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RESEARCH OF TEMPERATURE CHANGE OF PAVEMENT HEATING IN THE PROCESS OF HOT IN-PLACE RECYCLING OF ASPHALT CONCRETE

Об'єктом дослідження є технологія гарячої регенерації асфальтобетону методом «in-place». Температурні режими розігрівання асфальтобетонного покриття є одними з ключових технологічних параметрів, які впливають на якість вихідного регенерованого асфальтобетону. З метою встановлення залежності температури розігрівання покриття на різній глибині від часу розігрівання проведені натурні дослідження безпосередньо під час виконання робіт з гарячої регенерації асфальтобетону методом Reshape. Роботи виконувались при температурі навколишнього середовища 25–30 °С та безвітряній погоді. Регенерована гаряча асфальтобетонна суміш, що використовувалась при проведенні досліджень, за зерновим складом та вмістом бітуму відповідала суміші гарячій, дрібнозернистій, асфальтобетон щільний, типу А, непереривчастої гранулометрії, марки ІІ відповідно до ДСТУ Б В.2.7-119:2011. Вміст залишкового бітуму розпушеної асфальтобетонної крихти становив 6,0 %. При проведенні досліджень вимірювання проводили при різній швидкості руху (1,8 м/хв та 2,1 м/хв) термічної установки для розігріву асфальтобетонного покриття Wirtgen HM 4500 (країна виробник – Німеччина). Отримані графічні залежності та математичні моделі дали змогу визначити, що оптимальним режимом розігрівання покриття є поступовий розігрів. Такий режим дозволить уникнути випалювання бітуму та забезпечити розігрівання дорожнього покриття на рівні основи регенерованого шару, що дуже важливо при визначенні температури перемішування суміші. Аналіз графіків та математичних моделей дає змогу припустити, що зменшення температури розігріву покриття хоча б на 10–20 °С призведе до збільшення продуктивності роботи термічної установки. В такому випадку збільшення продуктивності може складати від 20 % до 25 %, що зменшить витрату газу та, відповідно, собівартість робіт. Таким чином, отримані залежності можуть бути використані при оптимізації технологічного процесу гарячої регенерації асфальтобетону методом «in-place».

Ключові слова: *регенерація асфальтобетону, автомобільна дорога, асфальтобетонне покриття, гарячий ресайклінг, поточний ремонт, економічна ефективність.*

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1. Introduction

Given current trends in the rise in the cost of road-building materials, an urgent task is their reuse [1]. One of the ways to solve this problem is the introduction of technology for the hot regeneration of asphalt concrete. In the world practice of road construction, the focus of state policy on resource conservation is the main engine for introducing technologies for the industrial recovery of asphalt concrete [2].

Depending on the method of preparation, there is a distinction made between the technology for preparing hot regenerated asphalt mixes at the factory and directly on the spot («in-place»). According to the world practice of road construction, hot recycling technology for road asphalt in place is classified depending on the type and purpose of work, manufacturing processes and the use of regenerated mixtures as follows [3]:

– Reshape method – profiling;
– Repave method – profiling with restoration of the wear layer;
– Remix method – regeneration with a change in the composition of old asphalt concrete by adding new materials in an amount up to 30 % (mainly up to 20 %) by weight;
– Remix Plus method – regeneration with a change in the composition of old asphalt concrete and the simultaneous installation of a layer of new asphalt concrete mixture in one pass.

According to [4], the economic effect of the application of on-site hot recycling technologies is 20–30 % compared to traditional technologies for repairing asphalt concrete pavements. The authors of [5] argue that the savings from using this technology can be up to 35 %. Studies [6] also show a reduction in the time taken to complete the work compared to traditional methods. However, they note about the unsuccessful experience of application. The main reason is called improperly selected areas for repairs, since the existing position of the pavement is not properly taken into account. At the same time, important factors in the cost-effectiveness of technology and the quality of work performed are the correct choice of the technological process and the accuracy of assessing the condition of objects and materials at the stage of engineering surveys [7]. One of the key components of the technological process of hot recycling of asphalt concrete using the «in place» method is the heating of the asphalt concrete pavement to a certain depth and, as a consequence, the mixing temperature [8].

The issue of the influence of pavement preheating on the quality of the regenerated material and the performance of the regeneration process itself is considered in [9]. The minimum temperature of the pre-heating of the pavement is established according to the research results – 120 °C, which can guarantee the quality of the regenerated pavement. Providing a temperature on the surface of the asphalt concrete pavement of 160–180 °C, the depth of asphalt concrete warming up to a plastic state (such that it allows reformation) reaches 4–6 cm at certain dimensions and the speed of the asphalt-pavement moving.

It is noted in [10] that the cost of hot recycling of asphalt concrete using the in-place method substantially depends on the gas consumption for pavement heating (in the case of pavement heating with infrared radiation burners).

Despite the large number of publications on this topic, questions of studying the influence of technological parameters on the temperature of the pavement heating is relevant. Establishing the laws of such an impact will determine the optimal temperature conditions of the remixer, which will reduce the gas consumption for pavement heating is and, as a result, the cost of the work. So, *the object of research* is the technology of hot asphalt concrete regeneration by the in-place method. *The aim of research* is to conduct field studies of changes in the pavement temperature, depending on the speed of the thermal installation for heating the asphalt concrete pavement and the heating time.

2. Methods of research

When performing the work, the following research methods are used:

– selective monitoring of the process of work;
– control measurements of basic physical quantities;
– analysis of the source data;
– expert assessment method;
– economic assessment in determining the cost indicators.

In practice, the pavement heats unevenly at depth. The heating temperature on the surface should not exceed 180 °C to prevent the burning of bitumen. In this case, it is necessary to ensure a minimum heating temperature at the level of the base of the regenerated layer, which will allow the mixture to be roasted without breaking crushed stone. The estimated minimum temperature in this case is 75–90 °C.

On the basis of practical observations, analysis of literary sources, as well as expert evaluation, the main factors that influence the heating process of asphalt concrete pavement are established:

1) air temperature;
2) time and intensity of heating;
3) type of pavement;
4) pavement moisture;
5) wind speed.

The most important of these are the first three factors.

In order to establish the dependence of the temperature of the pavement heating at different depths on the heating time, field studies are carried out directly when performing work on the hot regeneration of asphalt concrete using the Reshape method. The work is carried out at an ambient temperature of 25–30 °C and calm weather. The regenerated hot asphalt mix, which is used when conducting studies on the grain composition and bitumen content, corresponded to a hot, fine-grained mixture, dense asphalt concrete, type A, continuous granulometry, grade II, in accordance with DSTU B B.2.7-119:2011. Content of residual bitumen loosened asphalt crumb is 6.0 %. During the research, measurements are carried out at different speeds (1.8 m/min and 2.1 m/min) of the thermal installation for heating the Wirtgen HM 4500 asphalt concrete pavement (country of origin – Germany).

3. Research results and discussion

The research results are given in Table 1.

Table 1

The results of experimental studies

Indicator	Value							
Speed of movement 1.8 m/min								
Warming up time, min	1	2	3	4	5	6	7	8
Surface heating temperature, °C	82	110	127	142	149	167	170	185
Heating temperature at a depth of 3 cm, °C	45	49	51	57	87	107	130	135
Heating temperature at a depth of 5 cm, °C	45	47	49	51	55	68	77	85
Speed of movement 2.1 m/min								
Warming up time, min	1	2	3	4	5	6	7	8
Surface heating temperature, °C	75	100	120	135	142	160	150	–
Heating temperature at a depth of 3 cm, °C	45	48	51	54	80	98	108	–
Heating temperature at a depth of 5 cm, °C	45	47	48	50	54	66	75	–

Based on the obtained measurement data, graphical dependences of the temperature of asphalt concrete on the duration of heating by infrared radiation are constructed, which are shown in Fig. 1.

The obtained measurement results make it possible to establish mathematical models characterizing the functions of temperature change depending on the heating depth. Dependencies are modeled in Excel. In order to assess the suitability of the obtained models, the reliability parameters of the approximation were determined. For each of the models, this indicator is close to 1, so the model is of good quality:

$$y_1 = 63.214 + 23.738x - 1.119x^2,$$

$$RI = 0.9879,$$

$$y_2 = 70.571 - 31.869x + 10.22x^2 - 0.649x^3,$$

$$RI = 0.985,$$

$$y_3 = 46.982 - 2.3512x + 0.9107x^2,$$

$$RI = 0.9853,$$

$y_4 = 44.857 + 32.25x - 2.3929x^2,$

$RI = 0.9831,$

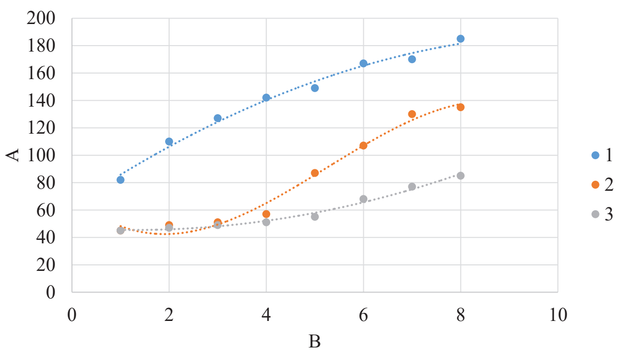
$y_5 = 62 - 21.722x + 7.1905x^2 - 0.4444x^3,$

$RI = 0.9741,$

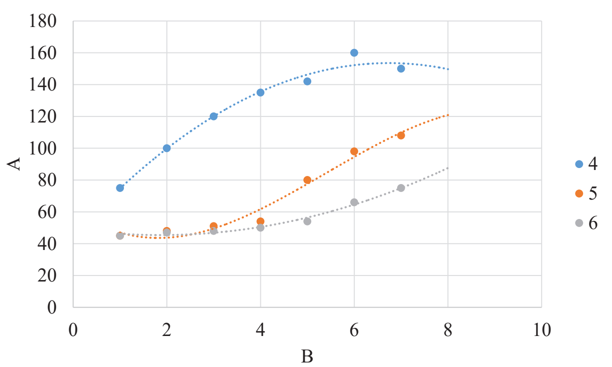
$y_6 = 49.286 - 4.1667x + 1.119x^2,$

$RI = 0.9822.$

Analyzing the graphs in Fig. 1, it is possible to conclude that the temperature of the heating of asphalt concrete significantly depends on the heating duration. The longer the heating process, the higher the heating temperature of the pavement on the surface. However, thermal efficiency can't increase too high, since the structure of bitumen located in asphalt concrete is disturbed by heating and its plastic properties are lost. At the same time, it must be taken into account that the heating curve at the base level of the regenerated layer does not grow so fast. Therefore, a large optimal heating mode is gradual heating.



a



b

Fig. 1. Graph of the temperature of the heating of asphalt concrete on the duration of heating, at the speed of movement of the thermal device: *a* – 1.8 m/min; *b* – 2.1 m/min

In Fig. 1: A – the heating temperature; B – the warm-up time; 1, 4 – dependence of the temperature of heating on the surface; 2, 5 – dependence of the heating temperature at a depth of 3 cm; 3, 6 – dependence of the heating temperature at a depth of 5 cm.

Having analyzed the graphs in Fig. 1 and mathematical models, it can be assumed that a decrease in the pavement heating temperature by at least 10–20 °C will lead to an increase in the performance of the thermal installation. In this case, the increase in productivity can be from 20 % to 25 %, which will reduce the gas consumption and, accordingly, the cost of work.

4. Conclusions

In the course of the work, field studies of changes in the temperature of the pavement heating depending on the speed of the thermal device for heating the asphalt concrete pavement and the heating time are carried out. The obtained graphical dependencies and mathematical models can be used to optimize the process of hot asphalt concrete regeneration using the in-place method, which will reduce gas consumption and the cost of work.

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