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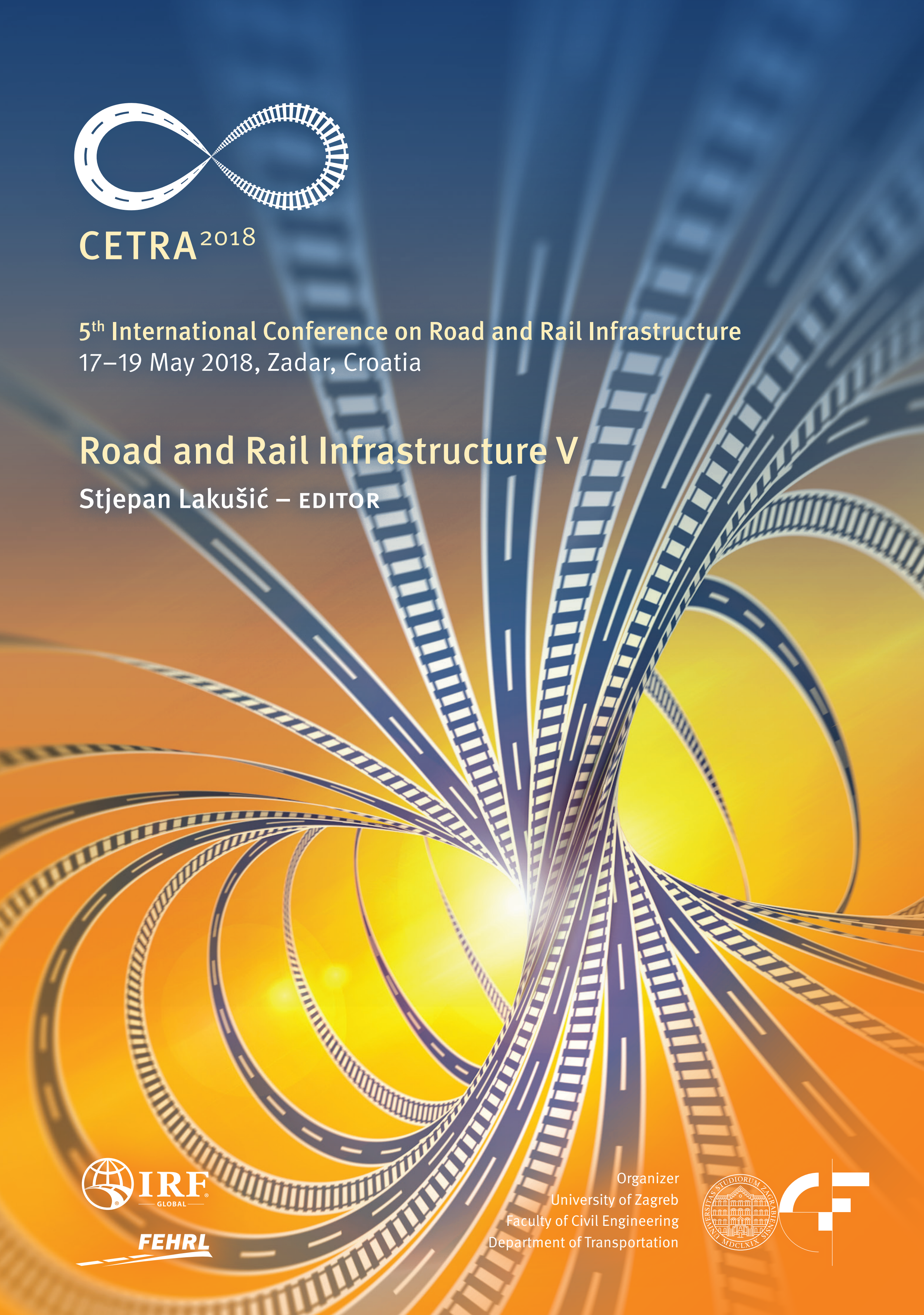
5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR



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USABILITY OF HEMP FIBER IN DENSE GRADED HOT MIX ASPHALT MIXTURE

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Abstract

The usage of fibers as an additive to reinforce the paving material have a long history like decades in the World. In stone matrix, open graded or porous mixtures, these fibers were commonly used to increase the adhesion between aggregate and binder and this property was usable in asphalt mixture for preventing the drain down of binder. Also, fibers were used for improving crack resistance and increasing stability in dense graded asphalt mixtures too. As, the aphalt is generally acknowledged as a strong material for compression loads and weak for tension loads. In theory, fibers that have high tensile strength can reduce the stresses relatively to weak asphalt mixtures by transferring the stresses for increasing the tensile strength of the mixture. For investigating the efficiency of the fibers there have been many types and forms of fibers used either experimentally or routinely in asphalt mixtures. These investigations leaded researchers to the plant-based fibers like woody (such as jute, flax, straw, and hemp), leaves and seeds. For this aim the usability of hemp fiber examined in this study. For examining the test results, specimens were prepared in four different proportions including reference specimens. Volumetric mix design was used to determine the optimum bitumen content. Then Indirect Tensile (IDT) Strength Test was applied to HMA specimens.

Keywords: hemp, fiber, dense grade, hot mix asphalt, indirect tensile strength

1 Introduction

The important part of highways is consisted of pavements. Hot mix asphalt pavements comprise of a great majority of pavements. Three important components of hot mix asphalt can be stated as aggregates, bitumen and additives. Even if aggregates are not adequate alone, they provide stability of mixture. Bitumen is a binder which needed for holding aggregates together and with the aid of bitumen, working of mixture together can be provided. This property is crucial for the life of pavement. Also, additive materials such as filler, rubber, plastic, fiber, antistripping agents and waste materials are used to increase the performance of mixture. Fibers are frequently used to increase the performance of pavements. It has been seen that, depending on fiber content of mixture, optimum asphalt rate, air void, void in mineral aggregate increase [1]. Reinforcement by fiber increases fatigue life and helps to resist rutting [2], enhances viscosity of binder [3]. Also, reinforcement with fibers provide required resistance to tensile strengths and improving in tensile strength increases the adhesion [4]. In their article, Abtahi et al. [5], have given place to some of different fibers such as polyester fibers, mineral fiber, cellulose fiber, carbon fibers, and glass fibers. In addition to these, natural fibers has been used in studies which are about asphalt concrete. The effect of jute fibers on the performance of warm mix asphalt at low temperature was evaluated [6]. Sisal and coconut fibers was used in discontinuous asphalt

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mixtures and these fibers displayed good strength [7]. Also, Kar [8] investigated the effect of natural fiber on stability of stone mastic asphalt by using sisal fiber. In addition to these, coir fiber and Posidonia oceanica fiber was added in asphalt mixtures to improve the performance [9, 10]. Hemp fibers which has different lengths were used by being added in asphalt mixtures different ratios for evaluate the effect of this fiber on the fatigue behaviour [11]. Hemp fiber, which has been used in present study too, is of strong and durable. Thus, in many products including building materials, using of hemp fiber may be desired. Hemp fiber was used to increasing the durability of hot mix asphalt. Therefore, hemp fiber is incorporated to structure of hot mix asphalt at three different rates (1, 2 and 3 ‰) with the help of Superpave Gyratory Compactor. Durability and tensile strength of obtained mixtures were tested.

2 Material and method

2.1 Aggregate

Limestone aggregate, supplied form Isparta Municipality, is selected for the study. An aggregate gradation according to volumetric mix design procedure is determined and shown in Figure 1. The basic properties of the aggregates are given in Table 1. The study is performed for the wearing course of the pavement.

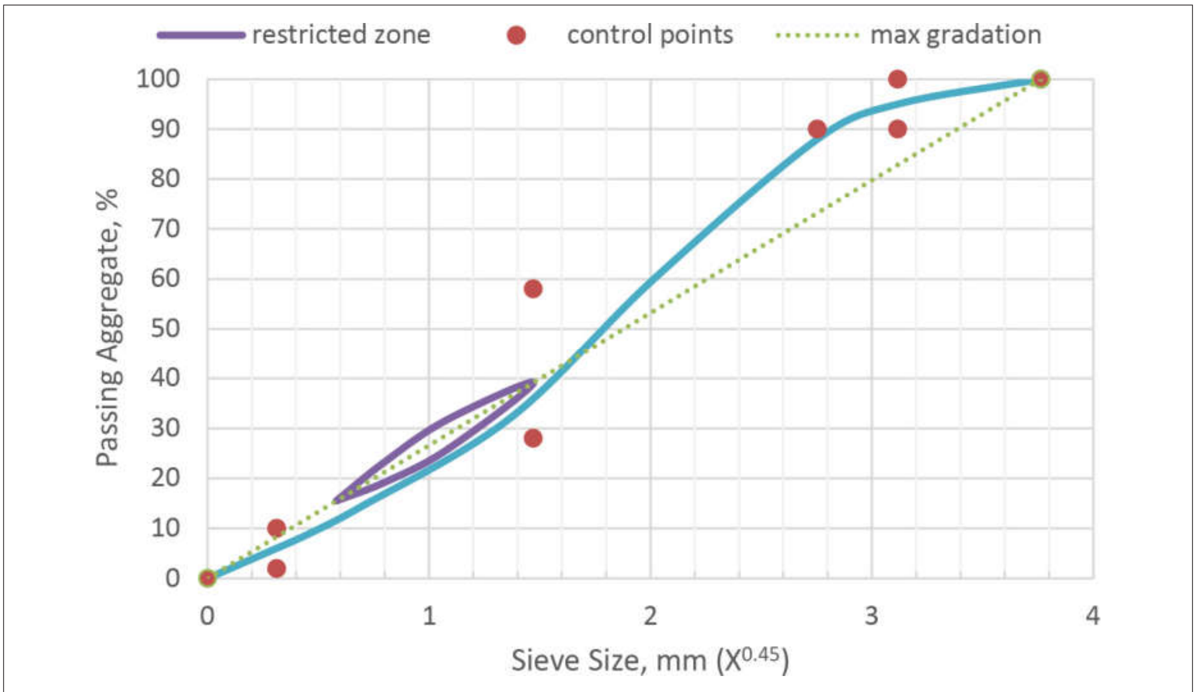

Figure 1 Selected aggregate gradation

Table 1 Aggregate properties used in this study

Sieve Diameter	Property	Value
0.075 mm	Specific Gravity (g/cm³)	2.71
4.75 – 0.075 mm	Specific Gravity (g/cm³)	2.76
	Water Absorption (%)	0.14
25 – 4.75 mm	Specific Gravity (g/cm³)	2.84
	Water Absorption (%)	2.78
	Abrasion Loss (%)	20.38

2.2 Bitumen

Bitumen is also supplied from Isparta Municipality with a penetration grade of 50/70. According to the Superpave binder tests, the performance grade of the bitumen is determined as PG 64-22. Basic bitumen properties are given in Table 2. Optimum bitumen content is determined according to the AASHTO (2001) Superpave volumetric mix design procedure. First, specimens were compacted with 4, 4.5, 5 and 5.5 % binder content using gyratory compactor for 125 gyros. Bitumen rate corresponding to the 4% air void is selected in accordance with the obtained air voids. The selected bitumen rate is the predetermined bitumen rate. The predetermined bitumen rate's void rate in mineral aggregates and voids filled rate in mineral aggregates should ensure the specification values. So, the predetermined bitumen content is selected as optimum binder content, 4.6 %.

Table 2 Basic binder specifications

Test	Average value
Penetration (25°C)	50-60
Flash Point	180°C
Combustion Point	230°C
Softening Point	53.1°C
Ductility (5 cm/min)	>100 cm
Specific Gravity (g/cm^3)	0.995

Hemp fiber, used in this study, is taken and cut for 3 cm long pieces (Fig. 2). So, the mixing procedure is more easy, the fiber don't get clumping and the fiber are long enough for establishing a good cohesion between bitumen coated aggregate. They have been added 1, 2 and 3 ‰ by weight of the mortar by mixing procedure. The specific gravity of the fiber is determined as 1.49 g/cm^3.

Figure 2 Sample of used hemp fiber

2.3 Indirect tensile strength test

To determine the moisture susceptibility and the strength values, indirect tensile strength (ITS) test has been done. The test is achieved in accordance with AASHTO T283 standard. Six mixings have been prepared and compacted for each hem fiber additive rate and reference specimen. The compaction was undertaken using Superpave Gyratory Compactor, and the specimens have been compacted till 5 % air void, specification limit of Turkey [12]. Half of them are conditioned (ITSc) and the other half is left as unconditioned (ITS_u).

3 Results and discussion

As the outputs of the test results, optimum binder content for each hemp fiber additive is given in Fig. 3. As shown, the optimum binder content is increasing by increasing the hemp fiber additive rate. Fig. 4 shows the indirect tensile strength values of each hemp fiber additive ratio. As seen in Fig. 4, the strength values of hemp fiber added specimens are decreasing by the increase of the additive ratio.

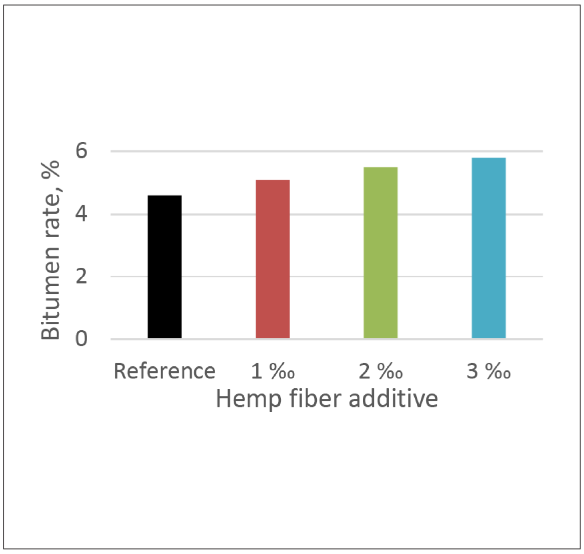

Figure 3 Optimum binder contents

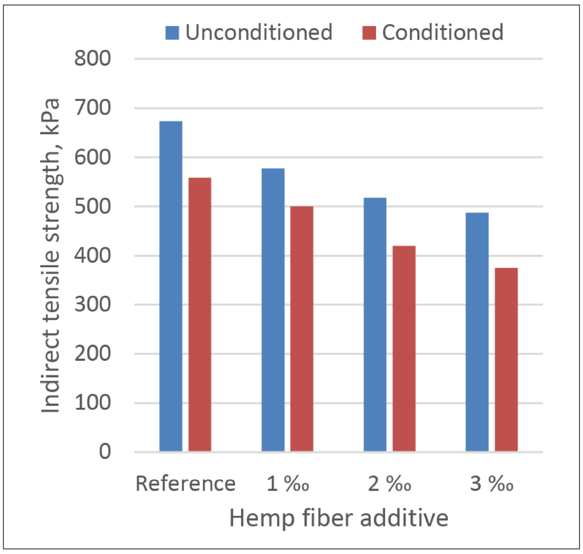

Figure 4 Optimum binder contents

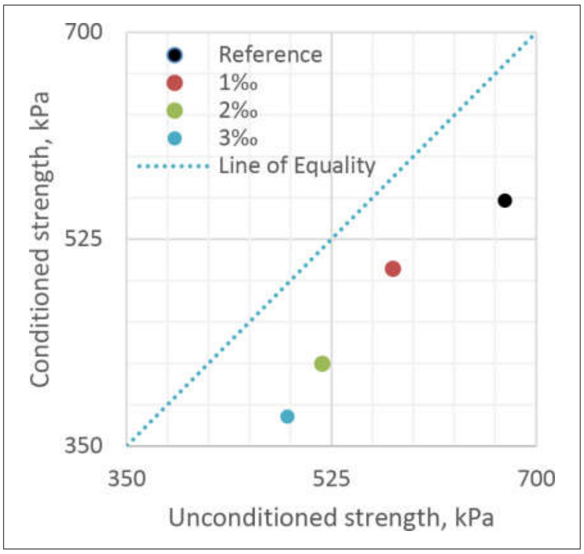

Figure 5 Comparison of the conditioned and unconditioned strength values

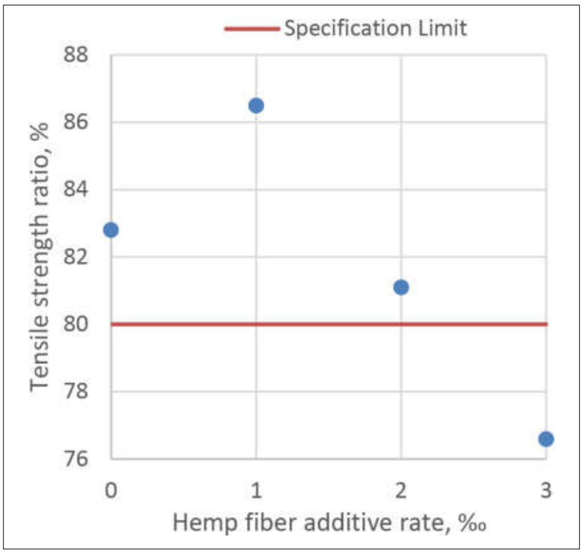

Figure 6 Tensile strength ratios

As seen in Fig. 5, the conditioned and unconditioned strength values and the distances to the line of equality is shown. The closest specimen is determined as 1 ‰ hemp fiber additive. The tensile strength ratios (TSR) are shown in Fig. 6. In according to the Fig. 6, 1 ‰ hemp fiber additive has the most TSR rate. However, 3 ‰ hemp fiber additive didn't ensure the TSR limit value.

4 Conclusion

Hemp as a fiber additive is studied in this paper. Therefore, hemp fiber is added into the mortar in three different rates (1, 2 and 3 ‰). Specimens have been testes for indirect tensile strengths and tensile strength ratios. As a result, hemp fiber additive decreases the strength values of the specimens. However, the results are usable in real conditions. According to tensile strength ratio values of the specimens, the moisture susceptibility of the specimen with 1‰ hemp fiber additive is lower than the reference specimen. But, adding more than 1‰ hemp fiber is decreasing the tensile strength ratio.

In general, hemp fiber in low additive rate is decreasing the moisture susceptibility of the specimens. However, future performance tests should be done for a precise decision.

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