THE EFFECT OF CRUMB RUBBER ON THE ASPHALT MIXTURE PROPERTIES

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Abstract

Crumb rubber for asphalt mixture modification can be used in two ways: incorporate to bitumen (wet process) or incorporate to aggregate (dry process) mixture before adding bitumen to mixer. Wet process has some disadvantages related to need of reasonable modification of asphalt plant. Dry modification process has more potential due to more simple technology and possibility to add higher quantity of crumb rubber comparing to the wet process. The performance of crumb rubber modified asphalt mixture mainly depends on several factors as crumb rubber type, content and rubber particles size. However, limited number of publications reported the results of dry process crumb rubber modified asphalt mixtures performance. This paper analyse the effect of different amount of crumb rubber on modified asphalt mixture air void content, water sensitivity and stiffness. Test results revealed the effect of crumb rubber and maximum recommended amount for asphalt mixture modification by dry process.

Keywords: crumb rubber, dry process, rubber modified asphalt mix, air voids, water sensitivity, stiffness

1 Introduction

Rising number of vehicles use cause international problem – numberless tire waste. The bright side is that globe is progressing towards circular economy and tire's materials can be recycled in various ways. For example, scrap tire can be grinded into crumb rubber of rubber powder and further reused as material in road sector. Steel from tire can be smelted and reused as desired. Textile fibers from tire can be reused in cleanup material, carpet, and fiberglass [1--3]. In road sector crumb rubber or crumb powder are used to compose rubberized asphalt pavement. There are two standard methods to incorporate crumb rubber into asphalt mixture: wet process and dry process. Crumb rubber particles are mixed with bitumen and then applied into the asphalt mixture in wet process. Contrary, crumb rubber particles are directly added into aggregate mixture before bitumen in dry process [4, 5]. As a result, wet process provides higher quality adhesion among crumb rubber and bitumen particles, following and better asphalt mixture performance. Due to, wet process is more approved by researches [6-9]. Nevertheless, larger amount of crumb rubber can be utilized in asphalt mixture during dry process [6, 10]. Moreover, there is no need to use additional equipment as bitumen modification plant for crumb rubber appliance during dry process.
Arabani et al. [11] used crumb rubber from 1.0 % to 5.0 % in asphalt mixture. Research revealed that reference mixture without crumb rubber has best stiffness values. Also, increasing amount of crumb rubber decreases values of stiffness [6,11]. Furthermore, crumb rubber usage causes a little drop of indirect tensile strength [12, 13]. Yet, even after a freeze-thaw

cycle there is no harmful effect for water sensitivity [12]. Asphalt mixture fatigue resistance improves after adding crumb rubber [14,15]. Also, asphalt mixture resistance to cracking improves using crumb rubber [16]. Abdul Hassan et al. [17] compared effect of different size of crumb rubber on asphalt mixture performance. Research showed that fine crumb rubber improves rut resistance most in comparison with coarse aggregate and reference mixture. Despite dry process benefits, the results of crumb rubber modified asphalt mixture depends on mixture type, bitumen amount, crumb rubber particle size and amount. Moreover, there is relatively low number of researches carried out with dry process, which means it is still unclear what amount of rubber is desirable and how crumb rubber modifies asphalts mixture properties. The goal of this research is to evaluate effect of crumb rubber and it's amount on asphalt mixture properties such as air voids, water resistance and stiffness.

2 Materials and test methods

2.1 Materials

In order to evaluate crumb rubber effect on asphalt mixture performance, two types of asphalt mixtures were selected – AC 16 PD and AC 16 AS. Entire list of components of asphalt mixtures are presented in Table 1. Crumb rubber fraction in mm 0-0.6. Three different amounts 0.5 %, 1.0 %, 1.5 % of crumb rubber and reference asphalt mixture with 0.0 % of crumb rubber were analysed in this research. Designed gradations of asphalt mixtures AC 16 PD and AC 16 AS are presented in Figure 1 and 2. Asphalt mixtures were mixed according to the requirements of the standard LST EN 12697-35.

Table 1 Components of asphalt mixtures

Asphalt mixture type	**Aggregate**	**Filler**	**Bitumen**	**Crumb rubber particles size** [mm]	**Bitumen content** [%]
AC 16 PD	dolomite	limestone	70/100	0-0.6	5.2
AC 16 AS	granite	limestone	50/70	0-0.6	4.2

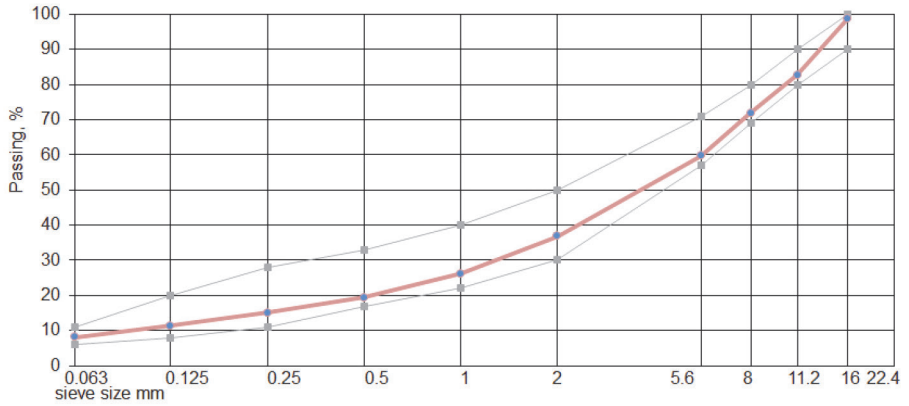

Figure 1 Gradation of asphalt mixture AC 16 PD

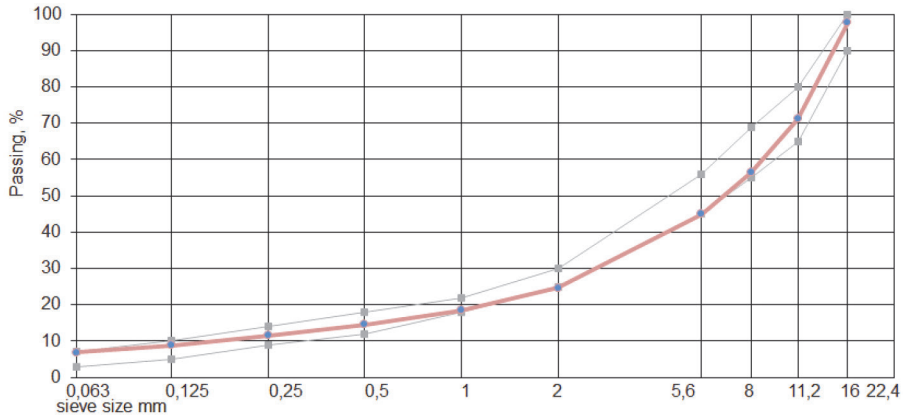

Figure 2 Gradation of asphalt mixture AC 16 AS

2.2 Methods

For crumb rubber modified asphalt mixtures and reference mixtures properties given in Figure 3 were determined.

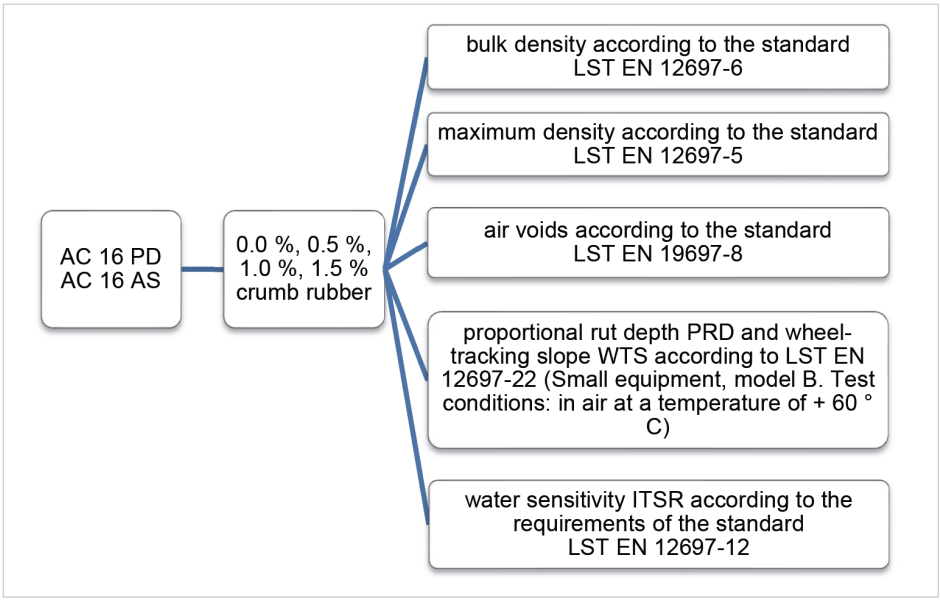

Figure 3 Test methods

3 Test results

3.1 Volumetric properties

The analysis of volumetric properties results shows that increasing amount of crumb rubber in asphalt mixture decreases bulk density and maximum density and increases air voids content for both mixtures AC 16 PD and AC 16 AS. The density of asphalt mixtures decreases because the density of crumb rubber is more than 2 times lower comparing to aggregates it replaces. The amount of air voids increases because the rubber-modified asphalt mix is more resistant to compaction (the rubber in the asphalt mix acts as an elastic filler). Detailed results are presented in Table 2.

Table 2 Results of volumetric properties of crumb rubber modified mixtures

Asphalt mixture type	**Amount of crumb rubber** [%]	**Bulk density** [Mg/m³]	**Maximum density** [Mg/m³]	**Air voids** [%]
AC 16 PD	0.0	2.475	2.558	3.2
	0.5	2.449	2.543	3.7
	1.0	2.441	2.540	3.9
	1.5	2.420	2.525	4.1
AC 16 AS	0.0	2.471	2.597	4.9
	0.5	2.440	2.588	5.7
	1.0	2.415	2.564	5.8
	1.5	2.404	2.568	6.4

3.2 Water sensitivity

Research showed that with increasing amount of crumb rubber, water sensitivity values (ITSR) of asphalt mixtures are decreasing. The ITSR values of asphalt mixture AC 16 PD decreases by 0.1–5.3 % and asphalt mixture AC 16 AS by 0.2–5.4 %. Nevertheless, all values obtained for the water sensitivity coefficient still meet the 90 % requirement that applies to the highest quality asphalt mixtures in some foreign countries. However, based on the results, it can be stated that adding more than 1.5 % crumb rubber (by weight of the asphalt mixture) into asphalt mixtures AC 16 PD and AC 16 AS would not provide sufficient water sensitivity and as a result lead to faster degradation of the surface due to environmental factors. Detailed water sensitivity values are given in Figure 4.
As shown in Figure 4 increasing the amount of rubber decreases the indirect tensile strength of asphalt mixture. The indirect tensile strength of wet samples of the asphalt mixture AC 16 PD decreased 8.0–27.0 %, and the indirect tensile strength of wet samples of the asphalt mixture AC 16 AS decreased by 12.4–31.3 %.

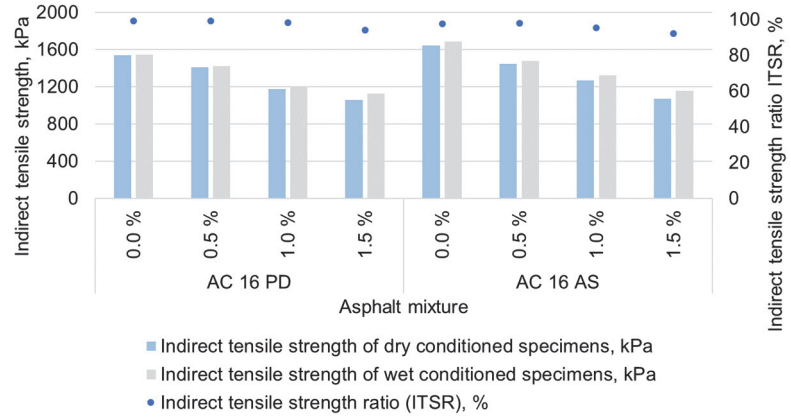

Figure 4 Results of water sensitivity

3.3 Stiffness

Stiffness of asphalt mixture AC 16 PD (at a test temperature of 20 °C) was found to be 2.4-8.4 % lower using 0.5-1.5 % crumb rubber compared to reference mixture without crumb rubber. Stiffness of AC 16 PD reference mixture is 6624 MPa. Increasing amount of crumb rubber (from 0.5 % to 1.5 %) decreases stiffness from 6468 MPa to 6065 MPa (Fig. 5).

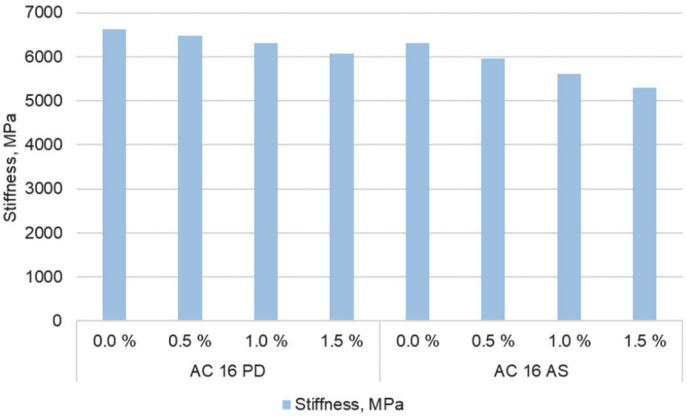

Figure 5 Results of stiffness of asphalt mixture AC 16 PD and AC 16 AS

Stiffness of asphalt mixture AC 16 AS (at a test temperature of 20 °C) was found to be 5.6-16.3 % lower using 0.5-1.5 % crumb rubber compared to reference mixture without crumb rubber. Stiffness of AC 16 AS reference mixture is 6316 MPa. Increasing amount of crumb rubber (from 0.5 % to 1.5 %) decreases stiffness from 5963 MPa to 5286 MPa.

4 Conclusion

This research has intended to investigate crumb rubber effect on asphalt mixture properties, when crumb rubber incorporated into asphalt mixture by dry process. Following conclusions can be drawn:

- Volumetric properties of crumb rubber modified asphalt mixture show that bulk density and maximum density decrease while increasing amount of crumb rubber. This could be explained by the fact that crumb rubber has a lower density than replaceable aggregates.
- The water sensitivity values of asphalt mixture AC 16 PD decreases by 0.1–5.3 % and of asphalt mixture AC 16 AS by 0.2–5.4 %, with increasing amount of crumb rubber. Although all the obtained values of the water sensitivity coefficient ITSR meet the 90 % requirement, which in some countries applies to the highest quality asphalt mixtures, 1.5 % by crumb rubber by weight of the asphalt mixture should be considered as the maximum possible quantity in terms of water sensitivity.
- As the rubber content increases from 0.5 % to 1.5 %, the asphalt stiffness values varies accordingly: AC 16 PD – from 6468 MPa to 6065 MPa, AC 16 AS – from 5963 MPa to 5286 MPa.
- The use of crumb rubber for the modification of asphalt mixtures AC 16 PD and AC 16 AS showed a relatively small decrease in water sensitivity values, so the recommended maximum rubber content is 1.0 % to 1.5 % by weight of asphalt mixture.

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