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Investigation of usability of basalt fibers in hot mix asphalt concrete

Nihat Morova *

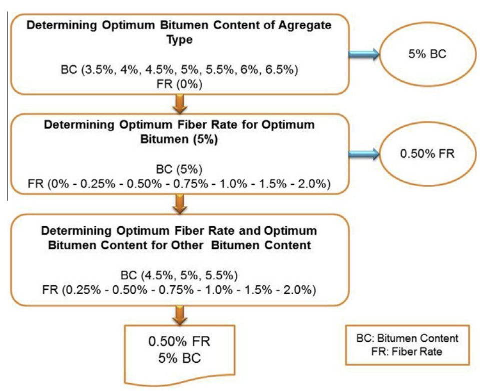
Manufacturing Engineering Department, Faculty of Technology Suleyman Demirel University, 32100 Isparta, Turkey

HIGHLIGHTS

- In this study, it was investigated that the usability of basalt fibers in hot mix asphalt concrete.
- Based on the determined value for the optimum bitumen content, specimen series with different fiber ratios were prepared.
- The best results were obtained for 5% bitumen content and 0.50% basalt fiber addition.

GRAPHICAL ABSTRACT

Flow chart of laboratory works.



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ABSTRACT

In this study, the usability of basalt fibers in order to bear the stresses occurring at the surface layer of pavement, which are directly subjected to the traffic effects, was investigated. In this context, specimens were produced and tested under Marshall Stability Test, and the optimum bitumen content value for the aggregates sample to be used was determined. Based on the determined value for the optimum bitumen content (5%), three specimens for each of a series of different fiber ratios were prepared. The optimum value for fiber ratio that results in the best stability value was determined. In order to determine whether the best fiber ratio (0.50%) might result in a better stability value for other bitumen contents, extra specimens were prepared with different bitumen amounts and with the best and five different fiber ratio values close to the optimum value. These specimens were tested under Marshall Stability Test and the obtained results were evaluated.

1. Introduction

Hot mix asphalt (HMA) concrete is a combination of aggregate and asphalt cement. The aggregate acts as the structural skeleton of the pavement and the asphalt cement as the glue of the mixture. The mineral aggregate, including coarse and fine particles in asphalt paving mixtures, encompasses approximately 90% of volume of HMA. The properties of the aggregate have direct and significant effect on the performance of asphalt pavements [1]. Asphalt concrete is the most commonly used material in pavement due to its superior service performance in providing driving comfort, stability, durability and water resistance [2,3].

Highways are rather high cost structures, and for that reason, it is obligatory that the materials to be used for their constructions should be appropriately designed. Flexible pavements are designed so as to have a 20 years project life. For that reason, the load distributions that would occur on these structures should also be

* Tel.: +90 246 211 14 24; fax: +90 246 237 12 83.
E-mail address: nihatmorova@sdu.edu.tr

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Table 1
Properties of aggregate used in the tests.

Sieve diameters	Properties	Standard	Limestone aggregate
4.75–0.075 mm	Specific gravity (g/cm^3)	ASTM C 127-88 [22]	2.660
	Saturated specific gravity		2.652
	Water absorption (%)		0.130
25–4.75 mm	Specific gravity (g/cm^3)	ASTM C 128-88 [23]	2.329
	Saturated specific gravity		2.428
	Water absorption (%)		2.800
	Abrasion loss (%) (Los Angeles)	ASTM C 131 [24]	20.38

calculated and included in the design process. The current research subjects 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 [4].

The researchers that previously worked on this subject clearly indicated that the use of fiber in the pavements and asphalt mixtures has a strengthening effect. Fibers can be used especially in the mixtures with continuous grading and in Stone Mastic Asphalt (SMA) mixtures in order to overcome the deterioration of asphalt during carriage and construction of the mixture, as well as in asphalt stabilization [5,6]. The use of fibers alters the visco-elasticity characteristics of the mixture [7]; enhances its dynamic modulus [8], enhances sensibility against humidity [9], enhances flow coherence, and provides resistance against the rutting [10,11]; as well as decreases the amount of reflective cracks in asphalt mixtures and pavement [12–14].

Considering the competition in the market and the ever-increasing economic and environmental requirements for reinforcements in polymer composites, the reinforcement potential of newer and newer fibers is investigated in the leading research institutes of the world. Basalt fiber is a possible polymer reinforcing material and can be applied in polymer matrix composites instead of glass fiber. The increasing application of basalt is noticed as an insulating material in the construction and automotive industry and less hazardous than asbestos fiber. Basalt fabrics are produced for the structural, electro-technical purposes. Structural applications include electromagnetic shielding structures, various components of automobiles, aircraft, ships and household appliances. Wide application of basalt fiber in following industry fields: building, automotive industry [15].

Basalt Fiber, which was developed by Moscow Research Institute of Glass and Plastic in 1953–1954, is a high-tech fibers invented by the former Soviet Union after 30 years of research and development, and its first industrial production furnace that adopted 200 nozzles drain board combination oven bushing process was completed in 1985 at Ukraine fiber laboratory. It has wide range of application and great prospects because of its high performance and cost-effective. Using a natural volcanic basalt rock as raw material, basalt fiber is a typical silicate fiber that were produced by putting raw material into furnace after their broken,

Table 2
Gradation limits of aggregates.

Sieve diameter (mm)	Limit values [25] passing %	Gradation of mixture % passing	Weight (g)
25 mm (1″)	100	100	0
19 mm (3/4″)	80–100	85	186.75
12.5 mm (1/2″)	58–80	70	186.75
9.5 mm (3/8″)	48–70	60	124.5
4.75 mm (No. 4)	30–52	40	249
2.00 mm (No. 10)	20–40	30	124.5
0.425 mm (No. 40)	8–22	15	186.5
0.180 mm (No. 80)	5–14	10	62.25
0.075 mm (No. 200)	2–7	6	49.8
Filler	0	0	74.7
Total	100%	100%	1245

Table 3
Basic physical characteristics of the bitumen.

Characteristics of Bitumen		
Test name	Average values	Standard
Penetration (25 °C)	60–70	ASTM D5 [26]
Flash point	180 °C	ASTM D92 [27]
Fire point	230 °C	ASTM D92 [27]
Softening point	45.5 °C	ASTM D36 [28]
Ductility (5 cm/min)	>100 cm	ASTM D113 [29]
Specific gravity	0.996 g/cm^3	ASTM D70 [30]

Fig. 1. Basalt fibers [31].

Table 4
Properties of basalt fiber [31].

Properties	Values
Thermal	
Sustained operating temperature (°C)	680
Minimum operating temperature (°C)	−2.60
Melting temperature (°C)	1450
Physical/mechanical	
Density (g/cm^3)	2.8
Filament diameter (μm)	13–20
Tensile strength (MPa)	2500
Elastic modulus (GPa)	89
Elongation at break (%)	3.15
Chemical resistance	
H_2O (%)	1.5
2*n* NaOH (sodium hydroxide) (%)	2.75
2n HCI (hydrochloric acid) (%)	2.2