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LABORATORY COMPARISON OF EVA BASED RESIN AND SBS MODIFIED BITUMINOUS BINDER

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ABSTRACT

Although the bitumen used too few in the asphalt concrete it is significantly liable to the performance of pavement. For this reason bitumen is frequently modified in order to enhance the performance of asphalt mixtures. Stiren butadiyen stiren (SBS) is a widely used polymer modifier for asphalt binders to improve the performance properties of hot mix asphalt. (SBS) is nearly indispensable when the binder properties do not satisfy the specification requirements under hot service temperatures. In this study the performance of an alternative additive named as ethylene vinyl acetate (EVA) based resin (EBR) to SBS was investigated. The SBS contents were kept constant at 3% and EBR contents were 2%, 3% 4% and 5% by weight of base bitumen. Modified binders were produced by mixing a 50/70 penetration grade base bitumen with SBS and EBR. Penetration, softening point, rotational viscometer tests were conducted to base and modified binders and results were compared with each other. In conclusion it was determined that EBR content have to be more than 3% in order to obtain the same performance with 3% SBS modification. 3% EBR modification gave satisfactory performance in terms of temperature sensitivity, high temperature resistance and workability.

Anahtar kelimeler: Modification, EVA, Styrene Butadiene Styrene, Bitumen, Rotational Viscometer

EVA BAZLI REÇİNE VE SBS MODİFİYELİ BİTÜMLERİN BAĞLAYICI MADDE OLARAK KARŞILAŞTIRILMASI

ÖZET

Bitüm, asfalt çimentosunda çok az sayıda kullanılmasına rağmen, kaplamaların performansından önemli derecede sorumludurlar. Bu sebeple, bitüm, asfalt karışımların performanslarını geliştirmek için sıklıkla modifiye edilmektedir. SBS, bitümlü sıcak karışım'ların performans özelliklerini geliştirmek için asfalt bağlayıcılar için sıklıkla modifiye edici olarak bir polimerdir. SBS, sıcak hizmet sıcaklıkları altındaki gereklilikleri karşılamadığı zaman, neredeyse vazgeçilmez olmaktadır. Bu araştırmada, ethylene vinyl acetate (EVA) bazlı reçine (EBR) isimli alternatif katkı maddesinin SBS e olan performansı incelenmiştir. SBS içeriği %3'de sabit tutulmuştur ve baz bitümün ağırlığına göre, EBR içeriği %2, %3, %4 ve %5 oranlarındadır. Modifiye edilmiş bağlayıcılar 50/70 penetrasyon derecesi baz bitümü SBS ve EBR ile karıştırarak üretilmiştir. Penetrasyon, yumuşama noktası, dönel viskometre testi baz ve modifiye bağlayıcılara uygulanmış ve sonuçları karşılaştırılmıştır. Sonuç olarak, EBR içeriğinin, %3 SBS modifiyesi ile aynı performansı elde etmesi için %3'den daha fazla olması gerektiği belirlenmiştir. 3% EBR modifikasyonu, hassasiyet, yüksek sıcaklık direnci ve çalışabilirlik açısından tatmin edici bir performans vermiştir.

Keywords: Modifikasyon, EVA, Stiren Butadiyen Stiren, Bitüm, Döner Viskozimetre

1. INTRODUCTION

Flexible pavements consist of subbase, base and surface layers. The surface layer, which is the most expensive part of the superstructure and in contact with the vehicle tires, can be constructed with different methods from surface treatment to hot mix asphalt (HMA). The HMA is a bituminous mixture that is both durable and expensive. The HMA's are formed by heating and mixing the aggregate and the bitumen in a stationary or mobile plant and then compressing them at a certain temperature. In HMA's, the aggregate provides the internal friction resistance and stability of the mixture, while the bituminous binder provides cohesion. The bituminous binder also binds the aggregate grains with each other to prevent them from being scattered under

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traffic loads, enhances driving comfort by providing smooth surfaces, improves the stability of the mixture, and provides impermeability by filling the gaps.

Modified bitumen or mixtures with improved properties are obtained by adding various additives to bituminous binders or mixtures in order to delay distortions such as wheel tracking, stripping, cracking and undulation which occur in flexible pavements depending on the increased traffic load and climatic conditions, to reduce the need for maintenance and renewal to less frequent intervals, and to improve the pavement performance [1-3]. The modification is carried out in two ways as wet and dry processes. The wet process is carried out by adding the additives directly to the bitumen, while the additives are added to the mixture in the dry process. In addition to the elastomer and plastomeric polymers, non-polymer chemical additives, as well as natural additives such as lake asphalts, rock asphalts, and gilsonites, are used in the production of modified bitumen. Among these additives, styrene-butadiene-styrene (SBS) block copolymers are the most commonly used ones. The SBS block copolymers included in the elastomer group of polymeric materials increase the elasticity of the bituminous binders. The effective generation of modification in SBS modified bitumen depends on many factors, such as SBS concentration, the structure of the bitumen, and the mixing temperature and duration. In many studies, it was determined that SBS increased the resistance of the mixtures to wheel tracking and fatigue at high temperatures [4-7]. SBS is also reported to enhances the temperature susceptibility and improves the aging properties. The most used amount of SBS is observed as 3% by weight of bitumen according to previous studies and field application [8-12].

The excessive consume of the SBS has been limiting the supplying it at the required time. Hence the researchers have focused on alternative additives which ensure a performance as good as the SBS modification. In this study, the bitumen was modified by an alternative additive such as EBR in 4 different ratios. The performance of EBR modified binders were compared to 3% SBS modified binders in terms of conventional properties.It was also aimed to enrich the studies to be carried out on this subject with ethylene vinyl acetate (EVA) based resins and polymers.

2. MATERIALS AND METHOD

50/70 penetration grade bitumen obtained by TÜPRAŞ Batman Refinery in Turkey was used as pure binder. The binder was modified by 2%, 3%, 4%, 5% ethylene vinyl acetate (EVA) based resin (EBR) and by 3% styrene-butadien-styrene (SBS) by weight of bitumen. EBR was supplied from Würth Company. Ethylene-Vinyl Acetate is the thermoplastic resins produced by the co-polymerization process of ethylene and vinyl acetate monomer in a high-pressure reactor [13].

SBS polymer (Kraton D-1101) was supplied from Shell Chemicals Company (Fig.1). Modified binders were obtained by adding the additive to the base binder at the detected amounts and then by mixing for 1 h at 170 °C constant temperature in a mixture that had a four-blade mixer at 1000 rpm. (Fig.2). The same mixing processes was also applied to pure binder in order to make more realistic comparison by eliminating the aging affect. The pure, EBR and SBS modified binder were compared in terms of softening point, penetration and viscosities.

Fig.1 SBS and EBR

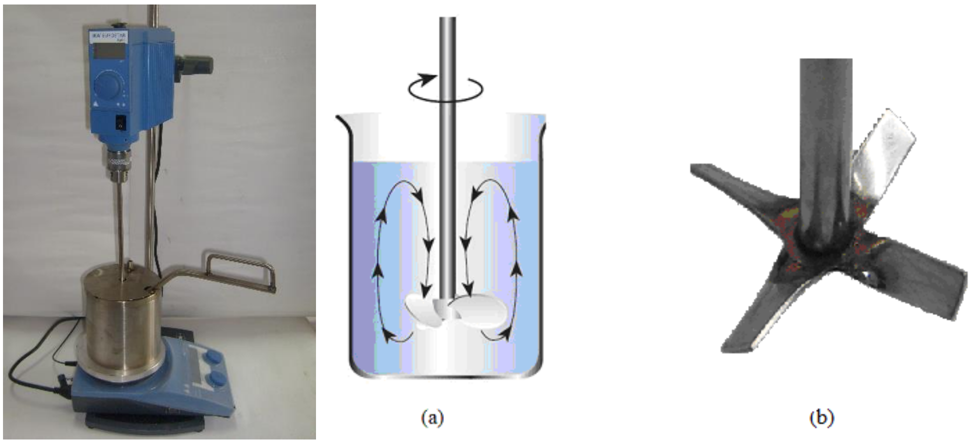

Fig.2 Laboratory type mixing device, mixing effect (a) and four-blade (b).

2.1. Penetration Test

This test was created according to ASTM D5. In this test, a needle of specified dimensions is allowed to sink into the bitumen under a constant load (100 g) at 25°C for 5 seconds. The distance of the needle sink (0.1 mm) is considered the penetration. The test is the basis upon which the penetration category of the asphalt binder is classified into standard penetration ranges. Penetration test also give an idea about the softness or hardness of a bitumen. The penetration value also designate the weather conditions in which a particular bitumen is suitable for use.

2.2. Softening Point Test

The softening point value of the asphalt binders is defined with ring and ball according to ASTM D36. Mixtures prepared with high softening point bituminous binders could nicely resist deformation at high temperature. This is tested to know the suitability of bitumen for road construction in a particular climate. Bitumen begin to flow at it's softening point temperature, hence if the softening point of a particular bitumen is higher than the pavement temperature it can be said that the bituminous mixtures can well resist to permanent deformations.

2.2. Rotational Viscosity Test

The viscosity value greatly affect the ability of bitumen to spread, penetrate into the voids of bituminous mixtures and cover the aggregates. The bitumen have to be heated up to an amount of temperature to maintain enough fluidity. The bitumen with high viscosity need to be heated up to high temperatures in order to obtain the desired density of mixtures in which it is used. On the other hand high viscosity ensure good resistance to permanent deformations at high temperature under heavy traffic loading [14]. The rotational viscometer test can evaluate the workability during the mixing and compaction processes of a bituminous binder. The specifications indicating that asphalt viscosity need to be lower than 3.0 Pa.s at 135ºC to maintain a reasonable level of workability, in other words, easy handling of hot mix asphalt during manufacturing and construction [15]. The rotational viscometer values of the bituminous binders were determined according to ASTM D4402 standard. In this study, a Brookfield DV-III rotational viscometer was used to determine the viscosity of binders.

3. EXPERIMENTAL RESULTS

3.1 Penetration Test Results

The results obtained from the penetration tests applied to pure and modified binders are given in Fig.3.

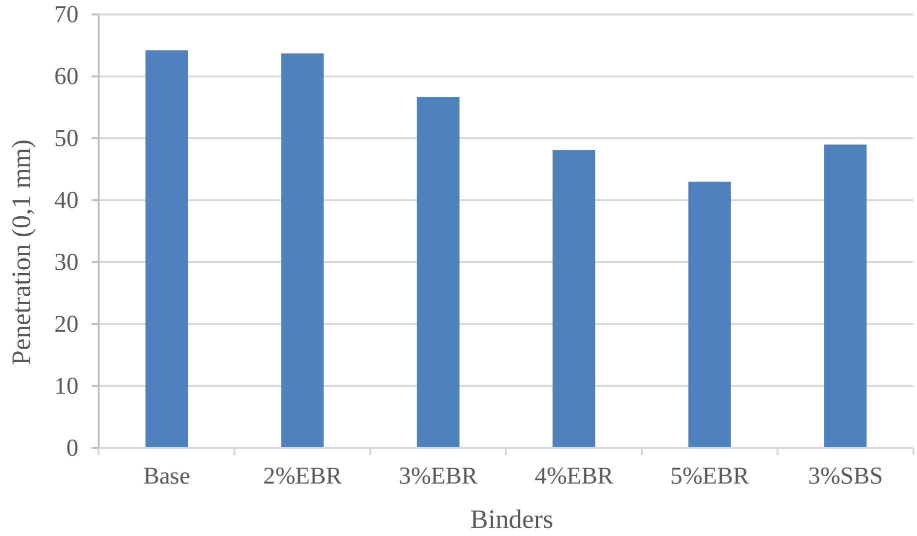

Fig.3 Variation on penetration values.

The penetration values of EBR modified bitumen reduce linearly with the increase of additive content. 2% EBR content does not have an important reduction on penetration compared to base binder. 4% EBR modified bitumen gives the same penetration value with the 3% SBS modified bitumen having 25% lover penetration compared to base bitumen. 3% EBR modification has a slightly stiffening effect on pure binder.

3.2. Softening Point Test Results

The results obtained from the softening point tests applied to pure and modified bituminous binders are given in Fig.4.

There is a high linear relation between the softening points and EBR content. EBR modification has a significant effect on softening point values. Softening points increases steadily with the increase of EBR content. 2%, 3%, 4% and 5% EBR modified bitumen have 5.6%, 10.1%, 14% and 17.2% higher values to that of the base bitumen respectively. The softening point value of 3% SBS modification can be achieved by 4.6% EBR. The increment effect of softening point is more pronounced for SBS than EBR modification. It is clear that both additives are able to contribute to high temperature resistance of hot mix asphalt in which they are used. However EBR additive needs to be used more than SBS additive in order to provide the same performance of SBS modification in terms of permanent deformation.

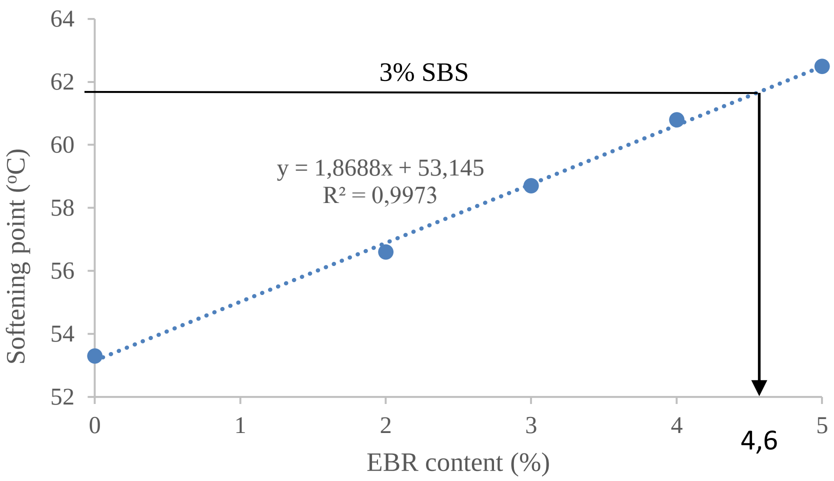

Fig.4 Variation on softening point values.

The penetration and softening point test determines the consistency of the binder, and its classification. Due to the bituminous binders are thermoplastic, they become harder at cold temperatures and softer at high temperatures. This characteristic is known as temperature susceptibility, and is one of the binder's most significant property. The penetration index (PI) value determined by penetration and softening point values represents a quantitative dimension of the response of asphalt binders to temperature changes. Knowing the penetration index of particular bitumen allows one to predict its behavior in an application. One of the best known PI determination is Pfeiffer and Van Doormaal equation:

$$A = (\log P_{25} - \log 800) / (25 - T_{SP})$$
$$PI = (20 - 500A) / (1 + 50A)$$

Where PI is Penetration Index, P_{25} is penetration of asphalt binder at 25ºC, T_{SP} is softening point temperature of asphalt binder. The PI values of binders are given in Fig.5.

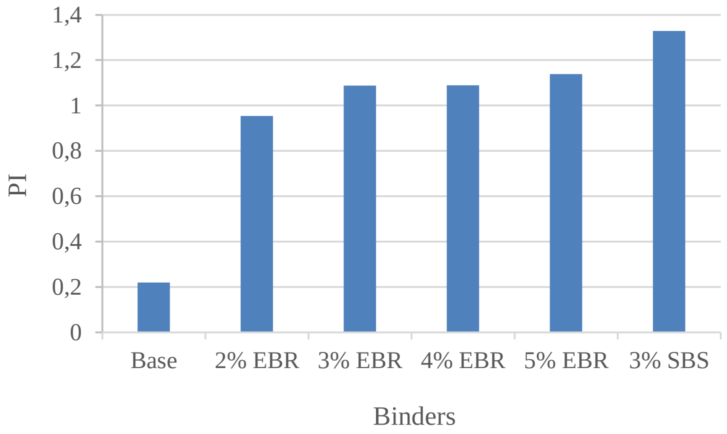

Fig.5 PI values of binders

3% SBS modified bitumen gives the highest PI value. 3%, 4% and 5% EBR modified bitumen have similar PI values at each other. It is seen that there is not any adverse effect on temperature sensitivity by using EBR additive. Furthermore after 3% EBR content PI values increase above +1 value. It is no need to use EBR content more than 3% in order to enhance the temperature sensitivity. 3%, 4% and 5% EBR modified binder gives approximately 5 times higher PI value compared to base bitumen.

3.3. Rotational Viscosity Test Results

The variation on viscosities of the pure and the modified binders at 135ºC and 165 ºC are given in Fig.6 and Fig.7 respectively.

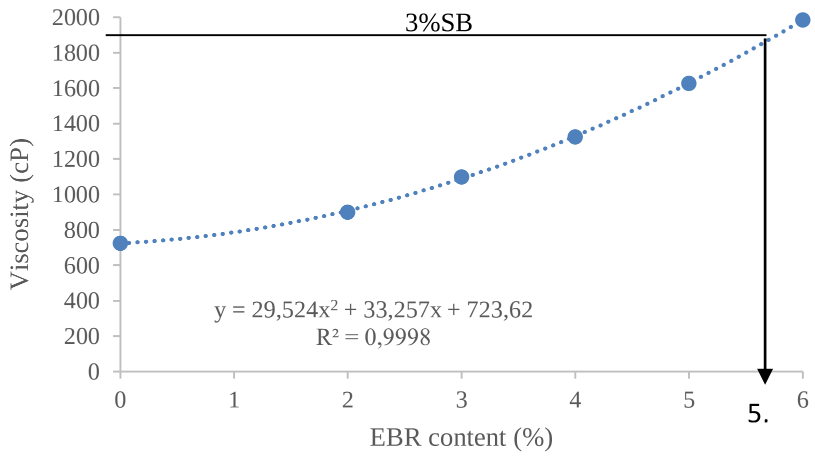

Fig.6 Viscosity values of binders at 135 ºC.

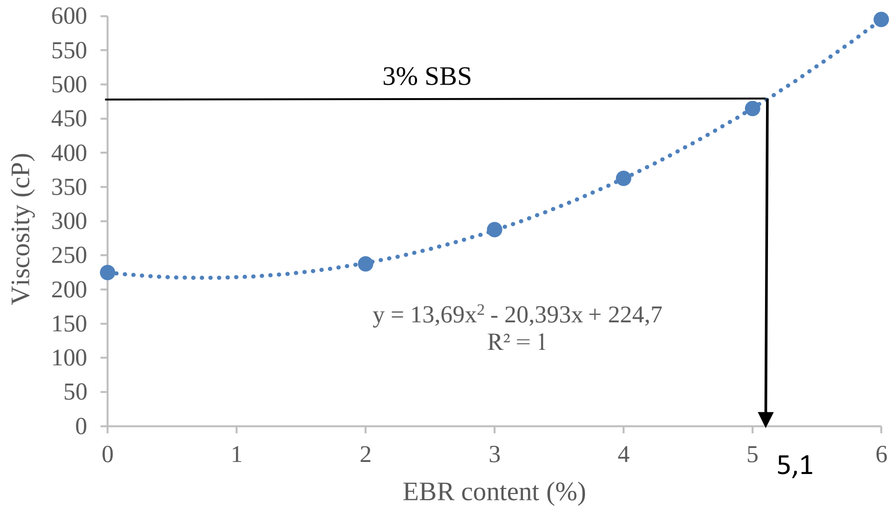

Fig.7 Viscosity values of binders at 165 ºC.

There is a polynomial increase in viscosities of EBR modified bitumen with the increase of additive content at both 135 ºC and 165 ºC. However there is no any workability problem even at the highest EBR content by not to exceed the 3 Pa.s viscosity value at 135 ºC. 6% EBR values were adjusted according to equation of the high correlated fitted curve. It is seen that the variation on viscosity trend is similar for 135 ºC and 165 ºC. 2%, 3%, 4% and 5% EBR modified bitumen give 24%, 52%, 83% and 124% higher viscosity values compared to base bitumen at 135 ºC respectively. 3% SBS modified bitumen has the highest viscosity value and induce 158% increase in the base bitumen' viscosity at 135 ºC. EBR content have to be 5.7% and 5.1% in order to obtain the same viscosity values of 3% SBS modification at 135 ºC and 165 ºC respectively. The mean value of 5.4% is needed to provide same performance with 3% SBS modified bitumen.

High viscosity value of bitumen enable to hot mixtures to resist against high temperature deformation under heavy loading, on the other hand it requires high mixing – compaction temperatures during the production and laying of bituminous mixtures. Therefore an index value determined by dividing the softening point to viscosity value is defined. The ratio of softening point to viscosity (μ) can represent the high temperature performance by considering the workability of bituminous mixtures. Softening point value is desired to be high for a good high temperature resistance on the other part the low viscosity is desired for a good workability. Therefore higher μ values is represent and improved high temperature resistance without any workability problem. The μ values of binders are given in Fig.8.

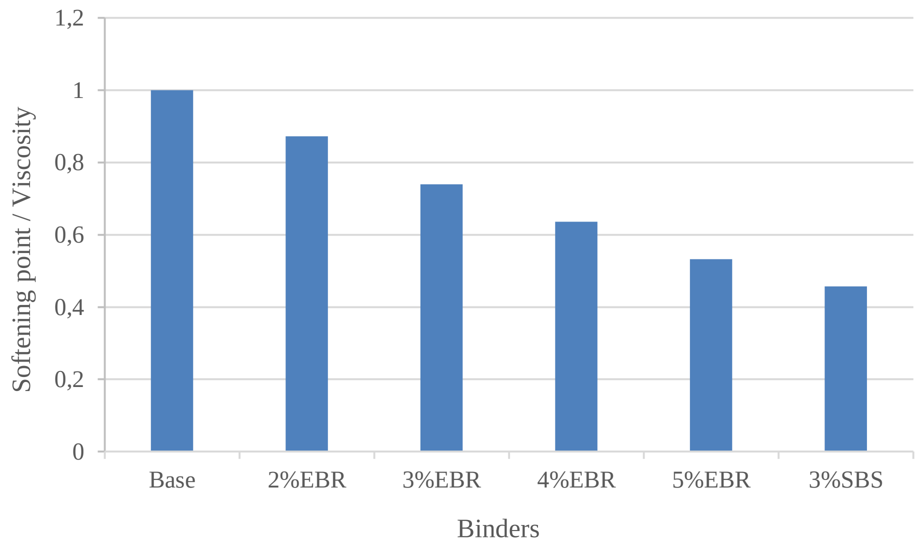

Fig.8 The variation on μ values of binders.

The μ values are negatively affected by the additive content. μ values decrease steadily with the increase of EBR content. 3% SBS modified bitumen give the least value among the binders. The base bitumen is seen the most suitable binder according to this approach. However if a threshold value for both softening point and viscosity value is assumed, the comparison would have been done within the high performance binders and give more realistic results. The threshold value can be determined according to weather temperature and traffic conditions where the asphalt pavement is constructed. If higher than 55 ºC softening point and higher than 1000 cP viscosity is assumed 3% EBR modification will be the most suitable binder.

4. CONCLUSION

The conventional properties of the base, ethylene vinyl acetate (EVA) based resin (EBR) modified and SBS modified bitumen were investigated. B50/70 bitumen was modified with 2%, 3%, 4% and 5% EBR and 3% SBS. The results obtained from the test were compared with each other. Based on the performed tests, the following conclusions could be drawn:

The penetration values of EBR modified bitumen reduce linearly with the increase of additive content. 4% EBR modified bitumen has the same penetration value with 3% SBS modification. 3% EBR modification has a slightly stiffening effect on pure binder.

EBR modification has a significant effect on softening point values. Softening points increases steadily with the increase of EBR content. The softening point value of 3% SBS modification can be achieved by 4.6% EBR. The increment effect of softening point is more pronounced for SBS than EBR modification.

There is not any adverse effect on temperature sensitivity by using EBR additive. More than 3% EBR content PI values increase above +1 value. It is no need to use EBR content more than 3% in order to enhance the temperature sensitivity.

The viscosity increases significantly with the increase of EBR content. However there is no any workability problem even at the highest EBR content. The mean value of 5.4% is needed to provide same viscosity value with 3% SBS modified bitumen. According to the ratio of softening point to viscosity, 3% EBR modification is the most suitable binder among the binders which have more than 55 ºC softening point and more than 1000 cP viscosity value.

Due to low cost than SBS, the EBR the performance of which is near to SBS can be used as an alternative additive material in application in the case of insufficient SBS.

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