Case studies & non-highway applications; Success and failure from real practice

Synthetic waste material as competitive stabilizing additive

Wojciech Sorociak[1,2], Bartłomiej Grzesik[2], Paweł Adamczyk[1], Paweł Garcarek[1]
[1]Eurovia Polska S.A., [2]Silesian University of Technology

Abstract

The paper presents results of SMA mix containing stabilizing additive made of synthetic material – HDPE originated from recycling processes. The paper contains both report on in field trial section made in August 2013 and laboratory tests. Laboratory tests enabled to make comparison between SMA containing commonly used cellulose fibers and HDPE additive without cellulose fibers. Analysis shows that HDPE additive has both stabilizing possibilities positive side effects concerning i.e. rutting resistance. After 5 years of traffic laboratory tests were repeated and trial section was analyzed in terms of its condition and certain parameters.

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1. INTRODUCTION

Nowadays rapid changes in modern civilisation are considered as standard phenomenon. Material engineering develops in many areas of industry including civil engineering. New material possibilities, increasing care for environment and sustainable development lead to the politics, which is based on the use of recycling materials, ensuring high quality of produced goods. In road engineering it means that there is a need for new solutions based on materials obtained from already built infrastructure. One of such examples is use of reclaimed asphalt pavement (RAP), which became a subject of interest of many scientists, road administrators and road engineering companies. The ongoing researches may result in both natural environment preservation and economic benefits. Another part of researchers attention is paid to anthropogenic aggregates. Granular materials that are by-products of various industry branches (coal mining, steel production, energy production (especially coal dependent)) may be opportunity for embankment or base course materials.

There are many more examples of recycling materials that may possibly be used in road engineering. The authors of the study conducted research broadening knowledge about possibility of using alternative recycling materials in road engineering. The research was carried out to extend range of available stabilizers of one of hot mix asphalt (HMA) types – SMA (stone mastic asphalt).

2. RESEARCH ASSUMPTIONS

HMA (hot mix asphalt) in general consists of aggregates and asphalt binder. Some types of mixes require, however, additives to fulfil all mechanical requirements. Some additives are used as adhesion promoters especially in case of use of aggregates coming from acidic rocks [5]. The SMA requires stabilizer that will protect asphalt binder from separating from aggregates e.g. during mix transport. Nowadays, as SMA stabilizer are used mainly cellulose fibres. Apart from cellulose fibres there are other types of fibres available on the market such as acrylic, being synthetic ones. The authors of the research decided that use of alternative, preferably recycling materials as SMA stabilizer may result in economic and environmental benefits, especially taking into consideration that SMA is one of the most popular mix types for wearing course and it is not the only one using the fibres. BBTM and porous asphalt mixes also require stabilizers.

Presented research focused on comparison of different materials used instead of cellulose fibres. The aim of the research was to find alternative for traditional stabilizers. The research was divided into two parts. First part was carried out by Eurovia Polska S.A. team. During first stage of testes in 2013 mineral wood and high density polyethylene (HDPE) dust were used in the mix instead of cellulose fibres. Second part of the tests was carried out in 2018 by mixed Eurovia Polska S.A. and Silesian University of Technology team. In the chapters below the results of every research stage are presented.

3. FIRST STAGE – YEAR 2013

First attempt to find alternative SMA stabilizer was strictly connected with available materials being economically competitive with currently used. Eurovia Polska S.A. team visited recycling facilities where HDPE dust was found interesting in terms of cellulose fibres replacement. Mineral wool seemed visually similar to cellulose fibres so it was also taken for laboratory tests as alternative material of different origin. Both materials seemed to consist of fibres. They were, however, different in terms of high temperature behaviour. HDPE has melting point of between 120°C – 180°C while mineral wool over 1000°C.

Asphalt mix for the tests was made of basalt and granite aggregates with binder of penetration grade 50/70. Soluble binder content was 6,0%, mix gradation is shown in Figure 1. SMA air void content was 2,6% with maximal density 2,543 Mg/m^3. Stabilizer in form of cellulose-binder granules was added in dry process directly into the mixer simultaneously with bituminous binder. Laboratory mixing time was 5 minutes.

First parameters comparison between cellulose fibres, mineral wool and HDPE dust was binder drainage (Schellenberg's method) according to standard PN-EN 12697-18 [2]. The test were carried out on SMA 11 with unmodified binder 50/70. The results of the test are presented in Table 1.

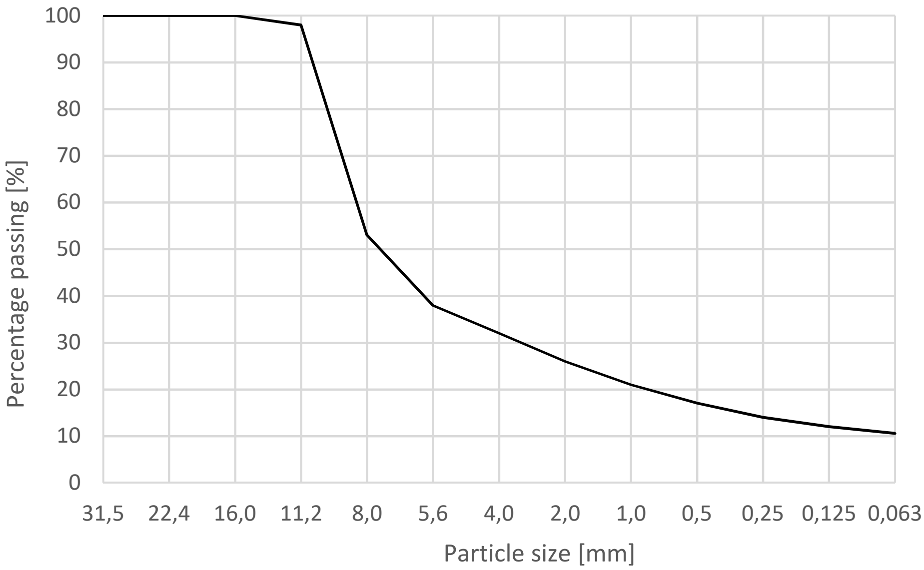

Figure 1. SMA gradation used for tests in the year 2013

Table 1. Binder drainage results (Schellenberg method)

Stabilizer type	Content of stabilizer (% of SMA mix)	Result
Cellulose granules	0,6	0,3%
Mineral wool	0,5	0,3%
HDPE dust	0,5	0,1%

On the basis of the results obtained in binder drainage tests HDPE dust was chosen for another comparison tests. Mineral wool characterised competitive result with cellulose fibres, nevertheless the HDPE dust gave better results and was economically more reasonable.

Further step of first research stage was to compare the most important parameters for SMA mix. According to polish technical documents (WT-2 [4]), the SMA for medium traffic should be examined in terms of water sensitivity (Indirect Tensile Strength Ratio (ITSR)) according to standard PN-EN 12697-12 [1] (method A) and wheel tracking (rutting resistance) according to PN-EN 12697-22 [3] in small device, method B in the air with temperature 60°C and 10 000 wheel passes. The tests were carried out for SMA containing HDPE dust as stabilizer. The results of rutting resistance were compared to the same mix containing cellulose fibres (Table 2), while ITSR results were compared to requirements according to polish technical documents (Table 3).

Table 2. Results of rutting resistance of SMA containing HDPE dust in comparison to traditional SMA

	PRD_{AIR} Result [%]
HDPE dust	6,9
Cellulose fibres	10,8

Rutting resistance results were presented as proportional rut depth [%]. Table 2 depicts significant difference between samples containing cellulose fibres and HDPE dust. After replacement of traditional stabilizer by HDPE dust the proportional rut depth decreased from 10,8% to 6,9%. In Poland in the past (before 2014) there was no requirement in terms of proportional rut depth for SMA for medium traffic, while technical document from 2014 [4] introduced requirement of 9% of proportional rut depth for SMA for medium traffic.

The difference between results of tested stabilizers is significant. It may be caused by melting of HDPE dust and consequently rising softening point of the whole binder in the mix. The rutting test results were obtained for mix compacted to designed air void content for both mixes so it did not play any role in terms of test result.

Table 3. Results of indirect tensile strength ratio of SMA containing HDPE dust in comparison to polish requirements

	ITSR [%]
HDPE dust	99
Requirements	90

Indirect tensile strength ratio results fulfilled requirements, therefore the decision has been taken to build SMA with HDPE dust stabilizer on trial section with controlled traffic. In August 2013 the trial section was built by weighbridge (Figure 2).

Figure 2. Trial section of SMA mix with HDPE dust stabiliser in August 2018, right after construction works

4. SECOND STAGE – YEAR 2018

After almost 5 years of wearing course service there were no visible damages of the mix. The fact urged to carry on with the research, as the mix withstood the test of traffic (all trucks at the facility must enter the weighbridge before leaving its premises), test of weather conditions (4 winters with frequent temperature drops below 0°C) and the test of time. The effect of the first HDPE use in SMA mix triggered start of another research programme but this time on Silesian University of Technology.

Apart from HDPE dust there were also rubber granules and polyethylene terephthalate (PET) used. Important factor is that HDPE was tested as material of different grading – HDPE dust (containing high content of fine particles) and 0/4 mm HDPE. PET material had grading 0/4 mm and rubber granules were of grading 0/2 mm. All the stabilizers were compared with mixture containing cellulose fibres (this time pure fibres without asphalt binder) and to the mix without stabilizer at all. SMA 11 with 50/70 binder was used for the test, similarly to the one used in the first stage of the research. SMA gradation is shown in Figure 3. The SMA had binder content 6,2%. Table 4 presents whole list of stabilizers used in the second stage of the research. Amounts taken for tests were chosen on the basis of international experiences with such materials described in literature. Figures 4, 5, 6, 7 and 8 present photographs of these stabilizers.

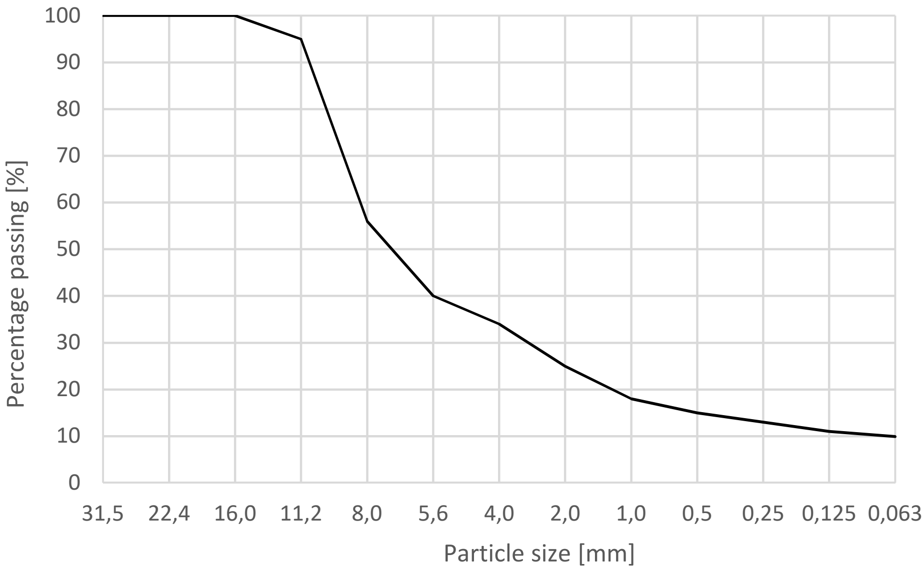

Figure 3. SMA gradation used for tests in the year 2018

Table 4. Content of specific SMA stabilizers used in the year 2018

Stabiliser	Content in relation to asphalt mix [%]
Cellulose fibres	0,3
PET 0/4 mm	0,5
HDPE 0/4 mm	0,75
HDPE dust	0,75
Rubber granules	1,3

Figure 4. Cellulose fibres

Figure 5. PET 0/4 mm

Figure 6. HDPE 0/4 mm

Figure 7. HDPE dust

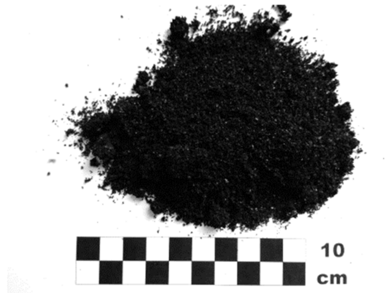

Figure 8. Rubber granules

First of all binder drainage tests were carried out. Similarly to the tests from 2013, Schellenberg method was used. The results of the test are presented in Table 5.

Table 5. Binder drainage results

Stabilizer	Binder drainage [%]	Requirements
None	0,46	≤ 0,3
Cellulose fibres	0,04	
HDPE 0/4 mm	0,18	
HDPE dust	0,10	
PET 0/4 mm	1,33	
Rubber granules	0,16	

The results of binder drainage show necessity of using stabilizer for SMA mix. The samples without any stabilizer did not fulfil requirements according to polish technical documents. Out of 5 different stabilizing additives PET 0/4 mm did not play its role resulting in rising binder drainage of the mix. Other stabilizers met the expectations and fulfilled requirements.

Results of water sensitivity test are shown in Table 6.

Table 6. Results of water sensitivity test

Stabilizer	**Mean value of indirect tensile strength**		**Water sensitivity**	**Requirements**
	ITS_w [kPa]	ITS_d [kPa]	ITSR [%]	ITSR [%]
None	841,8	902,1	93	90
Cellulose fibres	861,0	1013,2	85	
HDPE 0/4	762,9	836,4	91	
HDPE dust	1189,2	1307,2	91	
PET 0/4	686,3	698,2	98	
Rubber granules	818,2	900,9	91	

In terms of water sensitivity only traditional mix, containing cellulose fibres did not fulfil requirements. Unexpectedly, SMA without any stabilizer achieved better result in terms of ITSR. The most interesting reliance is visible in ITS_d results. Half of results is placed within range of 830 – 910 kPa. PET 0/4 mm affected the mix decreasing the ITSd value. Cellulose fibres and HDPE dust positively changed ITS values. Cellulose fibres enabled to achieve over 1000 kPa, while HDPE dust achieved impressive value of 1300 kPa.
Obtained ITSR results do not necessarily mean that use of cellulose fibres affects the mix negatively. Differences between results of tested stabilizers may be affected by repeatability of the testing method which is 15% according to [1].

The last test carried out in the research was rutting resistance. The results are presented in Table 7.

Table 7. Results of rutting resistance tests

Stabilizer	Results		Requirements [4]	
	PRD_{AIR} [%]	WTS_{AIR} [mm/1000 cycles]	PRD_{AIR} [%]	WTS_{AIR} [mm/1000 cycles]
None	12,42	0,32	≤ 9,0	≤ 0,15
Cellulose fibres	6,36	0,09		
HDPE 0/4 mm	3,62	0,02		
HDPE dust	3,94	0,02		
PET 0/4 mm	11,30	0,30		
Rubber granules	7,17	0,09		

Rutting resistance confirmed information gathered from binder drainage test. There is necessity of using stabilizer and PET 0/4 mm does not affect positively the mix. All other stabilizers fulfilled requirements of PRD_{AIR} and $WTS_{AIR,}$, according to polish technical documents [4].

5. DISCUSSION AND CONCLUSION

The research shows that there is possibility of broadening the range of used SMA stabilizers. Nowadays use of cellulose fibres is a certain option, however, civilizational changes and growing need of sustainable development make pressure to use recycling materials. The study shows potential of using HDPE dust as SMA stabilizer. It positively affected ITS values and rutting resistance without deteriorating ITSR value. It also withstood the test of time and traffic. In the nearest future it is planned to verify parameters of the trial section by drilling cores from the pavement. Apart from ongoing research it should be checked if the SMA mix containing HDPE dust can be recyclable and if there are any side effects of the change.

Use of HDPE dust as SMA stabilizer may be perceived as environmentally friendly action which goes along with economic benefits, as the HDPE dust is difficult to recycle due to its potential impurity. However, it is important to be sure about reproducibility of the HDPE stabilizer. It should be verified by e.g. continuous tests of maximal density or melting temperature. Currently it is important to answer remaining questions and, if everything will be verified, safely introduce the product.

ACKNOWLEDGEMENTS

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