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Road and Rail Infrastructure III

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LABORATORY AND FIELD EXPERIENCE WITH PMMA/ATH COMPOSITE DUST IN ASPHALT MIXTURES

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Abstract

Heavy loaded asphalt pavements must withstand formation of permanent deformations and cracking caused by temperature changes and fatigue. Ordinary paving grade bitumen has limited range of service temperatures. To expand range of service temperatures on most cases some costly polymeric materials like SBS are added. With this study we proved that addition of waste materials can be almost equivalent solution to improved asphalt properties. The PMMA/ATH – poly-methyl methacrylate (PMMA) filled with a fine dispersion aluminium trihydrate (ATH) is a composite used as a substitute for many indoor household ceramics. Processing and various polishing stages generate a considerable amount of waste powder. Mechanical properties of PMMA/ATH powder proved suitable for bitumen modification. Results of the study show that PMMA/ATH composite dust improves the performance of asphalt at high temperatures. Despite the advantages of PMMA/ATH composite dust on asphalt performance at high temperatures, it does not show a considerable influence on the low temperature performance of asphalt.

Keywords: asphalt mixture, composite dust, deformation, cracking, high temperature

1 Introduction

With reuse of waste materials in asphalt mixes environmental and economical advantage can be achieved by limiting the extraction of natural sources of material. But in such cases investors are mostly suspicious and they demand that performance of asphalt mix must be almost as good for the mixes made from traditional materials [1]. We managed to change a by-product, which was in former times considered as waste, to an additive for improving the performance of asphalt mixtures. PMMA/ATH composite dust is the waste material obtained by polishing of PMMA/ATH composite sheets. Final goal of our study was new asphalt mixture containing the PMMA/ATH composite dust. There are two ways to introduce PMMA/ATH dust as additive in asphalt mixture. First it was treated as additive to filler in asphalt mixtures (dry process) and second PMMA/ATH dust was treated as additive to bitumen (wet process). After first tests it was clear that the addition of dust even improves the quality of the asphalt layers. For dry process we had to determine the optimal ratio between ordinary filler and PMMA/ATH dust to achieved good mechanical properties of asphalt layer. Also for wet process optimal ratio between bitumen and PMMA/ATH dust had to be determined. We tried find out, if the bitumen modified with PMMA/ATH dust has similar properties as bitumen modified with other commercial additives. Several different asphalt mixtures containing PMMA/ATH dust were prepared in laboratory and several standard test methods were performed to evaluate asphalt mixtures (EN 12697-1, 2, 5, 6, 22, 30, 34, and 46). To address the human health and environment we assessed the risk for chemicals. We performed quantitative and qualitative analysis of dust and vapor, which are exhausted by heating of PMMA/ATH dust up to 180°C.

For 3 different types of asphalt mixtures industrial production was carried out, which means that we produced around 740 tones of asphalt mixtures, and laid them in a field test (normal road).

2 Input material and experimental work in laboratory

Industrial production of polymethylmethacylate/Aluminium hydroxide (PMMA/ATH) composite plates is taking place in Slovenia. These plates are due to high hardness, resistance to most chemical substances, mechanical and volume stability at low and high temperatures widely used for household ceramics and also outdoor. More than 50 wt. % of the plates consists of Aluminium hydroxide (Al (OH)3) which is chemically similar to Hydrated lime (Ca (OH)2). Hydrated lime is known as additive to improve adhesion between the binder and aggregate in asphalt mixtures [2, 3]. Similar effect was expected for (PMMA/ATH) composite materials. For asphalt mixtures prepared in laboratory paving grade bitumen B 70/100 and dolomite stone aggregate were used.

2.1 PMMA/ATH composite dust as additive to filler

First standard tests were performed to enable addition of PMMA/ATH composite dust as filler in asphalt mixture [4]. It was proved that adhesion between PMMA/ATH composite and bitumen is as good as expected. We had to assure that sieving curve (Tab. 1) and void content with Rigden test (Tab. 2) were in accordance with standardized requirements. We determined that weight ratio 5:1 between ordinary filler and PMMA/ATH composite dust is still in accordance with standardized requirements for filler.

Table 1 Sieving analyses according to method EN 933-10:2002 of ordinary filler, PMMA/ATH composite dust and their mixtures

Sieve [mm]	PMMA/ATH composite dust	Ordinary filler	Ordinary filler: PMMA/ATH composite dust = 5:1 wt.	Ordinary filler: PMMA/ATH composite dust = 8:1 wt.	Requirement according to EN 13043
2.00	100	100	100	100	100
0.125	74	98	94	95	85 – 100
0.063	41	89	81	84	70 – 100

Table 2 Voids according to method EN 1097-4:2008 of dry compacted ordinary filler, PMMA/ATH composite dust and their mixtures

PMMA/ATH composite dust	Ordinary filler	Ordinary filler: PMMA/ATH composite dust = 5:1 wt.	Ordinary filler: PMMA/ATH composite dust = 8:1 wt.	Requirement according to SIST 1038-1
53 %	34 %	37 %	36 %	28% – 38%

2.2 PMMA/ATH composite dust as additive to bitumen

Silverson L5M homogenizer was used for mixing different quantities of PMMA/ATH composite dust in paving grade bitumen B 70/100 [5, 6]. To ensure a good dispersion dust was mixed in bitumen for 1.5 h at 170°C. Additionally we prepared sample containing 3 wt. % of paraffin wax and 25 wt. % of waste PMMA/ATH. Several test methods were used to evaluate quality of produced modified bitumen such as needle penetration at 25°C, softening point, Fraass breaking point and rut resistance potential ($G^*/\sin(\delta)$ (Tab. 3). With RTFOT ageing procedure also ageing potential of modified bitumen was evaluated.

Table 3 Properties of PMMA/ATH composite dust modified bitumen

PMMA/ATH composite dust content wt. %	Softening point [°C]	Fraass breaking point [°C]	Penetration at 25°C, 0.1 mm	G*/sin(δ) before ageing	G*/sin(δ) after RTFOT ageing
0	46.2	-11	78	1330	4790
25	53.6	-15	55	3650	14500
0 (3% wax)	71.0	-13	54		
25 (3%wax)	93.8	-12	34	6120	18900

With simple test methods such as needle penetration at 25°C, softening point and Fraass breaking point only insignificant differences between base bitumen and bitumen modified with PMMA/ATH composite dust were determined (Tab. 3). Only addition of paraffin wax significantly affected softening point. But both additives together seem to have multiplicative effect on softening point of bitumen.
From G*/sin(δ) measurements with dynamic shear rheometer we found significant differences between asphalts containing base bitumen and asphalts containing bitumen modified with PMMA/ATH composite dust. From these results increased resistance to permanent deformations was expected.

2.3 Asphalt mixtures containing PMMA/ATH composite dust

For laboratory testing four AC 8 asphalt mixtures were prepared. First mixture contained PMMA/ATH composite dust as additive to filler in mass ratio 1:5, second contained PMMA/ATH composite dust in paving grade bitumen B 70/100 in mass ratio 1:3, third was similar to second with additionally 3 wt. % paraffin wax and fourth reference was without PMMA/ATH composite dust [5, 7].
For all asphalt mixtures wheel tracking parameters and water sensitivity were determined. Wheel tracking tests were performed at 50 °C. Proportional rut depth of mixture containing PMMA/ATH composite dust in paving grade bitumen B 70/100 is approximately 3 times lower in comparison to the reference mixture (Fig. 1). The results of wheel tracking test are in good agreement with G*/sin(δ) values determined with binder test.
Increased water resistance of samples containing PMMA/ATH composite dust (ITS ratio) implies that waste PMMA/ATH particles in asphalt binder improve the adhesion performance between aggregate and bitumen (Tab. 4). From result it can be seen that more effective is addition of PMMA/ATH in bitumen.

Table 4 Properties of PMMA/ATH composite dust modified asphalt

Samples of AC 8 surf	ITS ratio at 25 °C [kPa]	ITS ratio at 25 °C [%]	Proportional rut depth at 50 °C [%]	WTSAIR at 50 °C
Reference mixture	907	93.1	18.3	0.46
PMMA/ATH composite dust added in filler	895	94.4	9.0	0.16
PMMA/ATH composite dust added in bitumen	1102	99.2	6.3	0.09
PMMA/ATH composite dust added in bitumen + 3% wax	1215	97.5	3.5	0.03

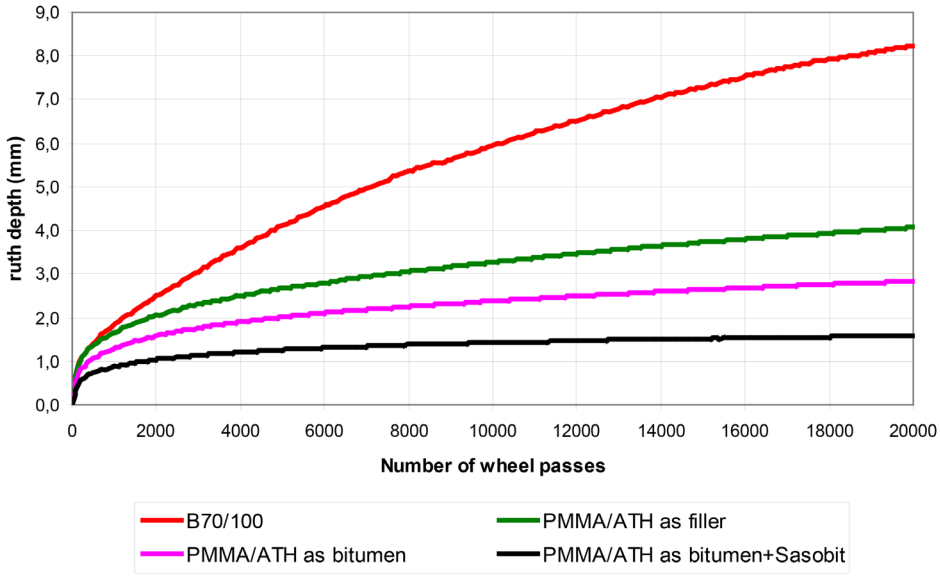


Figure 1 Results of wheel tracking test at 50 °C

For all asphalt mixtures compactability was determined and for three asphalt mixtures low temperature properties. Samples with PMMA/ATH composite dust added in filler give similar or even better results than reference mixture at these two tests. If PMMA/ATH composite dust is added in bitumen, than it is a bit harder to compact asphalt (compactability test gives higher result).

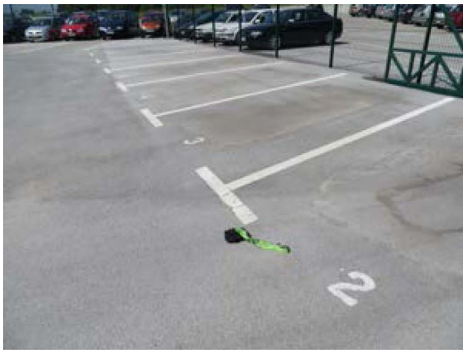
Table 5 Properties of PMMA/ATH composite dust modified asphalt

Samples of AC 8 surf	Compactability at 160 °C [kPa]	TSRST failure temperature [°C]	TSRST failure stress σ cry [MPa]	Tensile strength reserve, T Δβ, max. [°C]	Tensile strength reserve, Δβ, max. [MPa]
Reference mixture	26,4	-24,7	4,0	-8,4	3,8
PMMA/ATH composite dust added in filler	26,5	-28,1	4,4	-10,0	4,3
PMMA/ATH composite dust added in bitumen	30,4	-26,3	4,5	-6,3	4,4
PMMA/ATH composite dust added in bitumen + 3% wax	31,5				

3 Field experience

At the first two field trials we decided to use PMMA/ATH composite dust added in filler. In 2009 we produced 120 tons of asphalt containing PMMA/ATH composite dust and for comparison the same amount of ordinary asphalt. At construction of the test section with PMMA/ATH composite dust in binder course, workers noticed that in was easier to handle with asphalt containing PMMA/ATH composite. The driver of asphalt paver confirmed that workability of asphalt is improved, when it is containing PMMA/ATH composite dust. The test field with PMMA/ATH composite dust in wearing course is still monitored and there are no visible defects on the surface (fig 2).

a)



b)

Figure 2 Construction of test field with PMMA/ATH composite dust in wearing course in 2009 (a.) and the same test field in 2013 (b).

Test field with PMMA/ATH composite dust added in bitumen was built in 2013. We produced 500 tons of asphalt containing PMMA/ATH composite dust. The production of bitumen containing PMMA/ATH composite dust was carried out in bitumen tank with mixer (fig. 3). We did not notice any problem when asphalt containing modified bitumen was produced. Also at construction of binder course with this asphalt was carried out smoothly.

Figure 3 Production of bitumen containing PMMA/ATH composite dust.

4 Conclusions

From laboratory tests performed on bitumen and asphalt we concluded that addition of PMMA/ATH composite dust always improves quality of asphalt. To our opinion the reason for improved properties of asphalt is in increased adhesion between bitumen and stone aggregates. As already known from previous studies addition of paraffin wax in asphalt improves resistance to permanent deformation. With this study we found out that both additives together have multiplicative effect on resistance to permanent deformation.
With test production and test fields we proved that addition of PMMA/ATH composite dust can be applied in normal batch type asphalt plant. On asphalt plant CGP in Drnovo we performed both dry and wet process. Test field from 2009 is a proof that PMMA/ATH modified asphalt is at least equally durable as ordinary asphalt. Altogether we can proclaim that PMMA/ATH modified asphalt is sustainable solution.

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