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The “Engineer” publishes the most significant results of scientific and applied research carried out in universities of transport profile, as well as other higher educational institutions, research institutes, and centers of the Republic of Uzbekistan and foreign countries.

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Evaluation of the impact of dynamic loads on road pavements and pavement strength under temperature factors

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Abstract: This article presents the results of assessing pavement strength under temperature-dependent conditions using dynamic loading devices, as well as studying the influence of heavy vehicle loads on pavement deflection and service life of road structures.

The study highlights the significant effect of asphalt concrete temperature on test results and emphasizes the necessity of accounting for temperature variations when diagnosing in-service road pavements. This is achieved by converting field-measured results obtained at actual temperatures into a comparable form with design data, ensuring accurate evaluation and analysis.

Keywords: road pavement, surfacing, strength, dynamic loading, deflection, temperature, asphalt concrete, modulus of elasticity

1. Introduction

One of the main indicators of pavement condition is its load-bearing capacity. In this regard, significant attention is being paid to the maintenance, control, and evaluation of road structures during their design, construction, and operation.

The assessment of pavement strength, i.e., the comparison of its load-bearing capacity with the required design values, is regulated by normative and technical documentation. Until recently, this type of diagnostics was mainly reduced to two basic approaches:

– a visual assessment of pavement deformation conditions based on the calculation of a probabilistic strength coefficient, determined from an average score reflecting the most common types of structural defects;

– an instrumental method involving the application of calculated static and dynamic loads using testing devices under operational conditions. This approach allows for the measurement of pavement deflection and subsequent determination of the actual modulus of elasticity, which is then compared with the required design values.

However, visual assessment alone does not allow for a complete and reliable determination of pavement condition or the causes of its deformation. Moreover, maintenance activities involving surface layer replacement, as one of the most common interventions, can significantly distort the results of visual strength evaluation and do not always ensure the required service life of the pavement structure.[1]

Instrumental methods, however, are primarily based on determining the overall load-bearing capacity and do not allow for the assessment of the condition of individual structural pavement layers. In our country, in accordance with GOST 32729 and GOST R 59918, as well as in many leading foreign countries, studies on the strength of both the overall pavement structure and its individual layers are conducted using dynamic loading devices (Dina-4 FWD).

After installing the falling weight deflectometer device, the pavement is comprehensively evaluated based on deflection values measured at various distances from the load center.

In foreign practice, considerable attention is also paid to determining the elastic modulus of individual pavement layers, as well as to studying time- and frequency-based correction methods.

According to the current methodology for designing flexible pavements, calculations based on the elastic deflection criterion are performed when the temperature of the asphalt concrete layers exceeds 10°C. Therefore, in order to compare the actual and design parameters of the pavement's load-bearing capacity, it is necessary to adjust the test results obtained at different temperatures to the specified design reference temperature.

The initial data required for calculating the elastic moduli of layer materials include:

deflection basin parameters, layer thicknesses of the pavement structure, and dynamic loading parameters (actual load, loading plate area, and impulse duration).

In turn, pavement deflections depend on a number of factors, the main ones being:

- air and pavement temperature conditions;
- load magnitude from heavy vehicles;
- structural composition of the pavement;
- strength and quality characteristics of the materials used in pavement construction;
- condition of the subgrade soils.

Practical experience in testing shows that additional factors may also influence the results of strength assessment, and determining their combined contribution is rather complex. These factors include:

- presence of defects (primarily cracks) in the layers containing binding materials;
- actual service life at the time of testing (including the number of load applications under standard axle loads);
- accuracy and correctness of the testing methodology;
- technical condition of the measuring equipment.

As established in the conducted studies, one of the most significant influencing factors is the temperature factor.

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Previously, this factor was largely not considered in normative-technical documents and research works. Measurement of the temperature of asphalt concrete layers has rarely been performed due to its relative complexity and the difficulty of recording internal pavement temperature compared to air or surface temperature measurements.

The objectives of the experimental studies on which this article is based were as follows:

– to identify the most important temperature parameters for accounting for the service life of pavement structures;

– to evaluate the influence of temperature factors on pavement deflection basins and the overall elastic modulus;

– to determine the relationships between temperature conditions and deflection behavior in different types of road structures. [4]

2. Research methodology

The study of the effect of temperature on pavement deflections was carried out using the Dina-4 FWD dynamic loading device, which complies with the requirements of **GOST 32729**.

The operating principle of this type of device is based on dropping a load of a certain mass from various heights onto a system of dampers, which transmits an impulse to a loading plate that simulates a vehicle wheel. This process generates a short-term load with specified parameters on the pavement surface. Based on the test results, deflections are recorded at the center of loading and at various distances from it.

The pavement strength measurement system “Dina-4 FWD” is a dynamic device designed to assess the structural capacity of non-rigid (flexible) pavements.

Its technical characteristics fully comply with the requirements of **GOST 32729-2014** and ensure the measurement of elastic deflections of the pavement structure at seven points under impact loading.[8]

The impact energy is transmitted through a four-segment loading plate. Depending on the stiffness of the pavement structure, the vertical load can be adjusted in the range from 3.0 to 7.0 kN.

The device operates in a fully automated mode. Temperature corrections of the pavement are applied, and both dynamic and static elastic moduli are calculated.[2]

Fig. 1. Dina-4 FWD

Air temperature and pavement surface temperature are measured using thermometers installed on the dynamic loading device. To measure the temperature of asphalt concrete layers at different depths, mercury and electronic thermometers are used, with a measurement range from −30 to 100 °C and an accuracy of 0.1 °C.

Measurements are carried out in special holes drilled in the asphalt concrete layer, which are filled with a mixture of water and glycerin.

The measurement of temperature at different depths of the asphalt concrete layers is shown in Figure 2.

As the object of the study, a section of the public road of technical category Ib located at km 1400–1428 in the Sherobod area of the M-39 “Almaty–Bishkek–Tashkent–Termez” highway was selected.

Fig. 2. Scheme for measuring the temperature of asphalt concrete:

1 — asphalt concrete layer; 2 — pavement surface; 3 — thermometer; 4 — mixture of glycerin and water; 5 — base layer beneath the asphalt concrete.

To assess the effect of temperature, tests were conducted at the same points along km 1400–1428 of the M-39 “Almaty–Bishkek–Tashkent–Termez” highway under various combinations of temperature conditions.[3]

During the testing process, the following parameters were studied:

– ambient air temperature;

– asphalt concrete pavement surface temperature;

– temperature of the asphalt concrete at a depth of 5.5 cm.

The tests were carried out within the following temperature ranges:

– air temperature: from 41 °C to 46 °C;

– pavement surface temperature: from 64 °C to 68.5 °C;

– asphalt concrete temperature at a depth of 5.5 cm: from 61.5 °C to 65.3 °C.

The studied section (km 1400–1428) of the M-39 “Almaty–Bishkek–Tashkent–Termez” highway, located in the Sherobod area, has a capital-type pavement structure consisting of various structural layers and subgrade soils.

The thickness of the asphalt concrete layer reaches up to 24 cm, while the thickness of the pavement base layers ranges from 45 to 58 cm.[7]

Temperature has a significant impact on the structure of road pavements, leading to a reduction in the strength of each layer. It is well known that the elastic modulus of asphalt concrete decreases as temperature increases.

Fig. 3. Measurement of Asphalt Concrete Pavement Strength Using the Dina-4 FWD Equipment

For each measurement, the overall modulus of elasticity was calculated based on the deflection values at the center where the load was applied, using the following formula:

$$E = \frac{p \cdot D(1-\mu^2)}{1}$$

Here: p — the contact pressure under the plate, MPa;

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D — the plate diameter, mm; μ — Poisson's ratio, assumed to be 0.3; l — the deflection at the center of the applied load, mm.

3. Results

Based on the obtained experimental data, the following relationships were established for the 1402–1422 km section of the M-39 "Almaty–Bishkek–Tashkent–Termiz" highway located in the Sherobod area:

– the dependence of pavement structural strength, measured using the Dina-4 FWD device, on the pavement surface temperature and the overall modulus of elasticity;

– the dependence of pavement deflections and the overall modulus of elasticity on air temperature.

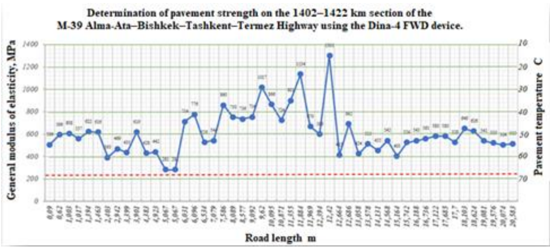

Fig. 4. Determination of pavement strength on the 1402–1422 km section of the M-39 highway using the Dina-4 FWD device

As a result of analyzing the obtained relationships, the temperature parameters that have the greatest influence on the overall modulus of elasticity and the deflection basin were identified.

Using the relationships presented in the given graph, the obtained pavement strength exceeded 230 MPa. The results showed that as the ambient air temperature increased, the pavement temperature reached the calculated range of 50–60 °C.

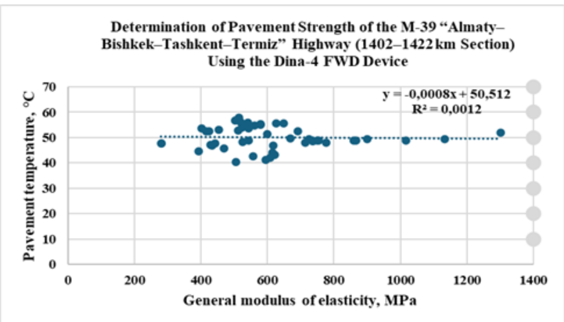

Fig. 5. Determination of pavement strength based on the relationship between general modulus of elasticity and pavement temperature on the 1402–1422 km section of the M-39 highway

Considering the proposed limitation of the maximum temperature of asphalt concrete pavements in this graph to 70 °C and above, the observed decrease in the required pavement elastic modulus of 230 MPa may, in turn, be associated with the viscoelastic–plastic behavior of asphalt concrete and the development of residual deformations in the pavement at elevated temperatures.

4. Conclusion

Transforming pavement strength into a form comparable with design parameters makes it possible to obtain objective information on the condition of structural layers of operating roads and improves the accuracy of determining maintenance and rehabilitation measures. At the same time, considering the diversity of pavement structures and materials used in our country, it is advisable to continue these studies further.

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