 Armen Atynian

PhD in Engineering, Associate Professor,
Department of Technology and Organisation of
Construction Production of the
A.M. Beketov Kharkiv National University of Urban Economy,
Kharkiv, Ukraine,
http://orcid.org/0000-0002-6667-6869

Makhmudzhan Dzhalalov

PhD in Engineering, Associate Professor,
Department of Technology and Organisation of
Construction Production of the
A.M. Beketov Kharkiv National University of Urban Economy,
Kharkiv, Ukraine,
http://orcid.org/0000-0002-6636-8700

Svitlana Butnik

PhD in Engineering, Associate Professor,
Department of Technology and Organisation of
Construction Production of the
A.M. Beketov Kharkiv National University of Urban Economy,
Kharkiv, Ukraine,
http://orcid.org/0000-0001-9737-9421

Roman Tkachenko

PhD in Engineering, Associate Professor,
Department of Heat and Gas Supply and Ventilation of the
A.M. Beketov Kharkiv National University of Urban Economy,
Kharkiv, Ukraine,
http://orcid.org/0000-0003-3899-1826
Inna Hovorukha
PhD in Engineering, Associate Professor,
Department of Technology and Organisation of
Construction Production of the
A.M. Beketov Kharkiv National University of Urban Economy,
Kharkiv, Ukraine,
http://orcid.org/0000-0002-0329-2702

IMPROVEMENT OF TECHNOLOGY OF PRODUCTION OF CRUSHED STONE-MASTIC ASPHALT CONCRETE MIXTURE BY ADDING REINFORCING ADDITIVES

Abstract. The design speeds and safety of road traffic are ensured with high indices of evenness, roughness, wear resistance, and adhesion of the pavement surface with the vehicle wheel. The requirements for the coefficient of adhesion are fulfilled by arranging rough pavements based on durable stone materials resistant to wear and grindability under the action of motor traffic. Currently, to improve the performance characteristics of pavements, it is recommended to use crushed stone-mastic asphalt concrete mixtures with an increased content of crushed stone grains. These include special compositions of open, draining, high-density, and crushed stone-mastic asphalt concrete mixtures, while maintaining performance characteristics for a long time. At the same time, in Ukraine, the improvement of road surface characteristics is addressed by the use of stabilizing additives, which do not always and not in all climatic conditions contribute to the solution of the set tasks. Only the use of new reinforcing additives and the improvement of road pavement production technology can fully solve this problem.

Keywords: crushed stone mastic mixture, asphalt concrete, fibre, reinforcing additives.

Introduction. Durability of road structures in Ukraine significantly depends on the impact of transport load, which has been increasing recently, as well as on the impact of natural and climatic factors. Crushed stone-mastic asphalt concrete (SMAC) has become the most promising material for improving surface performance characteristics (adhesion, roughness). Its characteristic feature and a significant difference from other types of asphalt concrete is the presence in its composition of a stabilising additive, the introduction of which contributes to increased resistance to delamination during transportation, laying and compaction of the mixture. In addition, the type of stabilising additive (mineral or organic) influences the optimum binder content in the mixture and the formation of physical...
and mechanical properties of crushed stone- mastic asphalt concrete. But even the introduction of stabilising additives does not always solve the problems of crack resistance and formation of bitumen stains on the surface after compaction. This indicates a high binder content and insufficient stabilising ability of the used additives. According to the earlier researches it has been established that introduction of fibrous materials into bituminous component contributes to acquisition of homogeneity of mixture and directly preservation of strength characteristics in time, thus increasing operational indicators of asphalt concrete. That is, it is necessary to introduce not only stabilising but also reinforcing additives to the asphalt mixture. The disadvantage of the use of SMAC is the appearance of bituminous stains on the surface of the pavement after compaction. This indicates a high binder content and insufficient stabilising ability of the used additives. On the basis of the above, the aim of the research was formed - Improvement of technology of production of crushed stone- mastic asphalt-concrete mixture.

In order to achieve this goal, the following objectives need to be addressed:

1. Consideration of the used reinforcing additives and their influence on the reinforced concrete flooring material
2. Selection of reinforcing additive as a complementary (synergistic) component of the reinforced concrete reinforcement.
3. Improvement of the technology of production of slag-mastic materials with the selected optimal composition.

**Materials and methods.** In Ukraine, a great scientific potential has been accumulated on the study of structural and mechanical properties of crushed stone-mastic asphalt concrete and calculation of road surfaces, which can and should be used in the design of mixture compositions. In order to optimise the mixture composition, it is proposed to determine, on the basis of the results of laboratory tests, the performance properties of the designed asphalt concrete, which characterise as fully as possible the serviceability of the road surface under specific conditions [1, 10]. Initially, the shear resistance of asphalt concrete is assessed by predicting the residual deformation accumulated in the pavement over its design life. Once reliable shear resistance values have been achieved, the crack resistance and other standardised asphalt pavement properties should be consistently improved.

Bitumen and stabilising additives, which are introduced into the composition of crushed- mastic asphalt concrete, create the microstructure of the entire asphalt concrete mixture, the strength and durability of which determine the operational properties of pavements.

In the production of road bitumen BND 60/90 of Kremenchug oil refinery, which is a binding material for road surfaces, was used [1, 2, 13]. BND bitumen differs from other grades by good adhesion to stone materials, has high plasticity at low temperatures. The main features of BND are viscosity, plasticity and heat resistance.
Table 1

Bitumen 60/90 Characteristics

<table>
<thead>
<tr>
<th>№</th>
<th>Name of indicators</th>
<th>Actual figures</th>
<th>DSTU requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Needle penetration depth, 0.1 mm:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) At 25° C</td>
<td>78</td>
<td>61-90</td>
</tr>
<tr>
<td></td>
<td>b) at 0° C</td>
<td>27</td>
<td>at least 20</td>
</tr>
<tr>
<td>2</td>
<td>Kish softening point,° C</td>
<td>52</td>
<td>at least 47</td>
</tr>
<tr>
<td>3</td>
<td>Stretchability, cm at 25° C at 0° C</td>
<td>99</td>
<td>at least 55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.7</td>
<td>at least 3.5</td>
</tr>
<tr>
<td>4</td>
<td>Fraas brittle point,° C</td>
<td>-23</td>
<td>no higher than - 15</td>
</tr>
<tr>
<td>5</td>
<td>Flash point,° C</td>
<td>240</td>
<td>at least 230</td>
</tr>
<tr>
<td>6</td>
<td>Change of softening temperature after heating,° C</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Indes Penetrations, IP</td>
<td>+0.5</td>
<td>-1.0 to +1.0</td>
</tr>
</tbody>
</table>

Source: authors' own development

Petroleum road bitumen used in the research was tested in accordance with the requirements of GOST 22245-90 “Viscous petroleum road bitumen, Technical Conditions” according to the methods of bitumen testing [1, 2, 13].

Crushed stone and sand from rock crushing sands produced by Poltava GOK according to DSTU-N B B.2.3-39:2016 were used [3, 4]. Properties of crushed stone and sand from crushing sands are given below.

Table 2

Crushed stone properties (Physical and mechanical characteristics)

<table>
<thead>
<tr>
<th>№</th>
<th>Name of indicators</th>
<th>Actual figures</th>
<th>DSTU requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>Content of crushed grains by weight (0-20mm), %, not less than</td>
<td>89,5</td>
<td>85</td>
</tr>
<tr>
<td>2</td>
<td>Content of lamellar (sparse) and needle-shaped grains by weight, %, not more than</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>Content of grains of weak rocks by weight, %, not more than</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Dusty and clay particles content, % by weight, not more than</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Clay content in lumps, % by weight, not more than</td>
<td>No</td>
<td>0.25</td>
</tr>
<tr>
<td>6</td>
<td>Crushability grade, not less</td>
<td>1200</td>
<td>1000</td>
</tr>
<tr>
<td>7</td>
<td>Degree of abrasion</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>
Table 3

Properties of sand from crushed crushed stone sands

<table>
<thead>
<tr>
<th>№</th>
<th>Name of indicators</th>
<th>Actual figures</th>
<th>DSTU requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>True density, kg/m³</td>
<td>2568</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Average density, kg/m³</td>
<td>2537</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Bulk density, kg/m³</td>
<td>1500</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Dusty and clay particles content, % by weight, not more than</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Crushability grade, not less</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>6</td>
<td>Degree of abrasion</td>
<td>I1</td>
<td>I1</td>
</tr>
<tr>
<td>7</td>
<td>Frost resistance grade, not lower</td>
<td>F200</td>
<td>F50</td>
</tr>
</tbody>
</table>

Source: authors' own development

Activated mineral powder produced by "PRO-MIX" company (Borispol, Ukraine) was used as a filler. Marks MPA1. Properties of the activated mineral powder are given in Table 4.

Table 4

Properties of activated mineral powder

<table>
<thead>
<tr>
<th>№</th>
<th>Name of indicators</th>
<th>Actual figures</th>
<th>DSTU requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grain composition, % by weight finer 1,25</td>
<td>100,0</td>
<td>at least 100</td>
</tr>
<tr>
<td></td>
<td>0,315</td>
<td>98,3</td>
<td>at least 90</td>
</tr>
<tr>
<td></td>
<td>0,071</td>
<td>82</td>
<td>at least 80</td>
</tr>
<tr>
<td>2</td>
<td>Humidity %</td>
<td>0,3</td>
<td>Not more than 1</td>
</tr>
<tr>
<td>3</td>
<td>Amount of clay impurities by weight</td>
<td>0,95</td>
<td>5</td>
</tr>
</tbody>
</table>

Source: authors' own development
Basalt fibre and Polypropylene fibre PoliArm certified for compliance with the requirements of EN 14889-2:2006 were used as reinforcing additives. Production of DIF company (Ukraine) in Figure 1

![Basalt fibre Polypropylene Fibre](image)

**Fig. 1. Basalt Fibre Polypropylene Fibre**

Source: authors' own development

### Table 5

**Cellulose fibre and polypropylene fibre (characteristics)**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Polypropylene fibre</th>
<th>Basalt fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength MPa</td>
<td>150-600</td>
<td>600</td>
</tr>
<tr>
<td>Fibre diameter</td>
<td>From 10 µm</td>
<td>13-18</td>
</tr>
<tr>
<td>Fibre length</td>
<td>2-40 mm</td>
<td>3-16 mm</td>
</tr>
<tr>
<td>Modulus of elasticity</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>Elongation factor %</td>
<td>20-150</td>
<td>3-4</td>
</tr>
<tr>
<td>Melting point</td>
<td>200</td>
<td>1450</td>
</tr>
<tr>
<td>Density</td>
<td>0,9</td>
<td>3</td>
</tr>
<tr>
<td>Fibre length</td>
<td>2-40 mm</td>
<td>3-16 mm</td>
</tr>
<tr>
<td>Modulus of elasticity</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>Elongation factor %</td>
<td>20-150</td>
<td>3-4</td>
</tr>
<tr>
<td>Melting point</td>
<td>200</td>
<td>1450</td>
</tr>
<tr>
<td>Density</td>
<td>0,9</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: authors' own development
Comparing the characteristics of the materials under consideration, we see that basalt fibre has an advantage in only one characteristic - melting point. For the possibility of filling with a large number of fibres, for modular elasticity and filling factor polypropylene fibre is the best choice. Thus, the scope of application of basalt fibre is fire resistant elements and heat resistant concretes. In all other applications, polypropylene fibre would be the best choice for use in pavement construction.

Bitumen BND 60/90 and limestone mineral powder were used for preparation of asphalt binder. The asphalt binder was prepared in a laboratory mixer with heated mixing chamber. Mineral powder was heated to 170°C and poured into the mixer, then bitumen was introduced and stirred for 1 minute until the bitumen was homogeneously distributed in the mineral powder. Asphalt binder samples were made using asphalt concrete moulds according to the technology of preparing asphalt concrete samples. Further, the physical and mechanical properties of asphalt binder and the optimum amount of bitumen in asphalt binder were determined and the bitumen holding capacity coefficient was calculated [5-12].

Stability of the mixture to delamination was determined according to DSTU B.2.7-127. For this purpose, the prepared crushed stone-mastic asphalt concrete mixture was placed in a beaker and kept for 60±1 min in a desiccator at a temperature of 170 oC. The beaker was then removed, and the mixture was removed by turning the beaker upside down without shaking it for 10±1 seconds. The beaker was then cooled for 10 min and weighed with the remaining binder and mixture adhering to its inner surface.

Binder flow B, %, was determined according to the formula:

$$B = \frac{g_3 - g_1}{g_2 - g_1} \times 100$$

where g1, g2, g3 - mass of the beaker empty, with the mixture and after its removal, respectively, g.

Strength and heat resistance of crushed stone-mastic asphalt concretes were evaluated by the compressive strength of the samples at temperatures of 0°C (R0), 20°C (R20) and 50°C (R50). The samples were tested on an electromechanical press. Water resistance of crushed stone-mastic asphalt concretes was evaluated by the values of water saturation W, swelling H, water resistance sq and water resistance to long-term water saturation according to DSTU B.2.7-127. Frost resistance of the investigated SHMA was determined according to the methodology set out in DSTU B B.2.7-127.

The shear resistance of the slab was evaluated according to GOST 12801-98 according to the internal friction coefficient tg φ and shear adhesion cπ. For this purpose, the maximum loads were determined by simultaneous measurement of the
corresponding limiting deformations of standard cylindrical specimens under uniaxial compression. Crack resistance was evaluated by the tensile strength at splitting Rp by testing cylinder specimens with diameter and height of 71.4±1.5 mm according to GOST 12801-98.

Results/ In order to identify the possibility of using polypropylene fiber as a reinforcing additive in asphalt binders, the properties of asphalt binder with the addition of fiber were investigated with respect to adsorption. For comparison, the properties of asphalt binders with standard activated mineral powder and the addition of PoliArm fiber were determined. The following asphalt binder compositions were adopted:

- bitumen and activated mineral powder;
- bitumen, activated mineral powder, and PoliArm fiber.

\[ \text{Table 6} \]

Properties of investigated asphalt binders

<table>
<thead>
<tr>
<th>Type of asphalt binder</th>
<th>Needle penetration depth, 0.1 mm</th>
<th>Ring and ball softening point,°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>at 0° C</td>
<td>at 25° C</td>
</tr>
<tr>
<td>Bitumen BND 60/90 and activated limestone mineral powder with fibre addition</td>
<td>23</td>
<td>47</td>
</tr>
<tr>
<td>Bitumen BND 60/90 and activated limestone mineral powder</td>
<td>20</td>
<td>59</td>
</tr>
</tbody>
</table>

Source: authors' own development

As we can see, the introduction of fibre into the binder reduces penetration at 25°C by almost 20% from 59 to 47 mm, which indicates an improvement in adhesion characteristics.

Since one of the considered negative characteristics of the road surface was the presence of bituminous stains on the road surface, we have to increase the bituminous capacity of the road surface by determining the optimum amount of fibre introduction.

To determine the physical and mechanical properties of the asphalt binder, four batches of samples were produced: without fibre addition and with fibre addition of 5, 10 and 20%. In each batch it was necessary to select an asphalt binder with the optimum amount of bitumen, at which the maximum value of average density and strength at 50°C is achieved, and water saturation is close to the minimum value. According to the research, the optimum amount of bitumen was 12% for fibreless asphalt pavement, 12.5% for 5% fibre, 13% for 10% and 15% for 20%.
## Table 7

### Indicators of physical and mechanical properties of asphalt binder of optimal structure with fibre

<table>
<thead>
<tr>
<th>№</th>
<th>Asphalt binder composition, %</th>
<th>Physical and mechanical parameters</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average density, g/cm³</td>
<td>Water saturation in % by volume</td>
<td>Compressive strength, MPa</td>
<td>Water resistance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>At 20°C C in water-saturated state</td>
<td>At 20°C C</td>
<td>At 50°C C</td>
</tr>
<tr>
<td>1</td>
<td>Min. powder - 100%, bitumen - 12 % of the weight of the min. part</td>
<td>2,3</td>
<td>0,09</td>
<td>4,5</td>
<td>5,33</td>
</tr>
<tr>
<td>2</td>
<td>Min. powder - 95%, fibre - 5 %; bitumen - 12,5 % of the weight of the min. part</td>
<td>2,25</td>
<td>0,08</td>
<td>5,6</td>
<td>5,39</td>
</tr>
<tr>
<td>3</td>
<td>Min. powder - 90%, fibre - 10 %; bitumen - 13 % of the weight of the min. part</td>
<td>2,20</td>
<td>0,07</td>
<td>6,89</td>
<td>6,77</td>
</tr>
<tr>
<td>4</td>
<td>Min. powder - 80%, fibre - 20 %; bitumen - 15 % of the weight of the min. part</td>
<td>2,17</td>
<td>0,3</td>
<td>6,03</td>
<td>6,44</td>
</tr>
</tbody>
</table>

Source: authors' own development

Thus, we can conclude that the addition of fiber slightly increases the bitumen capacity (0.5 - 3%). At the same time, analyzing the results given in the table, we can conclude that the optimal amount of additive will be the introduction of 10% fiber from the amount of mineral powder. Accordingly, we can design an improved composition of crushed stone-mastic asphalt concrete:

- SMAC-15
- Granite crushed stone of the 10-15 mm fraction - 40%;
- Granite crushed stone of the 5-10 mm fraction - 30%;
- Granite siftings of the 0-5 mm fraction - 17%;
- Limestone mineral powder - 12.87%;
- Fiber - 0.13% of the weight of the mineral part (10% of limestone mineral powder).
BND 60/90 grade bitumen - 6.5% of the weight of the mineral part (13% for the mixture with fiber). The designed compound was subjected to further studies. Investigation of the shear stability of shear-reinforced concrete pavement was conducted. Determination of the shear resistance of the samples made of slag materials was carried out under uniaxial compression. To assess the shear resistance, the coefficient of internal friction (tgφ) and shear adhesion at a temperature of 50°C (Cπ) were determined. The obtained results for the compositions of slag-mastic materials with the optimum content of mineral powder are presented in Table 8 and the optimum content of fiber.

Table 8

<table>
<thead>
<tr>
<th>Type of mixture</th>
<th>Internal friction coefficient, tg φ</th>
<th>Shear bond at temperature 50°C, Cπ, MPa</th>
<th>Angle of internal friction, φ, °</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMAC-15</td>
<td>0.94</td>
<td>0.2</td>
<td>43° 33'</td>
</tr>
<tr>
<td>SMAC-15 with fibre addition</td>
<td>0.97</td>
<td>0.34</td>
<td>43° 37'</td>
</tr>
</tbody>
</table>

Source: authors' own development

The increased index of shear adhesion of the fibre reinforced concrete paper with fibre addition in comparison with standard concrete paper is caused, firstly, by a high degree of bitumen structuring by fibre due to the increase of bitumen viscosity in the process of selective filtration of separate components into micropores of fibre particles; secondly, fibre particles have a developed surface and high roughness, which has a positive effect on the increase of internal friction and adhesion.

The crack resistance of crushed-mastic asphalt concretes was evaluated by the cracking tensile strength Rp.

Table 9

<table>
<thead>
<tr>
<th>Type of mixture</th>
<th>Tensile strength at splitting, Rp, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMAC-15</td>
<td>5.3</td>
</tr>
<tr>
<td>SMAC-15 with fibre addition</td>
<td>7.19</td>
</tr>
</tbody>
</table>

Source: authors' own development

As we can see by analyzing the tensile strength table, the crack resistance has increased by 35%, which in turn confirms the correctness of the chosen material. Investigation of the frost resistance of slag concrete was conducted. The frost resistance of the samples SMAC-15 and SMAC-15+fibre was determined according
to GOST 12801-98. Samples of fibre-modified and standard SMAC-15 were tested. After each set of 25 cycles of freezing and thawing, the samples were tested in compression at 20°C. The obtained results are presented in Table 10. The frost resistance of samples SMAC-15 and SMAC-15 modified by fibre is high enough, enduring 150 cycles of alternate freezing and thawing.

**Table 10**

**Strength of sandcrete samples in frost resistance test**

<table>
<thead>
<tr>
<th>Number of freezing and thawing cycles</th>
<th>Compressive strength at temperature 20°C, $R_{20}$, MPa</th>
<th>Coefficient of frost resistance, $k_{froz}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SMAC-15 Fibre standard Fibre standard</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>5.03 4.3</td>
<td>- 0.99 0.79</td>
</tr>
<tr>
<td>25</td>
<td>5.01 4.15</td>
<td>0.99 0.97</td>
</tr>
<tr>
<td>50</td>
<td>4.8 4.00</td>
<td>0.98 0.94</td>
</tr>
<tr>
<td>75</td>
<td>4.45 3.82</td>
<td>0.93 0.91</td>
</tr>
<tr>
<td>100</td>
<td>4.15 3.56</td>
<td>0.88 0.82</td>
</tr>
<tr>
<td>125</td>
<td>4.02 3.08</td>
<td>0.82 0.76</td>
</tr>
<tr>
<td>150</td>
<td>3.65 2.79</td>
<td>0.75 0.62</td>
</tr>
</tbody>
</table>

Source: authors' own development

The strength values at all frost resistance cycles are higher in fibre-modified compositions.

**Conclusions.** Experimental studies have confirmed the expediency of introducing reinforcing additives to improve crushed stone-mastic asphalt in order to increase the physical and mechanical, structural and mechanical, technological, and operational properties of SMAC. As a result of comparative characterization, the optimum reinforcing agent—polypropylene fiber—was selected. It has been revealed that the introduction of polypropylene fiber in the optimal amount into the sandcrete reinforced concrete contributes to an increase in strength properties and water resistance. According to the research, the improved composition of the sandcrete mix with an optimal addition of fiber (10% of the weight of activated mineral powder) was developed.

According to studies of the rheological characteristics of asphalt concrete mixtures, it has been shown that the use of fiber in crushed stone-mastic asphalt concrete mixtures increases the shear resistance and crack resistance of the mixtures. Higher indices of viscosity and stiffness at high summer temperatures, and lower
viscosity and stiffness at negative temperatures, have been established for crushed stone-mastic asphalt concrete modified with fiber, in comparison with standard asphalt concrete mixtures. It has been revealed that the inclusion of fiber in the compositions of macadam does not reduce the wear resistance of the macadam.

It has been established that the use of fiber in slag materials leads to an increase in crack resistance and shear stability of the material.

As a result of experimental studies, high frost resistance of fiber-modified SMAC-15 samples was established, which amounted to more than 125 cycles of alternate freezing and thawing.

Accordingly, the improved crushed stone-mastic asphalt concrete SMAC-15, modified with polypropylene fiber, can be used for the top layers of road, bridge, and aerodrome pavements.

References: