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The evaluation of the field performance of the neat and SBS modified hot mixture asphalt

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HIGHLIGHTS

- Neat and SBS modified hot mixture spread and compacted on a road with little traffic.
- Cores taken from the side and middle part of the pavement at different time periods.
- Stiffness modulus stability indirect tensile strength and fatigue resistance examined.
- Excessive hardening at samples over time determined.
- Temperature difference between neat and SBS modified cores 1–2 °C on the hottest days.
- Linear relation between total temperature index and mechanical properties determined.

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ABSTRACT

The reason of using additives in Hot Mix Asphalt (HMA) is related to shortage of raw materials, demand for a longer service life of roads, a need for better physical and mechanical properties of asphalt pavement and thus a decrease in the maintenance and repair expenses. Additives such as polymer are mostly used for this purpose. In the present study, firstly the stiffness modulus, Marshall Stability, indirect tensile and fatigue resistance of the core samples collected at four different periods over a year from a road which is comprised of neat and styrene–butadiene–styrene (SBS) modified HMAs are examined. Secondly, how the qualities of the pavement are influenced by the temperature and environmental factors over a year was examined.

1. Introduction

Bituminous hot mixtures complete their service life when they lose their resistance after a certain period of time due to two reasons: the first one is the mechanical stresses caused by traffic, and the other one is the physical stresses caused by the change of temperature. While the stresses caused by traffic result in plastic deformation and such deteriorations as fatigue cracks, the change of temperature and environmental factors cause low temperature cracks and peeling on the pavement even if there is no traffic loads. If the two factors coexist, the deterioration gets faster. Additives are used in order to increase the performance of the superstructure by enhancing the qualities of the bituminous hot mixtures. Additives could be either mixed with binder or added directly into the mixture [1]. Among additives which are mixed with bitumen, there are polymers that are used mostly [2]. Such polymers as styrene–butadiene–styrene (SBS), ethylene–vinyl acetate (EVA), styrene–ethylene–butylene–styrene (SEBS), poly ethylene (PE) and polypropylene (PP), polyvinyl chloride (PVC) have been tested in bituminous hot mixtures and it has been observed that this affects its many parameters such as stability, resistance against moisture damage and fatigue resistance [3–6].

Moisture damage seen in bituminous hot mixtures is defined as the loss of its integrity as a result of the binders losing its cohesion and the deterioration of the adhesion between the aggregate and the bitumen. Adhesion loss occurs when water seeps in between the bitumen and the aggregate and thus the binder comes out of the aggregate. On the other hand, cohesion loss occurs as a result of the deterioration of the binders [7]. The binding properties deteriorate due to the exposure to high heat in the production phase. The change in the mechanical and chemical structure of the binder

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continues at a lower rate during its service life [8,9]. The aging of the mixture during production, laydown and pressing is simulated by the rolling thin film oven (RTFOT) in the laboratory while the aging in a longer period is simulated by the pressure aging vessel (PAV) on the RTFOT's remnant. In many studies in the literature, the aging of the mixture has been examined by determining the aging characteristics of the binder in the mixture identified in the laboratory on the basis that the characteristics of the binder influence considerably the mixture itself. In one of the studies, it has been pointed out that the softening point of the neat binder in the 70/100 penetration type increased 8% and 18% after RTFOT and PAV, and its viscosity at 135 °C increased twice and three times more [10]. It has also been determined that when RTFOT was carried out for 85, 170 and 255 min, the viscosity of the neat binder increased 1.53–2.15 and 3.95 times more, leading to the increase of the neat binder asphalten rate. After the PAV test was applied to the same samples, these numbers increased 6–9.5 and 13.2 times more [11]. In the study, which examines the warm mixture additives that decrease the aging characteristic of binders, first neat and modified binders aged for a short period of time at RFOT. Then, they were aged for 100 days at 60 °C and 1 mm thickness. It was observed 100 days later that, the complex module of the neat binder increased 14 times more whereas that of the warm modified mixture got higher 7–11 times more [12].

Lu et al. examined the durability of polymer-modified binders in terms of resistance to aging, rutting and cracking. Asphalt samples were taken from test roads where polymer-modified binders were tested in different layers. The chemical and mechanical tests were also conducted on original binders and on those aged at laboratory by RTFOT and PAV. It was found that the polymer-modified binders demonstrated better rheological properties than the unmodified pen bitumen, even after several years in asphalt pavements. For the modified binders with styrene–butadiene–styrene (SBS) polymers, good aging resistance was also observed [13].

The main purpose of the present study is to examine how the stiffness, stability, indirect tensile and fatigue properties of the samples taken from the neat and SBS-modified pavement changed over a one-year period.

2. Material and method

In this study, the hot mixture half of which is neat and the other half is modified was laydown and compacted on a secondary road for 50 m. It was determined that 7432 equivalent standard axle loads passed on this road over a year. Since it was a secondary road, minor axle roads were ignored and not taken into examination. The effects of the temperature on stiffness, stability, and indirect tensile and fatigue resistance were studied.

As a neat binder, asphalt binder of B 50/70 type taken from TUPRAS refinery was used. In modification, KRATON D 1101, which contains Styrene–Butadiene–Styrene (SBS) block copolymer was used. The SBS rate was 5%. The physical properties of the neat and SBS bitumen were retained. Test values belong to neat and SBS binders. The penetration B-55, B-61, specific gravity 1.022 g/cm^3, 1.017 g/cm^3, fraass breaking point −17 °C, −17.5 °C, and the softening point 79.5 °C, 76.5 °C were determined, respectively. Binders have a value that is above the limits of the specification as softening point, but the other properties of binders stay within limits. Base bitumen aggregate characteristics and the gradation are given in Table 1.

The optimum bitumen content of the neat and modified mixtures were determined by 75 blows on both sides according to the Marshall Method. The optimum bitumen content were determined as 4.95% and 5.24% for neat and modified mixtures, respectively.

From the pavement laydown and compacted according to the predetermined design, the core samples were taken at four different time periods on the vehicle wheel passing line and banquette of the road. The thickness of the sub-base permanent way is 20 cm, the base layer is 20 cm, and the asphalt pavement is 10 cm were designed. The core samples were sized to those of Marshall Samples and they were tested by stiffness modulus, indirect tensile, fatigue and marshall tests.

The neat samples on road side are represented by NK; the SBS modified samples on road side are represented by SK; the neat samples on vehicle wheel passing line are represented by N, and the SBS modified samples on vehicle wheel passing line are represented by S. Fig. 1 shows the neat and SBS-modified layers and how the core samples were taken by the core device. The average volumetric characteristics of the core samples are given in Table 2.

3. Experimental study

3.1. Temperature measurement

Temperature measurements were taken at a depth of 20 mm from the coating surface. Fig. 2 shows how the temperature of the neat and SBS modified layers changed over a one-year period (from January to December).

Table 1
Aggregate characteristics and gradation.

Tested property	Standard		Coarse	Fine	Filler	Specification limit	
Abrasion loss% (Los Angeles)	ASTM C 131		20.5	–	–	Max 35	
Frost action% (with Na_2So_4)	ASTM C 88		1.20	–	–	Max 10	
Peel strength (%)	ASTM D903		60–70			Min 50	
Flatness index (%)	BS 812		16.1			Max 30	
Water absorption (%)	ASTM C127		0.38	0.88	–		
Specific gravity (g/cm^3)	ASTM C127		2.733	–	–		
Specific gravity (g/cm^3)	ASTM C128		–	2.678	–		
Specific gravity (g/cm^3)	ASTM D854		–	–	2.764		
Sieve size (mm)	12.5	9.5	4.75	2.00	0.425	0.18	0.075
Passed (%)	100	90.4	56.6	36.6	18.2	13.0	10.3

Fig. 1. The core samples taken.