Effects of (SBS) Styrene-Butadiene-Styrene on Physical properties of Bitumen

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ABSTRACT

The presence of water in the asphalt structure causes early weakening, leads decline in asphalt sturdiness in light of the loss of connection between total and folio (stripping) and may cause loss of solidarity and strength in admixture. The most common technique to mitigate moisture damage is by using polymer additives mixed with asphalt binder. The physical characteristics of bitumen are affected by the amount of Styrene-Butadiene-Styrene (SBS) used, with a five percent addition reducing penetration by 27.5% and a five percent addition increasing the softening point and viscosity by 32.35% and 25.4%, respectively. While when employing SBS, the elongation rises by more than 100. High temperatures are the main factor affecting roads, and using SBS additive causes the road resistance to heat to rise. As a result, when using 5% of SBS, the resistance to flash point and fire point increases by 19.4 and 20.4, respectively, while the elasticity is increased by 20%. The use of polymer SBS is important because it leads to reducing pressure and increasing ductility and resistance to temperatures and it has an effect on the physical and chemical properties. The ratios range from 4-5% of the best ratios to increase the life of the road and reduce the effect of high temperature. The ratio of 4% is better in the northern and central regions because the temperature it does not exceed 76C°, and it is more economical in terms of cost, while the percentage is 5% and higher for the southern regions, since temperatures are more than 76C°.

Keywords: Styrene-Butadiene-Styrene, physical properties, modified bitumen.

تأثيرستارين بيوتادين ستايرين(SBS)على الخصائص الفيزيائية للقير

د.عبدالباسط عزيز محمود قسم تقنيات بناء وأنشاءات/ كلية التقنية/ الجامعة التقنية الشمالية و
زينة اسامه يحيى قسم تقنيات بناء وأنشاءات/ كلية التقنية/ الجامعة التقنية الشمالية

الخلاصة

يؤدي وجود الماء في الهيكل الإسفلتي إلى ضعف مبكر ، ويؤدي إلى انخفاض متانة الإسفلت في ضوء فقدان الاتصال بين المكونات وقد يتسبب في فقدان التضامن والقوة في المزيج. الأسلوب الأكثر شيوعًا للتخفيف من ضرر الرطوبة هو استخدام إضافات البوليمر الممزوجة مع مادة رابطة الأسفلت. تتأثر الخصائص الفيزيائية للقار بكمية الستايرين - بوتادين - ستايرين (SBS) ، مع إضافة خمسه بالمائة تقلل الاختراق بنسبة

27.5٪ وإضافة خمسة بالمائة تزيد نقطة التليين واللزوجة بنسبة 32.35٪ و 25.4٪ على التوالي. . أثناء استخدام SBS ، ترتفع الاستطالة بأكثر من 100. درجات الحرارة المرتفعة هي العامل الرئيسي الذي يؤثر على الطرق ، واستخدام مضافة SBS يؤدي إلى ارتفاع مقاومة الطريق للحرارة. نتيجة لذلك ، عند استخدام 5٪ من SBS ، تزداد مقاومة نقطة الوميض ونقطة النار بنسبة 19.4 و 20.4 على التوالي ، بينما تزداد المرونة بنسبة 20٪. يعد استخدام البوليمر SBS مهمًا لأنه يؤدي إلى تقليل الضغط وزيادة الليونة ومقاومة درجات الحرارة وله تأثير على الخصائص الفيزيائية والكيميائية. وتتراوح النسب من 4-5٪ من أفضل النسب لزيادة عمر الطريق وتقليل تأثير ارتفاع درجة الحرارة. نسبة 4٪ أفضل في المناطق الشمالية والوسطى لأن درجة الحرارة لا تزيد عن 76 درجة مئوية ، وهي أكثر اقتصادا من حيث التكلفة ، بينما النسبة 5٪ فأعلى في المناطق الجنوبية ، حيث أن درجات الحرارة مرتفعة. أكثر من 76 درجة مئوية.

الكلمات الدالة: ستايرين بوتادين ستايرين، الخصائص الفيزيائية ، القير المعدل.

1. Introduction

It Is Impossible To Pinpoint The Wheel's Creation Date or location. It is difficult to believe that people in the Stone Age were unaware that round items, like pieces of tree trunks, roll. Most observers believe that tree trunks were utilized as rollers; not quite a wheel but a similar idea! The large megalithic tombs of the third millennium BC are evidence of ancient people's capacity to move enormous stones. However, it is undeniable that the domestication of the horse—which occurred in southern Russia or Ukraine around 4000 BC—was swiftly followed by the invention of the cart. It is also known that by the latter third millennium BC, the major towns of Egypt and Iraq had advanced to the point where pavements were required [1]. An asphalt pavement is made up of the subgrade, sub-base, base, surface, and wearing course, among other layers. The structural design recommends determining the appropriate pavement layer thicknesses even if a pavement's geometric, functional, and drainage elements all need to be taken into account during design [2]. In recent decades, polymer modification of asphalt binders has been viewed as a significant strategy for enhancing pavement longevity and rutting performance [3]. In order to provide the bitumen the appropriate characteristics, the bitumen is changed by adding the polymer by mechanical mixing or chemical reaction [4], [5]. With a widening world and the marked growth of haulage volumes, the demand for road networks and suitably designed pavements is increasing. Because obtainable natural resources became rare, so that, incorporation of recycled materials for construction purposes, such as flexible pavement construction, has become commonly [6]

The conditions under which the polymer is mixed, in addition to the amount applied, have a significant impact on the final product's qualities. Three crucial categories of mixing-related parameters can be subdivided: mixing temperature, mixing time (duration), and shear rate. Each is essential because it has an impact on how much bitumen the polymer can absorb or because it directly affects how long the bitumen lasts [7], [8], [9], [10], [11]. For a number of years, research has been interested in how mixing circumstances affect the properties of PMBs [12], [13], [14], [15]. Flexible pavements thermal cracking is noticeable and higher cost pavement failure mode is noticed in several sites of higher cool environments. The reason mainly concerns low temperatures occurrences, which produce paving materials tensile stresses as a results fracture occurred [16].

Less research has, however, attempted to link the aging of PMBs with the impact of mixing duration and shear rate on those materials' properties. Depending on the amount of SBS, the structure, and the butadiene: styrene ratio, this shift towards a continuous polymer matrix greatly alters the thermo-rheological characteristics of PmB. Its mechanical characteristics are enhanced as a consequence, and as a result, its performance in terms of fatigue, stripping, and permanent deformations is increased, making it a perfect material for infrastructure. [17], [18], [19], [20], [21].Asphalt polymer modification, which is the integration of polymers in asphalt material via mechanical mixing or chemical reaction, is a topic that has received extensive scholarly coverage in the context of highway building. The technique of modifying asphalt material and subsequently enhancing hot mixture asphalt uses a wide variety of polymers. There are two different varieties of these polymers. The first group is plastomers, which include ethylene-vinyl acetate (EVA), polyethylene (PE), polypropylene (PP), and ethylene butyl acrylate (EBA). In the second group are materials like styrene-butadiene-styrene (SBS), styrene-isoprene-styrene (SIS), and styrene-ethylene/butylene styrene (SEBS) [22]. The objective of this study is to examine the physical characteristics of modified and unmodified asphalt binder and hot mix asphalt (HMA), both of which are utilized in Iraq to pave surface courses, and to look into the effects of SBS, a modifier, on these characteristics.

2. Materials and Methods

2.1. Bitumen properties

The asphalt cement (40-50) penetration graded in this study, was acquired from AL-Kirkuk. The actual characteristics of this sort of asphalt cement showed in Table (1).Experimental Procedure.

Table 1 *The Asphalt Cement's Physical Characteristics*

No.	*Test*	*Unit*		*Results*	*Requirements*
1	*Penetration 25°C, 100 gm, 5 sec*	*1/10 mm*	*ASTM D5*	*30*	*--------*
2	*Ductility (25°C, 5 cm/min.)*	*Cm*	*ASTM D113*	*100+*	*Min.100Cm*
3	*Ring &ball Softening Point*	*C°*	*ASTM D36*	*68*	*Min.65 C°*
4	*Flash Point*	*C°*	*ASTM D92*	*232*	*Min.230 C°*
5	*Rotational Viscometer at 135C*	*Cst.*	*ASTM 4402*	*1830*	*Max.3000 Cst*

1.2 Polymers structure and classification

The word "polymer" is derived and means "of many parts." A polymer is basically a very large molecule created by chemically interacting several monomers, or tiny molecules, to create long chains. The chemical make-up, molecular weight, and arrangement of a polymer's monomers all affect its physical properties [23]. Polymers come in two varieties: elastomers and plastomers. The word "elastomers" (rubbers) refers to materials that may return to their original shape once a load has been removed. Styrene and butadiene copolymers are frequently found in elastomers. They also consist of synthetic and natural rubbers [24]. Thermoplastic or thermoset polymers are more commonly used to describe elastomeric and plastomeric materials. The complex structure that thermoset polymers first create is retained after chilling but cannot be altered by reheating. In contrast, thermoplastic polymers also produce a distinct, linked structure when they are cooled, albeit the structure that results from cooling can be altered by reheating [25].

Table 2 summarizes the various types of polymers and groups them based on their thermal and deformational characteristics [25].

Polymer Type	Examples	Deformational Classification	Thermal Classification
Natural Rubber (Homopolymers)	Natural Rubber (NR), Polyisoprene, Isoprene, Natural Rubber Latex (NRL)	Elastomer	Thermoset
Synthetic Latex / Rubber (Random Copolymers)	Styrene-Butadiene (SBR)	Elastomer	Thermoset
	Polychloroprene Latex (Neoprene)	Elastomer	Thermoset
	Polybutadiene (PB, BR)	Elastomer	Thermoset
Reclaimed Rubber	Crumb Rubber Modifiers	Elastomer	Thermoset
Block Copolymers	Styrene-Butadiene-Styrene (SBS)	Elastomer	Thermoplastic
	Styrene-Isoprene-Styrene (SIS)	Elastomer	Thermoplastic
	Styrene-Butadiene (SB) Diblock	Elastomer	Thermoplastic
	Acrylonitrile-Butadiene-Styrene (ABS)	Elastomer	Thermoplastic
	Reactive-Ethylene-Terpolymers (RET)	Elastomer	Thermoplastic
Plastics	Low / High Density Polyethylene (LDPE / HDPE), Other Polyolefins.	Plastomer	Thermoplastic
	Ethylene Acrylate Copolymer	Plastomer	Thermoplastic
	Ethyl-Vinyl-Acetate (EVA)	Plastomer	Thermoplastic
	Ethyl-Methacrylate	Plastomer	Thermoplastic
	Polyvinyl Chloride (PVC)	Plastomer / Elastomer	Thermoplastic
	Ethylene-Propylene-Diene-Monomer (EPDM)	Plastomer	Thermoplastic
	Acrylates, Ethyl-Methacrylate (EMA), Ethyl-Butyl-Acrylate (EBA)	Plastomer	Thermoplastic

Combinations	Blends of Above	Varies	Varies

2.2.1 The type of polymer used

SBS is a thermoplastic polymer that raises the stability, elasticity, and stiffness of asphalt binders to enhance the overall performance of asphalt pavement. SBS softens at high temperatures, making it simple to mix and add to the asphalt binder [26]. Kraton D1192 E is employed to modify bitumen for usage in paving and industry. Additionally, it might be appropriate for use in the creation of coatings, sealants, and adhesives as well as in the modification of polymers. Figure 1 displays Styrene-Butadiene-Styrene (SBS).

Figure 1 Styrene-Butadiene-Styrene (SBS)

2.2.2 Effect of Polymer (SBS) additives on bitumen

SBS polymer is used to modify asphalt because, among other things, it considerably improves the qualities of the modified asphalt [27]:

1. Resistant to high temperatures because polymer asphalt can prevent melting by having a softness point above 50°C.

2. Because polymer asphalt has a greater softening point and stiffness modulus than conventional asphalt, it can be utilised in traffic situations that are fairly dense in order to reduce high temperature deformation.

3. Shear force resistance, since polymer asphalt will increase shear force resistance.

4. Can lengthen the service life because the layer is thicker the greater the asphalt's thickness.

2.2.2 The way to mix Asphalt with SBS

Asphalt is mixed with Styrene-Butadiene-Styrene by using shear mixing. The asphalt is added to shear mixing and heated it to a temperature 180C°, when the temperature reaches to 180C°, Styrene-Butadiene-Styrene is added to bitumen. The mixing process continues to be in the shear mixing fora period of (30-40) minutes at180C°+5. By employing three percent of Styrene-Butadiene-Styrene (3, 3.5, 4, 4.5, and 5) by weight of asphalt, these polymers will be used to alter asphalt cement.

3. Tests the bitumen before and after adding the polymer(SBS)

3.1. Bitumen penetration test

The most traditional and typical test for asphalt cement. It is an empirical test that assesses an asphalt binder's stability (hardness) under particular test conditions. A standard needle with a total load of 100 g is applied to the sample surface at 25 °C for 5 seconds in the standard test procedure. After five seconds, the quantity of needle penetration is calculated in increments of 0.1 mm (or penetration unit). Testing is done in accordance with ASTM D-5 .Test results is listed in Table (3)

Table 3 Results of a bitumen penetration test

	SBS%					
Trial	0	3	3.5	4	4.5	5
Initial (0.1 mm)	0	0	0	0	0	0
Final (0.1 mm)	40	33	32	31	30.3	29
Penetration value (0.1 mm)	40	33	32	31	30.3	29

3.2. Ductility test

The ductility test examines the amount of strain that a typical bond sample can withstand at normal test speeds (5 cm/min at 25°C). Asphalt cement with extremely low ductility is typically thought to have weak adhesive characteristics and, as a result, poor service performance. The test is conducted in compliance with ASTM D113. Test results are listed in Table (4).

Table 4 Bitumen ductility test results

No. Sample	**SBS %**	**Ductility (cm)**
1	0	100+
2	3	100+
3	3.5	100+
4	4	100+
5	4.5	100+
Average	5	100+

3.3. Softening point test

Is the temperature at which, under specific test conditions, a material reaches a particular softening point. ASTM D-36 is used to calculate the asphalt cement's softening point. Test results are listed in Table (5) illustrate bitumen samples' softening point tests.

Table 5 Bitumen softening point results

No. Sample	**SBS %**	**Softening point (C°)**

1	0	68
2	3	70
3	3.5	75
4	4	78.5
5	4.5	86.5
6	5	90

3.4. Flash and fire point tests

A material's flash point is the lowest temperature at which it may ignite, in specified test conditions, the vapor of that substance ignites rapidly in the form of a flash. As a result, fire will vanish at this point and only make a fleeting appearance as a flash. It is possible to tell whether a particular grade of bitumen contains highly volatile and flammable compounds by looking at its flash point. In accordance with ASTM D-92, the test is carried out. Test results is listed in Table (6). Fire Point the lowest temperature at which bitumen ignites and burns for at least five seconds when test flame is applied.

Table 6 Bitumen flash &fire point test results

Test	**SBS %**					
	0	**3**	**3.5**	**4**	**4.5**	**5**
Flash Point (C°	232	250	263	270	275.5	277
Fire point (C°)	240	255	265	271	282	290

3.5. Specific gravity test

Is figuring out bitumen's specific gravity, which is one of its basic characteristics. As a result, it can be applied to the classification of bitumen binders used in paving. Table (7) lists the test results for the ASTMD D70 test specification. According the equation.

$$S.G = \frac{Wt. of\ sample}{(Wt.(\ Pycnometer\ +\ water) + Wt. of\ sample) - \left(Wt.(\ Pycnometer\ +\ water + sample)\right)}$$

Table 7 Specific gravity test results

	Un modified asphalt	**Modified asphalt with SBS**				
	0%	3%	3.5%	4%	4.5%	5%
Weight of sample (gm)	35	32	30.5	29	29	30

Weight of Pycnometer + water at 25ºC (gm)	1784.26	1784.26	1784.26	1784.26	1784.26	1784.26
Weight of Pycnometer + water at 25ºC + Sample (gm)	1784.942	1784.940	1784.938	1784.933	1784.930	1784.935
Ruselt	1.012	1.022	1.023	1.024	1.024	1.023

3.6. Viscosity Test

The connection between the applied shear stress and the shear rate is known as the viscous modulus. This coefficient represents the degree to which a fluid resists flowing. Viscosity is a popular name for it. The temperature of a fluid has a significant impact on its viscosity. With rising temperature, it falls. We must measure the viscosity of asphalt cement binders at various temperatures in order to ascertain the impact of temperature on that property. An ASTM 4402-compliant Brookfield viscometer is used to conduct the tests.

3.7. Elastic Recovery Test

It is feasible to gauge the elastic recovery of asphalt cement by analyzing the recovery of the binder thread formed by the elongation of a sample of the binder when it is cut with scissors under normal conditions. Testing for elastic recovery is done in compliance with AASHTO T3012013.

4. Result

When we using three percent of Styrene-Butadiene-Styrene (3, 3.5,4,4.5 and 5) percent by weight of asphalt, Styrene-Butadiene-Styrene (SBS) is modified the physical properties of asphalt as shown in the Table(8) and figure (2),(3),(4),(5),(6),(7)and(8) respectively.

Table 8 Asphalt cement with modified physical characteristics

No.	Test	Results Asphalt	SBS 3%	3.5%	4%	4.5 %	5%	Requirements
1	**Penetration 25°C, 100 gm, 5 sec(1/10mm)**	40	33	32	31	30.3	29	--------
2	**Ductility (25°C, 5 cm/min.)**	100^+	100^+	100^+	100^+	100^+	100^+	Min.100Cm
3	**Ring &ball Softening Point (C°)**	68	70	75	78.5	86.5	90	Min.65 C°
4	**Flash Point (C°**	232	250	263	270	275.5	277	Min.230 C°
5	**Fire point (C°)**	240	255	265	271	282	290	Min.230 C°
6	**Specific gravity test**	1.012	1.022	1.023	1.024	1.024	1.023	0.97-1.06
7	**Rotational Viscometer at 135C° (cst)**	1830	1979	2128	2279	2288	2295	Max.3000 Cst
8	**Elastic Recovery Test (cm)**	75	85	86	88	89	90	……….

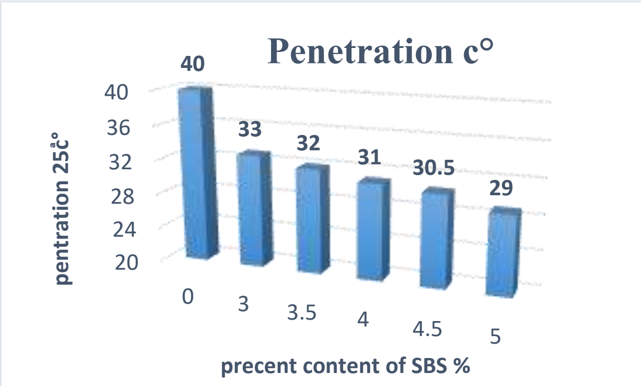

Figure 2 The relationship between Penetration and polymer content

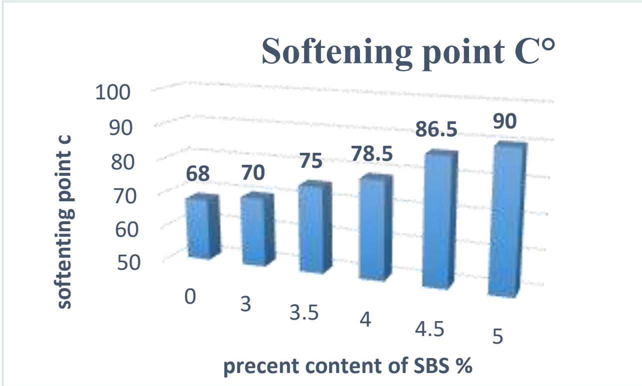

Figure 3 Bitumen softening point results

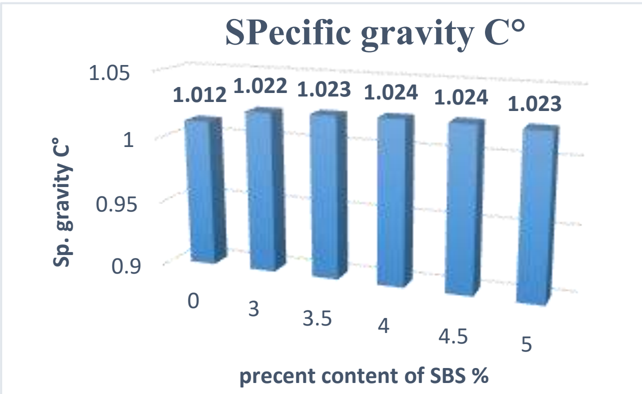

Figure 4 The relationship between specific gravity and polymer content

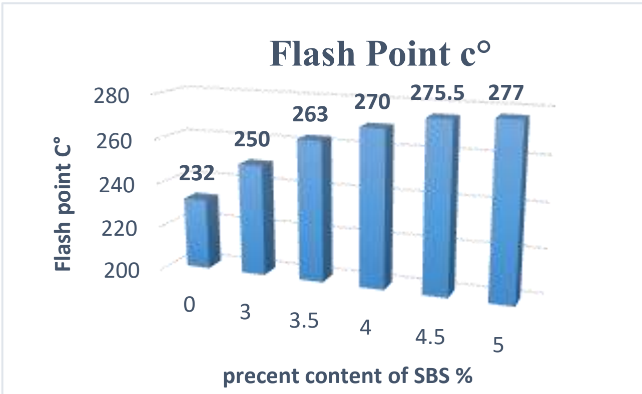

Figure 5 The relationship between Flash point and polymer content

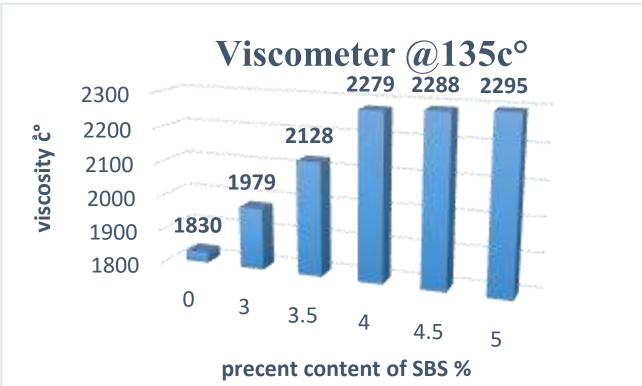

Figure 6 The relationship between viscometer @135 c° and polymer content

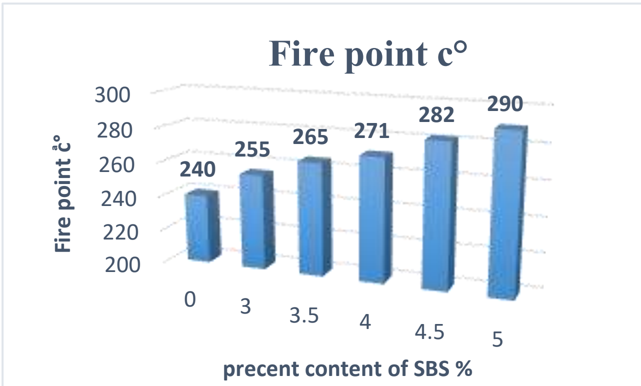

Figure 7 The relationship between Fire point and polymer content

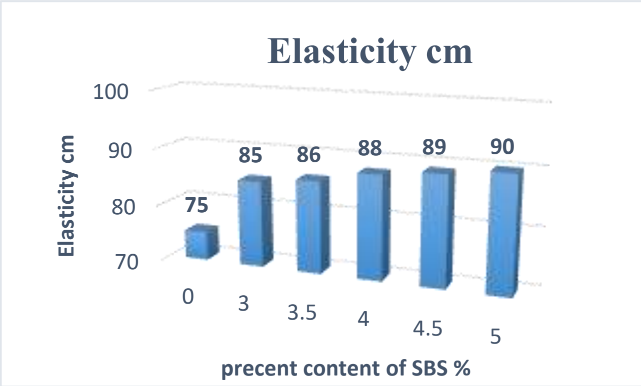

Figure 8 The relationship between elasticity and polymer content

5. Conclusions

By using Styrene-Butadiene-Styrene and how much it affects physical properties of bitumen, as shown below:

1. Turns out it has an effect on penetration, ductility, flash point, soft point and viscometer, when we use three percent (3, 3.5, 4, 4.5 and5) % of SBS by the weight of asphalt.
2. SBS has been used and added to bitumen to get the greatest outcomes, although the ratios of 4, 4.5, and 5% by bitumen weight are thought to produce the best results in high temperatures.
3. In order to prevent cracking and prevent pavement cracks from hardening at low temperatures, this helps to increase the asphalt cement's flexibility and hardness at high temperatures.
4. Butadiene Styrene The binder layer's elastic and adhesive characteristics are improved when styrene (SBS) is added to asphalt cement. Additionally, it improves the modified asphalt cement's rheological characteristics.

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