Asphalt mixture performance and testing

The effect of hydrated lime on asphalt mixtures with highly polymer modified bituminous bitumen (HiMA)

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Abstract

The paper presents the results of research conducted to investigate the effect of hydrated lime on the properties of asphalt mixtures containing highly polymer modified bitumen (HiMA). HiMA is a new type of polymer modified binder and is characterized by reversed-phase of polymer-bitumen blend i.e. polymer phase in the polymer-modified binder becomes continuous phase. The influence of the hydrated lime addition on the functional properties of asphalt mixtures has been known on the basis of literature and field performance, however the combination of hydrated lime with highly modified bitumen does not result such obvious and expected effects. As part of the research project, the following types of asphalt mixtures were tested: SMA 8 (surf), asphalt concrete AC 16 (bin) for binder courses, asphalt concrete AC 22 (base) for base courses. Each of the mixtures was prepared with highly polymer modified bitumen (PMB HiMA). Asphalt mixtures were prepared in two variants. First one was produced with limestone filler, second in which a part of the limestone filler was replaced with hydrated lime. The research program included determination of functional parameters of asphalt mixtures (rutting resistance at 60°C, water and frost resistance ITSR, low-temperature test). On the basis of the analysis of the obtained results, several conclusions concerning optimum binder content, rutting resistance, failure stress in the indirect tensile method, ITSR parameter and TSRST test were created.

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1. INTRODUCTION

The importance of road transport has been growing in recent years. The development of the road network influence on searching new solutions to improve the quality and durability of asphalt pavement. At the same time, increasingly stricter environmental requirements enforce the best ecological materials and technologies on the construction process members. The built or repaired road is expected to be safe and operated failure-free for the longest time as possible. This is a huge challenge for designers, contractors and manufacturers of road construction materials. In this context, the trend is to use more durable materials and more advanced technologies to extend the pavement life. These can be materials with a long history of use, such as hydrated lime or materials developed recently, e.g. highly polymer modified bitumens (HiMA – the abbreviation comes from American English - Highly Modified Asphalt). Each such material separately improves specific asphalt mixture properties and extends the pavement durability.

2. HYDRATED LIME

Hydrated lime has been known as an additive to asphalt mixtures ever since they were first used [1]. Particular attention was paid to it in the USA in 1970s. It was found that hydrated lime is one of the most effective asphalt mixture additives improving the bitumen's adhesion to aggregate [2], and consequently improving the asphalt mixture resistance to water and frost.

The data collected over forty years of experience in using hydrated lime in asphalt mixture indicate that it is not only effective as an improver of the bitumen adhesion to aggregate [1,3], but it also allows for reducing the chemical ageing of bitumens [4,5]. In addition, it was found that the addition of hydrated lime, stiffens the mastic slightly more than a mineral filler [5,6], which is noticeable only at elevated temperatures [1,6]. In studies [1], it was noted that the addition of hydrated lime to asphalt mixture improved the mechanical properties, compressive strength and stiffness modulus - observations for more than a half of the tested asphalt mixtures, while improvement in rutting resistance was noticed in over 75% of cases. The studies [8] on fatigue resistance of asphalt mixtures indicate that hydrated lime improves the fatigue performance in 77% of cases. Due to the fact, the addition of hydrated lime does not show a greater stiffening effect of the asphalt mixtures at low temperatures than a typical mineral filler, no negative impact on thermal cracking has been reported in the literature [6]. Hydrated lime is usually added in the amount of 1% ÷ 2% of asphalt mixture weight [1].

3. HIGHLY POLYMER MODIFIED BITUMENS - HiMA

The latest solution to the problem of building safe and durable road constructions are **hi**ghly **m**odified **a**sphalts (American English: asphalt = binder) – HiMA. The HiMA bitumens are a relatively new type of bitumen which is modified by more than 7% by mass of SBS block copolymers. Such a high quantity of SBS causes that the volumetric proportions between bitumen and polymer after the modification process are reversed, therefore the final bitumen is characterised by the reversed bitumen-polymer phase. The first attempts to use the HiMA bitumen were made in the USA in 2009 on road test section, and then on the experimental track in the US (NCAT Pavement Test Track) [14,17].

In October 2013, an experimental section of the road surface was made in Poland using PMB 65/105-80 HiMA. It was the first section with highly modified bitumen in Poland. To date, collective laboratory experiments and experimental sections enable stating that PMB HiMA have above-standard properties. The volume advantage of the polymer network and its physical continuity gives the bitumen its unique properties, more similar to the properties of an elastomer than bitumen. One of the main characteristics of the new bitumen is the significant improvement of the flexibility and high tolerance resistance to increasing tensile strains, as well as the other properties which result from it - fatigue performance, resistance to cracking, rutting resistance etc. [9].

4. THE GOAL OF THE PROJECT

The influence of PMB HiMA and the addition of hydrated lime separately on the functional properties of asphalt mixtures has been known on the basis of literature and field performance, however the combination of these two components has not been tested yet.

As part of the research project, the following types of asphalt mixtures were tested: SMA 8 surf (for wearing courses), asphalt concrete AC 16 bin (for binder courses), and asphalt concrete AC 22 base (for base courses). Each of the mixtures was prepared with highly polymer modified bitumen (PMB HiMA). Asphalt mixtures were prepared in two variants. The first one was produced with limestone filler (SMA 8 surf 0H, AC 16 bin 0H, AC 22 base 0H), and the second in which a part of the limestone filler was replaced with hydrated lime (SMA 8 surf 1.8H; AC 16 bin 0,8H; AC 16 bin 1.3H; AC 22 base 1.3H). Each variant was analysed as a function of bitumen content (m/m).

5. EXPERIMENTAL PROCEDURES AND MATERIALS

5.1. Materials

The following materials were used in the project:

Table 1. Composition of SMA 8 surf

Material	Type	Content in mineral mixture		Content in asphalt mixture	
		SMA 8 surf 0H	SMA 8 surf 1.8H	SMA 8 surf 0H	SMA 8 surf 1.8H
Coarse aggregate	Gabbro 5/8	64.5%	64.5%	function of bitumen content	
Coarse aggregate	Gabbro 2/5	7.0%	7.0%	function of bitumen content	
Fine aggregate	Glacial crushed-stone 0/2	18.0%	18.0%	function of bitumen content	
Filler	Limestone	10.5%	8.7%	function of bitumen content	
Filler	Hydrated lime	-	1.8%	-	function of bitumen content
		Final density of the mineral mixture: ρa = 2.90 Mg/m^3			
Bitumen	PMB 65/105-80 HiMA			5.8% 6.1% 6.4% 6.7% 7.0% 7.3% 7.6%	
Adhesion promoter				0.3% of bitumen mass	0%
Cellulose fibres				0.3%	

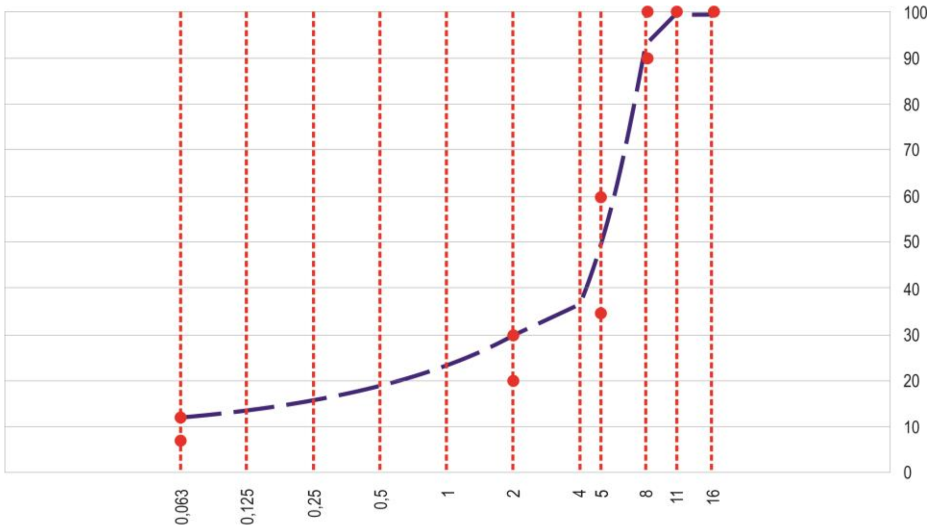

Figure 1: SMA 8 surf - Grading curve

Table 2. Composition of AC 16 bin

Material	Type	Content in mineral mixture			Content in asphalt mixture		
		AC 16 bin 0H	AC 16 bin 0.8H	AC 16 bin 1.3H	AC 16 bin 0H	AC 16 bin 0.8H	AC 16 bin 1.3H
Coarse aggregate	Gabbro 11/16	20%	20%	20%	function of bitumen content		
Coarse aggregate	Gabbro 8/11	14%	14%	14%	function of bitumen content		
Coarse aggregate	Gabbro 5/8	13%	13%	13%	function of bitumen content		
Coarse aggregate	Gabbro 2/5	14%	14%	14%	function of bitumen content		
Fine aggregate	Gabbro 0/2	33%	33%	33%	function of bitumen content		
Filler	Limestone	6%	5.2%	4.7%	function of bitumen content		
Filler	Hydrated lime	-	0.8%	1.3%	-	function of bitumen content	function of bitumen content
		Final density of the mineral mixture: $\rho_a = 2.98\ Mg/m^3$					
Bitumen	PMB 45/80-80 HiMA				3.9% 4.2% 4.5% 4.8%		
Adhesion promoter					0.3% of bitumen mass	0%	0%

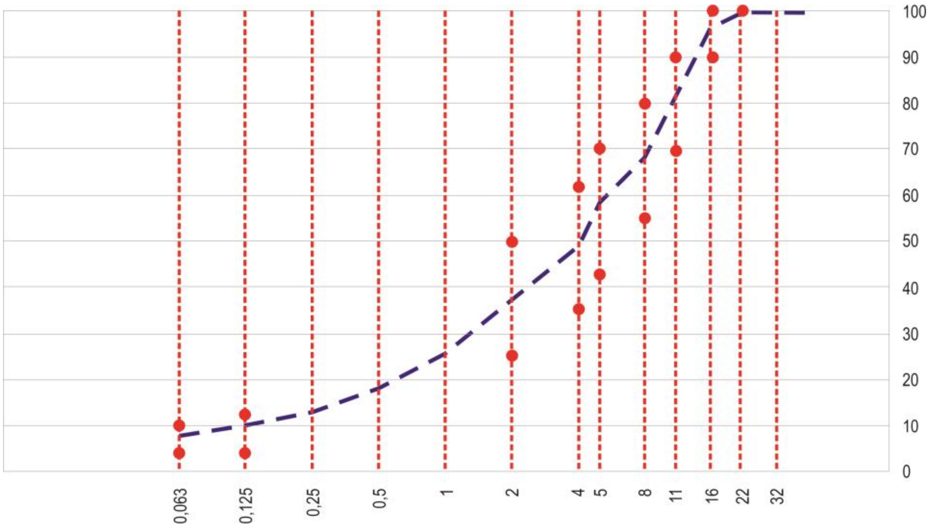

Figure 2: AC 16 bin - Grading curve

Table 3. Composition of AC 22 base

Material	Type	Content in mineral mixture		Content in asphalt mixture	
		AC 22 base 0H	AC 22 base 1.3H	AC 22 base 0H	AC 22 base 1.3H
Coarse aggregate	Gabbro 16/22	21.0%	21.0%	function of bitumen content	
Coarse aggregate	Gabbro 11/16	13.5%	13.5%	function of bitumen content	
Coarse aggregate	Gabbro 8/11	13.0%	13.0%	function of bitumen content	
Coarse aggregate	Gabbro 5/8	7.0%	7.0%	function of bitumen content	
Coarse aggregate	Gabbro 2/5	15.0%	15.0%	function of bitumen content	
Fine aggregate	Gabbro 0/2	25.0%	25.0%	function of bitumen content	
Filler	Limestone	5.5%	4.2%	function of bitumen content	
Filler	Hydrated lime	-	1.3%	-	function of bitumen content
		Final density of the mineral mixture: $\rho_a = 2.98$ Mg/m^3			
Bitumen	PMB 45/80-80 HiMA			3.6% 3.9% 4.2% 4.5%	
Adhesion promoter				0.3% of bitumen mass	0%

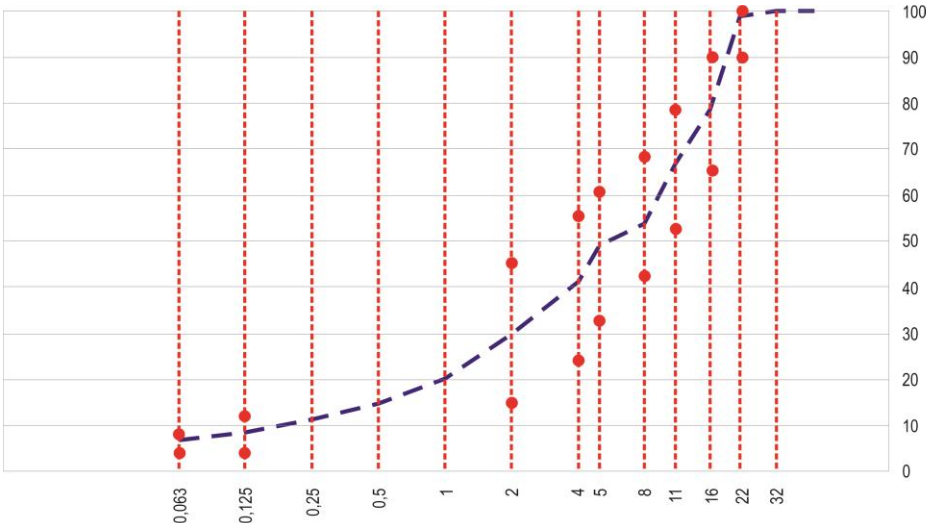

Figure 3. AC 22 base - Grading curve

5.2. Experimental procedures

The following tests were made in order to study the effects of PMB HiMA and the addition of hydrated lime on the asphalt mixtures properties:

- Rutting resistance acc. to EN 12697-22, small apparatus, method B in air, temperature 60 °C, 10,000 cycles;
- Water and frost resistance ITSR acc. to EN 12697-12, storage at 40 °C with one freezing cycle, test at 25 °C;
- SMA 8 surf, was also tested for resistance to low-temperature cracking TSRST acc. to EN 12697-46.

6. RESULTS

6.1. Rutting resistance

Analysis of the obtained results confirmed the conclusions presented among others researchers [18] - the amount of bitumen affects on the asphalt mixtures resistance to permanent deformation, in terms of both parameter: PRD_{AIR} and WTS_{AIR} (Fig. 5a-f).

On the other hand, the tests did not show an improvement of asphalt mixtures properties with the addition of PMB HiMA and hydrated lime in terms of percent rut depth and the rut growth rate. In the asphalt mixtures SMA 8 surf the differences were within the precision of the measurement (Fig. 5a and 5d), while in asphalt concretes - both for binder and base courses (Fig. 5a, 5e-f) - there were no significant differences. Absence of a visible improvement of parameters after the addition of hydrated lime may be effect of using too strong mineral skeleton in the asphalt mixture, applied test method or conditions. However, it should be noted that similar conclusions were presented according to application PMB and hydrated lime by Vansteenkiste S. et al. in [19].The options to be considered should include testing at a higher temperature, e.g. 70 °C, or testing in a large rutting apparatus acc. to EN 12697-22.

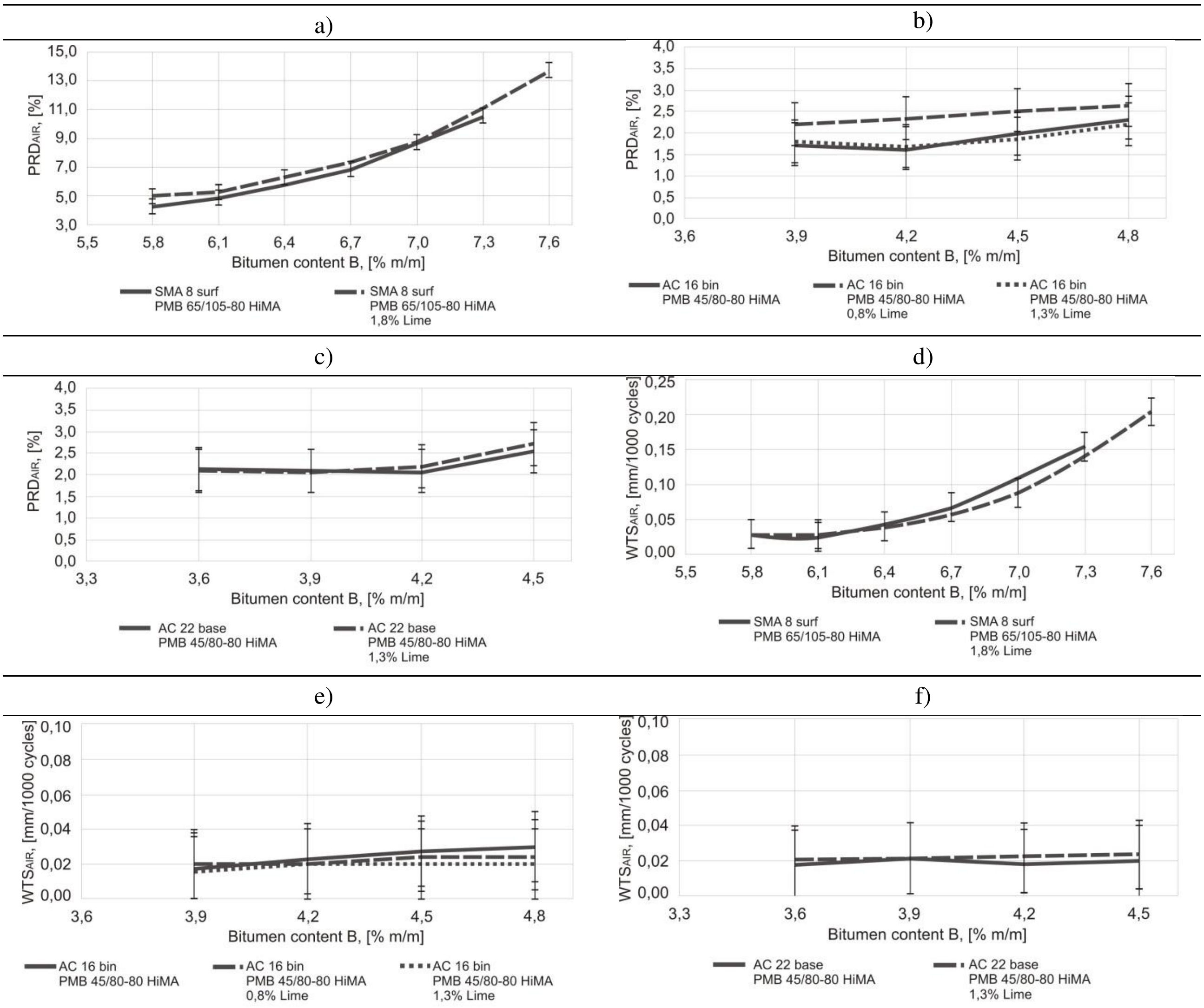

Figure 5. PRD_{AIR} a) SMA 8 surf, b) AC 16 bin, c) AC 22 base;
WTS_{AIR} d) SMA 8 surf, e) AC 16 bin, f) AC 22 base

6.2. Water and frost resistance

Figures 6a-c present the ITSR results with the estimated precision of the measurement (u = 5%). The obtained results did not show a clear impact of the amount of bitumen used in the asphalt mixture on the water and frost resistance – ITSR. For SMA 8 surf and AC 16 bin a certain maximum are observed (respectively 6,7% and 4,5%). However, due to the precision of the test, data from more studies are needed to prove this conclusion.

In the case of using PMB HiMA and hydrated lime in the asphalt mixture, no clear ITSR change has been observed either, which confirms the conclusions made by other authors when PMBs were applied [19].

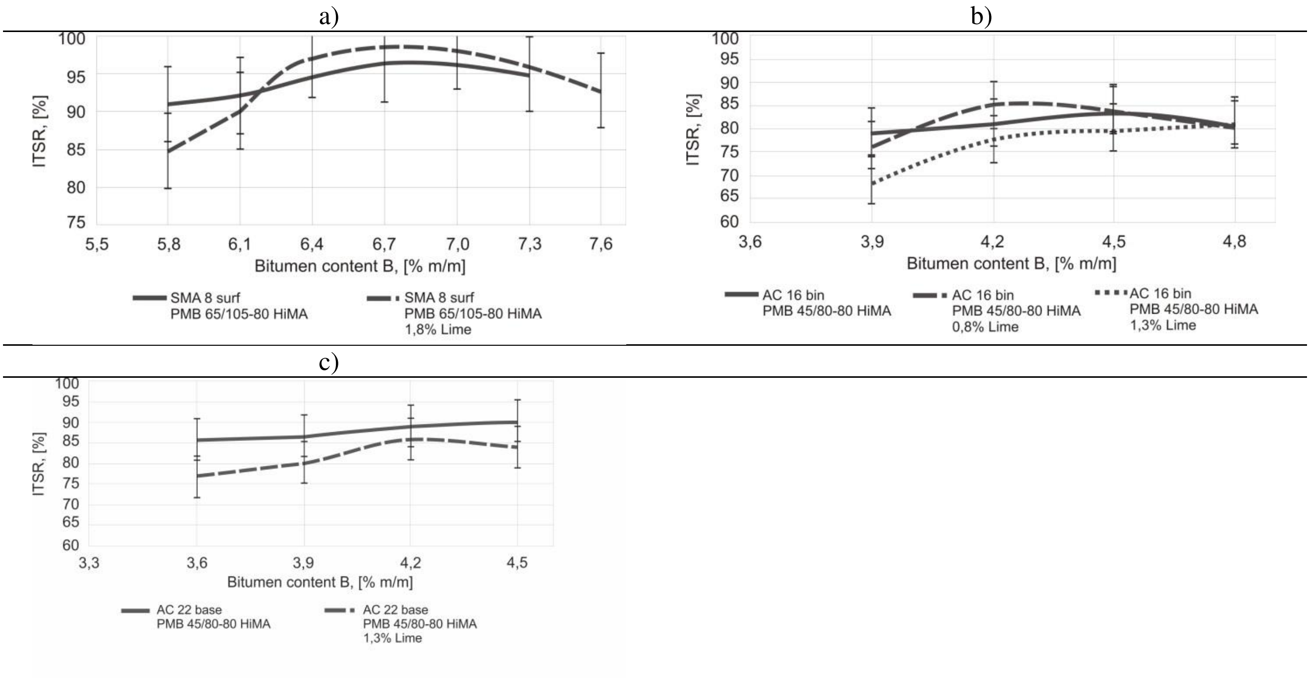

Figure 6. ITSR a) SMA 8 surf, b) AC 16 bin, c) AC 22 base

6.3. Low temperature cracking

Figure 7 shows test results of the asphalt mixtures resistance to cracking as a result of thermal shrinkage. In asphalt mixtures with PMB HiMA, it can be observed that if amount of bitumen is 6.1% $T_{failure}$= -33 °C, and if amount of bitumen is 7.3% $T_{failure}$= -36 °C (Fig. 7). Hence, it may be stated that the addition of bitumen improves the low-temperature performance of the asphalt mixtures.

Some differences were noticed in asphalt mixtures with PMB HiMA and the addition of hydrated lime in comparison to PMB HiMA asphalt mixtures without the addition of hydrated lime. Slight differences were observed in stresses at failure for these two asphalt mixtures. Furthermore, for mixtures with PMB HiMA and hydrated lime, some optimum can be observed for value of both fracture temperature and fracture stress. It can be assumed that hydrated lime affects on the binder and it would be important to determine the optimal ratio of hydrated lime to PMB HiMA. In presented (unit) case this ratio was 1.8: 7.0 = 0.257, so the proportions of hydrated lime to PMB HiMA <0.255 are no longer beneficial.

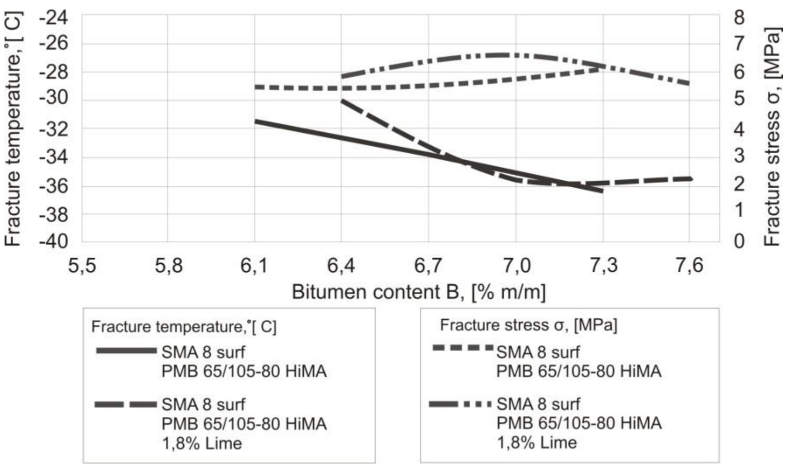

Figure 7. TSRST results SMA 8 surf

7. CONCLUSION

The tests described in the paper confirmed that the amount of used PMB HiMA has a significant impact on the asphalt mixture properties, such as: rutting resistance and resistance to cracking caused by thermal cracking. The impact of the amount of PMB HiMA on the resistance to water and frost is not clear, however there can be identified some optimal amounts in SMA 8 surf and AC 16 bin.

It is generally known that the addition of hydrated lime to the asphalt mixture with paving grade and polymer modified bitumens improves the asphalt mixtures properties in terms of rutting resistance and ITSR. Presented tests did not show improvement of properties in terms of rutting resistance and water and frost resistance in the case of using the PMB HiMA with addition of hydrated lime.

The increase of stress at failure in TSRST test of asphalt mixture with hydrated lime and PMB HiMA was confirmed, which proves that the addition of hydrated lime affects on the mastic in the asphalt mixture. Furthermore, appropriate proportions between hydrated lime and PMB HiMA in the mastic show some optimal values and it should be sought for each asphalt mixtures.

It should be borne in mind that too much hydrated lime may damage the asphalt mixture (when it's over the optimum point), symptoms of that could be observed in TSRST and ITSR results.

Lack of a visible improvement of properties of asphalt mixtures with PMB HiMA and hydrated lime can be a result of the specific character of the bitumen which contains a large amount of special SBS polymer. The PMB HiMA are characterised by the reversed bitumen-polymer phase. The volume advantage of the polymer network and its physical continuity gives the bitumen its unique properties, more similar to the properties of an elastomer than bitumen.

It should be noted that the described tests were conducted under standard conditions. Perhaps, in order to observe the impact of hydrated lime and PMB HiMA on asphalt mixtures properties more extreme test conditions are needed, e.g. higher rutting temperature, higher loads, more freezing-thawing cycles, or a weaker mineral skeleton in asphalt mixtures.

The tests on the use of hydrated lime and PMB HiMA bitumen should be continue because it can be a method to increase the durability of asphalt pavements.

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