Journal of Materials Sciences and Applications
2017; 3(5): 79-82
http://www.aascit.org/journal/jmsa
ISSN: 2381-0998 (Print); ISSN: 2381-1005 (Online)

American Association for Science and Technology

Keywords
SAS-(Surface-Active Substances),
"SP"-(SP-BWTP-Sulfur Product or Byproduct of Welding Electrode Production),
PBB - Polymer Bounded Bitumen

Received: April 22, 2017
Accepted: August 29, 2017
Published: November 16, 2017

Complex Influence of Structure-Forming Additives on the Adhesive and Cohesive Properties of Low-Viscosity Bitumen and Asphaltic Concretes

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Citation
Ibrahim Kasimov. Complex Influence of Structure-Forming Additives on the Adhesive and Cohesive Properties of Low-Viscosity Bitumen and Asphaltic Concretes. *Journal of Materials Sciences and Applications.* Vol. 3, No. 5, 2017, pp. 79-82.

Abstract
In this article was studied complex influence of the new created structure-forming additive of "SP" on the adhesive and cohesive properties of the low-viscosity bitumen, modified by polymer SBS «Kraton D1101». It is shown that structure-forming additive "SP" essentially improves the adhesive and cohesive properties of bitumen and polymer-bitumen. The most effective is complex application of polymer SBS «Kraton D1101» and new additive of "SP".

1. Introduction

Traditional SAS (surface-active substances) which applied in asphaltic concrete mixes, basically raises water and frost resistance of asphaltic concrete, and their efficiency depends on adhesion of bitumen with a surface of mineral materials.

In the course of adhesion there is a diffusion of molecules of bitumen through a surface of mineral materials. Basically this process depends on activity and conditions of interaction between components of bitumen, and also it depend on temperature and mixing technology.

Bitumen with the anionic type additive of promotes improvement of cohesion with a dry surface of mineral materials of carbonic, the ultra-alkaline and the alkaline rocks (limestones, dolomite, basalts, diabase, etc.), which contains more than 50% of oxides of heavy and alkaline-ground metals, and do not form strong communication with a surface of mineral materials of sour and ultra-sour rocks (quartzite, granite, etc.), which structure contains less than 30% of the specified oxides.

2. The Purpose of This Study

Modification of bitumen with polymers, surface-active substances and structure-forming additives allows to increase of durability, stability to plastic deformation, reduces cracking of asphalt pavement and also improves many other qualities of asphaltic materials.

Efficiency of application of surface-active substances (SAS), structure-forming additives (SFA) and other polymers in bitumen materials depends of type, quality and the chemical content of the additives. The greatest attention gives scientific researches of

last years on improvement bitumen was application of polymers. It is necessary for updating of bitumen by polymers containing in the structure of substances, molecules which consist of set of number of the repeating chains, allowing receiving polymer-bitumen binder (PBB) with demanded technical characteristics [32].

This researches and studies on modification of bitumen and asphaltic materials have a big scientific and practical value [1, 2].

3. Experimental Part

In our resent researches was using bitumen BPR 200/300 of "Kirishesky" petroleum refinery factory in Russia. Characteristics bitumen according Standard EN 12591:2009 are close to bitumen with penetration 160/220. Penetration of bitumen at 77 F- is 215 x 0.1 mm (EN 1426). Softening point is -100.4 F. (EN 1427). Brittleness temperature is 73.4. F. (EN 12593). Flash point of temperature is 444.2, F (EN ISO 2592).

PBB has ability to high elastic distortions in the wide range of temperatures (from 131 below till 140°F), and this is the reason of its high steadiness to warmth during excessive operating temperatures (122 to 140°F), elasticity, plasticity and stability to dynamic influence during below temperatures [9].

4. Objects and Research Methods

The most perspective type of the polymer additive is styrene-butadiene-styrene (SBS) a block copolymer. This product has a various parity of blocks butadiene and styrene of linear and radial structure. Polymer SBS - the thermoplastic synthetic rubber and characterized by molecules by the average block, linear or branched out, with firm polystyrene blocks. This polymer produces in Russia under the trade mark «KRATON» and most known representative of this group of materials.

Also we used Styrene-Butadiene-Styrene (SBS) thermal elastic plastic polymer named as a «Kraton D1101» and contains 31% of polystyrene. This copolymer is a famous and widely uses in asphalt mix production in road construction.

By our researches we created and implemented totally new anionic type of surface-active substances (SAS) additive as a byproduct of welding electrode production and can be produced from of coal tar pitch. New trade name is SP-BWTP- has Russian patent and short name is "SP"[8].

This new additive is ointment forming substance, water-insoluble, soluble in acetone, the toluene, containing basically the aromatic poly-cyclic rings (naphthalene, anthracene), with heterocyclic aliphatic groups of nitrogen, Sulphur, oxygen contained combination. It was obtained from byproducts of the coal pith after subsequent neutralization by ammonium. "SP" has molecular mass 210-330 and decomposes at +500°F.

Molecular mass contains is (in%): C = 5,00-5,22; H = 84,10-88,14; O = 2,00-2,30; N = 2,00-2,30; S = 1,00-1,58.

Initial raw materials for the SP contains of the sulphuric acid promoting of penetration of Sulphur group in an aromatic core:

$$\sum RAr - H + HOSO_3H \rightarrow \sum RAr - SO_3H + H_2O$$

Here: *Ar.*-aromatic core - a basis of polycyclic, aromatic and partially heterocyclic combinations.

R - Other hydrocarbons attached to a core.

The toxicological impact of using SP was studied in Research Center of Ecology and Toxicology of Institute of Oncology of State Department of Health Uzbekistan. In the air of working area safety level of impact of SP" was within norms.

In this research were used different mineral materials (aggregates and sand) from fossil rock and marble (alkaline) and granite and sand (sour).

Adhesion properties of bitumen with a surface of stone were defined according to standard EN 13614-2013 (Bitumen and the bituminous bindings). Adhesion was studied by immersion bitumen into the water. It was used photo colorimeter PC - 56 with accuracy characterized by deviation within 0.5% limits. Influence of SP on an adhesion strength of bitumen BPR 200/300 with mineral materials of the various nature are shown in figure 1.

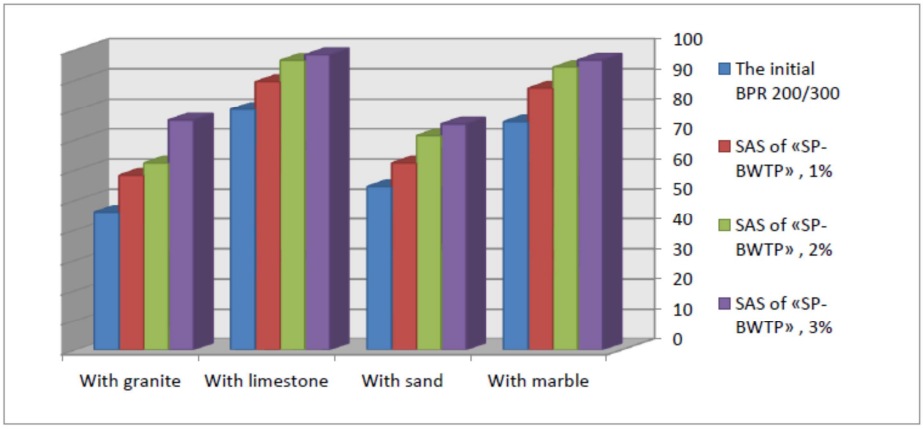

Figure 1. *Indexes of adhesion strength (cohesion: 0-100%) of bitumen BPR -200/300 on samples from a granite, fossil rock, sand and marble depending on contain of the additive of SP.*

Our result shows that with increase of quantity of the additive the influence of adhesion of bitumen to mineral materials also increases. However the optimum quantity of the additive depends of each particular asphaltic concrete mixes designs.

Bitumen with "SP", apparently, starts interaction with fossil rock with forming chemical bonding [3]. As it is known, the surface of grains of a granite is more dense and has the smaller quantity of pores, that is disturbs to a full covering of a surface by bitumen layer and resulting low adhesion. The similar phenomenon is observed when using sand.

At addition anion active "SP" is observed the best results to alkaline rocks, because of influenced decrease interfacial tension and angle of wetting of the bitumen which modified by polymer SBS «Kraton Д1101».

Results of our researches are in the certain consent with the data [1.10].

Cohesive strength of polymer bitumen, modified with SP was studied by our new developed technique, which indirectly describes behaviors of bitumen under natural conditions on the device call "M I I – 100". Two samples in beam shape from marble and a granite in the sizes 4x4x8 centimeter bonded lengthwise by bitumen and polymer bitumen with "SP" and received the sizes of 4x4x16 centimeter Depending on weight of gluing bitumen it was varied a thickness of a bitumen layer.

The nature of the surface of aggregates and its temperature essentially influence on cohesive strength of bitumen, therefore tests was made on the samples which was related to sour (granite) and the alkaline (marble) rocks. An applied mineral material in asphaltic concrete mixes is differ by the nature, and by dispersity and this predetermines a difference of the adhesive and cohesive communications. Thus the important role is played the shallow layer of bitumen which is in a contact zone between particles of mineral materials.

For an establishment of optimum quantity of bitumen in a contact zone the tests were carried out at a various thickness of a bitumen layer and that represents importance of research of the process of formation of asphaltic concrete structure and hardness of the modified bitumen with aggregates. For the ensuring of optimum cohesion hardness from the content of "SP" were tested the bitumen BPR 200/300 modified with 2,0% of polymer SBS «Kraton D1101» [4]. Maximum of these loads at which it is occurred tensile pressure at a bend of the sample, and this is characterized bitumen cohesion. Thickness of a bitumen layer was from 9 to 18 microns. Reduction of a thickness of layer of the modified polymer bitumen is resulted a structure destruction, because of shortage of binding substance in a contact zone. Researches have shown polymer bitumen modified with "SP", which has activity of anions, make positive impact on cohesive strength and forming of harden structure of the binding.

Because we were using bitumen BPR 200/300 with low cohesive strength, so test limits of samples were are limited by temperature 68.F. Application of the structure-forming additive of "SP" considerably raises viscosity of bitumen, that gives the chance the further test of samples at temperature 122.F.

Test data's have shown substantial increase of cohesive strength with additive "SP" on the basis of binding, modified with 2,0% polymer SBS «Kraton Д1101», especially at samples based on alkaline rock (marble) and that, apparently can be explained by chemisorption's of the modified bitumen with mineral materials of the alkaline rock. Our results are also shown phenomenon promotes modification of bitumen with the smaller contents of expensive polymer by using additive "SP".

Influence of polymer and the structure-forming additives on property of bitumen as wetting and flowing on a surface of mineral materials is important, because of bitumen can cover a surface of the mineral material with thin layer or remains on it in the form of a lens.

Decrease in interfacial tension and adsorption of surfaces of mineral materials by bitumen effects of quality of asphaltic concrete mix. It is explained with interaction electrostatic and capillary forces of bitumen with SAS which, moistening a surface of mineral materials, and fill its pores and a cracks. Monomolecular layer of SAS, interacting with grains of mineral materials, improves wettability of bitumen, and improves process of forming of the structure [5].

Using as criteria, along with viscosity, values of an interfacial angle of wetting and interfacial tension, allows defining more objectively the adhesive and cohesive properties of polymer bitumen with the additive of "SP". As a characteristics of bindings of surface of mineral materials in this case are objectively considered [6].

5. Conclusions

This new additive "SP" considerably influences on technical properties and a consistence of the bitumen mix modified by polymer SBS «Kraton Д1101». Modification of bitumen by polymer increases optimum mixing temperature by 86-91.4 °F. But additive of "SP" allows to decrease mixing temperature by 80.6-95 °F, so comes nearer to initial mixing temperature and decrease in energy consumption of the technological processes mixing of the modified bitumen and asphaltic concretes.

Bitumen with low viscosity improves wetting to aggregates, but weaken cohesion. Combination of uses polymer and the additive strengthens bitumen cohesion. At the first stage cohesion increases according quantity of polymer in bitumen. However with increase of the polymer content in bitumen, the smaller influence on cohesion is rendered by the additive of "SP". It is necessary to define optimum mix asphalt design with complex polymer and additives.

Our research of structure-forming additives of "SP" on componential composition of low-viscosity bitumen it is shown that additive leading result in to formation of new asphalts [7]. Adding of 1.0% of "SP" to bitumen result to

increase of content of toluene resins up to 22.0%, following increase quantities of the additive up to 4.0% result to increase which makes only 5,0-7,4% more. At addition of 1,0% of "SP" the quantity of spirit -toluene resins drops on 13,0%. Following increase quantities of the additive up to 4, 0% results in drops quantity of spirit -toluene resins up to 36.0%. 4, 5-5.4% additives are reduced by quantity, paraffin resins, aromatic resins and monocyclic-aromatic resins by 15.3% in comparison with initial bitumen.

It is possible to assume that at interaction of the structure-forming additive of "SP" to bitumen there is a reorganization of its structure and effects to the physical and chemical properties of bitumen. Thus practically does not change quantities with oil parts of bitumen, but decrease in quantity of resins by active interaction of the additives with resins, is thus formed structure of asphalts. Oxidized bitumen contains less oils, more resins and asphaltenes.

Bitumen with the additive of "SP" possesses higher viscosity and plasticity of bitumen at low temperature and viscosity and elasticity at the high temperatures. Thus, complex use of polymer SBS «Kraton D1101» and additives of "SP" positively influencing properties and bitumen structure form the additional super molecular features analytically defined as asphaltenes. Result from our research has been patented [7].

Efficiency of polymers concerning increase property of deformation of asphaltic concrete is high [4], and additives of "SP" improves the adhesive and cohesive properties of bitumen. [3].

Our researches have shown that bitumen with the additive of "SP" possesses high cohesive and adhesion properties of bitumen and also promotes increase water and frost resistances of asphaltic concrete pavement. Jointly uses of polymer SBS «Kraton D1101» and surface active substances "SP" in bitumen results individual effects from each additive. Significantly improves deformation, stability, increases of water, frost and crack resistance of polymer-asphaltic concrete pavement.

Our practical implementation of this innovation was made with Company " UZ Auto-road" in Toy-Tepa and Parkent counties in Uzbekistan by construction highway pavement using 1300 tons of new polymer-asphalt mix with application of new surface-active substances additive of "SP". This new implementation considerably improved quality of bitumen and polymer-bitumen, reduces energy and manpower in asphalt mix production. Efficiency of offered technology was confirmed by Research Center "Polymer building materials» in Moscow (Russia), by Companies "Tash auto road" and "Uzbek roof" and others.

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