Evaluation the effect of using polymers on the performance of wearing asphalt mixture

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ABSTRACT

In Iraq , the increasing in number of vehicles and trucks with their heavy traffic loading and under high temperature , a variety of pavement distresses continues to develop affecting the performance and economy of pavement construction. Polymer modified asphalt mixtures have been used to resist the distresses that produced and developed from the applied stresses. Several distresses effect on the performance of HMA. The primary forms of distress are fatigue cracking , rutting , moisture damage and thermal cracking. These distresses reduce the services life of HMA and increase the maintenance costs.

The main objective of this research is to find the effect of polymers on the performance of asphalt mixtureby using one asphalt cement grade (40-50) from Al-Daurah refinery with two types of locally available polymers (Low-Density Polyethylene LDPE and Styrene Butadiene Styrene SBS) with three percentages for each type. These percent are (1, 3 and 6) % for (LDPE & SBS) by weight of asphalt cement. Each type of these polymers is blended with asphalt cement by using the wet process. The experimental work showed that all polymer-modified mixtures have stability and indirect tensile strength higher than the control mixtures. It can be concluded that the addition of (1% LDPE) and (3% SBS) to asphalt mixtures showed better improvement on the performance properties of pavement modified with these polymers , in which the referred percent represent the optimum percent of concentration for blending polymers .

Keywords: Hot Mix Asphalt , polymer, Marshall Test, Indirect Tensile Strength Test

الخلاصة

في العراق ونتيجة لتزايد عدد المركبات والشاحنات وحمولتها المرورية العالية مع ارتفاع درجات الحرارة تراكم هذه العوامل مع الصيانة الغير كافية تسببت في حصول تشوهات وعيوب في طبقات التبليط تؤثر على أداء وكفاءة التبليط لذا فقد استعملت الخلطات الاسفلتية المعدلة بالبوليمرات لتقليل هذه التشوهات والعيوب في طبقات التبليط التي تقلل من العمر الخدمي للتبليط وتزيد من كلف الصيانة.

ان الهدف الرئيسي من هذا البحث هو تقييم تأثير البوليمرات على أداء الخلطات الإسفلتية باستخدام نوع واحد من الإسفلت ذو اختراق (50 –40) من مصفى الدورة معنوعين من البوليمرات المتوفرة محلياً وهي (البوليإيثلين واطئ الكثافة LDPE ،والستايرين البيوتادين الستايرين SBS) حيث تم استخدام ثلاث نسب لكل بوليمر وهذه النسب هي كالأتي(1 ، 3 ، 6)٪ من (SBS و LDPE) كنسب وزنية من وزن الإسفلت ويجري خلط كل نوع من هذه البوليمرات معا لإسفلت باستخدام الطريقة الرطبة حيث أظهرت النتائج المختبرية إن مقاومة الشد غير مباشر وقوة الثبات لكل الخلطات المعدلة بالبوليمرات أعلى من الخلطات الإسفلتية الاعتيادية غير المعدلة وكذلك يمكنا لاستنتاج بان إضافة (1 ٪ LDPE) و(3 SBS%) للخلطات الاسفلتية تعطي أفضل تحسن في خصائص الاداء للتبليط المعدل بهذه البوليمرات ، وان هذه النسب المشار لها تمثل النسب المثلى لخلط هذه البوليمرات معالإسفلت.

الكلمات الرئيسية: الخلطة الاسفلتية الحارة ،البوليمر،فحص مارشال ، فحص مقاومة الشد الغير مباشر.

1-Introduction :-

"Hot Mix Asphalt" or simply "HMA" is a paving material that consists of asphalt binder and mineral aggregate. The asphalt binder, which can be asphalt cement or modified asphalt cement, acts as a binding agent to glue aggregate particles into a cohesive mass. It is impervious to water, the asphalt binder also functions to waterproof the mixture. When bound by the asphalt binder, mineral aggregate acts as a stone framework to impart strength and toughness to the system. The behavior of the mixture is affected by the properties of the individual components (asphalt binder and mineral aggregate) and how they react with each other in the system**(SHRP, 1994).**

During periods of high temperature and under heavy traffic, a variety of pavement distresses continues to develop affecting the performance and economy of pavement construction. In flexible pavements , the primary forms of distress are fatigue cracking , rutting , moisture damage , and thermal cracking . These distresses manifest themselves most of the time due to construction material quality , poor maintenance , and improper design **, (AL-Khashaab , 2009) .**Polymer modified asphalts are commonly used to reduce pavement distress and to extend service life by enhancing the binder's adhesion, cohesion, and elasticity. The addition of polymers alters the rheological properties of asphalt so that it can retain sufficient flexibility at low temperatures while attaining a marked resistance to permanent deformation at high temperatures. It makes the binder more resistant to temperature variations and high traffic loads**(King *et.al.* , 1986).**

Modification of the asphalt binder is one approach taken to improve pavement performance. Currently the addition of polymers is a common method for binder modification. Polymer modified asphalts are effective in reducing rutting and improving fatigue and thermal crack resistance**(Othman *et.al.,* 1995).**

Two main classes of polymers are used in modified bitumen of road applications:

1- elastomers , as their name suggests, tend to improve the elasticity of asphalt binder at low temperatures, strength at high temperatures and increase the failure strain of asphalt concrete at low temperature **(Crossley , 1998) .** Typical elastomeric polymers used to modify asphalt binder include styrene butadiene styrene (SBS), crumb rubber (CR) and reclaimed from scrap tires (RR).

For SBS, it is the polystyrene end-blocks that impart strength to the polymer and the mid-block butadiene that gives the material its exceptional elasticity. This combination of strength and elasticity gives SBS modified asphalt the ability to resist permanent deformation and to minimize fatigue and low temperature cracking. The SBS polymer modifier made the HMA mixture softer and more ductile **(Airey , 2004).**

2- Plastomers, which enhance strength but not elasticity. A plastomeris a polymer that will deform in a plastic or viscous manner at melt temperatures and becomes hard and stiff at low temperatures. In other words , Plastomers increase the viscosity and stiffness of the bitumen.Low-Density Polyethylene (LDPE) is the most common plastomer used in asphalt and acts by making the polymer modified asphalt stiffer than conventional asphalt **(Crossley , 1998)**.

2-Research Objectives

The main objective of this research is to evaluate the effect of adding two types of locally available polymers with different percentages, such as styrene butadiene styrene (SBS) , Low-density polyethylene (LDPE) on the performance of asphalt mixtures.

3- MATERIAL CHARACTERIZATION

One type of asphalt cement , one type of aggregate , two types of polymers are used. The properties of asphalt cement , aggregate, and filler used in this work are predicated using routine type of tests and the obtained results are compared with the **SCRB (R/9, 2003)** specification requirements.

3-1-Asphalt Cement :-

One type of asphalt cement is used with (40-50) penetration grade brought from AL-Daurah refinery. The asphalt properties are shown in **Table (1)** below.

3-2- Aggregate :-

The coarse aggregate used in this study is crushed aggregate from Al- Najaf quarry. The fine aggregate obtained from Karbala quarry. The coarse and fine aggregates used in this work are sieved and recombined in the proper proportions to meet the gradation as required by SCRB specification **(SCRB, R/9 , 2003)** for wearing or surface course. The selected gradation with specification limits are presented in **Table (2)**.

Routine tests are performed on the aggregate to evaluate their physical properties. The results together with the specification limits as set by the **SCRB** are summarized in **Table (3)**.

3-3- Mineral Filler :-

In this study, one type of fillers is used; ordinary Portland cement.The physical properties of filler are presented in **Table (4)**.

3-4- Polymers :-

In this study , two types of polymers are used , these polymers are Low-Density Polyethylene (LDPE) and styrene butadiene styrene (SBS).

Low-Density Polyethylene (LDPE) and styrene butadiene styrene (SBS) are added to asphalt binder with (1%, 3% and 6 %) by weight of asphalt cement .

The process of mixing polymer with asphalt binder used in this study is the wet process, in which the polymer is added to the asphalt binder before introducing it in the asphalt concrete mixtureat blending time of (90 min) for LDPE and (60 min) for SBS while the temperature of mixing these polymer with asphalt binder are (170 – 180) ° C for LDPE and (170 – 190) ° C for SBS.

4- EXPERIMENTAL WORK

4-1- Marshall Mix Design:-

Four different percentages of asphalt contents (4 , 4.5 , 5 and 5.5) % are usedto find the optimum asphalt content using the Marshall mix design Method in accordance with **ASTM D-1559**.

Figure (1)shows Marshall mix design curves for optimum asphalt content and it is found(4.7 %), it is determined by averaging the three values shown below:

- Asphalt content at maximum stability.
- Asphalt content at maximum density.
- Asphalt content at 4 % air voids.

The optimum asphalt content (4.7%) will be used for control mix and modified mixes with polymers to maintain consistency throughout the research andeliminate the effect of asphalt content on the results analysis.

4-2 Indirect Tensile Test

The tensile strength of compacted asphalt concrete specimens is typically determined by the indirect tensile strength test,which is determined according to method described in **ASTM D-4123** .Specimens are prepared by Marshall method and left to cool at room temperature for 24 hours then placed in a water bath at (20 ˚C) for 30 minutes in order to evaluate the fatigue cracking.

To accomplish indirect tensile strength test, the specimens are removed from water bath and immediately placed into the loading apparatus. The compressive load is applied at a constant rate of 2inch/min. (50.8mm/min) and the ultimate load at failureis recorded. **Figure (2)** shows load configuration and failure plane for specimen in indirect tensile strength test.

The indirect tensile strength (I.T.S) is calculated , as follows:

$$I.T.S = \frac{2 P_{ult}}{\pi . t . D} \quad (1)$$

where:

I.T.S = Indirect tensile strength (Mpa)
P_{ult}= Ultimate applied load at failure (N).
t = Thickness of specimen (mm).
D = Diameter of specimen (mm).

5- TEST RESULTS AND DISCUSSION

5-1- Marshall Test

❖ **Effect of polymers on Marshall stability**

In this study , two types of polymers (low-density polyethylene LDPE and styrene butadiene styrene SBS) with three percent (1%, 3% and 6 % by weight of asphalt cement) are used to improve the Marshall stability taken into consideration the percentages of air voids for modifiedmixes . **Table (5)** shows air void percent of control mixture and asphalt mixtures modified by polymers. this table showed that the proportion of air voidsremains within limits (3-5) % to meet the SCRB specifications.

In order to investigate the effect of polymers on Marshall Stability for modified mixes, Marshall Stability is plotted against polymers content, as shown in **figure(3)**and**figure(4)**. From these figurethe following points can be concluded:

1- Marshall Stability of modified asphalt mixes with polymers is higher than that of the control asphalt mix.
2- Marshall stability decreases with the increase in LDPE contents.
3- The best content of LDPE which has the higher stability is 1 % by weight of asphalt cement.
4- The increase in SBS contents leads to increase Marshall stability.
5- Asphalt mix modified with (6 %) SBS has higher stability value by (35 %) than the control asphalt mix.

5-2-Indirect Tensile Strength Test

The indirect tensile test is used to evaluate the tensile strength of asphaltic mixtures. The results are shown in **Table (6)** . Three samples are used to obtain the average value.

❖ **Effect of polymers on Indirect Tensile Strength**

In order to investigate the effect of polymers on Indirect Tensile Strength for modified mixes, Indirect Tensile Strength is plotted against polymers content, as shown in **figure(5)** and**figure(6)**. From these figurethe following points can be concluded:

1- Indirect Tensile Strengthof modified asphalt mixes with polymers is higher than that of the control asphalt mix.
2- Indirect tensile strength values decrease relatively with the increase in LDPE content.
3- Maximum indirect tensile strength value occurs at 1 % of LDPE.
4- Asphalt mix modified with (3 %) SBS has higher Indirect tensile strength value by (40 %) than the control asphalt mix.

6- CONCLUSIONS AND RECOMMENDATIONS

1- Modified asphalt mixtures with polymer have the higher Marshall stability and higher indirect tensile strength as compared with control asphalt mix.
2- In comparison to control mix, Asphalt concrete mixes modified with (1 %) LDPE has shown an increased in Marshall stability and Indirect tensile strength at a rate of 14 and 38 percent, respectively.
3- The modified mixtures with (3% SBS) have good performance properties that lead to increase in Marshall stability and Indirect tensile strength at a rate of 27 and 40 percent, respectively.

7- References

Airey , G.D. (2004) , *"Styrene Butadiene Styrene Polymer Modification of Road Bitumen "* , University of Nottingham ,University Park, Nottingham, NG7 2RD, UK , Journal of Material Scenes 39 951– 959, pp1.

Al-Khashaab, Y. (2009), *"Development of Fatigue Prediction Model for Local Asphalt Paving Materials"* , Ph.D thesis, civilengineering, University of Baghdad.

ASTM D-1559.(2002), *" Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus "* , American Society of Testing and Materials .

ASTM D 4123.(2002), *" Standard Test Method for Indirect Tension Test of Bituminous Mixtures "* , American Society of Testing and Materials .

Crossley , G.A. (1998) , *" Synthesis and Evaluation of a New Class of Polymers for Asphalt Modification"* M.Sc. thesis, Queen's University Kingston, Ontario, Canada .

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 .

King, G. N., Muncy, H. W. and Prudhomme, J. B. (1986). *" Polymer Modification: Binder's Effect on Mix Properties "* Asphalt Paving Technology, Vol. 55 , pp. 519-541.

Othman , A., Figeroa, L. and Aglan, H. (1995) , *" Fatigue Behavior of Styrene-Butadiene-Styrene Modified Asphaltic Mixtures Exposed to Low-Temperature Cyclic Aging "* Transportation Research Board, Washington D.C., pp.129-134.

Strategic Highway Research Program, SHRP (1994), "*The Superpave Mix Design Manual for New Construction and Overlays*", SHRP-A-407, National Research Council, Washington, D. C. USA.

Table (1) : Properties of asphalt cement

Property	***ASTM Designation***	***penetration grade (40-50)***	
		Test Result	***SCRB Specification***
Penetration (25^0C,100gm,5sec),(0.1mm)	D-5	44	(40-50)
Ductility (25 C^0, 5 cm/min). (cm)	D-113	110	>100
Flash point , (˚C)	D-92	255	Min. 232
Specific gravity at 25˚C	D-70	1.04	-----
Softening Point (˚C)	D-36	54	-----

Table (2): Aggregate gradation for surfaceor wearingcourse .

Standard sieves (mm)	***English sieves (in)***	***% Passing***	
		Gradation	***Specification limit***
19	3/4"	100	100
12.5	1/2"	95	90-100
9.5	3/8"	83	76-90
4.75	No.4	59	44-74
2.36	No.8	42	25-58
0.3	No.50	13	5-21
0.075	No.200	6	4-10

Table (3): Physical properties of aggregate.

Property	***ASTM Designation***	***Coarse aggregate***	***Fine aggregate***
Bulk specific gravity	C-127, C-128	2.52	2.63
Apparent specific gravity	C-127,C-128	2.65	2.68
% water absorption	C-127,C-128	0.89	0.64
Abrasion (Los Angeles)	C-131	25 % Max 30 %	-
Angularity	D-5821	95 %	-

Table (4): Physical properties of the used filler**.**

Property	**Test results**
Specific gravity	3.13
Fineness, Blain, (cm^2/gm)	3100
Passing Sieve No.200	96 %

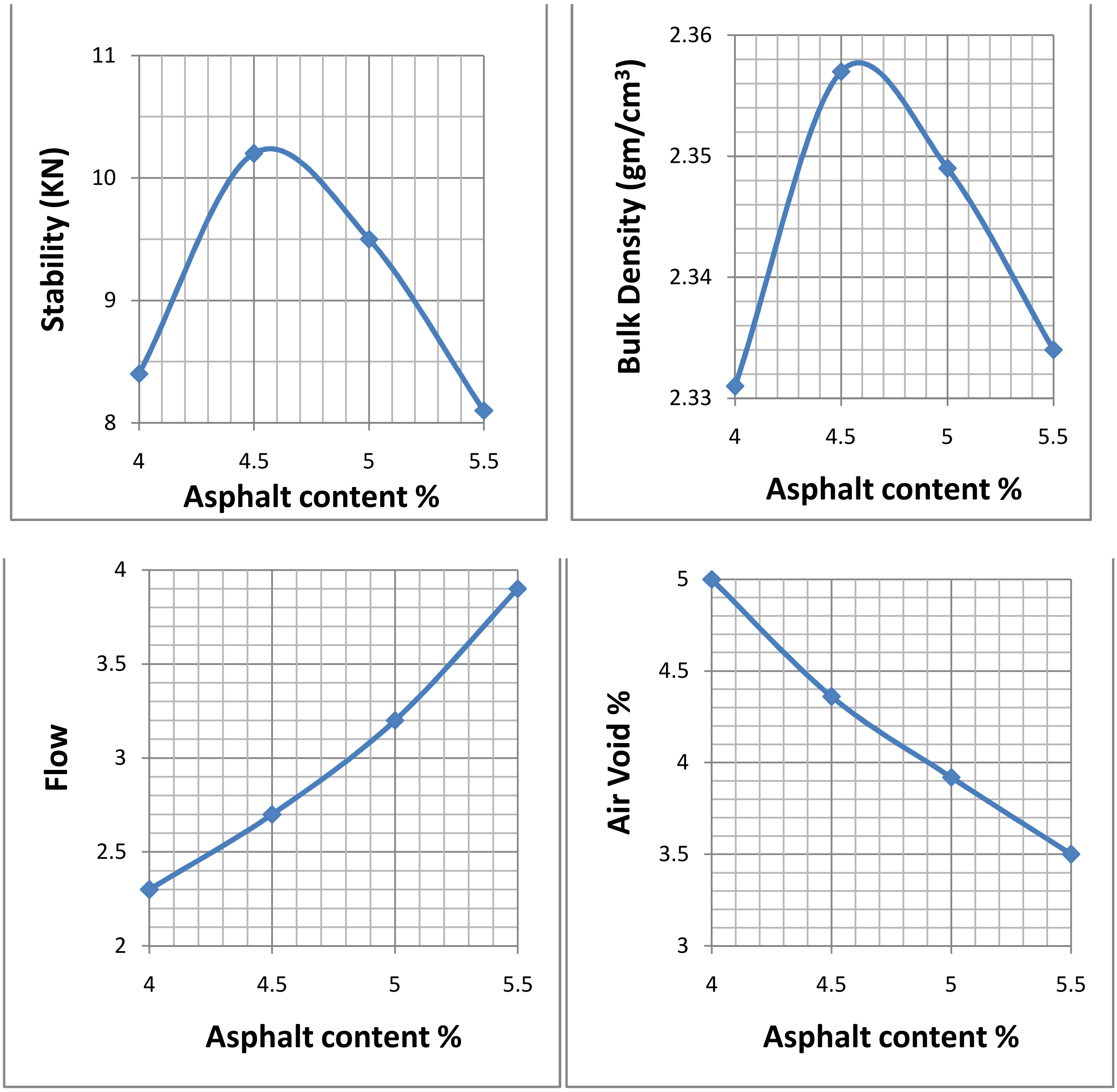
Table (5) Air Void results of control mixture and asphalt mixtures modified by Polymers

Sample	***Polymer Percent%***	***Air Void %***
Control	**0**	4.09
Modified with LDPE	**1**	4.27
	3	4.42
	6	4.78
Modified with SBS	**1**	4.32
	3	4.17
	6	4.90

Table(6) : Indirect tensile strength test results

Sample	*Polymer Percent %*	
control	0	1.925
Modified with LDPE	1	2.665
	3	2.203
	6	1.979
Modified with SBS	1	2.344
	3	2.699
	6	2.223

Figure (1): Marshall mix design curves for optimum asphalt content



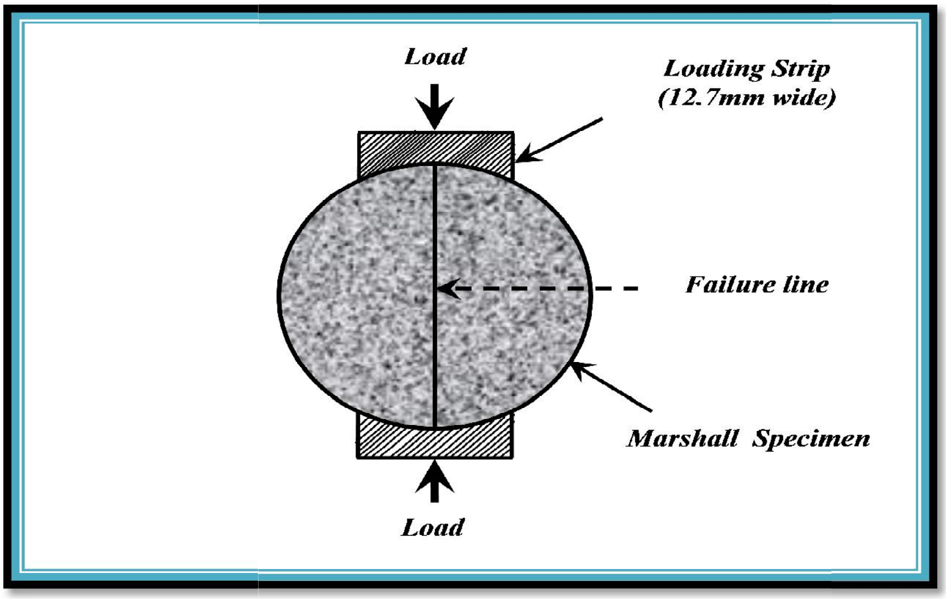


Figure (2) Load Configuration and Failure Plane for Specimen in Indirect Tensile Test

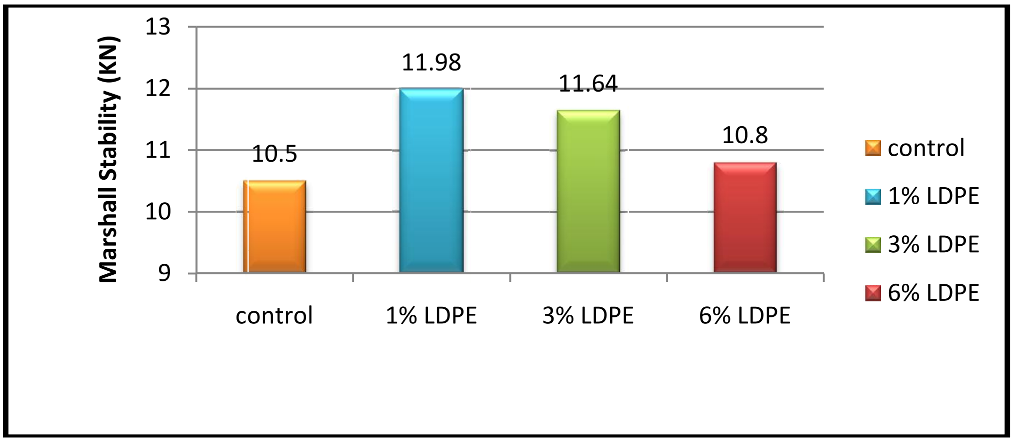


Figure (3) Effect of LDPE o Marshall Stability

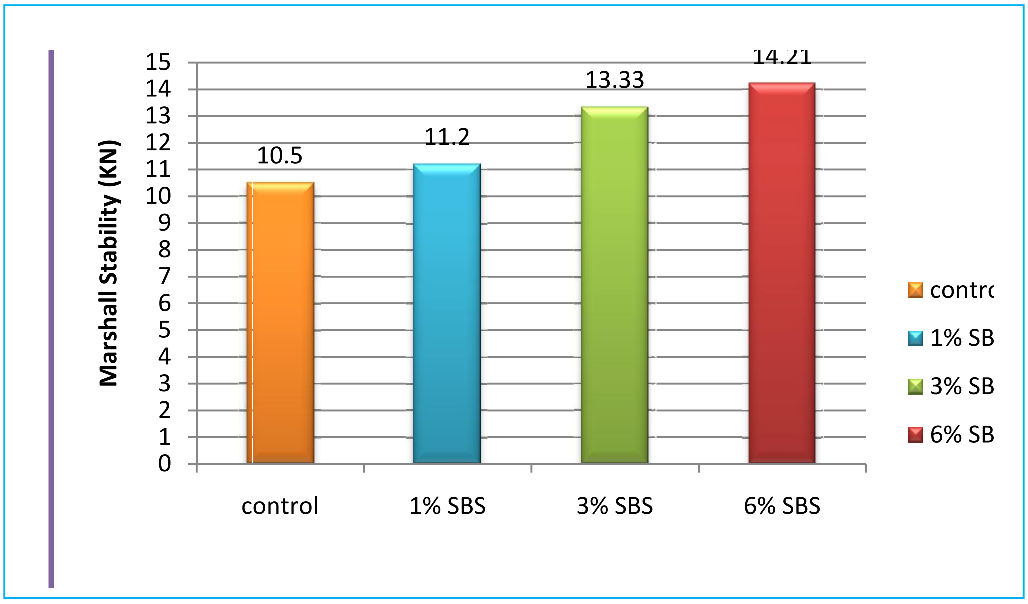


Figure (4) Effect of SBS on Marshall stability

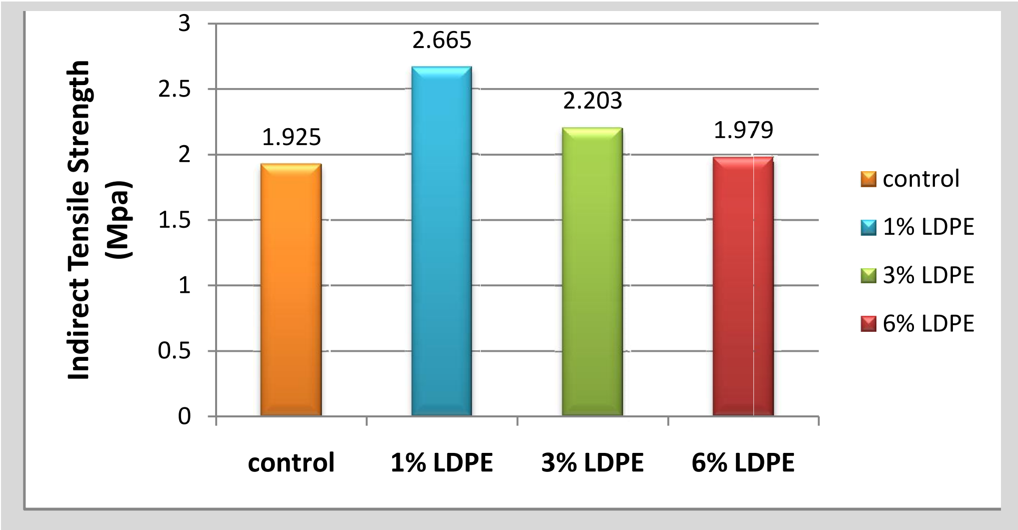


Figure (5) Effect of LDPE on Indirect Tensile Strength

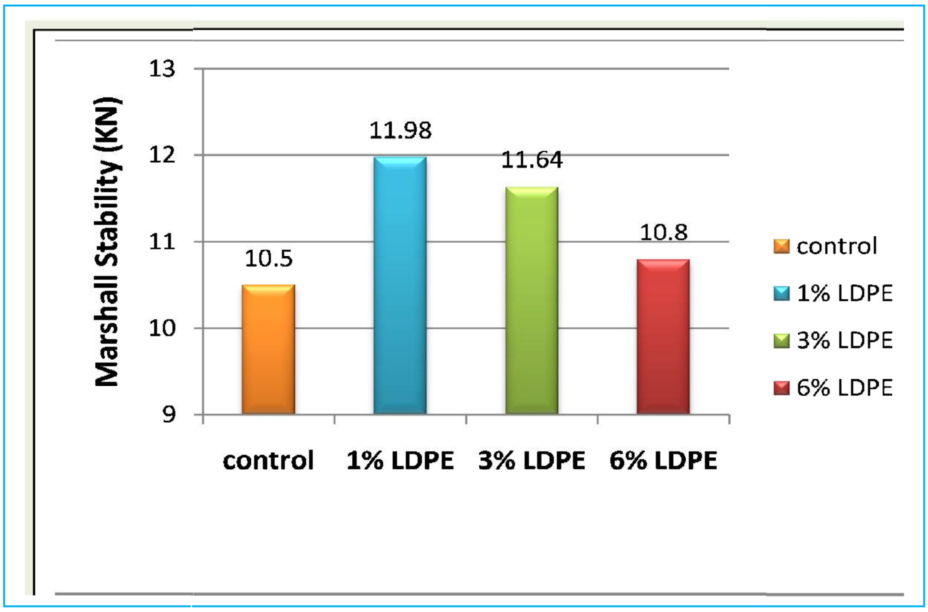


Figure (6) Effect of SBS on Indirect Tensile Strength