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EFFECT OF MODIFIED ASPHALT WITH SBS POLYMER ON MECHANICAL PROPERTIES OF RECYCLED PAVEMENT MIXTURE

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ABSTRACT
Due to the increase need for reclaimed asphalt pavement (RAP) and development of recycling technologies, RAP has been used as a substitute for the virgin asphalt binder and aggregates in hot-mix asphalt (HMA) pavements. The research investigates the influence of adding SBS polymer on asphalt mixture containing reclaimed asphalt pavement. In this study, one percentage of RAP (30% by weight of mixture) was used. The SBS polymer percentages used were 3, 4 and 5% by weight of asphalt were three different test methods are used to evaluate the asphalt mixtures: Marshall stability and flow test, indirect tensile strength test and double punch shear test. It can be noticed clearly that the loss in ITS for mixtures containing SBS is lower than mixtures without SBS, also Marshall stability and punching strength increase with the increases of SBS percentages and the flow decrease with the increase of SBS polymer. It was concluded that adding SBS polymer improve the performance of mixtures and it was found that 5% of SBS modified mixture gave the best results due to improve mechanical properties of the mixture compared with the control mixture. It was noted that ITSR, Marshall stability and punching strength increased by 5%, 26.4% and74.8%, respectively, while Marshall flow decreased by 10.5% when adding 5% of SBS polymer to asphalt mixture.

INTRODUCTION
Recycling hot mix asphalt material results in a reusable mixture of aggregate and asphalt binder known as Reclaimed Asphalt Pavement (RAP). Reclaimed asphalt pavement (RAP) has been used in most countries because of the environmental benefits and costs reduction, [1]. From resurface and rehabilitation projects, plenty of asphalt pavement materials are removed and treated as waste. It is essential to understand the fundamental properties of recycled asphalt binder as well as the interaction between the old binder in the recycled asphalt and the fresh binder in the new mix [2].The amount of recycled pavement that has been milled in every year is 90 million tons and 33% of all recycled RAP is reused in production of hot mix asphalt,[3]. In the Florida Department of Transportation (FDOT) from 1979 to 1994 it produced 22 million ton of RAP, [4].

The use of Polymer Modified Asphalt (PMA) to obtain better asphalt pavement performance has been investigated for a long time. Styrene-butadiene-styrene (SBS) copolymer modified asphalt was developed mainly for the reason that can improve the permanent deformation resistance, low-temperature cracking resistance, fatigue resistance and stripping resistance [5, 6]. There is a need for research into recycling issues involved with SBS modified asphalt mixtures.

The mix design process for hot mix asphalt (HMA) with RAP is similar to mix design for virgin HMA when the RAP percentage is lower than 25% [7]. Despite the similarity in mix design, some challenges remain for maximizing RAP used and routinely using high RAP content. Thus, there is also a need for research into the mix design for reclaimed SBS modified asphalt mixture and the application of RAP is still far from desired in some countries [8].

The purpose of this research is to **i**nvestigate the influence of adding different percentages of SBS polymer on asphalt mixture containing 30% by weight of mixture of reclaimed asphalt pavement (RAP).

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EXPERIMENTAL WORK

Materials

Asphalt cement

A 40-50 penetration grade asphalt cement was used in this work which was brought from Al-Daurah Refinery in Baghdad city. The physical properties of asphalt cement are illustrated in Table 1.

Fine and coarse aggregate

The crushed aggregates used in this study were obtained from Al-Nibaie Quarry. Table 2 provides the physical properties of the fine and coarse aggregates.

Filler

The filler used in this work was Ordinary Portland cement brought Karasta Company and the bulk specific gravity was 3.1. Table 3 shows the ordinary Portland cement filler gradation.

Reclaimed asphalt pavement

The RAP used in this work was collected from the same source, which was obtained from Mayoralty of Bagdad project office at Al-Karada region in Bagdad city. Extraction test was conducted to determine the asphalt cement content of RAP material in accordance to ASTM D2172 [20]. After extraction test, the properties of RAP were determined. Table 4 provides the properties of the RAP. Plate 1 show the extraction test and Figure 1 provided the gradation of the RAP before and after extraction test.

Table 1. The physical properties of asphalt cement.

Test	ASTM designation	Test result	SCRB specification
Penetration	D5	47.3	40-50
Ductility, cm	D113	110	>100
Softening Point, °C	D36	53.5	---
Flash Point, °C	D92	291	>232
Fire Point, °C	D92	305	---
Loss on Heating, %	D1754	0.29	---

Table 2. The physical properties and standard limitation for coarse and fine aggregates.

No.	Laboratory test	Test results				Adopted specification / Standard limits	
Coarse aggregate						ASTM	SCRP
1	Specific Gravity, ASTM C127	Sieve size (mm)	G_{sa}	G_{sb}	Abs,%		
		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.)**	---
Fine aggregate, ASTM C128							
1	Apparent specific gravity	2.655				---	---
2	Bulk specific gravity	2.635				---	---

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3	Water absorption, %	0.25	---	---

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

Table 4. The properties of the RAP after extraction test.

Laboratory Test		Test results	ASTM designation
Coarse aggregate	Apparent specific gravity	2.65	C-127
	Bulk specific gravity	2.6	C-127
	Water absorption, %	0.68	C-127
Fine aggregate	Apparent specific gravity	2.63	C-128
	Bulk specific gravity	2.5	C-128
	Water absorption, %	2.24	C-128
Asphalt cement, %		4.2	D2172

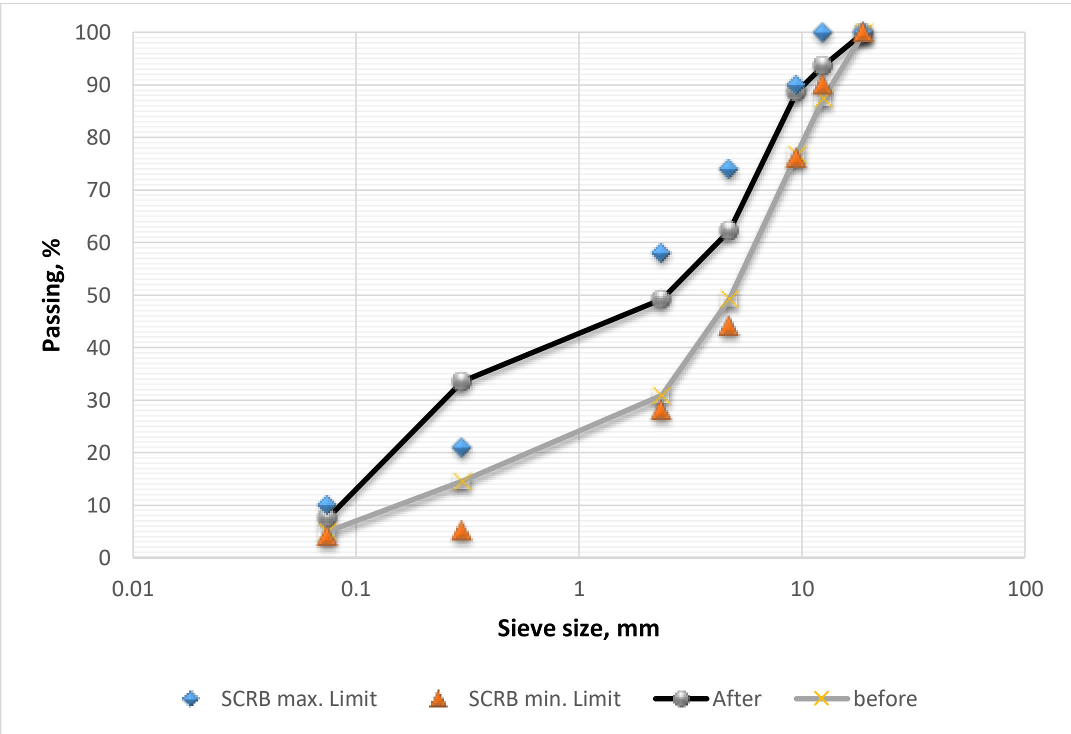

Figure (1): Specification limits and RAP gradation of (SCRB R9, 2003) for surface course layer.

Styrene- Butadiene- Styrene (SBS)
SBS polymer was used to modify the asphalt, which was brought from the Ministry of Industry and Minerals/ State Company for Mining Industries. Three percentages of SBS were added, these are 3, 4 and 5% by weight of asphalt.

Plate 1. The extraction test

Superpave mix design

NCHRP provided a technician's manual to use RAP in superpave mix design (NCHRP/ Report 452, 2001) [9]. One percentage of RAP (30%) was used in this study. The trial blends were established by incorporating RAP material depending on its gradation after extraction test with virgin aggregate at different percentages to meet the specification of SCRB/R9 (2003) [10] and AASHTO M323 [24] for surface course. Table 5 presents the aggregate structural design. The design asphalt content is 4.8% by weight of mix. Figure 2 show the aggregate structural design with limitations.

Table 5. The aggregate structural design.

Sieve size, mm	Control points (AASHTO M323, 2012)		Iraqi specification (SCRB R9, 2003) surface course		Aggregate structural design, passing %
	Min.	Max.	Min.	Max.	
19	--	100	100	100	100
12.5	90	100	90	100	95
9.5	90	--	76	90	85
4.75	--	--	44	74	50
2.36	28	58	28	54	34
1.18	--	--	--	--	24
0.6	--	--	--	--	17.5
0.3	--	--	5	21	13.5
0.15	--	--	--	--	10
0.075	2	10	4	10	4.5

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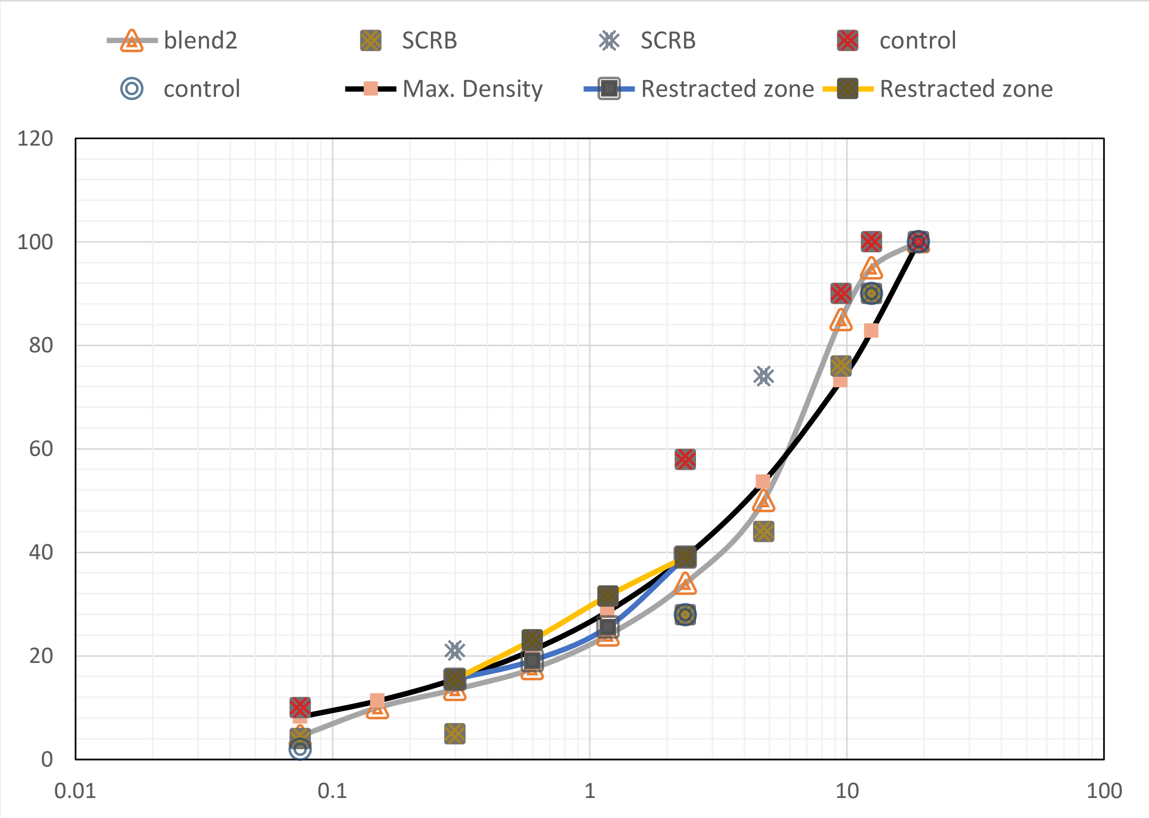

Figure 2: The aggregate structural design with limitations.

TESTING PROGRAM

Both unmodified and modified asphalt were evaluated by the following tests:

Indirect tensile strength test

To investigate the moisture susceptibility of asphalt mixture, the indirect tensile strength test was used according to AASHTO T283 [23] and ASTM D 4867 [22] Specimens prepared at 7±1 percent in air voids. SGC was used for compacted a total six specimens for each percentage of SBS (0, 3, 4 and 5%). Three specimens were tested without any conditioning and other three specimens were subjected to saturation followed by a freeze and thaw cycle. All six specimens are tested for indirect tensile strength.

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.

Marshall Test

Generally, the purpose of this test is to measure the stability and flow values for mixtures. The specimens were immersed in a water path at a temperature of 60± 1°C for a period of 30-40 minutes. Then, the sample was placed in the Marshall stability testing machine. The load is at a constant rate of deformation of 50.8 mm (2 in) per minute until failure. The maximum loading that causes failure of the sample was reordered as Marshall stability and the total amount of deformation had been taken as Marshall flow.

Double Punch Shear Test

This test procedure was advanced at the University of Arizona by Jimenoz (1974) [25] which was used for measuring the stripping of the binder from the aggregate. Marshall samples was used for test and three specimens were conditioned by placing them in water at 60 ± 1°C for 30 minute. The specimen was centered between two cylindrical steel punches (2.54 cm in diameter) perfectly aligned one over the other and then loaded a rate of (2.54 cm/minute) until failure. Then the maximum resistance was recorded. The punching strength is calculated by the equation:

$$\sigma_t = \frac{p}{\pi(1.2bh-a^2)} \quad (3)$$

where:

σ_t = Punching shear stress, Pa

p = Maximum load, N.

a = Radius of punch, mm.

b = Radius of specimen, mm.

h = Height of specimen, mm.

ANALYSIS AND DISCUSSION OF TEST RESULTS

Indirect tensile strength test

Indirect Tensile Test (ITS) is a method of determining the tensile strength of a sample by applying a compressive load on a cylindrical specimen. Tensile strength can be used to predict the water susceptibility of the sample. In this case, the tensile strength was measured before and after water treatment to determine the retained strength percentage. From Figures 3 and 4, the indirect tensile strength for unconditioned and conditioned sample increases with increasing SBS polymer content. Figure 5 illustrates the indirect tensile strength ratio. It can be clearly noticed that the loss in ITS for mixtures containing SBS is lower than mixtures without SBS.

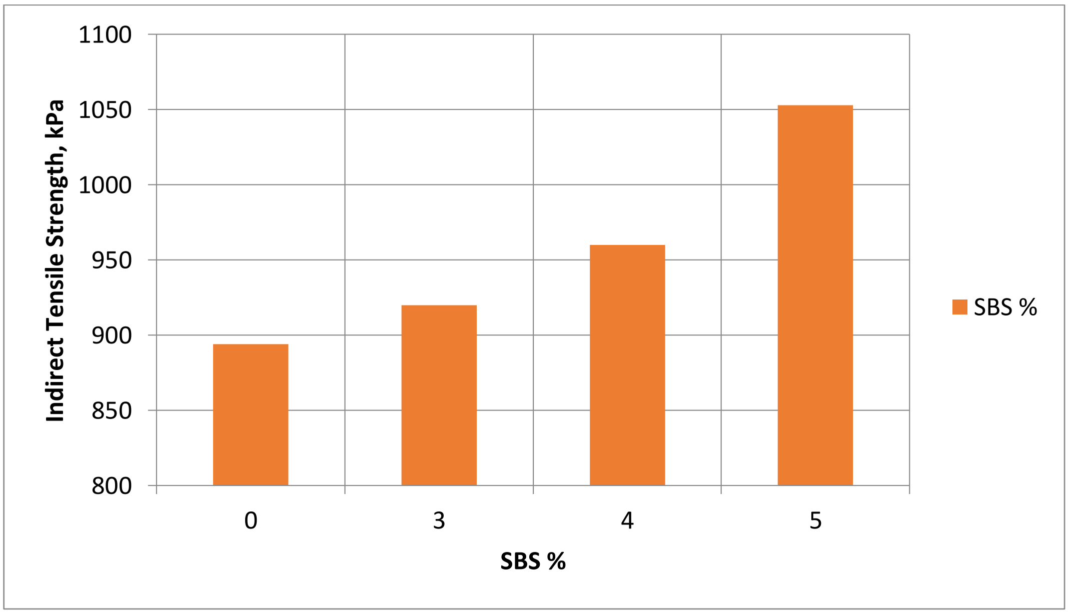

Figure 3. The indirect tensile strength for the unconditioned sample versus SBS polymer content.

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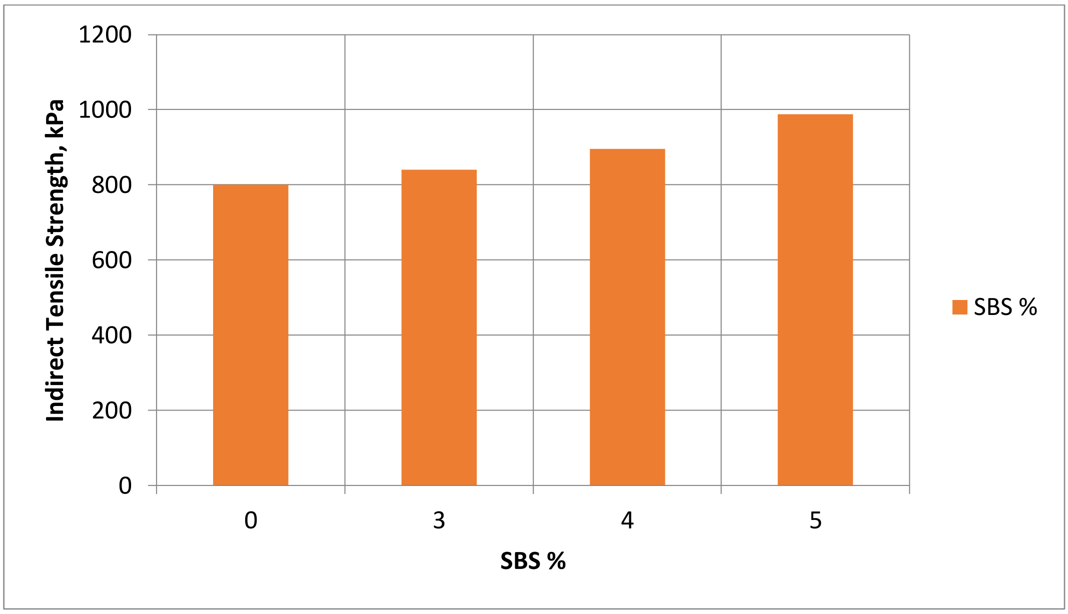

Figure 4. The indirect tensile strength for conditioned sample versus SBS polymer content.

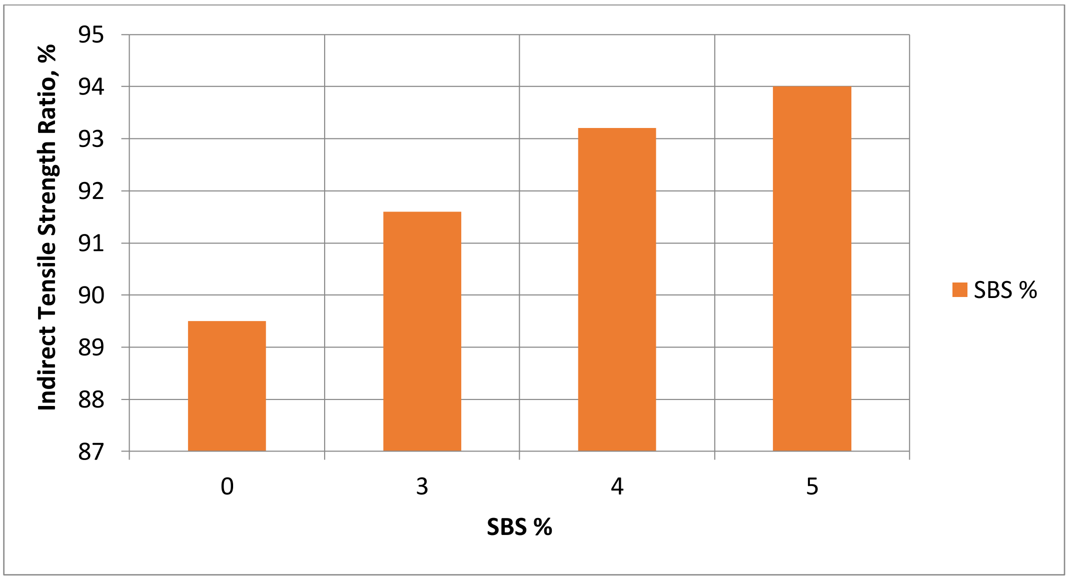

Figure 5. The indirect tensile strength ratio versus SBS polymer content.

Marshall stability and flow test

Marshall stability and flow test results are illustrated in Figures 6 and 7 respectively. Figure 3 shows clearly that the addition of the SBS polymer to hot recycled mixture has improved the Marshall stability. It is noticed that the stability increased by about 4.3, 17.2, and 26.4% when adding 3, 4 and 5% RAP content respectively. Regarding flow which represents the amount of vertical deformation of the specimen at failure, the results showed that the flow decreases with increasing in SBS content (Figure 7). It is noted that all results are within the specification range which is 2-4 mm according to SCRB/R9 (2003) [10].

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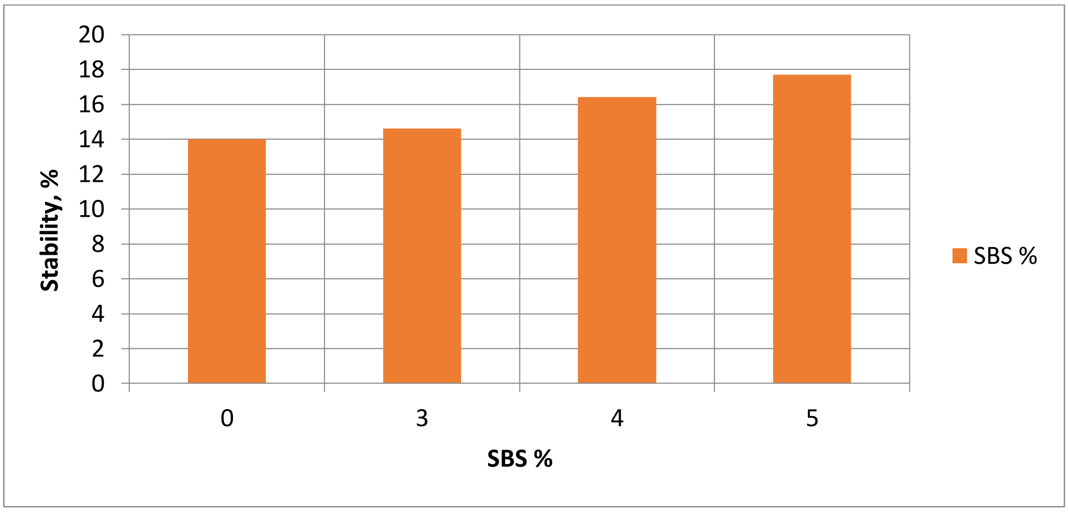

Figure 6. Marshall stability versus SBS polymer content.

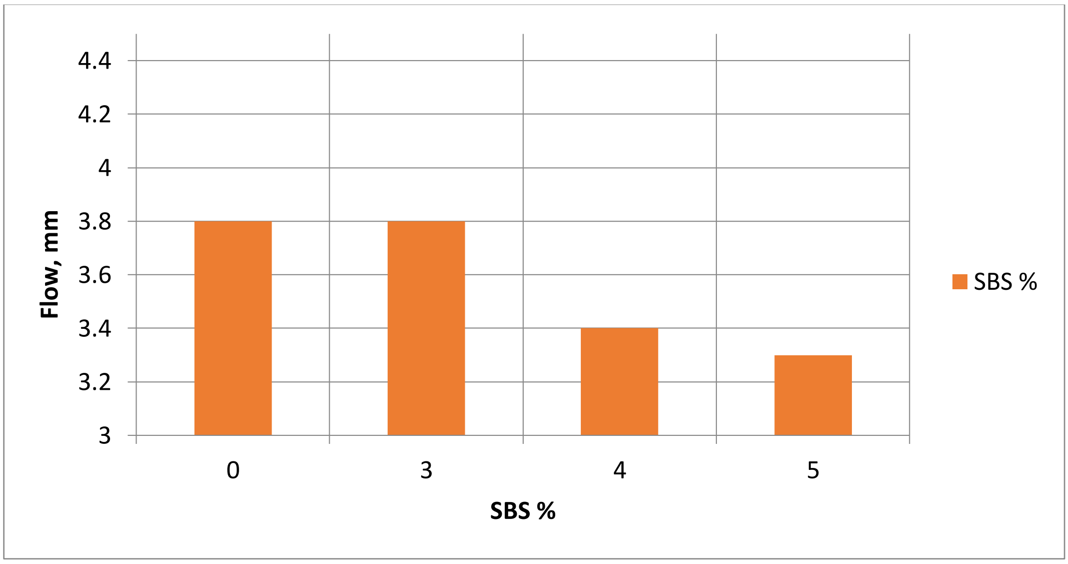

Figure 7: Marshall flow versus SBS polymer content.

Double punch shear test
Double punch shear test indicates the shear resistance action between aggregate and binder. Figure (8) presents double punch shear test results for hot recycled mixture. Three percentage of SBS polymer were added.

It can be seen that the punching strength values increase with increase SBS content. It is increased by about 26.1%, 59.5% and 74.8% when adding 3%, 4% and 5% SBS polymer content respectively for 30% RAP. This can be attributed to the fact that SBS modified asphalt improve the adhesive property of a mix which provides the desired properties of elasticity, plasticity and elongation and also increase the viscosity of binder, hence more resistance to the load carried by the machine (punching load).

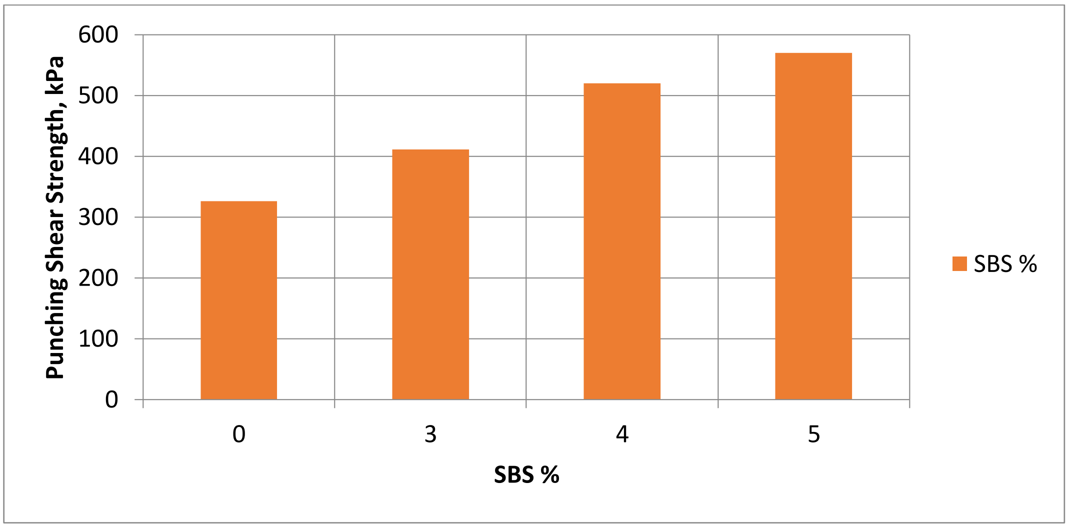

Figure 8: Double punch shear results versus SBS polymer content.

CONCLUSIONS

This article investigated the mechanical properties of hot recycled mixture and SBS polymer–modified asphalt mixtures. In the light of intense experimental tests, the following conclusions can be drawn. The following conclusions are based on the light of intense experimental work:

1. The indirect tensile strength (ITS) for unconditioned and conditioned sample increases with increasing SBS polymer content.
2. The indirect tensile strength ratio increases with increasing SBS content reaching its maximum ratio (94%) for 5% SBS content.
3. The addition of the SBS polymer to hot recycled mixture has clearly improved the Marshall stability by about 26.4% with 5% SBS content.
4. The punching strength values increase with increase SBS content which is increased by about 74.8% when adding 5% SBS polymer content for 30% RAP.
5. From the experimental results of the three percentages (3%, 4% and 5%) of SBS polymer for modified mixture and hot recycled mixture, it can be concluded that 5% of SBS modified mixture gave the best results due to its improvement of mechanical properties of the mixture compared with the control mixture.

REFERENCES

1. Perez F., Rodriguez M., De Visscher J., Vanelstraete A. and De Bock L., (2004), “Design and Performance of Hot Mix Asphalts with High Percentages of Reclaimed Asphalt- Approach Followed in the ARAMIXProject”, Proceedings of the 3rd Eurasphalt & Eurobitume Congress, Vienna, paper-098.
2. Huang, B., Li, G., Vukosavljevic, D., Shu, X., and Egan, B. K. (2005b). “Laboratory investigation of mixing hot-mix asphalt with reclaimed asphalt pavement.” ransportation Research Record 1929, Transportation Research Board, Washington, DC, 37–45.
3. FHWA. Federal Highway Administration , (2011), ― Reclaimed Asphalt Pavement in Asphalt Mixtures‖, Department of Transportation, Research , Development and Technology Turner –Fairbank Highway Research Center , United States.
4. Smith, L. (1996). “Wasting No Time: Florida's History of Successful Recycling for Transportation”, TR News No. 184:4-7.
5. P.L. Cong, J. Yu, S.F. Chen, Effects of epoxy resin contents on the rheological properties of epoxy/asphalt blends, J. Appl. Polym. Sci. 118 (2010) 3678–3684.
6. J. Wei, Z. Liu, Y. Zhang, Rheological properties of amorphous poly alpha olefin (APAO) modified asphalt binders, Constr. Build. Mater. 48 (2013) 533–539.

7. B. Colbert, Z. You, The properties of asphalt binder blended with variable quantities of recycled asphalt using short term and long term aging simulations, Constr. Build. Mater. 26 (2012) 552–557.
8. Cong, Zhang, Liu. Investigation of the properties of asphalt mixtures incorporating reclaimed SBS modified asphalt pavement. Constr. Build. Mater. (2016).
9. National Cooperative Highway Research Program (NCHRP), (2001). "Recommended Use of Reclaimed Asphalt Pavement in the Superpave Mix Design Method: Guidelines", Report 452, Transportation Research Board, Washington, DC.
10. SCRB (State Commission of Roads and Bridges), (2003) "hot mix asphalt concrete pavements section R9", revision of standard specifications for roads and bridges, ministry of housing and construction, department of planning and studies, Republic of Iraq.
11. ASTM (2012), "ASTM D5: Standard Test Method for Penetration of Bituminous Materials", Annual Book of Standards American Society for Testing and Materials, Vol.04.03, ASTM, USA.
12. ASTM (2012), "ASTM D36: Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)", Annual Book of Standards American Society for Testing and Materials, Vol.04.04, ASTM, USA.
13. ASTM (2012), "ASTM D92: Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester", Annual Book of Standards American Society for Testing and Materials, Vol.05.01, ASTM, USA.
14. ASTM (1999), "ASTM D113: Standard Test Method for Ductility of Bituminous Materials", Annual Book of Standards American Society for Testing and Materials, Vol.04.03, ASTM, USA.
15. ASTM (2012), "ASTM C127: Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate", Annual Book of Standards American Society for Testing and Materials, Vol.04.02, ASTM, USA.
16. ASTM (2012), "ASTM C128: Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate", Annual Book of Standards American Society for Testing and Materials, Vol.04.02, ASTM, USA.
17. ASTM (2012), "ASTM C131: Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine", Annual Book of Standards American Society for Testing and Materials, Vol.04.02, ASTM, USA.
18. ASTM (2012), "ASTM D1754: Standard Test Method for Effects of Heat and Air on Asphaltic Materials (Thin-Film Oven Test)", Annual Book of Standards American Society for Testing and Materials, Vol.04.03, ASTM, USA.
19. ASTM (2012), "ASTM D2041: Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures", Annual Book of Standards American Society for Testing and Materials, Vol.04.03, ASTM, USA.
20. ASTM (2012), "ASTM D2172: Standard Test Methods for Quantitative Extraction of Bitumen From Bituminous Paving Mixtures", Annual Book of Standards American Society for Testing and Materials, Vol.04.03, ASTM, USA.
21. ASTM (2012), "ASTM D 2726: Standard Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures", Annual Book of Standards American Society for Testing and Materials, Vol.04.03, ASTM, USA.
22. ASTM (2012), "ASTM D4867: Standard Test Method for Effect of Moisture on Asphalt Concrete Paving Mixtures", Annual Book of Standards American Society for Testing and Materials, Vol.04.03, ASTM, USA.
23. AASHTO, (2007), "AASHTO T283: Standard Method of Test for Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage", American Association of State Highway and Transportation Officials, Washington, D. C., USA.
24. AASHTO, (2012), "AASHTO M323: Standard Specification for Superpave Volumetric Mix Design", American Association of State Highway and Transportation Officials, Washington, D. C., USA.
25. Jimenez, R. A., (1974), ''Testing for Debonding of Asphalt from Aggregates'', Transportation Research Record 515, TRB, National Research Council, Washington, D.C., pp. 1–17.