ДОРОЖНЬО-БУДІВЕЛЬНІ МАТЕРІАЛИ

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APPLICATION OF NATURAL BITUMEN IN HIGHWAY AND AIRFIELD CONSTRUCTION IN UKRAINE

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ВИКОРИСТАННЯ ПРИРОДНИХ БІТУМІВ В ДОРОЖНЬОМУ ТА АЕРОДРОМНОМУ БУДІВНИЦТВІ УКРАЇНИ

Анотація. У статті наводяться результати випробувань та дослідного впровадження природного бітуму при будівництві асфальтобетонного покриття автомобільних доріг та аеродромів.

Метою роботи є встановлення ефективності використання природного бітуму в дорожньому та аеродромному будівництві України.

Об'єкт дослідження – природній бітум, який має природне походження і добувається в Албанії. Це екологічно чистий продукт, котрий є економічним та ефективним, що підтверджується численними лабораторними та практичними дослідженнями виконаними в Україні різними установами.

За результатами досліджень розроблено "Рекомендації по дослідному впровадженню добавки природного бітуму Selenizza SLN 120 для покращення властивостей асфальтобетонного покриття", "Тимчасовий технологічний регламент на виробництво дослідної партії сумішей гарячих асфальтобетонних з добавкою природного асфальту Selenizza SLN 120" та "Технологічна карта на влаштування дослідних ділянок автомобільних доріг з асфальтобетонними шарами із гарячої асфальтобетонної суміші типу А і Б та гарячої щебенево-мастикової асфальтобетонної суміші з добавкою природного асфальту Selenizza SLN 120".

Ключові слова: природний бітум, гільсоніт, класифікація природних бітумів, технічні характеристики, груповий склад бітуму.

Аннотация. В статье приводится результаты испытаний и опытного внедрения природного битума при строительстве асфальтобетонного покрытия автомобильных дорог и аэродромов.

Целью работы является установление эффективности использования природного битума в дорожном и аэродромном строительстве Украины

Объект исследования - естественный битум, который имеет природное происхождение и добывается в Албании. Это экологически чистый продукт, который является экономическим и эффективным, что подтверждается многочисленными лабораторными и практическими исследованиями выполненными в Украине различными учреждениями.

По результатам исследований разработаны "Рекомендации по опытному внедрению добавки природного битума Selenizza SLN 120 для улучшения свойств асфальтобетонного покрытия", "Временное технологический регламент на производство опытной партии смесей горячих асфальтобетонных с добавкой природного асфальта Selenizza SLN 120" и "Технологическая карта на устройство опытных участков автомобильных дорог с асфальтобетонными слоями с горячей асфальтобетонной смеси типа А и Б и горячей щебеночно-мастичной асфальтобетонной смеси с добавкой природного асфальта Selenizza SLN 120 ".

Ключевые слова: природные битумы, гильсонит, классификация природных битумов, технические характеристики, групповой состав битума.

Annotation. The article provides the results of tests and pilot implementation of natural bitumen in the construction of asphalt covering of roads and airfields.

The purpose of the study is defining the natural bitumen utilization efficiency in highway and airfield construction in Ukraine.

Object of study - Selenizza SLN-120 – natural bitumen, of naturally occurring and is produced in Albania. This is an ecologically pure and cost efficient product, which is confirmed by numerous laboratory and field trials, carried out in Ukraine by various establishments.

Following the results of the research elaborated were “Recommendations for trial introduction of the natural bitumen Selenizza SLN 120 additive for improvement of asphalt concrete pavement properties”, “Temporary process procedure for production of a trial batch of hot asphalt concrete mixes with the natural bitumen additive Selenizza SLN 120” and “Method statement for construction of highway trial

sections with asphalt concrete layers of asphalt concrete mix type A and B and hot stone mastic asphalt concrete mix with natural asphalt additive Selenizza SLN 120".

Keywords: natural bitumen, hilsonit, classification natural bitumen, specifications, the group structure bitumen.

Introduction

In the recent decades the climatic conditions for asphalt concrete pavements maintenance have been changing in Ukraine. In summer season, even in the northern regions, pavement temperature can reach +60 ºC. Along with the increase of axle load up to 12 -15 t/axle, the increase of tyre pressure up to 0,9 … 1,1 MPa and the increase of environmental temperature, this leads to acceleration of highways deterioration, particularly rutting. Added to this is the fact of degradation of oil refinery plants producing blown asphalt, being in need for development and reinstatement. This results in an increased quantity of imported road bitumen. In recent times natural bitumen has become frequently used as a part of highway technologies, being an additive to asphalt concrete mixes and bitumens, enabling improvement of road pavement transport operating parameters.

Challenge problem

From the mid 90s of the XX century, in Spain and France were developed road pavements with an increased modulus, for the purpose of improvement of mechanical properties, reduction of thickness, reduction of rutting extent, avoiding cracking in base course treated with hydraulic binder. Asphalt concrete is produced for pavement of hard bitumen (depth of needle penetration 12 – 15 dmm, softening point 70 ºC), bitumen consumption - 5,5%, grading with high content of aggregate and containing fine grained particles of mineral filler from 6 to 9%. Asphalt concrete elasticity modulus value is between 12 000 and 20 000 MPa, whereas the temperature is 15 ºC and deformation frequency is 10 Hz, which is close to the range of cement treated sand aggregate mix. Despite an enhanced value of the elasticity modulus the fatigue strength is maintained at the level of traditional dense asphalt concrete mixes. They are produced, paved and compacted using standard equipment, but the temperature during compaction should not fall below 140 ºC. Since 1992, pilot sections were established on the national road, and up to date they have behaved satisfactorily/ But data from many years is required for final conclusion.

In France the asphalt concrete with enhanced modulus has the elasticity modulus higher than 9000 MPa for wearing courses and higher than 12 000 MPa for other layers. There are mixes designed for strengthening intermediate courses. Grading - fr. 0-14 or fr. 0-10 discontinuous or continuous, with hard binder. Due to increasing of traffic density and axle load, the control over pothole and rutting occurrence has become the main priority, and the mixes are designed to ensure enhanced deformation resistance (less than 5 mm, and the temperature 60 ^{o}C). Recommended elasticity moduli (Sweden) are 2,4 times higher, than the moduli of standard bituminous mineral materials used in base courses, applied in the areas withstanding high loads.

Like on "Big Rock" highway, which is very popular in the USA, the same concepts are followed in the course of mix designs development, as in the case of SMA, that implies using a higher content of coarse aggregate, moderate proportion of dusty materials and an enlarged quantity of binder. Maximum size of particles is usually 32 or 64 mm, with fibres and polymers used as additives. Mixes containing aggregate higher than 35 mm should be prepared in specialized mixers, and the layer thickness should be 2 – 3 times higher than the maximum particle size.

Such mixes have been used in the recent years (Italy) for completion of road reconstruction, when the traffic was ceased only during in night time.

For mixtures used bitumen with the addition of polymer modifiers, and in recent years the use of natural bitumen.

Nowadays there are only four main active deposits of natural bitumen in the world: in Trinidad, USA (Utah), Iran and Albania.

From 1712 [1], when rich deposits of natural bitumen were found, it started to be used widely.

Stocks in USA, Canada, Venezuela, Kazakhstan and Tatarstan can provide $3 \cdot 10^{11}$ m^3 of organics, which is 3 times more than the world oil supplies [2].

The purpose of the study is defining the natural bitumen utilization efficiency in highway and airfield construction in Ukraine.

Main part

Natural bitumen classification

Natural bitumen is a residuary product of the slow evaporation process of light and medium fractions of oil outflow, its natural asphaltization and interaction of oil components with oxygen and sulphur.

Natural bitumen – organic substance, as a form of residuary product, formed in the process of natural oil asphaltization (evaporation of light and medium fractions) and interaction of oil components with oxygen and/or sulphur [1-4].

Natural bitumen types split into liquid, viscous and hard bitumen. Liquid natural bitumen – maltha is a viscous fluid, completely soluble in organic solvents.

Kir – is a variety of bituminous stock – soft formation, mainly represented by fine and sandy silt, saturated with natural bitumen sorts of various viscosities.

Deposits of natural bitumen differ from each other by origin, chemical and physical properties of formations [4-7].

Viscous natural bitumen types, usually containing mineral impurities, called natural asphalts. They contain 25-40 % of oils and 60-75 % of asphalt pitch. Viscous natural bitumen types can significantly vary by content of asphaltenes – from 10-16 % to 46-60 %. Asphalts with low content of asphaltenes and accordingly high content of resins and oils are approaching maltha, in terms of their properties.

Hard natural bitumen is called asphaltite. It contains less than 25 % of oils or more than 75 % of asphalt pitch. Asphaltites split into gregemit and gilsonite. Compared to gregemit gilsonite contains less asphaltenes, but are richer in resins. Gilsonite is used both in pure form, and with mineral admixtures (cindery asphaltite).

The most famous deposits of natural bitumen are situated in the Near East, Albania, USA, Canada, Trinidad and Tobago, Tatarstan, Kasakhstan [2 - 5].

In the countries of Western Europe and North America the natural bitumen varieties are used as additives to artificial road bitumen sorts, improving their properties.

Adding natural bitumen into a binder enhances pavement resistance to deformation, shoving in high summer temperature conditions, occurrence of low-temperature and fatigue cracks, which significantly extends the road operating lifespan. Natural bitumen has an advantage on other bitumen additives through its stability, usability and cost efficiency.

The field of application of natural bitumen is construction of upper layers of asphalt concrete, producing poured asphalt, wearing and high-strength base courses.

The most commonly encountered natural bitumen types are:

Trinidad asphalt – is produced on the lake of Trinidad and Tobago island;

Natural bitumen from Utah deposits in USA.

Gilsonite – a variety of hard bitumen produced on deposits near Kermanshah town (Iran).

Table 1 – Classification of natural bitumen

	Classification criterion	Subgroup
Types of bitumen	Content of oils	А) Oil > 65 %; Б) Maltha 40… 65 %; В) Asphalts 25… 40 %; Г) Asphaltite < 25 %.
Groups of natural bitumen	Consistency	1. Liquid (softening point lower than 35 °C); 2. Viscous (softening point between 35 and 90 °C); 3. Hard (softening point higher than 90 °C).
Varieties – Natural bitumen sorts and bituminous formations	Geological mode of occurrence	1) surface: “asphalt lakes”, kir flows, bituminous sands. 2) vein; 3) embedded: bituminous lime rock, dolomitic rock and sand rock (“bituminous formations”).
Bituminous formations	Structure and grading	1. Massive – dolomite: а) lime rock; б) dolomitic rock; 2. detrital sedimentary: а) soft formation – sand, silt, clay loam; б) cemented formation – sand rock; в) kir.

Selenizza (Selenizza SLN-120) – natural bitumen, is produced in Albania. This is an ecologically pure and cost efficient product, which is confirmed by numerous laboratory and field trials, carried out in Ukraine by various establishments.

According to Albanian legislation, the company (100% affiliated company of the French KLP group, working in mining industry and highway construction sector) is the first investor in Albania.

Commencement of activity beginning in 2000 - 2001.

Natural additive in Selenizza (Vlora – South Albania).

Product: Bitumen – natural bituminous composition (table 2).

Stock size is quantified as 6 million tons.

Production capacity are 4 – 6 thousand year.

Table 2 – Properties of natural bitumen Selenizza SLN-120

Measures	Norms	Value
Penetration 0,1 mm (100 g, 5c, 25 °C)	EN 1426	0
Softening point, °C ring-and-ball test	EN 1427	115…120
Index of Penetration, IP	-	> 3,0
Saponification number, mg KOH/ g	NFT 66 013	3,50
Asphaltene content, %		42,0… 50,0
Solvation in carbon disulphide		85 - 95%
Loss at + 163 ° C, in 5 hours		0,08
Density at 25 °C, not less than g/cm^3	NFT 66 004	1,16

Comparison of the main properties of natural bitumen types is shown on fig. 1.

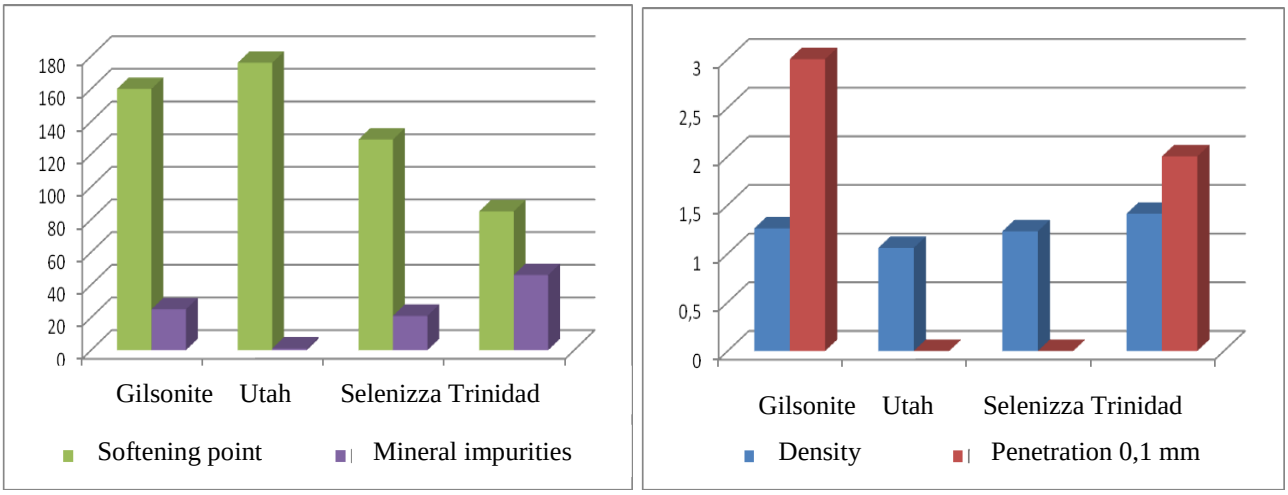

Figure 1 - Comparison of properties of natural bitumen types

Natural bitumen additive Se1enizza SLN-120 – black colour powder, with the maximum particle diameter 6 mm, packed in 500 kg packages, or 12 kg hexagonal blocks.

On request of LLC Dortek, in the laboratory of Lviv Polytechnic University "Oil" Faculty, was established the technical characteristics and structural group analysis of artificial (table 2 - 3), natural (table 3) and modified bitumen (table 3).

The technical parameters of the examined original bitumen fully comply with the requirements of DSTU 4044-2001 to bitumen BND 60/90, and the main characteristics meet the requirements of EN 12951 to bitumen 70/100.

Upon the main characteristics the modified bitumen can be attributable to BMP 60/90-52 according to DSTU B V.2.7-135:2007.

Structural-group composition of the bitumen and the modified bitumen is close to colloidal structure type "sol-gel", which is considered to be optimal for commercial bitumen.

Table 3 – Technical characteristics of original bitumen

Parameters	Actual value 70/100	Rate according to DSTU 4044-2001 for bitumen BND 60/90	Rate according to EN 12951 for bitumen 70/100
1 Depth of needle penetration (penetration) at the temperature 25 ^{O}C, м·10^{-4} (0,1 mm)	90	From 61 to 90	From 70 to 100
2 Softening point, by ring-and-ball test, ^{O}C	48	From 47 to 53	From 43 to 51
3 Ductility, м·10^{-2} (cm), 3.1 At 0 ^{O}C 3.2 At 25 ^{O}C	 6 140	 ≥ 3 ≥ 55	 - -
4 Properties variation after heating:			
4.1 Mass variation after heating, %,	0,4	≤ 0,8	≤ 0,8
4.2 Residual penetration, %,	68	≥ 60	≥ 46
4.3 Softening point variation, ^{O}C	3	≤ 6,0	≤9
5 Brittleness point, ^{O}C	-22	≤ -12	≤-10
6 Flash point in an open cup, ^{O}C	280	≥ 230	≥ 230
7 Adhesion with glass surface	88	Not rated	-
8 Waxes mass content, %	0	Not rated	-
9 Solvency in organic solvent, %	99,4	≥ 99,00	≥ 99,0
10 Penetration index	-1,0	From -2,0 to +1,0	From -1,5 to +0,7

Table 4 – Bitumen structural group analysis

No.	Component	Selenizza SLN-120	Bitumen 70/100 Mozyr	Bitumen 70/100 + 10 % Selenizza SLN-120	Optimal content % according to Kolbanovska A.K.		
					Type 1	Type 2	Type 3
		Component content, %					
1.	Carbenes, carboides and mechanical impurities		0	1,87	-	-	-
2.	Asphaltenes	42-59,9	24,45	25,93	>25	<18	21-23
3.	Oils	16,5	46,26	37,58	>50	<48	46-50
4.	Resins	22,3	29,29	34,62	<24	>36	29-34
5.	A/(C+O)		0,32	0,36	>0,35	<0,2	0,25-0,3
6.	A/(A+O)		0,35	0,41	>0,5	<0,3	0,39-0,44

Table 5 – technical characteristics of modified bitumen

Parameter	Actual value 70/100 + 10% PR	Rate according to DSTU 4044-2001 for bitumen BND 60/90	Rates for BMP 60/90-52 according to DSTU B V.2.7-135:2007
1 Depth of needle penetration (penetration) at the temperature 25 ^{O}C, m·10^{-4} (0,1 mm)	60	From 61 to 90	From 61 to 90
2 Softening point, by ring-and-ball test, ^{O}C	55	From 47 to 53	≥ 55
3 Ductility, m·10^{-2} (cm), 3.2 At 25 ^{O}C	43	≥ 55	- ≥ 25
7 Adhesion with glass surface	100	Not rated	≥ 75
8 Waxes mass content, %	0	Not rated	-

After modification approximately 2% of carbenes, carboides and mechanical impurities appear in the mix, affects negatively the performance characteristics of BMP, though not rated by current standards.

A possible reason of deterioration of pavements produced on the basis of the examined bitumen are:

- low cohesion strength (recommended for identification);
- nonconformity of mineral material;
- failure to comply with requirements for placing road pavement (overheating of binder; possible identification of bitumen parameters, extracted from road pavement sample).

Application of natural bitumen Se1enizza SLN-120 in asphalt concrete mixes enables qualitative improvement of physical and mechanical properties of road pavement – its strength, frost resistance, shoving resistance, rutting resistance and increases its lifespan.

Besides, the following factors get improved:

1. Environmental and health impact.

This material does not emit harmful fumes in the process of production, during production, transportation, placing and operation, which is particularly important for environment and health of workers as well as pedestrians and drivers. Such behaviour

of bitumen Selenizza SLN120 is contingent upon its ability to bind polycyclic aromatic hydrocarbons in the base bitumen, reducing activity of cancer-producing substance.

2. Reliability and capability.

Elasticity modulus of an asphalt concrete mix layer containing natural bitumen Selenizza SLN120 gets significantly increased, and reaches 19 000 MPa, in accordance with European Norms. Rutting occurrence probability is reduced, while the pavement lifespan is increased.

3. Produce ability.

Application of Selenizza SLN120 results in a little change, to the technology of production and placing of asphalt concrete mix. Along with the possibility to feed Selenizza directly into the Asphalt Plant mixer, it also enables modification of bitumen in asphalt plant heaters much simpler, faster and cheaper, than using modifiers of synthetic (chemical) origin.

Compaction of asphalt concrete is carried out immediately behind the asphalt paver. Quality of compaction is enhanced.

4. Statutory framework.

Selenizza SLN120 was awarded a «TECHNICAL CERTIFICATE of conformity of building products». The natural bitumen Selenizza SLN120 was verified as a modifying additive to asphalt concrete and stone mastic mixes (by the Ministry of Regional Development, Construction and Housing and Communal Services of Ukraine) on 14.02.2013.

The natural bitumen Selenizza SLN120 is compatible with all types of bitumen and it is brought under regulation of European standards EN 13108-1 i -4 “Bituminous mixtures - Material specifications” – Part 1 “Hot asphalt” and Part 4 “Asphalt concrete”.

Technology for modification of asphalt concrete mixes using natural bitumen

Preparation of asphalt concrete mixes with bitumen, modified natural bitumen, is carried out on asphalt plants similarly to preparation of hot asphalt concrete mixes [3].

Modification of asphalt concrete mixes using natural bitumen, by adding natural bitumen directly into an asphalt mixing plant, is carried out on asphalt plants, which should be additionally equipped with systems for proportioning and feeding

natural bitumen.

Content of natural bitumen in an asphalt concrete mix is 0,25 – 2,0 % of a mineral material mass (or 5 - 30 % of bitumen mass). In case of natural bitumen application it is necessary to specify the optimal content of bitumen in a mix (saving of construction bitumen can reach 20 %).

The necessary content of natural bitumen is identified taking into account recommendations of its maker, through a mix design development based on results of laboratory testing of asphalt samples, with various content of natural bitumen. In the course of natural bitumen content adjustment one should take into account its mineral constituent.

The process of preparation of asphalt concrete mix, modified with natural bitumen, consists of the following technological operations:

– heating, proportioning, feeding into a mixer and mixing of aggregate, sand and mineral filler for 30 … 60 seconds (depending on a type of mixing plant);

- proportioning, feeding of natural bitumen into a mixer and mixing it with mineral material for 10 … 20 seconds;

- proportioning, feeding of heated bitumen into a mixer and mixing it for 10 … 20 seconds;

- discharging of modified asphalt concrete mix from an asphalt mixer into a storage-buncker or a truck body.

The heating temperatures for aggregate, sand and bitumen, as well as the temperature for compaction of asphalt mix modified with natural bitumen, must comply with the requirements of table 12 and 13 of DSTU B V.2.7-119-2003, according to a bitumen grade.

Using of natural bitumen Selenizza SLN120 does not complicate the use of AVK software package, since it does not change the technology of road pavement construction, and includes the price of asphalt concrete mix as material price.

Construction bitumen, modified using natural bitumen, are characterized by enhanced cohesion strength, increased heat resistance (softening point increases by 5-15 °C), and extended lifespan.

During 2011 more than ten facilities were built using natural bitumen (see the list of facilities). The facilities are monitored on an annual basis. All the sections are in good or excellent condition. No defects or deteriorations have been recorded.

List of facilities constructed using the natural bitumen Selenizza SLN-120

List	Type of mix	Works completed
1. Mykolaiv, Zhovtneva bypass	Type B M1	06.08.2011
2. Mykolaiv, bypass	SMA 15	07.11.2011
3. Mykolaiv, Ingulskyi bridge	SMA 20	25.09.2011
4. Kyiv-Kovel highway km 308 – 314	SMA 20	07.11.2011
5. Kyiv, Artema str.	Type B 20	08.11.2011
6. Kyiv, Odeska square	Type B M1	21.09.2011
7. Odesa – Mykolaiv - Kherson highway	Type B M1	24.11.2011
8. Kyiv - Kovel highway, km 30+490 - 33+50	SMA -20	10.10.2013
9. Access to E 583(M21) road Zhytomyr – Mygylov - Podilskyi on P 18 Zhytomyr bypass	Type B -20	16.07.2014
10. Utility company “International airport “Kyiv (Zhuliany)”	Type B -10	2012-2014
	Type B -20	20.08.2015
11. Chernivtsi	Type B -10	25.10.2015
12. Khmelnytskyi	Type B -10	15.11.2015

Examples of asphalt concrete pavements with natural bitumen additive are shown on figure 2- 3.

Figure 2 – Pavement condition on road Kiev – Kovel (km 33+100 , Vorzel)

Figure 3 – General look, approach to the roundabout, Borodyanka

Comparison of properties of various types of bitumen modifiers is shown in table 6.

Table 6 - Comparison of properties of various types of bitumen modifiers

	Properties	Bitumen	Polymer additives	Natural bitumen (Selenizza)
1	2	3	4	5
1. Reliability:	Maintainability.	+	-	+
	Durability (cyclic impacts of transport loads).	-	+	+
	Crack resistance	-	+/-	+
	Ageing resistance	-	-	+
	Increase of original bitumen strength without any changes to elasticity properties of binder..	-	-	+
2. Produce ability	Feeding the additive directly into a mixer.		-	+
	No need to modify bitumen for a long period of time.		-	+
	Compacting immediately behind an asphalt paver, using heavy rollers.	-	+/-	+
	Opening to traffic immediately after compaction.	-	+	+
	Necessity to clean truck bodies and rollers.	+	+	-
	Limited time for storing of modified bitumen.		+	-

Continued Table 6

1	2	3	4	5
	Does not affect productivity and time of asphalt concrete mix preparation	+	-	+
3. Performance characteristics	Smoothness	-	-	+
	Rutting resistance	-	+	+
	Shoving resistance (buckling, heaving, corrugation)	-	+	+
4. Cost efficiency:	Cost saving (price) on producing (UAH)	1392	1803	2108 / 1584
	Saving on asphalt concrete thickness, upon compliance with strength criteria.	-	n/a	+
	Significant increase of durability upon remaining thickness of road pavement layers.	-	+/-	+
5. Environmental and health impact:	Composition.	Technical	Synthetic	Natural
	Binding of fugitive cancer-producing substances, and affecting their activity.	-	-	+
	No specific smell in the course of production, no symptoms of respiratory irritation, less complaints concerning headache.	-	-	+
	Allergic and cancer-producing constituents.	+	++	-+
	At further recycling – hot recycling, also no smell, evaporation of chemical elements etc.	-	-	+

Conclusions

Natural bitumen Selenizza is a new material, which knows no equals as a natural modifier of bitumen. There has been a technology elaborated for modification or improvement of organic binder properties. Natural bitumen additive does not complicate the existing production process.

Better compaction is observed, due to enhanced viscosity, which allows constructing road pavements faster and with higher quality, which significantly

enhances strength, frost resistance, shoving resistance and rutting resistance of road pavement.

Selenizza (green bitumen) is environmentally safe – it does not emit harmful fumes itself and binds them in a base bitumen.

There has been an estimate carried out identifying cost efficiency of natural bitumen application (lower cost of bitumen modified by polymers and of asphalt concrete pavement), and an increase of pavement durability.

Following the results of the research elaborated were "Recommendations for trial introduction of the natural bitumen Selenizza SLN 120 additive for improvement of asphalt concrete pavement properties", "Temporary process procedure for production of a trial batch of hot asphalt concrete mixes with the natural bitumen additive Selenizza SLN 120" and "Method statement for construction of highway trial sections with asphalt concrete layers of asphalt concrete mix type A and B and hot stone mastic asphalt concrete mix with natural asphalt additive Selenizza SLN 120".

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