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Utility of polyparaphenylene terephtalamide fiber in hot mix asphalt as a fiber

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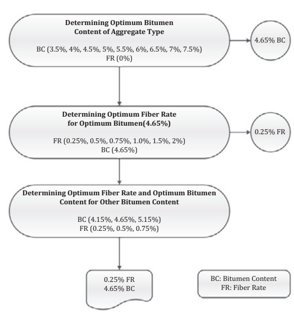
HIGHLIGHTS

- In this study, utility of PT as fiber in HMA is researched.
- The optimum bitumen content is determined as 4.65% by Marshall Stability test.
- Samples with different bitumen contents, and different fiber rates was produced.
- Optimum stability is obtained from 4.65% bitumen content and 0.25% fiber rate.

GRAPHICAL ABSTRACT

Flow chart of the study



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ABSTRACT

In this study, utility of polyparaphenylene terephtalamide (PT) was investigated in hot mix asphalt as a fiber. For this aim samples were prepared with limestone aggregate at different proportions. Marshall Stability test was applied and optimum bitumen content was determined. In the second stage of the study, new samples were prepared using different polyparaphenylene terephtalamide fiber (PTF) rates of 0.25%, 0.50%, 0.75%, 1.00%, 1.50%, 2.00% based on optimum bitumen content. When examining test results, samples which prepared using 0.25% PTF rate gave highest Marshall Stability result. At the final stage of the study, different bitumen contents (4.15%, 4.65% and 5.15%) were conducted for the best fiber rate (0.25%) and close to this result (0.50% and 0.75%). Thus, the effect of bitumen content on determined fiber rate at the second stage of the study was investigated. Also Indirect Tensile (IDT) Strength Test was performed on hot mix asphalt (HMA) samples preparing at 0.25%, 0.50% and 0.75% fiber rates and moisture sensitivities were determined. All results showed that, the best fiber rate was 0.25% and determined optimum bitumen content remain constant with the fiber additive for the reference samples. Besides, some sample groups which prepared using different PTF rates proved the specification limits and it was said that; PTF can be used in asphalt concrete as a fiber additive.

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1. Introduction

Hot mix asphalt – HMA was generally used in road construction. Asphalt concrete was preferred because of its ride comfort, stability and resistance to water. But pavement engineers were leaded to an alternative materials and techniques because of economical dimension of materials, good evaluation of energy and sources [1].

The aim of the pavement design is to determine the thicknesses of the layers that are needed to bear safely the repetitive loads under environmental circumstances without large deformations or cracking, based on the characteristics of the materials to be used in these layers [2,3].

One of the most important characteristics of the materials to be used in road construction is the contribution to the achievement of project requirements in an economical manner. Besides, the parameters such as long economic life, low maintenance/repair costs, low construction and repair time, compatibility with the environment, use of waste materials, and adaptability to quality control procedures should also be taken into consideration [3,4].

Current researches include the studies focusing on increasing the performance and lifetime of roads. It is aimed to increase the performance and lifetime of roads by using different additive materials [5–8].

In spite of a high number of applications with fibers, their use in pavement technology as asphalt binder inside bitumen is a rather new field of study [9,10]. Some researchers have recently used fibers in different forms in their studies [11–19].

In this study, the usability of PT as fiber on flexible pavements was investigated in order to bear the stresses occurring due to traffic loading. For this aim, Marshall Mixtures were prepared and evaluated by using these materials with different PTF contents and different bitumen contents. To determine the best fiber rate, Marshall Stability Test for the best stability and Indirect Tensile Strength Test for the most moisture susceptibility were performed.

Polyparaphenylene terephtalamide, one of the high performance textile fiber, was used in the study because of its high resistance properties. The fiber is a fiber that comes from aromatic polyamide family which resist five times more than steel [20–22].

In this study, it was observed that the use of PTF additions in HMA concrete had a positive impact for stability. But, it may be considered by adding them only to binder course in order to avoid the negative effects (i.e. come up to the top of the surface and damage the tires and comfort of drivers) due to PTF that can be damage for vehicle tires.

2. Materials

2.1. Aggregates

In this study, limestone aggregates were used obtained from Isparta region for the asphalt mixture. Physical and mechanical properties of aggregates used in the mixture were carried out through examinations according to the ASTM. Test results were given in Table 1 for the aggregates used in the mixture.

In this study, sieve analyses curve was obtained from Highway Specification when preparing mixtures (Table 2) [26]. Based on gradation limits below, top and bottom of sieve diameter of No.4 were considered when preparing mixtures.

2.2. Bitumen

B50/70 class of bitumen was used in this study. Bitumen used here was collected from Turkey Petroleum Refineries Corporation (TUPRAS). Properties of B50/70 class of bitumen were given in Table 3.

2.3. Polyparaphenylene terephtalamide fiber (PTF)

Scope of this study is to increase the stability of asphalt pavements using PTF. PT is chosen because it has the high resistance, and it can reside the chemical reactions caused by bitumen. Unlike the other fibers PT has the high temperature resistance [20]. With outstanding features (like high resistance, high elasticity modulus and thermal stability of PT), manufacturing costs is higher than the standard fiber. In addition with this features, PT has the low UV resistance. So that, if PT is used in the areas which exposed to directly sunlight it needs to coating. PT is commonly used in uniforms of dangerous work group especially ballistic, aircraft wings, military helmet, rope used at parachute, climbing and areas which sought high performance together with the lightweight [20–22].

PTF is in the form of multifilament which is waste of yarn bobbin. Fiber diameter is determined as ~18 μm by Motic light microscope and image analyzer on different single filament. Multifilament fibers was cut length of 30 mm, mixed homogeneously and used in the mix design. 30 mm (approximately 1 inch) fiber length is used to dispersion the fiber in the mix randomly. Cross-section of PTF, smooth and round, shown in the Fig. 1.

3. Experimental researches

3.1. Marshall Stability test results

In the study, samples were principally prepared according to the gradation limits, determined by General Directorate of Highways, and different bitumen contents (3.5%, 4%, 4.5%, 5%, 5.5%, 6%, 6.5%, 7%, and 7.5%). Different six graphs belonging to the test results were evaluated. Optimum bitumen content was determined as 4.65% from the graphs. The flow chart of the study was given in Fig. 2.

Study is discussed in three parts. First one is the determination of the optimum bitumen content, the second one is the determination of optimum fiber rate according to different PTF rates (0.25%, 0.50%, 0.75%, 1.00%, 1.50% and 2.00%) with optimum bitumen content. After all, the third one is the determination of Marshall Stability, flow value, Marshall Quotient (MQ), void volume value (Vh), voids filled with bitumen value (Vf), voids in mineral aggregate (VMA) value and bulk specific gravity of asphalt samples (Dp) (Figs. 3–9). The test results showed that the highest stability is obtained as 1087 kg from 0.25% fiber additive samples in terms of Marshall Stability. Also the lowest stability is obtained as 321 kg from 2.00% fiber additive samples. The stability of fiber samples increases as 18% compared to the reference samples.

After the rate of 0.25% fiber additive, stability decreases with the increase of fiber rate. Also after the rate of 0.50% fiber additive, the stability decreases under the stability of reference samples. Even more the stability of 1%, 1.5% and 2% fiber additive samples is decrease under the 750 kg, specification limit (shown in Fig. 3 with red line). Marshall Stability graph changing depend on fiber rate is given in Fig. 3. The upper and lower limits are shown on the graph.

According to the flow charts, the lowest flow value is obtained as 3.94 mm from 0.25% fiber additive samples and the flow values

Table 1
Aggregate properties.

Sieve diameter	Properties	Standard	Limestone
4.75–0.075 mm	Unit weight (g/cm^3)	ASTM C 127-88 [23]	2.830
	Water absorption (%)	ASTM C 127-88	0.130
25–4.75 mm	Unit weight (g/cm^3)	ASTM C 128-88 [24]	2.605
	Water absorption (%)	ASTM C 127-88	2.800
	Abrasion loss (%) (Los Angeles)	ASTM C 131 [25]	20.38