The Effect of SBS Content on The Warm Asphalt Concrete Mixtures Performance

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Abstract

Warm mix asphalt (WMA) represents a number of technologies used to decrease the mixing and compaction temperature. The reduction in temperature has many advantages such as: lower cost to produce such as mixtures, and environmental effects. In Iraq the WMA technology consider a new technology can be sued for the next years. The main objective for this research is to study the effect of polymer on the performance of WMA. In this study, three kinds of asphalt mixtures were used: Hot Mix Asphalt (HMA), Warm Mix Asphalt (WMA), and Polymer Modified WMA. The WMA has produced by adding Aspha- min® at rate 0.3%, and for WMA modified by SBS they contain SBS with rate (0.5-3.5) %.The performance tests consist on: Indirect Tensile Strength Ratio Test (moisture susceptibility), and Wheels – Track Test (rutting resistance). The results of these tests have indicated that, performance of HMA better than WMA, and the adding of SBS to WMA improve their performance. However, the using of SBS at rate (3%) and more improve the WMA performance against moisture damage and rutting.

Key words: Warm Asphalt Mixtures, Aspha-Min®, SBS, Indirect Tensile Strength Ratio, Wheels- Track Test.

الخلاصه

الخلطات الاسفلتيه الدافئه تمثل مجموعة التقنيات التي تساعد على تخفيض درجة حرارة المزج والحدل. ومن فوائد هذا التقليل في درجة الحراره : انخفاض كلفة انتاج هكذا نوع من الخلطات ،اضافة الي ذلك التاثير البيئي الجيد حيث تعتبر صديقة الي البيئه.و في العراق تعتبر الخلطات الاسفلتيه الدافئه من الوسائل الحديثة والغير مجربه، ويمكن استعمالها في السنوات القادمه. تهدف هذه الدراسه الي معرفة مدى تاثير محتوى المواد الملدنه على كفاءه هذه الخلطات. ومن اجل ذلك استعملت ثلاثة انواع من الخلطات وهي: الخلطات الاسفلتيه الحاره ، الخلطات الاسفلتيه الدافئه، والخلطات الاسفلتيه الدافئه والمطوره بمادة SBS.بنسبه(0.5−3.5)%. واشتملت فحوصات تقييم الاداء على : فحص نسبة الشد الغير مباشر(فحص حساسية الماء)، وفحص العجلة المتحركه(فحص عمق التخدد). اشارة نتائج هذه الفحوصات : الكفاءه الجيده للخلطات الاسفلتيه الساخنه مقارنة مع الخلطات الاسفلتيه الدافئه، والتاثير الجيد لمادة SBS على تحسين اداء الخلطات الاسفلتيه الدافئه المطوره.وبصورة عامة ،عند استعمال نسبة 3% من مادة SBS واكثر تحسن من اداء الخلطات الاسفلتيه الدافئة لمقاومة الاثر الضارللماء، وتزيد من مقاومة الخلطه الاسفلتيه للتشوهات الدائميه المتمثلة بالتخدد.

الكلمات المفتاحية :− الاسفلتية الدافئة ، فحص العجلة المتحرك ، لدائن فحص الشد الغير SBS ، مباشر (فحص حساسية الماء).

1-Introduction and Background

The term of warm mixtures asphalt (WMA) refers to asphalt mixtures produced and compacted at temperatures lower than temperature for ordinary mixtures. To achieve this reduction in temperatures many of additives use with asphalt binder and they are: Aspha-min®, WMA- Foam®, Sasobit®, Evotherm™, and Advera® WMA. All those additives reduced the viscosity of asphalt binder at given temperature and allow the aggregate to be fully coated at lower mixing temperature range(100-140c), which is lower than hot mixture asphalt(HMA)**(FHWA,2001; Prowell *et.al.*, 2007).** As the temperature reduced, their many of benefits of using WMA such as: economic (reduce amount of fuel),good workability(longer haul distance),and higher percentage of recycled asphalt can be used**(Button *et.al.*, 2007; Neitzke *et.al.*, 2009)**. Due to environmental factors, sustainable requirements, and economic reasons, the WMA has used to replace HMA. The first time for WMA application was in Europe in middle of Ninety and then in USA in 2002**(Angelo *et.al.*, 2008)**.

As the technology of Warm Mix Asphalt considers a new technology, the performance of these mixtures were evaluated and tested either in field or in libratory. The first field inspection was made in 2007, a team of U.S materials experts visited Belgium, France, Germany, and Norway to evaluate various sections of WMA through the Federal Highway Administration

International Technology scanning program. The scan team found that, performance of WMA was better or the same compare to performance of HMA. In another sites the performance where lower, especially to rutting and moisture. They concluded , the differences in performance related to the type of additives used, and the using of aggregate with lower water absorption will improve the resistance against rutting and moisture**(Prowell,2007,A and B).**. In another hand, **Prowell *et.al.*, 2005; Xiao *et.al.*, 2010)** studied the performance of WMA according to moisture and rutting resistance. They concluded, due to lower temperature either during mixing or compacting reduced the aging of binder and affected on performance. **Prowell *et.al.*, 2005** concluded, the lower compaction temperature used when WMA contain Sasobit or any such additives increase the moisture damage and potential of rutting. **Xiao *et.al.*, 2010** found in their study, the using of anti stripping additives (ASA) increase the moisture damage resistance and reduced the rut depth. The National Cooperative Highway Research Program (NCHRP) Rep No. 691, Mix Design Practices for Warm Mix Asphalt. It is found that WMA mixes, in general are more susceptible to moisture than typical mixes, and an anti-stripping additive should be used. Also, WMA processes with very low production temperatures may produce WMA mixes that are less resistant to rutting than HMA mixes. In short, a WMA mix produced with the same aggregate and binder as HMA will have similar properties with respect to volumetric. However, the short term stiffness value from laboratory-compacted samples of the WMA mix is lower than that of the HMA mix (**Bonaquist,2011**).

Generally, polymer modification has been long under study and its effectiveness for improving rheological properties of asphalt binder and performance of asphalt mixtures has been improved**(Illinois, 2005).** Four basic types of polymers have been used, and the most commonly type is the SBS **(Casola, 2006).** It has been identified that SBS can improve the mechanical properties of mixtures such as ageing**(Cortize *et.al.*, 2004)**, permanent deformation**(Tayfur, *et.al.*, 2007),(Vlachovicova *et.al.*, 2007)** , low temperature cracking **(Isacsson *et.al.*, 1997)**, and moisture damage resistance **(Shulers *et.al.*, 1990;Won *et.al.*, 1994)**. Moreover, a comparison with a widely-used polymer can help to get better of performance efficiency of asphalt mixtures.

Objective of the Studdy

The main objective of this study is to investigate the effect of SBS content on the performance of WMA. To achieve this purpose, one type of polymer has used (SBS), one kind of WMA additives used (Aspha-min®), and three types of mixtures use and they are: Polymer Modified Warm Mix Asphalt (PMWMA), Hot Mix Asphalt (HMA), and finally Warm Mix asphalt. The performance tests consist of: moisture damage resistance, and rutting resistance.

2-Material Characteristics

2-1Asphalt Cement

One sort of asphalt cement is used, with (40-50) penetration grade brought from AL - Daurah refinery. The physical properties of asphalt cement were evaluated according to ASTM standard **(ASTM, 2003)**, and compared with Iraqi specification **(SCRB/R9, 2003)**, as shown in **Table 1**.

2-2 Aggregate

The aggregate used in this study was originally obtained from AL Najaf quarries. The aggregate was sieved and recombined to meet the requirements of wearing course gradation according to SCRB specification **(SCRB, 2003)**. The physical properties of aggregate are shown in **Table2**, while **Table 3** shows the selected aggregate gradation.

2-3 Filler

Filler materials represent mineral particles that pass sieve (No.200). Filler used in this study was ordinary Portland cement at 7% content, which represents mid range value of SCRB specifications **(SCRB, 2003)**, **Table 4** shows the properties of filler.

2-4 Styrene-Butadiene-Styrene (SBS) polymer

The SBS polymer, used in this study, is brought from Baghdad. The SBS added to asphalt binder at content equal to (0.5%) and increased up to (3.5%) by the weight of binder.

2-5 WMA Additives

There are five kinds of WMA additives used to product Warm Mixtures asphalt (Asha-Min®, WMA- Foam, Sasobit, Evotherm, and Advera WMA). One type from these additives used in this study (Aspha-min®). Aspha-Min is a product of Eurovia Services GmbH, Bottrop, Germany. It is available in a fine white powdered form in 25 or 50 kg bags or in bulk for silos. It is a manufactured synthetic zeolite (Sodium Aluminum Silicate), which has been hydro thermally crystallized. The percentage of water held internally by the zeolite is 21 percent by mass and is released in the temperature range of 185° - 360° F. By adding Aspha-min to the mix at the same time as the binder, a very fine water spray is created. This release of water creates a volume expansion of the binder that results in asphalt foam and allows increased workability and aggregate coating at lower temperatures. Eurovia recommends adding Aspha-Min at a rate of 0.3 percent by mass of the mix, which can result in a potential 54° F reduction in typical HMA production temperatures **(FHWA, 2016).**

3- Labotatory Work

3-1 Asphalt Concrete Mixture Design

The asphalt concrete mixture design started by mixing mixture components (aggregate, filler material, and asphalt cement), and determining the optimum asphalt content using the Marshall mix design method in accordance with ASTM D 1559**(ASTM,2004).** The optimum content was found to be 5.2% by the total weight of sample. This value of the AC content will be constant, to eliminate the effect of asphalt content on the results analysis. The WMA sampled prepared for this study contain 0.3% of Aspha-min® as recommended, and the method used was the adding WMA additive to mixtures during production **(NCHRP, 2011)**

3-2 Indirect Tensile Strength Ratio Test

The indirect tensile ratio test (TSR) was conducted in accordance with AASHTO T283 **(AASHTO, 2007),** as standard performance test to evaluate the moisture sensitivity of bituminous mixtures. A static load is increasingly applied at rate of 50.8mm/min to the sample until failure. The result of this test is indirect tensile strength (ITS), and tensile strength ratio (TSR). In this test, two groups of samples were used, the first one represent control samples (UN conditioned samples) which they tested at 25^{o}c.The second one (conditional samples), were they submerged in water at 60^{o}c for 24 hr, and then tested at 25^{o}c. All specimens were compacted at 7% air voids. The indirect tensile strength is calculating according equation 1, and the tensile strength ratio calculating according equation 2 as shown below, the minimum TSR value80%.

ITS=2P/πdt———(1) **TSR= ITS(con)/ ITS(uncon) ≥80%——(2)**

$$ITS = 2P/\pi dt \quad (1) \qquad TSR = ITS(con)/ITS(uncon) \geq 80\% \quad (2)$$

ITS: indirect tensile strength, P: applied load, t: thickness of specimen, d: diameter of specimen

TSR: Tensile Strength Ratio, ITS (con): Indirect Tensile Strength for conditioned sample, ITS (uncon): Indirect Tensile Strength for unconditioned sample.

3-3 Wheels – Track Test

This test method describes a procedure for testing the rutting resistance for asphalt pavement samples by using the Hamburg Wheel- Tracking Test Device, and the results of this test is rut depth and the number of passes to failure. This test accomplished according to AASHTO designation T324-04 **(AASHTO, 2007).** Cylindrical samples with dimension (150mm x60mm) were used with target air voids 7%. The rut depth determines either at 20000 passes or 20mm which of them appear first.

4- Results Analysis

Table 5 summarized the results of Marshall Test for the asphalt mixtures used in this study. As listed in table, both of HMA and WMA (control) have characteristics such as: Marshall Stability, air voids, and flow meet the with SCRB specifications. The better values were for HMA, meaning that addition of Aspha-min® influence on the mixture characteristics especially in percent of air voids. This change related to the reduction in mixing and compaction temperatures. For modified WMA, they have superior values compare with control WMA. The Marshall Stability increased up to 16.8 Kn, and air voids reduced to 3.74%. Also the stiffness values for modified mixtures increased as SBS content increase. The optimum content of SBS was 3.5%.

The results of tensile strength ratio (TSR) test are shown in **Figure 1**. As appear, the HMA exhibited a better resistance to moisture damage than WMA, where TSR values for HMA and WMA are 83% &72%. The reduction on TSR value for mixtures contain Aspha-min® due to low temperature of mixing preventing the full drying of aggregate , and partial aging of binder which consequence on bonding forces between aggregate and asphalt film. When SBS used with WMA, the TSR values increased. These improvements happen because SBS consider as anti stripping additives, beside SBS created a network strengthen the bonding forces between mixture components, and reduce the stripping action of water.

Finally, the results of wheels- track test were represented in **Figure 2**. As shown the rutting depth for HMA was 10mm and for WMA was 14mm, that means the WMA has lower resistance to rutting. The lower temperature of compaction and high value of flow reduced the rutting resistance. After the application of SBS into WMA, the rutting depth decreased from 14mm to 6mm at SBS content 3%. This reduction in rut depth related to increase in stiffness, because the flow decrease and Marshall Stability increase at the same time. As a consequence the asphalt mixtures will have a good resistance when stiffness increased. For SBS percent 3.5% no significant change in rutting values.

5-Conclusions

According to the results obtained from the current study, a number of conclusions were drawn:

1. Both of the ordinary asphalt mixtures (HMA), and warm asphalt mixtures (WMA), have acceptable properties such as: Marshall Stability, and Air voids, and for the modified warm mixtures they have the best results.
2. According to the results of indirect tensile strength ratio test, the TSR value for WMA (control) was (72%) while TSR for HMA (83%), so the WMA more susceptible to moisture.
3. The results of wheels – track test showing that WMA have a lower resistance to rutting. The rut depth for WMA was 14mm, and for HMA was 10.1mm.
4. The addition of SBS to WMA improves the performance as shown in the moisture susceptibility test, and Wheel- tack test. The rate of increasing in TSR values equal to 16%,

and rate of decreasing in rut depth 56%. All of these results recorded when SBS content (3%), and for (3.5%) SBS content no significant changes were recorded.

5. Based on the above results, it concluded: the addition of Asph-min to asphalt mixtures has an effect on the performance of asphalt mixtures, and the addition of SBS have a significant impacts to improved WMA performance according to moisture and rutting resistance.

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Table1: Physical properties of asphalt binder

Property	ASTM designation	Test result	SCRB specification
Penetration ,25°c, 100gm, 5sec,0.1mm.	D-5	47	40-50
Ductility , 25°c, 5cm/min.	D-113	110	>100
Flash point, C⁰	D-92	280	Min 232°c
Specific gravity	D-70	1.034	1.05-1.01

Table 2: Physical properties of the aggregate

Property	ASTM Designation	Coarse aggregate	Fine aggregate
Apparent specific gravity	C-127	2.676	2.686
Bulk specific gravity	C-127	2.613	2.663
%wear (Los angles)	C-131	23 %(max30%)	————

Table3: Aggregate gradation (surface course, Type A)

Sevie size(mm)	19	12.5	9.5	4.75	2.36	0.3	0.075
%passing (SCRB)	100	90-100	76-90	44-74	28-58	5-21	4-10
% passing select	100	95	80	60	45	15	7

Table4: Physical properties of mineral filler (ordinary cement)

Property	Test method	Result
%passing sieve No.200	———	96
Specific gravity	ASTM C 128	3.13
Fineness	———	3123

Table5: Marshall and volumetric characteristics

Mixture type	Marshall stability,KN	Marshall flow,mm	Air voids, %	Asphalt content,%
HMA	13.5	3.1	3.72	5.2
WMA	10.5	3.9	4.7	5.2
WMA+0.5%SBS	10.8	3.9	4.5	5.2
WMA+1 %SBS	11.2	3.8	4.42	5.2
WMA+1.5 %SBS	12	3.8	4.25	5.2
WMA+2 %SBS	13.7	3.7	3.91	5.2
WMA+2.5 %SBS	14.5	3.6	3.78	5.2
WMA+3%SBS	16.7	3.5	3.76	5.2
WMA+3.5%SBS	16.8	3.5	3.74	5.2
SCRB Specification	**Min 8 KN**	**2-4mm**	**3-5%**	**4-6%**

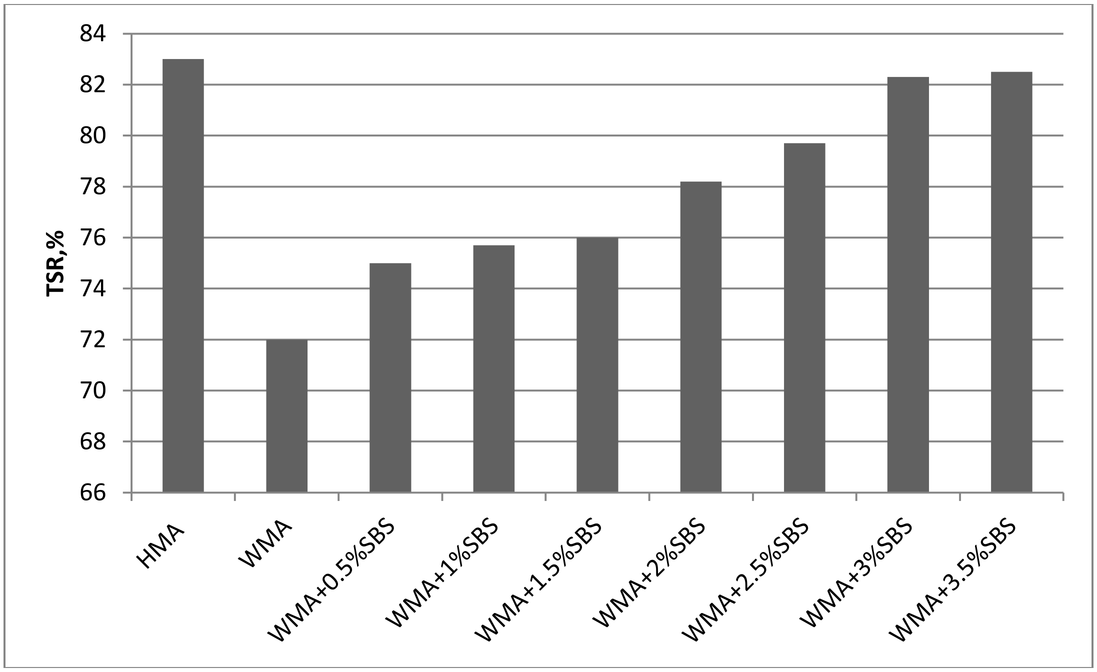

Figure 1: Results of Tensile Strength Ratio Test

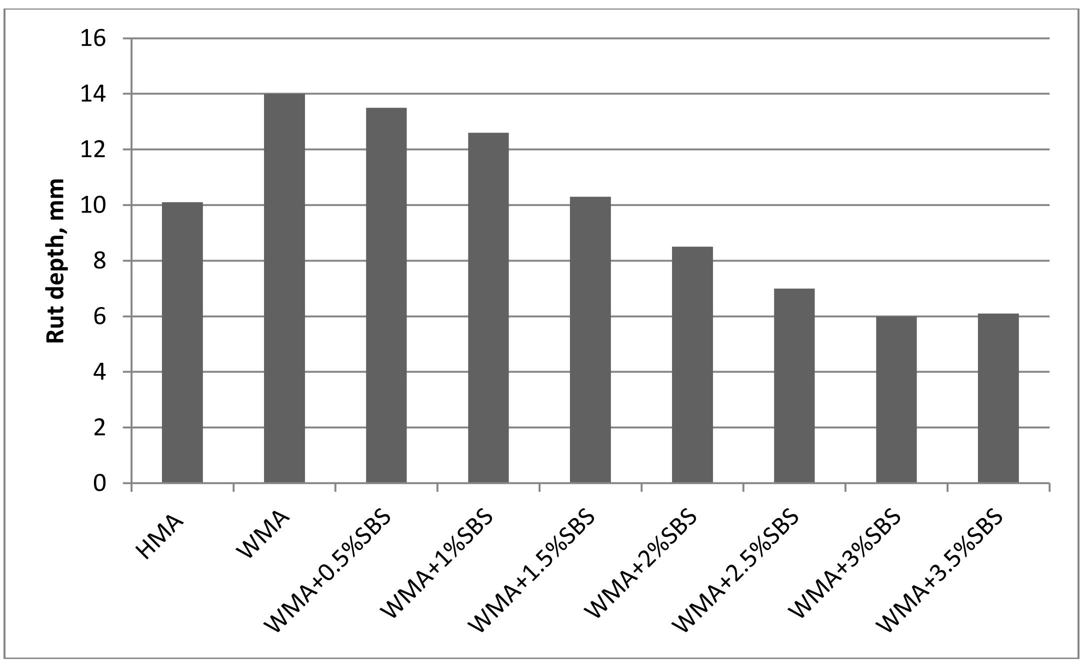

Figure 2: Results of Wheels- Track Test (T=50^{o}C)