DURABILITY OF SMA PAVEMENT WITH HYDRATED LIME ADDITIVE

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ABSTRACT

In order to ensure the required surface roughness of the SMA (stone mastic asphalt), the composition was supplemented by applying a quartzite sandstone aggregate. The lime stone was used as a mineral adhesive agent, and a liquid fatty amine agent was used as a reference. The required amount of hydrated lime was determined on the basis of SMA requirements such as: water and frost resistance according to the AASHTO T283, low-temperature cracking according to the PANK 4302, rut resistance test and static creep modulus test. In 1999 was made a pavement section, of SMA composition with hydrated lime and fatty amine agent, located in main street in Kielce (Poland). Over a period of 12 years the section was monitored by means of tests such as: surface condition, rut resistance test and roughness. It was found that the use of hydrated lime provided the satisfying durability of the SMA. Pavement condition of SMA, which included hydrated lime, does not deviate from the quality of SMA containing the liquid agent in reference to the water and frost resistance. However, the surface containing the hydrated lime additive has a greater rut resistance. The tests carried out on the basis of SMA samples taken from the pavement confirmed that the use of hydrated lime provided the required durability and greater resistance to the aging process in comparison with using fatty amine as an adhesive agent. It was also observed smaller changes of bitumen parameters in SMA containing hydrated lime.

Keywords: SAM pavement, hydrated lime, water and frost resistance, rut resistance, durability

1. INTRODUCTION

Road surface roughness plays an important role in ensuring the safety of traffic on moisture surface, especially in the initial phase of rain, while on the layer surface usually creates a tin film of the water which starts a skid effect and causes forming a "aquaplaning" effect. To prevent this undesirable phenomenon as soon as there is a need to drain a water from the pavement. For this reason, it is advisable to use such asphalt technologies that allow to perform wearing course layer with high expanded texture, and hence ensure quick drainage of water from the surface and ensure proper contact between the tread of the tire and the surface. An application in the 90's XX century stone mastic asphalt mix marked as SMA could be accounted for this type of technology. Except of SMA to this group belong a technologies such as porous asphalt and hot rolled asphalt for very thin layers. Researches of potential usability of this technologies in Polish conditions revealed that they are effective. It provide the required surface roughness in the initial period of its operation, ie for the first three - four years and appropriate durability [1, 2, 3]. Depending on the type of aggregate and mineral mix design in the following years the phenomenon of reducing or increasing of anti-skid resistance may take place. That why in the long period of operation of roads the essential role in ensuring its roughness plays a mineral material factor.

The primary criterion for assessing the desirability of aggregates in terms of anti-skid properties is its resistance to abrasion in the Los Angeles drum, according to EN 1097-2 and polishing expressed by using of an polished stone value index PSV according to EN 1097-8. The resistance of aggregate to the polishing has to bear with providing the surface to required macrotexture, which plays an important role in the initial period of its operation. On the other hand the resistance to the polishing is connected with a microtexture that ensuring a wearing course layer a good anti-skid properties in long term operation [1].

In Poland the quartzite sandstone could be accounted for the most resistant aggregate to abrasion and polishing process, which the one of the largest deposits is located on area of Kielce, near the Swietokrzyskie mountains [4]. An important advantage of the quartzite aggregates is its bright color in comparison with the color of the basalt aggregate, which is used as the standard aggregate in asphalt mixes. The use of the quartzite aggregates in asphalts causes significant brightening of the wearing course surface, which is important from the point of view of ensuring road safety at night. Also contributing to reduce the amount of electricity needed to provide the required stationary lighting on sections of pavement. Despite the advantages, which is characterized by the quartzite aggregates there are some disadvantages. Due to the high silica content up to 95% of its composition, it shows week affinity with the bitumen, which in some way, makes difficulty to use of this aggregates in asphalt mixtures. This property for some technological reasons from the beginning of 90's last century, limited the applicability of this aggregate. The studies that started of this period reveled that there aren't barriers to the use of this type of the mineral aggregate in asphalt mixtures [5, 6]. It was posed that it is necessary to apply the adhesives agent to improve the covering effect of this type of aggregate by bituminous binder. The most commonly adhesion agents ranks fatty amines. Unfortunately, they may cause an adverse effect on the bitumen parameters such the softening point that it may be reduced. Consequence of this influence of the adhesive agent is a decrease of the resistance to forming ruts. It is necessary using other adhesive agents that don't play a such important role regarding bitumen properties. Another type of adhesive agent is hydrated lime, which has been used in the Central and the Eastern Europe in the 60's of the twentieth century [7, 8]. However, due to technological difficulties in dispensing during production process into the bitumen, application of this adhesion agent was abandoned. The development the road technique on XX and XXI century contributed that the earlier problems had stopped to exist [9, 10, 11, 12, 13, 14]. In 1999, due to the renovation of Zelazna street in Kielce (Poland) which is the main communication street, the wearing coarse layer was built by application into SMA the composition of the quartzite aggregate. The second purpose of application of this type of aggregate was ensuring a high anti-skid resistance. In order to ensure proper affiliation between the bitumen and aggregate the hydrated lime was used. The fatty amine was used as a reference adhesive agent.

2. SMA PERFORMING

2.1 Project Outline

Modernization of pavement construction located at Zelazna street in 1999 was carried out with deep cold recycling technology. On the basis of measurements of traffic it was specified KR4 categories, which is characterized by the amount of L_{100} (ESAL - Equivalent Single Axial Loads) axle load of 100 kN per day per lane and it was calculated in the range from 336 to 1000.

The design of road construction met the requirements which was set out in guidelines developed by IBDiM [15]. The design consisted of a recycled sub-base layer in the cold recycling technology with a thickness was 20 cm with using of bitumen emulsion, cement and recycled materials derived from existing asphalt layers and stone foundations. The next layer was the binder coarse of 8 cm and the last was the wearing course made of SMA which thickness was 4.0 cm. Under the new layers was still a layer of aggregates with a variable thickness from 15 to 24 cm, which remained from the previous pavement construction. Road construction has been designed for 20 years of operation.

2.2 Study design

Tests program for determining the impact of the type of adhesion agent on the properties of SMA mixture and its preservation in terms of using quartzite aggregate was divided into two stages - laboratory and operational. In the first stage (laboratory), the special attention was paid on the mineral mix design and carrying out the necessary studies for assessing the impact of hydrated lime and fatty acid amines on the properties of SMA. After modernization of Zelazna Street continuously was conducted measurements layer condition parameters during operation. A current program of research of the first stage of SMA consisted of :

- standard properties,
- rut resistance,
- water and frost resistance.

The water and frost resistance of SMA was evaluated within the confine of the research program that was included:

- Indirect tensile strength reflected a influence of the existence of low temperature near 0°C, according to PANK 4302 of Finnish standards.
- The indirect tensile strength before and after cycles samples subjected to condition, according to AASHTO T283 standards, specifying the coefficient of resistance to water WR_w, and the coefficient of resistance to water and frost WR_{wm},

An important element of the study was to evaluate the homogeneity of the work. The measurements were taken only for samples whose void fraction content ranged between V - 2s ; V + 2s), where: V – is a mean void fraction content value in asphalt concrete, s – standard deviation. On this basis the identity of mean void fraction content values of the samples was assessed.

It should be noted that most studies in 1999 performed in accordance with the methodology, of that time, obligatory in Poland.

2.3 Mineral mix design

During designing of mineral mix of SMA, the main assumption was that, except quartzite aggregate (content was in scope of 50% and 70%) which was resistant to the abrasion and polishing process, the mineral mix should had an aggregate of smaller resistance to previously mentioned factors, ie the aggregate dolomite or limestone. This action was validated due to different grade of polishing for different aggregates. Therefore, during the operation, the texture of layer will have expanded. The consequence of this will be increase the value of the friction coefficient. It should be noted that the percentage of second aggregate in the mineral mix was selected on the basis of laboratory tests so that to not cause a reduction in the physical and mechanical properties.

It should be noted that the dolomite and limestone aggregates also plays an important role in improving the adhesion of the bitumen in the asphalt, reducing its negative potential due to the use of quartzite aggregate . Significant aspect in that way was contribution of the fine dolomite aggregate of 0/4 granulation. The expanded specific surface area contributes to the intensification of the chemical processes at the contact zone between aggregate - bitumen. The framework composition of SMA 0/12,8 which was performed in accordance with the guidelines of IBDiM [16] is summarized in Table 1.

Table 1 : The percentage of mineral materials in SMA 0/12,8.

Quartzite mix	
Component	Precentage share [%]
Limestone filler	10
Fine limestone aggregate 0/4	12
Dolomite aggregate 2/6	15
Quartzite aggregate - fraction 2/6,3 - fraction 6,3/12,8	 10 53
Total	100

Particle size distribution of SMA mix is summarized in Table 2

Table 2 : Particle size distribution o SMA mineral mix (passing)

sieve # [mm]	12,5	10	8	6,3	4	2	0,85	0,42	0,30	0,18	0,15	0,075
Mineral mix	90,4	72,9	61,4	51,1	34,0	25,0	19,4	16,7	15,3	13,8	13,2	11,4

Hydrated lime (HL) was added to a mineral mix by entering it as a substitute in mineral filler in an amount of 10, 20, 30, 40 and 50%. After mixing hydrated lime with the limestone filler it was received the “blended filler”, which was incorporated into a mineral mix.

2.4 Selected SMA properties

The asphalt of SMA contain a bitumen of D70, now it is marked as 50/70 in accordance with PN-EN 12591:2004. The bitumen was modified SBS polymer which was added to the binder in an amount of 2, 4 and 6% by weight. In order to ensure the proper adhesion of the bitumen to aggregate in control SMA mixture a fatty amine acid liquid adhesive agent was used (A).
The required amount of binder of 6.1% in SMA was determined on the basis of the Marshall tests. The same Marshall tests was used to gauge a recommended a liquid adhesion agent content which was of 0.2%. In order to determine the impact of hydrated lime and SBS polymer on the properties of SMA the statistical analysis was used by applying a following general mathematical regression model [17]:

$$y = b_0 + \sum_{i=1}^{n} b_i \cdot x_i + \sum_{i=j=1}^{n} b_{i=j} \cdot x_i \cdot x_j + \sum_{i=1}^{n} b_j \cdot x_j^2$$

Where x_i is the amount of polymer SBS in bitumen [%], x_j is the amount of hydrated lime [%] and $b_i \div b_j$ are the experimental ratios values.

During laboratory tests, as mentioned earlier, the physical and mechanical parameters were analyzed: void content (Vm), water absorption (A), static creep modulus (Es), rut depth (RD), water resistance (WRwm) and low temperature cracking resistance (Rr). The regression models of these features have been presented in figure 1, 2 and 3.

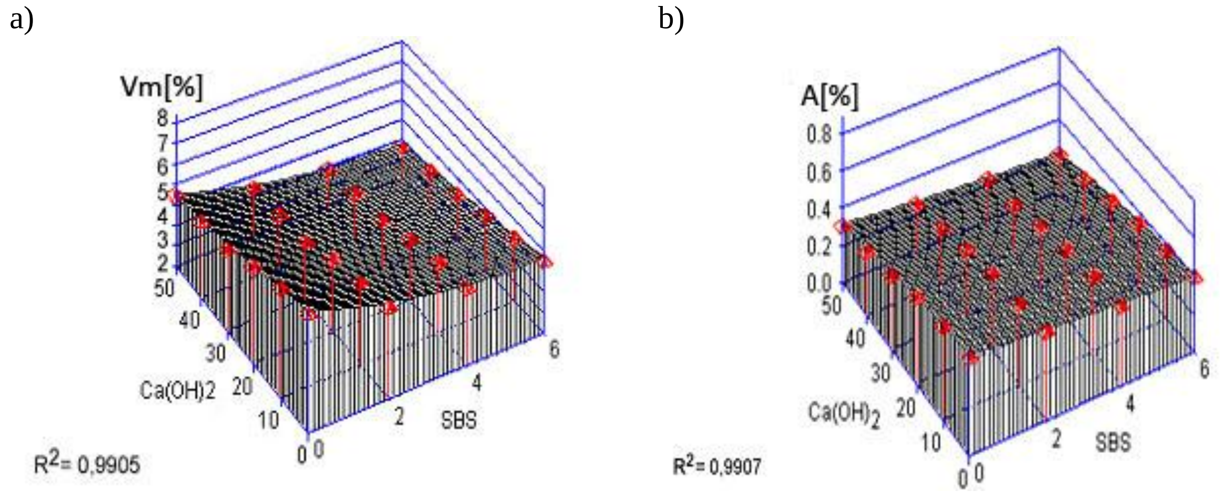

Figure 1 : The influence of hydrated lime ($Ca(OH)_2$) and polymer (SBS) on a) void contents (V_m), b) water absorption (A) of SMA asphalt

The assessment of R^2 and impact of the factors (V_m, A) have been presented in table 3. The values of R^2 indicate proper fitting of the obtained models.

Table 3: R^2 coefficient and the factors influence assessment

Parameter	R^2	Hydrated lime ($Ca(OH)_2$)	Polymer (SBS)
V_m [%]	0,9905	0.00011	0.00038
A [%]	0,9907	<.0001	<.0001

The tests results showed that the SBS polymer and content of hydrated lime had a significant influence on void fraction and the water absorption on significant level of 0,05. In case of water absorption the influence of both factors are much greater according to ANOVA analysis. The values of the experimental coefficients of the regression models have been given in table 4.

Table 4 : The values of the experimental coefficients for P_m, N_w

Parameter	b_0	b_1	b_2	b_3	b_4	b_5
V_m [%]	6,999524	-0,534167	-0,032221	0,047917	-0,00020	-0,00161
A [%]	0,516149	-0,024083	-0,00280	0,001042	0,00002	-0,000026340

Hydrated lime and SBS polymer significantly affects the void fraction and water absorption of SMA. Increasing the concentration of hydrated lime reduces the void fraction content and water absorption. It should be noted that the intensity of the impact of the content of hydrated lime on the void fraction content is higher than the water absorption. In accordance with the applicable requirements from 1999, the content of void fractions in SMA wearing course layer should be from 1.5 to 4.5%.The realization of this criterion for designated SMA mixtures is possible by using the hydrated lime and SBS modification bitumen both. By the way it should be noted that the SMA mixture used for wearing course layer must contain a SBS modified bitumen according to Polish standards. Analyzing the characteristic depending of void fraction in relation to the amount of hydrated lime and the amount of SBS polymer it can observe a positive synergistic effect of these two components on SMA. A similar character is the impact of hydrated lime and SBS polymer on water absorption of SMA.

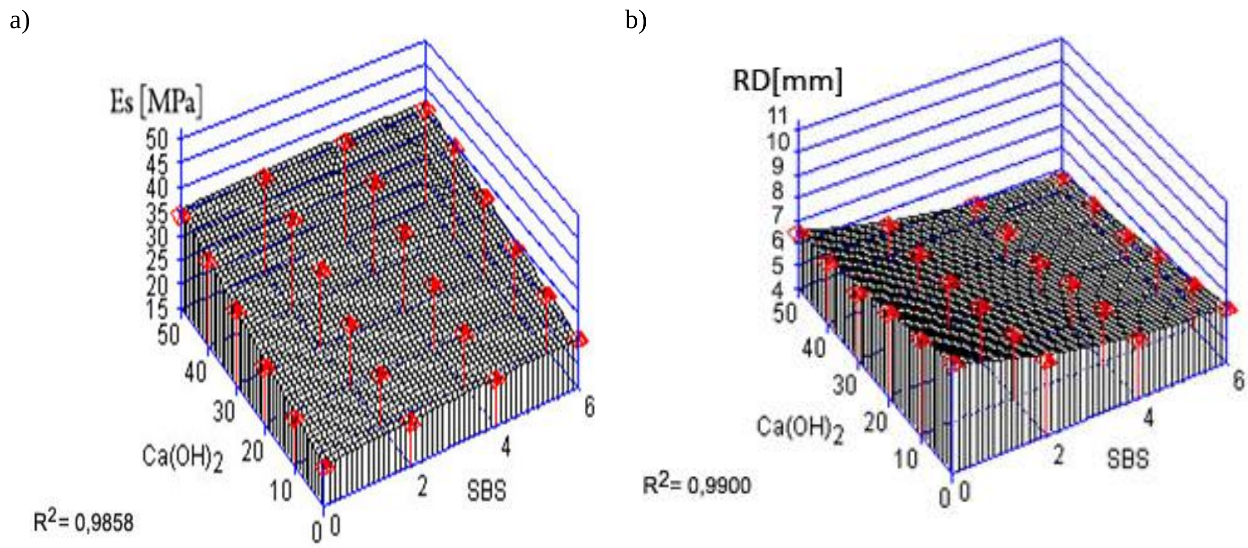

Figure 2 : The influence of hydrated lime ($Ca(OH)_2$) and polymer content (SBS) on a) static creep modulus (Es) and b) rut depth (RD) of SMA

The assessment of R^2 and impact of the factors (E_s, K) has been presented in table 5. The values of R^2 indicate proper fitting of the obtained models.

Table 5 : R^2 coefficient and the factors impact assessment

Parameter	R^2	Hydrated lime ($Ca(OH)_2$)	Polymer (SBS)
E_s [MPa]	0,9858	0.0007	0.0142
RD [mm]	0,9900	<.0001	<.0001

The tests results showed that the SBS polymer and content of hydrated lime had a significant influence on rut resistance and the static creep modulus (the p-value was lower than 0,05). In observed studies a hydrated lime played a main role in ensuring an increasing in static creep modulus. Values of the experimental coefficients of the regression models have been given in table 6.

Table 6 : The values of the experimental coefficients for E_s, K

Parameter	b_0	b_1	b_2	b_3	b_4	b_5
E_s [MPa]	22,844940	0,672024	0,234423	-0,047917	-0,003114	0,000281
RD [mm]	7,612083	-0,699762	-0,058227	0,058333	0,001257	0,000335

Influence of hydrated lime on the properties of SMA is more significant than the SBS polymer. At the same time it should be noted that the observed synergy (synergy) of both factors affected properties of SMA. In accordance with the applicable Polish standards requirements, obligatory of this time, the static creep modulus of SMA should be higher than 21 MPa. The content of 10% of hydrated lime in SMA, even without the use of polymer modified binder, caused satisfying this criterion. Both the influence of hydrated lime and SBS polymer are important for assessing rut resistance of SMA (Fig. 2b). In 90's the rut depth assessment was not in effect, so there was no criteria for assessing this parameter for SMA. The study was performed in a wheel tracking device. Ruts depth was assessed based on the ruts depth after wheels passing of 10^4 cycles. It should that the rut depth should not be greater than 10 mm. Research results show that, regardless of the SMA composition, it is realized. At the same time, with increasing concentration of hydrated lime and a SBS polymer there is a significant improvement in rut resistance (evaluated by means of rut depth) of SMA.

a) b)

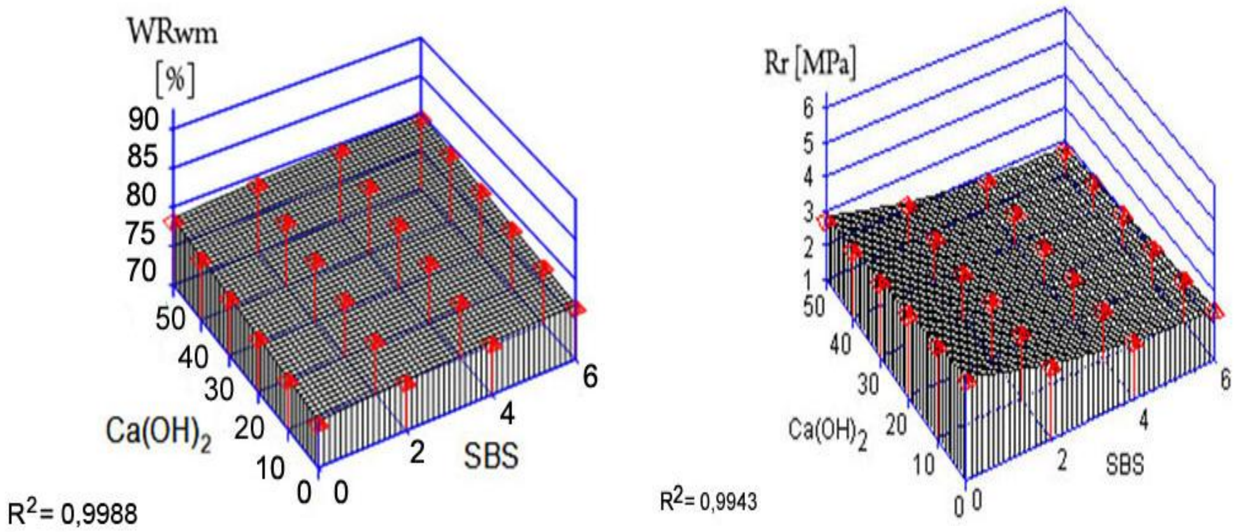

Figure 3 : The influence of hydrated lime ($Ca(OH)_2$) and polymer content (SBS) on water and frost resistance (WR_{wm}) and low temperature cracking (R_r).

The assessment of R^2 and impact of the factors (WR_{wm}, R_r) has been presented in table 7. The values of R^2 indicate proper fitting of the obtained models.

Table 7 : R^2 coefficient and the factors impact assessment

Parameter	R^2	Hydrated lime ($Ca(OH)_2$)	Polymer (SBS)
WR_{wm} [%]	0,99880	<.0001	0.0121
R_r [MPa]	0,9943	0.0011	<.0001

The test results showed that the SBS polymer and content of hydrated lime had a significant influence on resistance to the effect of climatic factors (the p-value was lower than 0,05)(Fig.3). In observed studies as previously a hydrated lime played a main role in ensuring an increasing in static creep modulus. All analyzed factors presented a high level of R^2 coefficient greater than 0,9. Values of the experimental coefficients of the regression models have been given in table 6. The values of the experimental coefficients of the regression models have been given in table 8.

Table 8 : The values of the experimental coefficients for WR_{wm}, R_r

Parameter	b_0	b_1	b_2	b_3	b_4	b_5
WR_{wm} [%]	75,647143	0,325060	0,061561	-0,021875	0,000414	-0,00008036
R_r [MPa]	3,908214	-0,296786	0,018089	0,018750	0,001571	0,000026786

It should be noted that the SMA mixture even without these modifiers meets the requirement which posed that water and frost resistance (WRwm) should be greater than 70%. The use of hydrated lime and SBS polymer is favorable for improving the characteristics of the SMA mixture. SMA usually has low temperature cracking resistance according to PANK 4032, if the indirect tensile strength is less than 4.8 MPa. The use of hydrated lime improves the characteristics of the SMA mixtures, but the intensity of impact of this factor is less than the SBS polymer. In this case it can be concluded that the SBS polymer plays a major role in improving behavior of SMA at low temperature.
The intensity of the impact of hydrated lime on the properties containing of SBS polymer is varied. On the basis of the Harington utility function it was developed by [18] expressed as:

$$U^{III} = \exp\left[-\exp\sum_{i=1}^{m} w_i \cdot \left(-\frac{y^{(i)} - y^{(i)}_G}{y_L{}^{(i)} - y_G{}^{(i)}}\right)\right]$$

where:

- $y^{(i)}$ SMA properties,
- w_i properties attributed weight $y^{(i)}$,
  $0 \le w_i \le 1$; $i=1,2,\ldots m$;

It was determined a recommended composition which ensured the best properties of SMA. The most preferred mixture contained of 30% of SMA hydrated lime in the blended filler, and 4% of SBS polymer in the bitumen.
In table 9 summarizes the characteristics of the recommended SMA mixtures included hydrated lime and fatty acid amine.

Table 9 : Selected SMA properties

No	SMA parameters		Kind of adhesive agent	
			HL	**A**
1	Void fraction content	[%]	3,5	3,7
2	Voids filled asphalt	[%]	79,2	78,5
3	Water absorption	[%]	0,28	0,35
4	Static creep modulus	[MPa]	24,8	22,5
5	Indirect tensile strength ITS	[MPa]	1,46	1,52
6	Maximum rut depth	[mm]	5,1	5,6
7	Low temperature cracking PANK 4302	[MPa]	2,2	3,1
8	Resistances according to AASHTO T283 standard: - water resistance WR_w - water and frost resistance WR_{wm}	 [%] [%]	 89,2 79,4	 86,1 77,8
9	Binder content	[%]	6,1	6,1
10	SBS polymer content in bitumen	[%]	4,0	4,0
11	Adhesive agent: - hydrated lime (variable in filler) - acid fatty amine	[%]	30	0,2

Analyzing of the impact of the type of adhesive agent on properties of SMA it can be concluded that during research process comparable level of parameters for two kind of adhesive agent were obtained by recommended contents of adhesive additive. However, using of hydrated lime in comparison to the fatty amine delivers higher properties of SMA.

3. OPERATION OF SMA

In 1999 SMA was made which was intended for wearing course layer of the experimental section of dual carriageway localized in Zelazna street in Kielce. On the eastern section of SMA it was built with the addition of the hydrated lime and the western section was built with liquid adhesive agent. During the production, transport and performing there weren't adverse effects caused by the adhesive agent. During the macroscopic evaluation it can be concluded that the kind of adhesive additive caused no impact on . The surface texture made from SMA does not depend on its composition. Only the color difference occurred. The use of hydrated lime in the composition of SMA made a surface dull the color of the control surface (fatty amine) was glossy. SMA was subjected to continuous monitoring in accordance with the methodology in Poland (SOSN - Pavement Condition Assessment System [19]). The examination concern the following basic operating parameters such as surface condition, evenness, roughness and rut resistance. The depth of macrotexture was also investigated using the volumetric method ([20] and PN-EN 13036-1). In order to obtain comparable results of the parameters it was performed the measurement on each year in April.
Particular attention during the test surface of SMA was paid on the impact of climatic factors and particularly the impact of water and frost on durability in aspect of the type of adhesion agent . Six types of defects of surface were selected, which may be caused by climatic factors and (Table 10).

Table 10 : SMA surface damage during operations

Nr	Damage type	Service time											
		2		4		6		8		10		12	
		Kind of adhesive agent											
		HL	A	HL	A	HL	A	HL	A	HL	A	HL	A
1	raveling	-	-	-	-	-	-	-	N	N	N	N	N
2	stripping	-		-		-	-	-	-	-	-	-	N
3	Low temperature cracks	-	-	-	-	-	-	-	-	-	-	-	-
4	Fatigue cracks	-	-	-	-	-	-	-	-	-	-		-
5	Mesh cracks	-	-	-	-	-	-	-	-	-	-	-	-
6	Longitudinal cracks	-	-		-	-	-	-	-	-	-	-	-
7	Transverse cracks	-	-	-	-	-	-	-	-	-	-	-	

symbol:
“ –“ – lack of damage,
“N” – rare symbolical damages,

Examination of the results of the surface condition, in aspect of water and frost impact, shows that the applied adhesive agents (hydrated lime, fatty amine) effectively realized their task. During a seven years operation on the surface of SMA there weren’t any damages caused by effect of water and frost. In case of SMA with fatty amine additive in eight year operation there were rare symbolical damages caused by water an frost effect, especially raveling of great particles of aggregate. Similar defects appeared on SMA pavement made of the hydrated lime in the blended filler but only after 10 years of operation. It should be noted that in 12 year of use of SMA layer with the liquid adhesion occurred a defect connected with stripping. After 12 years of operation SMA pavement can be concluded that the surface condition, regardless of the type of the adhesive additives, has still a very good quality (Figure 4, Figure 5).

a) b)

Figure 4 : View of surface texture of SMA after 12 years depending on type of adhesion agent
a) hydrated lime, b) fatty amine

a) b)

Figure 5 : View of surface of SMA after 12 years operation depending on type of adhesion agent
a) hydrated lime, b) fatty amine

An important stage in the study was to assess the operational performance of SMA in aspects of application of the adhesion agent. At the beginning the measurements of these parameters was made in accordance with Polish standards. It should be noted that the measurement of the surface roughness during the tests were performed using the dynamometric trailer SRT-3 and using the TRL English pendulum (PN-EN 13036-4). For a easier interpretation of this parameter the study of roughness was expressed in terms of the pendulum TRL.
Change in SMA operational parameter of surface were given in figure 6.

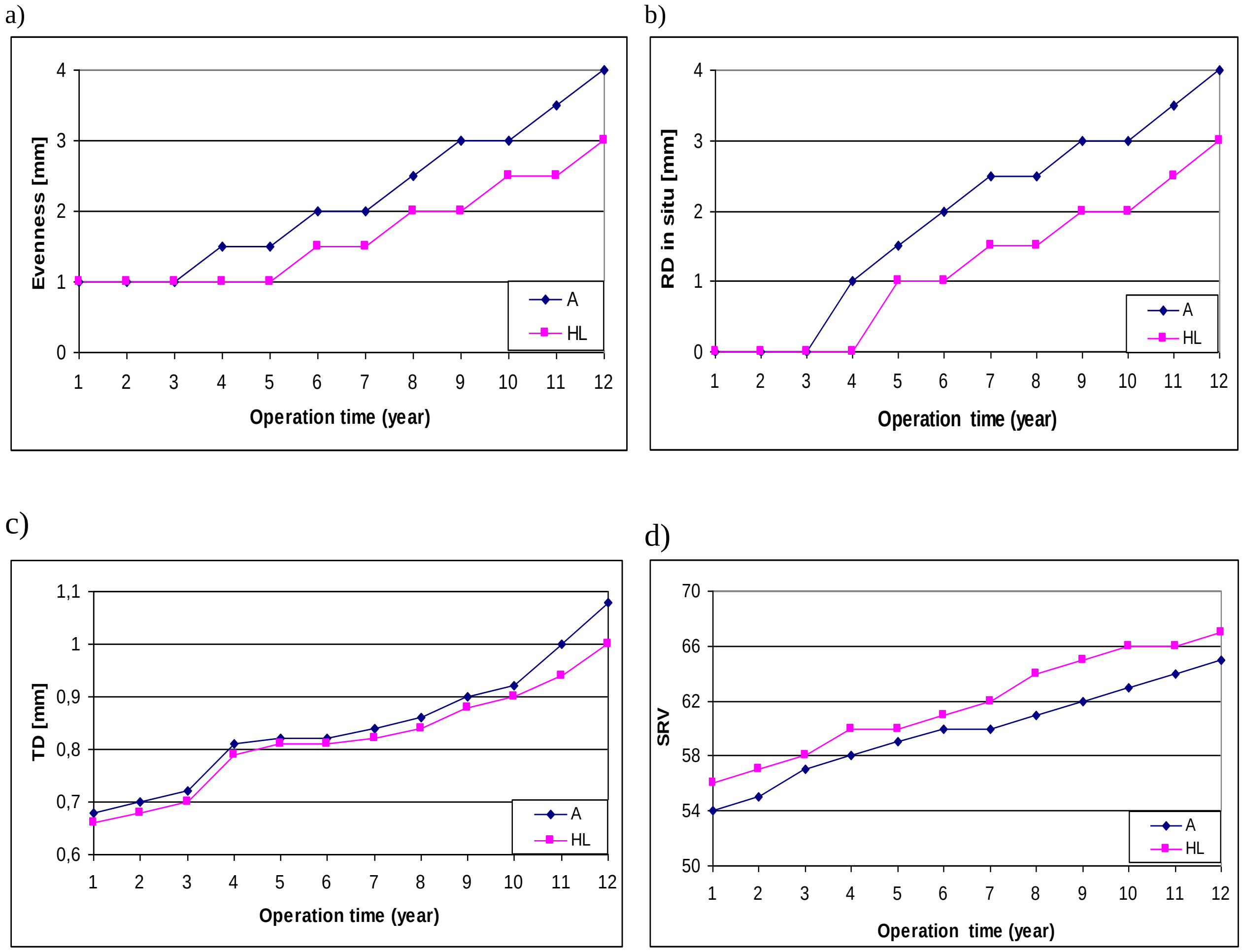

Figure 6 : Characteristic of SMA surface condition in operational
a) evenness, b) rut depth in situ (RD in situ), c) texture depth (TD), d) Skid Resistance Value (SRV)

Both the macroscopic evaluation as well as assessment of surface of SMA show that the condition of SMA is very good regardless of the type of the adhesion agent. It should be noted that the hydrated lime affects more favorable to SMA surface condition than the use of fatty acid amines. The intensity changes in operating parameters of SMA are less than the liquid adhesive agent was used. SMA pavement meets the requirements of the first class according to SOSN standard, which is the best class (bumps are smaller than 10 mm). Similarly, the rut depth during the operation period could be categorized to the first class - the best, because its depth is less than 10 mm regardless of type of the adhesion agent. In relation to the macrotexture depth of SMA pavement, it meets the requirements in relation to the vehicle speed above 120 km / h [20]. Moreover, analyzing of the SRV coefficient it can be concluded that the surface roughness is on the high level. It should be noted that the value of SRV coefficient still increases which is a consequence of selected aggregates.
Interested was an evaluation of time series of changing SMA surface parameters. Complex evaluation was assessed by means of the linear model. In addition, it was generated a forecasting for next 5 years of operation. The estimation error, slope and R^2 coefficient for the model were presented in table 11.

Table 11 : The estimation error, slope and R^2 coefficient for the model

Regression parameter	A(TD)	HL(TD)	A(RN)	HL(RN)	A(RD)	HL(RD)	A(SRV)	HL(SRV)
root MSE	0,029	0,021	0,2	0,217	0,252	0,226	0,43	0,456
slope	0,032	0,0228	0,28	0,189	0,384	0,285	0,944	1,034
R^2	0,935	0,956	0,959	0,9	0,965	0,95	0,983	0,984

* TD - texture depth, RN - evenness, RD - rut depth, SRV – skid resistance value, friction coefficient, A()- amine additive, HL()-hydrated lime additive

It was stated that mostly surface parameters of SMA with the hydrated lime content have favorable lower rates of the slope than situation of application of fatty acid. Only in case of SRV coefficient the growth rate of slope are greater in SMA with the hydrated lime. It indicates to increase of skid resistance of SMA which was mentioned in results [21]. The Pearson's R^2 coefficients were greater than 0,9 which pose of a good correlation of applied model. Simultaneously greater estimation was connected with estimation error describing a fluctuation of test results in area of a predicted linear model.
The relevant element of the study was to evaluate the stiffening transformation of bitumen properties (control C) during 12 years of operation SMA pavement. After extraction of the binder of SMA mixture, were assessed parameters such as: penetration (P) at 25ºC, softening point (T_{Pik}) and braking point temperature (TF) and elastic recovery at + 25^0C (ER) (Figure 7).

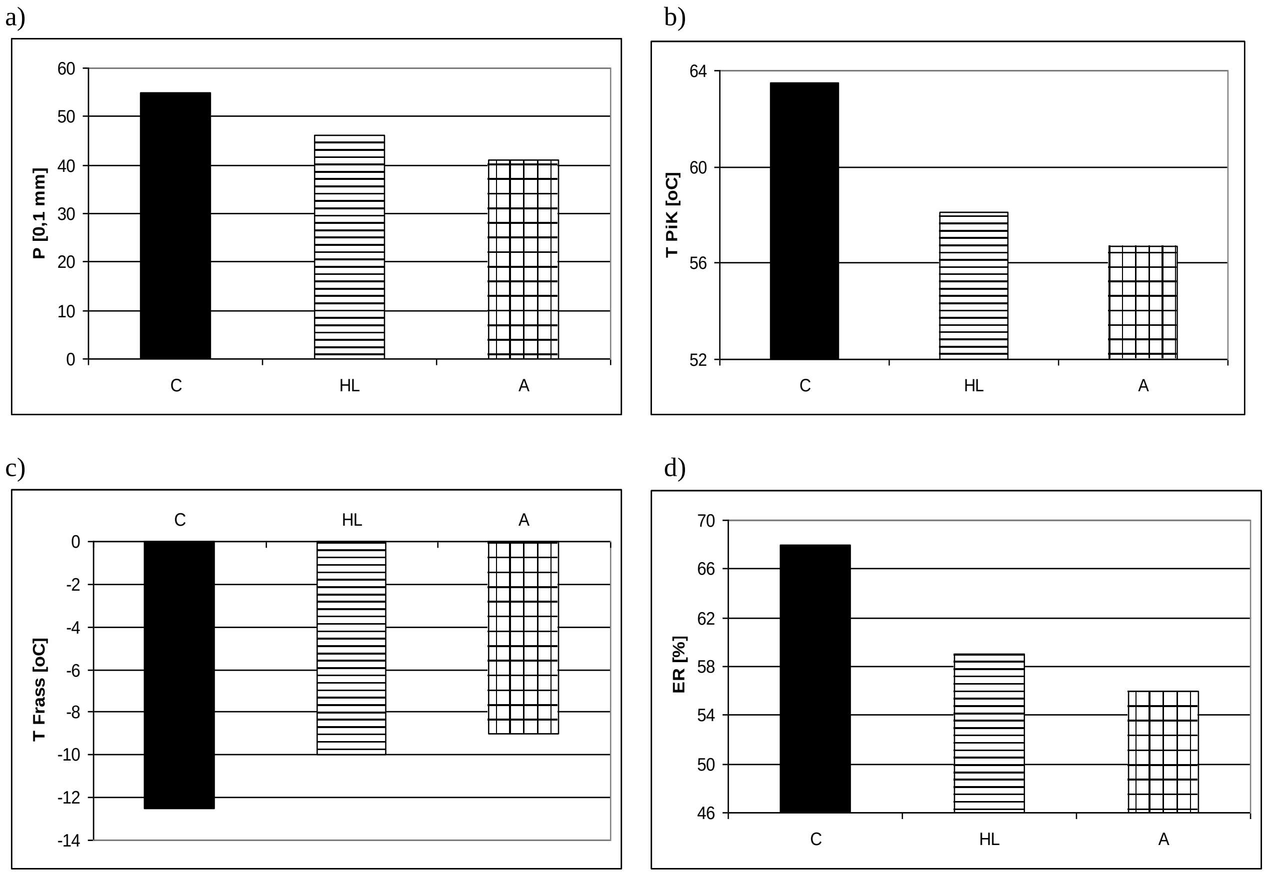

Figure 7 : Characteristic of the binder of SMA mixture: a) penetration (P) at 25ºC, b) softening point (T_{Pik}), c) braking point temperature (TF), d) elastic recovery at + 25^0C (ER)

Analysis of changes basic properties of SBS polymer modified bitumen in SMA shows that over 12 years of operation the aging process was took place as a result of the oxidation process and radiation (UV rays) [22]. It should be noted that changes in the parameters are not large. The scale of process likely depends on the type of crude oil which was derived from area of Russia. This bitumen comprised of a lot of oils, resins and low level of asphaltens. Also, the lower aging intensification was registered in the mastic with the hydrated lime than fatty amine. In this case the hydrated lime plays a main role as anti-oxidant. Beside of this the hydrated lime neutralized acids formed during the oxidation of the bitumen and polar compounds in a bitumen which reduces the increase in viscosity of asphalt. These conclusions also were taken into consideration by scientists [23, 24]. Thus it can be concluded that SMA with the hydrated lime in the subsequent period of operation will be more resistant to water and frost as well as the loss of adhesion. Additionally the SMA with a hydrated lime was characterized by less changes in elastic recovery and will by more resistant to action of vehicle axis then SMA with a liquid adhesive agent.

4. CONCLUSION

On the basis of the test results took from twelve period of operation the following conclusions can be drawn:

- the use of the hydrated lime in SMA does not generate a inconvenience during production, transportation and performing process;
- hydrated lime significantly influence on generating of physical and mechanical properties and water and frost resistance of SMA;

- increasing of the concentration of the additives (SBS polymer, hydrated lime) improves the mechanical properties of SMA mixtures such as a stability according to Marshall, a static creep modulus and a rut resistance;
- water and frost resistance of SMA was improved as a result of the use of hydrated lime in comparison with the use of fatty amines;
- hydrated lime plays an important role in ensuring the durability of SMA in relation to the climatic effect especially with using a quartzite aggregate;
- the use of the hydrated lime in an amount of 30% by the filler weight was slowed down a ageing process in comparison with the use of the liquid adhesion agent (fatty amine) of 0.2%,
- hydrated lime can be used in SMA mixture simultaneously replacing the liquid adhesive additives (fatty amines) influencing on the improvement the water and frost resistance to and rut resistance,
- SMA pavement condition with the hydrated lime (30% filler) during 12 years of operation is comparable to the situation when the fatty acid amine was used;
- the use of hydrated lime in an amount of 30% limestone filler in the composition, ensured the durability of SMA containing of SBS polymer during the 12 years period.

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