IMPROVE PERFORMANCE OF ASPHALT CONCRETE OVERLAY BY USING SBR AS MODIFIED

Hayder K. Shanbara
Assis. Lect.
Department of Civil Engineering
Al-Muthanna University
Iraq 2012
E-mail : Engineer_hayder82@yahoo.com
Tel : 964(0)7902274877

Dr. Abdulaziz A. Kifae
Professor
Department of Civil Engineering
Al-Muthanna University
Iraq 2012
E-mail : azizkifai0561@yahoo.com
Tel : 964(0)7803854187

Dr. Riadh A. Abass
Assis. Prof.
Department of Civil Engineering
Al-Muthanna University
Iraq 2012
E-mail : readh_56@yahoo.com
Tel : 964(0)7901734941

الخلاصة:

ان اداء الطريق الاسفلتي يعتمد على خصائص الاسفلت، خصائص الخلطة الاسفلتية وعلى العوامل الخارجية مثل الحجم المروري والظروف الجوية. طبقة الاكساء السطحية واحدة من اهم واسرع طرق الصيانة لمعالجة الطرق المتضررة لزيادة عمره الخدمي.هذه الدراسة تهدف الى اعداد خلطة اسفلتية عالية الاداء تستخدم في عملية الاكساء السطحية. استخدم ستايرين بيوتادين المطاط كمضاف للاسفلت بثلاثة نسب (3 ، 6 ، 9 % من وزن الاسفلت المستخدم) مع العلم ان الاسفلت المستخدم ذو نفاذية 50/40. تم فحص خصائص الاسفلت والاسفلت المحسن باستخدام ستايرين بيوتادين المطاط والتي هي (النفاذية ، درجة الليونة ، نقطة الوميض ، المطيلية). وتم تقييم اداء الخلطة الاسفلتية والخلطة الاسفلتية المحسنة وذلك عن طريق فحص مارشال واجهاد الشد غير المباشر وفحص العجلة الدوارة. بينت نتائج الفحوصات ان استخدام ستايرين بيوتادين المطاط كمضاف للاسفلت ادى الى تحسين اداء الاسفلت والخلطة الاسفلتية. وكذلك بينت هذه الفحوصات ان النسبة المثالية لهذا المضاف هي 6% التي اظهرت الصلابة الافضل للخلطات الاسفلتية. ان قوة ثبات مارشال ازدادت بنسبة 26% والجريان قل بنسبة 12.5% عند استخدام 6% من المضاف وكذلك مقاومة الخلطات الاسفلتية للتخدد ازداد بنسبة 61% عند استخدام نفس النسبة من المضاف.

تم اعتماد معدل ثلاث نماذج لخلطات مارشال اي عند استخدام فحصي مارشال وفحص اجهاد الشد غير المباشر وتم استخدام عتبة من الخلطة الاسفلتية عند فحص العجلة الدوارة بابعاد 50سم طول و 10سم عرض و 5سم ارتفاع (سمك).

Key words: AC overlay; Performance; AC modifiers

Abstract

The performance of asphalt concrete pavement depends on the bitumen properties, asphalt concrete mixtures volumetric properties and external factors such as traffic volume and environment. Overlay is one of the quickest preventive maintenance techniques that apply to retard asphalt pavement deterioration and prolonged service lives. This study focuses on prepare good performance and flexible modified thin hot mix asphalt used as an overlay. Styrene-butadiene rubber (SBR) at three contents (3, 6 & 9 % by asphalt weight) were used either alone to modify local asphalt penetration grade 40/50. Properties of modified and unmodified asphalt binder (Penetration, Softening point, Flash point and Ductility) were examined. Performance of modified and unmodified asphalt mixtures was evaluated through Marshall, Indirect Tensile Strength and Wheel Tracking Test. Test results showed that all properties of the base asphalt binder and asphalt mixes were improved by the addition of the modifier. The best improvements in the modified binders and modified mixes were obtained at 6% SBR. Stiffness of modified asphalt mixes were improved at 6% SBR was introduced. Marshall stability was increased by 26% and flow was decreased by 12.5% at 6% SBR. Resistant of the modified asphalt mixes to rutting was increased by 61% at the same modifier content.

The three mix types prepared and tested according to Marshall Method. Marshall Stability and Indirect tensile tests were conducted on Marshall specimens. Wheel tracking test were conducted on (50×10×5 cm) AC mix beams.

1- INTRODUCTION:

Any asphalt pavement, when designed and constructed properly, will provide years of service. Pavements continually undergo various types of stresses that induce minor or large defects into the pavement [Hussain, Ghaly, and Ibrahim, 2008].

The durability of asphaltic concrete is greatly influenced by the environmental changes during the year between hot and cold temperatures and between day and night. High temperatures can soften the bitumen and consequently reduce the stiffness of asphaltic concrete making the mix more susceptible to rutting. On the other hand, low temperature can increase the stiffness of bitumen and reduce the flexibility of the asphaltic concrete, hence, inducing fatigue failure. As a result, cracking of the pavement surface may develop which adversely affects the performance of the asphaltic concrete. Thus, high temperature stiffness and low temperature flexibility are important properties in bituminous mixtures respectively to avert rutting and cracking [Abdullahi,2007].

Over the years, road structures have deteriorated more rapidly than expected due to increases in traffic volume, axle loading and tire pressure and insufficient degree of maintenance. To minimize the deterioration and increase the long-term durability of a flexible pavement, the bituminous layers should be improved with regard to performance properties, such as resistance to permanent deformation, fatigue, wear, stripping and aging. One way of increasing the quality of a flexible material layer is the use of high quality asphalt [Dorina,2009].

Thin hot mix asphalt (overlay) is one of the quickest preventive maintenance techniques that apply on the existing pavement to retard asphalt pavement deterioration and prolonged service lives. Modifications of asphalt by the addition of flexible polymers to asphalt binder can significantly reduce these shortcomings and reduce the frequency of maintenance and provides much longer service life for maintenance treatments [Hussain, Ghaly, and Ibrahim, 2008].

Many different polymer modifiers for asphalt cement have been developed to help improve both the rutting and thermal cracking problems of HMA by altering the properties of the asphalt cement binder. Manufacturers of polymer modifiers claim the incorporation of their product with the asphalt cement binder in the manufacture of HMA can significantly extend the service life of HMA pavements. These polymer modified pavements are reputed to resist rutting, improve overall stability, and increase useful life. If additional service life can be achieved, then life cycle costs can be lowered, thereby allowing overall savings to the cost of maintaining pavements [Gayle, William, and Alfred, 1999].

The addition of polymers usually has the effect of increasing the stiffness of the binders at high service temperatures without increasing the stiffness at low service temperatures. This modification of binder properties means that the asphalt mixture could be more rut resistant at high service temperatures while its cracking resistance at low temperatures would not be lessened. Crumb rubber (CR) and styrene-butadiene rubber (SBR) are two of the commonly used asphalt additives for this purpose. The purpose of this study was to conduct a laboratory evaluation of the effects of the addition of crumb rubber and SBR on the rutting resistance of typical asphalt paving mixtures used in Florida [Chuang-Tsair, Mang & Byron].

The use of reclaimed ground tire rubber as an additive in various types of bituminous construction not only solves a waste disposal problem and offers the benefit of resource recovery, it is also of interest to the paving industry because of the additional elasticity imparted to the binder and pavement system [Freddy, Prithvi,., Ray Brown and Robert,1989].

2- LITERATURE REVIEW:

Rutting is one of the commonly encountered distresses, and one of the most criteria of the asphalt pavement performance. In general rutting is the depression due to permanent deformation in pavement layers and subgrade under the application of repeated loading [Li. and others ,1996]. The phenomenon of rutting have a longitudinal channel depression that forms in the wheel path due to compression or lateral movement of the pavement layers as a result of repeated traffic load application. Rutting is a manifestation of two different mechanisms: (a) densification (volume change) and (b) shear deformation (plastic flow with no volume change). In the densification process, materials are forced downward, and shear deformation causes material to flow laterally and upward [Al-Juraiban, and Jimenez, 1983].

There no absolute standards for relating rutting to safety. The problem is complex. It is not only a function of rut depth but also of vehicle speed, type of vehicle, type of tire, tire wear, porosity of the surface, intensity and duration of rainfall, cross slop of the pavement surface, etc. Nevertheless some generalization can be made: the committee of the Road and Transportation of Canada emphasizes that rut depth less than (12 mm) normally can not be a serious problem; rut depth over (25 mm) can be serious [Road and Transportation 1975.]. The AASHTO [AASHTO] guide determines the effects of the rut as below in table (1):

Use of (40-50) penetration grade asphalt results in high resistance to cracking with less permanent deformation in comparison with the results obtained for (60-70) and (85-100) penetration grades. They recommended using such kind of mixtures in west, mid and south of Iraq to protect the pavement from rutting and low temperature cracking [Safar, 1992], [Abdul., 2000].

The increase in stiffness results in longer fatigue lives at a given stress level. The mixture variable that affects the stiffness is also going to affect the fatigue life. Increasing voids reduces the fatigue life markedly by reducing stiffness and increasing stress concentrations. By increasing the asphalt content, voids will be reduced and the fatigue life will be increased [Pell, 1973].

Asphalt rubber mixes have greater resistance to reflective cracking than conventional dense graded mixes [Sousa., Shatnawi, and Cox, 1996].

The effect of reclaimed tire rubber on the properties of asphalt cement and asphalt concrete mixtures are studied by [Fayadh, 1987]. Reclaimed rubber was added or replaces the asphalt cement in an amount of 20% by weight of asphalt. She concluded that the mixtures prepared with asphalt-rubber blend show a decreased resistance to stripping with a very little increase in Marshall Stiffness.

3- MATERIALS AND EXPERIMENTAL:

3-1 Materials:

To obtain laboratory specimens with the same engineering characteristics as those used in pavement, the materials used in this paper are broadly used in asphalt paving industry in Iraq and they are described in the following sections.

3-1-1 Asphalt Cement:

The binder used in this paper is petroleum asphalt cement brought from Daurah refinery. The physical properties of the asphalt cement are presented in Table (2).

3-1-2 Aggregate:

The coarse aggregate (crushed) and fine aggregate as shown Physical Properties, Chemical Composition and Gradation in tables (3, 4, and 5) respectively.

3-1-3 Mineral Filler:

One type of mineral filler is used: ordinary Portland cement (from Kubaisa factory). It is thoroughly dry and free from lumps or aggregations of fine particles. The chemical composition and physical properties are shown in Table (6).

3-1-4 Styrene - Butadiene Rubber (SBR):

SBR is styrene-butadiene copolymer latex specifically designed for use in all areas of the building industry where improvements in the physical and mechanical properties of ordinary Portland cement systems are required. SBR may be used in applications which require the greater strength and flexibility characteristics given by SBR modified mixes; in areas which need a significant improvement in the bonding strength to various substrates, and where increased water impermeability and higher chemical resistance is required.

3-2 Preparation of Mixtures:

The first step in the mix design is the determination of relative proportions of the asphalt and aggregate as well as percent of each aggregate size fractions involving filler, and the efficiency of mixing procedure which provides homogeneous mix and uniform coating of aggregate with asphalt. The mixing procedure may by divided into two stages, as described in the following articles:

3-2-1 Preparation of Aggregate:

The aggregates are first dried to a constant weight at 110˚C, separated to the desired sizes by sieving and recombining with the mineral filler to conform the selected gradation requirements of SCRB specification for surface course (2003) [State Commission, 2003]. The total weight of the batch is approximately 1200gm to produce a specimen of 2.5 in. (63.5mm) height by 4in. (101.6mm) diameter. All aggregate sizes and filler are placed in the mixing bowl. The aggregate and the filler are heated before mixing to temperature of 160˚C for both conventional mixtures and that modified by SBR.

3-2-2 Preparation of Binder:

The asphalt cement for conventional mixture is heated in an oven to the temperature of 150˚C before mixing with aggregate. The procedure which is adopted to prepare the modified binder can be outlined, as follows:

The weight of SBR is determined by multiplying its percent by the required weight of asphalt content. Three percentages (3,6 and 9)% of SBR by weight of asphalt cement are used in preparing modified binders.

The asphalt cement with known weight is heated in an oven until it reaches a temperature of 150˚C, and the desired weights of additives are added (as quickly as possible approximately 10 second). The two components are mixed thoroughly under a temperature of (150-160˚C) until the homogeneous binder is attained.

3-2-3 Preparation of Mixture:

After the completion of original asphalt preparation or modified binder, it is weighted to the desired amount and then added to the heated aggregate and filler in the mixing bowl. All components are mixed thoroughly until all the aggregate and filler particles are completely coated with binder. The mixing temperature is maintained within the required limits of (153-158˚C)[Al-Ani, Jalal, and Zahrah] for the conventional mixtures, and (155-165˚C) for modified mixtures [Al-Zaiady, 1999].

3-3 Test Methods:

3-3-1 Preparation and Test of Marshall Specimens:

This method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixtures loaded on the lateral surface by means of the Marshall apparatus according to ASTM (D 1559) ["ASTM",1988]

This method includes preparation of cylindrical specimens which are 4 inch (101.6 mm) in diameter and 2.5 +/- 0.05 inch (63.5 +/- 1.27 mm) in height. The Marshall mold, spatula, and compaction hammer are heated on a hot plate to a temperature between (120-150˚C). The asphalt mixture is placed in the preheated mold and it is then spaded vigorously with the heated spatula 15 times around the perimeter and 10 times in the interior. The temperature of the mixture immediately prior to compaction is between (142-146˚C)[Al-Ani, Jalal, and Zahrah]. Then, 75 blows on the top and bottom of the specimen are applied with a compaction hammer of 4.535 kg sliding weight, and a free fall in 18 inch (457.2 mm). The specimen in mold is left to cool at room temperature for 24 hours and then it is removed from the mold.

Marshall stability and flow tests are preformed on each specimen. The cylindrical specimen is placed in water bath at 60˚C for 30 to 40 minutes, then compressed on the lateral surface at constant rate of 2in/min. (50.8mm/min.) until the maximum load (failure) is reached. The maximum load resistance and the corresponding flow value are recorded. Three specimens for each combination are prepared and the average results are reported.

The bulk specific gravity density ASTM (D 2726) ["ASTM",1988], and theoretical (maximum) specific gravity of void less mixture are determined at the laboratory. The percent of air voids is then calculated.

3-3-2 Preparation and Test of Indirect Tensile Strength Specimens:

The specimens are prepared in the same procedure given in article (3-2) for the Marshall Mix design method. The tensile strength of compacted asphalt specimens is typically determined by the indirect tensile strength test, which is determined according to method described in ASTM D4123 ["ASTM",1988]. The prepared specimens are left to cool at room temperature for 24 hours and then placed in a water bath maintained at the test temperature for 30 minutes in order to bring them to the specified test temperature.

To accomplish indirect tensile test, the specimens are removed from water bath and immediately placed into the loading apparatus. The compressive load is applied to two opposite loading strips of (12.7mm) wide and (63.5mm) long made of steel to distribute the load and maintain constant loading area. Each strip is curved at the interface with the specimen and has a radius equal to that of the specimen. The two loading strips are kept parallel to and centered on vertical diametrical plane. This loading configuration develops a relatively uniform tensile stress perpendicular to the direction of the applied load and along the vertical diametrical plane that ultimately causes the specimens to fail by splitting a long the vertical diameter. The compressive load is applied at a constant rate of 2inch/min. (50.8mm/min) and the ultimate load at failure is recorded. Figure (1) shows load configuration and failure plane for specimen in indirect tensile test.

The indirect tensile strength (ITS) is calculated, as follows:

$$I.T.S = \frac{2P_{ult}}{\pi . t . d} \qquad (3\text{-}1)$$

where:

I.T.S = Indirect tensile strength (kPa).

P_{ult} = Ultimate applied load at failure (kN).

t = Thickness of specimen (m).

d = Diameter of specimen (m).

3-3-4 Wheel Tracking Test:

The wheel tracking apparatus, is manufactured in Iraq to simulate the effect of traffic loading on asphalt concrete overlay[Technical, 2002] The beam of asphalt mixture has a length of 500 mm, a width of 100 mm, and a height of 50 mm and it is rested on two concrete blocks. The concrete blocks rest on 35cm of compacted soil and subbase layers.

To obtain an asphalt beam with the mentioned dimensions, approximately 5952.5 gm of asphalt mixture is prepared using electrical mixer.

To obtain the required beam density as Marshall specimens bulk density, static compaction is used by compression machine with different applied loads at the rate of 2.5mm per minute.

4- RESULS AND DISCUSSION:

4-1 Properties of Asphalt Concrete Mixtures:

The properties of asphalt concrete mixtures, such as, Marshall properties (Marshall stability, flow, bulk density, air voids, voids filled with asphalt, voids in mineral aggregate, Marshall stiffness), indirect tensile strength, and number of wheel passes, have been investigated to evaluate performance of asphalt concrete mixtures.

4-2 Optimum Asphalt Concrete Mixtures:

Five different percentages of asphalt contents (4.25, 4.75, 5.25, 5.75 & 6.25) % by weight of mixture and 12.5 mm aggregate maximum size are used with Portland cement as a filler.

The relations between asphalt content and Marshall Properties are typical to common trend in asphalt content mixes. The optimum asphalt content is 5%, it is determined from three Marshall properties (stability, bulk density, and 4% air voids) and checked with the other Marshall properties of flow, VMA, and VFA to be within the specification limits of SCRB shown in Table (7).

4-3 Marshall Stiffness:

The Marshall stiffness is calculated as the ratio between Marshall stability and corresponding flow for the different mixtures (table 8) [19]. Increased values of Marshall stiffness have been obtained by increasing Marshall stability (with the same value of flow) or decreasing flow (with the same value of Marshall stability). Marshall Stiffness can be increased by using harder asphalt grade and compaction efforts, compaction temperature, mixing temperature high enough and within the acceptable limits of specification.

4-4 Effect of SBR Content on the Properties of Asphalt Concrete Mixtures:

Three percentages (3, 6 and 9 %) of SBR modifier are added to asphalt concrete mixture at optimum asphalt content for 12.5 mm aggregate maximum size, and the tests described in following articles were conducted:

4-4-1 Marshall Test Result:

4-4-1-1 Marshall Stability:

Figure (2) illustrates the relationship between Marshall stability and SBR content. It is obvious that there is an optimum SBR content which yields maximum Marshall Stability, and this value is 6%. The higher stability value was obtained with mixes modified with 6% SBR, this is because the addition of SBR to the asphalt binder increased its stiffness and reduced its viscous at high service temperature.

4-4-1-2 Marshall Flow:

Figure (3) shows that there is a decrease in the values of Marshall flow as the percentage of the SBR content is increased. This is may be due to the stiff nature of SBR comparing to the base asphalt.

4-4-1-3 Bulk Density:

Figure (4) shows that the bulk density increased when the SBR percentages are increased until 9% SBR then decreased. The increase in additive may separate the coarse aggregate particles and hence decrease the density. This increase in bulk density may be due to the decreased in air voids content of such mixes.

4-4-1-4 Air Voids:

Figure (5) shows that the air voids decrease when the SBR are increased. This behavior illustrates the increase in bulk density. This may be as mentioned above due to compaction problems. It is also clear that mixes modified with SBR have lower air voids than conventional mixes. This may be due to that the SBR particles dissolved completely in bitumen during the modifying process, which led to decrease in the air voids percentage.

4-4-1-5 Voids in Mineral Aggregate (V.M.A.):

Figure (6) shows that the V.M.A. decrease when the SBR are increased until 9% and this behavior illustrates the increase in bulk density.

4-4-1-6 Voids Filled with Asphalt (V.F.A.):

Figure (7) shows that the V.F.A. increase when the SBR are increased until 9%.

4-4-1-7 Marshall Stiffness

Figure (8) shows the Marshall Stiffness with optimum asphalt content for three percentages of SBR. It is seen from this figure that the Marshall Stiffness increases when the SBR are increased. This is can be attributed to the increases in Marshall Stability and the decrease in Marshall Flow.

4-4-2 Effect of SBR Content on Indirect Tensile Strength Test:

Figures (9) show the effect of mixtures modified with SBR on indirect tensile strength at 25˚C. This figure show that the indirect tensile strength increases when the SBR are increased up to 9% then they are decreased. This behavior is similar to the behavior of Marshall stiffness.

After analyzing the percentages of SBR that affect the properties of the mixtures, an optimum percent of SBR modifier could be selected from the indirect tensile strength, Marshall properties, and Marshall stiffness, and this percentage can be used in the physical tests of asphalt binder and the Wheel tracking test. The optimum percentage of SBR modifier is selected to be 6% by weight of asphalt content.

4-4-3 Effect of SBR content on physical properties of asphalt binder:

Table (9) shows the effect of 6% SBR on physical properties of asphalt binder:

4-4-4 Effect of Optimum SBR Content on Number of Wheel Passes:

The results of the Wheel Tracking test are displayed in Table(10). It can be seen that the SBR modified asphalt mixtures show the highest reduction in rut depth as compared with the unmodified control mixtures (up to 66% at 10000 cycles).

5- CONCLUSIONS:

1. The results of this laboratory study show that the addition of SBR could increase the rutting resistance of asphalt paving mixtures.
2. The increase in Marshall Stability is an important factory in via of high traffic load besides the resistant to rutting.

Table (10) Effect of SBR on rut Depth

	Average rut depth (mm)			Reduction in Rut Depth compared with Base AC
	At 1000 Cycles	At 5000 Cycles	At 10000 Cycles	
Control mix	4.7	8.3	10.7	-
6% SBR	2.3	5.1	7.1	59%

3. The modified mixtures exhibited substantially lower rut depths in the Loaded Wheel tests than the unmodified mixtures.
4. Using SBR improve the Marshall and physical properties and rut resistance for modified asphalt binder and mixtures.
5. SBR can be used as flexible materials for asphalt binder modification.
6. Asphalt additives improve durability, crack & rut resistance, asphalt binder elasticity as well as increase the pavement life.

6- REFERENCES:

1. Hussain, M. H. M., Ghaly, N. F. and Ibrahim, I. M., 2008. Modified Hot Mix Asphalt for Road Maintenance. World Applied Sciences Journal 5 (2): 236-245, 2008, ISSN 1818-4952. Egyptian Petroleum Research Institute.
2. Abdullahi, A. M., 2007. A Study on The Physical and Mechanical Properties of Asphaltic Concrete Incorporating Crumb Rubber Produced Through Dry Process. Thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy.
3. Dorina, A. A., 2009. The Effect of Epoxy Bitumen Modification on Hot Mix Asphalt Properties and Rut Resistance. A project report submitted in partial fulfillment of the requirements for the award of the degree of Master of Engineering. University Technology Malaysia.
4. Gayle, E. A., William, F. B. and Alfred, B. C., 1999. Polymer Modified Hot Mix Asphalt Field Trial. Mississippi Department of Transportation Research Division.

5. Chuang-Tsair Shih, Mang Tia & Byron E. Ruth. Evaluation of The Effects of Crumb Rubber And SBR on Rutting Resistance of Asphalt Concrete. Department of Civil engineering, University of Florida.
6. Freddy, L. R., Prithvi, S. K., E. Ray Brown and Robert, L. D., 1989. Investigation and Evaluation of Ground tire Rubber In hot Mix asphalt. National Center for Asphalt Technology. NCAT Report No. 89-3
7. Li. Shove and others. A Study of Properties of Asphalt Mix Related to Rutting Performance Using Wheel Tracking Test. Proceedings of 1996 International Road Federation Asia – Specific Regional Meeting, vol. Iv, pp.91.
8. Al-Juraiban, S. A., and Jimenez, R. A., 1983. Rutting Properties of a Dune-Sand Paving Mixture. TRB 911, p.11.
9. Road and Transportation Association of Canada (Pavement Management Guide), 1975.
10. AASHTO Guide for Design of Pavement Structure
11. Safar, M. M., 1992. Influence of Temperature on Performance of Paving Materials. M.Sc. Thesis, University of Baghdad, Iraq.
12. Abdul Majeed, R. Z., 2000. Influence of Asphalt Overlay Variables on Pavement Performance. M. Sc. Thesis, University of Baghdad, Iraq.
13. Pell, P. S., 1973. Characterization of Fatigue Behavior. Highway Research Board Special Report 140, pp.49-63.
14. Sousa, J. B., Shatnawi, and Cox. J., 1996. An Approach for Investigating Reflective Fatigue Cracking in Asphalt – Aggregate Overlays. Proceedings of The Third International PILEM Conference on Reflective Cracking in Pavements, Delft University of Technology and Belgian Road Research Center, October, pp. 103-112.
15. Fayadh, S. S., 1987. Hydrated Lime and Rubber as Additives in Asphalt Paving. M.Sc. Thesis, University of Baghdad.
16. State Commission of Roads and Bridges (SCRB). Hot Mix Asphalt Concrete Pavements. Iraq Standard Specification, Ministry of Housing and Construction, Department of Design and Study, section R9, Revised edition (2003).

17. Al-Ani, H. M. H., Jalal, A. A. and Zahrah, A. H. Temperature Susceptibility of Paving Grade Asphalt Cement. Scientific Journal Published by the University of Technology, Baghdad, Vol.4, No.2.
18. Al-Zaiady, N. N., 1999.The Use of Reclaimed Tires Rubber Modified Asphalt in Asphaltic Concrete Mixes. M. Sc., Thesis, University of Technology, Iraq.
19. "ASTM", Annual Book of ASTM Standers, Section 4, Volume

04.03, 1988.

20. Technical Manual, 2002. Advanced Fiber Glass Technology for Asphalt Pavement Overlays. Canadian Patent 1240873.

Table (1) Rut Depth According to AASHTO

Mean rut depth	0.6 – 1.3 cm	1.3 – 2.5 cm	>2.5 cm
Severity level	Low	Medium	High

Table (2) Physical Properties of Asphalt Cement.

Test	Unit	Penetra. grade (40-50)	SCRB Spec. for (40-50) pen. grade
Penetration (25˚C, 100g, 5sec) ASTM D5.	1/10 mm	45	40-50
Ductility (25˚C, 5 cm/min). ASTM D 113.	cm	>100	≥ 100
Softening point (ring & ball). ASTM D 36.	˚C	52	50-60
Flash point (cleave land open cup) ASTM D92	˚C	328	≥ 240
After Thin-Film Oven Test ASTM D 1754			
Penetration Of Residue.	1/10mm	33	
Ductility Of Residue.	cm	>100	100^{+}
Loss in weight (163˚C, 50 gm, 5h),%	%	0.18	≤ 0.75

Table (3) Physical Properties of Aggregates

Property	Coarse Aggr.	Fine Aggr.
Bulk Specific Gravity (ASTM C127 and C128).	2.610	2.631
Apparent Specific Gravity (ASTM C127 and C128).	2.641	2.6802
Percent Water Absorption (ASTM C127 and C128).	0.423	0.542
Percent Wear (Los-Angeles Abrasion) (ASTM C131)	20.10	……

Table (4) Chemical Composition of Aggregates

Chemical Compound	% Content
Silica,SiO_2	82.52
Lime, CaO	5.37
Magnesia, MgO	0.78
Sulfuric Anhydride, SO_3	2.7
Alumina, Al_2O_3	0.48
Ferric Oxide, Fe_2O_3	0.69
Loss on Ignition	6.55
Total	99.09
Mineral Composition	
Quartz	80.3
Calcite	10.92

Table (5) Gradation of the Aggregate For 12.5mm A.M.S.

Sieve Size	Sieve Opening mm	Percentage Passing by Weight of Total Aggregate	
		Surface or Wearing Course	
		Specification Limit [SCRB]	Mid Point Gradation
1/2"	12.5	100	100
3/8"	9.5	90-100	95
No.4	4.75	55-85	70
No.8	2.36	32-67	49.5
No.50	0.3	7-23	15
No.200	0.075	4-10	7

Table (6) Chemical Composition & physical properties of Cement Filler Types Used.

Chemical Compound	% Content
Silica,SiO_2	21.51
Lime, CaO	62.52
Sulfuric Anhydride, SO_3	1.58
Alumina, Al_2O_3	5.64
Magnesia (MgO)	3.77
Ferric Oxide, Fe_2O_3	3.35
Loss on Ignition (L.O.I)	1.34
Total	99.44
Physical properties	
%Passing Sieve No. 200	98
Apparent Specific Gravity	3.13
Specific Surface Area(m^2/kg)	356

Table (7) S.C.R.B. Specification Limits and at 5% O.A.C

Properties	***S.C.R.B Specification Limits***	***12.5mm A.M.S***
Marshall Stability (kN)	8 minimum	10.8
Bulk Density (gm/cm^3)		2.321
Marshall Flow (mm)	2-4	3.2
Air Voids (%)	3-5	4.1
Voids Filled with Bitumen (%)	65-85	74
Voids in Mineral Aggregate (%)	14 minimum	16.3

Table (8) Marshall Stiffness of Conventional Mixes at O.A.C.

Type of Mix	12.5mm A.M.S.
Marshall Stiffness (kN/mm)	3.375

Table (9) Effect of SBR Content on Physical Properties of Asphalt

SBR content %	**Penetration 0.1 mm**	**Softening Point ˚C**	**Ductility cm**
0 (control)	45	52	> 100
3	45	53	> 100
6	44	57	> 100
9	42	63	> 100

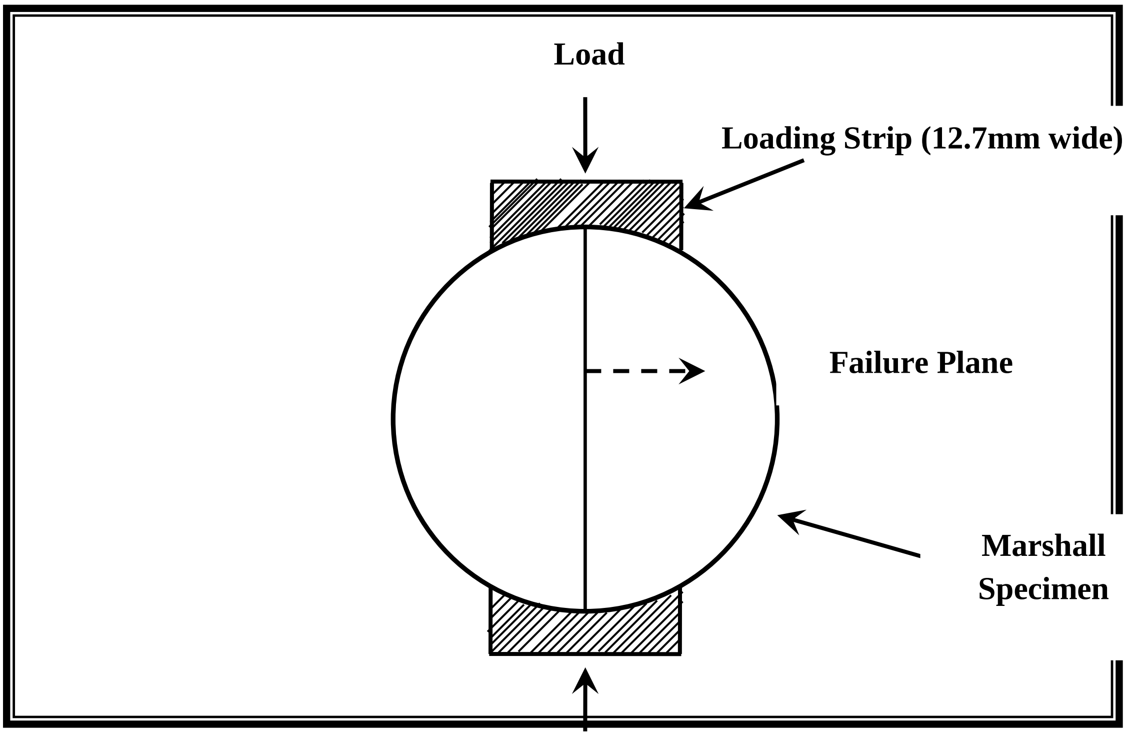

Figure (1) Load Configuration and Failure Plane for Specimen in Indirect Tensile Test

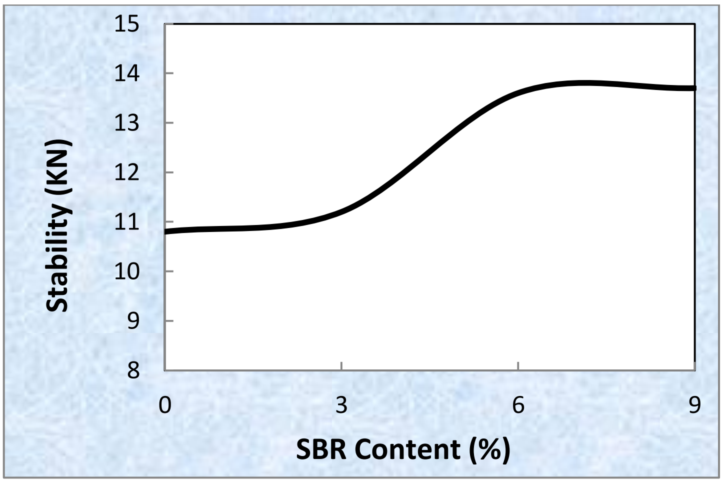

Figure (2) Effect of SBR Content on Marshall Stability

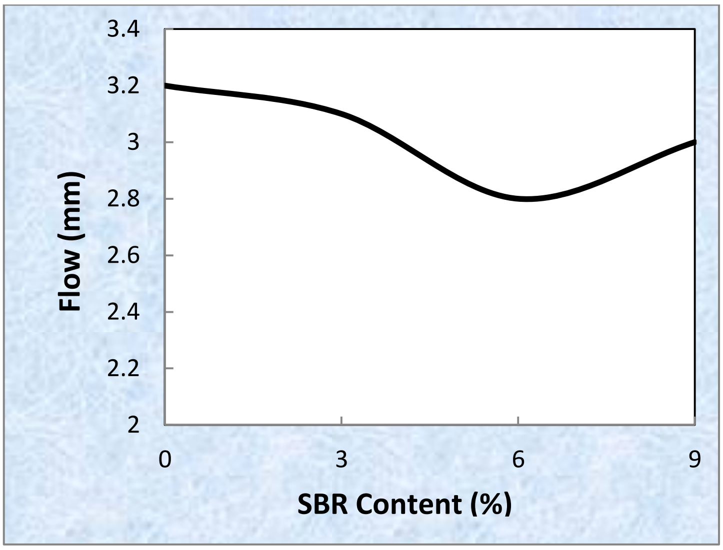

Figure (3) Effect of SBR Content on Marshall Flow

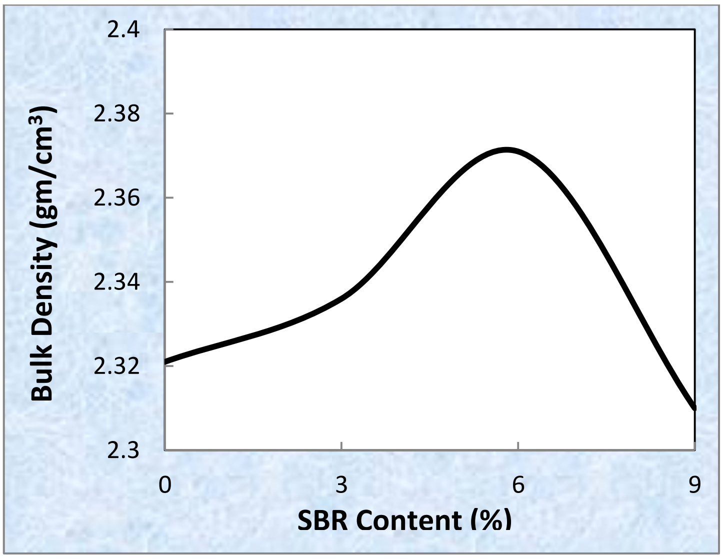

Figure (4) Effect of SBR Content on Bulk Density

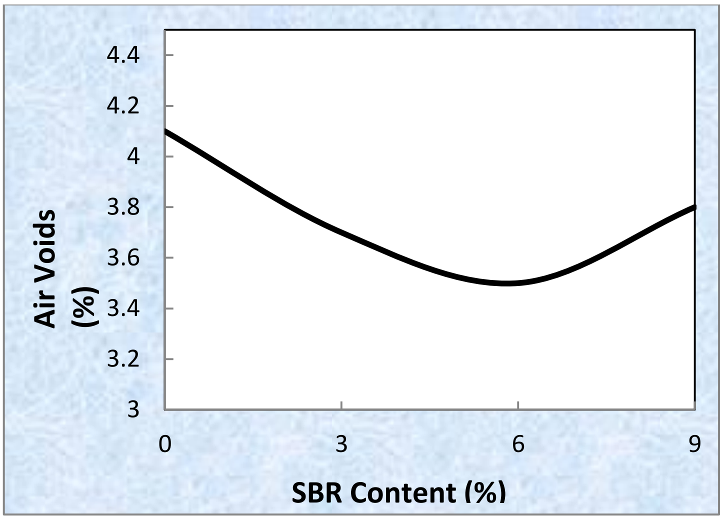

Figure (5) Effect of SBR Content on Air Voids

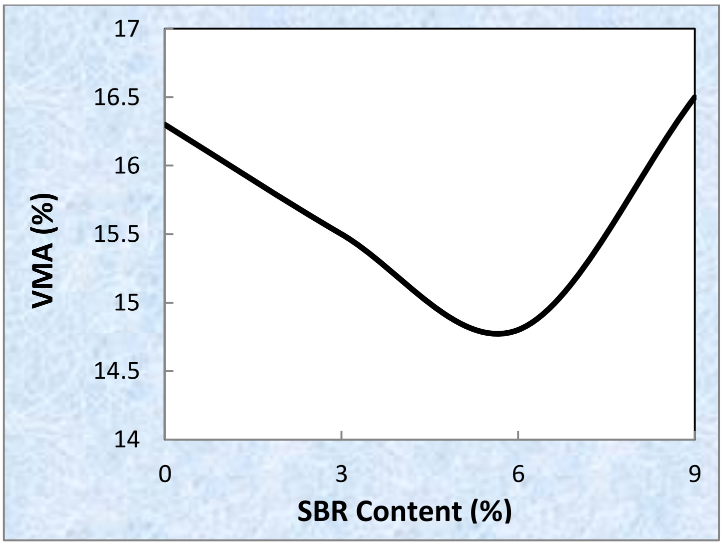

Figure (6) Effect of SBR Content on V.M.A

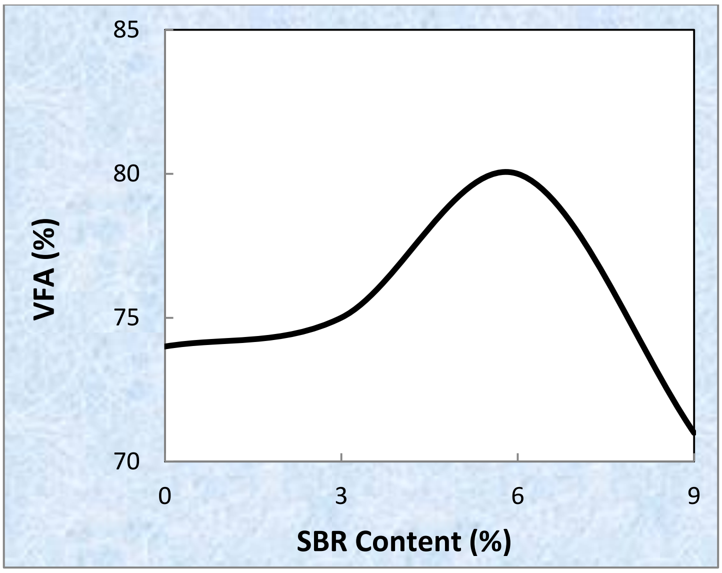

Figure (7) Effect of SBR Content on V.F.A

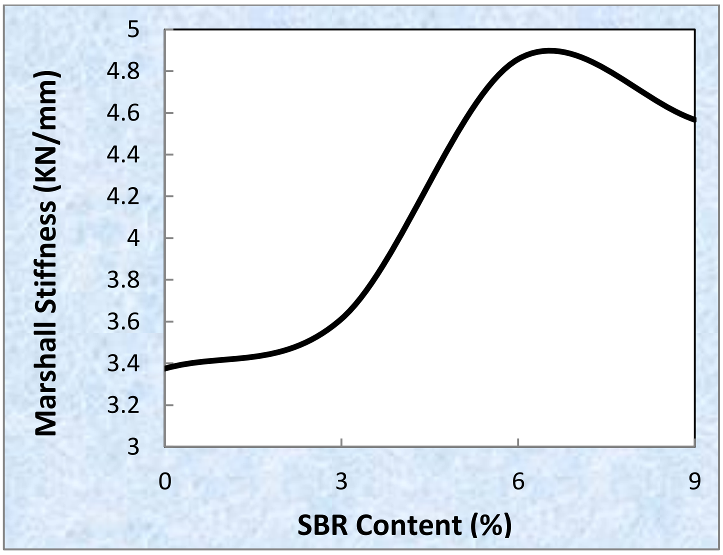

Figure (8) Effect of SBR Content on Marshall Stiffness

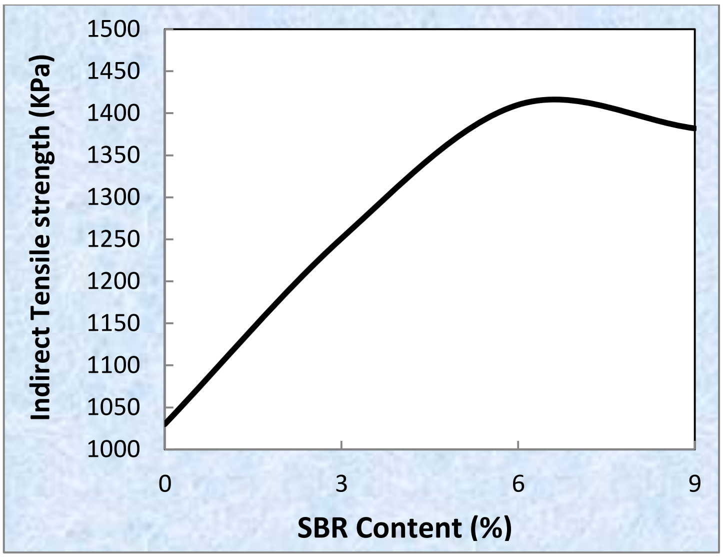

Figure (9) Effect of SBR Content on Indirect Tensile Strength at 25°C