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Modeling of organizational and technological solutions for quality management of the installation of the structural layers of asphalt concrete

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ABSTRACT

Objective: The studies considered in the work on improving the certification system are relevant, have novelty, contribute to the development of the certification system with the introduction of a method that allows predicting the period between repairs of asphalt concrete pavements based on standard indicators. Methods: The work was carried out using theoretical research methods that allow characterizing the research model in order to create an image of the scheme being developed with decreasing contradictions and determining its main direction of functioning. Results: The necessity of the problem of efficiency criteria and limitations is substantiated to be reduced to a system-target model based on the hierarchy of the structure of the transport system and the corresponding modeling of the reconstructed system of transport support goals, the contradiction between the needs of the practice of improving the certification system for the integrated use of the transport system and the state of the scientific and methodological base for predicting the period between repairs of asphalt concrete pavements. Conclusion: The considered method of substantiating the economic efficiency of calculating the period between repairs of asphalt concrete pavements will provide an opportunity to develop recommendations for its development in the interests of strengthening economic and environmental safety.

KEY WORDS: Maintenance, building materials, road engineering, construction engineering, technology.

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Modelado de soluciones organizacionales y tecnológicas para la gestión de calidad de la instalación de las capas estructurales de concreto asfáltico

RESUMEN

Objetivo: Los estudios considerados en el trabajo de mejora del sistema de certificación son relevantes, tienen novedad, contribuyen al desarrollo del sistema de certificación con la introducción de un método que permite predecir el período entre reparaciones de pavimentos de hormigón asfáltico en base a indicadores estándar. Métodos: El trabajo se llevó a cabo utilizando métodos teóricos de investigación que permiten caracterizar el modelo de investigación con el fin de crear una imagen del esquema que se desarrolla con la disminución de las contradicciones y la determinación de su dirección principal de funcionamiento. Resultados: Se fundamenta la necesidad de reducir el problema de criterios de eficiencia y limitaciones a un modelo sistema-objetivo basado en la jerarquización de la estructura del sistema de transporte y la correspondiente modelación del sistema reconstruido de objetivos de apoyo al transporte, la contradicción entre las necesidades de la práctica de mejoramiento del sistema de certificación para el uso integrado del sistema de transporte, y el estado de la base científica y metodológica para la predicción del período entre reparaciones de pavimentos de concreto asfáltico. Conclusión: El método considerado para fundamentar la eficiencia económica del cálculo del período entre reparaciones de pavimentos de hormigón asfáltico brindará la oportunidad de desarrollar recomendaciones para su desarrollo en aras de fortalecer la seguridad económica y ambiental.

PALABRAS CLAVE: Mantenimiento, materiales de construcción, ingeniería vial, ingeniería de la construcción, tecnología.

Introduction

One of the most important tasks in the construction and repair of pavements is the quality of the material, and testing and control are the means of ensuring the quality and reliability of asphalt concrete. A rational and logical combination of the regulatory framework and methods for assessing the quality of materials, taking into account the conditions of their work in pavement, will ensure the required level of reliability of pavement. Therefore, it is advisable to consider the issue of quality management of the installation of asphalt concrete structural layers of road pavement by increasing the regulatory effect of the certification system as a tool to ensure it's quality. Each material has its own characteristics and scope, and only compliance with

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technical standards, technological regulations guarantees the safety quality of materials and structures. This paper discusses the issue of increasing the regulatory action of the certification system on the quality of construction of asphalt concrete structural layers of road surfaces by moving from certification of materials and products to certification of structural layers and objects with the development of a methodology for determining the period between repairs of pavements for specific objects.

As a working hypothesis, an assessment of the quality of mixtures and material of structural layers is used on the basis of the certification system and the current regulatory framework in order to increase and determine the period between repairs. The hypothesis is based on regulatory requirements, data approximation based on a regression curve for normalized indicators. A theoretical assessment based on scientific and technical materials revealed the influence of various factors on the quality of asphalt concrete mixtures and materials. As a result, it was found that the certification system has a greater impact on the quality of the material by increasing its homogeneity. On the basis of the identified factors, it becomes necessary to theoretically improve the scheme of the certification system with the development of methods in order to increase their regulating action when using it to predict the period between repairs for specific construction projects and accumulate a database. The reliability of the research results is ensured by the following:

1. materials for quality control of the preparation of the material of mixtures from the asphalt concrete mixing plant (ACMP), selected by CJSC "SHOSSE";
2. data on quality control from linear facilities: M-9 "Baltia" in the section from 18 to 84 km during the pre-design survey of the existing road, JSC "SoyuzdorNII"; a bridge across the Don River, surveyed by JSC "SoyuzdorNII"; mixtures from small linear objects, selected by the employees of JSC "SoyuzdorNII" in the city of Moscow.

In the process of research, the formed database was processed by methods of mathematical statistics based on regression analysis as follows: grouping of materials was carried out; homogeneous groups were formed; physical and mechanical properties of mixtures and materials based on statistical distribution were analyzed; graphs were built to determine the quality of the material. The obtained results are partially disclosed in this paper. In

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subsequent works, the entire complex of the results of the research will be presented for publication.

1. Methods

General scientific methods of systems analysis, logical and mathematical modeling, systems theory, as well as methods of operations research and economic-mathematical methods, economic-visual modeling, research methods of operations were used. The arrangement of permanent access roads with asphalt-concrete pavement, which, after subsequent maintenance and revision, remain at the facility under construction for subsequent operation, should be arranged in stages, which makes it possible to make the adjoining temporary roads less extended. This methodological technique makes it possible to significantly reduce the overall labor intensity of work, the energy intensity of production and increase the level of labor mechanization. The arrangement of asphalt concrete pavements of temporary and access roads is in many respects similar to the arrangement of road pavements of streets, which, during the preparatory period of construction, allows starting their temporary operation during the period of zero-cycle work and the erection of overground building structures of a building or structure at a construction site. The recommended professional approach allows the arrangement of roads at a construction site to be carried out according to the approved design documentation agreed with the participants in the construction, which has passed the examination and accepted by the construction manager of the facility.

Analysis of the economic aspects of the problem of transport provision at a construction site shows the insufficiency of work devoted to the study of the problem (with regard to individual private parties) of the effectiveness of the use of an integrated road transport system. There is a need to create a modern scientific and methodological base for assessing the effectiveness (quality) of the integrated use of the arrangement of highways, in particular, road surfaces for the use of temporary roads at the construction site at the level of model indicators and the reconstructed hierarchy of the road transport system. The methodological basis of the study is a probabilistic and statistical method for assessing the quality of materials, infographics,

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control of the preparation and use of road-building materials, analysis of the current certification system and regulatory framework.

2. Results

The objective of the method is to improve the scheme of the certification system aimed at creating a database for predicting the period between repairs of asphalt concrete pavements.

The method for calculating the period between repairs of asphalt concrete pavements includes:

1. substantiation of the rational volume of samples from the standpoint of statistics to obtain reliable results;
2. the principle of forming a database for each parameter obtained during testing and examination of specific construction sites and ACMP (asphalt concrete mixing plant);
3. statistical methods of data processing;
4. substantiation and appointment of control time points in order to determine the period between repairs;
5. calculation method based on the proposed method of time intervals.

We will calculate the weighed portion for making a sample according to the formula:

$$m_0 = \pi * (d/2)^2 * d * \rho^m \quad (1)$$

Conditional accepted density for fine-grained asphalt concrete – 2.44 g/cm^3, standard size test piece. Using formula 1, we obtain:

m_0=3.14*(7.14/2)^2*7.14*2.44= 697.2 g

Let's determine the mass of the sample mixture for the preparation of samples in the laboratory in the amount of 24 pcs. according to formula 2 with the initial data:

sample geometry: height (h) – 71.4 mm;

average density of hot dense asphalt concrete for USP – 2.44 g/cm^3 (for a given design case).

$$m = 1.2 * n * (S * h) * \rho^m \quad (2)$$

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where: m - mixture weight in kg;

n – the number of samples at the request of the standards (24 pcs.);

S – contact area of the sample, cm^2;

h – sample height - 7.14 cm;

1.2 – mixture loss factor

ρ^m – average density of asphalt concrete of the top layer - 2.44 g/cm^3

According to formula 2:

m=1.2*24*(3.14*(7.14/2)^2)*7.14*2.44= 20.08 kg

Let's calculate the volume of the mixture taken at the ACMP during its manufacture (for this case). The initial accepted conditions: substantiation of the rational volume of samples on the basis of the Telttomat plant with a capacity of 200 t/h with the top layer of the pavement 5 cm thick.

Calculation of the shift productivity of the plant at a rational plant productivity of 75% of the maximum and 8-hour work shift:

$$M=P_0*0.75*t \quad (3)$$

where: M - plant productivity per shift, t;

P_0 - plant productivity per hour, t/hour;

0.75 - additional factor taking into account rational loading;

t - shift time, h.

According to formula 3:

M=200*0.75*8=1200 t

Determination of the area of asphalt concrete pavement arranged during the shift, taking into account the initial data:

pavement width (b) – 7.5 m;

thickness of the structural layer (h_l) – 0.05 m;

ρ^m – average density of asphalt concrete of the top layer – 2.44 g/cm^3.

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The area of the asphalt concrete pavement that will be laid per shift is calculated using formula 2:

$$S = \frac{M_{ACMP}}{h_l} \quad (4)$$

where: h_l – layer thickness, 5 cm;

M – mass of the mixture produced by the ACMP per shift, t.

Using formula 4:

$$S = \frac{1200}{0.05} = 24000m^2$$

The results are presented in table 1.

Indicator name	Value
Changeable capacity of the Telttomat plant (M), t	1200
Structural layer thickness (h), cm	5
Area laid per shift (S), m^2	24000
Number of samples taken according to standards (n_s), pcs	3

TABLE 1. Baseline indicators.

In accordance with the requirements of the current regulatory documents, the number of test samples was counted (Table 2):

for sand mixture – 15 (18) pcs.;

for a fine-grained mixture – 24 pcs.;

for coarse-grained mixture – 12 pcs.

Let us determine the minimum allowable statistical volume of samples by the mass of the sampled cores (according to formulas 5 - 9).

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The number of core samples taken (according to formula 5), pcs:

$$n_c = S/ S_s \bullet n_s , \quad (5)$$

where: S – area laid per shift, m^2

S_s – coring standards (S_s), m^2

n_s – the number of samples taken according to the standards (ns), pcs

The mass of the samples taken (according to formula 6), kg:

$$m_s = n_c \bullet d2/4 \bullet \pi \bullet \rho^m \bullet h, \quad (6)$$

where: n_c – number of core samples (n_c), pcs.;

d – core sample diameter, mm;

ρ^m – average density of asphalt concrete of the upper layer in g/cm^3 (2.44);

h – structural layer thickness (h), cm.

Number of samples made from cores (according to formula 7), pcs.:

$$n_{made} = m_s/ m_o \quad (7)$$

where: m_s – sample mass (ms), kg;

m_o – calculated weight for making a sample (depending on the mixture), g.

The number of complete mixtures (according to formula 8), pcs.:

$$n_{cm} = n_{made}/ n_c, \quad (8)$$

where: n_{made} – number of samples made from cores, pcs.;

n_c – number of core samples taken, pcs.

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The number of parallel mixtures that can be formed when determining the sample mass of the mixture for sample preparation in the laboratory for 24 pcs. Is determined by formula 9. The results are presented in table 3.

Indicators \ Mixture name	Sand	Fine-grained	Coarse-grained
1	2	3	4
Sample diameter, mm	50.5	71.4	101.0
Approximate amount of mixture per sample, g	220-240	640-670	1900-2000
Average density of material, g/cm^3	2.2	2.3	2.4
Number of samples by R0, pcs	3	3	-
Number of samples by R50, pcs	3	3	3
Number of samples by R20, pcs	3	3	3
Number of samples by R20 for K_v, pcs	3	3	3
Number of samples by R20 for K_{vd}, pcs	3	3	3
Number of samples by R_{split}, pcs	3*	3	-
Number of samples by $R50_{axis}$, pcs	No shear testing	3	No shear testing
Total number of samples for testing in accordance with regulatory requirements, pcs:	15 (18*)	24	12

Note: * samples are made at the request of the Customer

TABLE 2. Number of test samples in accordance with regulatory requirements.

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$$n_{\mathrm{pm}} = \frac{\mathrm{M_{ACMP}}}{m} \quad (9)$$

where: m – mixture mass, kg.;

M_{ACMP} – weight of the production rate of the plant taking into account the rational productivity of the plant.

Core sample diameter (d), mm	Weight of the production rate of the ACMP taking into account the rational productivity of the plant (M_{ACMP}), kg	Mixture mass (m), kg	Number of parallel mixtures (n_{pm}), pcs
150mm	51.7		2.6
100mm	23	20.08	1.15
80mm	14.7		0.7

TABLE 3. Number of parallel mixtures to form samples.

At n_{pm}=2.6, we get two complete test mixtures and 0.6 – incomplete sample for further set of mixture with additional samples.

At n_{pm}=1.15, we get one complete test mixtures and 0.15 – incomplete sample for collection of statistics or rejection.

At n_{pm}=0.7– It is impossible to carry out a complete test on a given volume of cores, therefore, it is required either to abandon the use of this size of cores, or to arrange a second section and conduct a joint test (in 2 days).

According to the calculation results (formulas 2, 4), we obtain:

- production rate of the ACMP - 1200 t, which allows arranging an area of 24000 m^2, 5 cm thick;

- determination of the mass of the mixture sample for the preparation of samples in the laboratory according to regulatory documents with a sample diameter of 71.4 mm, the mass of the mixture is approximately 20 kg.

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The resulting table 4 shows that the amount of taken material does not provide complete quality control:

- when sampling three cores from an area of 3000 m2 with a core diameter of 150 mm, the shift area equal to 24000 m2, we have 3 parallel mixtures of 24 samples or one mixture under the condition of testing 9 samples for each indicator, as well as 2 samples for rejection;

Coring standards (S_s), m^2	Number of controlled shift areas (n_{sa}), pcs	Core sample diameter (d), mm	Number of coring samples taken (n_c), pcs	Sample mass(m_s), kg	Number of samples made from cores (n_{made}), pcs	Number of complete mixtures (n_{cm}), pcs
1	2	3	4	5	6	7
		150		21.5	30	7
7500*	3.2	100	10	9.6	13	3 (0)
		80		6.1	8	1 (-3)
		150		51.7	74	3 (2)
3000*	8	100	24	23	32	1 (8)
		80		14.7	21	0.8(-3)
		150		17.2	24	3(0)
10000***	3.3	100	8	7.6	10	1 (2)
		80		4.9	7	0.8 (-1)

TABLE 4. Substantiation of the rational volume of samples of the standard amount.

Note: * - until 2012, ** - current regulations, *** - suggested values for the number of samples exceeding the requirement for testing the mixture

- when taking three cores from an area of 3000 m^2 with a core diameter of 100 mm, the shift area equal to 24000 m^2, we have 1 mixture of 24 samples and 8 samples for rejection or increasing the number of samples according to the parameters of interest, bringing them to 5 pieces;
- when sampling three cores from an area of 3000 m^2 with a core diameter of 80 mm, the shift area equal to 24000 m^2, we have 0.8 mixture, i.e. 21 samples, although 24 samples are

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required, which indicates that it is not advisable to use this sample size for assessing the quality of construction work.

Thus, at a core sampling rate of 7000 m^2, 3000 m^2 and 10000 m^2, the use of 80mm cores does not ensure the rationality of quality control in terms of the number of samples produced or the production rate of the ACMP, therefore it is advisable to designate the size of the optimal site for quality control of asphalt concrete pavements, taking into account the requirements of statistics, depending on standardized sampling requirements.

3. Discussion

The most important task of the construction and repair of road pavements is the quality of the material and the choice of a system of requirements – the technology of preparation, laying of mixtures and structural layers from them. On the basis of the conducted analytical studies using the theoretical method of cognition in the form of a mathematical model, it is possible to describe and explain the relationship between the values of the indicators of asphalt concrete. Firstly, physical, mechanical and geometric indicators are combined into groups to identify patterns of change in indicators, applying the method of statistical processing of data results using mathematical techniques, quantitative calculated values, and secondly, in mathematical modeling, such methods of mathematical statistics as the sample mean, regression and correlation analysis, factor analysis, and graphical display of data trends are used. At the initial stage, it is planned to enter the information into tables, which are assigned the corresponding numbers.

The next step is to reduce the number of variables (data reduction) due to defects or errors in production, then the minimum and maximum values are determined, as well as the average values and the coefficient of variation for the selected group of indicators are found. To visualize the dependencies, the data records must be summarized in graphs. Regression analysis shows the dependence of the physical, mechanical and geometric indicators selected for the study (sample population) from each other and determines the spread of the dependent variable. The results are formed in graphical form - trend lines. Of the six existing types of trend (exponential, linear, logarithmic, polynomial, power, linear filtration), the logarithmic

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approximation can most accurately describe the behavior of asphalt concrete indicators, since these values of indicators initially grow or decrease rapidly, and then stabilize.

Statistics have a huge impact on the functioning, production growth, and also contributes to the change in quality indicators. The basis for the development of the methodology is the analytical data of testing materials on specific objects and a mathematical model in the form of the dependence y=f(x). The resulting database is processed based on five temporary checkpoints:

The first one is the physical and mechanical data of testing asphalt concrete samples from mixtures from ACMP;

The second is the physical and mechanical data of testing the material from mixtures from the laying;

The third is the physical, mechanical and geometric data of testing cores (samples) from the structural layer during the control of hidden works. It is required to recommend the size of the core and the optimal area that provides a sufficient amount of material to obtain reliable results;

Fourth - physical, mechanical and geometric test data of the structural layer during acceptance work on the basis of an improved certification system with the issuance of a certificate of conformity for an object or coating to prevent premature destruction of road pavements;

Fifth - physical, mechanical and geometric data of the structural layer of non-rigid road pavements after the warranty period to assess the degree of destruction of the existing pavement and the prospects for its safe operation.

After the warranty period (3-6 years) of the operated road, the procedure for confirming the certificate of conformity takes place, which includes an evenness indicator, track depth and additional coefficients taking into account the increase in traffic intensity. The estimated time interval is determined by approximation, taking into account regulatory requirements, depending on the achievement of permissible normalized values. The interval between the normalized value of the first and the last parameter is fixed, which makes it possible to assess the dynamics of changes in the properties and parameters of the coating material. The limit time value for each specific indicator is fixed along the trend line.

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The use of a logarithmic trend line ensures the accuracy of the approximation close to unity. By the totality of these values associated with violation of regulatory requirements, the inter-maintenance period is determined. As a result, the calculation base of the inter-maintenance period methodology is formed (Fig. 1), in which the "core" is the traditional control - incoming, operational, acceptance control using the certification system 3a; the time of the warranty period is taken into account, in accordance with which the parameters of the indicators are determined according to the regulatory framework and the significance of the object is taken into account. Since the sampling of the mixture is a random sample control; the first and second control points confirm the homogeneity and quality of the mixture material; third, fourth and fifth points - coring should be performed at precisely set points, which will eliminate the influence of the heterogeneity factor on the forecast of inter-maintenance period.

A new approach to strengthening the regulatory effect of the certification system on the quality of the construction of asphalt concrete structural layers of road pavement consists in the possibility of predicting the overhaul life of the constructed road section at the initial stages when introducing a certification system for a structural layer or the entire road pavement (Medvedev 2006, Radovskiy 2007, Krupin 2014, Nikolsky 2017, Brock et al 2020, Doroshin et al 2020, Kazaryan 2020).

The main conclusions of the proposed methodology for objectively obtaining quality improvement results:

1. using the existing regulatory framework and certification system, it is advisable to assess the quality of the structural layer material, and not asphalt mixtures;
2. the current domestic and foreign regulatory framework for assessing the quality of the structural layer material requires development;
3. it is required to provide for a system of certified control of work, depending on the complexity and importance of the object;
4. it is required to increase responsibility for the quality of work due to the interest of construction organizations in order to increase the overhaul life for pavement of roads by introducing a scoring system in order to obtain advantages when participating in a tender.

The results are described by a mathematical model in the form $y(x)=a\cdot\ln(x)+b$.

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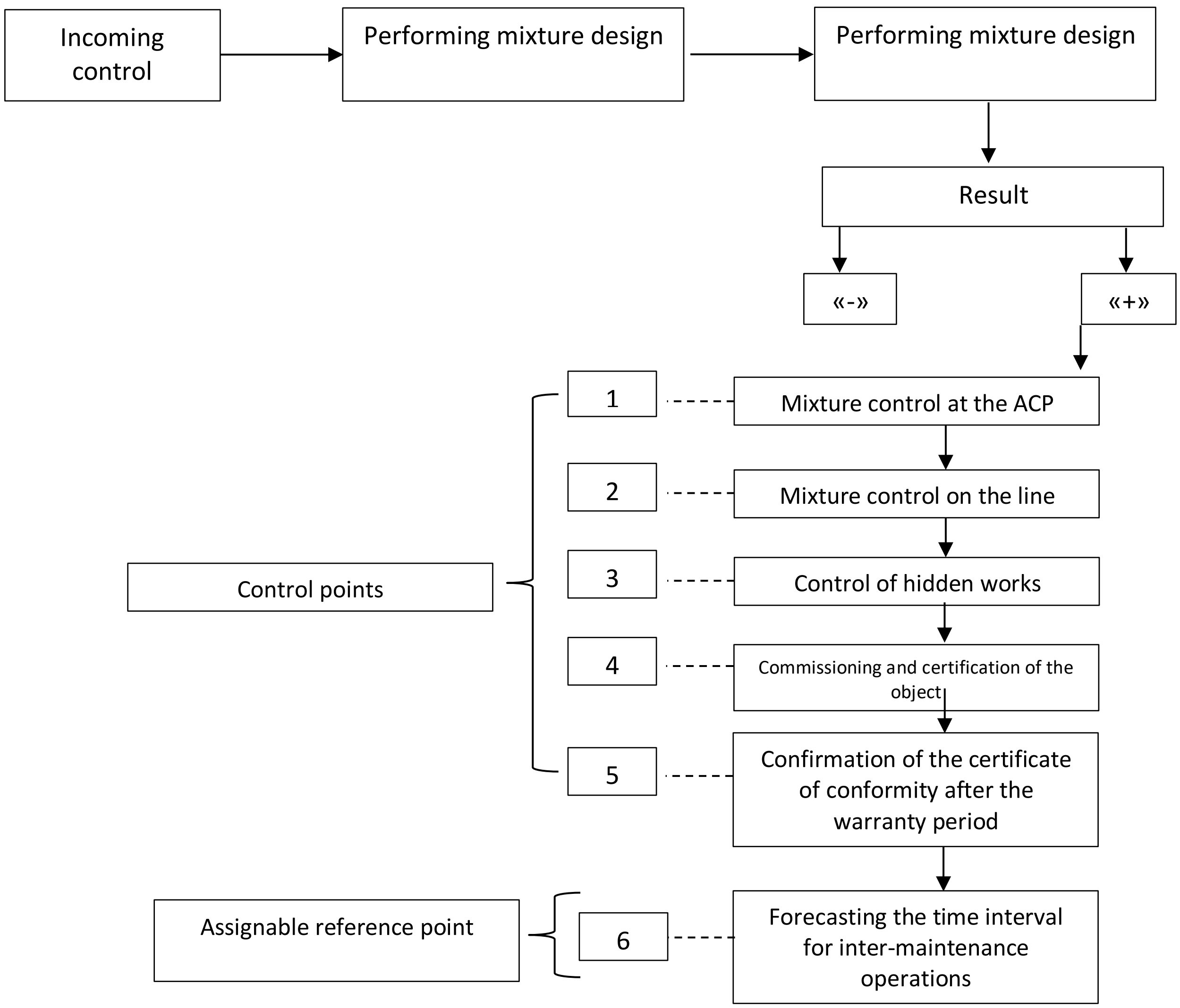

FIGURE 1. Certification scheme of the proposed methodology for calculating the overhaul life of a structural layer or the entire road surface

Conclusions

The problem of assessing the quality and choosing a system of requirements for the preparation technology of any material in order to improve quality is one of the cardinal problems. Each standard has its own characteristics and scope, and logical and professional compliance with technical standards and technological regulations guarantees the quality of materials and structures made from them. Quality management is based on such parameters as metrological assurance, standardization and certification.

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A study of a large number of literary sources, which used the results of the influence of various factors on the quality of asphalt concrete pavements, showed that controlled indicators are not enough to ensure high-quality coverage, but the introduction of a certification system improves quality by increasing the uniformity of physical and mechanical indicators, and also largely depends on effectiveness of the control system. Due to the fact that the quality of asphalt concrete pavements today does not meet the requirements of the traffic flow, it is necessary to propose a method to improve the quality of the structural layers of asphalt concrete pavements.

The effectiveness of technical control can be increased by building a new quality control system, which will be based on a system of conformity assessment according to standard physical and mechanical indicators to predict the performance and ensure the durability of coatings under the influence of loads from vehicles for a structural pavement or the entire structure of a highway. The current acceptance control on the basis of the sampling method does not have the required effect on the construction, but with its help, the level of quality of the finished product is determined. The batch contains products manufactured under uniform conditions, therefore, road construction products should be considered as a single linear element.

Therefore, the research vectors, namely: *aim*- on the basis of existing linear and artificial structures, to assess the regulatory impact of the certification system on the quality of structural layers of asphalt concrete, *object*- the current certification system and factors affecting the quality of asphalt concrete mixtures and structural pavement layers from them, *subject*- the regulatory action of the certification system for road building materials, as well as operational and acceptance control during the construction of highways, *scientific novelty*- the following were proposed: a) a scheme for the formation of a database on objects and their structures for further work in statistical research; b) a scheme of certification of the structural layer or the entire road surface; c) a method for predicting the period between repairs for specific objects based on strengthening the regulatory action of the certification system on the quality of the structure of structural layers are considered in the article.

The proposed calculation method makes it possible to:

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1. Timely and efficiently select a method for strengthening or repairing pavements based on the results of the application of a complex of technical control within the framework of certification of an object.
2. Predict the period between repairs of road pavements without the occurrence of damage;
3. Determine the service life of pavements with asphalt concrete coating of different thickness, composition and type of asphalt concrete.
4. Evaluate the homogeneity of the layers and determine the need for strengthening the coatings without waiting for the appearance of cracks.
5. Accumulate a database for further statistical processing to determine the influence of seasonal conditions of asphalt concrete laying on the period between repairs for each climatic zone for road building.

The main provisions of the proposed method:

1. Taking into account the heterogeneity of the properties of both materials and technology in the process of preparing and laying asphalt concrete mixtures, the quality of the pavement is a priority task of a statistical nature.
2. The obtained data of physical, mechanical and geometric parameters with the joint use of the certificate of conformity and technical control will show that the materials and methods of construction of the highway meet or do not meet the established criteria and regulatory requirements.
3. A solution to the problem of predicting the dynamics of changes in the coating structure material using a quantitative assessment using regression analysis in the form of a logarithmic trend line is proposed, ensuring the accuracy of the approximation within acceptable limits at $R2 \geq 0.85$ (Fig. 2).
4. The results of the method are described by a mathematical model in the form $y(x)=a \cdot \ln(x)+b$. In this case, the forecast of the period between repairs will be based on the obtained results of the initial materials and technological parameters of the already existing technical control, but with the addition of a certification system of the structure or the entire coating layer during acceptance control.

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A huge amount of factual material has been accumulated in the field of certification: theoretical proposals and practical recommendations have been developed. However, this system was not subject to reform for a long time. Therefore, the scientific task of developing methods and models of the economic efficiency of the organization and technology for the construction of access roads with asphalt concrete pavement during the preparatory period of construction is being formed. Conventionally, the directions of development can be divided into four sectors. First – takes into account the accumulated theoretical and practical experience and the established laboratory base. Second – adopted optimized models and shapes of samples of the test material. Third – the availability of research and ease of processing the results with their sufficient reliability. Fourth – a new approach to assessing the quality of road building materials, taking into account their operating conditions in a structure based on optimized laboratory samples with an assessment of the anisotropic and wave characteristics of materials, followed by the formation of a fundamentally new regulatory framework.

The problem of assessing the quality and choosing a system of requirements for the technology of preparing any material in order to improve the quality is one of the cardinal tasks of construction. Compliance with technical standards and technological regulations guarantees the quality of materials and constructions. The method allows balancing the interests of enterprises and citizens, transport organizations and enterprises with the interests of investors. These interests are often contradictory and even opposite. In similar situations, a system of state regulation is recommended for managing the joint activities of all participants in the functioning of the unified road transport system (Medvedev 2006, Radovskiy 2007, Krupin 2014, Lyovin et al volume 1,2,3-2016, Nikolsky 2017, Brock et al 2020, Doroshin et al 2020, Kazaryan 2020, Kazaryan et al 2020, Kazaryan 2021).

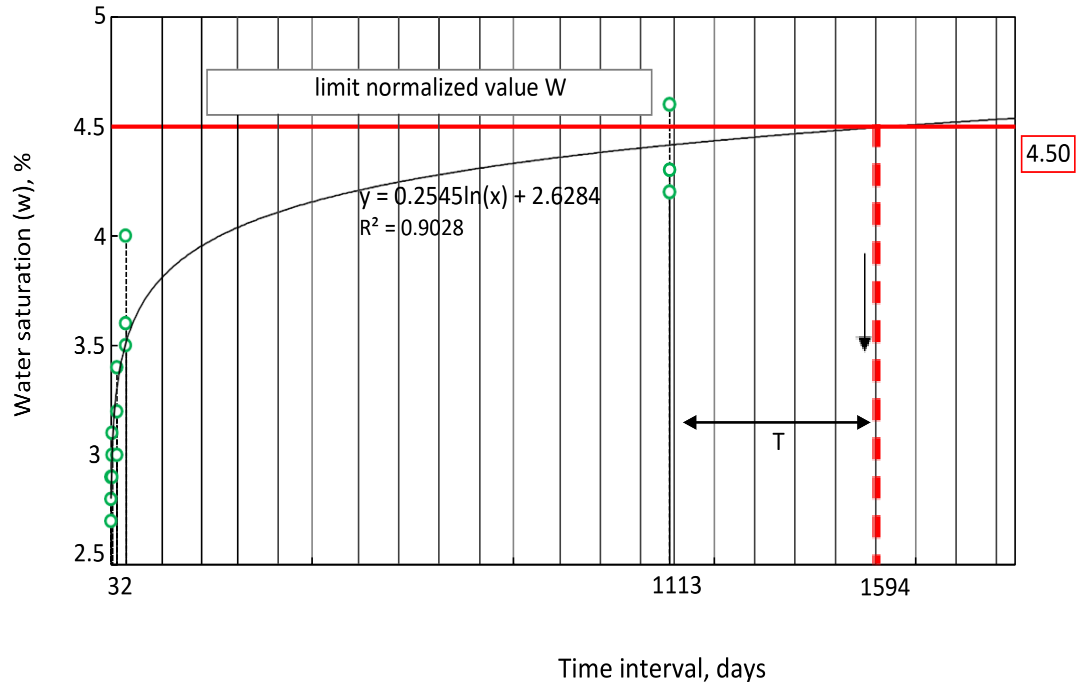

FIGURE 2. Forecasting by logarithmic dependence using the example of water saturation

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