

PREFABRICATED AND DISASSEMBLABLE ROAD SURFACE MADE OF PRECAST CONCRETE SLABS**Zinevich Sergey Ivanovich¹⁾,****Kayumov Azizjon Karimjon ugli¹⁾**¹⁾ Belarusian National Technical University (Minsk, Republic of Belarus)

Annotation. *This paper studies the possibility of using precast concrete slabs in the construction, reconstruction and major repairs of highways. Based on the analysis of existing structures, this paper proposes a precast road surface consisting of slabs with an isosceles trapezoid cross-section (i.e. slabs with inclined edges). The technology for installing these slabs is considered, which allows accelerating the pace of construction. Due to the inclination of the side edges, the technological operation of butt joints of slabs is excluded, since welding of butt clamps is labor-intensive work, which significantly slows down the pace of construction.*

The angle of the edge is of no small importance. When setting the angle of the side edge of the slab, it is necessary to take into account such factors as: the "heaving" effect, since with a rigid connection of the slabs, as a result of thermal expansion, the integrity and evenness of the coating will be destroyed; the strength of the inclined edge, due to loading and unloading, as well as during operation when vehicles run over, there is a risk of breaking this edge; also the "jamming" effect, which allows you to exclude a butt joint, thereby accelerating the pace of construction.

An economic effect was calculated, which is achieved by eliminating, during the construction of the coating, the operation of monolithing the slabs between themselves..

Keywords: *prefabricated covering, edge angle, "rising" effect, "jamming" effect, strength, trapezoidal section, butt joint*

Аннотация. В настоящей работе изучался вопрос возможности использования при строительстве, реконструкции и капитальном ремонте автомобильных дорог сборных бетонных плит. На основании анализа существующих конструкций, в настоящей работе было предложено сборно-разборное дорожное покрытие, состоящее из плит, имеющих в сечении форму равнобедренной трапеции (т.е. плиты с наклонными гранями). Рассмотрена технология устройства данных плит, позволяющая ускорить темпы строительства. Из-за наклона боковых граней исключается технологическая операция стыковых соединений плит, т.к. сварка стыковых скоб — это трудоемкая работа, что значительно замедляет темпы строительства.

Немаловажное значение имеет угол наклона грани. При установлении угла боковой грани плиты необходимо учесть такие факторы как: эффект «вздыбливания», т.к. при жестком сопряжении плит, в результате температурного расширения, будет разрушена целостность и ровность покрытия; прочность наклонной грани, за счет погрузки и разгрузки, а также в период эксплуатации при наезде транспорта есть вероятность облома данной грани; также эффект «заклинивания», что позволяет исключить стыковое соединение, тем самым ускоряя темпы строительства.

Был сделан расчет экономического эффекта, которая достигается за счет исключения, в процессе строительства покрытия, операции монолитирования плит между собой.

Ключевые слова: сборное покрытие, угол наклона грани, эффект «вздыбливания», эффект «заклинивания», прочность, трапециевидальное сечение, стыковое соединение.

Introduction

Cement concrete road surfaces are more durable and long-lasting compared to asphalt concrete [1,2]. One type of concrete surface is precast surface, made from

individual concrete slabs [3,4]. Such surfaces have their pros and cons. The pros include the fact that these slabs are manufactured in factories with strict adherence to technological rules and concrete care regimes, which ensures their high quality. The advantage is undoubtedly the possibility of opening traffic immediately after the pavement is installed, i.e. there is no need to wait for the concrete to gain strength, as is the case with the construction of monolithic concrete pavements. This makes it possible to use precast concrete pavements during reconstruction or major repairs of an existing road, when it is not possible to close traffic for a long time [5]. An important circumstance in favor of precast concrete pavement compared to monolithic concrete pavement is that it can be installed throughout the year, and thus there is the possibility of year-round construction. In addition, the cost of precast concrete pavements is approximately 1.5 times lower than that of monolithic reinforced ones.

At the same time, the device of precast concrete pavements has not found wide application today. One of the reasons for this is the labor intensity of connecting the slabs, i.e. arranging butt joints of the slabs, which is done manually.

Analysis of existing types of plates and their connections

Road slabs are an effective solution for the construction of temporary and permanent road surfaces. They are easy to install and dismantle, which allows them to be reused. Due to their high strength and resistance to frost, these slabs remain reliable and safe even in adverse weather conditions. They are especially popular in the construction of temporary bypass roads, which makes the slabs indispensable in construction and ensuring comfortable traffic.

A design of reinforced concrete road slabs for the construction of precast concrete pavements, rectangular in shape [6], is known, used in the construction of permanent and temporary roads and marked 2PP 30-18-30 (1 - permanent roads, 2 - temporary roads) with geometric parameters of 3000x1750x170 mm (Figure 1).

The disadvantages of this slab are the labor intensity of the installation of assembly joints during the assembly of the covering, since each joint is connected manually.



Figure 1 – General view of the road slab 2PP 30-18-30

Also known is a device for a prefabricated road surface [7], where the slab has the shape of a triangular prism, the cross-section of which is an equilateral triangle.

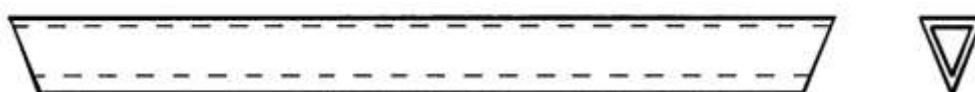


Figure 2 – General view of the plate

Instead of traditional rectangular slabs, a unique two-layer design is used here. The top layer forms a rectangular canvas, providing a flat and smooth road surface. The bottom layer, which is the basis of the entire structure, is a series of long, isosceles, bilaterally truncated hollow prisms united by rectangular sides (Figures 3 and 4).

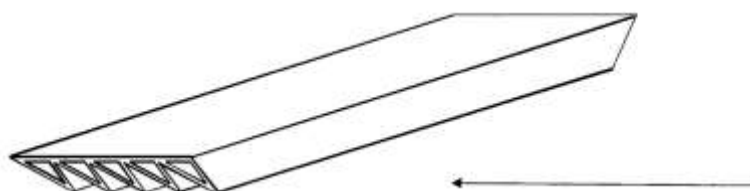


Figure 3 – Fragment of the structure of the precast road surface device

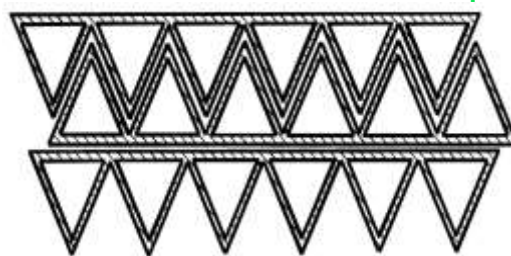


Figure 4 – Precast road surface consisting of triangular slabs

The disadvantages of this technical solution are the high labor intensity of the installation of the prefabricated covering due to the small size of the slabs, which leads to significant time costs.

Road slab shape and pavement technology

Based on the analysis of existing structures, this paper proposes a prefabricated road surface consisting of slabs with a cross-section in the shape of an isosceles trapezoid (i.e. slabs with inclined edges) (Figure 5). A patent for an invention was obtained for these slabs [8].

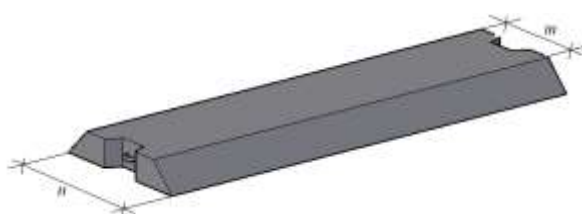


Figure 5 – General view of a road slab with inclined edges

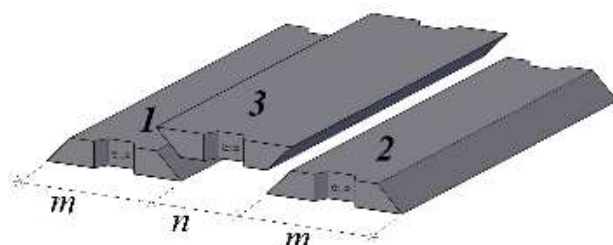


Figure 6 – Technology of laying slabs

The technology for installing coverings from the proposed slabs is as follows.

The slabs are transported to the road construction site and laid across the traffic flow. First, 2 slabs are laid with the larger base down at a distance from each other equal to the width of the smaller base of the slab, and then a third slab is laid between them with the smaller base down, as shown in Figure 6. And so on until the end of the road.

The general appearance of the coating is shown in Figure 7.

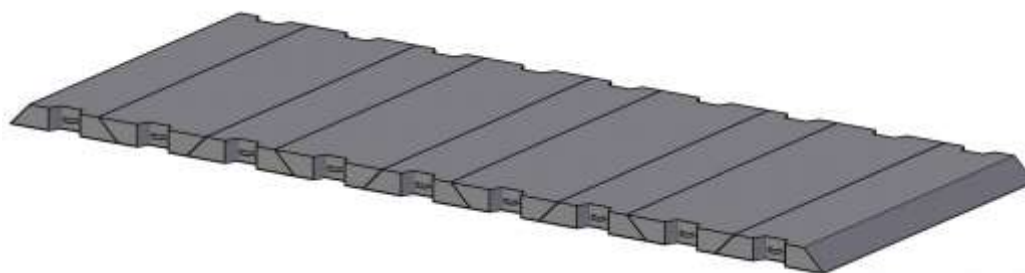


Figure 7 – General view of the road surface

With this technology, there is no need to monolith the slabs at the joints, since their monolithing occurs due to the wedging effect, which significantly reduces the time for the construction of the prefabricated covering.

Determining the angle of the inclined edge of the road slab

When using this slab in the coating, the angle of the side face is of great importance. When determining its optimal value, it is necessary to:

- 1) ensure a wedging effect;
- 2) eliminate slab heaving during thermal expansion;
- 3) eliminate destruction of the inclined face (during deformation of the slab connection unit).

For the wedging effect, a small change in the angle of the slab edge other than 90° is sufficient (for example, 85° will be sufficient for the wedging effect). At the same time, with a rigid connection of the slabs, as a result of their thermal expansion, there is a possibility of heaving in the slab joint and loss of evenness of the entire coating.

The proposed design assumes that the slabs shift relative to each other along the inclined edge. The first problem to be solved is to determine a sufficient angle at which the effect of heaving is eliminated, i.e. at which sliding of the slabs along the inclined edges is ensured.

This problem was solved using trigonometric formulas (Figure 8).

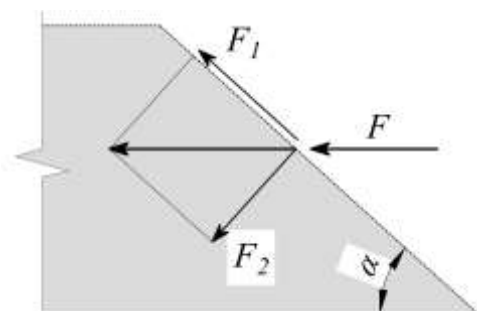


Figure 8 – Force decomposition diagram

In our case, the action of the adjacent plate on the inclined face of this plate is represented as a horizontal force F , conditionally equal to $10t$. Given the angle α , the values of the forces F_1 and F_2 were determined using trigonometric formulas. In order to ensure sliding along

the inclined face, the condition $F_1 > F_2$ must be met, while the friction force F_{tr} acts on F_1 , which is determined by the formula:

$$F_{tr} = \mu \cdot F_2$$

μ – coefficient of friction (for concrete $\mu=0.6$)

$$F_1 = 10 \cdot \cos \alpha - F_{tr}$$

$$F_2 = 10 \cdot \sin \alpha$$

The calculation results are presented in Table 1.

Table 1. Result of force calculation

α									
F_1	2.83	3.80	4.56	4.75	4.94	5.12	5.30	5.48	5.66
F_2	7.07	6.43	5.88	5.74	5.59	5.45	5.30	5.15	5.00

Considering that the coefficient of friction of concrete on concrete is $\mu=0.6$, it can be assumed that at an angle of 31° or less, one slab will slide relative to another along the inclined edge.

At the same time, at these insignificant angles, there is a possibility of destruction of the inclined edge under the dynamic impact of the load, as well as

during transportation and installation of the slabs. The strength of the inclined face, however, depends on the class of concrete, the load applied to it, as well as the height and width of the slab.

To determine the angle of inclination at which the inclined face will not collapse under the effect of a load, a computer program was written, by means of which the calculation of normal σ and shear stresses τ was performed, at different angles of inclination. The obtained results must correspond to the conditions $\sigma, \tau < \bar{R}$, where $\bar{R}$ is the tensile strength of concrete in bending (as required by GOST 26633 [9]).

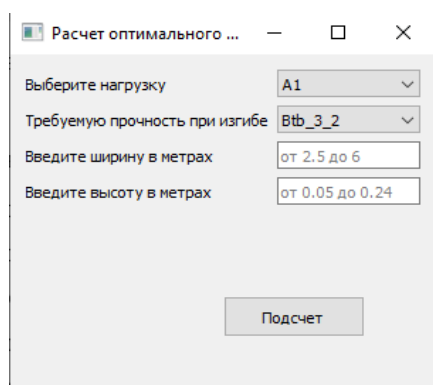


Figure 9 – Interface of the computer program
“Optimal Angle”

If the conditions are not met, the calculation is repeated for the next angle, and so on until the limit is reached.

To simplify the calculation of the inclined edge of the slab from the point of view of ensuring strength, a computer program was created (Figure 9), in which the input data were: load, slab width and angle of inclination.

Considering that road slabs must be made of concrete with a tensile strength class in bending of at least Btb 4.0, the smallest angle at which the edge will not collapse is taken to be 75°.

To sum up, we can conclude that to ensure the “jamming” effect, the angle should be no more than 85°, the elimination of the “rising” effect during temperature deformations is possible with an inclination of the edge angle at the joint of the plates of at least 30°, and to ensure sufficient strength, the angle should be at least 75°.

To resolve the abovementioned contradictions regarding the angle size, the following is proposed in this paper:

1) to reduce the coefficient of friction of the surface of inclined edges by treating them with a polymer material (for example, bitumen mastic). Reducing the coefficient of friction will allow to increase the angle somewhat, thereby reducing the probability of breaking the inclined edge. In addition, such treatment will prevent moisture from getting into the base of the road surface;

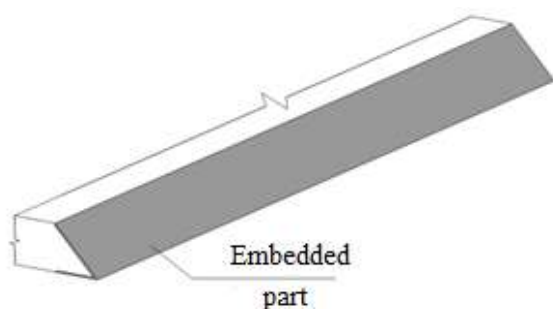


Figure 10 – Embedded part

2) when manufacturing the plate, provide for the placement of a metal embedded part in the area of the inclined edge (Figures 10). This will reduce the friction coefficient (steel on steel $\mu=0.25$), and will also generally strengthen the inclined edge;

After installing the embedded part, when calculating the optimal angle that allows for temperature deformations of the slabs without "heaving", it is necessary to take into account the friction coefficient of the material. The calculation results are presented in Table 2.

Table 2. Result of force calculation using embedded part

α	45°	44°	43°	42°	41°	40°	39°	38°	37°
F1	5.30	5.46	5.61	5.76	5.91	6.05	6.20	6.34	6.48
F2	7.07	6.95	6.82	6.69	6.56	6.43	6.29	6.16	6.02

Economic efficiency of decisions taken

Let us calculate the possible economic efficiency of a covering constructed from slabs with an inclined edge, i.e. slabs whose connection is ensured by wedging them. We will present the economic efficiency by eliminating the device of butt joints.

The cost of material consumption for the device of one butt joint of a slab is presented in Table 3.

Table 3 – Cost of materials for the device of 1 butt joint

Name of materials and structures	Unit of measurement	Quantity	Cost, rubles	
			Units of measurement	on 1 joint
Bitumen-polymer mastic	t	0,005	2640	13.2
Electrodes E42 with a diameter of 2 mm	t	0,002	10780	21.56
Sand-cement mortar	m3	0,004	106.88	0.43
Water	t	0,001	2.34	0,002
Total				35.19

CONCLUSIONS

The shape of the slab is also of great importance for the stable operation of the coating, and also affects the speed of its installation. The adopted design, due to the rapid installation of prefabricated road surfaces, as well as the installation of temporary roads, will lead to an acceleration of the pace of road construction as a whole.

The technology of installing a covering from these slabs is very easy and does not require additional costs. At the same time, there is no need to arrange monolithic joints or other types of slab connections, since they will be connected (wedge) from their own weight and the weight of passing vehicles, which will simplify assembly and speed up the construction process.

Taking into account the calculations performed in this work, it is recommended:

- to ensure thermal expansion (to eliminate the “heaving” effect), install slabs with a side edge angle of 38°;
- to ensure the strength of the inclined edges, additionally install a steel embedded part.

The possible economic efficiency of the adopted solutions for coverings from slabs with inclined edges due to the exclusion of monolithing of joints amounted to 35 rubles. For the device of 1 km of road, 571 joints will be required, the expected economic effect will amount to 20 thousand rubles.

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