Modified asphalt production from the hydrocarbon resin, SBS and LDPE

Safwat Jamal Ali Salih Al-gharagholi, Haydar Mohamad Abdul-Hameed
Department of Environmental Engineering, University of Baghdad, Baghdad, Iraq
Corresponding Author E-mail: alkawasir94@gmail.com

Abstract:

Modern highway transportation faces many challenges such as high traffic density, heavy load and high speed thus the asphalt pavements are founded to be subjected to various types of distress. That can be done by looking for good material to be added to the asphalt mix such as polymers LDPE, SBS and HR as shown by some researchers. The main objective of the work is to find new bitumen mix which is compatible with the Iraqi standard and saved the environment. The result indicates an improvement in most of the modified bitumen with HR, SBS and LDPE. 10% WCO, 88% bitumen and 2% HR give 60 mm Penetration, 99.3% solubility, 95 ductility, 44 ^{o}C softening point and 288 flash point were seen to be optimum with the selected standard. At the end, the study indicates that a good quality bitumen can be achieved using HR, SBS and LDPE.

إنتاج الأسفلت المعدل بواسطة راتنجات الهيدروكربون ، SBS و LDPE

الخلاصة:

يواجه النقل بالطرق السريعة الحديثة العديد من التحديات مثل الكثافة المرورية المرتفعة والحمل الثقيل والسرعة العالية ، وبالتالي فإن أرصفة الإسفلت تم إنشاؤها لتتعرض لأنواع مختلفة المشاكل . يمكن القيام بذلك من خلال البحث عن مادة جيدة تضاف إلى خليط الإسفلت مثل البوليمرات LDPE و SBS و HR كما هو موضح من قبل باحثين آخرين. تشير النتيجة إلى تحسن في معظم البيتومين المعدل باستخدام HR و SBS و LDPE. 10٪ WCO ، 88٪ بيتومين و 2٪ HR تعطي الاختراق 60 مم ، 99.3٪ ذوبان ، 95 ليونة ، 44 نقطة تليين و 288 نقطة وميض.

Introduction

Hot-Mix Asphalt (HMA) is the most commonly used paving material around the world. It's known by many different names: HMA, asphaltic concrete, bituminous concrete, plant mix, bituminous mix, and many others. HMA is a combination of two primary ingredients: asphalt binder and aggregates, whereas; aggregates include fine and coarse materials, typically a combination of different size rock and sand [1]. The aggregates total is approximately 95% of the total mixture weight. They are mixed with approximately 5% asphalt binder to produce HMA. The typical volume of HMA mixture is approximately 85% aggregate, 10% asphalt binder, and 5% air voids. To enhance the performance and workability of many HMA mixtures, additives are added in small amounts. Asphalt pavement is called flexible pavement because it is much more flexible than cement concrete pavement [2]. Asphalt pavement performance is affected by several factors, e.g., the properties of the components (binder, aggregate and additive) and the proportion of these components in the mix. The performance of asphalt mixtures can be improved with the utilization of various types of additives, these additives include: polymers, latex, fibers and many chemical additives [3, 4]. It’s proven that the addition of certain chemical or materials additive to asphalt mix can improve the performance of final mixture. The addition of polymers typically exhibit improved durability, greater resistance to permanent deformation in the form of rutting and thermal cracking. In addition, it increases stiffness and decreased fatigue damage. There are other additives that would enhance the life of the road pavement and also solve many environmental problems [5, 6, 7]. In order to improve the performance of asphalt pavements, many polymeric substances have been incorporated in asphalt mix as additives in many forms. Polymer modification of bitumen and asphalt mix offers several benefits. These include enhanced fatigue resistance, improved thermal cracking resistance, decrease in temperature susceptibility, and improve rutting resistance [7]. The aim of this work is to identify mixture characteristics and the efficiency of the asphalt binder designed using styrene-butadiene-styrene (SBS), low density polyethylene (LDPE) and hydrocarbon resins (HR) also studying the characterization of the modified bitumen to meet the Iraqi standard.

Experimental work:

Materials needed for this study are the constituents of hot mix asphalt with SBS, LDPE and hydrocarbon resin. To improve the viscosity and adhesion of the modified asphalt, a series of trial and error tests were conducted to select the appropriate modifiers as shown in Figure (1). Hard asphalt particles, black granular solid materials containing 41.2% asphaltenes and 32.4% resins was made from residual oil and was applied to enhance the viscosity, adhesion and temperature stability. Hydrocarbon resin, a kind of yellow particle, can be used to improve the viscosity and adhesion of the bitumen mixture. The bitumen used in the experiment was compatible with the Iraqi standards R9. Table (1) shows the properties of the bitumen 40/50.

Table (1) Specification of bitumen R9 Iraqi standard

property	unit	Specification
Specific gravity @ 25 ^oC	kg/cm^3	1.01/1.06
Penetration @ 25 ^oC	mm/10	40/50
Softening point 25 ^oC	^oC	52/60
Ductility @ 25 ^oC	cm	100 min
Flash point ^oC	^oC	250 min
Solubility	Wt%	99.5 min

There are infinite varieties of bitumen's that can be made; tests that can characterize different grades are needed. The major function of these tests is to indicate the endurance, durability workability and withstanding all the weathering and environmental condition that may limits the bitumen usage according to the standards. Penetration, ductility, solubility and softening point are the key measurements most commonly used to classify bitumen. The American Society for Testing and Materials (ASTM) publish a standard method for testing bitumen and they have been followed in the testing laboratories were the sample have been tested.

Bio-asphalt preparation:

The bio-asphalt was prepared by the definite procedures as follows:

1) The moisture degree of WCOR is 3%, so WCOR sample was uniformly heated to 170 ^{o}C firstly to remove moisture, but the maximum heating temperature should be less than 180 ^{o}C to avoid the composition loss and excessive oxidation.

2) Then, WCOR and HR was added heated to 170^{O}C and then stirred for 60 min at 400 rpm.

3) Finally, the temperature was reduced to 155 ^{o}C, then the LDPE were added (stirring for 50 min at 400 rpm to ensure the polymers swell adequately).

Table (2) Material percentage

binder	WCOR%	bitumen %	HR%
1	10	88	2
2	10	86	4
3	10	84	6
4	10	82	8
5	10	80	10
6	10	78	12
7	10	76	14
8	10	74	16
9	10	72	18
10	10	70	20

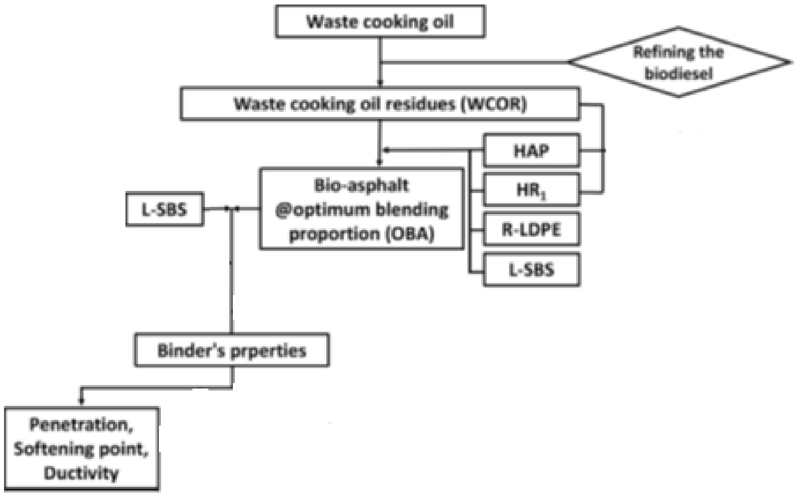

Fig. (1) mixing and analysis diagram

Result and discussion for SBS , LDPE ,HR

The test results and discussion on (i) bituminous binder (ii) rheological properties of bituminous binders and its variation by addition of modifiers. Bitumen, 40/50 was modified with different percentage of SBS, HR and LDPE. R9 represent the standard properties for comparison as shown in Table (3).

Table (3) conventional test results for modified binders without LDPE/SBS

Binder	WCOR %	bitumen %	HR %	penetration	soft point	ductility	solubility	flash point
1	10	88	2	60	44	95	99.3	288
2	10	86	4	60	47	98	99.2	282
3	10	84	6	57	49	100	99.2	286
4	10	82	8	56	51	100	99.3	281
5	10	80	10	51	54	100	99.4	278
6	10	78	12	50	54	100	99.4	273
7	10	76	14	46	56	100	99.4	268
8	10	74	16	46	56	100	99.3	267
9	10	72	18	45	57	100	99.3	263
10	10	70	20	43	58	100	99.3	263

Table (4) conventional test results for modified binders with LDPE

Binder	WCOR %	bitumen %	HR %	LDPE %	penetration	soft point	ductility	solubility	flash point
11	10	75	14	1	47	53	100	99.2	261
12	10	74	14	2	46	55	100	99.1	262
13	10	73	14	3	46	56	100	99.1	259
14	10	72	14	4	45	57	100	99.1	257
15	10	71	14	5	43	58	100	99.1	257
16	10	70	14	6	41	58	100	99.1	257

Effect on Penetration values with different Modifiers

The penetration values of bitumen modified with different percentage of SBS, HR and LDPE are shown in Figure (2 and 3).

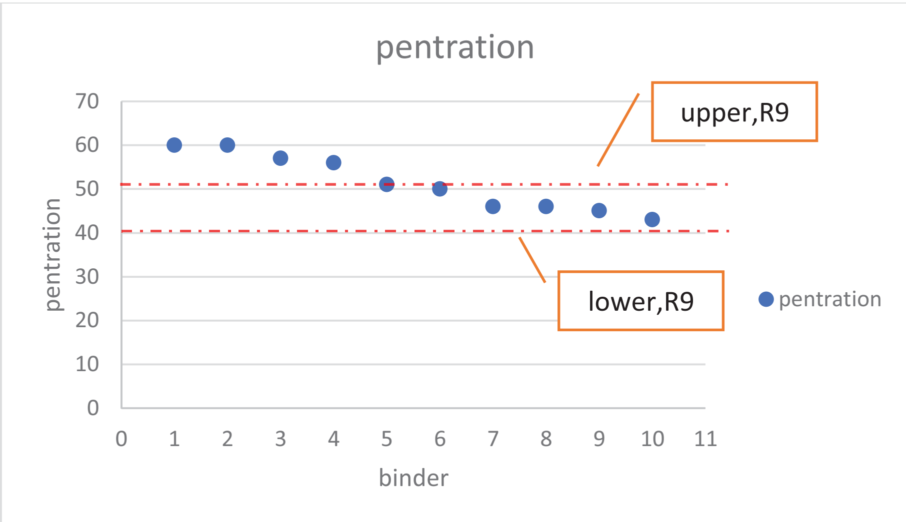

Fig. (2) the effect of different binder composition on The penetration without LDPE

The penetration values are slightly decreased steadily from 60 in binder 1 to 43 in binder 10. This indicates that the increase in the HR decreases its penetration value at constant waste cooking oil. Figure (3) shows the effect of waste cooking oil and HR on the penetration behavior of modified bitumen. It can be seen from this Figure that the increases of the HR decrease the penetration of the resulting binder. The decrease in penetration also discovered by [8]. It's also noticed that all binders do not achieve the standard R9.

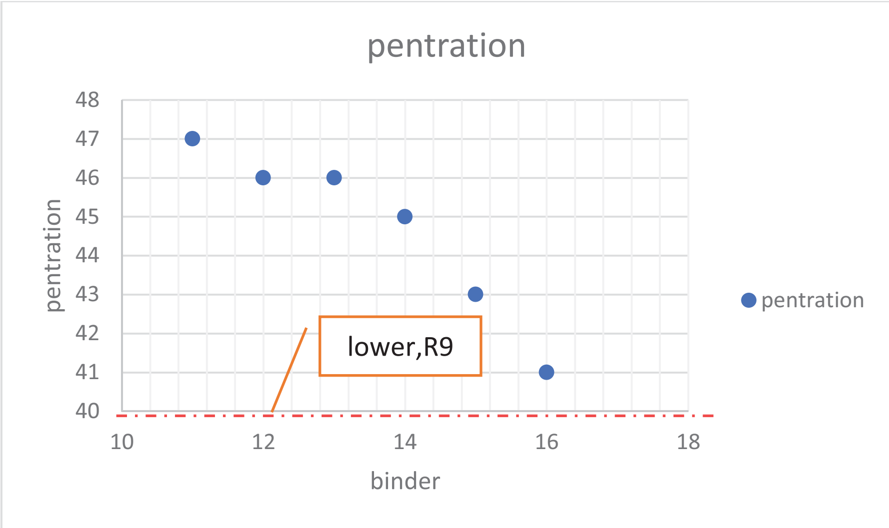

Fig. (4) the effect of different binder composition on The penetration for the tested binders with LDPE/SBS

The penetration values are slightly decreased significantly from 47 in binder 11 to 41 in binder 16. This behavior is due to the presence and increase of the LDPE and SBS at constant percentage of WCO and HR.

Figure (4) shows the effect of waste cooking oil, HR, SBS and LDPE on the penetration behavior of modified bitumen. It can be seen from this Figure that the penetration of the resulting binder was decrease with the increase of LDPE. The decrease in penetration also proven by [9]. This may be inferred from the reduction in viscosity of binder with increase in modifier content.

Effect on Softening point at different binders

The softening point values of bitumen modified with different percentage of modifiers are given in Figures (4 and 5).

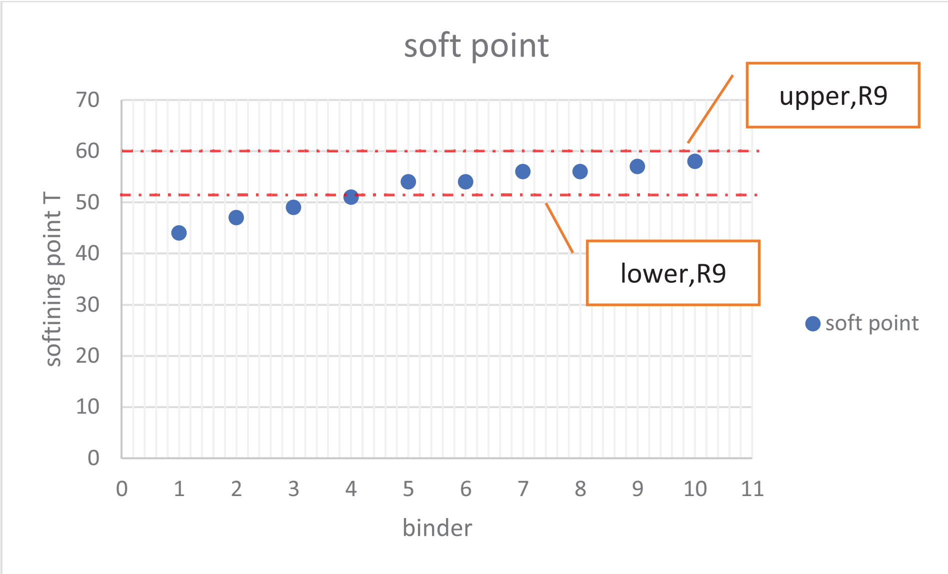

Fig. (4) the effect of different binder composition on softening point test for each bind er without LDPE

Figure (4) shows the softening point behavior of modified bitumen. It was found that as the softening point of modified bitumen increases, also the HR increases from 2% to 20%, where the highest softening point was 58 for binder 10. The increase in the softening point brought by HR can be attributed to the softening of HR. The increase in softening point also reflects that the viscosity of the binder decreases while blending. This result was also supported [8]. The binders can reach to the standard R9 at the binders 5, 6,7,8,9 and 10.

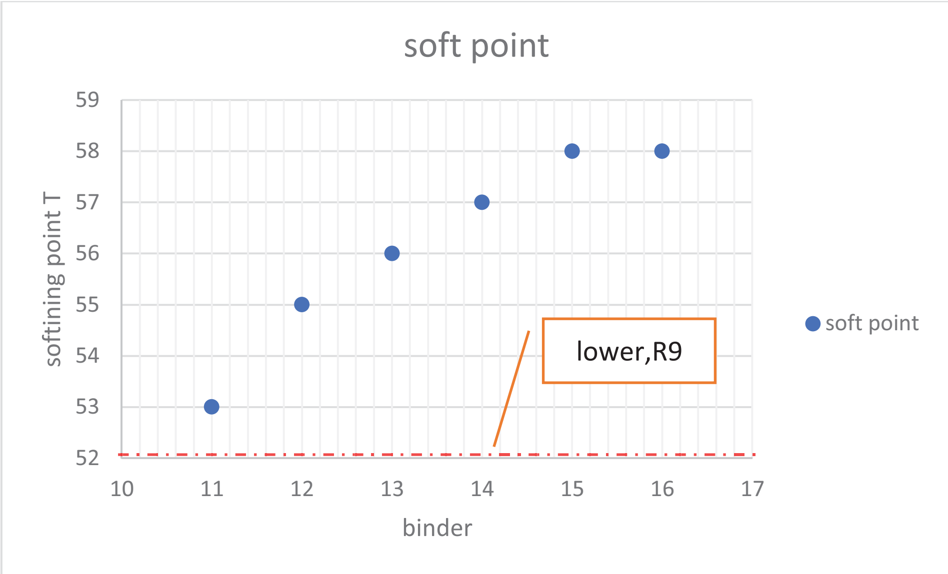

Fig. (5) the effect of different binder composition on softening point test for each binder with LDPE/SBS

Figure (5) shows the softening point behavior of modified bitumen with the addition on LDPE and SBS. The softening point increase from 53 to 58 at the increase of the LDPE rate from 1% to 5% . The increase in the softening point brought about by LDPE increase while other additive remain constant can be attributed to increase in adhesive properties of modified bitumen as LDPE content increased. This is in accordance with the findings [9]. All binders with LDPE matched with standard R9.

Effect on Ductility values

Effect of various percentages of modifiers with and without LDPE and SBS on ductility can be seen in both Figures (6 and 7).

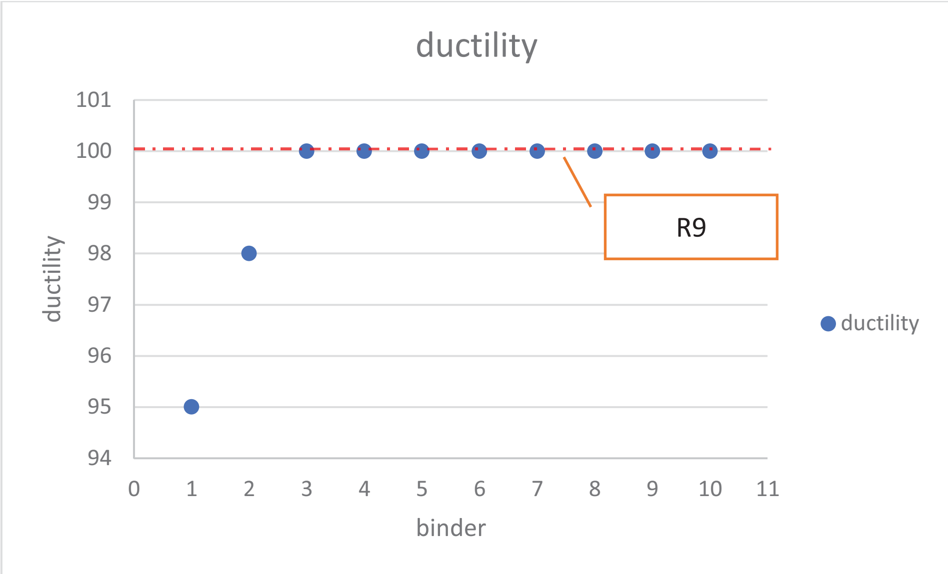

Fig. (6) the effect of different binder composition on Ductility test on different binders without LDPE

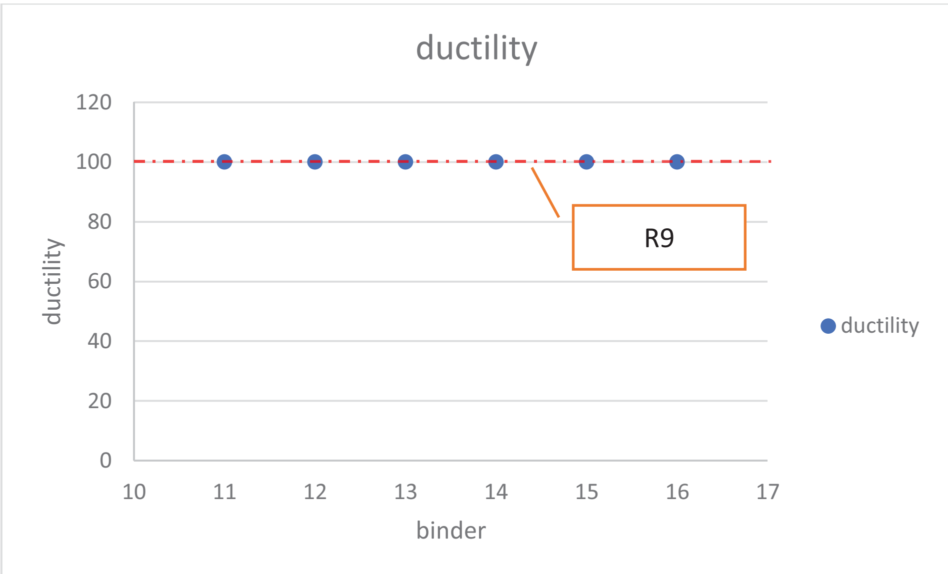

Fig. (7) The effect of different binder composition on Ductility test on different binders with LDPE and SBS

Figure (6) which show the Ductility test on different binders without LDPE. It is observed that the ductility value increases with increase of HR. The ductility value increased from 95 in binder 1 to 100 in binder 3.

Ductility value remain constant at HR percent higher than 6% as noticed from binder 3 to binder 10. The increase in ductility with HR was also approved by [8]. Figure (7) shows no effect of the LDPE and SBS on the ductility value.

Effect on flash point values

Effect of various percentages of modifiers on the flash point is shown in Figure (8)

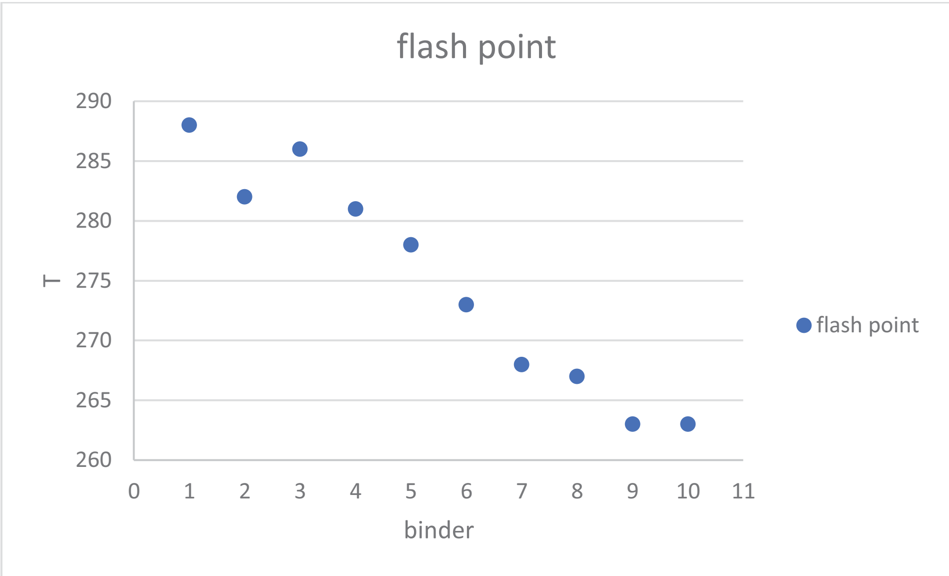

Fig. (8) The effect of different binder composition on flash point test for different binders without LDPE

The flash point value was decreased from 288 C for binder 1 to 263 for binder 10 were the sharp decrease was due to the increase in the HR from 2% to 20%. All the binders were not compatible with the R9 standard.

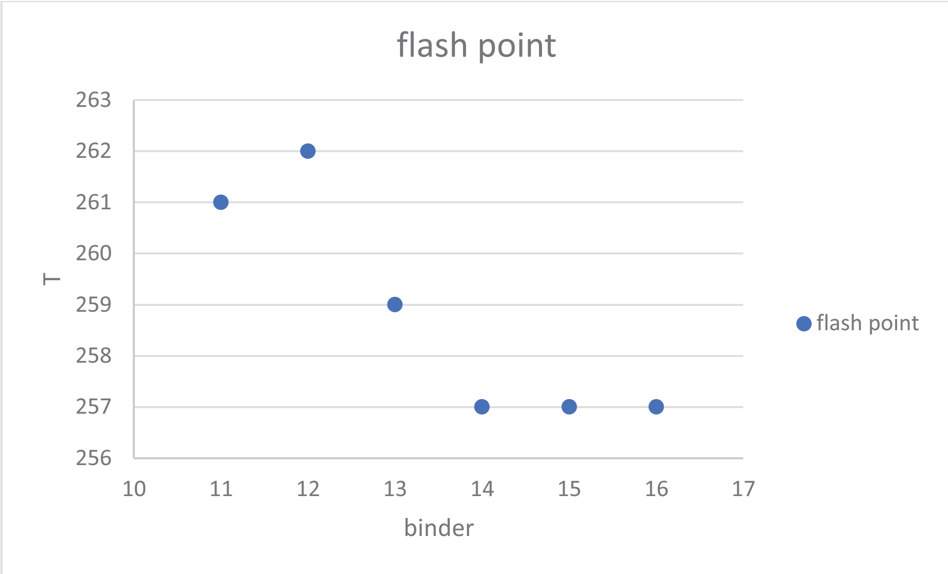

Fig. (9) the effect of different binder composition on flash point test for different binders with LDPE and SBS

Figure (9) shows the effect of adding LDPE and SBS to the bitumen mixture. The flash point value was decreased from 261 C for binder 10 to 257 for binder 14 were the sharp increase was due to the increase of LDPE from 1% to 3% . the flash point remains constant at LDPE percent higher than 3%.

Effect on solubility

The solubility of the asphalt mix was studied within/ without LDPE as shown in Figures (10 and 11).

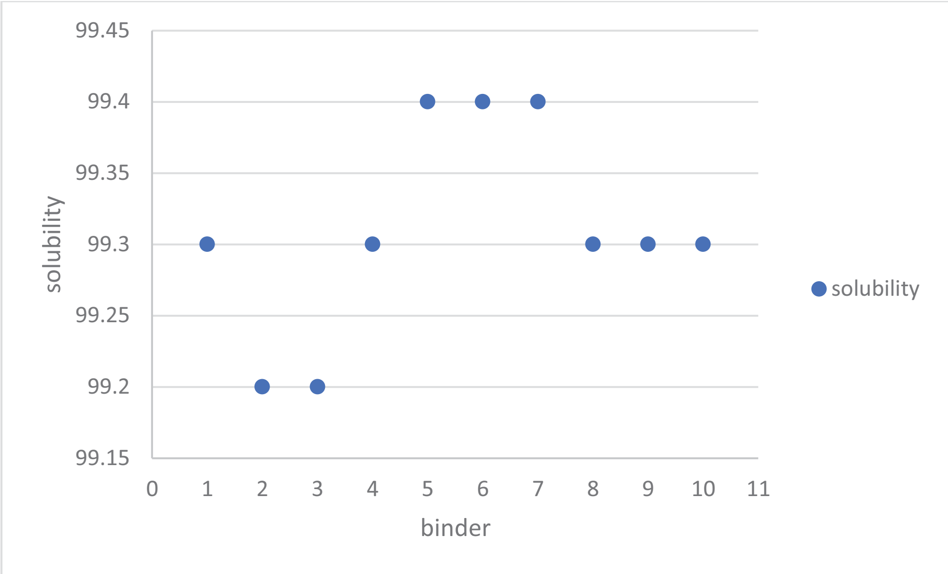

Fig. (10) the effect of different binder composition on solubility test for different binders without LDPE

Figure (10) shows that the solubility value increase with the increase of HR from 2% to 10%. Also, any further increase in the HR percent has no effect on the solubility of the bitumen mix. Almost, all binders have close solubility value to the standard R9.

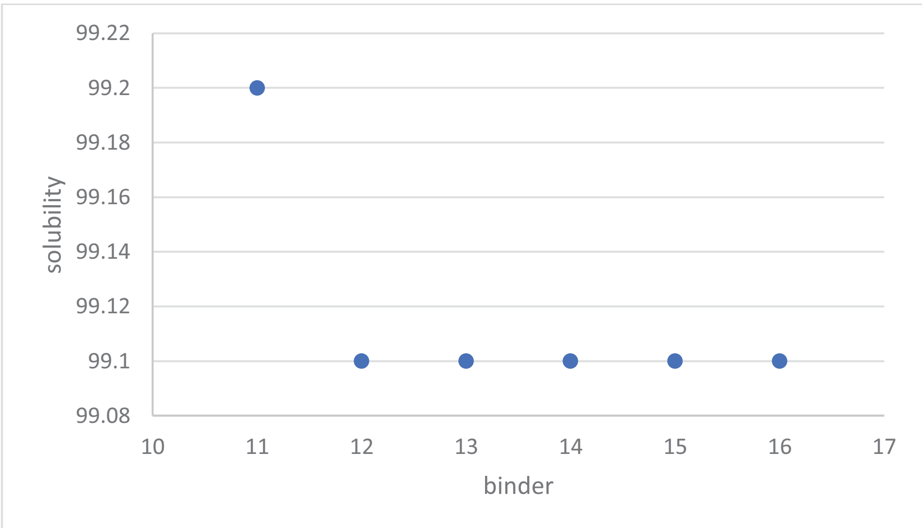

Fig. (11) the effect of different binder composition on solubility test for different binders with LDPE and SBS

From Figure (11) were the effect of adding the LDPE and SBS to the bitumen mix shows a decrease in the solubility of the mixture from 99.2 at 1% LDPE for binder 11 to 99.1 at 2% LDPE. The solubility remains constant at 99.1 for LDPE percent higher than 2%.

Conclusion

The penetration values are slightly decrease significantly from 47 in binder 11 to 41 in binder 16. the softening point of modified bitumen increases steadily while Ductility value remain constant at HR percent higher than 6% as noticed from binder 3 to binder 10. The flash point value was decreased from 288 C for binder 1 to 263 for binder. Solubility value increase with the increase slightly of HR from 2% to 10%. All thementioned binders are all compatible with the Iraqi standard and these material are wieldy available in the plastic waste which make the bitumen mix cost efficient environmentally.

Nomenclature

HR: Hydrocarbon resin
R9: Iraqi asphalt quality standard
AC: Asphalt concrete
LDPE: Low-density polyethylene
SBS styrene-butadiene-styrene

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