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DETERMINING THE EFFECT OF REINFORCING ASPHALT-CONCRETE COATING WITH SYNTHETIC NETS ON ITS PERFORMANCE INDICATORS

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The object of this study is an asphalt concrete cover, the upper layer of which is reinforced with the synthetic material GlasGrid. The subject of research is the performance indicators of asphalt concrete coating.

Experimental studies on the effect of reinforced asphalt concrete with synthetic nets on the evolution of rutting and bond strength between layers have been conducted.

It has been established that reinforcing the asphalt concrete coating with synthetic nets reduces rutting. At 10,000 load cycles and a temperature of 50 °C, the average value of the rut depth in slab samples without a reinforcing joint was 3.8 mm, and at a temperature of 60 °C – 3.7 mm. In the case of reinforcing the upper layer with a GlasGrid®GG100 net, the depth of the rut at an operating temperature of 50 °C was 3.3, and at an operating temperature of 60 °C – 2.6 mm. With a total number of 20,000 load cycles, the average value of the rut depth without reinforcement of the slab sample is 7.5 mm, and with reinforcement – 5.9 mm.

It was established that the rutting resistance of slab samples with reinforcing synthetic nets, in comparison with slab samples without reinforcing material, after the first stage of testing was 13.2 % and 29.7 % after the second stage of testing.

It has been established that the maximum vertical shear force that occurs during the destruction of asphalt concrete layers without reinforcement is higher than asphalt concrete layers reinforced with a synthetic mesh. The values of the vertical shear forces without reinforcing the samples are 21.63 kN and 18.46 kN when the samples are reinforced with a synthetic mesh. At the same time, the maximum shear stresses between layers of asphalt concrete core samples without reinforcement are 1.169 MPa, and with reinforcement – 0.988 MPa.

Reinforcing the upper layer of the asphalt concrete coating with synthetic meshes will lead to an increase in the durability of the asphalt concrete coating along road sections

Keywords: asphalt, synthetic grids, reinforcement, rutting, adhesion between asphalt concrete layers

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1. Introduction

The most common material for road surfaces is asphalt concrete, made of non-rigid roadbeds. During operation, the asphalt concrete coating is exposed to many adverse factors and influences [1]: precipitation, daily and seasonal temperature fluctuations, high temperature, alternating freezing and thawing of water in pores and damaged areas, the influence of anti-icing reagents, cyclic loading from vehicles, etc. There are often issues related to delamination of asphalt concrete layers, which leads to the formation of pits on the road surface and rutting (Fig. 1). This is a common problem while ensuring the durability of an asphalt concrete coating.

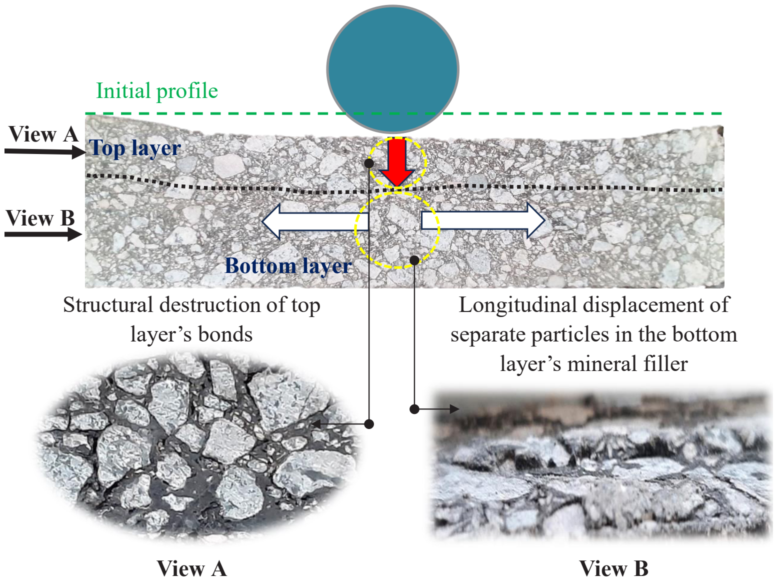


Fig. 1. Schematic showing the formation of rutting in the structural layers of an asphalt concrete coating

the thermally stressed state of multilayer road surfaces was carried out without estimating the rutting resistance with the use of reinforcing synthetic meshes. In [9], there are also no studies o the rutting resistance of the road surface, taking into account the reinforcement of the surface. At the same time, work [10] investigated the effect of microfibers on the crack resistance and rutting of an asphalt concrete coating without conducting research on the effect of synthetic meshes on the rutting resistance of the coating. One of the reasons is the lack of full-fledged experimental studies evaluating the effectiveness of asphalt concrete coating reinforcement for rutting. In practice, they try to compensate for this with measures to regulate the properties of asphalt concrete and improve the construction of roadbeds [4].

The main reason for the formation of a rut on an asphalt concrete coating is the fact that most roads were designed for loads of 100 kN and 60 kN per axle. However, over time, not only the traffic intensity increases during the operation of highways but also the traffic load parameters increase [11].

The formation of cracks and ruts in the asphalt concrete coating on highways significantly affects the deterioration of vehicle control, negatively affects the reaction of drivers, which can cause dangerous conditions in an accident [2]. In addition, the frequent performance of repair works creates inconvenience for the passage of vehicles.

Therefore, ensuring the rutting stability of the asphalt concrete coating is an important task during the construction of streets and roads. This issue becomes especially relevant due to the increased need for reconstruction or repair of the existing old coating, which already has transverse cracks and ruts. In this case, temperature cracks quickly appear in the asphalt concrete layers above the existing cracks in the base.

Modern conventional solutions [3] with the selection of grain composition [4], the introduction of modifying additives do not fully solve the problem of increasing the rutting resistance of the asphalt concrete coating to ensure its necessary durability [5].

Increasing the rutting resistance of an asphalt concrete coating can be achieved by reinforcing it [6]. Of particular interest is the use of synthetic GlaGrid® grids [7]. When justifying the effectiveness of their use, this could ensure an increase in the tensile strength of asphalt concrete coatings. It would also improve the ability to accept tensile stresses and vertical residual deformations from vertical loading of pneumatic vehicle tires and variable temperature effects. Given this, the resistance of asphalt concrete layers to tensile stress and resistance to the accumulation of plastic vertical deformations could increase. This would help increase the rutting resistance of the asphalt concrete coating. Therefore, the issue of experimental studies on the effectiveness of using reinforcing synthetic nets to improve the rutting resistance of asphalt concrete coating on highways and the adhesion between the layers of the surfaces is relevant.

2. Literature review and problem statement

In work [8], it is stated that the most common type of destruction of the asphalt concrete coating is thermal transverse cracks [9] and rutting [10]. However, in [8], the assessment of

As a result, the insufficient resistance of the asphalt concrete cover of the non-rigid road surface to the formation of a rut significantly reduces both the strength of the entire structure of the road surface and, especially, the level of traffic safety. This is due to the fact that the effect of aquaplaning is created in places of water stagnation and winter slipperiness. Also, the quality of adhesion of the road surface to the rigid base laid on the subgrade plays a significant role [12].

In work [10], it is proved that the durability of asphalt concrete can be increased by means of macro reinforcement, using synthetic meshes. However, the work did not evaluate the effect of reinforcement of the upper layer of the asphalt concrete coating on rutting resistance.

Despite the large number of reported experimental numerical studies and devised practical measures for the prevention and avoidance of transverse cracks and ruts, these types of damage still remain one of the most widespread defects of the asphalt concrete coating [13]. This is due to the fact that the appearance of thermal transverse cracks and ruts is often the root cause of the destruction of the asphalt concrete coating itself and significantly accelerates it. Such cracks and ruts can make up a large part of all damage, which leads to a weakening of the entire structure of roadbed. At the same time, the integrity of the coating in the crack zone is violated, and as a result of a significant decrease in the load-bearing capacity of the coating layers, overstressing of the base layers and the subgrade soil occurs. This leads to the acceleration of the appearance of various types of destruction under the influence of traffic loads and climatic influences, both of the asphalt concrete coating itself and of the road surface as a whole.

In work [14], it was established that one of the reasons for the reduction of the residual resource of asphalt concrete coating on bridges is insufficiently conducted research on the efficiency of the use of polymers. This is due to the fact that the use of polymer materials makes it possible to adjust the properties of asphalt concrete. In addition, paper [15] established that the use of methyl methacrylate materials makes it possible to increase the load-bearing capacity of bridge beams. However, in works [14, 15] no studies were conducted on the influence of synthetic nets on the rutting resistance of an asphalt concrete coating.

In [16], the impact of modified bitumen on the crack resistance of asphalt concrete coating was assessed. However, the work did not conduct research on the effectiveness of using synthetic nets.

Paper [17] reports the results of the effect of adhesion on the formation of rutting in an asphalt concrete coating. However, the work did not evaluate the adhesion of synthetic nets to asphalt concrete nets.

Our review of the literature [8–17] has established that attention is mostly paid to the use of conventional solutions for improving the quality of asphalt concrete mixtures. This is due to the improvement of the selection of the composition, the introduction of various modifying impurities, the improvement of the technology of preparation of mixtures, etc. However, this does not fully solve the problem of increasing the rutting resistance of the asphalt concrete coating. One of the promising methods for increasing the rutting resistance of asphalt concrete coatings is the use of synthetic nets. However, no studies have been found that would allow us to evaluate the effectiveness of the use of reinforcing synthetic meshes for asphalt concrete coatings. Also, there were no experimental studies on the effectiveness of the use of reinforcing synthetic grids of the GlasGrid series for reinforcing asphalt concrete layers of highways. This does not allow for a purposeful and effective influence on the rutting resistance of the asphalt concrete coating when it is used during the operation of highways. Therefore, an unsolved task is an experimental evaluation of the effectiveness of using reinforcing synthetic nets to increase the rutting resistance of asphalt concrete road surfaces.

3. The aim and objectives of the study

The purpose of our work is to determine the effectiveness of reinforcing the asphalt concrete coating with synthetic meshes, which would make it possible to improve its operational performance.

To achieve the goal, the following tasks must be solved:

– to conduct experimental studies on the rutting resistance of an asphalt concrete cover reinforced with synthetic meshes;

– to conduct experimental studies on the adhesion between layers of asphalt concrete cover reinforced with synthetic meshes.

4. The study materials and methods

4. 1. The object and hypothesis of the study

The object of our study is an asphalt concrete coating, the upper layer of which is reinforced with synthetic GlasGrid grids.

The main hypothesis of the research assumes that the performance of laboratory experimental studies could make it possible to establish the effect of reinforcing the asphalt concrete coating with synthetic meshes on the rutting resistance of the surface. It is assumed that the inclusion of synthetic nets during maintenance with the appearance of tensile stresses in the asphalt concrete coating would make it possible to increase resistance to tensile forces and resistance to the accumulation of plastic deformations under the action of vertical loads of vehicles and the action of variable temperature influences.

4. 2. Methodology for manufacturing asphalt concrete slab samples reinforced with synthetic nets and their experimental testing for rutting resistance

In order to carry out studies on the rutting resistance of an asphalt concrete cover reinforced with synthetic meshes, slab samples were fabricated under laboratory conditions. Testing of each series of asphalt concrete samples was performed in accordance with the requirements of the current regulatory documents: DSTU EN 12697-22:2018, EN 12697-48:2018, DSTU EN 12697-24:2018 and DSTU B V.2.7-319:2016.

GlasGrid® GG100 reinforcing synthetic mesh was used as a reinforcing material [7]. It is a self-adhesive strong grid with a rigid structure made of E-type fiberglass. The mesh is covered with an elastomeric polymer and a self-adhesive bottom layer. Activated by pressure, with a tensile strength of 115×115±15 kN/m and a maximum relative elongation of 2.5±0.5 %.

Asphalt-concrete mixture of type A with a maximum grain size of 20 mm was used for the production of slab samples with the use of road viscous bitumen of the BND 70/100 grade in accordance with DSTU B B.2.7-119. The process of forming slab samples is shown in Fig. 2.

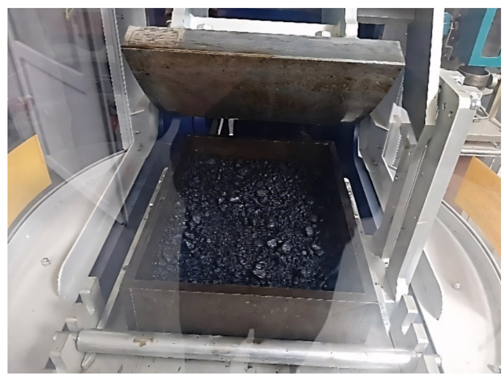


Fig. 2. The process of forming asphalt concrete slab samples

Imitation of a crack in the lower slab was made by cutting an asphalt concrete slab sample on a stone cutting machine. The thickness of the slab of the lower layer is 4 cm, the upper layer is 5.0 cm. The upper layer is arranged after the production, hardening, cutting (simulation of a crack) of the lower layer, and laying on it, according to the technology and instructions for laying, the corresponding reinforcing synthetic mesh. As a result, we received a slab sample reinforced with synthetic nets for rutting resistance testing (Fig. 3). A simulated crack can be seen in the lower part of the slab.

It should be noted that the upper layer is arranged without heating the form of the roller compactor. The average density of the compacted material is 2.44 g/cm^3, the residual porosity is 3.2 %. The average density of slab samples was determined by forming test slabs for the upper and lower layers with the calculated weight of the material. Bitumen cationic rapidly disintegrating emulsion with a bitumen content of 60 % (EKSH-60) was used as a binder emulsion.

The dosage of emulsion consumption for GlasGrid® GG100 reinforcing grids was 0.3 kg/m^2. It should be noted that the binder emulsion must completely disintegrate before laying the top layer of asphalt concrete. To activate the glue of the self-adhesive reinforcing synthetic material, two passes of the roller compactor are performed. Next, we checked the adhesion of the synthetic mesh with the asphalt concrete sample-slab (Fig. 4), at a rate of at least 5 kg/m^2.

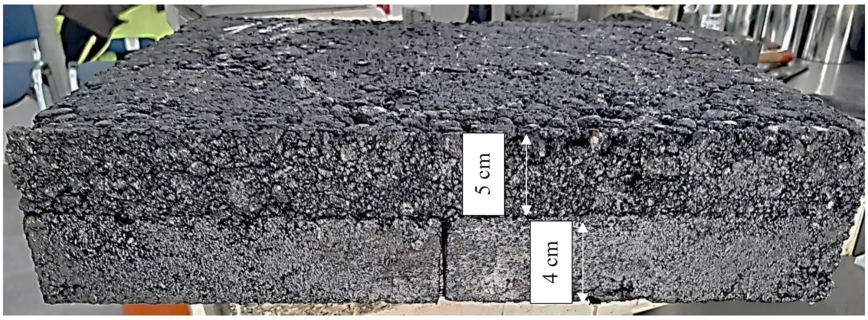


Fig. 3. Slab sample for rut depth testing

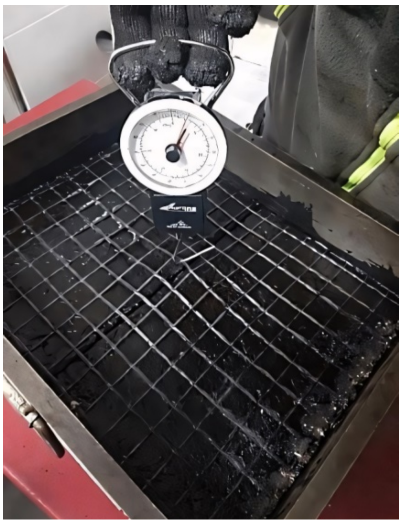


Fig. 4. Checking the bond strength of the reinforcing synthetic mesh with a slab sample

Tests to determine the resistance of an asphalt concrete cover reinforced with synthetic nets to the formation of a rut under the action of a load were performed on a special test unit. The DWT installation for testing the rutting of asphalt concrete, manufactured by CONTROLS (Italy), is shown in Fig. 5.

Fig. 5. Installation for testing the rutting resistance of asphalt concrete slab samples

This installation simulates a moving load. A wheel with a rubber tire has an outer diameter of 200–205 mm and a width of 50±5 mm. The load from the wheel is 700 N.

The tests were conducted in two stages. At the first stage, the operating temperature was 50 °C, and at the second – 60 °C. The number of load cycles in each stage was 10,000 (20,000 passes). Before each stage of the test, the slab samples were thermostated for 6 hours.

4. 3. Methodology for determining adhesion between layers of asphalt concrete samples

Tests to determine adhesion between layers were performed in accordance with EN 12697-48:2018. One of the regulatory tests described in this document is the Shear Bond Test (SBT), which applies to layers thicker than 15 mm. The shear stress at the interface $\tau_{SBT,\max}$ and shear bond strength (SBT) are determined by the experimental method. The maximum shear stresses are calculated from the following formula:

$$\tau_{SBT,\max} = \frac{F_{SBT,\max}}{\pi \times \left(\frac{D}{2}\right)^2} \times 1000, \tag{1}$$

where $\tau_{SBT,\max}$ is the maximum shear stress at the separation boundary, expressed with an accuracy of 0.01 MPa; $F_{SBT,\max}$ – maximum vertical shear force, kN; D is the initial diameter of the sample in the intermediate layer, mm.

To conduct sample tests, core samples were cut from the manufactured slab samples (Fig. 6).

Core samples with a diameter of 153.5 mm were taken from preformed asphalt concrete two-layer slabs. One type of core samples is two layers of asphalt concrete without reinforcement with reinforcing synthetic mesh. The second type of core samples is two layers of asphalt concrete, reinforced with reinforcing synthetic grids – Adfors GlasGrid GG100 self-adhesive geogrid.

Before the test, the samples were placed in a drying cabinet for thermostating at a temperature of +21 °C (Fig. 7). The time of thermostating was six hours.

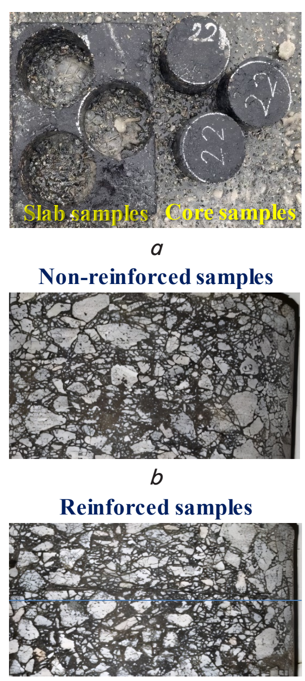
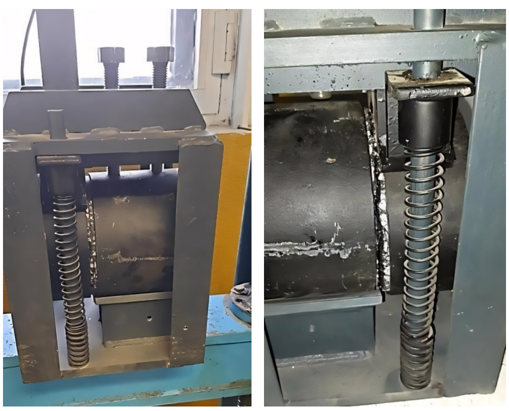


Fig. 6. Cutting cores from slab samples for testing: *a* – view of slab samples and core samples; *b* – unreinforced samples; *c* – reinforced samples

Fig. 7. Thermostating core samples

After carrying out all the preparatory operations, the sample was placed in the test device, which was installed on the frame. A breaking machine was used as a frame, which can change the speed of vertical movement by adjusting the frequency of the current. The general appearance of the sample tested in the testing equipment before and after the test is shown in Fig. 8.



a *b*

Fig. 8. General view of arranging the sample tested in the test equipment: *a* – before the start of the test; *b* – after the test

During the tests, the speed of vertical movement was 50 mm/min. The sample was loaded using a Zemic H3-C3_3.0t strain gauge connected to a personal computer with appropriate software. That made it possible to record the maximum shear force and obtain a graphical dependence in real time.

5. Results of experimental studies on performance indicators of asphalt concrete cover reinforced with synthetic nets

5. 1. Results of research on the rutting resistance of an asphalt concrete coating

Before starting the formation of slab samples, the dynamic viscosity of the organic binder used in the mixture was determined using a Brookfield rotary viscometer, and the optimal heating temperatures during the preparation and compaction of the mixture were selected (Table 1).

The ability of reinforced asphalt concrete to deform is estimated by measuring the depth of the rut, which occurs as a result of repeated passage of a loaded wheel at a constant temperature. The results of experimental studies of the rolling resistance of unreinforced and reinforced asphalt concrete are given in Table 2.

The results of experimental studies (Table 1) show that reinforcing the asphalt concrete coating with synthetic nets reduces rutting. At 10,000 load cycles (or 20,000 passes) and a temperature of 50 °C, the average value of the rut depth in slab samples without a reinforcing joint was 3.8 mm, and at a temperature of 60 °C – 3.7 mm. In the case of reinforcing the upper layer with a GlasGrid® GG100 grid, the depth of the track at an operating temperature of 50 °C is from 3.3, and at an operating temperature of 60 °C – 2.6 mm. With a total number of 20,000 load cycles (or 40,000 passes), the average value of the rut depth without reinforcement of the slab sample is 7.5 mm, and with reinforcement – 5.9 mm.

The increase in rutting resistance (i.e., the reduction of the rut depth and the total rutting plane) of slab samples with reinforcing synthetic materials GlasGrid® GG100 in comparison with the slab sample without reinforcing material, namely after the 1st stage of testing, amounted to 13.2 %. And after the second stage of testing, 29.7 %.

Table 1

Determination of the release temperature and compaction of the mixture

Actual temperature, °C	Dynamic viscosity, Pa·s	Momentum, mN·m	Bitumen viscosity at release, Pa·s	Bitumen viscosity during compaction, Pa·s	Release temperature, °C	Sealing temperature, °C
135.0	0.415	0.00	0.17±0.02	0.28±0.03	159.4–163.7	146.4–152.9

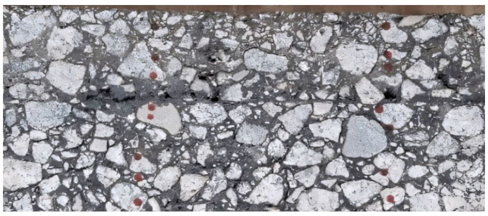
Table 2

Test results for determining the rutting of an asphalt concrete coating

Type of reinforcing synthetic mesh	Rut depth, mm					
	Operating temperature, °C					
	50		60		Σ	
	Number of cycles (passes)					
	Basic 10000 (20000)		Additional 10000 (20000)		Total number 20000 (40000)	
	parallel tests	average	parallel tests	average	parallel tests	average
No reinforcing synthetic mesh	3.6	3.8	4.4	3.7	8.0	7.5
	4.0		2.9		6.9	
GlasGrid®GG100	3.5	3.3	2.2	2.6	5.7	5.9
	2.3		1.8		4.1	
	4.2		3.8		8.0	

Analysis of the ends of samples-slabs of the asphalt pavement without mesh reinforcement (Fig. 9) revealed that there was movement of the mineral aggregate in the upper and lower layers.

a

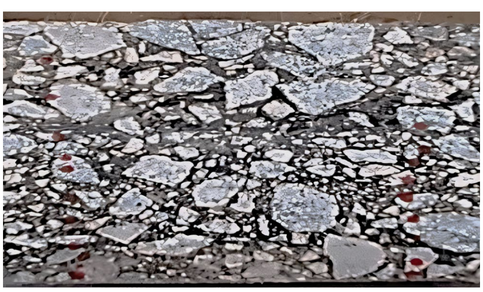


b

Fig. 9. Rut formation on samples without reinforcing synthetic nets: *a* – view from the end of the sample; *b* – longitudinal section

In the upper asphalt concrete layer of the samples, the destruction of the bonds between the mineral aggregate and the organic binder was observed, cracks were formed. There was also displacement of material near the edges of the track onto the surface (beyond the line of the initial profile). When in the lower asphalt concrete layer, a longitudinal shift of individual particles of coarse aggregate was visually observed.

It is interesting that in the slab samples reinforced with GlasGrid®GG100 reinforcing synthetic materials (Fig. 10), the destructive processes in the upper and lower layers are concentrated in the projection of the track, not significantly exceeding the limits, and amount to 70–85 mm.



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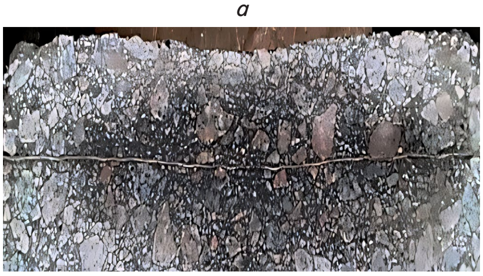

b

Fig. 10. Rut formation on samples reinforced with synthetic grids GlasGrid®GG100: *a* – end view; *b* – rut formation, longitudinal section

At the same time, in the slab samples without a reinforcing synthetic mesh, the deformations significantly exceed the limits of the track projection and amount to more than 100 mm.

5. 2. Results of investigating the adhesion between layers of asphalt concrete coating

The appearance of core samples after experimental tests is shown in Fig. 11.

a

b

Fig. 11. General view of non-reinforced core samples of the asphalt concrete coating after the tests: *a* – unwashed core sample; *b* – reinforced core sample with a synthetic mesh

In both cases, the core samples were completely destroyed. The results of determining the maximum vertical shear forces and shear stress values are given in Table 3. In this case, the value of the shear stresses was obtained using (1).

Table 3

Results of determining the maximum vertical forces and shear stresses when testing asphalt concrete core samples

Description of the material	Test temperature, °C	Sample diameter, mm	Average maximum vertical shear force $F_{\text{SBT, max}}$, kN	Average maximum shear stress, $\tau_{\text{SBT, max}}$, MPa
Asphalt concrete layers without reinforcement with synthetic nets	+20	153.5	21.63	1.169
Asphalt concrete layers reinforced with Adfors GlasGrid GG100 synthetic self-adhesive geogrid	+20		18.46	0.988

Table 3 demonstrates that the maximum vertical shear force that occurs during the destruction of asphalt concrete layers without reinforcement is higher than asphalt concrete layers reinforced with a synthetic mesh. The values of the vertical shear forces are 21.63 kN and 18.46 kN, respectively. At the same time, the maximum shear stresses between the layers of asphalt concrete core samples without reinforcement are 1.169 MPa, and the reinforced ones are 0.988 MPa.

The graphical dependence of displacement on the shear load shows that the sample displacement time is from 4 to 8 seconds, and the corresponding displacement is from 3.3 to 6.6 mm.

6. Discussion of results based on experimental studies of rutting resistance and adhesion between layers of asphalt concrete coating

Experimental studies on the effectiveness of using synthetic nets to increase rutting resistance and adhesion between layers of asphalt concrete have been conducted. The results of studies on rutting resistance showed a spread of rutting depth indicators during tests (Table 1). This is explained by the inhomogeneity of the asphalt concrete mixture during the production of slab samples, the change in humidity and air temperature in the room during the test, and the testing of a small number of samples.

Based on the results of the tests, a significant increase in rutting resistance (i.e., a decrease in the depth of the rut and the total plane of rutting) of slab samples with reinforcing synthetic grids of the GlasGrid® GG100 type was observed. After the first stage of the tests, the rutting resistance increased by 13.2 % and after the second stage, i.e., after the end of the test, by 29.7 %. These results coincide with the results of tests conducted at the University of North Carolina (USA) for GlasGrid® materials [18–20]. With a different composition of the asphalt concrete coating, a temperature of +50 °C and 400,000 cycles of wheel loads, a 25 % decrease in the depth of the rut was observed in the reinforced asphalt concrete coating in comparison with the unreinforced pavement.

In addition, after the tests, the ends of the slab samples were analyzed. As the scheme in Fig. 8 shows, in the upper asphalt concrete layer of the samples, the destruction of the bonds between the mineral aggregate and the organic binder was observed, and cracks were also formed. There was also displacement of material near the edges of the track onto the surface (beyond the line of the initial profile). In the lower asphalt concrete layer, a longitudinal shift of individual particles of coarse aggregate was visually observed.

It is interesting that in slab samples reinforced with GlasGrid® GG100 reinforcing synthetic grids, the destructive processes (Fig. 9) in the upper and lower layers are concentrated in the projection of the track, not significantly exceeding the limits, and amount to 70–85 mm. At the same time, in the slab sample without reinforcing material, deformations significantly exceed the limits of the track projection and amount to more than 100 mm (Fig. 8). As a result, we believe that one of the reasons for the unsatisfactory performance of the asphalt concrete coating without reinforcement is the excess of deformations of the boundaries of the track projections under the action of the cyclic loading of the pneumatic wheels of transport. As a result, a large rut depth is formed, and the total area of rut formation increases.

When using reinforcing synthetic grids GlasGrid® GG100, under the top layer of the asphalt concrete coating, the general working conditions of the coating are significantly improved. When reinforcing the asphalt concrete coating, the depth of the rut and the area of rutting are reduced. This significantly increases the rut resistance and durability of the asphalt concrete coating.

Experimental tests of asphalt concrete core samples were carried out to determine the adhesion between layers based on the maximum forces and shear stresses (Table 2). When testing asphalt concrete core samples without reinforcement with synthetic meshes, the maximum vertical shear forces $F_{SBT,\max}$ were 21.63 kN. The corresponding values of the maximum shear stresses $\tau_{SBT,\max}$ were 1.169 MPa. At the same time, in samples reinforced with Adfors GlasGrid® GG100 self-adhesive geogrid, the average value of the maximum vertical shear force $\tau_{SBT,\max}$ was 18.46 kN. And the average value of the maximum shear stress $\tau_{SBT,\max}$ was 0.988 MPa (Table 3). This is explained by the fact that the adhesion rates are higher in asphalt concrete layers without reinforcement, compared to samples reinforced with Adfors GlasGrid GG100 self-adhesive geogrid. At the same time, the smallest spread of indicators and, accordingly, the highest value of the maximum shear stresses $\tau_{SBT,\max}$ was found in samples that do not have a reinforcing layer.

A significant spread of indicators in the series of samples that contain a reinforcing layer is explained by the practical difficulty of maintaining the homogeneity of the asphalt concrete mixture in small volumes (laboratory conditions) and a uniform amount of primer between layers. This, in turn, makes it difficult to ensure uniform adhesion of the reinforcing material during the manufacture of samples in laboratory conditions.

The average values of the maximum vertical shear forces $F_{SBT,\max}$ obtained during the study for asphalt concrete layers reinforced with Adfors GlasGrid reinforcing synthetic materials completely coincide in magnitude and rating with the values performed by the German laboratory Asphalta Prüf-und Forschungs laboratorium GmbH (Berlin) [21]. Other compositions of asphalt concrete mixtures and other types and amounts of bituminous emulsions were used.

There are no requirements for the value of the maximum shear stresses $\tau_{SBT,\max}$. In the literature [22], there is a mention of a regulatory document that regulates that the numerical value of the shear resistance of a core with a diameter of 0.15 m, tested according to the EN 12697-48 method, should be at least 15 kN. Thus, it can be stated that ADFORS GlasGrid GG100 reinforcing grids meet the European requirements for the adhesion of reinforced asphalt concrete layers.

The practical significance of our results relates to the possibility of their application in the reinforcement of asphalt concrete with synthetic meshes on real roads and streets. This will ensure the durability of the asphalt concrete coating, as it has been established from experiments that the rutting resistance increases with the reinforcement of the asphalt concrete coating.

One of the limitations of the present research is that the determination of the effectiveness of the use of synthetic grids and their effect on rutting resistance and adhesion between the layers of the asphalt concrete coating was carried out only when using ADFORS GlasGrid GG100 grids. The disadvantage of our research is the small number of test samples and the difficulty of ensuring the homogeneity of the mixture on small sample plates and cores. Adhering to the requirements of homogeneity of the mixture and testing a larger number of samples in each series would reduce the spread of resulting indicators. The further development of this area of scientific research is to conduct studies on the influence of other types of nets and synthetic materials on the values of rutting resistance and adhesion between layers of asphalt concrete.

7. Conclusions

1. The results of experimental studies show that reinforcing the asphalt concrete coating with synthetic nets reduces rutting. At 10,000 load cycles (or 20,000 passes) and a temperature of 50 °C, the average value of the rut depth in slab samples without a reinforcing joint was 3.8 mm, and at a temperature of 60 °C – 3.7 mm. In the case of reinforcing the upper layer with ADFORS GlasGrid GG100 grid, the rut depth at an operating temperature of 50 °C was 2.9 mm, and at an operating temperature of 60 °C – 2.0 mm. With a total number of 20,000 load cycles (or 40,000 passes), the average value of the rut depth without reinforcement of the slab sample is 7.5 mm, and with reinforcement – 4.9 mm.

We have observed an increase in rutting resistance of asphalt concrete slab samples reinforced with ADFORS GlasGrid GG100 synthetic grids, compared to slab samples without reinforcing grids. After the first stage of tests, the increase in rut resistance was 13.2 %, and after the second stage of tests – 29.7 %.

2. The maximum vertical shear force required for complete destruction of asphalt concrete core samples without reinforcement with synthetic grids is higher than asphalt concrete core samples reinforced with ADFORS GlasGrid GG100 synthetic grid. The values of the vertical shear forces are 21.63 kN and 18.46 kN, respectively. At the same time, the maximum shear stresses between the layers of asphalt concrete core samples without reinforcement are 1.169 MPa, and with reinforcement with ADFORS GlasGrid GG100 synthetic grids they are 0.988 MPa.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

All data are available, either in numerical or graphical form, in the main text of the manuscript.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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