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USAGE OF NEW MATERIALS DURING REHABILITATION OF ROAD STRUCTURES USING COLD RECYCLING TECHNOLOGY

Kateryna Krayushkina, Tetiana Khymeryck, Kyrylo Fedorenko
National Aviation University, National Transport University, Kyiv, Ukraine

Abstract

Until recently, the most common way for recovering of damaged and worn asphalt pavements on Ukrainian roads remains the provision of additional reinforced layers over the old pavement with patching. However, such measures give only a short-term effect because after one or two years, the existing deformations and fractures beneath reinforced layers occur, especially in conditions of insufficient strength of the foundations. But nowadays, recycling technology of different variations became the main method of existing pavement renovation. The economic attractiveness of cold recycling technology is primarily in the reuse of existing road material for arrangement of new pavement layers, so there is no need to arrange special areas for storage and disposal of old asphalt. In addition, the use of such technology helps to minimize the harmful impacts on the environment during road repair works. The essence of cold recycling technology, which is the most widely used in Ukraine for the arrangement of a road foundation layer, is in the fact that the defective and destroyed pavement layers are strengthened directly by complex admixtures of organic (hot bitumen, bituminous emulsion, foamed bitumen) and mineral suspensions, lime) binders. Cold recycling, according to the complications of the work, is divided into several types, depending of the depth of cutting. The choice of a particular type of recovery depends mainly on the condition of the entire pavement structure, which is determined prior to the start of repair works. Optimal mis design of the organic and mineral mixture for the arrangement of the road foundation layer by cold recycling technology is also executed before the beginning of the works. Actually, the main direction of cold recycling technology research in Ukraine is the usage of new materials such as fiber - basalt or polymer, stabilizing additives (ionic or polymeric), industrial waste - slags of various types of production or other by-products. Performed studies have shown that the use of organic and mineral mixtures of optimal design with the insertion of basalt fiber increases crack resistance and durability of the arranged road foundation layer.

Keywords: road consrtructiony, cold resycling, basalt fiber

1 Introduction

In Ukraine, as well as throughout the world, asphalt concrete is the main material for the construction of road pavement. Asphalt concrete pavements during the entire service life must provide regulatory riding qualities. However, during the operation of road pavement under conditions of constantly increasing loads, wear and aging of all constituent materials occurs, which leads to the accumulation and increase of deformations, defects and destruction of road pavements.

Road repair and construction organizations in Ukraine annually perform big scopes of work to eliminate defects and deterioration of highways. Rehabilitation of pavement is carried out by different ways, methods and materials which jointly determine the lifetime, the cost and the quality, i.e. the efficiency of the repairs performed. The main purpose of these works is to ensure safe and continuous traffic of motor vehicles with the given speeds [1].
During the recent years in Ukraine, for arranging the non-rigid pavements, the cold recycling method was used on the basis of machines of Wirtgen Group (FRD) - a recycler WR2500, a concrete –water suspension preparation plant WM1000 and a milling cutter [2]. Usage of the milling cutters of Wirtgen company production allows milling the existing asphalt pavement resulting in the formation of so called asphalt crumbs.
The reclaimed mixture designed by the authors is used on the roads of Ukraine and includes asphalt crumb, cement, bituminous emulsion and basalt fiber in the volume of up to 5 % of total mass of mixture. The result is an organo-mineral dispersion-reinforced mixture based on the reuse of milled asphalt concrete.
The three-dimensional chaotic distribution of basalt fiber in the mixture improves the physical and mechanical properties of the material providing high crack resistance of the pavement, increased resistance to shock and dynamic loads, wear resistance, that is, increase the service life. The tensile strength at bending limit, corrosion and weather resistance is increased. The bearing capacity of the pavement is increased by 1.2-1.5 times, and the operation durability by 40-50 %.
The source material for basalt fiber is basalt rock which is a fine-grained, effusive raw material of volcanic origin. Basalt fiber is obtained by melting of basalt stone and drawing fiber from the resulting melt and subsequent splitting into small fibrous elements. The obtained fibrillated fibers that had a circular transverse section, are cut into pieces of various lengths - mono- and multifilament fibers - fiber. A large number of types of fibers are known: mineral, basalt, diabase, metal, cellulose, synthetic. All types of fibers differ in nature, size, application and impact on material properties. The main technical characteristics of various types of fibers are shown in Table 1. As can be seen from the data in Table 1, basalt fiber, in comparison with fibers made from synthetic materials, is characterized with high tensile strength and low elongation at break, which will allow creating a spatial grid of dispersed reinforcement in the binder when mixing, improving structural and mechanical, technological and operational properties of organic and mineral mixture with basalt fiber.

Table 1 Characteristics of the fibers type that are used

Fiber	Density [g/m³]	Elasticity modulus [MPa]	Tensile strength [MPa]	Elongation at break [%]
Polypropylene	0,9	3500-8000	400-700	10-25
Polyamide	0,9	1900-2000	720-750	24-25
Polyethylene	0,95	1400-4200	600-720	10-12
Acrylic	1,1	2100-2150	210-420	25-45
Nylon	1,1	4200-4500	770-840	16-20
Viscose extra strong	1,2	5600-5800	660-700	14-16
Polyester	1,4	8400-8600	730-780	11-13
Cotton	1,5	4900-5100	420-700	3-10
Carbon	1,63	280000-380000	1200-4000	2,0-2,2
Carbonic	2,0	200000-250000	2000-3500	1,0-1,6
Glass	2,6	7000-8000	1800-3850	1,5-3,5
Asbestos	2,6	68000-70000	910-3100	0,6-,07
Basalt	2,6-2,7	7000-11000	1600-3200	1,4-3,6
Steel	7,8	190000-210000	600-3150	3-4

2 The main part

For research, basalt fiber obtained at the PJSC NVP "Teploizolyatsiya" (Ukraine) with a diameter of 14 microns, a strength of 1900 MPa, and a density of 2.7 g / cm³ was used. Due to the chemical composition, basalt fiber is characterized by high acid and alkali resistance, low wettability, which ensures high adhesion to the molecules of the mineral and organic binder, and, accordingly, to the grains of stone material, as well as evenly distribution in the mixture, that is, absence of clumping during mixing (hedgehog form formation). The general view of fiber is shown (Figure 1).

Figure 1 Basalt fiber, the fiber length is 20-25 mm and the diameter is 13-20 mm

Organic and mineral mixture was prepared according to the following procedure: PC 400 cement, bitumen emulsion (cationic, of average decomposition) and basalt fiber were added to the mixture of milled asphalt crumb, followed by thorough mixing. After preparing the samples at laboratory, the compaction load within the range from 20 MPa to 40 MPa was applied for approximately 3 minutes. Schematic representation of the organic-mineral mixture with basalt fiber is shown (Figure 2).

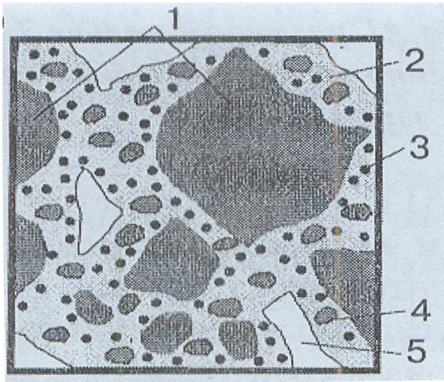

Figure 2 Structure of dispersed-reinforced organic-mineral mixture (1 - Asphalt crumb; 2 - film of cement paste with the inclusion of droplets of emulsion bitumen; 3 - basalt fiber; 4 - grains of asphalt crumb with size less than 2 mm; 5- air voids)

As a result of the studies, the authors found that the introduction of basalt fiber has a positive impact on the structure formation of the organic and mineral mixture, the number of bonds between the particles (grains) of asphalt crumb is increased, which increasing the deformation-strength characteristics and the density of the composite material.

The strong spatial structure of the mixture, which is occurred by the introduction of fiber due to the interaction of the dispersed-reinforced binder with particles of the aggregate, allows evenly distributing the stresses from the moving load and increasing the shear stress resistance of the arranged pavement layer. The results shown an increase in the ability of the dispersion-reinforced mixture with basalt fiber to resist rutting and cracking were obtained. Comparative tests of organic and mineral mixtures with the addition of basalt fiber and without it on rutting on the "wheel" device are shown in Figure 3.

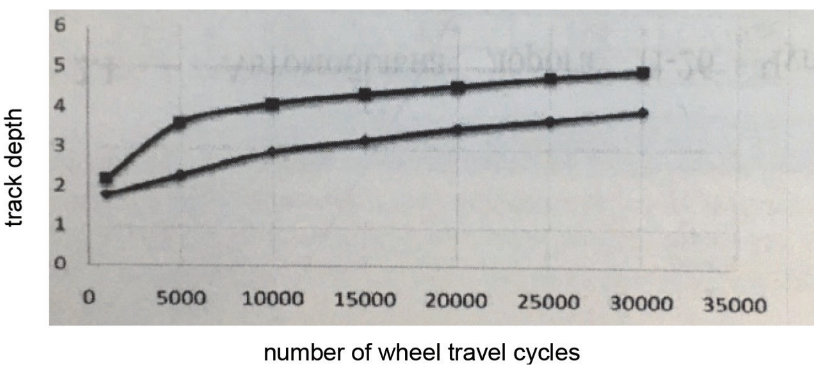

Figure 3 Number of wheel travel cycles (1 - polymer-bitumen binder mixture, 2 - mixture on bitumen with additive Forta)

It is known that the structure of the recycled mixture with the addition of a bitumen emulsion (cationic medium decomposition) is formed for a rather long time. The introduction of basalt fiber accelerates the process of structure formation of the mixture due to chemical interaction with bitumen droplets during the decomposition of the emulsion, which accelerates the layer formation and allows opening the movement of vehicles on the regenerated pavement almost immediately after the compaction.
The length of the basalt fiber of 20-25 mm is typical for discrete offcut of polymer or carbonic materials, which are used for dispersed reinforcement.
The use of basalt fiber with a length of 20-25 mm leads to an increase in the number of micro-particles of a binder connected by one offcut of fiber with the formation of a spatial grid, the nodes of which are the connected structures of sufficient strength, which is due to the strength of the basalt fiber and expressed by high values.
As a result, the strength of the dispersed-reinforced organic and mineral mixture is increased not only in compaction, but also in tension at bending.
Physical and mechanical characteristics of the designed organic-mineral mixture with basalt fiber, depending on different degrees of compaction load, are given in Table 2.

Table 2 Physical and mechanical parameters of the organic-mineral mixture with basalt fiber

Fiber	Density [g/m³]	Elasticity modulus [MPa]	Tensile strength [MPa]	Elongation at break [%]
Polypropylene	0,9	3500-8000	400-700	10-25
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Analysis of the data indicates that the increase of the compaction load decreases the level of organic and mineral mixture water saturation, increase the average density, and increase the compressive strength and the water resistance coefficient (both, short-term and long-term).
The optimal choice of the binder's quantity of cement, emulsion, as well as basalt fiber was confirmed by determining the dependence of frost resistance coefficient on different quantity of binder, as shown (Figure 4).

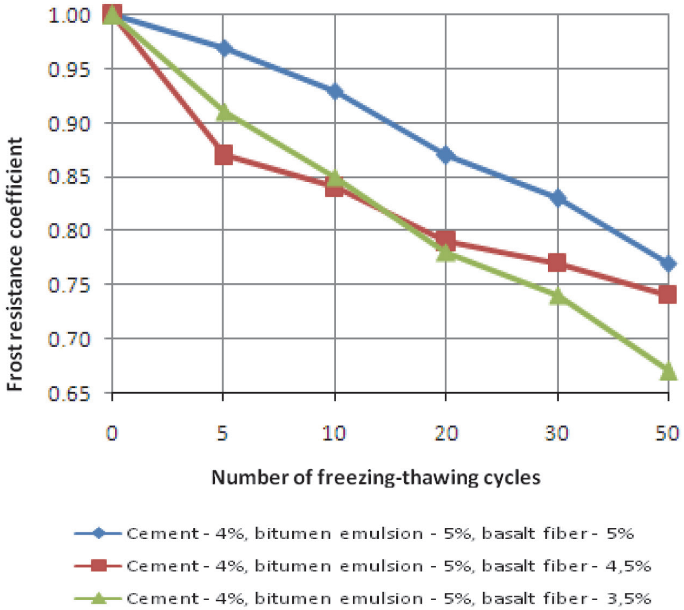

Figure 4 Dependence of frost resistance coefficient on different quantity of binder

As can be seen from the data shown in Figure 4, the organic and mineral mixture of 4 % cement, 5 % cationic bitumen emulsion and 5 % basalt fiber has the highest values of the frost resistance coefficient.

3 Conclusions

The use of organic and mineral mixtures, consisting of milled asphalt concrete with the addition of cement, cationic bitumen emulsion and basalt fiber for the arrangement of the top layer of the pavement during works by the cold recycling method, allows obtaining a durable, crack-resistant, water- and frost-resistant strength structural layer of non-rigid pavement which is meet the modern requirements of road traffic.

The use of an organic and mineral mixture based on milled dispersed-reinforced asphalt concrete will increase the volume of repair work with a significant decrease of their material consumption due to the reuse of existing asphalt concrete will provide high performance of the arranged pavement layer.

The introduction of basalt fiber into the organic and mineral mixture promotes the formation of a durable homogeneous structure of the material, accelerates the process of layer formation and does not complicate the technological process of preparation, which is a positive factor in its use.

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