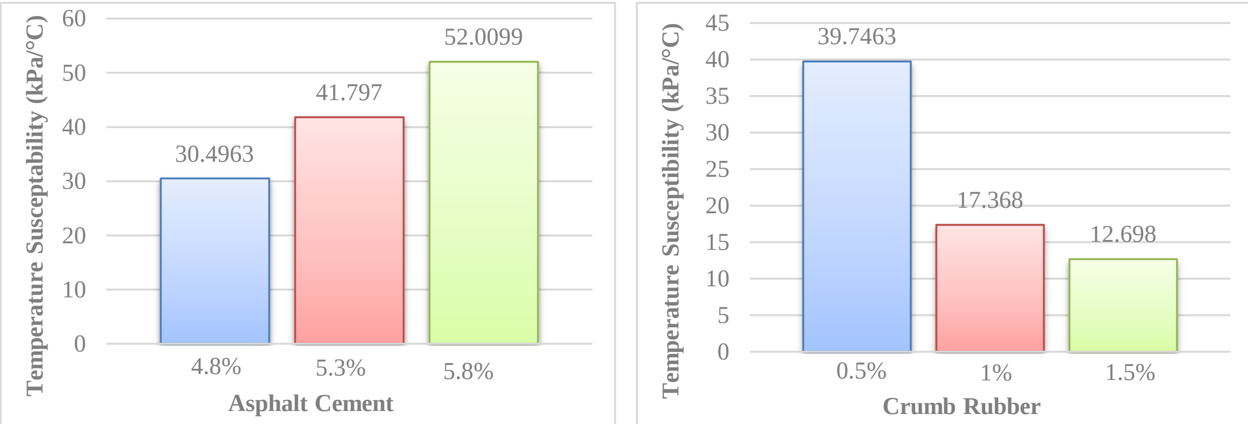

Figure 12. Temperature Susceptibility of asphalt concrete mixture and asphalt concrete mixture with recycling agent (crumb rubber)

When the Marshall specimens tested for Double Punch test, the results showed that the punching shear rises with rising Crumb Rubber percentage at optimum asphalt content 5.3% but was remained lower than control mixture for (0.5, 1 and 1.5)% of Crumb Rubber, the variation percentage was 84.02% for 0.5% of polymer. Figure 13 illustrates the Double Punching Shear Results.

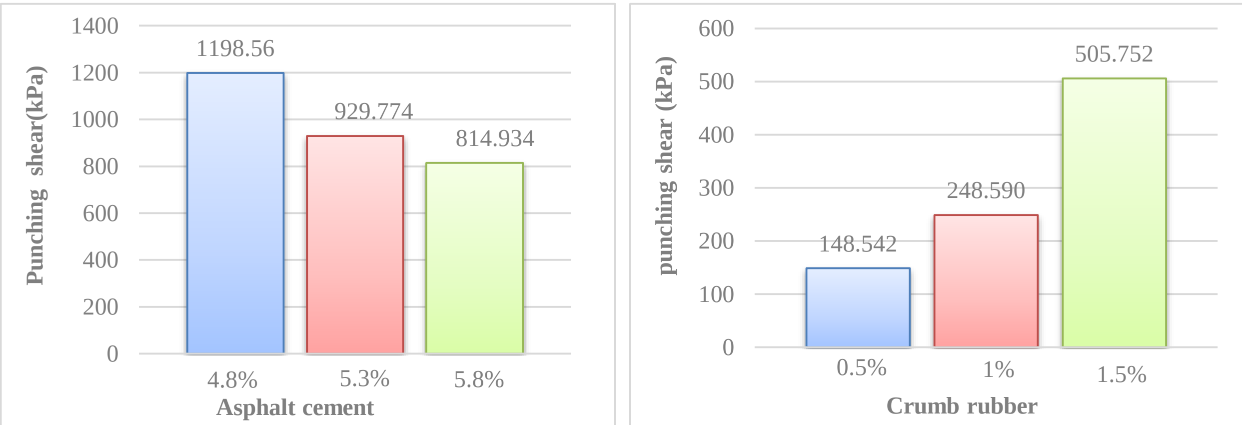

Figure 13. Punching Shear of asphalt concrete mixture and asphalt concrete mixture with recycling agent (crumb rubber)

TSR results for asphalt mixture increase with increasing percentage of Crumb Rubber content and (1.5) % of this polymer achieved the highest value at optimum asphalt content (5.3) %,variation percentage (3.3)% at (1.5)% crumb rubber comparing to control mixture. Figure 14 illustrates TSR results.

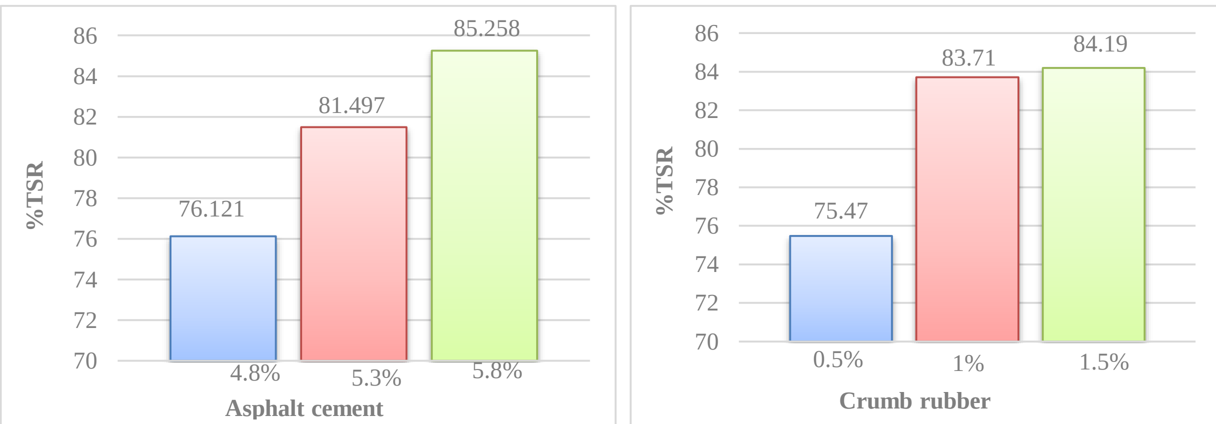

Figure 14. TSR of asphalt concrete mixture and asphalt concrete mixture with recycling agent (crumb rubber)

8. Conclusions

From this study, the following conclusions can be drawn:

- Good performance results can be obtained from Recycled Mixtures with agent that regard recycled of (aged asphalt cement mixed with Polyethylene (Low Density), the variation percentages for mixtures traits compared to control mixture(reference mixture) were (8.883%, 43.981%, 72.34% and 3.92%)for properties of (indirect tensile strength at 25 °C and for 1.5% polyethylene at optimum asphalt content , temperature susceptibility at 0.5% polyethylene , double punch test at 1.5% polyethylene, TSR test for 1.5% polyethylene).
- Recycled Mixtures with agent that regard recycled of (aged asphalt cement mixed with (Crumb Rubber) showed results of good performance, the variation percentages for mixtures traits compared to control mixture (reference mixture) were (24.03%, 69.618%, 84.023% and 3.30%) for traits of (indirect tensile strength for 1.5% crumb rubber at best content of asphalt and at 40°C , temperature susceptibility for 1.5% crumb rubber , double punch test at 0.5% crumb rubber, TSR test for 1.5% crumb rubber.
- Using (aged asphalt + Crumb Rubber) agent that regard recycled achieved mixture of asphalt concrete with lesser susceptibility value of temperature than the other recycling agent (aged asphalt + Polyethylene (Low Density)).
- Recycled Mixtures with agent that regard recycled of (aged asphalt cement mixed with (Crumb Rubber) showed lower resistance to moisture damage at optimum asphalt content compared to Recycled Mixtures with agent that regard recycled of(aged asphalt blended with polyethylene (low density)).

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9. Conflicts of Interest

The authors declare no conflict of interest.

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