PECULIARITY PLANNING EXPERIMENT OF THE INVESTIGATION THERMOPHYSICAL PROPERTIES OF ASPHALT MIXTURES

VLADIMIR A. ZORIN[1], NATALIA I. BAUROVA[1],
EKATERINA A. KOSENKO[2]
[1]*Doctor of Technical Science, Full Professor, [2]PhD, Associate Professor*
State Technical University-MADI , 64, LeningradskiyProsp., Moscow, 125319, Russia
Corresponding author's email: nbaurova@mail.ru

Abstract: *The article describes the main stages of experimental design in the study of thermophysical properties of asphalt mixtures. The results of experimental studies. Based on the results experimental studies have constructed graphs showing the dependence of the cooling time of the asphalt concrete mixture on environmental conditions and the method of thermal insulation of the asphalt concrete mixture during its transportation. Thermograms of experimental samples are presented, which clearly show the effectiveness of various methods of thermal insulation of asphalt concrete mixes. The choice of a regression model characterizing the dependence of the cooling time of an asphalt concrete mix on variable factors is substantiated. The methods of statistical analysis of the experimental data results.*

Keywords: *analysis, asphalt mix, experiment, quality indicators, thermal properties.*

I. INTRODUCTION

Ensuring the quality of asphalt concrete pavements of roads while maintaining high rates of their construction and repair is impossible without improving the technology of installation and compliance with technological regimes. One of the main tasks facing the producers of asphalt-laying works is to maintain the temperature of the asphalt concrete mixture at the stages of its transportation, laying and compaction. For different types and brands of asphalt mixes, this value may be different and is set by the regulatory documents governing the implementation of this type of work.

Currently, the problem of ensuring the temperature regimes for laying asphalt concrete pavement is successfully solved by introducing asphalt concrete loaders into the technological process, which allow to achieve temperature and fractional homogeneity of the asphalt concrete mixture and increase the rate of work production. With a significant removal of the object of construction or repair of pavements, the possibility of placing mobile asphalt concrete plants near the place of laying asphalt concrete pavement is being considered.

Temperatures can also be provided by arranging transportation of the asphalt concrete mixture using thermal insulating materials and setting the maximum transportation distance taking into account environmental conditions (temperature, humidity, wind speed, etc.), as well

as the type of the mixture being transported.

The intensity of cooling of asphalt mixes largely depends on the ambient temperature and is characterized by the coefficient of thermal diffusivity, which is expressed by the formula:

$$a = \frac{\lambda}{c\rho} \tag{1}$$

Where a is the coefficient of thermal diffusivity, m^2/s; λ is coefficient of thermal conductivity coefficient, W / (m°C); ρ is the density of the material, kg/m^3; and c is the specific heat capacity, J/(kg °C).

It is known [1] that the specific heat capacity of the asphalt-concrete mixture is higher, the lower the percentage of crushed stone in its composition. Thus, in accordance with expression (1), it can be concluded that asphalt-concrete mixtures of different granulometric composition will cool at different speeds, ceteris paribus.

Based on the theoretical analysis of the thermophysical properties of asphalt mixes, it is possible to identify the main factors affecting the intensity of their cooling: the particle size distribution of the mixture, the ambient temperature, the method and means of thermal insulation. The processes occurring in the volume of building materials when constructing pavements differ from the processes that are studied in laboratory conditions, therefore, when processing the results of studies conducted on specially prepared samples (on a scale of 1: 4000), it is necessary to use the mathematical apparatus of similarity theory and physical modeling [2].

II. EXPERIMENTAL PROGRAM
2.1. Materials

To conduct laboratory research to determine patterns of cooling of asphalt-concrete mixtures and assess the level of significance of determining factors, laboratory samples of asphalt-concrete mixtures of type A, brand I, type B, brand I, type D brand II were prepared.

In tables 1-3 presents the composition of the researched asphalt-concrete mixtures.

Table 1. Composition of fine-grained asphalt concrete mix type A, brand I

The name of the material	The composition of the mineral part of asphalt-concrete mixture (bitumen over 100%)	The composition of the mineral part of asphalt-concrete mixture (bitumen in 100%)	Dosage of materials for batch 1000 kg in kg
Crushedstone (5-20 mm)	43,0	41,0	410
Crushed stone (5-10 mm. gabbro diabase)	11,0	10,5	105
Naturalsand	19,0	18,1	181
Sand from the screenings of crushing 0-5 mm.	20,0	19,1	191
Mineralpowder	7,0	6,7	67
BitumenbrandBND 60/90	4,8	4,6	46

Table 2. *Composition of fine-grained asphalt concrete mix type B, brand I*

The name of the material	The composition of the mineral part of asphalt-concrete mixture (bitumen over 100%)	The composition of the mineral part of asphalt-concrete mixture (bitumen in 100%)	Dosage of materials for batch 1000 kg in kg
Crushedstone (5-20 mm)	39,0	37,1	371
Crushed stone (5-10 mm. gabbro diabase)	8,0	7,6	76
Naturalsand	42,5	40,5	405
Mineralpowder	10,5	10,0	100
BitumenbrandBND 60/90	5,0	4,8	48

Table 3. *Composition of fine-grained asphalt concrete mix type D, brand II*

The name of the material	The composition of the mineral part of asphalt-concrete mixture (bitumen over 100%)	The composition of the mineral part of asphalt-concrete mixture (bitumen in 100%)	Dosage of materials for batch 1000 kg in kg
Naturalsand	82,5	76,7	167
Mineralpowder	17,5	16,3	163
BitumenbrandBND 60/90	7,5	7,0	70

2.2. Experimental methods

During the experiment, the change in the rate of cooling of asphalt concrete mixes (Y) depending on the ambient temperature (X_1), the method of thermal insulation (X_2) and the percentage of crushed stone in the composition of asphalt concrete mixtures (X_3) is investigated.

Table 4. *Values of the main, upper and lower levels of each factor during the experiment*

Name	Factorvalues		
	X_1	X_2	X_3
Mainlevel	10	Using a tarpcover	45
Upperlevel	20	Using bunker thermal insulation method	52
Lowerlevel	0	Without the use of thermal insulation	0

To obtain the most accurate research data, an experiment is conducted for three levels for each factor. Then, suppose that the dependence of the criterion - the cooling time of the transported mixture - on the indicated factors will be expressed by means of the regression equation of the response surface.

Figure 1 shows the measurement scheme of samples of asphalt concrete mixture by five points. Prepared samples of asphalt mixes weighing 5 kg were heated to a temperature of 160°C and subjected to cooling to 120°C at different ambient temperatures: at temperature t = 0°C, t = 10°C and t = 20°C.
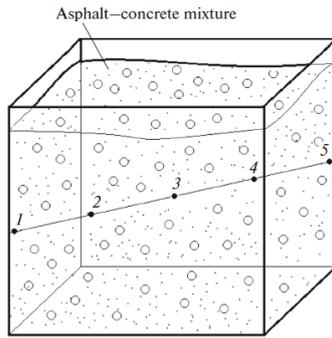
Asphalt–concrete mixture

Fig 1. *Sample for studying the cooling rate of asphalt–concrete mixtures: (1-5) measurement points*

During transportation, the most intensive cooling of the asphalt concrete mixture occurs through the open surface of the mixture in the vehicle body, therefore, it is possible to evaluate the effectiveness of various methods of thermal insulation by measuring the temperature of the asphalt concrete mixture using a thermal imager. For research was used thermalimager Testo 875-1i.

III. RESULTS AND DISCUSSIONS

According to the results of the studies were obtained graphics. Figure 2 presents the graphs showing the dependence of the average value of the cooling rate of asphalt concrete mix type A, brand I on the ambient temperature, taking into account the method of thermal insulation.
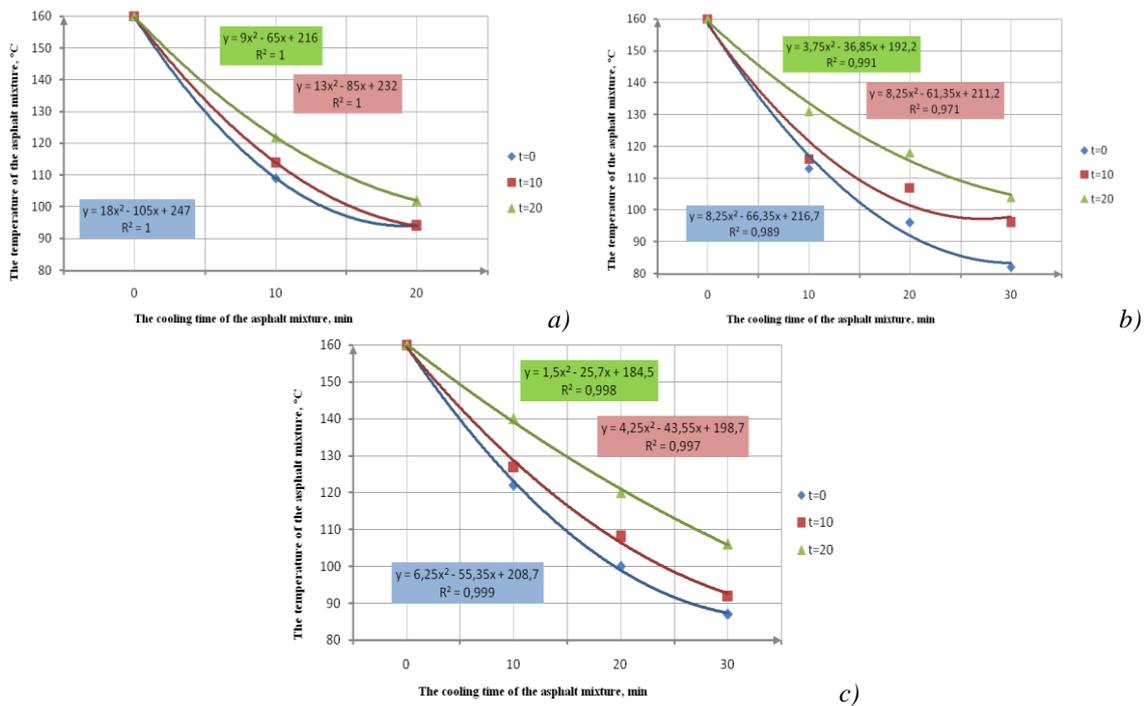

Fig 2. *Graphs of temperature change of asphalt-concrete mix type A brand I depending on the ambient temperature, taking into account the method of thermal insulation of the vehicle body:*
a) without the use of thermal insulation means; b) using cover with a tarpaulin;
c) using a bunker thermal insulation method

Graphs of changes in the temperature of asphalt-concrete mix type A brand I, depending on the method of thermal insulation, taking into account the ambient temperature, are presented in figure 3.
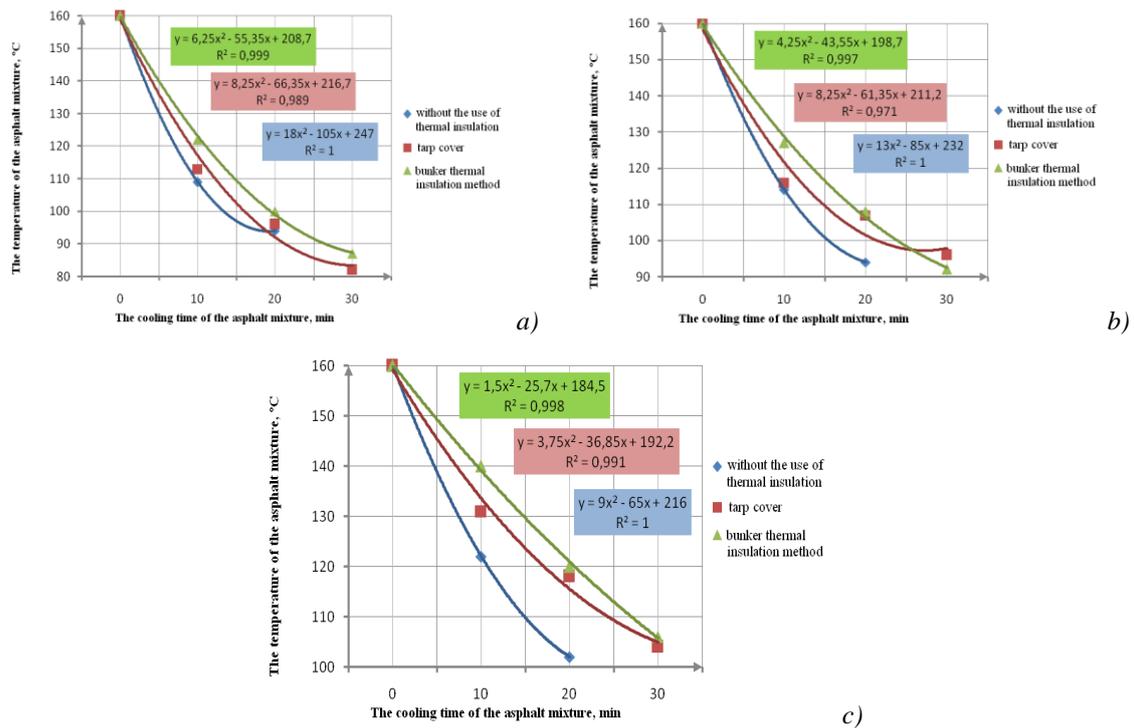
a)

b)

c)

Fig 3. *Graphs of changes in the temperature of asphalt-concrete mix type A brand I, depending on the method of thermal insulation, taking into account the ambient temperature: a) at t = 0°C; b) at t = 10°C; c) at t = 20°C*

As a result of the research, thermograms of samples were obtained before and at the end of the studies (figure 4).

The measurement results showed that the lowest rate of cooling of asphalt mixes provides a bunker method of thermal insulation.
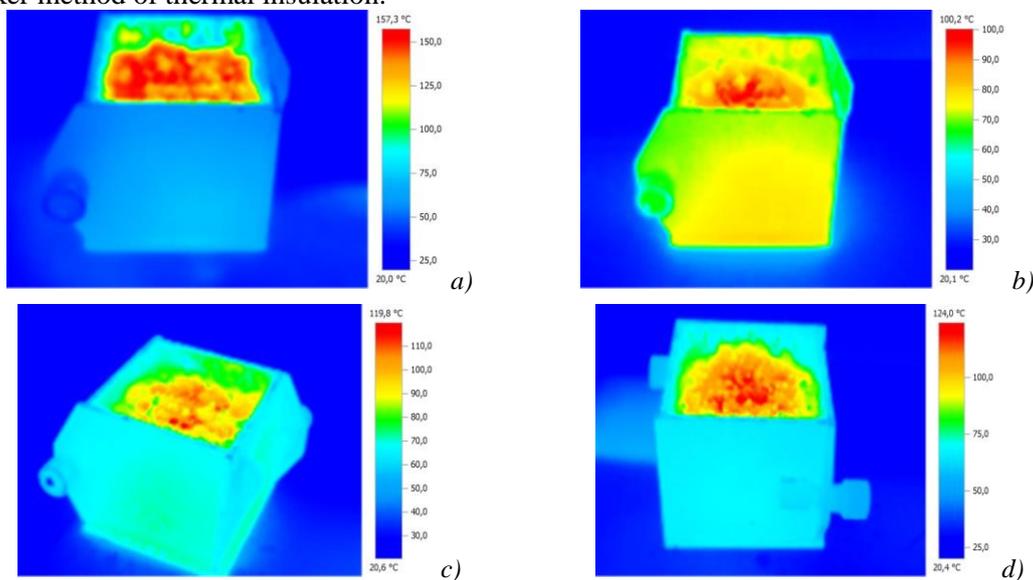

a)

b)

c)

d)

Fig 4. *Thermograms of the sample in the study of the process of cooling the asphalt mixture: a) at the beginning of measurements b) at the end of transportation without means of thermal insulation; c) at the end of transportation using a cover with a tarpaulin; d) at the end of transportation using the bunker method of thermal insulation*

Analysis of the results of the experiment is the most important and crucial stage of the study, since it is at this stage that the main regularities of the studied phenomena are established. However, any pattern can only reflect a finite number of basic bonds in an infinite set of unexplored bonds, which leads to inaccurate implementation of patterns with some deviations. To account for random deviations, it becomes necessary to apply the methods of probability theory and statistical methods [3].

Statistical methods for assessing the accuracy and mathematical description of the technological process make it possible to build a mathematical model that serves as a control object when carrying out the operation of transporting asphalt concrete mixture in the technological process of paving [4].

As a result of the application of statistical methods for studying the influence of independent variables on the dependent variable, a regression model is defined that reflects the dependence of criterion (*Y*) on predictors (*X*) [5].

Most often, the following regression models are used to display the dependence of the criterion on predictors: simple regression, multiple regression, factor regression, polynomial regression, regression of the response surface, regression of the mixture surface [4].

An analysis of the use of regression models is presented in table 5.

Table 5. *Analysis of the use of regression models*

№	Nameofregression	Regressionequation	Description
1.	Simpleregressionplan	$Y = b_0 + b_1X_1$ $Y = b_0 + b_1X_1^n$	Only one predictor is used. If a simple regression plan uses effects of a higher order X, then the values of the plan matrix will be raised to a power corresponding to the nth order level.
2.	Multipleregressionplan	$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3$	It is a simple regression for 2 or more continuous predictors.
3.	Fullfactorialregressionplan	$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_1X_2$ $Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + ...$ $... + b_4X_1X_2 + b_5X_1X_3 + b_6X_2X_3$	Defined as a plan in which all possible observations of continuous predictors are presented. For example, the full factorial regression plan for two continuous predictors X_1 and X_2 will contain the main effects X_1 and X_2 and the effect of their second X_1 and X_2 interaction, which is the product of the values X_1 and X_2, for each observation. The factorial regression plan can also be fractional, and the effects of a higher order can be removed from the plan.
4.	Polynomialregressionplan	$Y = b_0 + b_1X_1 + b_2X_1^2 + ...$ $...b_3X_2 + b_4X_2^2 + b_5X_3 + b_6X_3^2$	It contains both the main effects and the effects of higher orders of continuous variables, but it does not include the interaction of predictors. The maximum degree of the effects of polynomial regression can be different for different predictors.
5.	Second order response surface regression plan	$Y = b_0 + b_1X_1 + b_2X_1^2 + b_3X_2 + ...$ $... + b_4X_2^2 + b_5X_3 + b_6X_3^2 + ...$ $+ b_7X_1X_2 + b_8X_1X_3 + b_9X_2X_3$	It is a hybrid of the polynomial regression plan and the fractional factorial regression plan. This type of plan is used in applied research (for example, in industrial planning and analysis of experiments)
6.	Regression surface of the mixture	$Y = b_1X_1 + b_2X_1^2 + b_3X_2 + ...$ $... + b_4X_1X_2 + b_5X_1X_3 + b_6X_2X_3$	It is an analogue of second order factorial regression without a free term.

The mathematical model of a full-factor experiment for three factors with three levels for each factor is:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1X_1 + b_{22}X_2X_2 + b_{33}X_3X_3 + \ldots$$
$$\ldots + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3$$

Where b_0, b_1, b_2, b_3, b_{11}, b_{22}, b_{33}, b_{12}, b_{13}, b_{23}, – regression coefficients.

Statistical analysis is performed in accordance with the generally accepted method of processing and analysis of tests [4, 5].

IV.CONCLUSION

The results of experimental studies have shown that the accepted norms for cooling asphalt concrete mixes [6, 7] are averaged and too high at an ambient temperature of 20°C and underestimated at an ambient temperature of 10°C. Unjustified overestimation of the cooling time of the asphalt concrete mixture may lead to the rejection of the asphalt concrete mixture due to non-observance of temperature conditions. The use of a smaller period of time for cooling the asphalt concrete mixture during the execution will lead to a decrease in the efficiency of the pavement construction process.

Thus, it can be concluded that in order to avoid economic losses as a result of a violation of the temperature regimes of the technological process of laying asphalt concrete mixture, it is important to determine the cooling time of the asphalt concrete mixture for each composition and method used to transportation to the pavement construction site.

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