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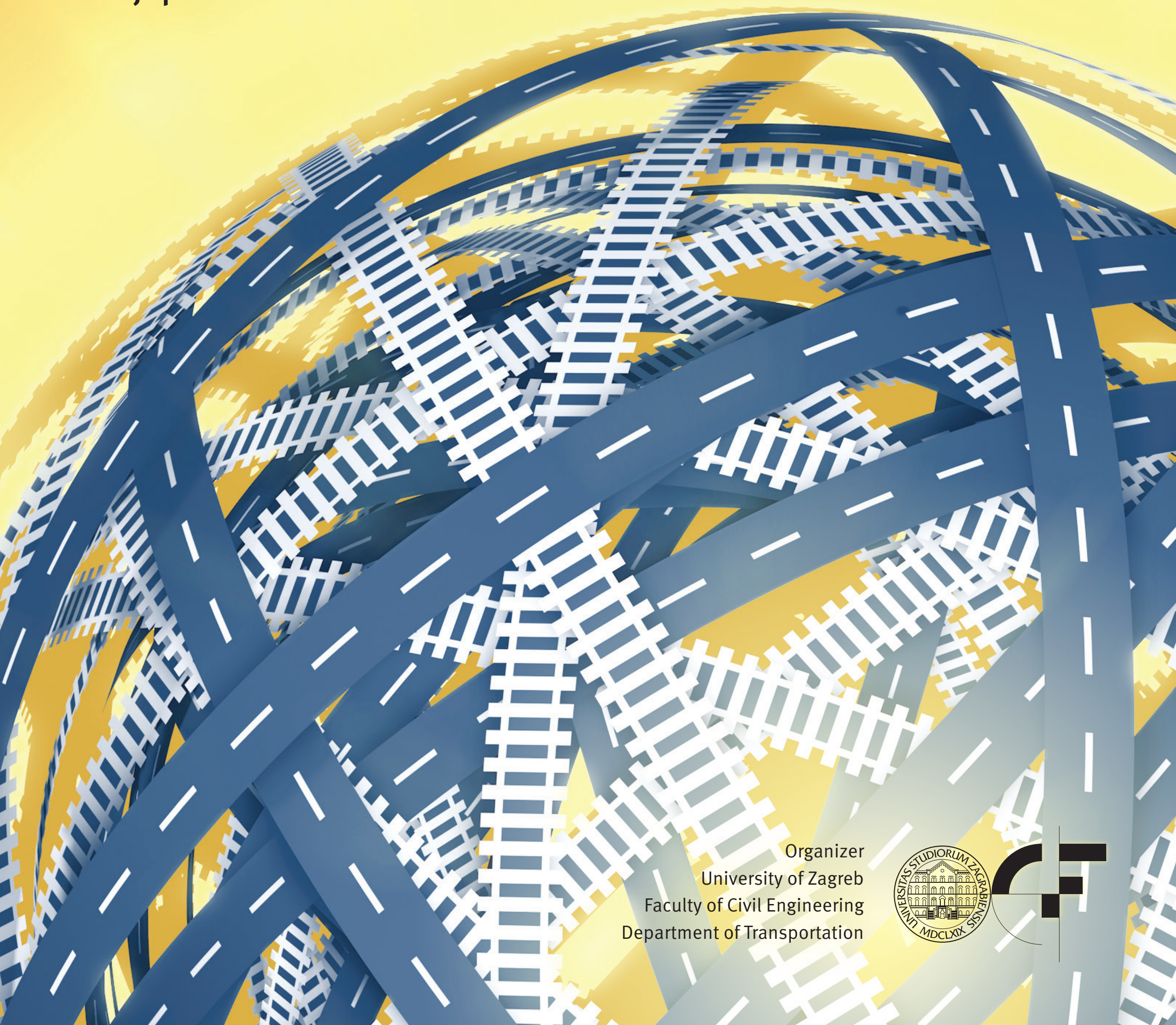
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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Road and Rail Infrastructure IV

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EFFECT OF TYPE OF MODIFIED BITUMEN ON SELECTED PROPERTIES OF STONE MASTIC ASPHALT MIXTURES

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Abstract

Wearing course is the layer directly in contact with traffic loads and weather conditions. It should be resistant to water and frost, plastic deformations and meet the required threshold of skid resistance. SMA (Stone Mastic Asphalt) is one of the most popular mixture intended for wearing courses of road pavement for very heavy traffic loads. Therefore it contains materials of superior quality. This paper presents the experimental results of selected properties of SMA11 with two typical modified binders (ORBITON PMB 45/80-55, ORBITON PMB 45/80-65) and newly developed highly modified binder (ORBITON PMB 45/80-80 HiMA). These modified bitumens have similar penetration range but they differ in the type of polymer and its contents. Therefore that significantly affects on the differences in standard and functional parameters such as elastic recovery, force ductility etc. The primary purpose of highly-modified binders (HiMA type) is to counteract pavement cracking, plastic deformations and consequently to increase the life span of asphalt courses. It should be noted that tested SMA mixtures had the same aggregate particle-size distribution of mineral mixtures. The study of SMA aimed at determination of the water sensitivity expressed in ITSR (Indirect Tensile Strength Ratio) according to the standard 12697-12 (method A) and rutting resistance according to standard EN 12697-22 in the small apparatus (method B). Comparison of the results of those tests showed some differences between binders and mixtures. Specific situation was observed with rutting resistance where strong SMA skeleton decreased influence of binder type. In addition, evaluation of the skid resistance mixtures of the tested SMA were carried out using the Wehner/Schulze machine. Results may be valuable information for proper maintenance of existing pavements and on the stage of designing.

Keywords: Highly Modified Asphalt, Stone Mastic Asphalt, Polymer Modified Bitumen, wearing course, Wehner/Schulze machine

1 Introduction

SMA (Stone Mastic Asphalt) is widely used mixture intended for wearing courses of road pavement for very heavy traffic loads in Poland. The primary advantage of wearing course made of SMA is to ensure very good resistant to water and frost, better rutting resistance than conventional dense-graded asphalt mixtures [1]. This is possible because the SMA is gap-graded asphalt mixture which is characterized by a strong skeleton due to the high content of superior quality coarse aggregate in the mineral mixture (from 70 to 80%). Additionally, the amount of coarse aggregate allows to achieve high macrotexture. Due to that fact wearing course made of SMA mixture has better skid resistance at high speeds than asphalt concrete mixture [2]. However skid resistance depends on both macrotexture and microtexture. Due to the low

amount of fine aggregates used, microtexure of SMA mixtures is almost completely related to resistance to polishing of coarse aggregates [3]. Therefore aggregates with PSV (Polished Stone Values) above 50 should be used for SMA mixtures in order to meet the required level of skid resistance.
However durability of wearing course made from SMA mixtures is especially related to the type of binder. In weather conditions characterized by very frequent cycles of freezing and thawing only modified bitumen should be applied for SMA mixtures. It allows to achieve higher durability than with paving grade bitumens (unmodified).
Studies have shown that the increasing content of the polymer in asphalt significantly improves durability of road pavement [4-7]. However such a significant quantity of SBS for binder modification must consider its specific technical consequences for the production and application of modified binder. Research conducted in the United States have led to the development of highly modified binder. The primary purpose was to counteract pavement cracking, plastic deformations and consequently to increase the fatigue resistance of asphalt courses. To achieve that, high polymer content in excess of 7% (by weight) is used, which leads to volumetric phase reversal in the mixture of binder with the polymer. Then continuous polymer network works in asphalt mixtures like an elastic reinforcement which limits crack propagation, low-temperature cracking and improving rutting resistance [8, 9].
This paper presents the comparison of selected properties of SMA 11 mixtures with two typical modified bitumens and highly modified binder.

2 Research program

2.1 Polymer modified bitumen

In this study two conventionally SBS modified binders (ORBITON PMB 45/80-55, ORBITON PMB 45/80-65) and newly developed highly modified binder (ORBITON PMB 45/80-80 HiMA) were used. All PMBs are produced according to EN 14023 and Polish National Annexe to this standard. These modified bitumens have similar penetration range (45-80 [0.1 mm]) but they differ in the type of polymer and its content. Therefore it significantly affects the differences in Softening Point R&B and other parameters such as elastic recovery and force ductility. Table 1 shows properties of the tested modified bitumen.

Table 1 The results of selected properties of tested modified bitumen

Property	Test method	ORBITON PMB 45/80-55	ORBITON PMB 45/80-65	ORBITON PMB 45/80-80 HiMA
Penetration at 25 °C [0.1 mm]	EN 1426	65	57	63
Softening point R&B [°C]	EN 1427	55.8	80	94.5
Breaking point (Fraass) [°C]	EN 12593	not tested	not tested	-23
Elastic recovery at 25°C [%]	EN 13398	74	87	94
Force ductility at 10°C [J/cm^2]	EN 13589 EN 13703	not tested	not tested	5.5

2.2 SMA11 mixtures

Tested SMA11 mixtures with three types of modified bitumen (ORBITON PMB 45/80-55, ORBITON PMB 45/80-65, ORBITON PMB 45/80-80 HiMA) were designed according to EN 13108-5 and Polish National Specification WT-2: 2014. Fine and coarse aggregates produced from melaphyre rock were used. PSV (Polished Stone Value) of coarse aggregate was 52. Each of SMA11 mixtures was designed with the same binder content – 6.6 % (by weight) and aggregate particle-size distribution in mineral mixtures (Table 2). Volumetric parameters of SMA11 mixtures are presented in Table 3.

Table 2 Aggregate particle-size distribution

Particle size distribution								
Sieve [mm]	**0.063**	**0.125**	**2**	**4**	**5.6**	**8**	**11.2**	**16**
Passing fraction [%]	10.6	13	25	33	40	61	96	100

Table 3 Volumetric parameters of SMA 11 mixtures

Parameters	**Test method**	**SMA 11 PMB 45/80-55**	**SMA 11 PMB 45/80-65**	**SMA 11 PMB 45/80-80 HiMA**
Density ρ_{mv} [Mg/m^3]	EN 12697-5	2.417	2.419	2.410
Bulk density ρ_{bssd} [Mg/m^3]	EN 12697-6	2.361	2.347	2.340
Air voids V_m [%]	EN 12697-8	2.3	3.0	2.9
Voids filled with Binder VFB [%]	EN 12697-8	86.5	83.2	83.6
Voids in mineral aggregate VMA [%]	EN 12697-8	17.2	17.8	17.7

2.3 Experimental procedure

2.3.1 Water sensitivity test

Water sensitivity test of SMA11 mixtures was carried out according to EN 12697-12 (method A) and Polish National Specification WT-2:2014. Ten specimens for each mixture were divided into two parts: “dry set” and “wet set”. Specimens from “dry set” were conditioned at temperature 20±5°C. Specimens from “wet set” were saturated with distilled water under vacuum (6.7±0.3 kPa, 30 minutes) and left in water for 30 minutes under atmospheric pressure. Then specimens were conditioned in water at temperature 40°C for 72 hours. In next step plastic-foiled specimens were freezed in -18°C for 16 hours, than they were put in water at temperature 25°C for 24 hours. Finally the ITS (Indirect Tensile Strength) test in accordance with EN 12697-23 on both sets of specimens has been conducted. The ITSR values was calculated according to Eq (1).

$$ITSR = \frac{ITSw}{ITSd} \cdot 100\% \qquad (1)$$

where:
ITSd – mean values of ITS for specimens from “dry set” [kPa];
ITSw – mean values of ITS for specimens from “wet set” [kPa].

2.3.2 Rutting test

Rutting resistance of SMA mixtures was conducted according to EN 12697-22 in small apparatus (method B), in air. Two specimens from each mixture were prepared. Before testing specimens were conditioned at 60°C for 4 hours. The apparatus consists of the loaded wheel that repeatedly passes over the test specimen. The load of wheel was 700 N, frequency of 26.5±1.0 load cycles per minute. Test was performed at 60°C during the test. Evaluation of resistance to rutting is made on the basis of:

• RD (rut depth) after 10 000 cycles [mm];
• PRD (proportional rut depth) after 10 000 cycles as a percentage of the specimen thickness [%];
• WTS (wheel-tracking slope) [mm/10^3 load cycle].

2.3.3 Skid resistance test

The Wehner/Schulze machine (Fig. 1a) was used for evaluation of the skid resistance in laboratory conditions. The machine consists of two heads: one for polishing and for measurement of friction coefficient PWS. Three specimens from each mixture were made. The polishing action is performend by means of three rubber cones mounted on rotary disc and rolling on the specimen surface (Fig. 1b). The rotation frequency is 500 tours per minute. A mix of water with quartz powder was projected on the specimen surface during the rotations. Measurement of friction coefficient PWS is conducted after polishing and then washing of a specimen. The second measuring head is composed of three small rubber sliders disposed at 120° on a rotary disc (Fig.1 c). The disk rotates at tangential velocities up to 100 kph. Water flows over the surface being tested. The rotating disk is then dropped onto the wet surface and the coefficient of friction is measured. In this study coefficient of friction PWS at slip speed 60kph was taken. Measuring of PWS was conducted before polishing and after 2000, 4000, 6000, 8000, 10 000, 12 000, 14 000, 16 000, 18 000, 20 000, 40 000, 60 000, 80 000, 100 000, 160 000, 180 0000 passes of polishing head.
It should be noted that Wehner/Schulze machine enables to the compare the skid resistance of different types of mixtures under specified conditions simulating polishing processes. In the case of new asphalt specimens it is recommend to clean bitumen from aggregates by using the grid blasting cabinet. Due to the fact that objective of the study is influence of different types of bitumen on the properties of the mixtures, this operation was not performed.

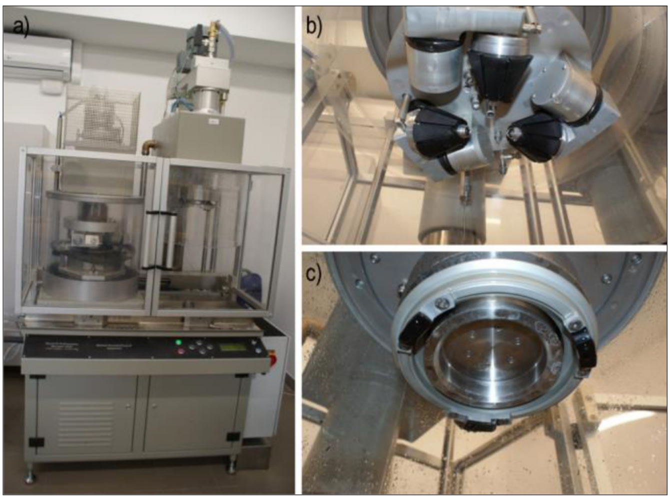

Figure 1 a) Wehner/Schulze machine; b) polishing rotary head; c) friction measuring rotary head

3 Results and analysis

ITSR results were similar for all mixtures: SMA11 PMB 45/80-55 – 98%, SMA11 PMB 45/80-65 – 95% and SMA11 45/80-80 HiMA – 99%. However the results of the ITS values show some significant differences between particular mixtures which depend on the type of binder. Graphical interpretation of ITS test results is shown in Fig. 2.

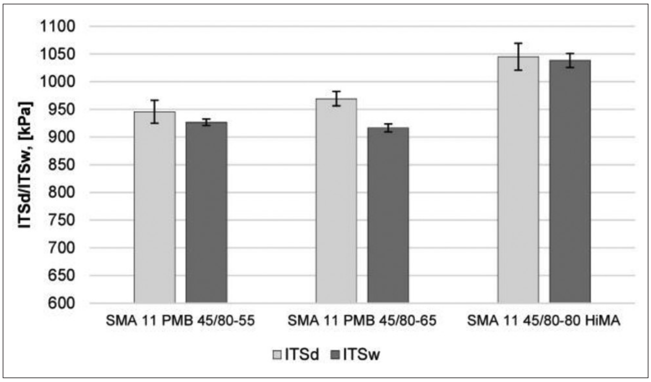

Figure 2 Mean values of ITS with 95 % with confidence interval

The highest value of ITS was obtained for SMA11 PMB 45/80-80 HiMA. Differences between mean values of ITSd and ITSw are insignificant for highly modified binder, about 10% higher than for mixtures with lower SBS content.
SMA11 mixtures have comparable resistance to rutting. The results obtained are the following: RD – 1.5 mm; PRD – 3.8%; WTS – 0.03 [mm/10^3 load cycle] . This was caused by very strong SMA skeleton based on stone-to-stone contact which decreased influence of the binder type. The changes of the friction coefficient PWS are presented in Fig. 3.

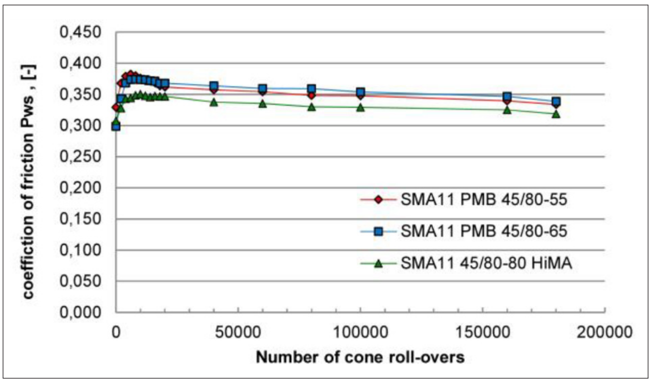

Figure 3 Changes of the friction coefficient PWS in polishing process

The lowest values of PWS have been registered before polishing process, because aggregate surface was covered with binder layer. During polishing process binder was worn away from the aggregate exposing their virgin microtexture. This takes place in the initial stage of the process. The highest values of PWS were obtained after 8000 passes of polishing head. Then it was followed by the decrease in the value PWS for each mixture. However SMA 11 PMB 45/80-55 and PMB 45/80-65 had higher coefficient of friction PWS than SMA11 with highly modified binder. Images of the surface were taken with the optical microscope at the end of polishing process for better understanding of phenomena occurring on the surface of mixtures. Based on observations it was noticed that the binder covering aggregate was not completely removed from each mixture. However a much larger surface of coarse aggregate was discovered on SMA11 mixtures with typical modified binders than highly modified binder (Fig. 4). This caused lower PWS for SMA11 45/80-80 HiMA in comparison with other test mixtures.
Binder layer on the coarse aggregates contributes to the slipperiness during the initial period of pavement life. That is why should be applied gritting from aggregate of nominal size 4 mm

during compacting of SMA mixture. This treatment accelerates wear of the coarse aggregates from the asphalt and ensures increase of initial skid resistance [1]. Obtained results show that the use of highly modified bitumen could lead to extend the time needed to expose aggregate surface.

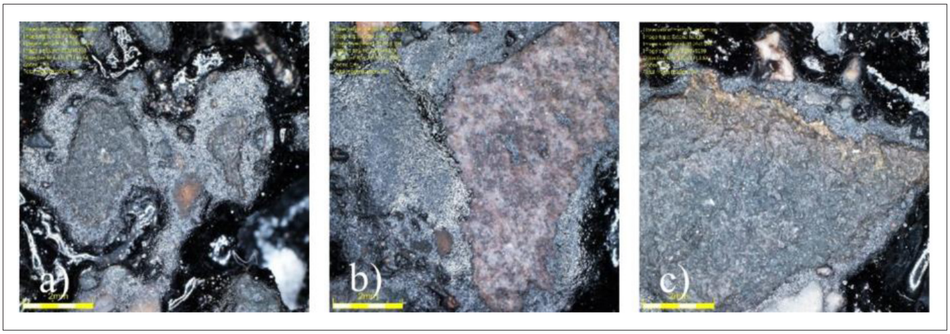

Figure 4 Comparison surfaces of SMA11 a) PMB 45/80-80 HiMA b) PMB 45/80-65 c) PMB 45/80-55

4 Conclusions

The type of modified binder plays important role in durability of road pavements. Highly modified binder which has been used in Poland since 2015 may improve fatigue life, rutting resistance and low-thermal cracking resistance. Therefore this type of modified bitumen should be use to SMA mixture which is intended for wearing course for very heavy traffic load. However control of skid resistance properties should monitored in the initial period of pavement life.

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