The Stabilizing Additive from Natural Zeolite for Stone Mastic Asphalt

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Abstract. The article describes the possibility to use natural zeolites as a stabilizing additive for Stone mastic asphalt. Stone mastic asphalt is highly resistant to damage caused by traffic and natural climatic conditions. It is possible to use natural zeolites economically exploited in the Republic of Sakha (Yakutia) as a stabilizing additive, a characteristic feature of which is the presence of voids and channels threading through the entire frame in a dense lattice. In this study, comparative tests of crushed stone-mastic asphalt with various stabilizing additives. As a control group of samples, the stabilizing additive “Stilobit” was used. As a result, data were obtained that natural zeolites are suitable for use as stabilizing additives in the composition of crushed stone-mastic asphalt concrete. In this study, according to the test results, it can be concluded that the natural zeolites are suitable for the use as a stabilizing additive in the composition of stone mastic asphalt. Preliminary mechanical activation of zeolites allows improving the “stone material - binder” interaction at the phase boundary, which is confirmed by improved water resistance parameters of SMA.

1. Introduction

Stone mastic asphalt (SMA) was developed in Germany in the 1960s and is one of the promising construction materials for road pavements, which is highly resistant to damage caused by the traffic flow and natural climatic conditions.

A special feature of the SMA structure is a stone skeleton, in which all voids between the coarse aggregate are filled with a mixture of bitumen with crushed sand, mineral powder, and a stabilizing additive. The stabilizing additives are added to provide adequate stabilization of bitumen and to prevent drainage along the edges of the crushed stone during transportation and placement of ready mixture. The type and properties of these additives are of great importance for providing the required binder content and improving the quality of the mixture [1-3].

Stabilizing additives for SMA can be divided into the following types (figure 1) [4-11].
Figure 1. Types of stabilizing additives.

Owing to the low cost and easy manufacturing, the most common are cellulose additives, presented in the form of fibrillated fibers or granules. A distinctive feature of such additives is their highly porous structure, as a result of which they have a high sorption capacity for the bitumen [6, 12].

2. Tasks
The stone mastic asphalt is being actively introduced into federal-aid highways passing through the territory of the Republic of Sakha (Yakutia) since they were designed specifically for the increasing rate of traffic flow and for increasing mass of transit freight transport.

At present, there is no cellulose industry in Yakutia. Therefore, stabilizing additives have to be imported from other regions. Finding a material that can perform the functions of a stabilizing additive in stone mastic asphalt is an urgent problem.

An economically exploitable natural zeolite from the Kempendyaysky deposit can be considered as one of such materials. Natural zeolites are aluminosilicates built from the $\text{AlO}_4^-$ and $\text{SiO}_4^-$ groups. A characteristic feature of zeolites is the presence of cavities and channels threading through the entire frame in the dense crystal lattice, i.e. their structure resembles a fine-pored sponge, owing to which zeolites have a high specific surface.

3. Examination of physical-mechanical characteristics of stone mastic asphalt
Earlier studies have revealed that the preliminary mechanical activation of zeolite in a planetary mill for 1 minute allows increasing its specific surface area by more than 20% and increasing the pore volume by more than 60% [13-15].

The composition of SMA with one of the common additives Stilobit was chosen as the control group to obtain a comparative characteristic of the physical-mechanical properties of SMA with the use of a stabilizing additive from the natural zeolite. The selection of the SMA-10 composition was performed according to GOST 31015-2002 “Asphalt concrete mix and stone mastic asphalt. Technical conditions”. The determination of the physical-mechanical characteristics of the SMA samples was accomplished according to GOST 12801-98 “Materials based on organic binders for road and airfield construction. Test methods”.

The grain composition of the mixture was selected following table 1 of GOST 31015-2002. Afterwards, in terms of residual porosity of SMA, the amount of bitumen in the mixture was determined by the experiment, and it was 6 wt. % for samples with “Stilobit” additive and 6.5 wt. % for samples with the addition of natural zeolite.

Moreover, when selecting the composition of stone mastic concrete, the main criterion is the indicator of the binder drainage, since the mixtures must be resistant to disintegration during transportation and placement [16-18].

The rate of binder drainage is regulated by GOST 31015-2002 and should be in the range from 0.07 wt. % to 0.15 wt. %. According to the graphs presented in figure 2, the content of the stabilizing additive for the samples with the addition of "Stilobit" is 0.4 wt. % and it is 5 wt. % for the samples with zeolite. The high porosity of natural zeolite subjected to mechanical activation and a large volume of pores allows achieving good rates of the binder draindown with a relatively low content of stabilizing additive in the bitumen - stabilizing additive system [11, 19 - 21].
Figure 2. The dependence of the binder drainage rate on the amount of stabilizing additive.

After selecting the composition of SMA, control batches of samples were manufactured and were subjected to tests according to GOST 12801-98. The main physical-mechanical characteristics of the samples of stone mastic asphalt are presented in table 1.

Figure 3 demonstrates the dependence of the compressive strength of the SMA samples on the type of stabilizing additive. It has been established that the samples with natural zeolite have reduced strength properties compared with the samples containing "Stilobit" in its composition. Thus, the compressive strength of the samples with natural zeolite at 20 °C is 1.25 times lower than the compressive strength of the control group of samples. The compressive strength at 50 °C is 1.27 times lower. However, it should be noted that the strength parameters meet the requirements of GOST 31015-2002.

Figure 3. Compressive strength of stone mastic asphalt at temperatures of 20 °C, 50 °C.
1 - SMA with the addition of "Stilobit"; 2 - SMA with activated natural zeolite.

One of the most important parameters of SMA is the water resistance at long-term water saturation, which makes it possible to indirectly assess the durability of road pavements: the higher the indicator of water resistance is, the higher the resistance of a material is against atmospheric corrosion. As table 1 shows, the samples with a stabilizing additive from natural zeolite have distinguished water resistance. Thus, the water resistance of the samples with zeolite in its composition is higher than the water resistance of the control group of samples by 48%. Moreover, the SMA samples with natural zeolite have a high value of crack resistance. The shear resistance characteristics of the internal friction coefficient are almost equal.
Table 1. Physical-mechanical properties of stone mastic asphalt with various stabilizing additives.

| Parameter | Performance standard according to GOST 31015-2002 | Stabilizing additive | | | |
|-----------|-----------------------------------------------|----------------------|----------------------|----------------------|----------------------|
| Porosity of mineral part, %: | from 15 to 19 | 15.82 | 16.37 | | |
| Residual porosity, % | from 1.5 to 4.0 | 2.18 | 2.70 | | |
| Compressive strength, MPa at temperatures: | | | | | |
| 50°C | Not less than 0.6 | 2.03 | 1.63 | | |
| 20°C | Not less than 2.0 | 5.96 | 4.67 | | |
| Shear resistance | | | | | |
| Internal friction coefficient | Not less than 0.92 | 0.92 | 0.95 | | |
| Adhesion at shear at a temperature of 50°C, MPa | Not less than 0.16 | 0.39 | 0.30 | | |
| Water resistance at long-term water saturation | Not less than 0.9 | 0.70 | 1.04 | | |
| Crack resistance according to tensile strength at the split at a temperature of 0°C, MPa | From 2.0 to 5.5 | 1.8 | 3.0 | | |
| Indicator of binder drainage, %: | From 0.07 to 0.15 | 0.13 | 0.07 | | |

4. Conclusion

1. Stone mastic asphalt is highly resistant to damage caused by traffic and natural climatic conditions. An essential feature of the SMA structure is a macadam frame, in which all voids between the coarse aggregate are filled with a mixture of bitumen with crushed sand, mineral powder, and a stabilizing additive. A distinctive feature of SMA stabilizing additives is their highly porous structure, as a result of which they have an increased sorption capacity for the bitumen.

2. It is possible to use natural zeolites economically exploited in the Republic of Sakha (Yakutia) as a stabilizing additive, a characteristic feature of which is the presence of voids and channels threading through the entire frame in a dense lattice. In this study, according to the test results, it can be concluded that the natural zeolites are suitable for the use as a stabilizing additive in the composition of stone mastic asphalt. Preliminary mechanical activation of zeolites allows improving the “stone material - binder” interaction at the phase boundary, which is confirmed by improved water resistance parameters of SMA.

3. It has been established that at a temperature of 0 °C, an increase in the crack resistance parameter of the SMA samples with the natural zeolite in its composition and an improvement in the shear stability index are observed. All physical-mechanical characteristics of SMA meet the requirements of GOST 31015-2002. Thus, stone mastic asphalt with a stabilizing additive from natural zeolite can be used in the construction of roads in Yakutia.
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