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INFLUENCE OF HYDRATED LIME ON DURABILITY OF SMA ASPHALT PAVEMENT WITH QUARTZITE AGGREGATE

Abstract

The durability of pavement layer desponds on the type of mineral aggregate. In 1999, while rebuilding road infrastructure in Kielce (Poland), a SMA wearing coarse layer with hydrated lime was placed on the town's main streets. SMA mixture contained 63% of quartzite aggregate. The hydrated lime was dosed into the SMA mixture to replace 30% of the filler mass. The pavement surface condition after 12 years life was very good. The hydrated lime additive was found to have a positive effect on water resistance of SMA pavement.

Keywords: hydrated lime, SMA, durability, quartzite aggregate, water resistance

1. Introduction

In Poland the quartzite sandstone could be considered as the most resistant aggregate to abrasion and polishing process. One of the largest deposits of this material are located in the vicinity of Kielce, near the Świętokrzyskie 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. It also contributs to reduce the amount of electricity needed to provide the required stationary lighting on sections of pavement. Despite the advantages of 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 it difficult to use 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 at this period reveled that there are no barriers to the use of this type of the mineral aggregate in asphalt mixtures [2]. 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 common adhesion agents are fatty amines. Unfortunately, they may cause an adverse effect on the bitumen parameters such the softening point that it may be reduced. A consequence of this influence of the adhesive agent is a decrease of the resistance to forming ruts. It is necessary to use other adhesive agents that don't play such an 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 [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 [3, 7, 9].

In 1999, due to the renovation of Zelazna street in Kielce (Poland) which is the main communication street, the wearing coarse layer was built with 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

Modernization of pavement construction located at Żelazna street in 1999 was carried out with deep cold recycling technology. On the basis of measurements of traffic it was specified as KR4 category [6].

The design of road construction met the requirements which were set out in guidelines developed by IBDiM [13]. The design consisted of a recycled sub-base layer in the cold recycling technology with a thickness of 20 cm with using 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 [14]. Under the new layers there 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.

2.1. 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), special attention was paid to 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 measurements were continuously conducted of 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 (PANK 4302 of Finnish standards and 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 majority of studies in 1999 were performed in accordance with the methodology, at that time, obligatory in Poland.

2.2. Mineral mix design

During designing of mineral mix of SMA, the main assumption was that, except for quartzite aggregate (whose content was in scope of 50% and 70%) which was resistant to the abrasion and polishing process, the mineral mix should have aggregate of smaller resistance to previously mentioned factors i.e. 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 an increase in 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 as not to cause a reduction in the physical and mechanical properties.

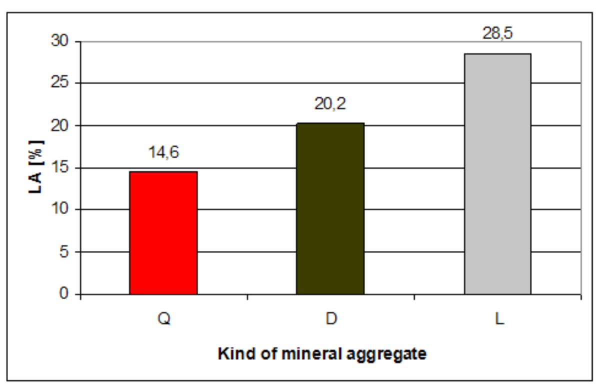
It should be noted that the dolomite and limestone aggregates also play an important role in improving the adhesion of the bitumen in the asphalt, reducing its negative potential due to the use of quartzite aggregate. Significant aspect in that way was contribution of the fine dolomite aggregate of 0/4 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 was performed using aggregate coming from the Świętokrzyskie Mountain. The mentioned mineral mix consisted of the following composites:

- the quartzite sandstone (Q): granulation 2/6.3 mm and 6.3/12.8 mm,
- dolomite (D): granulation 2/6 mm,
- the Devonian limestone (L): granulation 0/4 mm.

The primary aggregate properties such as: resistance to abrasion in the Los Angeles drum according to EN 1097-2, the resistance to the effect of the frost (PN-S-11112), water absorption and PSV coefficient according to EN 1097-8 and the content of the silica SiO_2 were presented in Figure 1.

a)



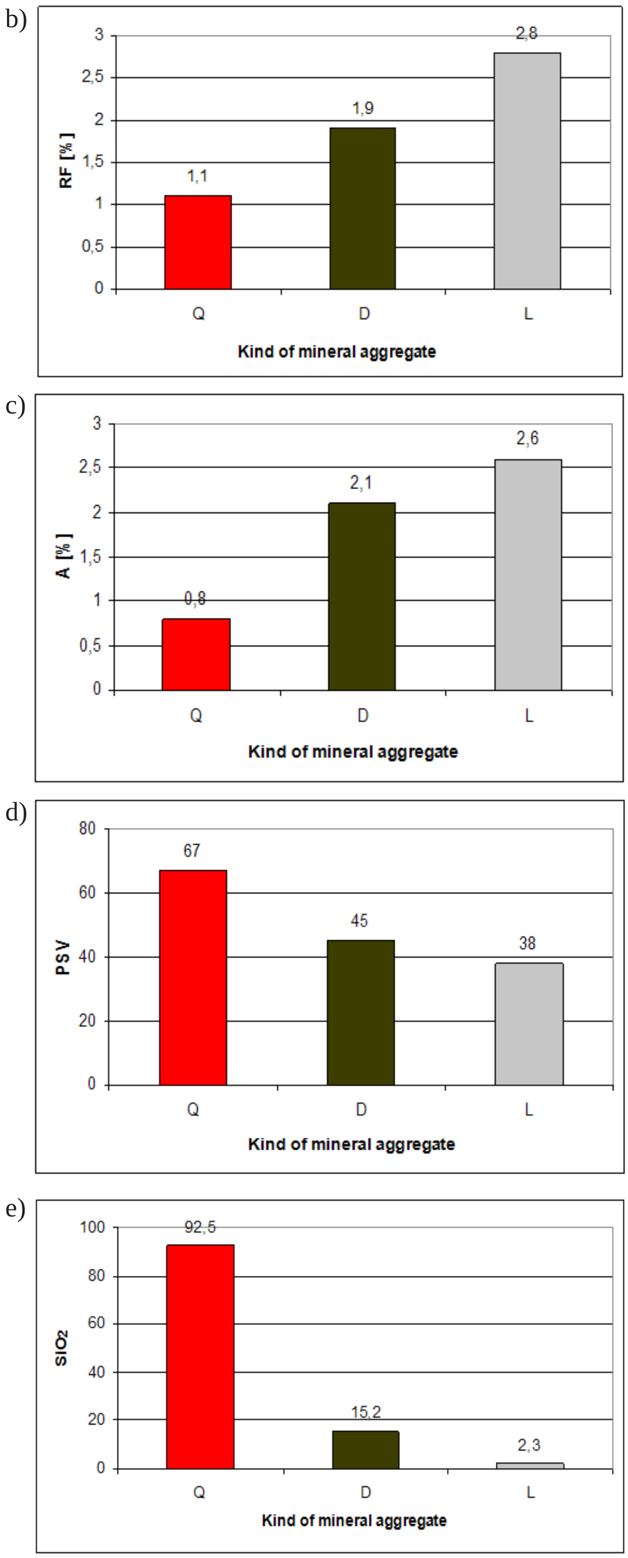


Fig. 1. Properties of SMA mineral mix; a) resistance to abrasion in the Los Angeles drum LA, b) resistance to the effect of the water and frost RF, c) water absorption A, d) polished stone value PSV, e) silica content SiO_2 [6]

The aggregate from the quartzite sandstone is characterized by a lower level of the indicator LA that testifies about its high resistance to the crushing process. It is classified to the aggregate group of the greatest resistance to crushing according to methodologies LA. The application of the quartzite sandstone wearing coarse layer, like SMA, ensures its high resistance to the effect of the stress coming from axle. Moreover, it delivers a high level of roughness of the layer [4, 10]. The dolomite aggregate is less resistant to crushing process in comparison with a quartzite sandstone. The indicator LA characterizing this aggregate has the value of 20.2%, hence it was within the limit of hard aggregates applied to wearing coarse layers for category traffic from KR4 to KR6 (the type the motorway) and a soft aggregate applied to regional road of the category of KR3 and lower rank. Devonian limestone turned out to be very poor and at least it was able to apply for local traffic category of KR1 and KR2.

Values of the PSV indicator correlate with the resistance to crushing of the aggregate according to LA methodologies. The most resistant on polishing process is the quartzite sandstone aggregate whose indicator of PSV amounts to 67. It is most resistant to polishing aggregates among natural aggregates in Polish conditions. This type of aggregate guarantees retaining optimal level of the roughness in the long service life. The dolomite aggregate, applied as an independent component in SMA, was characterized by the value of PVS amounted to 45 and it does not guarantee ensuring the roughness of the surface during operational period. The aggregate with Devonian limestone is characterized by much smaller value of the indicator PSV (PSV = 38) than the dolomite aggregate.

The aggregate from the quartzite sandstone thanks to its smaller water absorption and higher water and frost resistance will be resistant to the destructive climatic factors. The dolomite aggregate is less resistant to these destructive climatic factors. However, the aggregate with Devonian limestone is characterized by highest water absorption and low frost resistance. To sum up, it is less resistant to the effect of the water and frost.

Properties of the examined aggregates are connected with a mineralogical composition of the rock from which they were derived. Very essential is the content of the silica SiO_2 which decides about a mechanical parameters of the aggregate. The aggregate from the quartzite sandstone contains 92.5% silica in the mineralogical composition. That is why it is characterized by such large resistance to the crushing process and has a high level of PSV value. The dolomite limestone contains far less silica than the quartzite sandstone, that is why its resistance to crushing and polishing process is proportionately smaller than the quartzite sandstone. However, the Devonian limestone contains only minute quantities of the silica, therefore from those examinated aggregates it has the least resistance level to the crushing and polishing process.

The silica SiO_2 has a very favorable influence on mechanical parameters of aggregates, but unfortunately in a very negative way influences the affinity of bitumen and the aggregated. Thereby, SMA performed with a quartzite sandstone can not be resistant to the effect of the water and frost [4]. However, the mix of dolomite and limestone aggregate is distinguishes by a very good affinity with the bitumen.

The use in the SMA mineral mix aggregates with different resistance to crushing and polishing could provide a good roughness during long service life. However, the addition of the dolomite and Devonian limestone aggregate have a good influence on the adhesion of entire SMA components included affinity with a quartzite sandstone.

It should be noted that the dolomite and limestone aggregates also play 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 the 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 [14] is summarized in Table 1.

Table 1. The percentage of mineral materials in SMA 0/12.8

Quartzite mix	
Component	Percentage 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

Hydrated lime (HL) was added to the 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 the “blended filler” was received, which was incorporated into the mineral mix.

2.3. SMA properties

Table 2 summarizes the characteristics of the recommended SMA mixtures included hydrated lime and fatty acid amine.

Table 2. 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 hydrated lime in comparison to the fatty amine higher properties of SMA are achieved.

3. SMA pavement

In 1999 SMA was made which was intended for wearing course layer of the experimental section of dual carriageway localized in Żelazna street in Kielce. On the I section of SMA it was built with the addition of the hydrated lime and the II section was built with liquid adhesive agent. During the production, transport and performing there were no adverse effects caused by the adhesive agent. During the macroscopic evaluation it can be concluded that the kind of adhesive additive caused no impact. 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 in color of the control surface (fatty amine) which was glossy. SMA was subjected to continuous monitoring in accordance with the methodology in Poland (SOSN - Pavement Condition Assessment System [12]). The examination concerned the following basic operating parameters such as surface condition, evenness, roughness and

Table 3. SMA surface damage during operations

No.	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

rut resistance. The depth of macro texture was also investigated using the volumetric method ([11] and PN-EN 13036-1). In order to obtain comparable results of the parameters the measurement on each year in April was performed.

Particular attention during the test surface of SMA was paid to 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 (Table 3).

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 were no 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 and 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 had a defect connected with stripping.

After 12 years of operation of SMA pavement it can be concluded that the surface condition, regardless of the type of the adhesive additives, has still very good quality.

4. SMA properties after 12 years operation period

According to schedule contracts 2.33/1.28 the evaluation of SMA mixture was made with the following parameters:

- void fraction contents Vm according to PN-EN 12697-8,
- water resistance ITSR according to PN-EN 12697-12 and WT2-2010 standards,
- water resistance TSR [1].

Average values of void fraction content Vm [%] in SMA pavement in section I (hydrated lime HL) and II (fatty amine A) in rut (RD) and out of rut (N) were presented in Figure 2.

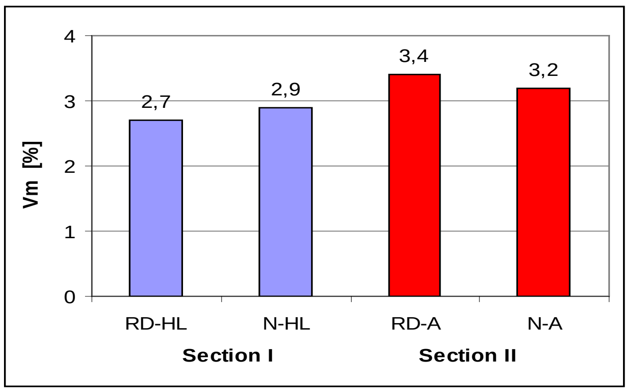


Fig. 2. Void fraction content Vm in SMA pavement [6]

Test results revealed that the void fraction contents in the pavement were lower then their amount determined during laboratory design. It means that the compaction during rolling process is more efficient than Marshall method in the laboratory.

The void content in SMA pavement in section I is greater than in section II. The use of the hydrated lime beneficial influenced the compaction process than application of the fatty amine. The level of the void fraction content in section I in rut is lower then the rest area of the pavement. It testifies that the pavement is permanently compressed because of stress from traffic load. However, in section II a beginning of destructive process as a result of the loss of adhesion between bitumen and aggregate caused by the interaction of climatic factors and traffic can be observed.

The evaluation of the void fraction content of SMA pavement indicated that the hydrated lime has a favorable influence on ensuring a proper durability and resistance to the climatic factors in comparison to application of fatty amine during 12 year service life.

The resistance on the influence of water (ITSR parameter) of the surface SMA in section I and II determined in accordance with PN-EN 12697-12 was reported in Figure 3. It should be noted that the assessment was carried out on specimens taken from the pavement with the same compaction level in compliance with the requirements in standards.

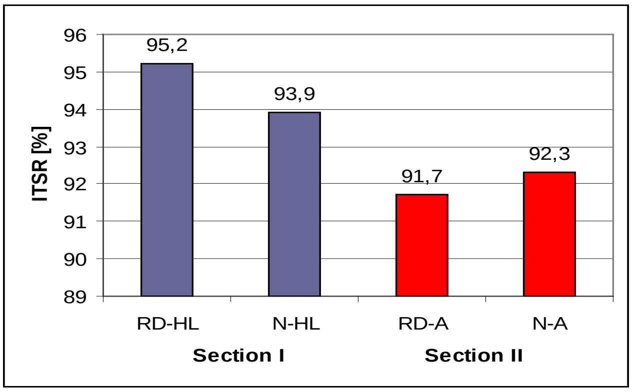


Fig. 3. Water resistance of SMA pavement – ITSR parameter [6]

The test result revealed that the void content Vm and the type of the additive have a great influence on the water resistance according to PN-EN 12697-12 in section I and II.

SMA pavement in section I located in rut has a high value of ITSR parameter amounted to 95.2%. The permanent compaction process caused by the traffic is responsible for this. It should be noted that the minimal value of ITSR is 90% according to PN-EN 12697-12. The water resistance out of the rut has a similar value of ITSR which amounts to 93.9%. SMA pavement out of the root was not subjected to regeneration process, hence it did not neutralize a adverse moisture effect out of the rut. The opposite effect appeared in section II. Much more resistant to the effect of the water is pavement out of the rut where ITSR parameter amounts to 92.3% and it is greater than ITSR for specimens received from the rut (ITSR = 91.7%). It proves that in section II there is a beginning of destructive process of the pavement. According to the macroscopic investigation a raveling effect was found.

The resistance to the water effect of TSR (after 6 conditioning cycles) of SMA pavement in section I and II was determined by application of specific procedure relying on cyclic freezing through 15 h at temperature of -18ºC and the next thawing through 24 h in 60ºC according to standards mentioned in [1].

Average values of moistures effect TSR in SMA pavement in section I and II in rut (RD) and out of rut (N) were presented in Figure 4.

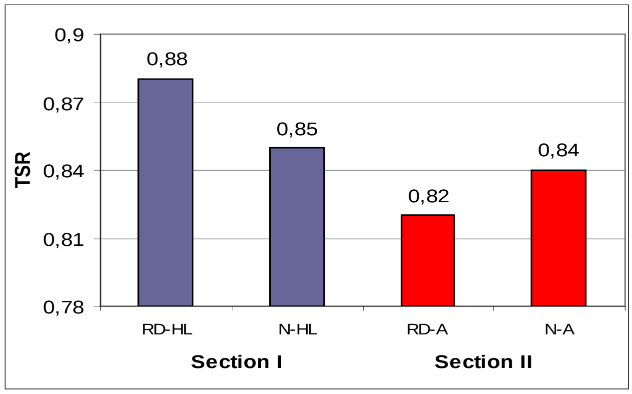


Fig. 4. Water resistance TSR of SMA pavement in section I and II [6]

Based on the analysis of TSR ratio results it can be concluded that the SMA surface on sections I and II is resistant to water and frost. The determined factors TSR of SMA pavements in both Sections I and II are greater than the required value of 0.80. The TSR parameter for specimens performed in laboratory should be characterized by value = 0.80. Therefore, it can be concluded that the SMA pavement in sections I and II is characterized by continuous high water and frost resistance. Analyzing the indicator TSR of SMA pavements expressed in terms of the type of adhesion agent (HL, A) it can be concluded that there is a similar relationship in relation to the ITSR methodology in accordance with PN EN 12697-12.

The highest resistance to water and frost (TSR) is characterized by SMA in section I (TSR = 0.88). A lower value gained a TSR parameter in section I (TSR = 0.85). The traffic permanently increased density index, hence the resistance to the effect of water and frost is higher in the rut then out of the rut. In section II the level of the TSR is lower in the rut than in adjacent area, which suggest the loss of adhesion in the rut. The use of fatty amines as an adhesion agent in a mixture of SMA is less effective than the use of hydrated lime for ensuring adhesion and durability during long operating period of SMA pavement.

5. Conclusion

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

- 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 resistance of SMA mixture to the effect of climatic factors especially with using the quartzite aggregate (aggregate with a high silica content), for example the sandstone;
- hydrated lime can be used in SMA mixture simultaneously replacing the liquid adhesive additives (fatty amines) influencing the improvement the water and frost resistance,
- SMA pavement surface condition with the addition of hydrated lime (30% filler) in the 12 years of operation is comparable (even better) to SMA pavement with the fatty acid amine;
- the use of hydrated lime in an amount of 30% of limestone filler in the composition delivers the durability of the pavement by application of 4% SBS modified polymer (which was noticed during the 12 years service life).

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Wpływ wapna hydratyzowanego na trwałość nawierzchni SMA z kruszywem z piaskowca kwarcytowego

1. Wstęp

Istotną zaletą kruszywa kwarcytowego jest jego jasna barwa. W porównaniu z barwą kruszywa bazaltowego, które jest uznawane jako kruszywo standardowe do mieszanek mineralno-asfaltowych, można przyjąć, że jest ono białe. Zastosowanie kruszywa kwarcytowego w nawierzchni asfaltowej powoduje znaczne jej rozjaśnienie, co ma istotne znaczenie dla zapewnienia bezpieczeństwa ruchu drogowego w warunkach nocnych. Wpływa również na zmniejszenie ilości energii elektrycznej potrzebnej do zapewnienia wymaganego oświetlenia nawierzchni na odcinkach, na których ze względów na natężenie ruchu samochodowego oraz bezpieczeństwo stosuje się oświetlenie stacjonarne.

Pomimo zalet, jakimi charakteryzuje się kruszywo kwarcytowe, posiada ono jednak pewien niedostatek. Ze względu na dużą zawartość krzemionki, dochodzącą nawet do 95% jego składu, wykazuje brak powinowactwa z asfaltem, co w pewien sposób utrudnia wykorzystanie tego kruszywa w mieszankach mineralno-asfaltowych. Niezbędne jest stosowanie środków adhezyjnych. Mineralnym środkiem adhezyjnym jest wapno hydratyzowane, które w krajach Europy Centralnej i Wschodniej było stosowane jako środek adhezyjny w latach 60. XX wieku [8]. Ze względu jednak na trudności technologiczne dozowania go w procesie wytwarzania mieszanki mineralno-asfaltowej w tym czasie stosowanie jego zostało zaniechane. Rozwój techniki drogowej pod koniec lat 90. XX wieku spowodował, że przesłanki tego rodzaju przestały istnieć [3, 5, 7, 9].

W 1999 roku w związku z remontem ul. Żelaznej w Kielcach (Polska) stanowiącej główny ciąg komunikacyjny zostawano, w celu zapewniania w długim okresie eksploatacji wymaganej szorstkości nawierzchni, wykonanie warstwy ścieralnej z mieszanki SMA z kruszywem z piaskowca kwarcytowego. W celu zapewnienia prawidłowej adhezji asfaltu do kruszywa zastosowano wapno hydratyzowane i jako środek kontrolny aminę kwasu tłuszczowego

2. Właściwości mieszanki SMA

Modernizowaną konstrukcję nawierzchni ul. Żelaznej w 1999 roku zaprojektowano z wykorzystaniem technologii recyklingu głębokiego na zimno. Na podstawie wykonanych pomiarów ruchu pojazdów określono kategorie ruchu na KR4.

Konstrukcja nawierzchni odpowiadała wymaganiom przedstawionym w wytycznych opracowanych przez IBDiM [13]. Składała się ona z warstwy recyklowanej podbudowy w technologii na zimno o grubości 20 cm z zastosowaniem emulsji asfaltowej i cementu oraz materiału istniejących warstw asfaltowych i podbudowy kamiennej. Następną warstwą jest warstwa wiążąca o grubości 8 cm wykonana z betonu asfaltowego i warstwa ścieralna z mieszanki SMA o grubości 4,0 cm [14]. Pod nową konstrukcją nawierzchni znajdowała się jeszcze warstwa kruszywa o zmiennej grubości od 15 do 24 cm, które pozostało z poprzedniej konstrukcji nawierzchni. Konstrukcja nawierzchni została zaprojektowana na 20 lat eksploatacji

2.1. Program badań

Program badań dotyczący określenia wpływu rodzaju środka adhezyjnego (wapna hydratyzowanego i aminy kwasu tłuszczowego) na właściwości mieszanki SMA i jej trwałość w aspekcie zastosowanego kruszywa kwarcytowego podzielono na dwa etapy – laboratoryjny i eksploatacyjny. W ramach pierwszego etapu (laboratoryjnego) szczególną uwagę zwrócono na zaprojektowanie mieszanki mineralnej oraz wykonanie niezbędnych badań pozwalających dokonać oceny wpływu wapna hydratyzowanego i aminy kwasu tłuszczowego na właściwości SMA.

Szczegółowy program badań pierwszego etapu polegał na określeniu:

- właściwości normowych mieszanki SMA,
- odporności na powstawanie kolein mieszanki SMA,

– odporności na oddziaływanie wody oraz wody i mrozu mieszanki SMA (PANK 4302 i SHTO T283, określając wskaźnik odporności na oddziaływanie wody WR_w oraz wskaźnik odporności na oddziaływanie wody i mrozu WR_{wm}).

Istotnym elementem badań była ocena jednorodności wykonywanych prac. Do badań przyjmowano tylko próbki, w których zawartość wolnych przestrzeni zawierała się w przedziale (V - 2s ; V + 2s), gdzie: V – średnia wartości wolnych przestrzeni w mieszance SMA, s – odchylenie standardowe zawartości wolnych przestrzeni w badanych mieszankach SMA.

Należy podkreślić, że większość badań w 1999 roku wykonano zgodnie z wówczas stosowaną w Polsce metodyką badawczą.

2.2. Projekt mieszanki mineralnej

Opracowując mieszankę mineralną SMA kierowano się założeniem, że w mieszance mineralnej oprócz odpornego na proces ścierania i polerowania kruszywa kwarcytowego, którego zawartość może wahać się w przedziale od 50% do 70%, powinno znajdować się również kruszywo o mniejszej odporności na te procesy tj. kruszywo dolomitowe lub wapienne.

Zaprojektowano mieszankę mineralną SMA wykorzystując następujące rodzaje kruszywa: piaskowiec kwarcytowy (Q), dolomit (D) oraz wapień dewoński (L). Zastosowano również w jej składzie wypełniacz podstawowy zawierający 95% węglanu wapnia $CaCO_3$.

Podstawowe parametry kruszywa takie jak odporność na rozdrobnienie wg metodyki Los Angeles (EN 1097-2), odporność na oddziaływanie wody i mrozu (PN-S-11112), nasiąkliwość wagową oraz wskaźnik PSV (EN 1097-8) przedstawiono na rysunku 1.

Na podstawie wykonanych badań dokonano oceny przydatności badanych kruszyw do mieszanki SMA.

Projekt mieszanki mineralnej SMA 0/12,8 opracowanej zgodnie z wytycznymi IBDiM [14] zestawiono w tabeli 1.

Wapno hydratyzowane (HL) dodawano do mieszanki mineralnej wprowadzając go zamiennie do wypełniacza mineralnego w ilości 10, 20, 30, 40 i 50%. Po dokładnym wymieszaniu wapna hydratyzowanego z wypełniaczem wapiennym uzyskiwano wypełniacz mieszany.

2.3. Właściwości mieszanki SMA

Właściwości rekomendowanej mieszanki SMA z wapnem hydratyzowanym oraz aminą kwasu tłuszczowego zestawiono w tabeli 2.

Dokonując analizy wpływu rodzaju zastosowanego środka adhezyjnego na właściwości mieszanki SMA można stwierdzić, że przy rekomendowanej ich zawartości praktycznie uzyskano bardzo porównywalne wartości badanych parametrów. Niewiele korzystniejsze jest zastosowanie wapna hydratyzowanego w porównaniu z aminą kwasu tłuszczowego w składzie mieszanki SMA.

3. Program badawczy eksploatowanej nawierzchni SMA

W 1999 roku wykonana została z mieszanki SMA warstwa ścieralna odcinka doświadczalnego dwujezdniowej nawierzchni ul. Żelaznej w Kielcach. Na jezdni północnej (sekcja I) wbudowano mieszankę SMA z dodatkiem wapna hydratyzowanego, a na jezdni południowej (sekcja II) wybudowano SMA z płynnym środkiem adhezyjnym.

Szczególną uwagę w czasie badania powierzchni nawierzchni SMA zwracano na wpływ czynników klimatycznych, a zwłaszcza oddziaływanie wody i mrozu na jej trwałość w aspekcie zastosowanego rodzaju środka adhezyjnego. Wyróżniono sześć typów zniszczeń nawierzchni, które mogą być spowodowane oddziaływaniem czynników klimatycznych oraz składem mieszanki mineralno-asfaltowej z określonym rodzajem środka adhezyjnego (tab. 3).

Analiza przedstawionych wyników pomiarów stanu powierzchniowego w aspekcie odporności na oddziaływanie wody i mrozu nawierzchni SMA pokazuje, że zastosowane środki adhezyjne (wapno hydratyzowane, amina kwasów tłuszczowych) skutecznie spełniają swoje zadanie. Po okresie 12 lat eksploatacji nawierzchni SMA można stwierdzić, że jej stan powierzchniowy niezależnie od rodzaju zastosowanego środka adhezyjnego jest bardzo dobry.

Dokonując oceny makroskopowe stanu nawierzchni SMA sekcji I i II można stwierdzić, że praktycznie nie widać występowania na niej uszkodzeń powierzchniowych oraz kolein.

4. Właściwości nawierzchni SMA po 12 latach eksploatacji

Zgodnie z planem badań dokonano oceny następujących właściwości warstwy nawierzchni wykonanej z mieszanki SMA:

– zawartość wolnych przestrzeni Vm, zgodnie z PN-EN 12697-8,
– odporność na oddziaływanie wody ITSR, zgodnie z PN-EN 12697-12 i WT2 z 2010 roku,
– odporność na oddziaływanie wody [1].

Zawartość wolnych przestrzeni w nawierzchni SMA oraz jej odporność na oddziaływanie wody ITSR, zgodnie z PN-EN 12697-12 i WT2 z 2010 roku oraz odporność na oddziaływanie wody wg [1], charakterystyczną dla sekcji I i II określone w koleinie

(RD) i poza koleiną (N) przedstawiono graficznie na rysunkach 2, 3 i 4.

Analiza wyników badań pozwoliła stwierdzić, korzystny wpływ wapna hydratyzowanego na analizowane parametry nawierzchni SMA. Okazał się on jeszcze bardziej korzystny w przypadku nawierzchni w koleinie, niż w nawierzchni bez deformacji trwałych.

5. Wnioski

Na podstawie wykonanych badań laboratoryjnych oraz terenowych w czasie 12 lat eksploatacji nawierzchni SMA można sformułować następujące wnioski:

– wodo- i mrozoodporność mieszanki SMA ulega poprawie w wyniku zastosowania wapna hydratyzowanego w porównaniu z wykorzystaniem amin kwasów tłuszczowych;
– wapno hydratyzowane odgrywa istotną rolę z zapewnieniu trwałości mieszanki SMA w zakresie oddziaływania czynników klimatycznych, szczególnie w przypadku zastosowania w niej kruszywa o dużej zawartości krzemionki np. piaskowca kwarcytowego;
– wapno hydratyzowane może być stosowane w mieszance SMA zastępując ciekłe środki adhezyjne (aminy kwasów tłuszczowych) wpływając na poprawę odporności nawierzchni na oddziaływanie wody i mrozu;
– stan powierzchniowy nawierzchni SMA z dodatkiem wapna hydratyzowanego (30% w wypełniaczu) w okresie 12 lat eksploatacji jest porównywalny z nawierzchnią SMA w której zamiennie stosowano jako środek adhezyjny aminę kwasu tłuszczowego, a nawet nieznacznie lepszy;
– zastosowanie wapna hydratyzowanego w ilości 30% w składzie wypełniacza wapiennego zapewniło trwałość nawierzchni wykonanej z mieszanki SMA, modyfikowanej 4% polimeru SBS w okresie 12 lat jej eksploatacji.