Increase of a Roadway Covering Durability by Using the Cement-Concrete Base Fragmented with the Geogrid

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Abstract. Presents the results of studies of innovative materials in the field of in road construction. The paper presents an alternative method of increasing the cracking resistance of the roads asphalt-concrete pavement, constructed on the cement-concrete base, due to its fragmentation with the volumetric plastic geogrid while constructing. Theoretical, laboratory and field experimental studies of this design were conducted, as well as the effectiveness of the proposed solution was proved. The use of this design can improve the durability of the roadway coverings and reduce the costs for the roads repair and maintenance.

1 Introduction

In recent years, Russia has significantly increased and altered the vehicle stock, which is associated with the vehicles affordability due to the extended car loans and a variety of purpose-oriented programs. Traffic flow now includes trucks of not only domestic, but of foreign production, which are characterized by a large carrying capacity and significant axial loads. The growth and the composition change of the traffic flow means that there is a necessity to work out the new approaches to the construction and design of the roadway coverings. It also means there is a need to use the new high-strength and durable materials, including cement-concrete pavements and bases.

Abundance of the advanced materials, including synthetic ones, allows to design fundamentally new roadway coverings and road base structures, which helps to reduce the costs for their construction, repair and maintenance, to improve the properties of the traditional materials, and to lengthen the periods between the repair works [1- 5].

Asphalt-concrete is the most common material in the world, and particularly in Russiaб for constructing pavements. According to the data of March 13, 2013, the share of federal roads with asphalt-concrete pavement in Russia is 90.8% [6]. Asphalt-concrete is used due to its positive properties and a relatively simple construction technology.

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An extensive range of materials is used to construct a roadway covering base. The choice of the material depends on a number of factors, in particular, on the region of construction and the availability of supply.

In the course of the roadway covering construction, one of the best construction solutions is the structure with the concrete base and asphalt-concrete pavement, which is of high strength and durability. This structure is referred to the roadway coverings of a rigid type [7].

Roadway coverings of a rigid type with the asphalt-concrete pavement and cement-concrete base have approved themselves in rough climatic conditions and on roads with the high traffic density.

Usage of cement-concrete base allows to:

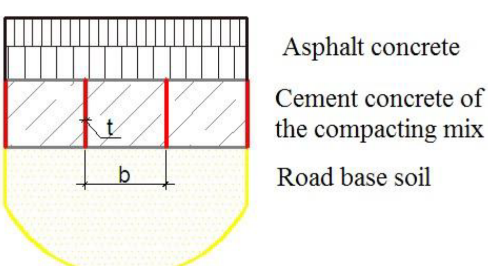
- reduce the need for imported rock material by reducing the thickness of the layer;
- reduce the rutting process;
- reduce the pressure of the vehicle stock on the underlying layers due to the load distribution over a larger area.

Despite the advantages of these roadway coverings, there is also a significant disadvantage - the formation of cracks in the pavement. The cause of this problem lies in the different thermal and physical properties of the base and pavement materials, and also in the absence of the design and construction practice of the structural and technological solutions to reducing the cracking [8, 9].

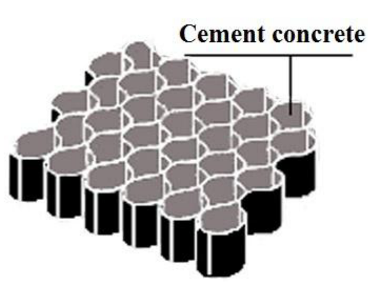
There are various ways to increase the cracking resistance of the asphalt-concrete pavement in order to lengthen the periods between the repair works [1 - 5]. These include: reinforcement of the asphalt-concrete pavement or asphalt-concrete mix; the use of modified bitumen-based asphalt concrete; constructing the pavements of increased thickness at a single lift; construction of the expansion joints in the pavement, etc. [10 - 17]. These methods have their own significant drawbacks [10, 18].

2 Subjects and methods

In order to increase the cracking resistance of the pavement, the alternative method is suggested – the use of the small-section concrete base. Such base can be obtained in the process of construction by fragmentation of the cement-concrete layer with the volumetric plastic grid (Figure 1).



a)



b)

Fig.1. Roadway covering structure with the cement concrete, fragmented with the plastic geogrid:
a) structural scheme of the roadway covering:
b – geocell grid spacing; t – geocell wall thickness;
b) geogrid in expanded form, filled with cement-concrete mix.

The use of the geogrid can reduce thermal stresses in the concrete slab, thus the grid walls, involved in the joint slab work, take up the linear deformations caused by the temperature fluctuations.

Theoretical, laboratory and field experimental studies of the suggested method were conducted at the Highways and Airfields Department of TSUACE. The obtained results demonstrated the effectiveness of the structure.

3 Results

During the research, the theoretical dependences were obtained, which allow to assess the changes of the deformation properties of the concrete slab with the volumetric geogrid [19].

The thickness of the asphalt-cement pavement and concrete base is determined by the condition of tensile strength in bending under the influence of the external loads and temperature fluctuations. [7]

After solving the plane elastic problem, it was found that the final thermal stresses in the concrete slab (fragmented with the grid) depend on the geogrid parameters, in particular, the wall thickness and cells size [19] (Fig. 2).

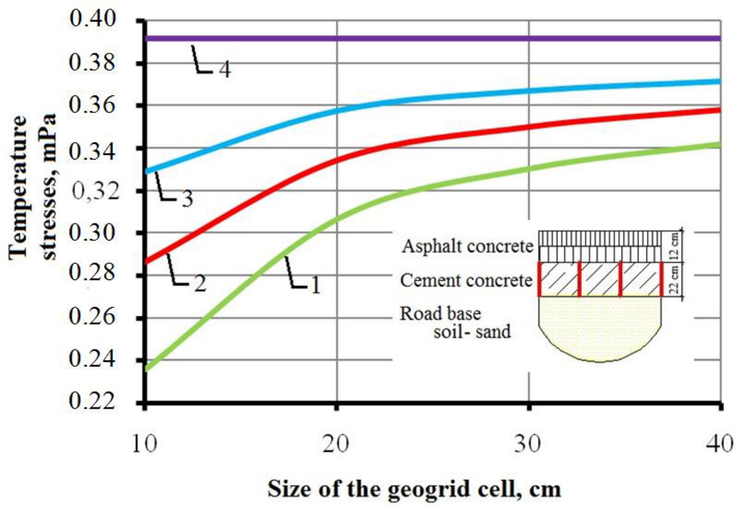


Fig. 2. Concrete slab thermal stresses dependence on the geogrid parameters with the geocell wall thickness (t):
1 – t=2.0 mm; 2 – t=1.35 mm; 3 – t=0.8 mm; 4 – without grid

Thermal stresses reduce by increasing the grid wall thickness and reducing the cell size. Thus, durability coefficient increases, and accordingly, the probability of cracking of the asphalt-concrete pavement on the cement-concrete base reduces.

When the roadway covering is full-strength, the base fragmentation allows to reduce the thickness of the structural layers.

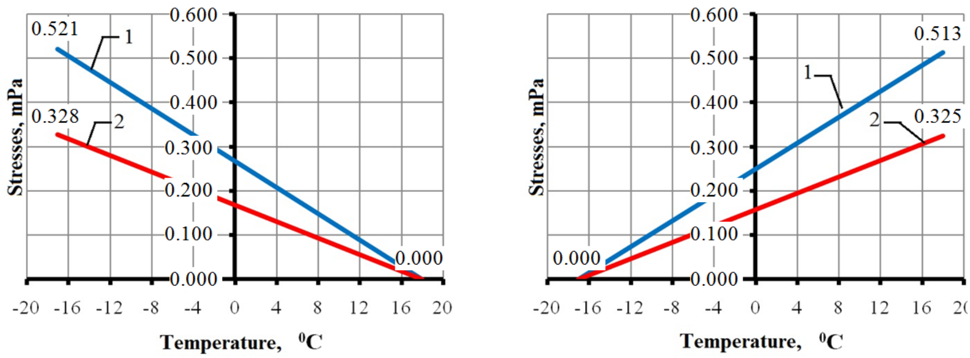
To prove the theoretical results, a series of experiments were set up in the Department laboratories [20].

Initially, cement-concrete slabs of B12.5 grade were made. One slab was fragmented with the plastic grid, and the second one was made with no grid. Then, the slabs were placed into a freezing chamber for the experimental studies.

The purpose of the first stage of the experiment was to determine the stress in the concrete slab arising from changes in ambient temperature. Over thirty observations had been made, each of which was accompanied by lowering the temperature in the freezer down to -170C, followed by disconnecting the chamber and raising the temperature up to + 180C.

To determine the stresses arising from the temperature changes, PL-60 resistance strain gages were used. The resistance strain gages were thin film based. These thin films were attached to the side face of the cement concrete. To determine the temperature, the electronic temperature sensors were used. The “ITC-03p” device was used to determine the stresses while lowering and raising the temperature in the freezing chamber.

The experiment results showed that stress in the concrete slab fragmented with the plastic grid is lower than the one in the slab without the grid. On average, the stress became 1.6 times lower (Fig. 3). This result matches the theoretical values obtained earlier.

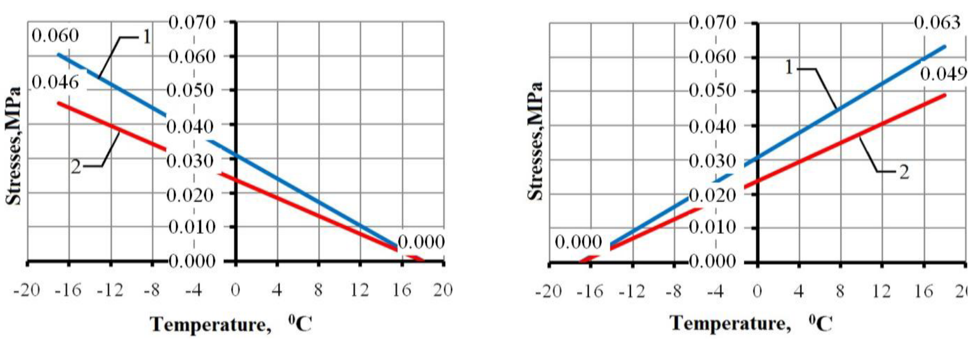


a) b)

Fig. 3. The measurement results of the thermal stresses in the concrete slab: a) when freezing (transition from +180C to -170C); b) when thawing (transition from -170C to 180C). 1 – without fragmentation; 2 – with fragmentation.

Later on, an experiment was conducted to determine the stresses in the asphalt-concrete layer on the cement-concrete base. To determine the stresses arising from the temperature change, PL-30 resistance strain gages were used.

The measurement results showed that the stress in asphalt-concrete layer on the fragmented cement-concrete slab became 1.3 times lower. (Fig. 4).



a) b)

Fig. 4. The measurement results of the thermal stresses in the asphalt-concrete pavement: a) when freezing (transition from +180C to -170C); b) when thawing (transition from -170C to 180C). 1 – without fragmentation; 2 – with fragmentation.

To prove the theoretical calculations and laboratory tests, a construction solution for the concrete base fragmentation was reflected in the working project "Overhaul of the roads with constructing the asphalt-concrete covering in the Leninsky administrative district of Tyumen".

The project passed the State examination and received positive findings.

In summer of 2014, in accordance with the project, the trial lot was constructed in Pyatnitskaya and Venskaya streets in Tyumen.

The roadway covering base was made of cement concrete of B15 grade and with the thickness of 18 cm. The base layer was fragmented with the volumetric perforated geogrid of 15 cm high, and with the protective layer of 3 cm thick. The pavement was constructed of the dense asphalt concrete (mark II) of 6 cm thick.

At the same time, a similar lot with the same structure of a roadway covering was built, but without fragmentation of the concrete base.

Construction included several phases: preparatory works, installation of the volumetric plastic geogrid, construction of the cement-concrete base followed by the compression and construction of the asphalt-concrete pavement (Fig. 5) [21].

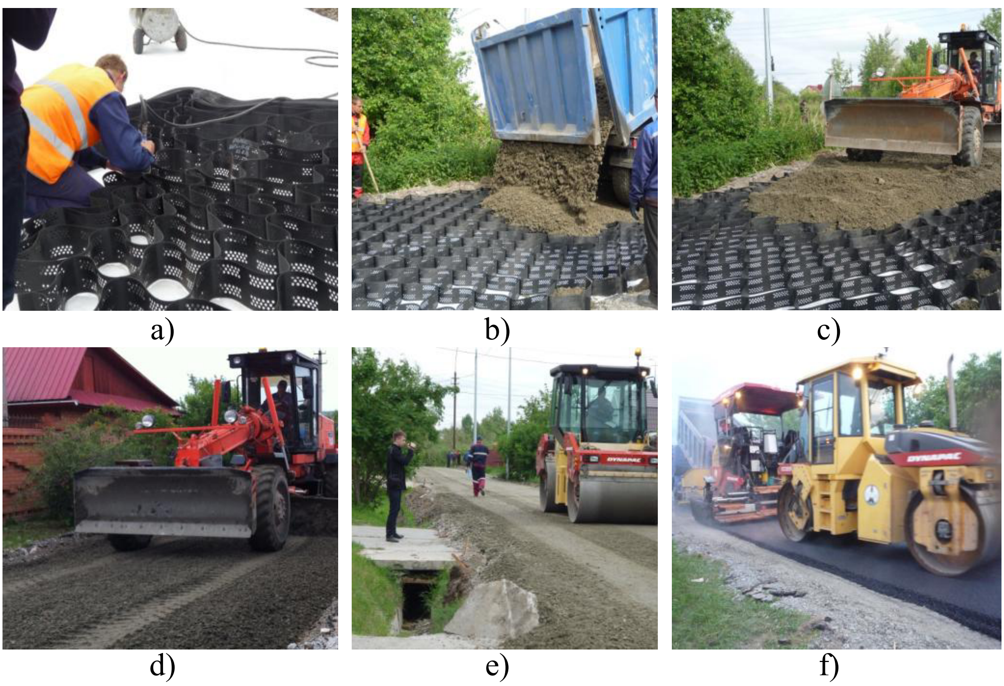


Fig. 5. Construction of the trial lot:a) installation of the volumetric plastic geogrid; b) filling the cells with the cement-concrete mix; c) distribution of the mix; d) shaping the base surface;e) compression the base; f) construction of the asphalt-concrete pavement.

Seven days after the constructing completion, for the monitoring of the trial lot, the PL-30 resistance strain gages were attached to the side faces of the asphalt-concrete layer.

Measurements of the stresses in the structure of the roadway covering had been taken during 4 months from July to October, 2014.

Analysis of the results showed that at the lot where the concrete base was fragmented with geogrid, the stresses occurring on the surface of the side faces of asphalt-concrete pavement were 1.33 times lower.

In early spring of 2015, the occurred cracks in the asphalt-concrete pavement were assessed on the trial lot.

The results showed that the number and opening width of cracks is lower in the lot with the fragmented cement-concrete base than in a similar lot without fragmentation (Fig. 6).

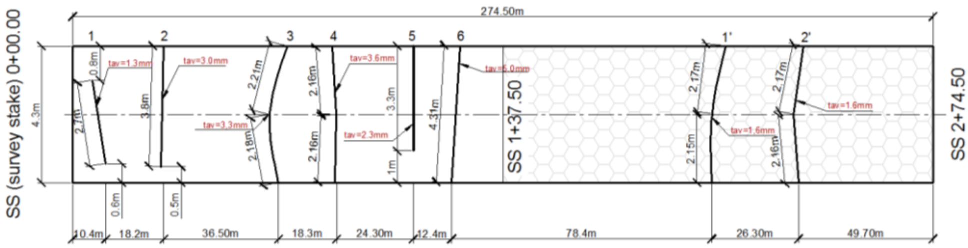


Fig. 6. Scheme of the opening of cracks in the trial lot (lot plan): tav - the average opening width of cracks in mm.

The total extent of cracks in the lot with fragmentation was 8.65 meters with an average opening width of 1.6 mm. In the same lot without fragmentation, the total length of cracks was almost 2.5 times bigger, that is 22.82 m, with an average opening width of 3.0 mm.

Economic efficiency of the suggested solutions was measured in accordance with the reduced total (discounted) costs for: construction, maintenance, repair and overhaul of the roads sections with the fragmented and non-fragmented cement-concrete base. Total costs for the roadway covering with fragmentation is by 13% lower than without fragmentation (Fig. 7).

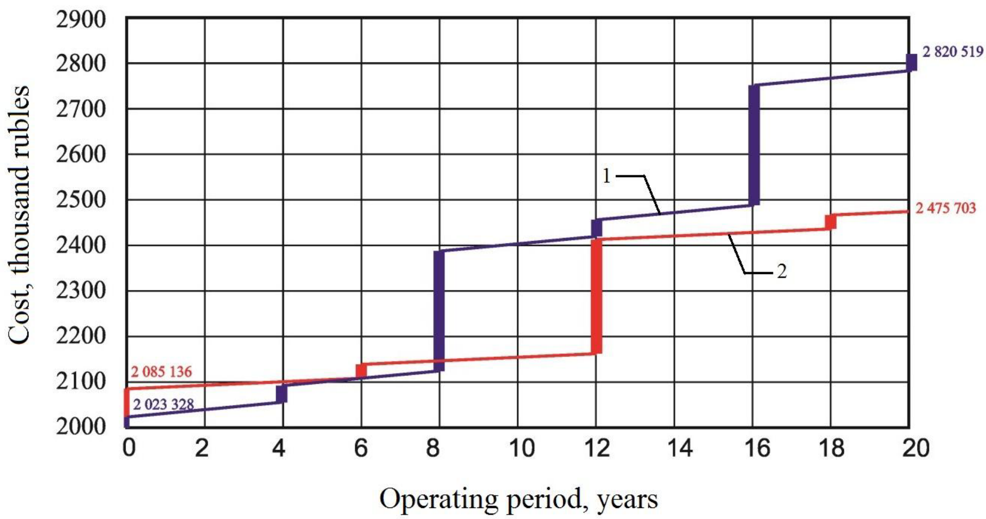


Fig. 7. Diagram of the reduced total costs for the structure of the roadway covering:
1 – without fragmentation; 2 – with fragmentation.

4 Conclusion

After analyzing the results of the theoretical and laboratory research, monitoring the trial lot, one can draw the following conclusions:

- ensuring crack resistance of roadway structures made of cement concrete base and asphalt-concrete pavement is an urgent task at designing and construction;

- method of increasing of crack resistance of road pavements by using small-size cement-concrete blocks for roadway base was proposed;
- theoretical dependencies which allows to calculate the proposed pavement structure were received;
- laboratory experiments which confirms the theoretical studies have been done;
- the proposed method of increasing of crack resistance has been tested at construction of experimental site.

It's found that:

- fragmentation of the cement-concrete base reduces the thermal stresses occurring in the structural layers of the roadway covering by 1.3-1.6 times;
- the use of the small-section concrete base increases the cracking resistance of the asphalt-concrete pavement by 2-3 times;
- in general, the use of the fragmented cement-concrete base, will allow to increase the periods between the repair of the roadway covering by 1.5 times, as well as it will allow to reduce the operating costs for repair and maintenance of roads by 10-20%.

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