Wollastonite-based asphalt concrete

T I Shishelova¹, V V Fedchishin² and M A Khramovskih³
¹Department of Physics, INRTU, Lermontov Street, 83, Irkutsk 664074, Russia
²Energy department, INRTU, Lermontov Street, 83, Irkutsk 664074, Russia
³Department of Construction Production, INRTU, Lermontov Street, 83, Irkutsk 664074, Russia

E-mail: Hramovskih.misha@yandex.ru

Abstract. Developing an asphalt concrete composition with improved physical, mechanical and operational characteristics is an urgent issue all over the world. To improve the asphalt mix proportion, reinforcing components are added to its composition. An advanced reinforcing filler is wollastonite. The research aim: to study the possibility of utilizing wollastonite concentrate instead of traditional limestone fillers in the asphalt mix proportion and to determine its effect on the durability of the road surface. The objects of the study are some samples of asphalt concrete with a different quantitative ratio of wollastonite fillers and various types of crushed aggregate. Research methods: in accordance with standard techniques, the physical and mechanical characteristics of the samples were determined. Research results: the optimum amount of wollastonite concentrate for the asphalt concrete composition was found; the improvement of physical and mechanical characteristics of asphalt concrete due to the applying of wollastonite concentrate was acknowledged; the optimum roadway surfacing that consists of several layers was developed.

1. Introduction

World practice applicable to road construction is aimed at improving the core factors, which affect the state of modern highways. First, this is conditioning of pavement base, and secondly, it is road surfacing development. The best surfacing for highways is known to be asphalt concrete. Its serviceable life varies and depends on many factors: hydrogeological and climatic conditions, relief of the terrain, the technology applied for spreading asphalt concrete mix, as well as materials used, etc. [1, 2].

To improve the physical and mechanical properties of asphalt concrete surfacing, reinforcing components are added into its composition [3]. Wollastonite has a high potential in this area [4-10]. Wollastonite is a natural calcium silicate with the chemical formula CaSiO₃. It consists of arrow-head crystals, which turn into acicular shape grains when crushed. It is resistant to organic solvents and water. The hardness of wollastonite on Mohs' scale is 4.5. Its density is 2900 kg / m³.

The acicular shape of wollastonite grains makes it an efficient material as a reinforcing element in the asphalt concrete composition. The number of undeveloped deposits and high production potential deposits, as well as the possibility to apply the technology for artificial synthesis of wollastonite makes it possible to obtain raw materials massively [11-18].
2. Methods and materials
The physical and mechanical characteristics of the experimental samples were identified by means of standard techniques. The objects under study were some samples of asphalt concrete with different amounts of wollastonite fillers and various types of crushed aggregate.

3. Results and discussions
In order to justify the possibility of using wollastonite as a reinforcing component when producing materials employed in road building, standard samples of hard-textured hot fine-grained asphalt concrete were tested.

The analysis of the test results showed that asphalt concrete compositions with the wollastonite filler are characterized by increased contractibleness. It allows reducing the amount of the cementing medium in asphalt concrete compositions despite the high bitumen content of wollastonite.

Construction and performance criteria of asphalt concrete with wollastonite as an additive scores much better in comparison with those demonstrated by limestone asphalt concrete. The shear resistance at 50°C increases by 13.6 %, the crack resistance at 0°C increases by 10.4%, while the damping capability at 20°C rises by 8.9%. The frictional coefficient, which is a quality measure for the interaction between the surface of asphalt concrete and wheels, increases by 6.7% at 20°C. The roadway surfacing contractibleness rises by 40.8%.

After justifying the feasibility of adding wollastonite to the asphalt concrete mix, the research in optimizing the composition of asphalt concrete with wollastonite concentrate were done. The optimal amount of wollastonite concentrate in the tested compositions of asphalt concrete mixtures is equal to 6-8%. This value corresponds to the optimal content of any other mineral fillers in the mineral composition of the asphalt concrete mix and is consistent with its maximum density. Replacing the carbonate mineral filler in the optimal composition of fine-grained asphalt concrete with wollastonite increases its shear resistance by 32-44%, and boosts its load-bearing capacity in the roadway surfacing by 40%.

The results of the experimental studies to determine life duration and quality of the road surfacing with the upper four-centimeter layer of fine-grained asphalt concrete with wollastonite are shown in Table 1. The modulus of elasticity of asphalt concrete top roadway surfacing \((E_{AC})\) is determined by the relative deformation of a pre-compressed sample, i.e. the measurement is applicable for a roadway surfacing sample taken after several months of its service, but not for a freshly spread surfacing. The weight of wollastonite filler in the test samples is from 6% to 8%, respectively. The values with the index “a” correspond to the samples with crushed limestone fillers, those with the index “b” are referred to granitoid fillers.

Table 1. Performance indicators of roadway surfacing with a wollastonite concentrate upper layer.

| Indicators                                                                 | The composition of asphalt concrete with the upper 4-cm surfacing layer with wollastonite concentrate |
|---------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
|                                                                           | With granitoid fillers | With limestone fillers | No. 1a | No. 1b | No. 2a | No. 2b | No. 3a | No. 3b |
| The modulus of elasticity of asphalt concrete surfacing, \(10^6\) N / m².  | 1928                  | 2734                  | 1145   | 2243   | 1349   | 2324   | 934    | 1910   |
| The indicator of the fall rate of asphalt surfacing load-bearing capacity at 0°C, | 0.0082                 | 0.0068                 | 0.0168 | 0.0122 | 0.0201 | 0.2076 | 0.20   | 0.0212 |
\[ \alpha_{AC} \]

Permissible elastic strain of the upper layer at 0\(^\circ\)C, \[ \lambda_{AC} \]

|                | 0.0080 | 0.0054 | 0.0141 | 0.0067 | 0.0108 | 0.0051 | 0.0170 | 0.0073 |
|----------------|--------|--------|--------|--------|--------|--------|--------|--------|

Required final modulus of elasticity of asphalt concrete \( E_{TR} \), \( 10^5 \text{ N/m}^2 \).

|                | 1278   | 1899   | 726    | 1516   | 944    | 2011   | 600    | 1392   |
|----------------|--------|--------|--------|--------|--------|--------|--------|--------|

Actual modulus of elasticity of asphalt concrete \( E_{AC} \), \( 10^5 \text{ N/m}^2 \).

|                | 1246   | 1308   | 1429   | 1399   | 1350   | 1382   | 1501   | 1480   |
|----------------|--------|--------|--------|--------|--------|--------|--------|--------|

Relative life duration of asphalt concrete.

|                | 0.975  | 0.689  | 1.969  | 0.923  | 1.430  | 0.687  | 2.50   | 30.1063|
|----------------|--------|--------|--------|--------|--------|--------|--------|--------|

The analysis of the experimental results showed that the use of asphalt concrete with wollastonite fillers becomes the most efficient when wollastonite is employed in the upper four-centimeter layer of the roadway surfacing, while the road lower layer is made of asphalt concrete with carbonate mineral fillers. Such a composition of the roadway layers contributes to increasing the performance index significantly compared to the asphalt concrete surface comprising only the carbonate mineral filler:

- by increasing the service lifetime of the roadway surfacing by 1.54-2.58 times;
- by improving the damping capability of the roadway surfacing by 1.46-2 times;
- by increasing the crack resistance of the roadway surfacing by 1.36-2.13 times.

In the two-layer roadway surfacing structure with the upper four-centimeter layer of asphalt concrete with the wollastonite filler, the elastic modulus of the composition after some compression (by moving transport) reduces in comparison with the elastic modulus of the asphalt concrete of the lower roadway surfacing. Consequently, a softer surfacing of asphalt concrete with high damping capacity wollastonite fillers is spread on the surface of the lower layer. Its high damping capacity and the way to interact with wheels will ensure high comfort and safety for automobile transport.

The reduction of the modulus of elasticity of compressed asphalt concrete of the upper layer composition with wollastonite fillers significantly improves its crack resistance compared with the crack resistance of the lower layer asphalt concrete and, therefore, improves the crack resistance of the whole layered structure.

Thus, increased crack resistance (increased value \( \lambda_{ac} \)), rise in the elastic modulus of the roadway surfacing due to its having the lower layer of high-rigidity asphalt concrete comprising carbonate mineral fillers, as well as the decrease in the required modulus of elasticity (\( E_{TR} \)) of the roadway surfacing due to the increase in the permissible elastic strain of the upper layer \( \lambda_{ac} \), significantly boost the roadway surfacing life duration of the layered structure.

4. Conclusion

In the research the possibility of employing wollastonite as a reinforcing filler to manufacture asphalt concrete is considered and justified. The optimal amount of wollastonite concentrate in the asphalt-concrete mix was calculated.

The results obtained in the experimental studies showed that changing the carbonate mineral filler for the wollastonite concentrate in the composition of asphalt concrete significantly increases its shear resistance and load-bearing capacity.

The design of the roadway surfacing comprising the upper four-centimeter layer of wollastonite-based asphalt concrete and the lower layer of carbonate mineral asphalt concrete was developed. This
roadway surfacing structure is optimal in terms of its performance quality and cost efficiency. Compared with standard roadway surfacing, which consists of a single layer of carbonate-based asphalt concrete, the developed wollastonite concentrate composition is characterized by the service life increase, by improving damping capability and crack resistance, as well as by contributing to safety of traffic through improving the interaction of wheels with the roadway surface.

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