EFFICIENCY OF USING BITUMEN AND ASPHALT CONCRETE MODIFIERS IN REPAIR OF TRUNK ROADS

ЕФЕКТИВНІСТЬ ВИКОРИСТАННЯ МОДИФІКАТОРІВ БІТУМУ ТА АСФАЛЬТОБЕТОНУ ПРИ РЕМОНТІ МАГІСТРАЛЬНИХ АВТОМОБІЛЬНИХ ДОРІГ

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Summary. According to the results of studies it was determined that when adding the natural bitumen, softening point increases linearly by 0.7°C when adding 1% of the natural bitumen, and penetration decreases logarithmically. Compressive strength raises 1.3-1.7 times at the temperature 20°C and 1.4-2 times at the temperature 50° for the natural bitumen and synthetic wax accordingly.

Linear dependence of the compressive strength increase at a temperature +20°C and +50°C for the asphalt concrete of type A against content of the natural bitumen Selenizza SLN 120 in percent by mass from the mass of bitumen BND 60/90 is observed.

During visual inspection of the pavement condition it was identified that at the section with SMA-20 modified with natural bitumen there generated 7 times less defects than at the section of pavement modified with synthetic wax.

This evidences that in this case asphalt concrete pavement modified with natural bitumen is more efficient than the pavement modified with synthetic wax.

Keywords: modifier, natural bitumen, asphalt concrete.

Introduction. Due to increased loads on motor roads, in particular, increase of axle loads and pressure in pneumatics of heavy vehicles, which leads to a quick destruction of road pavement, it is necessary to perform studies to identify the reasons of destruction and to take optimum decisions to solve this problem.

The article publication necessity is due the fact that after reconstruction of the motor road section that was executed more than five years ago, at two adjacent road sections paved with different modifiers, the defects in a form of transverse and longitudinal cracks having non-standard frequency have occurred. At the same portion of the pavement, modified with synthetic wax, there generated 7 times more cracks than at that one modified with the natural bitumen.

It is generally agreed that modifying bitumens and asphalt concrete with synthetic wax additives and natural bitumens allows to increase durability of asphalt concrete in a pavement of motor roads. Comparing asphalt concrete modified with synthetic wax and natural additives to asphalt concrete on usual bitumen, it differs by increased resistance to formation of plastic deformations at high temperatures and considerable resistance to crack formation at low (below zero) temperatures. The degree of improvement of these properties depends on the content of modifier in bitumen or asphalt concrete and their quality.

Primary trends of bitumen technologies at the current moment are reduction of energy consumption through reducing technical process temperatures and increasing ecological safety by means of decreasing emissions of hazardous hydrocarbon into atmospheric air. It is anticipated herewith that the new technical process solutions shall not result in worsening quality of bitumens and bitumen-based materials. Currently, a plenty various options are being developed to achieve these objectives. Moreover, the new terminological definitions have been introduced: hot, warm, semi-warm, cold asphalt concrete mix.

One of the options to solve the problem is to add into a bitumen or directly into an asphalt concrete of the modifiers intended for improvement of mechanic characteristics within the region of moderate operation temperatures and reduction of viscosity of the binder at high technological temperatures. When temperature decreases, their viscosity increases, they are being crystallized and serve as either a fine-dispersion filler of bitumen or create own structural grid, both shall increase bitumen viscosity.

Materials and Methods. Main question of this study is determination of the efficiency in modifiers of bitumen and asphalt concrete, namely, identification of the reason of destruction of the pavement laid with adding two different additives into asphalt concrete during reconstruction. The sections which were paved adjacent to each other and were in use for the same period and under impact of relatively identic systematic loads.

Study subject. Study subject is M-07 Kyiv-Kovel-Yahodyn Motorway on the section from km 307+120 to km 309+500. Also synthetic wax and natural bitumen modifiers, which were added into asphalt concrete mix during reconstruction of this section, were subjected to study.

Study methods. Experimental studies under traditional tests of binders (penetration, ball-and-ring), that were performed according to the existing standards. Core sampling was carried out to determine physical and mechanic properties of asphalt concrete mix SMA-20 and saturation of material with water. Elastic deflection of the pavement was determined by means of plate bearing method. Respective researches have been executed to calculate statistical data of quantity and frequency of defects formation on the pavement.

Results and Discussion

The influence of the modifiers on properties of bitumen and asphalt concrete mix

Characteristics and properties of bitumen modifiers applied during reconstruction of the section of M07 Kyiv-Kovel-Yahodyn on the section from km 307+120 to km 309+500.

Natural bitumen increases asphalt concrete elasticity modulus and softening point. It provides asphalt concrete with high fatigue resistance, thermal and shear resistance. This enables to reduce the risk of formation of damages on pavement, such as ruts, potholes, therethrough, increases durability of pavement. It can be added directly into asphalt concrete mix.

Synthetic wax (energy-saving additive) allows to reduce temperature of asphalt concrete mix paving by 15-20°C. It can be added directly into asphalt concrete mix. It increases pavement’s rutting resistance and thermal resistance. Strength characteristics of asphalt concretes rise less than when adding synthetic wax. It increases bitumen softening point by 20-40°C. It increases bitumen viscosity. Bitumen cohesion strength remains practically unchanged. Improves adhesion properties of bitumen up to 90%.

Polimer additive is amorphous polyolefin – mixture of ethylene polymers recycled from recoverable resources. Adding of the polimer additive into stone-mastic asphalt concrete results in increasing compressive strength values (1.13 times for compressive strength at 20°C and 1.33 times for compressive strength at 50°C), tensile strength in bending (1.26 times at 0°C and 1.42 times at 20°C) and tensile strength in splitting at 0°C (1.74 times).

There are comparative characteristics of bitumen modifiers which were applied for the reconstruction of M-07 Kyiv-Kovel-Yahodyn Motorway on the section from km 307+120 to km 309+500 in the table 1.

It is worth to note that at the reconstruction section there was used an asphalt concrete modified also with third polymer additive, but it was not taken for further analysis, because the concern has arisen to the section whereat longitudinal crack with significant length formed along the axis of pavement, dividing asphalt concrete layer paved with synthetic wax (energy-saving additive) and with natural bitumen. Whereon were also interesting cases of opening of transverse cracks to the entire pavement width.

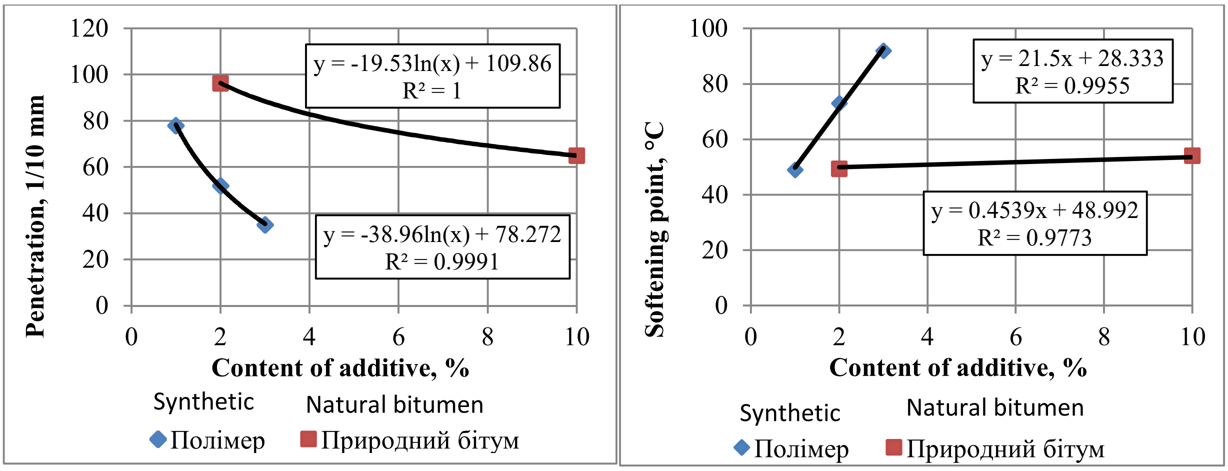
Table 1 – Comparison of properties of used modifying additives to the bitumen BND 60/90 (road petroleum bitumen)
Таблиця 1 – Порівняння властивостей використаних модифікуючи добавок на бітум БНД 60/90

No.	Property name	Actual data	
		Natural bitumen	Synthetic wax
1	Mass colour	Black	White powder
2	Real density, g/cm^3	1.23	1
3	Penetration at 25°C, 0.1 mm	0	3
4	Softening point, °C	129	120-130
5	Content of mineral particles, %	21	
6	Ash content, %	-	
7	Moisture content, %	0	

Test results for determination of the softening point and funnel viscosity of bitumen depending on content, modified with natural bitumen and synthetic wax are shown in the tables 2-3.

Table 2 – Properties of the bitumen modified with synthetic wax or natural bitumen
Таблиця 2 – Властивості бітуму модифікованого синтетичним воском або природнім бітумом

Modifier	Content additives, %	Penetration at 25 °C, 1/10 mm	Softening point, °C
BND 60/90	-	78	49
Synthetic wax	2	52	73
Synthetic wax	3	35	92
BND 60/90 +	-	96.3	49.5
Natural bitumen	10	65	54.25
Natural bitumen	20	51.3	57.75



a) b)

Figure 1 – Dependence of the penetration a) and softening point b) from the content of synthetic wax and natural bitumen modifiers

Рисунок 1 – Залежності пенетрації a) та температури розм'якшення b) від відсотку вмістумодифікаторів синтетичного воску та природнього бітуму

Determination of physical and mechanic properties of the asphalt concrete mix in which the bitumen modified with synthetic wax and natural additive added, was carried out in accordance to DSTU B V.2.7-127:2015 "Asphalt concrete mixes and stone mastic asphalt concrete. Technical conditions" and the following data was obtained as outlined in the table 4.

As a comparison, the table 5 and the Fig. 2 outline the results of determination of the influence of the content of the Selenizza SLN 120 natural bitumen against BND 60/90 bitumen, % (by mass in 100% of bitumen) on physical and mechanic properties of hot fine-grained dense asphalt concrete mix, type A, continuous gradation, grade 1, BND 60/90 (АСГ.ДР.Щ.А.НП.1..БНД 60/90) according to DSTU B. V.2.7-119:2011 "Asphalt concrete mixes and road and aerodrome asphalt concrete. Technical conditions".

Table 3 – Physical and mechanic properties of asphalt concrete mix SMA-20

Таблиця 3 – Фізико-механічні властивості асфальтобетонної суміші ЩМА 20

Modifier	Water saturation, %	Strength limit at temperature, kgf/cm^2			Density	Quantity of binder in the mix, %
		0°C	20°C	50°C		
DSTU requirements	1.5-3.0	–	>21	>6	–	5.5-6.5
Natural bitumen	2.8	–	28	8.5	2.37	5
Synthetic wax	1.35	–	31	12.75	2.35	5.01
Polymer No.2	1.79	–	35.3	12.5	2.374	5.24+0.35

Table 4 – Physical and mechanic properties of hot fine-grained dense asphalt concrete mix, type A, continuous gradation, grade 1, BND 60/90 (АСГ.ДР.Щ.А.НП.1..БНД60/90)

Таблиця 4 – Фізико-механічні властивості асфальтобетону із суміші АСГ.ДР.Щ.А.НП.1..БНД60/90

Content of Selenizza SLN 120 in bitumen, % (by mass in 100% of bitumen)	Content of bitumen, % (more 100%)	Volume density, g/cm^3	Water saturation, %	Compressive strength, MPa, at	
				R20	R50
0	5.9	2.42	2.2	4.5	1.7
6	5.9	2.42	0.55	4.6	2.1
16.5	5.9	2.41	2.2	5.4	2.3
25	6.5	2.41	0.81	5.8	2.9
50	6.3	2.40	1.2	7.1	3.6

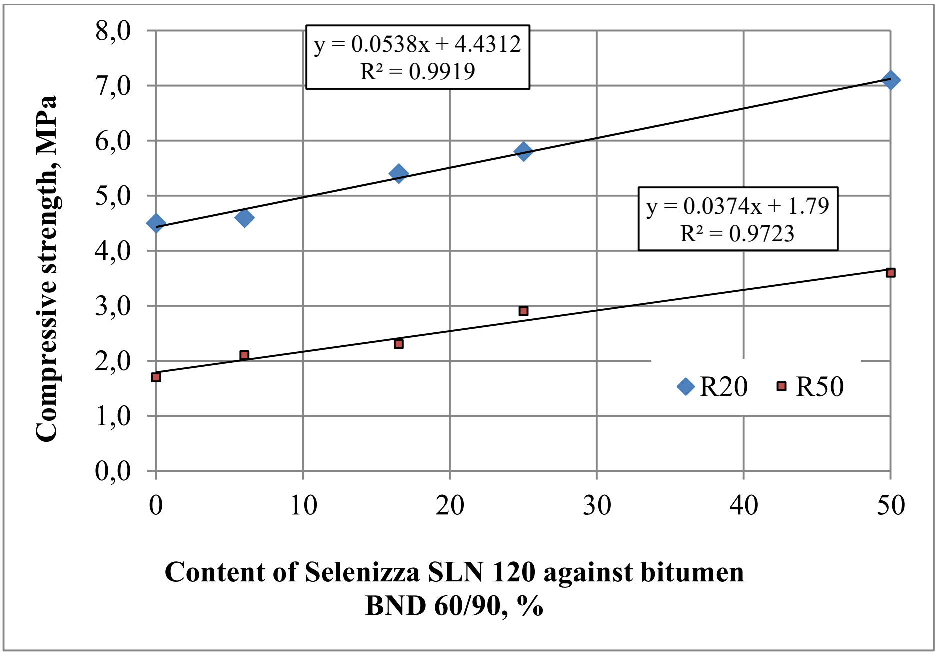


Figure 2 – Dependence of the compressive strength of asphalt concrete against content of natural bitumen Selenizza SLN 120 in percent by mass from the mass of bitumen BND 60/90

Рисунок 2 – Залежність міцності на стиск асфальтобетону від вмісту природного бітуму Selenizza SLN 120 у відсотках за масою від маси бітуму БНД 60/90

Linear dependence of compressive strength increase at a temperature +20°C and +50°C for the asphalt concrete of type A against content of the natural bitumen Selenizza SLN 120 in percent by mass from the mass of bitumen BND 60/90 is observed.

Results of determination of density and water saturation of samples taken from asphalt concrete pavement on the section No.1-2 during inspection performed in autumn 2016 are shown in the table 6 and the Fig. 3.

The inspection was participated by the Chief of the laboratory of Road Service in Rivne region Hryhorieva Nina Serhiivna, PhD courses O.S. Palieshev, PhD courses S.V. Reneiska from National Transport University, junior scientist of non-rigid road pavement department A.D. Yeremeichuk, junior scientist of non-rigid road pavement department D.A. Larin, senior scientist of non-rigid road pavement department V.M. Katukova from "DerzhdorNDI" DP (State Enterprise).

Table 5 – Results of determination of density and water saturation of asphalt concrete pavement samples

Таблиця 5 – Результати визначення щільності та водонасичення зразків асфальтобетонного покриття

Number of taken sample	Density, water saturation					
	Mass of dry sample, g	Mass of sample in water, g	Mass of sample after water, air-exposed, g	Density, g/cm3	Mass after water saturation, g	Water saturation, %
Core no.3 PK	1017.2	600.6	1019.8	2.43	1022.8	1.34
Core No.5 PK 307+320 L	1089.4	645.6	1092	2.44	1093.8	0.99
Core No.6 PK 380+200 L	1082.4	636.8	1084.6	2.42	1087	1.03
Core No.10	1099.8	643	1105.8	2.38	1114.6	3.2
Core No.11	980.4	571.8	984.4	2.38	990.2	2.38

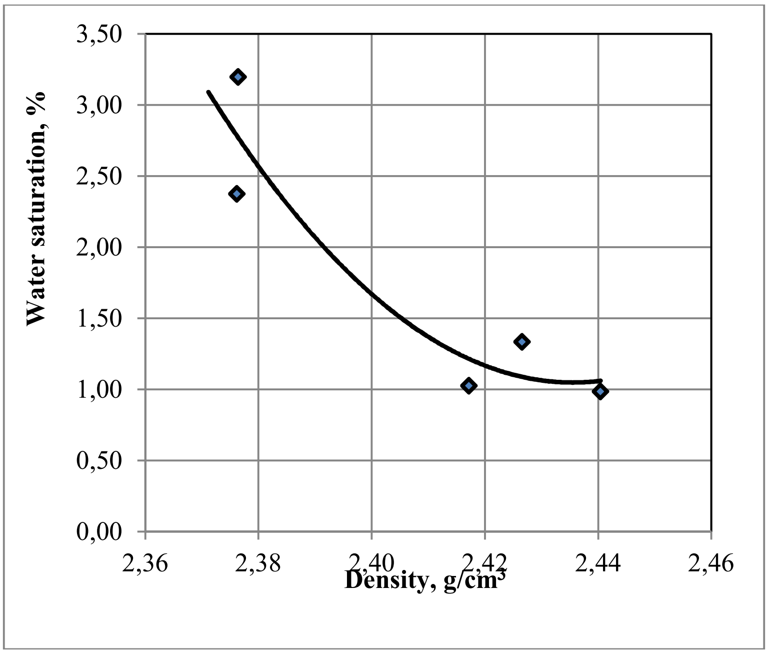


Figure 3 – Dependence of asphalt concrete samples water saturation from material density

Рисунок 3 – Залежність водонасичення зразків асфальтобетону від щільності матеріалу

a) b)

Figure 4 – General view of the section No.1(a) (with circulation of freight traffic) and No.2 (24.10.2013) (b)

Рисунок 4 – Загальний вигляд ділянки № 1(а) (з рухом ВВТЗ) та № 2 (24. 10.2013 р.) (б)

Determination of the elastic deflection of asphalt concrete pavement

Tests were performed in August 2016 using plate bearing method. This method has been improved and today, despite the relatively low productivity, is one of the most precise for determination of elastic deflection and, accordingly, modulus of deformation and modulus of elasticity of grained layers. Study in general was composed of few stages: 1 – gathering of data about the road pavement structure; 2 – performance of visual and instrumental inspections over the road pavement condition by strength and deformability; 3 – office processing and analysis of obtained results. In order to change elastic deflection of pavement surface to the general modulus of elasticity of road pavement it is used a known dependence according to VBN V.2.3-218-186-2004 “Non-rigid road pavement”.

Figure 5 – Longitudinal crack along the pavement axis on the section PK 308+577 (it is seen a difference between SMA structure) modified with synthetic wax (left) and natural bitumen (right)

Рисунок 5 – Поздовжня тріщина по осі покриття на ділянці ПК308+577 (видно різницю в текстурі ЩМА) модифікованого синтетичним воском (зліва) та природним бітумом (вправа)

Figure 6 – Transverse crack in the SMA layer modified with synthetic wax, which is positioned perpendicular to the longitudinal crack along the pavement axis

Рисунок 6 – Поперечна тріщина в шарі із ЩМА модифікованого синтетичним воском, яка розташована перпендикулярно до поздовжньої тріщини по осі покриття

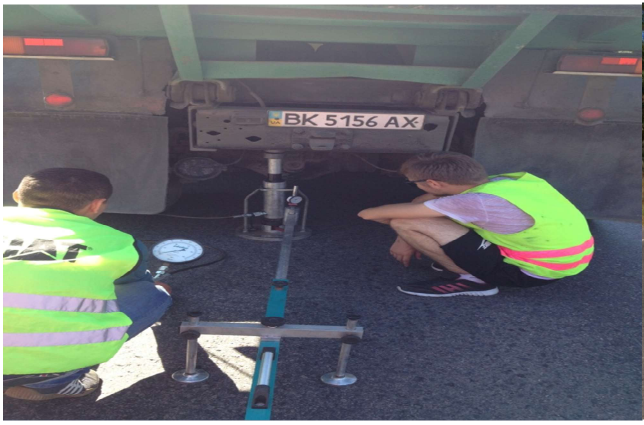


Figure 7 – Measurement of elasticity modulus of road pavement with plate equipment “Infratest”, 2016

Рисунок 7 – Вимірювання модуля пружності дорожнього одягу і штамповим обладнанням "Infratest", 2016 р

Figure 8 – General view of the section 2016 p

Рисунок 8 – Зовнішній вигляд ділянки 2016 р

Modulus of elasticity of soil or material in uniform structure, as well as general modulus of elasticity of layered structure, tested with load by means of rigid plate, equals to

$$E_{gen} = 0.25 \cdot \pi \frac{pD(1-\mu^2)}{l} \cdot 10^{-3}, \text{MPa}, \qquad (1)$$

where

- p - maximum (calculated) pressure from the plate, MPa;
- D - diameter of rigid plate, D= 0.30 m;
- μ - Poisson’s ratio (for soils of subgrade μ = 0,35, for base materials μ = 0,25, and when calculating general modulus of elasticity μ = 0,3);
- l - elastic deformation, which corresponds to this load, mm.

In order to measure elastic deflection, it was used one beam by loading the structure through the rigid plate. Results of inspection on Kyiv-Kovel-Yahodyn Motorway are shown in the table 6 below.

Table 6 – Results of determination of elastic deflection of the road pavement of Kyiv-Kovel-Yahodyn Motorway, km 307 – km 330

Таблиця 6 – Результати визначення пружного прогину дорожнього одягу ділянки а/д Київ-КовельЯгодин, км 307 – км 330 (t pavem.= 40 °С)

No.	Location of measurement point		Carriageway	Value of deflection of the stamp under the load, mm	Value of deflection of the stamp after removal of the load, mm	Elastic deflection, mm (measured at existing temperature)	Elastic deflection, mm (in conversion to +10^{0}C) in cm	Static modulus of elasticity, MPa	Note
	km	+							
1	307	100	left	4.81	3.55	1,26	0,076	170	29.08.2016
2	307	220	left	6.60	5.28	1.32	0.079	162	rut
3	307	220	left	3.58	2.59	0.99	0.059	216	without rut
4	308	577	left	5.26	4.45	0.81	0.049	265	
5	308	577	right	5.43	4.65	0.78	0.047	275	
6	309	000	left	4.83	4.00	0.83	0.050	258	
7	309	000	left	5.80	4.63	1.17	0.070	183	

Analysis of defects on the pavement section. In the course of studies conducted on the section from km 308+577 to km 309+295 of M-07 Motorway the following defects in asphalt concrete pavement have been identified: longitudinal cracks, transverse, attenuated, diagonal cracks which are opened to the entire width of the structure. Left lane (if moving from km 308 toward km 309) was paved with natural bitumen additive and 17 cracks have been formed since putting into operation in 2011. Right lane (if moving from km 308 toward km 309) was paved with additive of synthetic wax whereon 71 cracks have been formed since the reconstruction. Longitudinal cracks at the lanes themselves have not been detected, except for the crack along the axis to almost entire section of the pavement, which separated layers paved with different additives. Table 7 and Fig.s 6-7 show static processing of data of determination of the distance between cracks on the sections with synthetic wax and natural bitumen additives.

Conclusions and References. According to the results of studies it was determined that when adding the natural bitumen, softening point increases linearly by 0.7°C when adding 1% of the natural bitumen, and penetration decreases logarithmically. Compressive strength raises 1.3-1.7 times at the temperature 20°C and 1.4-2 times at the temperature 50° for the natural bitumen and synthetic wax accordingly.

Linear dependence of the compressive strength increase at a temperature +20°C and +50°C for the asphalt concrete of type A against content of the natural bitumen Selenizza SLN 120 in percent by mass from the mass of bitumen BND 60/90 is observed.

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This evidences that in this case asphalt concrete pavement modified with natural bitumen is more efficient than the pavement modified with synthetic wax.

Table 7 – Statistic data about quantity and frequency of cracks on the surface
Таблиця 7 – Статистичні дані кількості та частості тріщин на покритті

Additive	Synthetic wax (transverse cracks)	Natural bitumen (transverse cracks)	Transverse cracks to the entire width of the pavement
Quantity of data	71	17	11
Maximum distance between cracks, m	50.00	262.50	262.50
Minimum distance between cracks, m	1.00	3.00	3.00
Scale	49.00	259.50	259.50
Average distance between cracks, m	10.00	48.47	61.27
Standard	9.387	77.726	88.385
Variation coefficient	93.87	160.36	144.25

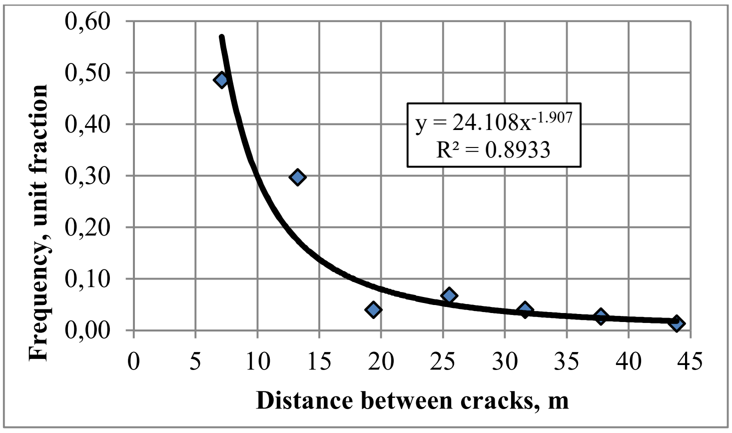

Figure 9 – Frequency of falling into determined interval (distances between cracks) for the section with synthetic wax additive
Рисунок 9 – Частість попадання в заданий інтервал (відстані між тріщинками) для ділянки з добавкою синтетичного воску

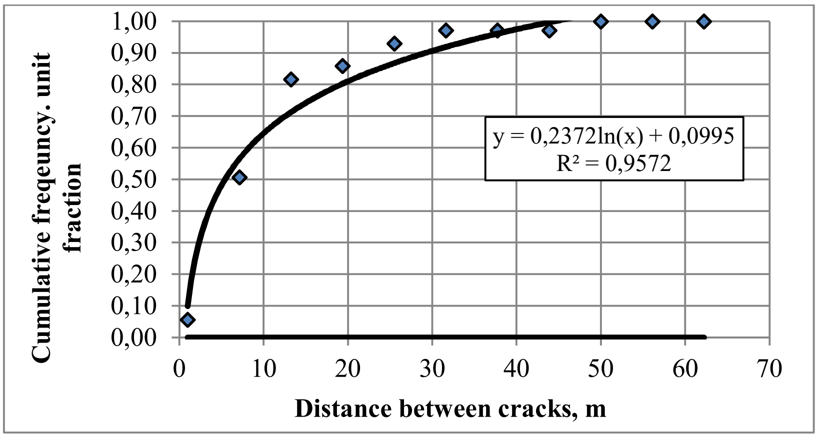

Figure 10 – Cumulative curve of distribution of distances between cracks for the section with synthetic wax additive
Рисунок 10 – Інтегральна крива розподілу відстані між тріщинами для ділянки з добавкою синтетичного воску

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ЕФЕКТИВНІСТЬ ВИКОРИСТАННЯ МОДИФІКАТОРІВ БІТУМУ ТА АСФАЛЬТОБЕТОНУ ПРИ РЕМОНТІ МАГІСТРАЛЬНИХ АВТОМОБІЛЬНИХ ДОРІГ

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Анотація. У даній роботі наведені дані експериментально-аналітичних дослідження впливу модифікаторів на фізико-механічна властивості асфальтобетону та на властивості бітуму. Визначена ефективність використання синтетичного воску та природного бітуму при реконструкції автомобільної дороги.

Головним питанням даного дослідження стало визначення ефективності модифікаторів бітуму та асфальтобетону, а саме встановлення причини руйнування покриття влаштованого при введенні двох різних добавко в асфальтобетон під час реконструкції. Ділянки які влаштовані суміжно одна одній та прослужили однаковий строк і на які здійснюються відносно однакові систематичні навантаження.

Обстеження було направлене на визначення ефективності модифікаторів бітуму та асфальтобетонної суміші, що значною мірою може вплинути на економічну вигідність застосування добавок, оскільки дає поняття про те як змінюються фізико-механічні характеристики вихідного матеріалу в залежності від відсотку вмісту добавок та їх влив на довговічність покриття.

За результатами досліджень встановлено, що при добавці природного бітуму температура розм’якшення зростає за лінійним законом на 0,7°С при додаванні 1% природного бітуму а пенетрація зменшується за логарифмічним законом. Міцність на стиск зростає в 1,3 – 1,7 рази при температурі 20°С та 1,4 – 2 при температурі 50°С відповідно для природного бітуму та синтетичного воску. Спостерігається лінійна залежність росту міцності на стиск при температурі 20°С та +50°С асфальтобетону типу А від вмісту природного бітуму Selenizza SLN 120 у відсотках за масою від маси бітуму БНД 60/90.

Під час проведення візуального обстеження стану покриття було виявлено, що на ділянці з ЩМА 20 модифікованого природним бітумом утворилось в 7 разів менше дефектів, ніж на ділянці конструкції, модифікованого синтетичними восками.

Це свідчить про те, що в даному випадку асфальтобетонне покриття, модифіковане природнім бітумом, виявилося більш ефективним, ніж покриття модифіковане синтетичним воском.

Ключові слова: модифікатор, природний бітум, асфальтобетон.

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