Innovative Procedures for Production of Polymer Modified Asphalt and Related Case Studies

Zsolt BOROS
TPA S.R.O. Service Company of STRABAG SE (Slovakia)

Filippo MONTANELLI
ITERCHIMICA S.R.L. (Italy)

***Abstract*— Changing the asphalt production using, instead of polymer modified bitumen binder, a normal road binder modified by the polymer added to the asphalt mixer in the form of thermoplastic polymer granules seriously simplifies the production process. It is a valuable challenge to produce the polymer modified asphalt mixture in a simpler and therefore cost-effective and greener way.**

Keywords—bitumen, asphalt, polymer, pavement layers

I. INTRODUCTION

Systematic search for the ideas to improve the asphalt production process in order to achieve even higher quality of asphalt and also keep a considerable degree of homogeneity of the polymer modified bitumen and closely related asphalt mixture, leads our company to the decision for verification of the solution of ITERCHIMICA company to modify the asphalt mixture with thermoplastic polymer added to the asphalt mixer in the form of granules within the framework of trial section. This solution proposed by the ITERCHIMICA sounds revolutionary. The trial section is still in preparation but the laboratory tests shows promising results, which are in correlation with a plenty of worldwide references.

II. POLYMER MODIFIED ASPHALT

The polymer modification of the bitumen (PmB) is the common way to significantly improve the performance properties of the bitumen and also the properties of related asphalt mixture and corresponding pavement layers (increasing the viscosity at high temperature and giving elasticity at low temperature). Common production of the pre-blended PMB is connected to the corresponding industrial process and machinery. The transport and storage of the PmB to the asphalt mixing plant requires consequent following of the strict qualitative procedures.

The other equivalent way of polymer modification of the bitumen is by adding the polymer modifier in the form of granules already into asphalt mixture (into the asphalt mixer), which significantly simplifies the production process. In the picture below is for better comparison illustrated the production process of the polymer modified asphalt mixture by using the common way (adding PMB into the aggregate mixture) and the alternative process (PMA by adding into the aggregate mixture a normal road bitumen and polymer granules).

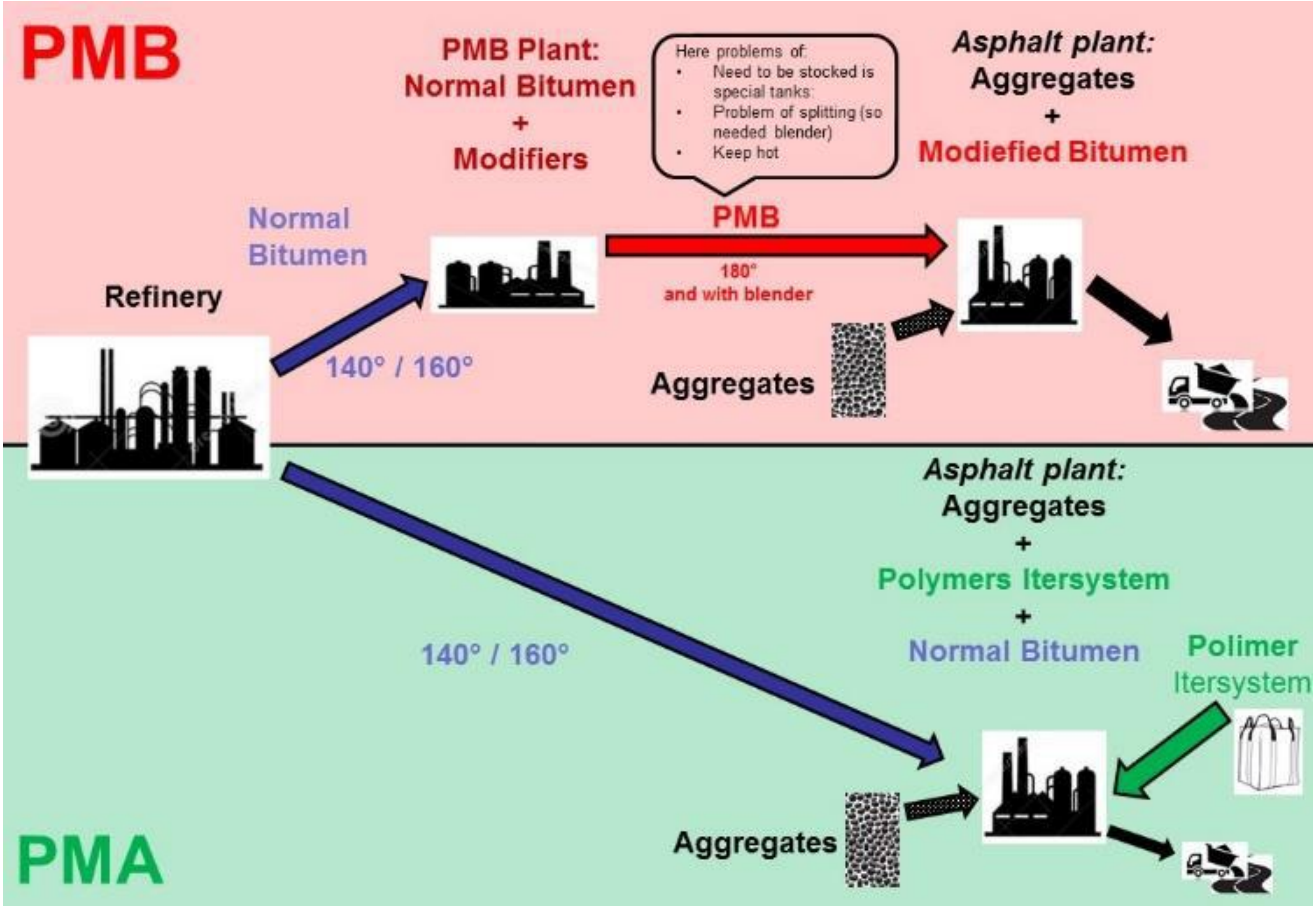

Fig. 1. Description of the production process of asphalt mixture with improved quality using traditional proces (PMB) and the new solution (PMA).

A. The polymer compound

The used product for polymer modifying of asphalt names SUPERPLAST produced by ITERCHIMICA Company.

Fig. 2. View on the polymeric compound.

It is a polymeric compound of selected polymers made of flexible granules which, when added to the asphalt mix, increases the pavement strength, the fatigue resistance, the resistance to rutting and stripping and allows to obtain high resilient modulus asphalt mixes.

In the graph below, some typical stress-deformation curves for different types of polymers are compared. SUPERPLAST is a flexible compound because it resists to deformation and it is ductile. Its initial modulus is greater than the one given by elastomers but still plenty of tenacity.

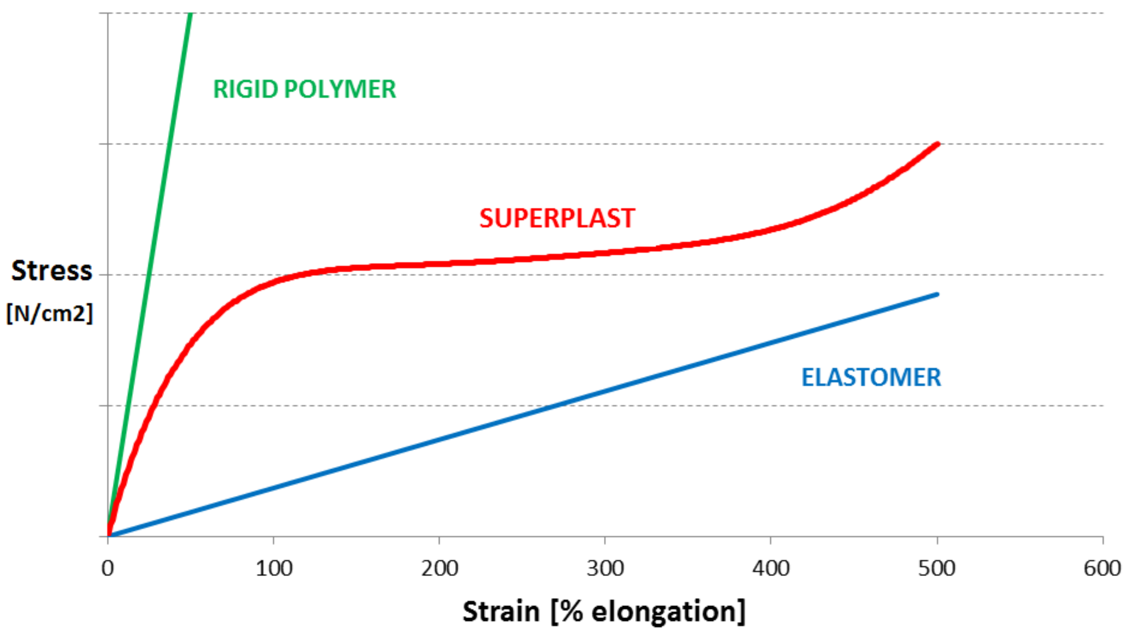

Fig. 3. Stress-deformation curves for different types of polymers.

III. Case Studies and References

In the following paragraphs, the use of the SUPERPLAST technology is described and performance properties and tests results are given for two case histories of well-studied pavement technologies such as Splittmastix Asphalt and EME2 high modulus pavement.

1) Case History of Splittmastix Asphalt (SMA) according to Rumenian Standards

The Splittmastix Asphalt is a tough, stable, rut-resistant mixture that mostly relies on stone-to stone contact to provide strength and a rich mastic binder to provide durability. SMA can be used as a wearing course for roads and other trafficked surfaces. It represents a standard method of construction in motorways, roads and city streets under heavy traffic conditions. In fact, wearing courses made with splittmastix asphalt are particularly stable and show a marked durability. They have proven their superior performance under all kinds of weather conditions showing the following characteristics [5]:

- Better resistance to permanent deformation;
- High wearing resistance;
- Less cracking due to cold or mechanical stress;
- Coarse surface texture;
- Good state of the macro roughness;
- Good long-term behavior.

When designing SMA mixtures, there are several factors that must be met. Among these are [6]:

- Provide stone-to stone contact through the selection of the proper gradation;
- Determine an aggregate gradation yielding stone-on-stone contact;
- Use hard, cubical and durable aggregates;
- Design at a bitumen content of at least 6% and an air void content of 3-6%;
- Design for voids in the mineral aggregate (VMA) such that at least 17% is obtained during production and also check and meet the moisture and draindown requirements.
- Use proper bitumen and choose an adequate modification formula (by using polymers and fibers) to ensure the performance and the life-cycle expectancy.

In the following Figure 4, it is possible to notice the difference between SMA and dense-graded conventional mixtures:

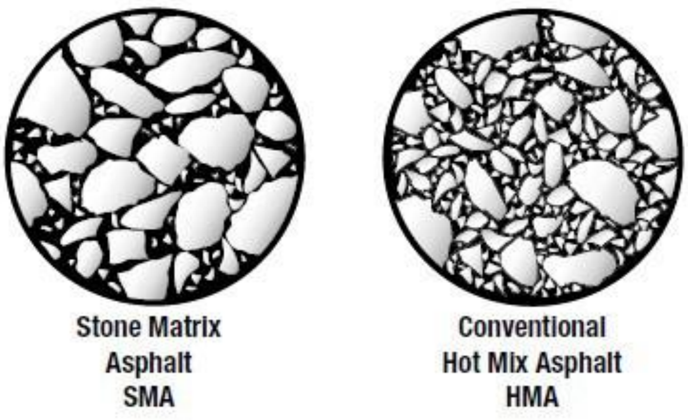

Fig. 4. SMA and dense-graded mixture comparison [6].

In terms of contents, SMA consists in 2 parts: a coarse aggregate skeleton and a mastic rich in bitumen, filler, fibre and polymer. SMA's stone-on-stone concept is illustrated in the following Figure 5:

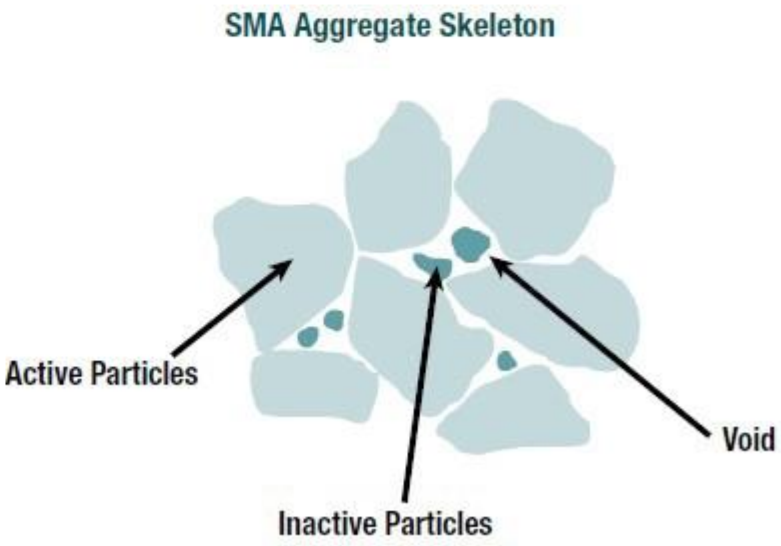

Fig. 5. SMA aggregate skeleton [6]

An important property of SMA's particle size distribution is a typical discontinuous curve as a consequence of less sand inside the mixtures as shown in the following particle size distribution (Figure 6).

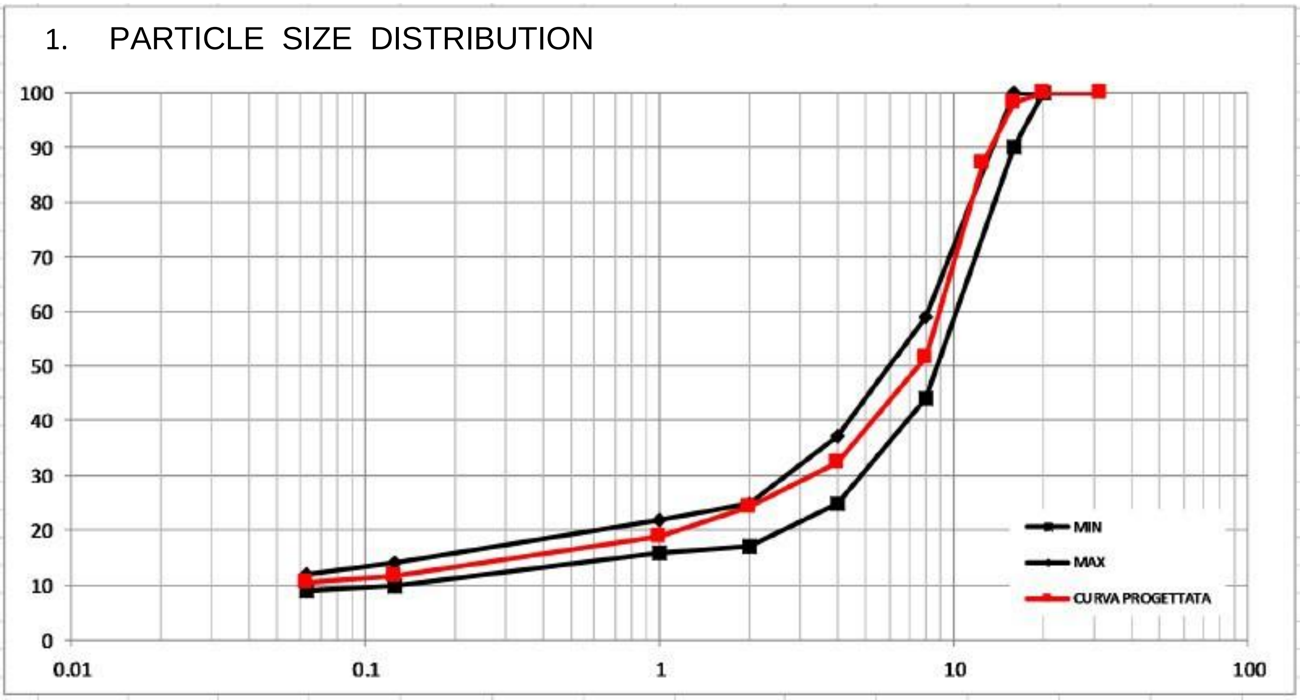

Fig. 6. SMA's particle size distribution [3;4].

Considering the discontinuous curve and considering the specific constitution of a SMA mixture, it is of a fundamental importance to promote and introduce innovative technologies in order to conceive high interlocking for different aggregate's size, high quality and durable mixtures. In fact, in order to have high resistance against rutting, the use of a polymer-modified asphalt technology (PMA) is strongly suggested. The choice of a "non adequate bitumen" and an "incorrect modifying recipe" brings to diminished mechanical properties, in particular, high rutting depth phenomena as seen in Figure 7 shown below:

Fig. 7. Rutting depth entities in a unmodified and with Superplast modified asphalt concrete.

Considering the importance of using SMA for road pavements in Europe, it is fundamental to verify that the courses made with SMA meet the Performance requirements in terms of:

TABLE I. REFERENCE PARAMETERS TO CONSIDER FOR SMA COURSES

Parameters	**Standards**
Behavior against the rutting phenomena- Deformation at 50°C, 300 kPa at 10000 cycles	< 20.000 μm/m
Deformation speed	< 1.0 μm/m/cycle
Stiffness modulus at 20 °C	> 4600 MPa
Residual voids at 80 cycles	< 5%
Low Water sensibility	ITSR > 80%
Loss in bitumen's weigh - Schellenberg test	< 0.2%

In order to obtain the requested results, it was necessary to perform pre-qualifying laboratory tests using exclusively quality aggregates to prepare the following mixtures as given in table 2.

- Mix 1 : Aggregates + natural bitumen + fibers.
- Mix 2: Aggregates + natural bitumen+ fibers + Superplast.

The same mixtures were tested in different laboratories to prove the differences in performance while using the Superplast as PMA modification within the mix.

TABLE II. PRODUCTION RECIPE AND ADDITIVES DOSAGE

Material/Product	***% on aggregates***	***% on the mix***	***% on bitumen***
Mix 1: MAS 16+ITERFIBRA C-PLUS			
TOTAL BINDER CONTENT	6.3	5,90	---
ANTISTRIPPING TYPE: ITERLENE PE31-F	---	---	0,2
CELLULOSE FIBRE: ITERFIBRA C-PLUS	0,5	---	---
Mix 2: MAS 16+ ITERFIBRA C-PLUS+ SUPERPLAST			
TOTAL BINDER CONTENT	6,3	5,9	---
ANTISTRIPPING TYPE: ITERLENE PE31-F	---	---	0,2
CELLULOSE FIBRE: ITERFIBRA C-PLUS	0,35	---	---
POLYMER TYPE: SUPERPLAST	---	---	3,5

Summarizing the results of the two mixes 1 and 2, the results are shown in the following table III, where it is possible to compare the results coming out from the tests on the mixtures containing only fibers and mixtures containing both fibers and Superplast (PMA solution). The results show that:

- The mixture MAS 16 with only fibers and "no Superplast" does not meet the requirements in terms of deformation entities and speed of deformation at 50 °C. The rutting depth at 60°C is also not satisfied by the mixture even though the stiffness modulus and the other parameters are positive. This mixture shows permanent deformation problems.
- The mix MAS 16 with both "fiber and Superplast" successfully passes all the laboratory tests showing a 12% improvement stiffness modulus compared to the mixture with only fibers. Furthermore, the mixture containing Superplast shows a good behavior against the rutting phenomena at 70 °C, value that is becoming more and more important due to the always improving environmental temperatures.

In recent years, the rutting has become the main damage form of highway in several countries. Due to high temperature, rainfall, and overloading, the asphalt pavement early damage is relatively serious. The results coming from the Laboratory show that the lack of the polymeric compound inside the mixture (No Superplast) leads to a number of problems mostly related with high permanent deformation entities and rutting problems. The introduction of Superplast in the mixture, on the other hand, helps to meet all the requirements in terms of Standard Specifications.

TABLE III. COMPARISON BETWEEN MIXTURES A AND B BLENDED IN LABORATORY

Parameters	MAS 16 Fiber	MAS 16 Fiber + SUPERPLAST	STANDARDS
Marshall Stability at 60 °C [kN]	11,1	11,5	---
Flow at 60°C [mm]	3,6	3,6	---
Marshall Stiffness [KN/mm]	3,0	3,2	---
Marshall voids [%]	3,1	3,1	3.0 – 4.0
Sensibility to water ITSR [%]	96	88	>80
Residual voids @ 80 cycles [%]	2,25	1,6	<5
Shellenberg test [%]	0,02	0,02	< 0.2
Cyclic compression test: Deformation at 50 °C., 300 kPa at 10000 pulses µm/m	28’492	17’156	< 20000
Deformation speed at 50°C, 300 KPa a 10000 pulses, µm/m/cycle	1,5	0,37	< 1.0
Cyclic compression test: Deformation at 60 °C., 300 kPa at 10000 pulses µm/m	36’835	30’007	---
Deformation speed at 60°C, 300 KPa at 10000 pulses, µm/m/cycle	3,4	0,75	---
Stiffness Modulus at 20°C, 124 ms, MPa	6’007	6’712	> 4600
Rutting deformation speed at 60°C, mm/1000 cycles	0,11	0,06	Max 0.3
Rutting depth at 60°C, % compared to the initial height	5,4	2,2	Max 5.0
Rutting deformation speed at 70°C, mm/1000 cycles	0,17	0,19	---
Rutting depth at 70°C, % compared to the initial height	7,1	6,1	---

2) Case History of High Modulus Asphalt (HiMA): The Mechanical Performances using Superplast following French Specifications – Politecnico of Milano Laboratory: “Dédoublement de la RN01 entre Berrouaghia et Bouhezoul”

French engineers developed high modulus asphalt concrete (EME) to reduce the thickness of the base course in the early 1980s [7]. EME2s were also used in the base layer of long life asphalt pavement in America [8]. Considering the good performance of EME2s, they were used widely in the construction of the base and wearing course to improve rutting resistance and limit the maximum thickness of the asphalt layer for heavy traffic sections in several European countries as well as in South Africa and China.

EME2s can be obtained by three methods: hard grade asphalt, rock asphalt modification, and plastomer polymer compound modification. Compared with the traditional asphalt binder, hard grade asphalt binder and EME2 modified by rock asphalt have a reduced Temperature sensitivity and lower self-healing ability. In addition, the EME2s modified by plastomer polymer compounds have better performances with regard to thermal cracking and fatigue than hard-grade binders and rock asphalt modified binders [9]. Therefore, in order to increase the rutting resistance of pavement in extremely high traffic conditions, it is preferable to use plastomer polymer compounds modified asphalt to produce EME or BBME used in base or wearing courses.

Following the French Specifications, by adding Superplast in the asphalt mix it’s possible to achieve the performances of an High Modulus Pavement (EME2 or BBM2). The performance may be achieved using a bitumen with a conventional penetration of 50/70 instead of a stiffer/harder bitumen (penetration 10/20) which is normally suggested to manufacture an EME2 and at the same time increase temperature excursion resistance, reduce thermal cracking and increase fatigue resistance.

TABLE IV. COMPARISON BETWEEN SUPERPLAST MIXTURES RESULTS AND SPECIFICATION

LABORATORY OF POLITECNICO OF MILANO						
High Modulus Asphalt Pavement – French Specifications for EME and BBMB						
TEST	***EME2 0/20***		***EME2 0/14***		***BBME2 0/10***	
	Superplast	***Spec.***	***Superplast***	***Spec.***	***Superplast***	***Spec.***
Rutting Test: 30000 cycles @ 60°C [%]	5,2	≤ 7,5	3,1	≤ 7,5	4,1	≤ 7,5
Complex Modulus @ 15°C [MPa]	14893	≥ 14000	17208	≥ 14000	16996	≥ 12000
Fatigue Test: @ 1 milion cycles @ 10°C, 25 Hz [µdef]	≥ 130	≥ 130	≥ 130	≥ 130	≥ 100	≥ 100

EMEs constitute a modern, high-performance asphalt technique to address problems of increasing aggressivity of traffic while contributing to the concept of sustainable development. The reduction of thickness leads to savings on non-renewable resources, a reduction in excavation work in urban areas, and renovation of road shoulders.

Fig. 8. EME2 and BBME with Superplast asphalt concrete paved in Northern Africa.

IV. Conclusion

The selected case studies clearly shows that the modification the asphalt mixture with thermoplastic polymer added into the asphalt mixer in the form of granules types SUPERPLAST not only substitutes and simplifies the common technology of modified asphalt production by using the pre-blended PMB, but also significantly improve the functional behavior of the asphalt layer. The results from tests performed also in the TPA laboratories correlates with the plenty of worldwide references and for the application on projects in Slovakia is technically everything prepared.

Other point is, that there is no legislative or normative background for the product (asphalt mixture) obtained by described procedure yet. Therefore, the widespread use of this modification method of asphalt mixture is a question of a more distant future.

However, when evaluating the asphalt mixes in term of performance properties measured by means of laboratory testing such as fatigue, stiffness modulus, rutting the improvement in the asphalt mix is quite evident especially in terms of life expectancy and durability.

However, we hope to use this solution for a functional projects or projects with special requirements.

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