



LABORATORY EVALUATION OF MODIFIED ASPHALT WITH SBS POLYMER ON RUTTING RESISTANCE OF RECYCLED PAVEMENT MIXTURE

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ABSTRACT

This research investigates the influence of recycled mixture modified with styrene-butadiene-styrene (SBS) polymer on rutting resistance. The reclaimed asphalt pavement (RAP) mixture percentages were used 10, 20 and 30% by weight of original mixture and one percentage of SBS polymer which was 5% by weight of asphalt cement. The moisture susceptibility and rutting were taken into consideration in this study. The results indicated that the recycled asphalt mixture containing on SBS polymer gives better moisture susceptibility and better rutting resistance. It is noted that indirect tensile strength ratio (ITSR) increases when adding SBS with 5% percentage polymer and reaching its maximum ratio 94.5% for 20% RAP and the rut depth decreases by 66.7% when adding SBS with 30% RAP content.

KEYWORD: Reclaimed asphalt pavement, Modified asphalt with SBS, Rutting resistance.

1. INTRODUCTION

As increasing environmental considerations and rising costs of construction materials, reclaimed asphalt pavement (RAP) has been frequently added into asphalt paving mixtures. [Santucci \(2007\)](#) mentioned that hot recycling of RAP is the most widely used asphalt recycling method in the world. Hot recycling is the process of combining RAP with new or “virgin” aggregates, new asphalt binder, and/or recycling agents (as required) in a central plant to produce a recycled mix.

Surface rutting occurs due to plastic deformation in the paving material, a general subsidence of subgrade and overlay asphalt layer ([Van de Loo, P.J., 1974](#)). Several research works have been conducted on permanent deformation of asphalt concrete materials. Most of these research works were conducted on different materials using various testing procedures ([Garba, 2002](#)).

However, the rehabilitation of distressed pavement using recycling techniques methods has evaluated in developed countries as the best practice to improve the pavement serviceability level and structural capacity with low cost.

The aim of asphalt binder modification is to improve the durability of Hot Mix Asphalt (HMA). Binder additives range from the recycled materials, such as old Reclaimed Asphalt Pavement (RAP) or crumb rubber from the tires to chemical additives such as styrene–butadiene rubber (SBR) or poly-phosphoric acid (PPA) ([Bahia et al. 2001](#)).

Even with the economic and environmental advantages of adding RAP to virgin HMA mixtures, there is a concern about a long-term performance of the HMA pavements containing RAP. RAP characteristics such as: increasing oxidation levels due to aging, increased RAP binder stiffness, and non-uniformity of aggregate type and gradation may significantly effect on the fatigue properties, rutting resistance, as well as moisture susceptibility of a RAP-modified HMA ([Maupin et al. 2009](#)). Rutting resistance is one of the primary characteristics that control durability and structural capacity of the pavements.

In most case, the RAP in asphalt mixture can increase the stiffness of the asphalt mixture, which is beneficial for the resistance to permanent deformation at high service temperatures ([Noureldin et al. 1987](#)). But it also makes the asphalt mixture to show an increase in stiffness and brittleness at low temperature, which results a reducing in resistance to fatigue and low temperature cracking ([Luo et al. 2013](#)).

Reclaimed asphalt pavement (RAP) mixtures have shown a good resistance to rutting for hot-mix asphalt (HMA) pavement. Mixtures with polymer modified binders such as styrene-

butadiene-styrene (SBS) have also shown a good performance against rutting and cracking (Kim et al. 2009).

The main objective of this work is to specify the maximum amount of RAP for HMA with unmodified and modified binder (40-50) for improving moisture susceptibility and rutting resistance of surface course. Thus, the following tasks will be carried out for recycled mixtures: using superpave system to design recycled mixtures for 10, 20 and 30% of RAP by weight of mixture; determining the physical properties of asphalt modified with 5% SBS by weight of asphalt binder; evaluating the ITSR for unmodified and modified mixtures; and evaluating the rutting performance and specify the best percentage for both unmodified and modified recycled mixtures.

2. MATERIALS AND MIX DESIGN

2.1. Materials

The crushed aggregates that used in this work were brought from Al-Nibaie Quarry. For surface course, the nominal maximum aggregate size was 12.5 mm. Table 1 presents the physical properties for crushed aggregates.

Asphalt cement with (40-50) penetration grade was used in this research which supplied from Al- Daurrah Refinery in Baghdad city. The physical properties of asphalt cement are shown in Table 2.

Ordinary Portland cement supplied from Karasta Company with bulk specific gravity 3.1 was used as a filler. Table 3 illustrates the Ordinary Portland cement gradation.

RAP material used in this study was collected from the same source which was brought from Mayoralty of Baghdad project office. The asphalt content of RAP was 4.2% which that was determined by centrifuge extractor method according to ASTM D2172. AASHTO T27 and T30 were followed to determine RAP gradation before and after the extraction of the binder respectively, to find if they meet the grading envelope of a conventional surface course mixture adopted by (SCRB/R9, 2003) as illustrated in Fig. 1, while Plate 1 shows the extraction test apparatus.

Table 1. The physical properties and standard limitation for coarse and fine aggregates.

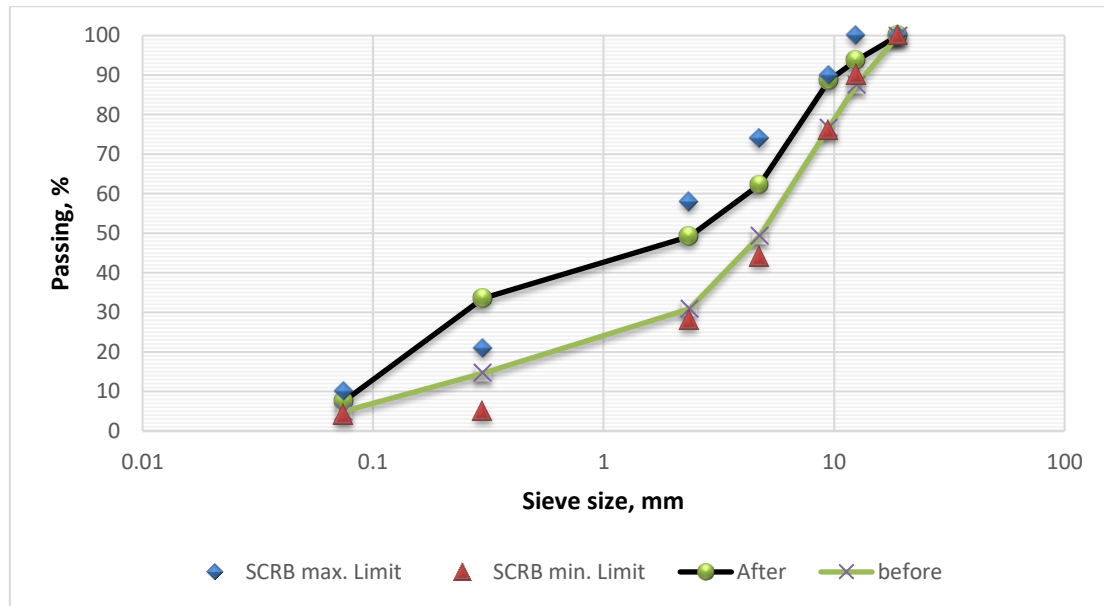
No.	Laboratory test	Test results				Adopted specification	
						/ Standard limits	
Coarse aggregate							
1	Specific gravity, (ASTM C127)	Sieve size (mm)	G_{sa}	G_{sb}	Abs,%	ASTM	SCRB
		12.5	2.674	2.651	0.32	---	---
		9.5	2.591	2.585	0.09	---	---
		4.75	2.582	2.57	0.18		
2	Wear by Los Angeles abrasion, % (ASTM C131)	21.3				35 (Max.)	30 (Max.)
Fine aggregate, (ASTM C128)							
1	Apparent specific gravity	2.655				---	---
2	Bulk specific gravity	2.635				---	---
3	Water absorption, %	0.25				---	---

Table 2. The physical properties of asphalt cement.

Test	ASTM designation	Test result	SCRB specification
Penetration	D5	47	40-50
Ductility, cm	D113	110	>100
Softening point, °C	D36	53	---
Flash Point, °C	D92	291	>232
Fire Point, °C	D92	305	---
Loss on Heating, %	D1754	0.29	---
Viscosity determined by rotational viscometer, (Pa. sec)	D4402	0.369@135 0.112@165	---

Table 3. The ordinary Portland cement filler gradation.

Sieve size (mm)	SCRB Specification R9, (2003)	Percentage passing by weight (%)
0.6	100	100
0.3	100-95	98
0.075	100-70	97

**Plate 1. The extraction test.****Fig. 1. Specification limits and RAP gradation of SCRB R9 (2003) for surface course layer.**

2.2. Superpave mix design

The superpave mix design procedure was employed to design the recycled mixtures according to National Cooperative Highway Research Program (NCHRP)/ Report 452 (2001). Mix design included three percentages of RAP (10, 20 and 30%).

The trial blends were established by incorporating RAP material depending on gradation with virgin aggregate at different percentages for the three percentage of RAP to meet the specification of SCRP/ R9 (2003) and AASHTO M323 for surface course. Table 4 presents the aggregate gradation design. The design asphalt content for 10% RAP was 5% and for 20 and 30% RAP was 4.8%, and it represented the total from the existing asphalt surrounding RAP aggregate and new asphalt binder suggested to add. The volumetric mix design properties of mixtures are shown in Table 5.

3. BLENDING MACHINE

The mechanical mixer with 2000 rpm was used for blending the hot asphalt with 5% SBS by weight of asphalt binder is shown in Plate 2. A special heating Jacket design was locally developed as shown in Fig. 2 to prevent air entering the mixing process and to ensure regular heat distribution and this is the role of heating liquid. The addition of SBS polymer to neat asphalt before it is used to make HMA known as the wet method.

Adding SBS to asphalt binder makes it stiffer and more viscous. The blending process was carried out at a temperature of 180°C (170 to 190°C) under a heating period of 2-3 hours (Mohammed, 2014). Table 6 shows the physical properties for modified asphalt cement. Addition of SBS polymers to asphalt binders can reduce penetrations, increase ring and ball softening points, ductility and viscosity (Roque et al. 2005).

Table 4. The aggregate structural design.

Sieve size, mm	Control points (AASHTO M323, 2012)		Iraqi specification (SCRB R9, 2003) surface course		Trial combined blends % passing		
	Min.	Max.	Min.	Max.	10%	20%	30%
19	--	100	100	100	100	100	100
12.5	90	100	90	100	96	95	95
9.5	90	--	76	90	83	84	85
4.75	--	--	44	74	55	52	50
2.36	28	58	28	54	33	33	34
1.18	--	--	--	--	24	23	24
0.6	--	--	--	--	18	17	17.5
0.3	--	--	5	21	14	14	13.5
0.15	--	--	--	--	10	10	10
0.075	2	10	4	10	5	5.5	4.5



Plate 2. The mechanical mixer.

Table 5. The volumetric properties of recycled mixtures.

Blend No.	V _a %	Asphalt Content, %	V _{MA} %	V _{FA} %	% G _{mm} @ N _{ini}	DP ratio
10%	4	5	14.65	72.8	87	1
20%	4	4.8	15.4	73.85	86.9	1.11
30%	4	4.8	15.1	73.4	87sarg	0.95

Table 6. The physical properties for modified asphalt cement.

Test	ASTM designation	Test result	SCRB specification
Penetration	D5	27	40-50
Ductility, cm	D113	120	>100
Softening point, °C	D36	64	---
Viscosity determined by rotational viscometer, (Pa.sec)	D4402	0.293 @ 135 1.008 @ 165	---

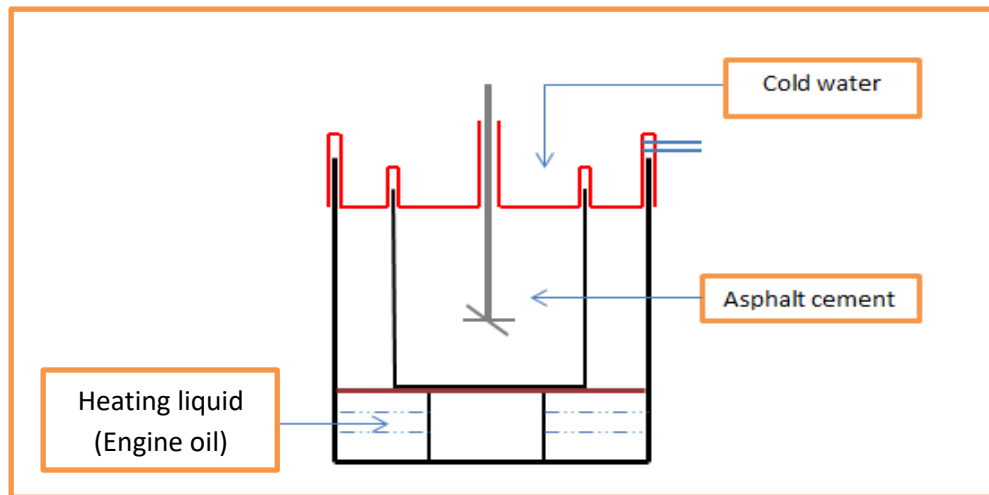


Fig. 2. The special heating Jacket design.

4. TESTING PROGRAM

Unmodified and modified mixtures were evaluated with the indirect tensile strength ratio and wheel tracking tests.

4.1. Indirect tensile strength ratio test

Indirect tensile strength test is used to evaluate the moisture sensitivity of the asphalt mixture which can be further related to the cracking properties of the pavement. It was conducted in accordance to standard specification ([ASTM D4867, 2012](#)) and ([AASHTO T283, 2007](#)) Specimens are prepared to approximately 7% air voids. After measuring G_{mm} , the compaction process was stopped at specified G_{mb} which was calculated as follows:

$$G_{mb} = G_{mm} - \left(\frac{V_a}{100} * G_{mm} \right)$$

Where:

G_{mb} = bulk specific gravity,

G_{mm} = maximum theoretical specific gravity at the design asphalt content,

V_a = air voids which was $(7 \pm 0.5) \%$.

One subset of three specimens was tested dry and the other subset was tested after partial saturation and moisture conditioning. The wet subset is subjected to vacuum saturation followed by an optional freeze cycle at a temperature of $-18 \pm 3^\circ\text{C}$ for a minimum of 16 hours followed by a thaw cycle by keeping them at $60 \pm 1^\circ\text{C}$ in water bath for 24 ± 1 hours. Then the two subset were tested for indirect tensile strength after placing the specimen in water path ($25 \pm 1^\circ\text{C}$) for 2 ± 1 hours.

Indirect tensile strength is determined as follow:

$$S_t = 2P/(\pi * t * D) \quad 1$$

where:

S_t = tensile strength, kPa

P = maximum load, N

t = specimen height immediately before tensile test, mm.

D = specimen diameter, mm.

Then the tensile strength ratio is determined as follow:

$$TSR = (S_2/S_1) \times 100 \quad 2$$

where:

TSR = tensile strength ratio, percent

S_2 = average tensile strength of conditioned subset, kPa, and

S_1 = average tensile strength of the dry subset, kPa.

4.2. Permanent deformation test

The most popular test method for measuring permanent deformation is wheel tracking test. In this research, compacted asphalt slabs were prepared at air voids equal to (4%) using roller compactor device at the National Center for Construction Laboratories and Researches (NCCLR) according to ([EN 12697_ PART33; 2003](#)). The dimensions of the slabs used in this research are (300mm×300mm× 50mm). The rut depth was measured after 10000 cycles, and the test temperature was 55°C.

5. ANALYSIS AND DISCUSSION OF TEST RESULTS

5.1. Indirect tensile strength test

[Fig.s 3 and 4](#) show the results of indirect tensile strength for unconditioned and conditioned specimens at 25°C respectively. Indirect tensile strength values for both types of specimens increase with increasing RAP content. It is noted that indirect tensile strength for unconditioned sample increased about 12% when the RAP increased from 10 to 20%, while it is increased by 17.5% when the RAP is increased from 10 to 20%. It is noticeable that indirect tensile strength for conditioned specimen increased by 14.5% when the RAP increased from 10 to 20%, while increased by 20.8% when the RAP increased from 10 to 30%.

Fig. 5 illustrates the increase in indirect tensile strength ratio with increasing RAP content. This can be attributed to the increasing of RAP content increase the viscosity of the binder. In other word, the increase in strength might be the subsistence of the aged asphalt because indirect tensile strength is a test that is more dependent on asphalt binder. It can also be noted that the indirect tensile strength for unconditioned and conditioned samples is increased by adding SBS content as shown in Figs 3 and 4. For example, the indirect tensile strength for unconditioned and conditioned increased by 34.5% and 39.6%, respectively when adding 5% of SBS. ITSr also increased when adding SBS polymer to the mixture and the maximum value was 94.5% for 20% RAP content and 5% SBS content as shown in Fig. 5. These results are higher than minimum value of superpave criteria which is 80% (Asphalt Institute, 2007).

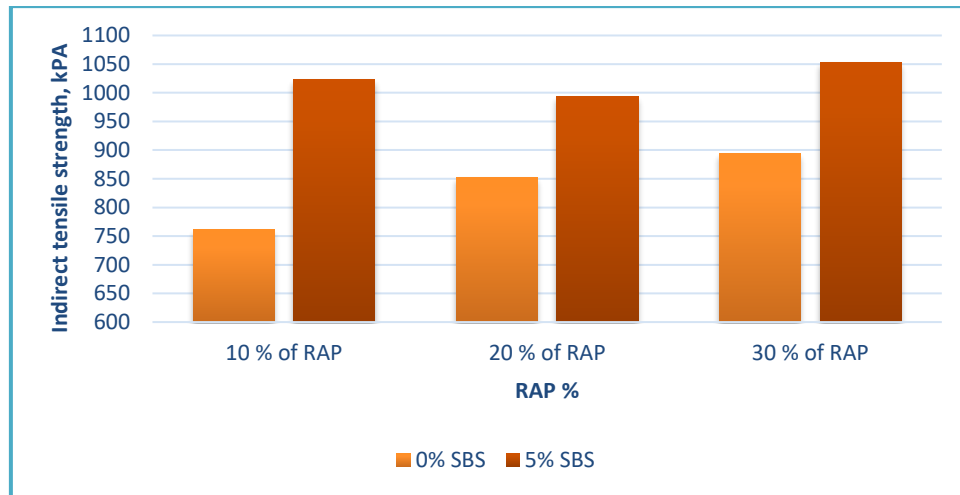


Fig. 3. The indirect tensile strength for the unconditioned sample versus RAP content.

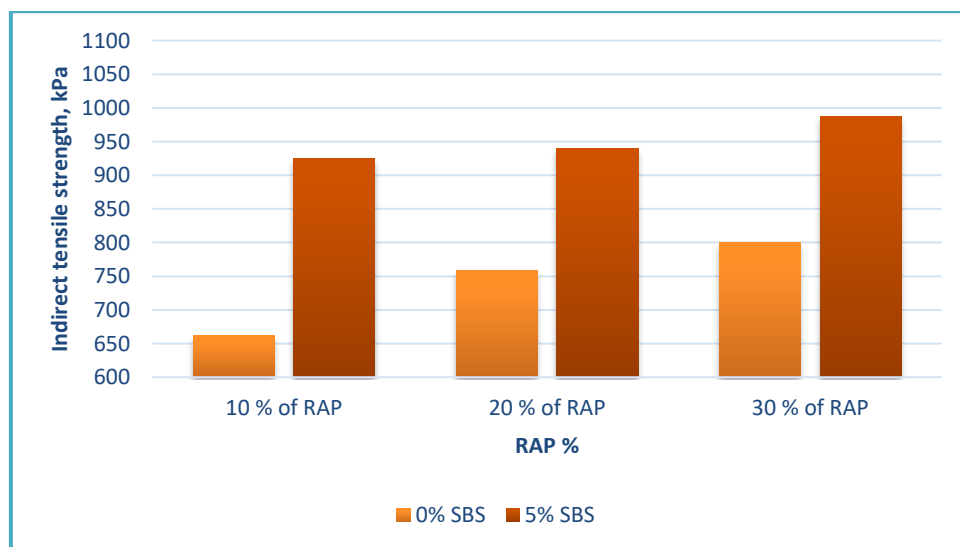


Fig. 4. The indirect tensile strength for the conditioned sample versus RAP content.

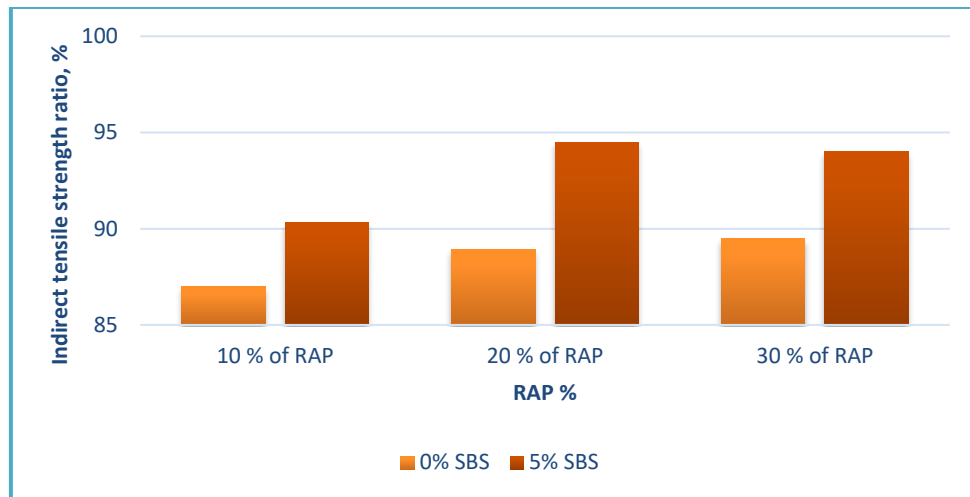


Fig. 5. The indirect tensile strength ratio % versus RAP content.

5.2. Rutting test results

Results of the wheel trucking test are plotted on a graph displaying rut depth versus the number of passes, as show in Fig. 6. It can be seen that the rut depth is decreased when adding 20% of RAP and then increase slightly at 30% at RAP. It can be noted that rut depth decreases when adding 5% SBS polymer. For example, the rut depth decreases by 66.7% when adding 5% SBS to 30% RAP content. It can also note that the rut depth did not show a significant different between different amount of RAP material in mixtures without polymer- modified binder when compared with the mixture with polymer- modified binder. This agrees with the findings of (Kim et al. 2009). It can be concluded that binder modified with SBS polymer makes the mixture stiffer than unmodified asphalt binder.

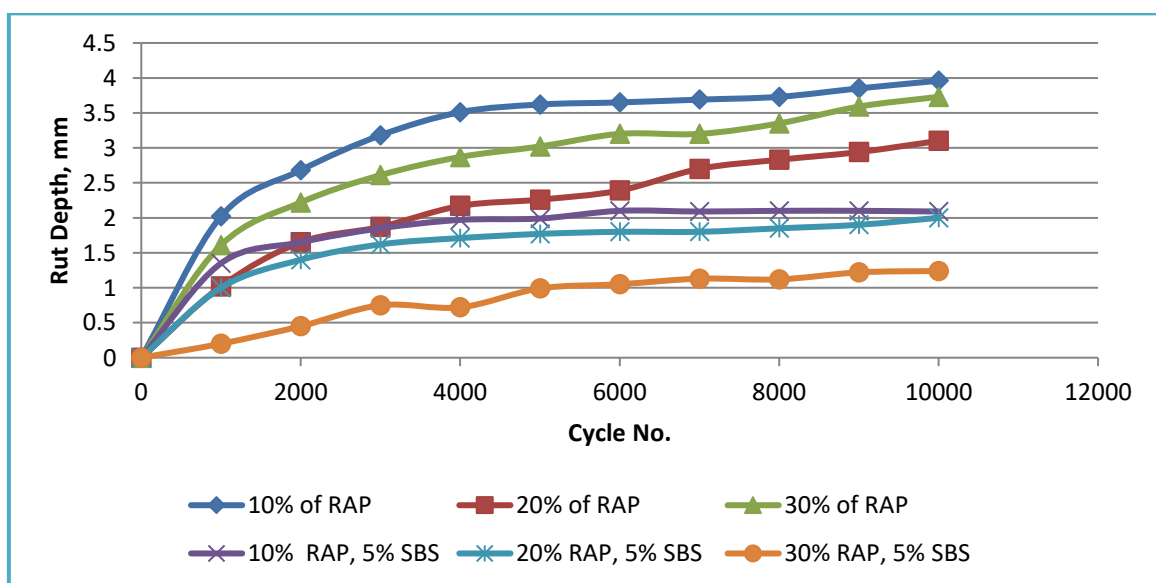


Fig. 6. The rut depth versus RAP content.

6. CONCLUSIONS

This study investigated the permanent deformation and moisture susceptibility of hot recycled mixture and SBS polymer–modified asphalt mixtures. On the basis of the results and their analyses, the following conclusions can be summarized:

1. The indirect tensile strength (ITS) for unconditioned and conditioned sample increases when adding SBS polymer to the recycled mixture.
2. The indirect tensile strength ratio increases when adding 5% of SBS polymer and reaching its maximum value 94.5% for 20% RAP content.
3. The addition of the SBS polymer to the hot recycled mixture has clearly improved the permanent deformation where the best performance was clear in 30% RAP mix with 5% SBS content.
4. From the experimental results of the three percentages (10, 20 and 30%) RAP, it can be concluded that 20% of RAP content for unmodified mixture gave the best results for rutting performance resistance which is 3.1 mm. While for modified mixture, 30% of RAP content gave the best performance which is 1.24 mm.

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