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waste PMMA/ATH, modified bitumen, paraffin wax, asphalt mixture performance

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ALTERNATIVE PMB PRODUCED FROM RECYCLING WASTE PMMA/ATH

Summary. With development of production processes in refineries production of bitumen is decreasing, as well as the quality of produced bitumen. On the market this brings increased demand for bitumen accompanied by the demand for additives to improve such low quality bitumen. Many different types of additives are used, but most commonly SBS is added. Usage of additives bring additional direct costs, due to market price of additives and indirect cost due to adjustments in the technological process as such as additional mixing device in bitumen tanks, elevated temperature of asphalt or prolongation in mixing time. A topic of our research was development low price asphalt additive from waste poly-methyl methacrylate filled with a fine dispersion aluminium trihydrate (PMMA/ATH). Additionally with paraffin wax it was used as modifying agents for 70/100 paving grade bitumen.

With regard to performance of modified asphalt mixtures, it was found that both additives considerably reduce moisture susceptibility and formation of ruts. With laboratory tests and field trial we found that combined technology PMA (polymer modified asphalt) and WMA (warm mix asphalt) technologies resulted in optimized production and excellent performance of pavement material.

ALTERNATYWNE PMB PRODUKOWANE Z ODPADÓW RECYKLINGOWYCH PMMA/ATH

Streszczenie. Wraz z rozwojem procesu produkcyjnego w rafineriach zmniejszyła się produkcja bituminu, jak również jakość produkowanego bituminu. Niesie to ze sobą zwiększenie zapotrzebowania na bitumin, towarzyszy; temu popyt na dodatki uszlachetniające. Używanych jest wiele rodzajów dodatków, lecz najczęściej dodawanym jest SBS. Użycie dodatków powoduje dodatkowe koszty bezpośrednie – jest to spowodowane ceną rynkową dodatków – jak również koszty pośrednie, co jest spowodowane zmianami w procesie technologicznym, takimi jak dodatkowe urządzenia mieszające w kadziach bituminowych, wzrost temperatury asfaltu lub wydłużenie czasu mieszania. Tematem badań było osiągnięcie niskiej ceny dodatku asfaltu z odpadów polimetylowego metakrylanu wypełnionego dobrze zdyspersowanym trihydratem aluminium (PMMA/ATH). Dodatkowo użyto wosku parafinowego jako środka modyfikującego dla bituminowych płyt chodnikowych 70/100. W odniesieniu do wydajności zmodyfikowanych mieszanin asfaltowych stwierdzono, że oba dodatki znacznie zmniejszyły podatność na wilgoć i powstawanie kolein. Z badań laboratoryjnych i prób w terenie wynika, że połączenie technologii PMA (asfalt modyfikowany polimerowo) oraz WMA (ciepła mieszanka asfaltowa) zaowocowało technologiami zoptymalizowanymi w produkcji i doskonałą wydajnością materiału nawierzchni.

1. INTRODUCTION

Reuse of existing alternative materials in asphalt mixes implies an environmental and economical advantage by limiting the extraction of natural aggregates. If waste material is used, then performance of asphalt mix must be almost as good for the mixes made from traditional materials [1]. When waste material improves the final product, it can be considered as alterative material or even modifier. In our study we intend to show how a by-product, which was in former times considered as waste, can become an additive for improving the performance of asphalt mixtures.

PMMA/ATH composite dust is the waste material in the production of PMMA/ATH composite material. Producers of this material asked us if we can use the dust in asphalt production. So the main goal of our research was a new product, i.e., a new asphalt mixture containing the PMMA/ATH composite dust.

First aim of research was to introduce the use of PMMA/ATH dust as additive to filler in asphalt mixtures. In preliminary investigations we found that the addition of such dust even improves the quality of the asphalt layers. Further research included optimization of asphalt production, where we determined the optimal ratio of filler and PMMA/ATH dust to achieved good mechanical properties of asphalt layer. With such production additional investments in the stage of industrial production of these asphalt mixtures were not required.

In laboratory we prepared several different asphalt mixtures containing PMMA/ATH dust. For the analysis of asphalt mixtures, we used standard methods (EN 12697-1, 2, 24, 26, 30, 34, 41, 43, and 46). To reduce the use of solvents we introduced the method of incineration EN 12697-39 to determinate the content of bitumen in asphalt mixture.

For 2 different types of asphalt mixtures industrial production was carried out, which means that we produce around 240 tones of asphalt mixtures, and laid them in a field test (normal road). The behavior of test fields in different weather conditions such as low temperature and precipitation will be monitored for a longer period (1-10 years).

In the second phase we added PMMA/ATH dust directly to the bitumen and tried to determine if the PMMA/ATH dust modified bitumen has similar properties as bitumen modified with other commercial additives.

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 150^{o}C.

2. INPUT MATERIAL AND EXPERIMENTAL WORK

Polymethylmethacylate/Aluminium hydroxide (PMMA/ATH) composite plates are used mainly as desks and counters. Due to high hardness, resistance to most chemical substances, mechanical and volume stability at low and high temperatures of such plates, they can be used also outdoor. Round 60 wt. % of the dust is Aluminium hydroxide ($Al(OH)_3$) which is chemically similar to Hydrated lime ($Ca(OH)_2$). Hydrated lime is known as additive to improve adhesion in asphalt mixtures, particularly for siliceous aggregates. It improves resistance to water in two major ways. First on the surface of aggregates it improves compatibility between the binder and aggregate [2]. Second, lime reacts with acid components of the asphalt binder to create insoluble calcium salts that are hydrophobic. The elimination of the acid components in the binder promotes the formation of strong nitrogen bonds between the asphalt and the aggregate [3].

2.1. Preliminary laboratory tests on PMMA/ATH composite dust as additive to filler

We performed several standard tests before PMMA/ATH composite dust could be used as filler in asphalt mixture [4]. First we had to check, if adhesion between PMMA/ATH composite and bitumen is as good as expected. Then we had to fulfill the requirements for filler, so we had to check sieving curve (Tab. 1) and void content with Rigden test (Tab. 2).

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%

To be able to prepare asphalt mixture we had to determine also density of PMMA/ATH composite dust (1.74 Mg/m^3). We found out that with weight ratio 5:1 between ordinary filler and PMMA/ATH composite dust we still fulfill standardized requirements for filler.

2.2. Preliminary laboratory tests on PMMA/ATH composite dust as additive to bitumen

First we had to mix PMMA/ATH composite dust in paving grade bitumen B 70/100 [5, 6]. Laboratory preparation of modified binders was done by Silverson L5M homogenizer. Different percentages of waste polymer were mixed at 170^{o}C for 1.5 h to ensure a good dispersion of PMMA/ATH in bitumen. Sample with 3 wt. % of paraffin wax and 25 wt. % of waste PMMA/ATH preparation was carried out in two steps. First, 3 wt. % was mixed with bitumen for 30 min at 150^{o}C and then pre-weighted PMMA/ATH powder was added to the mixture. To evaluate modified bitumen first needle penetration at 25^{o}C, softening point and Fraass breaking point in accordance with EN 1426, EN 1427, and EN 12593 were measured. Rut resistance potential ($G^*/\sin(\delta)$ of modified bitumen was determined by using dynamic shear rheometer (Anton Paar Physica MCR 301) equipped with parallel plates.

From table 3 it can be seen that simple test methods such as needle penetration at 25^{o}C, softening point and Fraass breaking point predict insignificant differences between base bitumen and bitumen modified with PMMA/ATH composite dust. Addition of paraffin wax significantly affected softening point. Both additives together seem to have multiplicative effect on softening point of bitumen.

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

On the contrary from G*/sin(δ) measurements with dynamic shear rheometer we can expect significant differences between asphalts containing base bitumen and asphalts containing bitumen modified with PMMA/ATH composite dust in resistance to permanent deformations.

2.3. Laboratory tests on asphalt mixtures containing PMMA/ATH composite dust

Four 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].

From wheel tracking test at 50 °C proportional rut depth (PRD) (Fig. 1) and wheel-tracking slope WTS_{AIR} (Tab. 4) were obtained. 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. 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 at 25°C (kPa)	ITS ratio at 25°C (%)	Proportional rut depth at 50°C (%)	WTS_{AIR} 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

3. CONCLUSIONS

From test result performed on bitumen and asphalt it can be seen that addition of PMMA/ATH composite dust always improved quality of asphalt. 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. From test result it can be seen that more effective is addition of PMMA/ATH in bitumen. As already known addition of paraffin wax in asphalt improves resistance to permanent deformation. With our study we found out that both additives together seem to have multiplicative effect on resistance to permanent deformation.

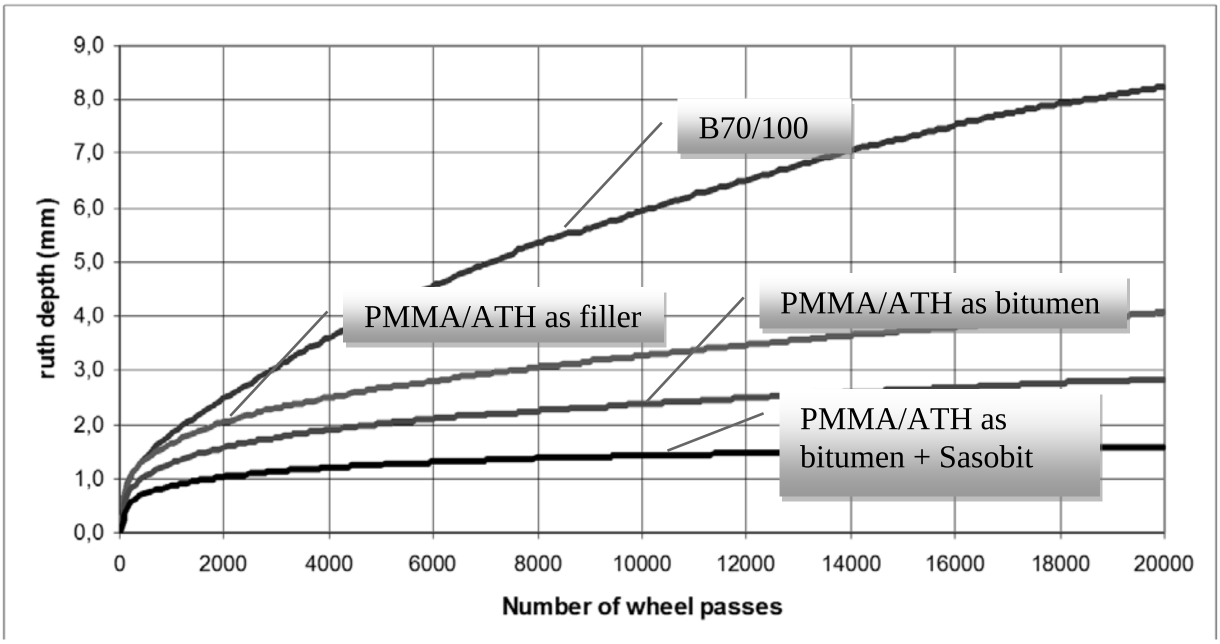

Fig. 1. Rut propagation at wheel tracking test at 50°C
Rys. 1. Propagacja kolein w teście śladów kół w temperaturze 50°C

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