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A.B. Kayratdinova
Karakalpak State University named after Berdakh
trainee teacher

B.B. Tajetdinova
Karakalpak State University named after Berdakh
trainee teacher

T.B. Mambetaliev
Karakalpak State University named after Berdakh
graduate student

ELIMINATION OF TEMPERATURE-INDUCED DEFORMATIONS OF CEMENT CONCRETE COATINGS AND CURING OF BASALT FIBER CONCRETE

Abstract: *This article analyzes the long-term performance of cement-concrete pavements, their structural properties related to the seam system and deformations caused by temperature. Technological approaches to the management of the connection between the cementitious coating and its base, the function of the compression and expansion joints and the effect of their correct placement on road strength are described with scientific justification Based on the experience of the United States and Europe, the distances between the seams, their types, resonance events and the causes of fissures in the plates are analyzed. The results of the study show that compression joints are a key structural element in the management of tensile and compressive stresses arising from temperature changes in a cement concrete coating. The article focuses on improving the strength of road pavements, preventing the formation of cracks, and increasing the operating cycles of cement concrete pavements based on the use of basalt fiber concretes.*

Key words: *concrete paving, compression seal, expansion seal, thermal deformation, road paving, paving slabs, asphalt-concrete foundation, resonance, road construction, concrete slab, basalt fiber concrete, and the like.*
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Introduction

Today, the role played by highways and airports in bringing the peoples of the world closer together and establishing and developing political, economic, social and cultural ties between them is unprecedented. Improving the quality of road pavements, extending their service life and ensuring their resistance to extreme climatic conditions is one of the main goals of modern scientific research In particular, the problem of deformations, wheel tracks, cracks and premature wear of the coating, which are frequent on roads built in high-temperature regions, remains relevant.[1] This leads to frequent road maintenance, increased overhead, and disruption to traffic flow. That's why it's important to use materials that are strong and durable, and that retain their properties when exposed to heat. Over the past 10-15 years, the construction of concrete pavements in Uzbekistan has improved significantly Nowadays, modern cement-concrete technologies have been introduced on roads such as Tashkent, Navoi, Kungirat-Beyneu, and there is a growing interest in the construction of such coatings in the country. In this regard, today it is possible to build coatings with a long service life, strong, high load-bearing capacity through the use of cement concrete coatings.[2] The construction of motorways is one of the most important directions of development of transport infrastructure today**.**

The question of whether to provide a bond between a cemented concrete surface and its cemented base, or, conversely, to seek a smooth contact between them, has long been debated. It was concluded that it is now advisable to separate them from each other For this purpose , a thin layer of geotextile canvas or a hot asphalt-concrete mixture is laid on a base of thin concrete or fine stone reinforced with cement. Numerous data have been collected on the behaviour of cement concrete coatings on different substrates under the same operating conditions. So, in 1967, I-65 was built with eight experimental roadblocks with a 23 cm thick cement-concrete pavement and a cantilever beam every 9 meters. During the 33-year service period , the total number of accounting fire loads passed along one lane of the running part was about 25 million The road was thoroughly inspected in 2001.[3] The worst-performing plots were 15 to 23 cm thick cemented soil and 9 to 14 cm thick cemented sandstone. Asphalt-concrete foundation thickness of 10 cm was the best The interstitial space was occupied by a base of crushed fine stone, over which a thin layer of asphalt-concrete (less than 2.5 cm) was laid, simply to protect the base from moisture during construction in the event of rain.

After 33 years of operation on asphalt-concrete base , 94% of the plates are not seriously damaged The average height of the scaffolding was 5.9 mm in the case of non-stuccous scaffolding on a slate base and 4.2 mm in the case of cemented scaffolding, and 4.8 mm in the case of slate scaffolding on a slate base and 2.5 mm in the case of cemented scaffolding. On an asphalt-concrete base, even without rails, the average step height was only 1.5 mm after 33 years of service Under the top foundation layer of a solid pavement, one or more additional foundation layers are often laid in the US and Europe. The additional foundation should reduce the penetration of fine particles from the roadbed into the foundation, improve drainage, reduce the buildup of frost, serve as a passage for construction machines and vehicles during the construction of the foundation and coverage In determining the additional base thickness, data on the depth of groundwater deposition, freezing depth and the freezing tendency of the road surface are used. Deformed seams have a major impact on the performance of a rigid roadbed It's not hard to explain the necessity of hand-clamping. So let's imagine that we've tried to make a continuous, seamless strip of cemented concrete. Concrete is laid and solidified in summer at an average daily temperature of 15°C. In winter, the temperature drops to minus 20°C. What happens to the folding? So let's imagine that we have three sections A, V, and C of equal length. Let's look at plot V (Figure 1) If A and C were not adjacent, then B would have shrunk in length as a result of cooling.

$$\Delta l = \alpha \cdot (T2-T1)\, l \qquad (1)$$

where T1 is the initial temperature, T2 is the final temperature (at a given point in time); α is the coefficient of linear temperature deformation, α ≈ 1×10-5 l/°C for cemented concrete So the relative deformation of the coating is going to be like this.

$$\varepsilon_T = \Delta l/l = \alpha \cdot (T_2-T_1) \qquad (2)$$

But there are adjacent segments A and C, which, when cooled, tend to decrease their lengths by balancing the slope of segment V. As assumed in Sopromat, we discard the neighboring plots and replace their influence on plot V with reactions in the form of opposite voltages generated at the boundaries of the plot in sections I-I and II-II (Fig. 1).

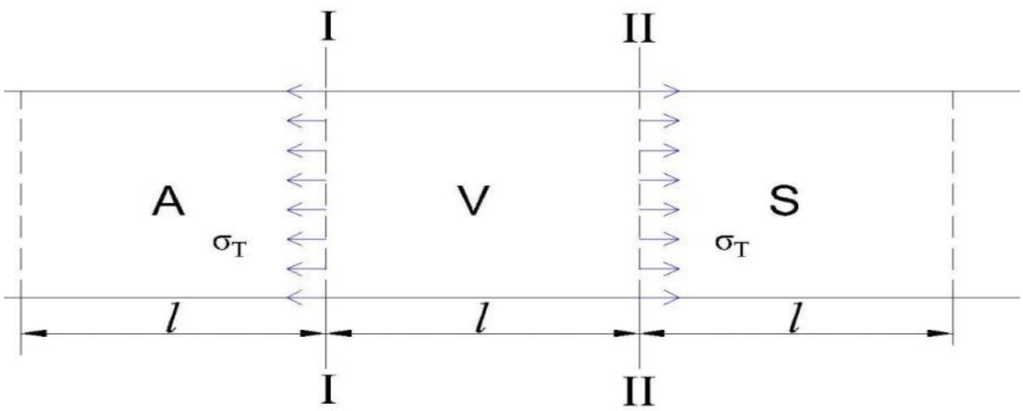

Figure 1. The longitudinal compression joints are installed so that the concrete surface cools without forming zigzag cracks.

The relative deformation of the coating $\varepsilon_T = \alpha\cdot(T_2\text{-}T_1)$ is due to the occurrence of "temperature" stresses equal to $\sigma_T = -E\varepsilon_T$. According to Hooke's law, it is impossible to realize. We conclude that longitudinal stresses are formed in a seamless concrete coating when cooled to -20°C in winter.

$$\sigma_T = -E\alpha\cdot(T_2\text{-}T_1) \qquad (3)$$

The typical modulus of elasticity for cement concrete is E=30x103 MPa, and from formula (3) it follows that the temperature stresses resulting from cooling are as follows:

$$\sigma_T - 30\times10^3\times1\times10^{-5}\times(-20\text{-}15)=10{,}5\ MPa,$$

This is approximately 2.5 times the axial tensile strength of ordinary road concrete. Therefore, when a seamless concrete pavement cools, transverse cracks inevitably appear in it. The seamless pavement would have irregularly spaced cracks through which rainwater would have seeped into the base. Such a crooked crack, which appeared in a "weak spot," would be very difficult to clean and seal with sealant.

To prevent the formation of irregular cracks in the coating, thermal joints are used, which are actually formed cracks. Since the coating tends to shrink when cooling, these joints are called shrinkage joints. To do this, in freshly laid or hardened concrete, a groove is artificially made 1/4-1/3 of the thickness of the slab in order to deliberately loosen the section at the site of the future crack. Thus, the coating is divided into separate plates. The distance between the joints is considered to be approximately 20 times the thickness of the cement concrete coating. Typically, the distance between shrinkage joints in the USA is 3.5-5 m. Shrinkage joints are necessary not only during cooling, but also to allow for the possibility of reducing the length during the shrinkage of the concrete as it hardens.

The primary (but not the primary) purpose of joint sealing is to prevent water from seeping through the crack into the subfloor.

The primary purpose of joint sealing (as with joint sealing) is to prevent the coating from becoming clogged with small solid particles during use. If the joints become clogged, they will not close when the temperature rises, which will cause the slabs to bulge and separate from the base, forming a triangular "springboard".

In fact, buckling is the loss of longitudinal stability of the coating when heated. The reason for buckling is easy to explain. Let us return to the example and assume that the cement concrete coating with expansion joints was laid last summer at an average temperature of 15°C. Therefore, this summer at a temperature of 15°C the expansion joints should "close". On a very hot summer day, at about 5-6 o'clock in the afternoon, the average temperature of the coating throughout its thickness rose to 40°C. The coating had expansion joints after 6 m and contraction joints after 30 m. When its temperature rose to 40°C, the increase in the length of the coating between the expansion joints should be as follows according to formula (1):

$$\Delta l = \alpha\cdot(T_2\text{-}T_1)l = 1\times10^{-5}\times(40\text{-}15)3000 = 0{,}75\ см,$$

where 3000 cm is the distance between adjacent expansion joints.

Thus, the expansion joint should have provided the possibility of increasing the length by only 0.75 cm - from 3000 cm to 3000.75 cm. Then, according to the Pythagorean theorem (Fig. 2), the height of the "tent" in this example is 67 cm, which approximately corresponds to the photos.

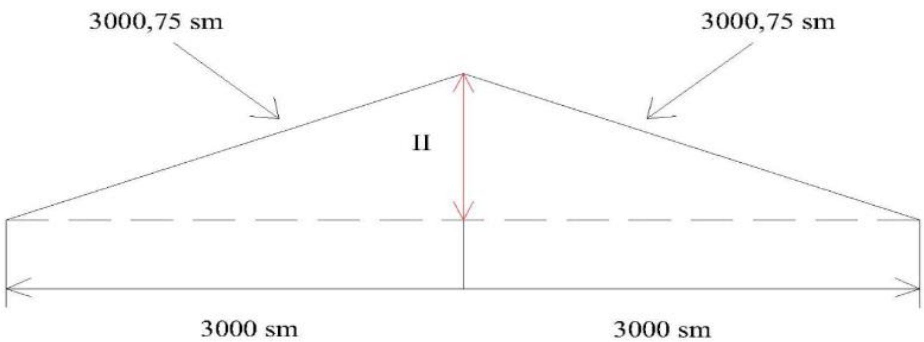

Figure 2. Estimation of the possible bulging of the coating when the expansion joint is not working: H = √3000.752 - 30002 = 67 cm

Studies conducted after 1970 showed that it is not advisable to install expansion joints everywhere. It turned out that during uplift, each plate expands from the center to the edges, regardless of which of the joints - expansion or compression - is in contact with the plate. Unilateral expansion of all points of the plate from the compression joint to the expansion joint has not been observed [5]. At the same time, due to the stretching of the plates, the width of the compression and expansion joints is smaller in the compression joint and larger in the expansion joint, since the expansion joint is made along the entire thickness of the plate and movement occurs more freely in it. Gradually, it was concluded that it is not necessary to install expansion joints through several compression joints. It is enough to use one necessary type of joint - a compression joint of sufficient width to eliminate the expansion deformation of each plate separately. Such a joint can serve as both a compression and an expansion joint. As it is known [6], after several years, with repeated drops and rises in temperature, the expansion joints gradually close, and therefore the compression joints open excessively during frost heaving. In this case, the bite between adjacent plates in the compression joint disappears (at the place where the initial crack in the artificially loosened section of the plate opened), and thus the load transfer from the plate to the adjacent plate worsens, and the tightness of the compression joints is also violated. The installation of expansion joints was gradually abandoned [5].

Currently, expansion joints are only constructed at bridge crossings, as well as at the junction of concrete pavement with observation wells, drainage pipe heads, and the foundations of structures.

We see that the periodicity of forced vibrations when the distances between the transverse joints are equal can indeed lead to resonance at the speeds typical for a truck or bus. Since the speeds of movement can be different, the only solution is to de-rhythmize the system, that is, to abandon the same distance between the joints. Resonance is highly undesirable both from the point of view of ease of movement and load retention, and from the point of view of the corrosive effect of the load on the coating.

In California, resonance problems were observed in the traffic of large trucks. To avoid resonance, in California, it was initially decided to set variable distances between the joints: 4; 5.8; 5.5 and 3.7 m. However, the 5.8 and 5.5 m plates turned out to be too long: their bending under the influence of temperature led to the appearance of transverse cracks in the middle of the plate (Figure 3). Eventually, in the 1980s, a sequence of distances between the joints of 3.7, 4.6, 4.0 and 4.3 m was settled on, which led to success [7]. The recommendations of the American Association of State Highway and Transportation Officials also recommended not to install plates of the same width and to avoid plates of 2.3 m in length [8]. This advice was especially important when the joints were made without a lance and the height of the steps increased rapidly. Now, the problem of resonance in the harmonic vibrations of a moving car is not so relevant.

a)

b)

Figure 3. Cracks formed in the middle of the slab under the influence of temperature: "new" cracks above; a - in the cement-concrete coating; b - cracks after pouring the sealant.

In order to eliminate cracks in the middle of the slab due to temperature, basalt fiber concrete has become widely used in road construction. Compared to conventional concrete, basalt fiber concrete is made by pressing under high pressure, which results in significantly higher density, water resistance, and mechanical strength [9]. This type of concrete also has a much longer service life and requires less maintenance during operation. However, in extreme heat conditions, even conventionally pressed concrete begins to lose its properties, as the cement stone decomposes above 400 °C and the overall strength of the concrete decreases dramatically [10].

One of the promising solutions to this problem is to strengthen concrete by adding basalt fibers. Basalt fibers are obtained from natural basalt rock and are characterized by their high heat resistance, mechanical strength, and chemical stability. They retain their properties at temperatures up to 700-800 °C, and in some cases can withstand up to 1000 °C [11]. Basalt fibers act as three-dimensional reinforcement in the concrete, holding microcracks formed under the influence of loads and preventing their development. Due to this, the cracking resistance of concrete increases, thermal deformations are controlled, and the overall strength loss is slowed down.

Basalt fiber concrete has a high density, low water absorption, and much lower thermal conductivity than ordinary concrete. These properties are especially important for road surfaces, since in the summer months, asphalt concrete surfaces soften as a result of heating to 60-70 ° C, wheel marks and cracks appear [12]. If basalt fiber concrete is used as a base layer, thermal and mechanical loads from above are effectively distributed, the degree of deformation is reduced, and the coating has a long service life.

Laboratory studies show that ordinary concrete loses most of its strength at temperatures up to 600 °C, while basalt fiber concrete retains 30-35% of its strength under the same conditions. In addition, due to the heat resistance of basalt fiber concrete, crack propagation is also significantly reduced. For example, experiments conducted in 44 regions of Uzbekistan with a hot climate showed that basalt fiber concrete is 1.5 times more resistant to high temperatures than ordinary concrete [13].

The experience of foreign countries also confirms this. As a result of tests conducted in the US states of Arizona and Nevada, it was found that the service life of basalt fiber concrete roads increased by 20% compared to ordinary concrete [14]. In Japan, basalt fiber concrete was used in railway sleepers and proved to maintain its strength despite high temperatures and seismic activity.

The main advantages of basalt fiber concrete are: high thermal stability, prevention of microcracks, resistance to deformation, long service life, economic and environmental efficiency. Since basalt fiber is a natural material, it is environmentally safe, and it is also economically convenient to obtain it from local mines. In addition, the reduction in the need for road reconstruction reduces operating costs by 20-25% [15].

In general, the scientific foundations and practical results considered in the article confirm the need to design cement concrete pavement structures based on a scientific approach. A correctly selected base, an optimal joint system, and structural solutions appropriate to operational conditions significantly increase the strength and service life of the road.

Based on the above, the following recommendations have been developed:

Based on the above, there are a number of issues that have not yet been resolved in this regard. Of course, it is convenient to lay a cement-concrete coating on a dense asphalt-concrete base, but the cost of such a base is quite expensive. In addition, it is advisable to ensure the drainage of water from under the slab. In addition, the reliability, long service life and high load-bearing capacity of cement-concrete pavements make them one of the most optimal solutions in the modern transport system. Studies show that choosing the right constructive solutions between the coating and its base, in particular, separating them from each other, using a thin layer of geotextile or asphalt concrete, significantly improves the operational condition of the coating. The results of long-term monitoring of coatings built on various bases confirm that the asphalt-concrete base gives the most stable results.

Internal stresses in concrete slabs caused by temperature do not allow them to operate in a seamless state. Therefore, the correct placement of expansion joints and strict adherence to the specified distances are one of the main factors in the strength of the pavement. Practical experience shows that it is not necessary to install expansion joints everywhere - they are used only in special structural transition zones. And the expansion joints effectively absorb temperature-dependent deformations of the slabs and prevent the appearance of irregular cracks. In addition, basalt fiber concrete is an effective material for use in the base layer of highways in high-temperature conditions. It can withstand not only mechanical loads, but also thermal effects, the deformation of the pavement is reduced, and the service life of the road is extended. Therefore, it is advisable to expand applied research on the use of this material in regions with a warm climate, establish local basalt fiber production, and apply innovative technologies in road construction.

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