Journal of Babylon University/Engineering Sciences/ No.(4)/ Vol.(22): 2014

Laboratory Evaluation of Modified Asphalt Mixture Properties and Aggregate Grading by Superpave System

Mohammed Aziz Hameed Al-Shaybani **Nahla Yassoub Ahmed**
Department of Civil Engineering/Babylon University.
mohammedalshaybani@yahoo.com nahlayassub@yahoo.com

Abstract

In Iraq, the using of conventional asphalt cement in mix design causes unnecessary road maintenance. It is necessary to use additive materials in pavement construction as modifiers which could improve the performance of asphalt concrete pavements mixture. The major objective of this research is to evaluate the effects of polymer modification and aggregate gradation for Superpave system on the properties of hot mix asphalt by using asphalt from Al- Daurah refinery with two locally polymers. These polymers are represented by high density polyethylene (HDPE) and styrene butadiene styrene (SBS) with using three aggregate gradations [(Above Restricted Zone) (A), Through Restricted Zone (T), and Under Restricted Zone (U)]. The performance of polymer asphalt mixtures are evaluated using indirect tensile test and wheel track test. The results confirm that the indirect tensile strength and resistance to rutting of polymer asphalt mixtures are largely dependent on polymer type, polymer concentration and aggregate gradation. It is concluded that the addition of polymer to asphalt mixtures shown the permanent deformation are decreased by (189%) at 40°C and by (271%) at 50°C and indirect tensile strength is increased by (42%), after compared with control mixtures. The addition of SBS and HDPE with 3% for each one to asphalt mixtures showed better properties of pavement. Also the gradation above restricted zone give a good tensile strength and high resistance to rutting from other gradations. Increasing the test temperature from (40 to 50)°C, the permanent deformation (rutting depth) also increased by (100%).

Key Words: asphalt, pavement, Superpave, polymer, aggregate, gradation, performance.

الخلاصة

في العراق يستعمل الاسفلت التقليدي في تصميم المزيج مما يسبب صيانة للطرق وبعد فترة قصيرة من الانشاء .اذن من الضروري استخدام المضافات عند انشاء التبليط تعمل كمادة معدلة والتي من الممكن ان تحسن اداء التبليط بالخرسانة الاسفلتية .

إن الهدف الرئيس لهذا البحث هو تقيم تأثير مواد اللدائن المختلفة وتدرج الركام لنظام التبليط الاسفلتي الفائق الاداء ال(Superpave) على خواص الخلطات الإسفلتية باستعمال مواد متوفرة محليا، حيث تم استخدام مادة الزفت من مصفى الدورة واستعمال اللدائن التالية البولي اثيلين عالي الكثافة (HDPE) و الستايرين بيوتادين ستايرين ((SBS واستخدام ثلاث تدرجات للركام هي تدرج يمر اعلى وخلال واسفل المنطقة المقيدة وحسب نظام ال(Superpave).

وتم إجراء الفحوصات المختبرية (فحص مارشال وفحص الشد الغير مباشر وفحص التشوه ألدائم تحت عجلة المسار) وتمت مقارنة نتائج الإسفلت الحاوي على اللدائن مع الإسفلت الاعتيادي بالإضافة إلى مقارنة تأثير تدرج الركام.

أثبتت النتائج إن قوة الثبات ومقاومة الشد الغير مباشر ومقاومة التخدد باستعمال الإسفلت الحاوي على اللدائن تعتمد بشكل كبير على نوع المضاف وتركيزه بالإضافة إلى تدرج الركام. وقد دلت النتائج إن إضافة اللدائن تحسن من مواصفات الخليط الأسفلتي وبالتالي تحسن أداء التبليط نلاحظ ان التشوه الدائم يتناقص بنسبة ١٨٩% عند ٤٠ سيليزية وبنسبة ٢٧١% عند ٥٠ سليزية، ومقاومة الشد غير المباشر ازداد بنسبة ٤٢% وثبات مارشال ازداد بنسبة ١٦٧% عند المقارنة مع الخلطات ذات الاسفلت غير المعدل، فإضافة (٣%) من SBS و HDPE هي النسب الأفضل للحصول على مواصفات جيدة للتبليط بالإضافة ان تدرج الركام الذي يمر فوق المنطقة المقيدة (A) يعطي قوة ثبات ومقاومة للشد الغير مباشر جيده ومقاومة عالية للتخدد بالمقارنة مع التدرجات الاخرى. إن زيادة درجة حرارة الفحص من (٤٠ إلى ٥٠) سيليزية يسبب زيادة في التشوه الدائم بنسبة ١٠٠%.

الكلمات المفتاحية: الاسفلت، التبليط، التبليط الاسفلتي فائق الاداء، البوليمر، الركام، التدرج، الاداء.

1- Introduction

The recently introduced Superpave is a comprehensive asphalt mixture design system intended to ensure good field performance of long-lasting asphalt pavements under various traffic loading and climatic conditions. Applicability of Superpave to modified asphalt mixture systems are two important issues that need to be addressed. One of the characteristics of the aggregate gradation criteria in Superpave is the restricted zone. This is a zone lying on the maximum density curve extending from the 300 μm sieve to the 2.36 mm sieve size through which it is considered undesirable for the gradation to pass. The restricted zone is intended to discourage the use of fine sand or natural sand, in order to achieve adequate voids in mineral aggregate (VMA), **(Kim, 2006)**.experimental work and validation. To prevent systematic rejection of good economical mixes by the restricted zone criteria, the effects of the restricted zone on the performance of asphalt pavement needs to be determined. Due to increased traffic loading and traffic volume, the use of modifiers in hot mix asphalt has become a very popular practice. laboratory studies suggest that binders with the same PG grade but prepared using different modifier types.

2- Objectives

This study has two main objectives:

1. To determine the effects of aggregate gradation on permanent deformation (rutting depth) and tensile strength of asphalt mixtures.
2. To determine the effects of polymer modified binders on permanent deformation (rutting depth) and tensile strength of asphalt mixtures.

3- Materials for Asphalt Mixtures

3-1 Aggregates

Locally available crushed limestone aggregates are used in this study. The fine and coarse aggregate are sieved and recombined in the proper proportions to meet the gradations required. In order to examine the aggregate restricted zone introduced by Superpave system, three gradations are used [(Above Restricted Zone) (A), Through Restricted Zone (T), and Under Restricted Zone (U)]. A- typical dense gradation with a nominal maximum size of aggregate of (12.5 mm), for passing above, through and under the restricted zone are shown in figure 1. The percent passing from the 19.0 mm to the 4.75 mm particle size are the same for all three gradations; while the percent passing for the particle sizes smaller than 4.75 mm varies, **(Asphalt Institute, 2004)**.

3-2 Asphalt Binders

The typical asphalt binders used for construction of pavements in Iraq are PG 70-16, **(Abbas, 2009)**. Styrene Butadiene Styrene (SBS) and High Density Polyethylene (HDPE) are used modified binders. Three PG 70-16 binders (SBS modified, HDPE modified, and unmodified binders) used in this study were prepared by a supplier from the same base asphalt. The modified asphalts were prepared by adding 3% SBS and HDPE by weight of asphalt binder.

4- Laboratory Specimen Preparation and Test Methods

4-1 Mix Design

Standard method of Marshall as in **(ASTM D-6927, 2006),** specifications is used to find the optimum asphalt content for compacted asphalt concrete specimens. The results of Marshall tests show almost typical relationships between Marshall properties and asphalt content. Three different percentages (4.2, 4.8, 5.4) % of Daurah PG (70-16) asphalt cement are used with ordinary Portland cement (filler) and three gradations are used [(Above Restricted Zone) (A), Through Restricted Zone (T), and Under Restricted Zone (U)] for (12.5) mm nominal maximum size of aggregate for dense mix in accordance with SCRB specification (R9), for wearing course type (A), **(SCRB, 2003)**.

The optimum asphalt content (O.A.C) of the various mixes is determined from the following Marshall curves, (stability, flow and 4% of air voids). The optimum asphalt content for three gradation, above (A), through (T) and under (U) restricted zone are (5.2, 4.9, 4.8) , respectively, as shown in table1.

4-2 Specimen Preparation

Duplicate test specimens of controlled air void contents were prepared in the laboratory. For the wheel track apparatus (WTA) test, specimens 150 mm in diameter x 60 mm in height with 4% air void contents are prepared using the compaction apparatus. For the indirect tensile strength (ITS) test, specimens 100 mm in diameter x 60 mm in height are prepared using the compaction apparatus to have 4% air void contents.

4-3 Wheel Track Apparatus (WTA) Test

The WTA test is conducted dry to 6000 passes (3000 cycles) at 40˚C and 50˚C in which the rut depths are measured continuously. WTA test is conducted on two cylindrical samples at one time and compacted with standard Marshall compacter. In case that WTA is a completion of the 6000 passes at 40˚C and 50˚C, the testing was manually stopped and rut depth is recorded, **(AASHTO T324, 2005)**.

4-4 Indirect Tensile Strength (ITS) Test

Indirect tensile strength (Fatigue Cracking Analysis). This test is used to analyze mixtures for fatigue cracking resistance. For intermediate analysis, use a test temperature 20°C or less for fatigue cracking analyses. Lower the temperature of the environmental chamber to the test temperature with (± 0.2°C) is achieved, allow each specimen to remain at the test temperature from 3±1 hours prior to testing. In this test, the specimen is loaded at a constant deformation rate of 2 inch per minute (50 mm per minute) of vertical ram movement. The specimen is loaded until failure – peak load is measured throughout the test **(AASHTO:T 322, 2005)**.

5- Laboratory Test Results and Discussion

5-1 Results of WTA Rut Tests

Results presented in table 2 indicate that the polymerized asphalt mix has higher resistance to permanent deformation (rutting depth) than the control mixtures (control mixture is the conventional mixture without modifiers). It is clear, from figures 2 and 3, considering all data, above restricted zone (A) mixes have higher resistance to permanent deformation (rutting depth), through restricted zone (T) mixes generally performed well, but under restricted zone (U) mixes demonstrate more susceptible characteristics to rutting than the (A) and (T) mixes, because of the fine gradation is stronger than the coarse gradation and the aggregate gradation passing above the restricted zone produces a lower value of air voids, as compared with the gradation under and through the restricted zone. The effect of temperature is illustrated in table 2, for rutting depth after 6000 passes at 40˚C and 50˚C, in which the results are presented in figures 2 and 3. It is clear that when the temperature increases to 50˚C rutting depth increased. However, at higher test temperatures, mixes with polymer modified binder are performed relatively better than mixes with an unmodified binder. The mixes with above restricted zone (A) gradation show the least amount of rutting at 50˚C, whereas mixes with under restricted zone (U) gradation show highest amount of rutting, mixes with gradation through the restricted zone (T) show slightly least amount of rutting from mixes with gradation under the restricted zone (U) at 50˚C.

5-2 Results of ITS Tests

The results of this test are shown in table 3, Also, figures 4 and 5. ITS for 3% SBS and HDPE modified content is greater than control mixture (conventional mixture without modifiers).The fine gradation is stronger than the coarse gradation and the aggregate gradation passing above the restricted zone produces a lower value of air voids, as compared with the gradation through and under the restricted zone, mixes above restricted zone gradation (A) had higher tensile strength than another gradations (T) and (U).

6- CONCLUSIONS

Based on the research findings, the following conclusions are presented:

- Mixes with above restricted zone (A) gradation have higher values of resistance to permanent deformation and tensile strength when compared with mixes of through (T) and under (U) restricted zone gradations.
- The values of permanent deformation for modified mixtures are decreased by (189%) at 40°C and by (271%) at 50°C after compared with control mixtures. The values of the indirect tensile strength is increased by (42%) at (20°C) after compared with control mixtures.
- Test temperature plays an important role in permanent deformation, when increasing test temperature from (40 to 50)°C permanent deformation (rutting depth) increased by (100%).

7- References

AASHTO 2005. AASHTO designation: T322, Determining the Creep Compliance and Strength of Hot-Mix Asphalt (HMA) Using the Indirect Tensile Device, The American Association of State Highway and Transportation Officials, Washington, D. C.,USA.

AASHTO 2005. AASHTO designation: T324, Hamburg Wheel-Track Testing of Compacted Hot-Mix Asphalt (HMA). The American Association of State Highway and Transportation Officials, Washington, D. C., USA.

Abbas, A. 2009. “Implementation of Performance Grade System for Local Asphalt Cement”, M.Sc. thesis, Civil engineering, University of Baghdad.

Asphalt Institute, 2004.“Superpave Mix Design”, Manual Series No.2, (SP-2), Asphalt Institute, Lexington, Kentucky.

ASTM D-6927, 2006. “Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus”, American Society of Testing and Materials.

Hozayen, H.,and Othman,A.2008.“Improving Mechanical Properties of Asphalt Concrete MixturesUsingThermoplasticPolymerAdditives”,GulfConferenceon Transportation, Dubai, UAE.

Kim, Y. 2006. “Restricted-Zone Requirements for Superpave Mixes Made with Local Aggregate Sources”, Civil Engineering, University of Nebraska-Lincoln.

SCRB/R9, 2003. General Specification for Roads and Bridges, Section R/9, Hot-Mix Asphalt Concrete Pavement, Revised Edition. State Corporation of Roads and Bridges, Ministry of Housing and Construction, Republic of Iraq.

LIST OF TABLES

TABLE 1 Volumetric Properties of the Unmodified Mixtures.

TABLE 2 Wheel Track Test Results for Control Mixture and Asphalt Mixtures. Modified by 3% SBS and HDPE After (6000) passes for Temperature at (40˚C) and (50˚C).

TABLE 3 Tensile Strength Test Results for Control Mixture and Asphalt Mixtures Modified by 3% SBS and HDPE.

LIST OF FIGURES

FIGURE 1 Aggregate gradation used for laboratory tests.
FIGURE 2 Wheel Track Test Results for Control Mixture and Asphalt Mixtures Modified by SBS.
FIGURE 3 Wheel Track Test Results for Control Mixture and Asphalt Mixtures Modified by HDPE.
FIGURE 4 Tensile Strength Test Results for Control Mixture and Asphalt Mixtures Modified by SBS.
FIGURE 5 Tensile Strength Test Results for Control Mixture and Asphalt Mixtures Modified by HDPE.

Table1: Volumetric Properties of the Unmodified Mixtures.

Mix No.	Stability (KN)	Flow (mm)	Air voids (%)	Selected Optimum Asphalt Content (%)
A	١١,٤	٢,٢٠	٤	٥,٢
T	١٢,٣	٢,١٨	٤	٤,٩
U	١٠,٩	٢,٠٥	٤	٤,٨

Table 2: Wheel Track Test Results for Control Mixture and Asphalt Mixtures Modified by 3% SBS and HDPE After (6000) passes for Temperature at (40˚C) and (50˚C).

Sample		Polymer percent(%)	Rut depth (mm) at (40˚C) after (٦٠٠٠)passes	Rut depth(mm) at (50˚C) after (٦٠٠٠)passes
Control	U	0	٣,٩٤	٦,٠٩
	T	0	٣,٤٢	٥,٩١
	A	0	٢,٨٠	٥,٦١
Modified (SBS)	U	3	٢,٠٠	٢,٢٨
	T	3	١,٥٣	٢,١٤
	A	3	١,٣٤	١,٥١
Modified (HDPE)	U	3	1.61	2.89
	T	3	1.45	2.67
	A	3	1.31	2.28

Table 3: Tensile Strength Test Results for Control Mixture and Asphalt Mixtures Modified by 3% SBS and HDPE.

Sample		Polymer (%) percent	Thickness (mm)	P Max load ((KN	ITS = (dtπp\(٢) (Mpa)
Control	U	٠	٦٤,٠	٢٣,٨٨	٢,٣٧٧
	T	٠	٦٤,٠	٢٣,٦٠	٢,٣٤٩
	A	٠	٦٤,٠	٢٦,٩٢	٢,٦٧٩
Modified (SBS)	U	٣	٦٥,٠	٢٨,٩٢	٢,٨٦٥
	T	٣	٦٥,٦	٢٩,٣٦	٢,٨٥١
	A	٣	٦٤,٣	٣١,٣٢	٣,٠٦٩
Modified (HDPE)	U	3	65.3	33.10	3.229
	T	3	64.3	33.79	3.347
	A	3	65.7	35.26	3.418

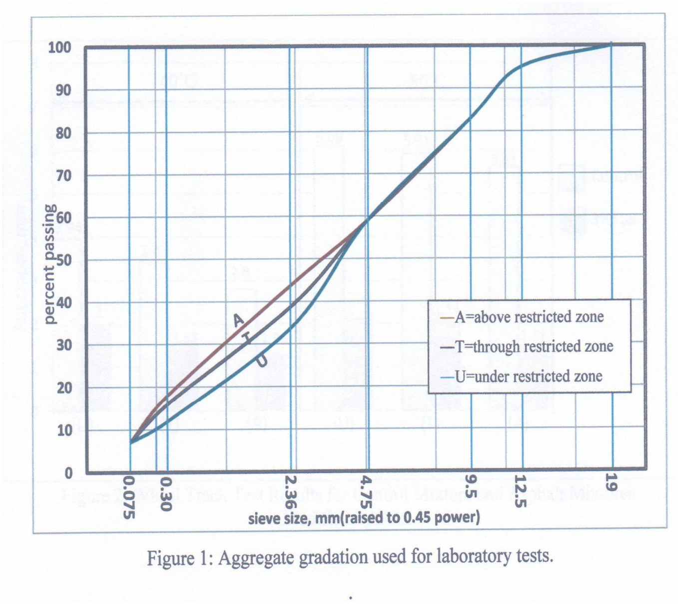

Figure 1: Aggregate gradation used for laboratory tests.

.

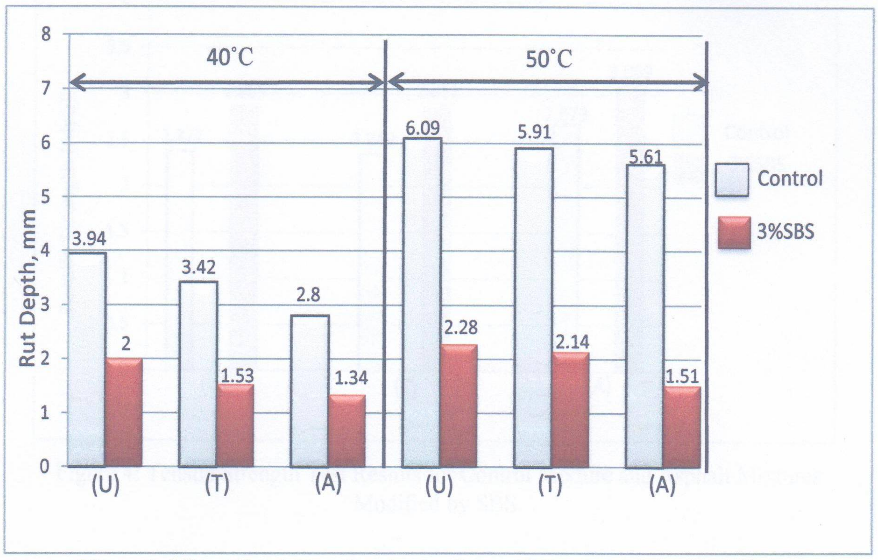

Figure 2: Wheel Track Test Results for Control Mixture and Asphalt Mixtures Modified by SBS.

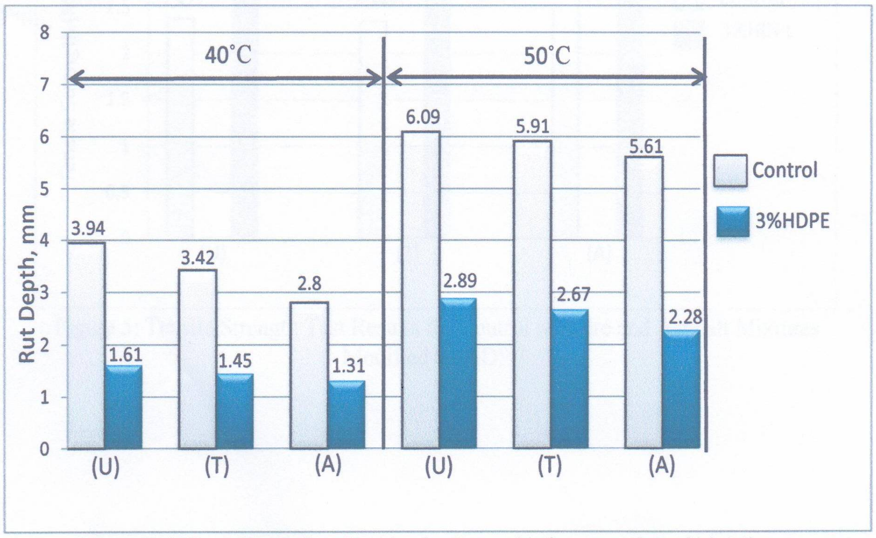

Figure 3: Wheel Track Test Results for Control Mixture and Asphalt Mixtures Modified by HDPE.

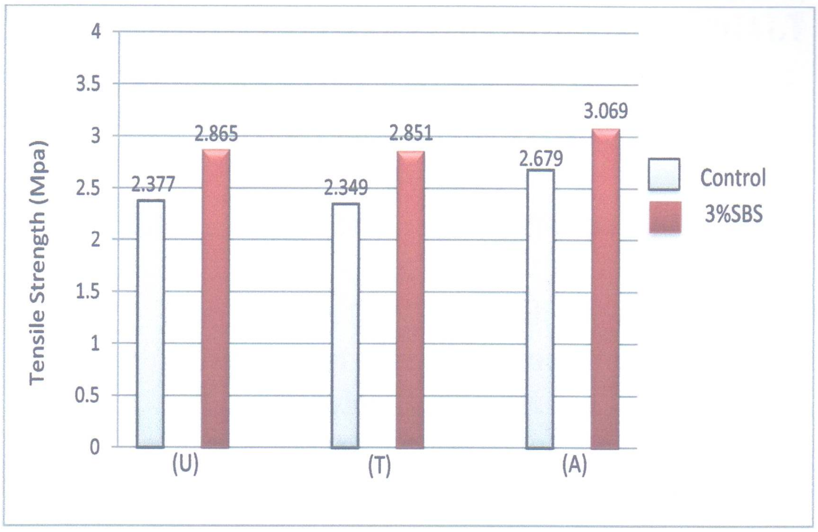

Figure 4: Tensile Strength Test Results for Control Mixture and Asphalt Mixtures Modified by SBS.

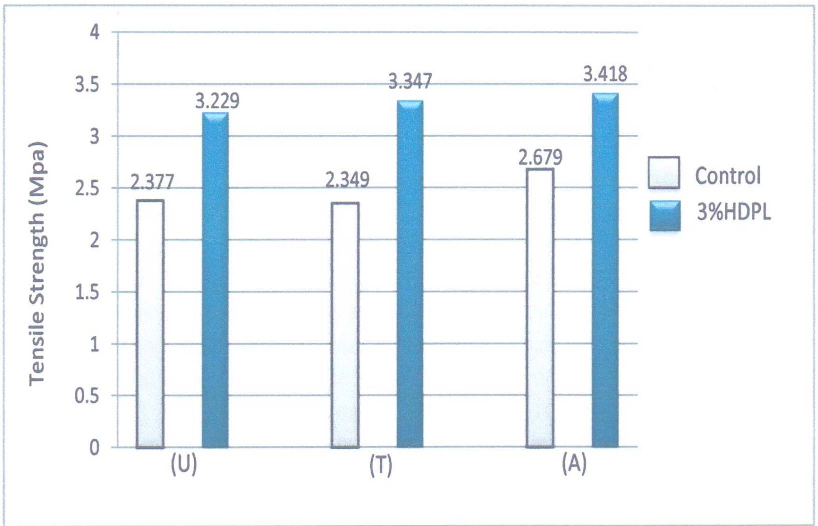

Figure 5: Tensile Strength Test Results for Control Mixture and Asphalt Mixtures Modified by HDPE.